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ACCESSION NBR: 8106180356 DOC. DATE: 81/06/16 NOTARIZED: NO DOCKET #
 FACIL: 50-387 Susquehanna Steam Electric Station, Unit 1, Pennsylv 05000387
 50-388 Susquehanna Steam Electric Station, Unit 2, Pennsylv 05000388
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SUBJECT: Forwards revised response to NUREG-0737, Item II.B.3, "Post-Accident Sampling Sys" re Chemical Engineering Branch, Technology Section Questions 3, 4, 5 & 6. Response to Questions 1 & 2 will be submitted prior to fuel load.

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June 16, 1981

Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S Nuclear Regulatory Commission
Washington, D.C. 20555

Docket Nos. 50-387
388

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ER100450 FILE 841-2
PLA-848

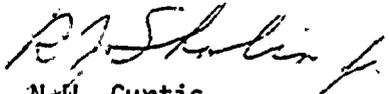
Dear Mr. Schwencer:

This letter revises the text of PP&L's response to NUREG-0737 Item II.B.3, Post Accident Sampling Systems which was transmitted to you in PLA-798. This response address Questions 3, 4, 5, and 6 from the Chemical Technology Section of the Chemical Engineering Branch.

Responses to Questions 1 and 2 will be prior to fuel load.

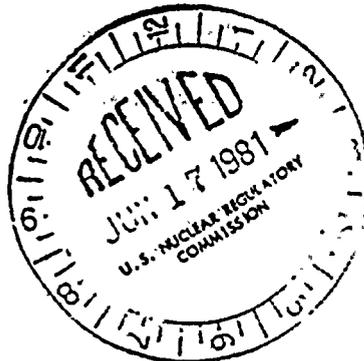
If you have any questions, please contact us.

Very truly yours,



N.W. Curtis
Vice President-Engineering and Construction-Nuclear

cc: R.M. Stark - NRC



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X.1.21 Post Accident Sampling (II. B. 3)

X.1.21.3 Statement of Response

X.1.21.3.1 Introduction

A design and operational review of the existing reactor coolant and containment atmosphere sampling system was performed to determine its ability to meet this requirement. The existing sampling system does not meet this requirement and therefore an additional system dedicated to post-accident sampling will be installed. This system was designed to satisfy all the requirements as stated in NUREG-0578 and the clarification of item II.B.3. The system will be installed and operational by fuel load.

The Post-Accident Sampling System (PASS) concept is based upon obtaining grab samples for remote laboratory analysis, having a minimum of operating complexities, having very little "in-line" instrumentation, having modular construction for maintenance and contamination control purposes, and being compact in size so as to require less shielding and to better fit into existing plants. This concept results in a three-step sampling/analysis process. The samples are obtained via a Post Accident Sample Station located adjacent to secondary containment. They are then transported to a sample preparation area which consists of a wet chemistry laboratory with the capability to perform the required chemical analyses as well as prepare the samples for radioisotopic analysis. The final step involves transporting the samples to a counting area with a sufficiently low background to permit accurate gamma-ray spectroscopic analysis.

X.1.21.3.2 Description of Sampling System

The underlying philosophy in the design of the sampling system is to meet the requirements of item II.B.3, to minimize exposure by minimizing the required sample sizes, to optimize the weight of the shielded sample containers in order to facilitate movement through potentially high-level radiation areas, and to provide adequate shielding at the sample station. The system is designed to provide useful samples under all conditions, ranging from normal shutdown and power operation to post-accident conditions.

The P&ID for the PASS is shown in Figure X.1.21-1. The equipment includes isolation and control valves, piping station, sample station, and control panels.

X.1.21.3.2.1 Sample Points

a) Wetwell and Drywell Atmosphere

Provision will be made to obtain gas samples from two separate areas in both the drywell and wetwell. The sample lines will tap into the containment air monitoring system (CAMS) sample lines outside of primary containment and after the second containment isolation valve. The two drywell sample taps are on the highpoint line, sampling at elevation 790' and the midpoint line, sampling at elevation 750'.

b) Secondary Containment Atmosphere

A sample line will be installed to allow sampling of the secondary containment atmosphere. The location of this point has yet to be determined. This sample point would be useful in determining the post accident accessibility of the reactor building.

c) Reactor Coolant and Suppression Pool Liquid Samples.

When the reactor is pressurized reactor coolant samples will be obtained from a tap off the jet pump pressure instrument system. The sample point will be on a non-calibrated jet pump instrument line outside of primary containment and after the excess flow check valve. This sample point location is preferred over the normal reactor sample points on the reactor water clean up system inlet line and recirculation line since the reactor clean-up system is expected to remain isolated under accident conditions, and it is possible that the recirculation line containing the sample line may be secured. The jet pump instrument line has been determined to be the optimum sample point for accident conditions since: 1) the pressure taps are well protected from damage and debris, 2) if the recirculation pumps are secured, there is normally excellent circulation of the bulk of the coolant past these taps (natural circulation), and 3) the taps are located sufficiently low to permit sampling at a reactor water level which is even below the lower core support plate.

A single sample line is also connected to both loops in the RHR system. The sample lines will tap off the high pressure switch instrument lines coming off the common section of the RHR system return line. This sample point provides a means of obtaining a reactor coolant sample when the reactor is not pressurized and at least one of the RHR loops is operated in the shutdown cooling mode. Similarly, a suppression pool sample can be obtained from an RHR loop lined up in the suppression pool cooling mode.

X.1.21.3.2.2 Isolation Valves and Sample Lines

Containment isolation for the drywell and wetwell gas sample lines are provided by the existing CAMS sample line isolation valves. The jet pump instrument sample line containment isolation is provided by an existing isolation valve and excess flow check valve upstream of the sample tap. All gas sample lines from the sample taps to and including the first flow control valves are seismic category 1 except for the secondary containment sample line which has no control valve before it enters the sample panel. The sample lines from the RHR system are seismic category 1 through both system isolation valves and a flow restricting orifice. The sample line from the jet pump instrument system is seismic category 1 to the flow control/isolation valve. All containment isolation valves upstream of the sample taps can be overridden from the control room. All isolation and control valves shown in Fig. X.1.21-1 which are within the Q boundary are controlled by a single

permissive switch in the control room and individually controlled at the sampling control panel located adjacent to the sample station.

The solenoid isolation and control valves which are part of the post accident sample system to the Q boundary will be environmentally qualified. The gas sample lines are heat traced to prevent precipitation of moisture and the resultant loss of iodine in the sample lines.

X.1.21.3.2 Piping Station

The piping station, which is to be installed within the reactor building, includes sample coolers and control valves which determine the liquid sample flow path to the sample station. The location for the piping station is shown in Figure X.1.21-2. Cooling water will come from the Reactor Building Closed Cooling Water System.

X.1.21.3.2.4 Sample Station and Control Panels

The location of the sample station, control panels and associated equipment is shown in Figure X.1.21-3. The sample station consists of a wall mounted frame and enclosures. Included within the sample station are equipment trays which contain modularized liquid and gas samplers. The lower liquid sample portion of the sample station is shielded with 6 inches of lead brick, whereas the upper gas sampler has 2 inches of lead shielding. The control instrumentation is installed in two control panels. One of these panels contains the conductivity, and radiation level readouts. The other control panel contains the flow, pressure, and temperature indicators, and various control valves and switches. A graphic display directly below the main control panel which shows the status of the pumps and valves at all times. The panel also indicates the relative position of the pressure gauges and other items of concern to the operator. The use of this panel will improve operator comprehension and assist in trouble shooting operations. The various sample lines and return lines enter the sample station enclosure (which is mounted flush against the secondary containment wall) through the back by way of a penetration in the steam tunnel wall.

