

PSE&G RESPONSE TO NUREG 0737, ITEM II.B.3

NRC EVALUATION CRITERIA GUIDELINES

FOR

POST ACCIDENT SAMPLING SYSTEMS

AUGUST, 1983

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1.0 INTRODUCTION

This submittal documents how PSE&G has satisfied each criterion of NUREG-0737, Item II.B.3. The responses to the criteria cover the design and operation of the Post Accident Sampling System for Salem Units 1 and 2. PSE&G has installed a single sampling system which can service either Units 1 or 2 during accident conditions.

The system is installed on the Unit 2 side of the station. The installed system consists primarily of a Sentry Equipment Corporation, Model A Post Accident Sampling System (PASS). The PASS is capable of obtaining a containment air grab sample, reactor coolant grab sample (diluted and undiluted) and perform various analyses using in-line instrumentation. Design of the PASS enables PSE&G to respond to emergency conditions by initiating sampling exercises that obtain the chemical and radionuclide data for determining conditions within the core and reactor coolant system.

The main components of the PASS are the Liquid Sampling Panel (LSP), Chemical Analysis Panel (CAP) and Containment Air Sampling Panel (CASP). These panels are designed to minimize operator exposure and to satisfy the three hour time frame for obtaining data. The following sections of this report detail the estimated integrated dose and times to perform the sampling operations as well as the interfaces with the various plant systems and facilities.

2.0 Criterion 1

2.1 Criterion

The licensee shall have the capability to promptly obtain reactor coolant samples and containment atmosphere samples. The combined time allotted for sampling and analysis should be 3 hours or less from the time a decision is made to take a sample.

2.2 Clarification

Provide information on sampling(s) and analytical laboratories locations including a discussion of relative elevations, distances and methods for sample transport. Responses to this item should also include a discussion of sample recirculation, sample handling and analytical times to demonstrate that the three-hour time limit will be met (see (6) below relative to radiation exposure). Also, describe provisions for sampling during loss of off-site power (i.e. designate an alternative backup power source, not necessarily the vital (Class IE) bus, that can be energized in sufficient time to meet the three-hour sampling and analysis time limit).

2.3 Response

The Post Accident Sampling System (PASS) is located on the Unit 2 side of the Auxiliary Building on the 100' elevation. The arrangement of the room is shown on the General Arrangement drawing included in Appendix C. The drawing also shows the location of the Chemistry Lab and Counting Room relative to the PASS Room. The PASS Room contains the following equipment:

- a. Liquid Sampling Panel #813 (LSP)
- b. Containment Air Sampling Panel #812 (CASP)
- c. Chemical Analysis Panel #815 (CAP)
- d. CASP Control Panel #816
- e. Chemical Monitor Panel #817
- f. Air Operated Valves Control Panel #814
- g. Primary Heat Trace Control Panels #913A-1 & 913A-2
- h. Secondary Heat Trace Control Panels #913B-1 & 913B-2

The equipment within the PASS Room allows a technician to obtain the following grab samples and perform the following in-line analyses:

- a. Undiluted Reactor Coolant (depressurized)
- b. Diluted Reactor Coolant (depressurized)
- c. Undiluted Reactor Coolant (pressurized)
- d. Reactor Coolant Stripped Gas
- e. Containment Air
- f. Containment Air (partitioned)
- g. Conductivity
- h. Chlorides
- i. pH
- j. Dissolved Oxygen
- k. Dissolved Hydrogen

In addition to performing the above, a technician can operate all valves from the PASS Room (Panel 814) necessary to obtain a reactor coolant or containment air sample from either Unit 1 or 2.

Once obtained, the grab samples are transferred to the Chemistry Lab for boron analysis and preparation for isotopic analysis. Shielded transfer carts are used to transport the samples from the PASS Room to the Chemistry Lab. The Chemistry Lab is on the Unit 1 side of the Auxiliary Building at Elevation 100'. The distance from the PASS Room to the Chemistry Lab is approximately 100 feet.