X.1.21.3.2.4a Gas Sampler

The gas sample system is designed to operate at pressure ranging from sub-atmospheric to the design pressures of the primary containment one hour after a loss-of-coolant accident. The gas samples may be passed through a particulate filter and silver zeolite cartridge for determination of particulate activity and total iodine activity by subsequent gamma spectroscopic analysis. A radiation monitor is mounted close to the filter tray to measure the activity buildup on the cartridges. Alternately, the sample flow bypasses the iodine sampler, is chilled to remove moisture, and a 15 milliliter grab sample can be taken for determination of gaseous activity and for gas composition by gas chromatography. The gas is collected in an evacuated vial using hypodermic needles in a manner analogous to the normal off-gas

samples. When purging the drywell and wetwell gas sample lines to obtain a representative sample, the flow is returned to the wetwell; however, during purging of the secondary containment line and when flushing the sample panel lines with air or nitrogen, flow is returned to secondary containment. The sample station design allows for flushing of the entire sample panel line from the four position selector valve through the needles with either air, nitrogen, or the gas to be sampled. This capability will minimize any possible cross contamination between the various samples.

X.1.21.3.2.4.b Liquid Sampler

The liquid sample system is designed to operate at pressures from 0 to 1500 psi. The design purge flow of 1 gpm is sufficient to maintain turbulent flow in the sample line and serves to alleviate cross contamination between samples. The purge flow is returned to the suppression pool. The liquid sampling system is designed to allow routine demineralized water flushing of the system lines from a point between the two coolers in the piping station through the sampling needles. Using the hydro-test connection which is outside the sample panel, it is also possible to backflush all the liquid sample lines through the sample tap point. This will allow for clearing of plugged lines. All liquid samples are taken into 15 milliliter septum bottles mounted on sampling needles. In the normal lineup, the sample flows through a conductivity cell (0.1 to 1000 micromhos/cm and through a ball valve bored out to 0.10 milliliter volume. After flow through the sample panel is established, the ball valve is rotated 90° and a syringe, connected to a line external to the panel, is used to flush the sample plus a measured volume of diluent (generally 10 milliliters) through the valve and into the sample bottle. This provides an initial dilution of up to 100:1. The sample bottle is contained in a shielded cask and remotely positioned on the sample needles through an opening in the bottom of the sample enclosure. Alternately, the sample can be diverted through a 70 milliliter bomb to obtain a large pressurized volume. This 70 milliliter volume can be circulated and depressurized into a gas sampling chamber. A 15 milliliter gas sample can then be obtained through a hypodermic needle for gas chromatographic and radioisotopic analyses of the dissolved gases associated with the 70 milliliter liquid volume. Ten milliliter aliquots of this degassed liquid can then be taken for off-site (or on-site depending on activity level) analyses which require a relatively large undiluted sample. This sample is obtained remotely using the large volume cask and cask positioner through needles on the underside of the sample station enclosure.

X.1.21.3.2.4.c Sample Station Ventilation

The sample station enclosure will be vented to secondary containment via the main steam line tunnel. Ventilation is motivated by differential pressure between the turbine and reactor buildings. The ventilation rate required for heat removal during operation is about 40 scfm. The ventilation duct is sized for less than 100 scfm at 1/4 inch of water differential pressure when the enclosure is opened for maintenance. Standby air flow will be about 13 scfm and can be reduced by taping all

openings. A pressure gauge is attached to the sample station enclosure to monitor the pressure differential between the enclosure and the general sampling area in the turbine building. This will assure the operator that airborne activity in the sample enclosure will be swept into secondary containment.

X.1.21.3.2.4.d Sample Station Sump

The sample station is provided with a sump at the bottom of the sample enclosure which will collect any leakage within the enclosure. This sump can be isolated and pressurized, discharging into the sample station liquid return line to and hence into the suppression pool.

X.1.21.3.2.4.e Sample Handling Tools and Transport Containers

Appropriate sample handling tools and transporting casks are provided. Gas vials are installed and removed by use of a vial positioner through the front of the gas sampler. The vial is then manually dropped into a small shielded cask directly from the positioning tool. This allows the operator to maintain a distance of about three feet from the unshielded vial. This cask provides about 1-1/8 inches of lead shielding. A 1/8 inch diameter hole is drilled in the cask so that an aliquot can be withdrawn from the vial with a gas syringe without exposing the analyst to the unshielded vial.

The particulate and iodine cartridges are removed via a drawer arrangement. The quantity of activity which is accumulated on the cartridge is controlled by a combination of flow orificing and time control of the flow valve opening. In addition, the deposition of iodine is monitored during sampling using a radiation detector installed in the sample station next to the cartridge. These samples will hence be limited to activity levels which will not require shielded sample carriers.

The small volume (diluted) liquid sample cask is a cylinder with a lead wall thickness of about two inches. The cask weighs approximately 65 pounds and has a handle which allows it to be carried by one person.

The 10 milliliter undiluted sample is taken in a 700 pound lead shielded cask which is transported and positioned by a four-wheel dolly. The sample is shielded by about 5-1/2 inches of lead.

X.1.21.3.2.4.f Sample Station Power Supply

The PASS isolation and control valves, sample station control panels, and auxiliary equipment are connected to an Instrument AC Distribution Panel which is powered from an Engineered Safeguard System (ESS) bus. Following loss of off-site power, the ESS bus is powered from the on-site diesel generators and backed up by batteries. The Reactor Building Closed Cooling Water System, which is needed for the sample coolers, is also powered from the emergency diesel generators following loss of off-site power. Compressed air for the air-operated valves comes from compressed air cylinders, thus eliminating any dependence on the plant compressed air system.

X.1.21.3.3 Description of Sample Preparation/Chemistry and Nuclear Counting Facilities

After the samples are obtained from the sample station, they will be transported to a sample preparation/chemistry area. There they will be diluted as necessary and appropriate aliquots taken for chemical and radioisotopic analyses. The radioisotopic analysis will be done in a separate counting area where background radiation can be kept to a minimum. Two different facilities will be available to plant personnel to perform the above tasks. The primary facility is the existing chemistry laboratory and counting room which is at elevation 676, the ground level of the control structure. A backup sample preparation/chemistry area and counting room will be built as part of the Emergency Operations Facility (EOF) which is located 2500 feet south-west of the control structure. In addition to these on-site and near-site facilities, which are intended to handle the gas samples and the diluted liquid samples, prior arrangements will be made with an independent off-site laboratory for analysis of the undiluted 10 ml liquid samples.

X.1.21.3.3.1 On-Site Chemistry Laboratory and Counting Room

The plant shielding study results, presented in Section X.1.20.3 show that following an accident, the chemistry laboratory will be a Zone III area (≤ 100 mR/h). Therefore, the existing facilities will be accessible at least for intermittent use following an accident. The most direct route between the sample station and these facilities is through areas of the turbine building which should be Zone I areas (≤ 15 mR/h) following an accident. The chemistry laboratory is or will be equipped to provide the capability to handle the gas samples and the 0.1 ml diluted liquid samples. The maximum activity of these samples will be 0.7 Ci and 0.3 Ci, respectively, using one-hour decay and the fractional releases of core inventory specified by NUREG-0578 (see Section X.1.21.3.5).

The laboratory will maintain a dedicated inventory of items such as lead bricks for shielding, gas syringes, gloves, reagents for analyses, etc., which will be needed in case of an accident. The laboratory will be equipped with a gas chromatograph, pH meter, conductivity meter, turbidimeter and other instrumentation needed to perform the required analyses. This equipment however, may not be dedicated exclusively to post-accident analysis. Supplied air or self-contained breathing masks will be available in the event of high activity levels in the ventilation supply or accidental spills in the laboratory.

The existing counting facility located adjacent to the chemistry laboratory is well equipped to handle the gamma spectra analyses required for post-accident samples. The counting room is equipped with two Ge (Li) detectors with four inch lead shields connected to a computer based analyzer system. The system has automatic peak search and isotope identification capabilities. The Ge(Li) detector and shelf assembly in the lead shield can be well isolated and the capability to purge the volume within the shield with compressed gas will be provided. This will help

prevent atmospheric noble gas activity released during an accident from swamping the detector.

X.1.21.3.3.2 EOF Sample Preparation/Chemistry and Counting Facilities

The sample preparation and counting rooms located in the near-site EOF will serve as backups to the on-site facilities. The EOF is 2500 feet from the control structure and is directly accessible from the site by road. Travel time from the sample station to the EOF will be less than 30 minutes. The backup facilities will be activated whenever the on-site facility becomes inaccessible or if additional lab space or counting equipment is needed to handle the increased work load in the on-site facility resulting from an accident. The sample preparation/chemistry room will be furnished with a radioisotope laboratory hood, about 14 feet of laboratory cabinets and benchtop working space, a small sink draining to a removable carboy, and at least a 5-gallon supply of demineralized water in plastic carboy mounted on the wall over the sink. The hood will be equipped with a HEPA filter unit. Although some analytical instrumentation may be kept in this room, it is not meant to completely duplicate that in the on-site laboratory. However, the facility will be fully equipped to handle the necessary dilutions and manipulations to prepare samples which come directly from the sample station for gamma spectroscopic analysis. Additional instrumentation for the required chemical analyses will be brought from the on-site laboratory as needed. Chemical reagents, glassware and other miscellaneous equipment will be stocked in the facility. A supply of lead bricks will also be kept in this room for use as temporary shielding. A lead brick cave for storage of samples will also be provided. The EOF counting room will contain as a minimum a high resolution gamma-ray spectrometer system. The system will be capable of characterizing and quantifying the gamma activities of reactor coolant and containment atmosphere samples. The intent is to make this system similar to the on-site system.

The EOF will have its own diesel generator which will be capable of supplying the electrical power needs for the facility during loss of off-site power.

X.1.21.3.3.3 Arrangements for Off-Site Analyses

A key part of the SSES approach to post-accident sampling is the establishment of prior arrangements with an off-site independent laboratory for confirmatory and supplemental analyses. The capability of the off-site laboratory will also be used to meet the requirement for chloride analysis. The reason for using the off-site laboratory for chloride and as a backup for other analyses is to prevent having to handle and analyze undiluted coolant samples which may have activity levels in the curie per milliliter range. The on-site and EOF facilities are not designed to handle sources of this magnitude. The analyses of undiluted samples can be done in a safer manner by laboratories with facilities and personnel specifically built and trained to handle high-activity sources. The following is a description of

the significant features being requested of the off-site laboratory:

- a) A formal mechanism will be established to allow for initiation of post-accident services at any time (24 hours/day).
- b) Written procedures will be established, controlled, and maintained for each of the analyses described in Table X.L.21-1. The analysis procedures must be qualified for use at the activity levels given in the table. This requirement may be satisfied by referencing the appropriate literature, by calculations, or by undertaking a testing program.
- c) Laboratory equipment and facilities for the required analyses must be available and maintained in working order such that analyses may be completed within 24 hours of the receipt of the sample.
- d) Provision will be made for the practice or exercise of each aspect of the off-site analysis work at the option of the utility.
- e) Equipment will be available for the timely transmission and receipt of information and results (telecopier and/or telex)
- f) The laboratory will be operational for at least chloride analysis by fuel load.

X.1.21.3.4 Summary Description of Procedures

X.1.21.3.4.1 Sample Collection and Transport Procedures

After a decision is made to obtain a sample, the designated sample station operators (2) will proceed to the sample station with the necessary equipment.

Since all the post-accident sample lines (except for the secondary containment atmosphere) tap off-lines which are isolated following a containment isolation signal, the sample station operator must confirm with the control room that the necessary isolation valves are open. (A telephone extension to the control room will be installed close to the sample control panels for this purpose). The control room must also activate the "Accident Sample Station Permissive Switch" to allow the sample station operator control of the "isolation and control valves" which are part of the post-accident sampling system.

After switching the "Master Shutoff Valve Control" to the "open" position, the operator is ready to open the valve(s) controlling flow from the desired source to the sample station. After opening the necessary control valve(s), the operator goes to the "sample station control panel". This panel controls the valves which are part of the piping station and those in the sample station enclosure in the turbine building.

Following a series of presampling checks and procedures including: adjustment of the enclosure damper to insure adequate cooling, checks of demineralized water and nitrogen supplies, flushing of system with demineralized water, draining the trap and sump, etc., the system is ready for obtaining the samples.

X.1.21.3.4.1.a Procedure for Obtaining Gas Sample

A standard 14.7 milliliter off-gas vial is placed in the gas vial positioner and inserted into the gas port on the front of the sample station. The desired sample location is selected by switch and the gas is circulated until the sample lines are flushed out with the gas being sampled. The vial and a small volume of tubing remains unflushed; however, the vial and this tubing volume are then evacuated. The sample is then drawn into the vial by pressing and holding a pushbutton switch. If cross-contamination is suspected due to incomplete evacuation of the vial, the evacuation and fill sequence can be repeated using air or nitrogen flush before taking the final sample, or the sequence can be repeated with the desired sample gas until the operator is assured that he has a representative sample. Following an air or nitrogen purge of the sample lines, the gas vial positioner is then removed from the port and the vial inserted into the gas vial cask. The length of the vial positioner allows the operator to remain about three feet from the vial during this operation. The cask has a 10-inch carrying handle and can be easily carried by one person down the stairs in the turbine building to the chemistry laboratory.

X-1.21.3.4.1.b Procedure for Obtaining an Iodine Particulate Sample

The desired filter cartridge(s) are placed into a cartridge retainer which is placed into the gas filter drawer. This drawer slides into an opening in the front of the sample station enclosure. The appropriate critical orifice is also chosen and placed in the cartridge retainer. This will determine the flow rate through the sampler and thereby control the amount of activity deposited on the filters. The operator then selects a sample location and flushes the sample line except for a short piece of tubing going to the sample drawer. However, this line can be flushed with air or nitrogen prior to sampling if cross-contamination between samples is suspected. In addition, as part of the normal sampling procedures, this line is flushed with air or nitrogen after completion of each sample sequence and should therefore be free of contamination for the following sample. The operator has the option of using an automatic timer to obtain samples with collection times between 0 and 30 seconds or of manually timing the sample for longer collection times. After starting the sample collection sequence, the operator will be able to follow activity buildup on the filters by observing the radiation level readout on the control panel from the probe inserted next to the cartridges in the gas sample panel. After sample collection is completed, the cartridges are evacuated using the vacuum from the gas pumps and then flushed with air or nitrogen to remove the noble gases. The filter drawer is withdrawn and the cartridge retainer with filters is placed in a plastic bag. The bag is then closed, and depending on the measured dose rate, it is carried by hand or attached to a pole and carried to the chemistry laboratory. No shielding cask is provided for these samples since it is possible to regulate the amount of activity deposited on them. In addition, for ease of counting, it is desirable to keep the activity levels on these samples low.

X-1.21.3.4.1.c Procedure for Obtaining a Diluted Liquid Sample

A 15 milliliter sample bottle with a neoprene cap is placed in the small volume cask which is then placed into a positioner attached to the sample station support frame. The sample needles are exposed by pulling out the lead shielding drawer under the sample station enclosure. The cask holding the sample bottle is then swung into position under the sample station and the sample bottle raised into position so the needles penetrate the neoprene cap. After aligning the proper valves, the sample lines from the selected source through the piping station are flushed with return flow to the wetwell. After these lines are flushed, the bypass valve in the piping station is closed and the sample flows to the sample station through the calibrated volume sample valve and back to the wetwell. After sufficient flushing, the calibrated valve is rotated 90° into alignment with the line to the sample bottle. A syringe filled with up to 10 ml of demineralized water is connected onto a line at the front of the sample station and this water is injected to wash the sample captured in the ball valve into the sample bottle. The syringe is then removed, filled with air, re-attached and the air injected to force out all water remaining in the line through the

sample needle and into the sample bottle. The rinsing action of the water followed by the air purge of the line should reduce cross-contamination between different samples. The calibrated sample valve is returned to the purge position and the sample lines, from the second cooler in the piping station, through the sample valve and back to the suppressor pool are rinsed with demineralized water. The operator then returns to the sample station, remotely lowers the sample bottle into the cask, screws a top plug with carrying handle into the cask. The cask is then carried down the stairs to the chemistry laboratory. Although one person can carry the cask, a pole with a hook in the middle will be available to allow two people to carry the cask more easily.

X.1.21.3.4.1.d Procedure for Obtaining a Large Liquid Sample (undiluted) and/or a Dissolved Gas Sample

A standard off-gas sample vial is placed in the gas vial positioner and inserted into the dissolved gas sampling port on the front of the liquid sample panel and a 15 milliliter sample bottle is placed in the large volume sample cask. The sample cask is positioned under the sample enclosure using a four-wheeled cart. The cask is raised into position and the sample bottle raised out of the cask and onto two needles using a remote mechanism. When the cask is properly positioned, the operators will be shielded from the sample during all subsequent operations. After attaining the proper valve lineup, the sample lines are first flushed through the piping station and then through the sample station lines including the 70 milliliter hold up cylinder and gas breakdown circulation loop. After completing the flush cycle a fixed volume of the pressurized liquid is isolated and a measured amount of a tracer gas is injected. The isolated volume is then depressurized by opening a valve to a previously evacuated 15 milliliter gas collection chamber. The operator now has the option of either collecting the dissolved gas sample in an evacuated vial or releasing it to the suppression pool atmosphere. If a dissolved gas sample is collected, it is handled and transported in the same manner as the containment gas sample discussed previously. The operator also has the option of collecting a 10 milliliter sample of the degassed liquid or allowing it to be flushed to the suppression pool during the subsequent demineralized water flush cycle. If a large volume sample is desired, it is drawn into the evacuated 14.7 milliliter sample bottle. To minimize cross-contamination, the system can be cycled several times through all the above steps before taking the final large volume sample. The dissolved gas and liquid sample system is then flushed with demineralized water to minimize radiation levels while removing samples from the station.

The sample bottle is then remotely lowered from the needles into the shielded sample cask which is lowered on the cart and pulled out from under the sample enclosure. A lead plug is then inserted in the opening of the cask and the cask can be easily moved to the elevator in the control structures using the positioning cart. By using this elevator no steps are encountered when moving the cask from the sample station to ground level. The shielding study results (X.1.20.3) indicate

that this elevator should be accessible from a radiation level standpoint. In case of loss of off-site power, the elevator will be out of service since no emergency power is provided. However, the undiluted sample is only essential for determining the chloride concentration which is not required until four days after sampling. This will allow a reasonable time for the restoration of off-site power. However, if after two days off-site power is not restored, arrangements can be made to lower the sample cask from the turbine operating floor to ground level through one of three open hatches. Since the undiluted sample is to be sent to an off-site laboratory, prior arrangements will be made to have a shipping container sent from the off-site laboratory or have one available on-site. The current intent is to have several shipping containers built which will hold the large volume casks, thus avoiding the exposure which would result from trying to transfer the sample from the sampling cask to another container.

X.1.21.3.4.2 Chemical/Radiochemical Procedures

X.1.21.3.4.2.1 Introduction

The Post Accident Sample System (PASS) provides a means of obtaining primary coolant, suppression pool, and primary and secondary containment air samples for radiochemical and chemical analysis following a major reactor accident. Because of the extremely high radioactivity levels associated with extensive fuel damage, the PASS and its auxiliary support was developed with the philosophy of providing the capability of obtaining the necessary samples and of performing on a timely basis those analyses, as required, for immediate plant needs, or as defined by regulatory requirements. Procedures and arrangements will be established for shipping samples to facilities having the experience and equipment appropriate to performing detailed and accurate chemical analyses on multi-Curie level samples.

The analytical procedures chosen will satisfy the philosophy of performing only those analyses as required for operational support, of minimizing personnel exposure and contamination hazards, and of depending upon outside analysis for extensive analysis and long-range operational needs. Tests were performed by General Electric to assess the effects of high fission product levels on the suggested analytical methods. The type of fuel damage associated with the release of megacurie quantities of iodine and other activities also has the potential for releasing kilogram quantities of stable or very long lived fission products. It is conceivable that the primary coolant might contain 10-20 ppm of iodide and bromide. Also, the release of a major fraction of the core inventory of cesium and rubidium may slightly raise the primary coolant pH. Such releases will also cause an increase in the coolant conductivity while radiolysis of the water will probably contribute to the formation of low levels of hydrogen peroxide. Depending upon the concentrations, these are all possible analytical interferences with the required analysis. Of these, the iodide/bromide interference with the chloride procedure is probably the most severe. However, since the requirement for chloride analysis will be satisfied by sending the samples to an off-site laboratory, the chloride

procedure being proposed for the on-site laboratory is only to obtain a rough upper limit. The effect of radiation interference have been generally evaluated and are summarized in Appendix A.

X.1.21-3.4.2.2 Sample Preparation

All sample bottles, iodine cartridges, etc., will be numbered or otherwise identified prior to sampling. This will eliminate unnecessary exposure as a result of handling high level samples for the purpose of attaching labels. A centralized logging system will be developed to keep track of sample aliquot identification, dilution factors, sample disposition, etc.

Liquid samples will be taken at the sample station in septum type bottles and transported to the analysis facility in lead containers. Sample aliquots are then taken from the septum bottles for analysis or further dilution. Aliquoting and transfer will be performed using shielded containers, or behind a lead brick pile. Calibrated hypodermic syringes will be used for aliquoting the higher activity samples. Tongs or other holding/clamping devices will be available for holding the sample bottle during the transfer and dilutions to reduce hand and body exposure. Unless prohibited by the intended analysis, dilutions will be done using very dilute (about 0.01N) nitric acid as the diluent to minimize sample plate-out problems.

Reactor coolant activity levels on the order of 1 to 3 Curies per gram would require a dilution factor of 1×10^5 , or larger, for gamma ray spectroscopy samples. As an example, a typical series of dilutions might be 0.1 ml (100 lambda) added to 10.0 ml at the sample station, followed by further diluting of 0.1 ml to 100 ml in the laboratory. An aliquot of 0.1 ml would then be taken from the second dilution for counting purposes.

Gas samples are taken at the sample station in the same 14.7 ml septum bottle used in the normal offgas sampler. A lead carrier is furnished with a small hole at the septum end so that a gas sample can be withdrawn from the carrier using a hypodermic syringe without having to handle the bottle.

Samples taken from the gas sample bottle will either be injected into a gas chromatograph for analysis or used to dilute the gaseous activity for gamma spectroscopy purposes. The dilutions will be performed in a manner analogous to the liquid samples. Fractional milliliter samples can be transferred to new 14.7 ml gas bottles without concern for sample leakage due to pressurization. For larger volume aliquots a gas syringe will be used to draw a partial vacuum in the bottle prior to sample transfer.

Since there is no initial dilution of the gaseous activity at the sample station, extensive dilution may be required in the laboratory.

X.1.21-3.4.2.3 Chemical Analysis

a. Introduction

The chosen procedures are not necessarily the most sensitive nor the most accurate. They were chosen primarily on the basis of simplicity, stability and availability of reagents, minimum radiation exposure, and least likely to cause major contamination problems. They have been tested for radiation sensitivity and are suitable for use at the PASS design basis source term of 2.8 Ci/gm, and where applicable, with the design basis 0.1 ml to 10 ml dilution at the sample station.

Other methods may be equally, or even better suited. At lower activity levels it may be preferable to use the normal laboratory procedures and equipment

b. Boron Analysis - Carminic Acid Method

The chosen HACH method closely follows the ASTM D3082-74, "Standard Test Method for Boron in Water, Method A - Carminic Acid Colorimetric Method." The HACH procedure is suggested because the reagents and standards are available in small quantities, are conveniently packaged, and can be quickly prepared. It is estimated that the complete analysis, including reagent preparation, can be performed in 40 minutes.

This method was tested to be satisfactory for use at the maximum expected activity levels. The analysis is designed for boron concentrations in the range of 0.1 to 10 ppm of boron. This sensitivity is particularly suited to the sample station's 0.1 ml to 10.0 ml dilutions since this corresponds to a range of 100 to 1000 ppm in the undiluted coolant.

c. Chloride Analysis - Turbidimetric Method (see also the discussion on conductivity)

The chosen method was developed by the General Electric Reactor Chemistry Training group. The procedure is very similar to a HACH Chemical Co. procedure, "Turbidimetric Determination of Trace Chloride in Water".

The minimum quantity of measurable chloride by this procedure is 0.5 ug. If 5 ml of the 0.1 to 10 ml primary coolant dilution is used for analysis, the minimum measurable concentration would be 10 ppm.

Using the 10 ml. direct primary coolant sample greatly increases the sensitivity for measuring chloride. A one ml of aliquot of this sample could be analyzed at the 0.5 to 1.0 ppm level.

Tests of the radiation sensitivity of the method showed that activity levels comparable to the PASS design basis source terms resulted in the equivalent of 1.8 ppm Cl⁻ in the primary coolant for the 0.1 to 10 ml dilution. This was deemed to be insignificant, as it is below the sensitivity limit, and more importantly, interference from the large amount of stable fission product halides potentially associated with the source terms will far out-shadow the radiation effect itself.

Tests were also performed on the addition of 500 ug of boron added to 0.5 to 20 ug of chloride. No interference was observed with the turbidimetric procedure.

d. Measurement of pH

pH indicator paper will be used for activity levels below 10% of the design basis source terms.

The irradiation tests indicated that at 10% of the design basis source terms, the color stability was adequate given only a drop of solution and less than a 5-minute exposure.

Using this method, pH measurements can be taken at the small volume sampler by placing a piece of the paper into the sample bottle and using an air filled syringe to blow several approximately 0.1 ml aliquots from the sample valve into the bottle to moisten the paper.

This type of sampling approach can also be used to obtain a small sample for possible electrochemical pH measurement. Lazar Research Labs, Inc. manufactures a micro-pH electrode which functions on microliter samples. This electrode or similar micro-probe is currently being evaluated for use at source term greater than 10% of design basis.

pH indicator paper can cover the range from pH 1-11 and distinguish differences of 0.25 pH units.

At very low conductivities, conductivity itself may be the best indicator of the pH. For instance, at 0.2 micromho/cm, the pH is bounded by 6.3 to 7.6, which is well within the technical specifications for normal operation. Thus, the conductivity should serve as an adequate indicator of pH as long as conductivity is sufficiently low that it is impossible to be outside the technical specifications limit.

e. Conductivity Measurements

The Post Accident Sample Station is equipped with a 0.1 cm⁻¹ conductivity cell. The conductivity meter has a linear scale with a six position range selector switch to give conductivity ranges of 0-3, 0-10, 0-30, 0-100, 0-300, and 0-1000 micromho/cm when using the 0.1 cm⁻¹ cell. This conductivity measurement system will be used to determine the primary coolant or suppression pool conductivity. During normal operation the BWR technical specifications require maintaining the primary coolant below one micromho/cm, and conductivity measurements are the primary method of coolant chemical control.

Conductivity measurements are, of course, non-specific, but they serve the important function of indicating changes in chemical concentrations and conditions. Perhaps even more important, in the case of the BWR primary coolant, the conductivity measurements can establish upper limits of possible chemical concentrations and can eliminate the need for additional analyses. For example, if the conductivity is measured to be 5.0

micromho/cm, the upper limit on the chloride concentration is 1.4 ppm.

The conductivity measurement can also be used to bound the possible range of pH values. This relationship is shown in Figure X.1.21-4.

At a specific conductance of 1.0 micromho/cm the pH must be between 5.6 and 8.7. Furthermore, a pH of 5 and a specific conductance of 1.0 is an impossible situation since the conductivity is not large enough to support a hydrogen ion concentration of $10^{-5}M$. Figure X.1.21-4 can, therefore, be used to great advantage in checking on agreement between pH and conductivity measurements and possibly eliminating the need for pH measurement if the conductivity is very low. In general, accurate pH measurements are difficult to make in very low conductivity water as the impedance of the solution may be significant compared to the impedance of the measuring device, and conductivity measurements are usually considered a better indicator of the maximum H^+ or OH^- concentration.

X.1.21.3.4.2.4 Radiochemical Analysis--Gamma Ray Spectroscopy

After the samples have been brought to the chemistry laboratory and appropriately diluted, they can be carried without shielding to the counting room which is adjacent to the chemistry laboratory. The appropriate dilution factors will be somewhat dependent upon the detector and shelf arrangements available. A prior determination of the maximum desirable dose rates for the various shelf configuration will be made to minimize this problem. The present high resolution, high efficiency Ge(Li) detectors, coupled with the multichannel analyzers, and computer data reduction in the on-site counting room will easily handle the analysis of these samples.

The gas samples will be counted in the standard off-gas sample vials and the liquid samples will be counted in the standard sample bottles used during normal operation since calibration curves for these geometries will be available and regularly updated. Calibration curves will also be available for the particulate filter and iodine cartridge geometries. In general, the counting of the post-accident samples will follow the normal counting room procedures. A special post-accident library will have to be developed for use by the computer peak search and identification routine to supplement the normal isotope library. The post-accident peak search and identification library will contain the principal gamma rays of the following isotopes in addition to the standard activated corrosion products:

Noble gases:	Kr-85, Kr-85m, Kr-87, Kr-88, Xe-131m, Xe-133, Xe-133m, Xe-135
Iodines:	I-131, I-132, I-133, I-135
Cesiums:	Cs-134, Cs-137
Others:	Ba/La-140, Ce-141, Ce-144, Ru-106, Te-129, Te-129m, Te-131, Te-131m, Np-239

If the levels of noble gases in the ambient atmosphere surrounding the detector is high enough to cause significant interference or overload the detector, a compressed air or nitrogen purge of the detector shield volume will be maintained.

X.1.21.3.4.2.5 Gas Analysis-Gas Chromatography

A gas chromatograph will be used to measure hydrogen, nitrogen and oxygen concentrations in containment atmosphere and dissolved gas samples. The gas chromatograph will be located in the chemistry laboratory and vented to a laboratory hood. Samples for gas analysis will be used undiluted from the sample vials and injected into the gas chromatograph. Since the sample sizes needed for the analysis will range from 0.1 to 1 milliliter, it may be necessary to place a temporary lead shield around the instrument. The analysis of the drywell, wetwell, and secondary containment samples will be done using standard procedures. Calibration curves for the instrument will be prepared and periodically updated.

In the mixture of hydrogen, oxygen, nitrogen, and possibly Krypton, the analysis sensitivity should be sufficient to detect any of these constituents at the 0.1% by volume level, or lower, providing the Kr:N ratio in this mixture does not vary by more than a factor of 10 in either direction. At the 0.5% level the analysis should be accurate to within 20% of the measured concentration. At concentrations above 1%, the analysis should be accurate to within 5% of the measured concentration.

The dissolved gas sample will contain krypton or other tracer in addition to oxygen, nitrogen, and possibly hydrogen. Although the analysis of the dissolved gas sample for hydrogen should be reliable, the analysis for oxygen and nitrogen presents several difficulties. The major problem is due to the incomplete evacuation of the sample vial which initially contains air. A partial vacuum (4-5 psia) is drawn on the vial before the sample is taken, however, this leaves a significant amount of air in the vial. This may not be a significant problem if the amount of dissolved oxygen or nitrogen stripped from the coolant is large compared to that left in the evacuated vial, since a correction can be made based on the pressure measurements taken before and after taking the sample. However, dissolved oxygen and nitrogen is not required by NUREG-0737, which states that determination of dissolved hydrogen gas in the coolant is adequate. In case the need should arise, a procedure will be established to tap off the sample line in the sample station and run this to an in-line oxygen monitor. The flow would then return to the liquid return line to the wetwell.

X.1.21.3.4.3 Storage and Disposal of Sample

Short term sample storage areas will be provided in the chemistry laboratory and counting rooms in both the on-site and EOF facilities. An area for long term storage of the samples will be designated at a later date. Low level wastes generated by the chemistry procedures will be flushed to radwaste in the on-site chemistry laboratory and collected in removable carboys in the EOF. The carboys will then be taken to an on-site location for

disposal to the radwaste system. Ultimate procedures for disposal of the samples will be determined later; however, after a sufficiently long decay period, the activity levels will be significantly reduced. This will ease exposure problems during disposal.

X.1.21.3.4.4- System Testing and Operator Training

To ensure the long-term operability of the PASS, it will be tested semiannually. Samples will be taken from all gas sample points; however, the number and type of liquid samples taken will be based on the operating status of the reactor at the time. The semiannual functional testing will also serve to maintain operator proficiency. In addition to the scheduled tests, the system will be used for operator training on an as-needed basis.

To ensure an adequate pool of qualified PASS operators, a formal training program will be established. This program will be part of the chemistry technician qualification program. All plant chemistry technicians and chemistry management personnel will be required to show competence in the operation of the sample station and the chemical analysis procedures.

X.1.21-3.5 Dose Rate Analysis

Radioactivity source terms were calculated for use in design of the Post Accident Sampling System (PASS) shielding. These source terms are for a Loss of Coolant Accident (LOCA) assuming a fuel release of fission product activity as defined by NUREG 0578. Source terms were calculated for a three year reactor operation at 3293 MWt. For the purposes of specifying shielding design source terms, a decay period of one hour has been assumed between reactor shutdown and initial sampling. Although there is no decay period specified in NUREG 0578 the source terms calculated for PASS still result in a conservative design. The PASS is designed to limit operator whole body exposure to 100 mRem as a result of taking and analyzing the sample. NUREG 0737, on the other hand, limits the operator exposure to less than 5 Rem whole body exposure for the entire operation.

Using a one hour decay and the fractional releases of core inventory specified by NUREG 0578, the primary coolant and primary containment atmosphere fission product concentrations are calculated to be 2.6 Ci/gm and 0.046 Ci/cc, respectively. Using these fission product concentrations, gamma radiation source terms were determined in terms of MeV/sec for ten gamma energy groups. These radiation source terms were used for shielding design and sample dose rate calculations. Assuming point sources, the calculated dose rates per unit volume of coolant and containment atmosphere are 125 R/h/gm and 1.8 R/h/cc at 4 inches, respectively.

Thus, the 0.1 milliliter reactor sample would have a maximum exposure rate of about 12 R/h at 4 inches and 14.7 milliliter vial of containment atmosphere at STP would have an exposure rate of 25 R/h at 4 inches. Using the calculated source terms, dose rate estimates resulting from activity in the sample station and sample casks were calculated for various distances. The results are given in Table X.1.21-2. These dose rates will be used in a time-motion study to estimate the total integrated dose expected during sampling and analysis after the sample station is operational.

TABLE X.1.21-1

Chemical and Radiochemical Analytical Capabilities
Required of Off-Site Laboratory

A. Liquid Samples

The laboratory must be capable of handling up to 10 ml of undiluted reactor coolant/suppression pool water with activity levels up to 3.0 curies per ml. The laboratory will be required to perform the following analyses within the range and accuracy indicated.

1. Radioisotopic Analysis

a. Gamma-Ray Spectroscopy

Identify and quantify with accuracy of $\pm 20\%$ all isotopes which have gamma-ray peaks in the spectrum from 50 to 5000 keV with a net peak area of greater than 5% of the total spectrum counts within a ± 5 times full width at half maximum (FWHM) band about the centroid of the peak. The spectrometer system must be capable of analyzing samples with total concentration of gamma-ray emitting isotopes as low as 0.01 microcuries per ml.

b. Beta Activity

Gross beta and quantitative determination of Sr-89 Sr-90 (up to 10 days permitted for completion of this analysis).

c. Alpha Activity

Gross alpha count and relative alpha activities by alpha spectroscopy.

d. Uranium and Plutonium

Identify and perform semiquantitative analyses for these elements.

2. Conductivity

Range: 0.1 to 10,000 micromhos per cm.
Accuracy: $\pm 20\%$

3. pH

Range: 1 to 13
Accuracy: ± 0.3 pH units

4. Chloride

Range: greater than 50 ppb

Accuracy: $\pm 10\%$ if greater than 500 ppb
 ± 50 ppb if less than 500 ppb

5. Boron

Range: 0.1 to 10,000 ppm

Accuracy: $\pm 50\%$ if less than 1 ppm
 $\pm 20\%$ if greater than 1 ppm and less than
100 ppm
 $\pm 5\%$ if greater than 100 ppm

B. Gas Samples

Gas samples will be obtained from the following sources: drywell, wetwell, secondary containment, and dissolved gases from liquid samples. The laboratory must be able to handle 15 ml gas samples with activity levels up to 0.06 curies per ml. The laboratory will be required to perform the following analyses within the range and accuracy indicated:

1. Radioisotopic analysis by gamma-ray spectroscopy.
See Section A.1.a for requirements.

2. Elemental Analysis

Identify and quantify by volume % the following: Hydrogen, oxygen, nitrogen and Kr (spike added to dissolved gas samples). The analysis sensitivity should be sufficient to detect any of these constituents at the 0.1% by volume level. At the 0.1% level the analysis should be accurate to $\pm 20\%$. At concentrations above 0.5% the analysis should be accurate to within $\pm 5\%$.

C. Particulate and Iodine Cartridge Samples

The laboratory must be able to handle and perform gamma-ray spectroscopic analysis on particulate, silver zeolite, and charcoal filter cartridges. The maximum activity anticipated for any of these cartridges is 0.1 curies. The analysis should be able to identify and quantify with an accuracy of $\pm 50\%$ all isotopes which have gamma-ray peaks in the spectrum from 100 to 4000 keV with a net peak area of greater than 5% of the total spectrum counts within a ± 5 times FWHM band about the centroid of the peak.

Table X.1.21-2 Dose Rates from PASS and Transport Casks⁽¹⁾

Source	Thickness of Lead Shielding in Inches	Dose Rate in mR/h		
		0 ft	3 ft	8 ft
Liquid Sampler ⁽²⁾	.6	5300	310	55
Gas Sampler ⁽²⁾	2	8800	220	110
Small Volume Cask (0.1 ml sample)	2	1600	4	<1
Large Volume Cask (10 ml sample)	5 1/2	260	5	<1
Gas Cask (14.7 c.c. sample)	1 1/8	5500	50	<1

(1) Based on source term 1 hour following shutdown

(2) Dose rates from the sample panels will be present for only a few minutes while the sample is flowing.

APPENDIX A

IRRADIATION EFFECT ON ANALYTICAL PROCEDURES*

*Test Performance

Conductivity and pH: H. L. Kenitzer
Chloride and Boron : C. R. Judd

INTRODUCTION

Some scoping tests were performed to study the effect of high fission product levels on the proposed analytical procedures. The core inventory of individual nuclide beta energies in terms of MeV/second/MWt after one hour decay was taken from the same CINDER run as used to calculate the PASS activity source terms. The NUREG-0578 release fractions were used to determine the fraction of the core inventory dissolved in the primary coolant. The "all other" category was ignored as at a 1% release fraction the dose contribution from these nuclides is negligible compared to the 50% halogen and 100% noble gas releases. The results are shown in Table 1. For the sake of simplicity, it was assumed that the gamma energy deposition in the sample was negligible compared to the beta energy deposition. It was also assumed that 100% of the beta energy was absorbed in the sample. The net result, 1.92×10^6 Rads/hr, is conservative as the gamma energy absorption for small samples would be much less than the beta energy escaping the solution.

Dose rates approaching 2×10^6 R/h are available in the VNC Co-60 irradiation facility. At 93 ergs/g/R/h, this corresponds to 1.8×10^6 Rads/hr, and approximates the calculated maximum energy deposition possible for the reactor coolant. Tests were run to determine the effects of radiation on the conductivity, pH, chloride, and boron analytical procedures. The true energy deposition within the irradiated sample holders was determined by Fricke dosimetry using the sample holders as dosimeters. Except for conductivity and pH measurements, the dose rates were considerably larger than would be encountered with the PASS source terms. These higher dose rates were used to achieve a better measurement of the radiation effect, and it was then assumed that this effect would be linear with dose rate. It is hoped to verify this assumption in later studies.

TABLE 1-
CALCULATION OF COOLANT BETA DOSE
RAD/HR AT 1 HR DECAY

	1	2	3
	β MeV/s (a) per Mwt at One Hour	Col.1*F(b) β MeV/s per Mwt, T= 1 hr Released	Col.2*M(c) Coolant Rad/Hr
I-131	1.78E14	8.88E13	6.28E4
I-132	7.26E14	3.63E14	2.57E5
I-133	8.15E14	4.08E14	2.89E5
I-134	1.06E15	5.30E14	3.75E5
I-135	6.67E14	3.33E14	2.36E5
Br-83	2.04E13	1.02E13	7.22E3
Br-84	7.72E13	3.86E13	2.73E4
Xe-133	2.06E14	2.06E14	1.46E5
Xe-135	1.16E14	1.16E14	8.18E4
Xe-138	5.85E13	5.85E13	4.14E4
Kr-85	2.55E12	2.55E12	1.80E3
Kr-85 ^m	4.95E13	4.95E13	3.50E4
Kr-88	1.33E14	1.33E14	9.40E4
Kr-87	3.71E14	<u>3.71E14</u>	<u>2.63E5</u>
		2.71E15	1.92E6

(a) From CINDER run 8/18/80, SNUMB 2100T, Core Inventory
3 yr burn

(b) F = 1.0 for noble gases and 0.5 for halogens

(c) $M = \frac{3293 \text{ Mwt} \cdot 3600 \text{ s/h} \cdot 1.6E-6 \text{ erg/MeV}}{(2.68E8 \text{ g}) \cdot (100 \text{ erg/g/Rad})} = 7.077 \times 10^{-10}$

CONDUCTIVITY

A 0.1 cm Balsbaugh conductivity cell and stainless steel holder was irradiated at various positions in the 4½-in. dia. Co-60 irradiation tube. The flow path from this conductivity cell was connected to a 0.1 cm Beckman conductivity cell downstream of the cell under irradiation. Both static and flowing irradiation tests were performed. The flow tests were performed at ca. 125 cc/min with a 3 to 4 min flow delay between the Balsbaugh and Beckman cells. The Beckman cell, therefore, served to determine if there were any relatively long lived radiation products remaining in solution. An in-line thermometer was mounted in the flow system downstream of the Beckman cell.

CONDUCTIVITY OF PURE WATER

A Gelman Water-1^R purification unit was installed in the conductivity cell flow loop. The output conductivity of the water from the purification unit was 0.055 $\mu\text{S}/\text{cm}$, as indicated by the purification units built in the conductivity meter. The water flow was from the purification unit through the two conductivity cells under study and back to the reservoir of the purification unit. The output of the conductivity meter associated with the irradiated cell was continuously recorded. The highest radiation field in the 4½ in. irradiation tube, as measured by a Victoreen R Meter, was 7.4×10^5 R/h. The actual cell energy absorption rate at this position was determined by removing the conductivity element and using the cell holder as a Fricke dosimeter container. The result, 9.8×10^5 Rads/hr was also used to convert the R/h measurements at the other elevations to Rads/hr by assuming a constant ratio between the field intensity and the energy absorption. (This is not strictly true as the photon energy distribution varies with the elevation in the irradiation facility. Consequently, the fraction of the photons penetrating the stainless steel cell holder will vary slightly.)

The results of these experiments are summarized in Table 2. There was apparently some pickup of impurities from the flow loop materials as 0.10 $\mu\text{S}/\text{cm}$ was the lowest loop conductivity observed. The 0.06 $\mu\text{S}/\text{cm}$ at the output of the purification unit was confirmed by connecting one of the flow cells immediately at the output.

In the case of the flowing measurements, there was a steady increase in conductivity from 0.11 to 0.65 $\mu\text{S}/\text{cm}$ as the irradiation intensity increased from 1.3×10^4 to 6.6×10^5 Rads/hr. The conductive species which were formed were relatively stable as there was little difference between the conductivity as measured at the irradiated cell and the downstream cell. In fact, when the flow was stopped and the conductivity of the irradiated cell was allowed to come to equilibrium, the cell could be removed from the radiation field and the conductivity would remain constant, at least up to several hours, the longest

TABLE 2

CONDUCTIVITY OF PURE WATER UNDER IRRADIATION

		Temp. °F	IRRADIATED CELL (0.1 cm Balsbaugh) μS/cm	UNIRRADIATED CELL (0.1 cm Beckman) μS/cm
No Irradiation	Flow	63.5	0.10	0.11
	No Flow	--	0.14	0.11
1.3x10 ⁴ Rad/hr	Flow	65.0	0.11	0.12
	No Flow	--	1.4	--
6.6x10 ⁴ Rad/hr	Flow	65.5	0.13	0.14
	No Flow	--	2.2	--
1.3x10 ⁵ Rad/hr	Flow	65.8	0.18	0.20
	No Flow	--	2.2	--
2.6x10 ⁵ Rad/hr	Flow	66.0	0.31	0.37
	No Flow	--	2.1	--
6.6x10 ⁵ Rad/hr	Flow	64.5	0.65	0.64
	No Flow	--	1.8 to 1.4*	--
9.8x10 ⁵ Rad/hr	Flow	65.5	0.65	0.66
	No Flow	--	1.7**	--

* Still dropping slowly after 5 min

** Very steady value

period observed. The flow was secured at each irradiation intensity and the conductivity was monitored until a steady-state condition was attained. From the data in Table 2 it would appear that a maximum conductivity is attained at about 2.2 $\mu\text{S}/\text{cm}$, and that the conductivity diminishes with increasing radiation intensity. The steady-state difference in cell behavior at 6.6×10^5 and 9.8×10^5 Rads/hr is unexplained.

It is suspected that the conductivity is due to the formation of hydrogen peroxide, but this has not been confirmed. It is obvious that there will be some radiation effect on the conductivity at very high fission product concentrations. This does not appear too serious, however, as 2.2 $\mu\text{S}/\text{cm}$ corresponds to a NaCl concentration of 1.0 ppm. The concentration of stable fission products, particularly I-127 and I-129, associated with the high Curie concentrations will at the same time result in considerably higher conductivities.

CONDUCTIVITY OF 10 ppm CHLORIDE (Cl^-) SOLUTION

Irradiation tests were performed to determine the radiation effect on the conductivity of a dilute NaCl solution. It was anticipated that if the pure water conductivity increases under irradiation were due to the formation of H_2O_2 , this might be suppressed by the presence of the Cl^- ions. In this experiment the NaCl solution was pumped from a reservoir through the two conductivity cells and back to the reservoir. A common conductivity bridge was used to alternately determine the conductance of each cell, and thereby eliminate any bias between different bridges. The testing was done at the highest available irradiation level, 9.8×10^5 Rads/hr. The solution temperature, as indicated by a flow thermometer downstream of the unirradiated cell, ranged from 59.5 to 60.2°F. Several alternate conductivity readings were taken on each cell approximately five minutes after each change in condition, and when the cell conductances had reached a steady value. The average result for each condition is given in Table 3. The difference between the cell readings for any given set of conditions is attributed to errors in the stated cell constants. The conductivity of the flowing stream increased by approximately 0.6 $\mu\text{S}/\text{cm}$ for both cells before and after irradiation, which may be the result of the generation of some long lived species. This possibly is supported by the Beckman cell, which although located outside the radiation field, showed a 0.6 $\mu\text{S}/\text{cm}$ increase in conductivity during irradiation. The puzzling observation was the large drop in conductivity of the static solution during irradiation. This should be investigated further.

TABLE 3

CONDUCTIVITY OF 10^5 ppm Cl^- SOLUTION IN NaCl

		Unirradiated Cell (0.1 cm Beckman) <u>$\mu\text{S}/\text{cm}$</u>	Irradiated Cell (0.1 cm Balsbaugh) <u>$\mu\text{S}/\text{cm}$</u>
No Irradiation	Flow	27.7	32.1
	No Flow	27.7	32.0
	Flow	27.4	32.7
9.8×10^5 Rads/hr	Flow	27.9	33.6
	No Flow	28.0	25.1
	Flow	28.0	34.0
No Irradiation	Flow	28.0	33.4
	No Flow	28.1	32.2

pH

Solutions of pH 3.8 and 10.0 were made up using HCl and NaOH, respectively. Lo-Ion^R pH test paper was placed in aliquots of these solutions and the solution was inserted into the 9.8×10^5 Rads/hr position (as determined by Fricke dosimeter). A 10.0 minute exposure for a total dose of 1.6×10^5 Rads completely destroyed the color in the acid solution and reduced the color intensity of the basic solution to a pale green. This test was then repeated using a 1.0 min exposure at the same intensity level for an exposure of 1.6×10^4 Rads. This exposure shifted both solutions about 1/2 pH unit to the more acid side. The results would not necessarily indicate that pH indicator paper cannot be used at the highest dose rates, but more importantly, that the paper cannot be immersed in a relatively large volume of solution. If the paper were merely moistened by a drop or so of solution, most of the beta particles would escape the paper with little energy deposition and the paper would not be surrounded by a highly radioactive solution with the resultant beta field and water excitation products. This subject is still under consideration.

At source terms on the order of 10% or less of the maximum*, the irradiation effect, for even an immersed strip, would be tolerable at exposures less than 5 min, as it would result in less than an 0.5 pH unit shift.

*The originally calculated source term was 1.9×10^6 Rads/hr. Thirty-five percent of this source intensity, however, is due to noble gases which would escape solution in the sampling process. A 10% source term for pH measurement would then be approximately 1.2×10^5 Rads/hr and a 5-min exposure would correspond to a 1×10^4 Rad energy absorption, which is approximately the exposure causing a 0.5 pH shift.

Some measurements were also made to determine the effect of irradiation on pH electrodes. Long leads are needed on the pH electrodes in order to reach in the Co-60 irradiation facility, and these electrodes were not available. We intend to order some new electrodes and will continue this study. In the meantime, we have irradiated a glass membrane pH electrode to 1.6×10^5 Rads at a 9.85×10^5 Rad/hr intensity and found it still functions following irradiation.

TURBIDIMETRIC CHLORIDE PROCEDURE

Using the maximum source term of 2×10^6 Rads/hr, ml diluted primary coolant sample would have an internal beta exposure of 2×10^4 Rad/hr. The turbidimetric method calls for a total volume of 25 ml. Therefore, even if the entire 10 ml of diluted sample were used, the dose rate of the final analysis solution would be less than 8×10^3 Rad/hr. Test solutions containing 0, 1, 5, and 20 μ gm of chloride in 25 ml were processed through the chloride test methods in pairs. During the 15-min turbidity-formation period, one sample of each set was irradiated at an absorbed dose rate of 4.4×10^5 Rad/hr as determined by Fricke dosimetry. The maximum observed radiation effect was a difference of about 10 turbidity units between the irradiated and unirradiated 1 μ gm Cl^- solutions. This difference is equivalent to about 10 μ gm of chloride in the 25 ml of solution being processed. Assuming this increase in turbidity is proportional to the dose, the maximum effect would be $(10 \mu\text{gm})(8 \times 10^3 / 4.4 \times 10^5) = 0.18 \mu\text{gm}$. If only 0.1 ml of reactor water were used for the original sample, this would be equivalent to 1.8 ppm of Cl^- in the primary coolant. This error is probably insignificant as the interference from all the stable iodine associated with the high radiation intensity is likely to be far larger.

The test data also indicated that as little as 5 μ gm of Cl^- in the 25 ml of test solution inhibits the formation of the radiation-induced turbidity. It is suspected that the increased turbidity is due to the precipitation of silver peroxide and the 5 μ gm Cl^- inhibited the formation of hydrogen peroxide. In any event, it was concluded that the test method is useful for highly radioactive solutions above the 10 ppm level, or for less radioactive solutions above the 1 ppm level. For low activity samples which do not need to be diluted and where at least a 1 ml of sample is available, the method is useful above the 100 ppb level.

CARMINIC ACID BORON ANALYSIS

Using the maximum source term of 2×10^6 Rad/hr, an 0.1 ml to 10 ml diluted primary coolant sample would have an internal beta exposure of ca. 2×10^4 Rad/hr. The colorimetric method calls for a total volume of 25 ml. Therefore, even if the entire 10 ml of diluted solution were used, the dose rate of the final analysis solution would be less than 8×10^3 Rad/hr. Test solutions containing 0 and 20 μgm of boron were processed through the boron test methods in pairs. During the 40-min color development phase, one sample of each pair was irradiated at an absorbed gamma-radiation dose level of 4.4×10^5 Rad/hr as determined by Fricke dosimetry. The maximum irradiation effect observed was a difference of 0.854 absorbance units between the irradiated and unirradiated blank solutions. This difference is equivalent to about 27 μgm of boron in 25 ml of solution being processed. Assuming this difference in absorbance is proportional to the dose, the maximum effect would be $(27 \mu\text{gm})(8 \times 10^3 / 4.4 \times 10^5) = 0.49 \mu\text{gm}$. If only 0.1 ml of reactor water were used for the original sample, this is equivalent to a 5 ppm error in the primary coolant analysis. This error is totally negligible in terms of the levels of boron required for reactor shutdown.