The liquid sample is contained in a glass bottle which has a septum cap. The liquid sample transfer cart is capable of inserting the bottle into the LSP and removing the filled bottles. Once the cart has been moved into the Chemistry Lab an aliquot of the sample can be withdrawn from the bottle while still in the cart.

Containment air samples are trapped within a small piece of tubing (flasks) contained within the transfer carts. The transfer carts are plugged into the front of the CASP using quick disconnect fittings. Containment air is then routed through the tubing (flasks) within the cart. After purging containment air through the cart, a sample is then isolated within the cart. The sample is withdrawn from the cart in the Chemistry Lab for isotopic or hydrogen analysis. Appendix B lists the detailed procedures which cover air and liquid sampling as well as the analyses.

Obtaining and analyzing a reactor coolant grab sample for boron and radionuclide analysis is expected to take 4 hours. These analyses are considered to be the most critical during the initial phase of an accident and the most time consuming. The 4 hour time is based on PSE&G experience to date on operating the PASS and from NUS/Sentry Equipment Corporation time studies. The following is a breakdown of the tasks and times to obtain the data. It is expected that these times will show improvement as more experience is gained from PASS operation.

Boron and Radioisotope Analysis

| <u>Step #1</u> | <u>Task</u> | <u>Time</u> |
|----------------|---|----------------|
| 1a | Mobilize Personnel & Equipment | 30 min. |
| 1b | Prepare REP | -- |
| 2 | Brief Personnel | 15 min. |
| 3a | Recalibrate Instrumentation (if required) | 30 min. |
| 3b | Prepare Reagents | -- |
| 3c | Perform PASS Valve Lineup | -- |
| 4 | Purge Sample Lines | 60 min |
| 5 | Obtain Sample | 20 min |
| 6 | Transport to Chemistry Lab | 10 min |
| 7 | Prepare Sample for Analysis & Counting | 15 min |
| 8a | Perform Boron Analysis | 30 min |
| 8b | Count Sample | -- |
| 9 | Assess Results | 30 min |
| | | <u>240 min</u> |

Note: Several tasks can be done concurrently as indicated above.

The equipment located in the PASS Room receives power from the Class 1E buss. Chemistry Lab and Counting Room equipment are not on the Class 1E buss. Therefore, a backup power source is needed to supply the Chemistry Lab and Counting Room in the event of the loss of off-site power. The backup power to these two areas is the Class 1E power provided to the PASS Room. Since the counting equipment and boron analysis equipment only require 120 volt a.c. (unregulated) power, temporary lines can be run from the PASS Room to power this equipment. Routing temporary power would be done during the mobilization step and will not add to the total time for sampling and analysis because of the close proximity of the areas.

3.0 Criterion 2

3.1 Criterion

The licensee shall establish an onsite radiological and chemical analysis capability to provide, within three-hour time frame established above, quantification of the following:

- (a) certain radionuclides in the reactor coolant and containment atmosphere that may be indicators of the degree of core damage (e.g., noble gases; iodines and cesiums, and nonvolatile isotopes);
- (b) hydrogen levels in the containment atmosphere;
- (c) dissolved gases (e.g., H₂), chloride (time allotted for analysis subject to discussion below), and boron concentration of liquids.
- (d) alternatively, have inline monitoring capabilities to perform all or part of the above analyses.

3.2 Clarification

- (a) A discussion of the counting equipment capabilities is needed, including provisions to handle samples and reduce background radiation to minimize personnel radiation exposures (ALARA). Also a procedure is required for relating radionuclide concentrations to core damage. The procedure should include:
 - 1. Monitoring for short and long lived volatile and non volatile radionuclides such as Xe-133, I-131, Cs-137, Cs-134, Kr-85, Ba-140, and Kr-88 (See Vol. II, Part 2, pp. 524-527 of Rogovin Report for further information).
 - 2. Provisions to estimate the extent of core damage based on radionuclide concentrations and taking into consideration other physical parameters such as core temperature data and sample location.
- (b) Show a capability to obtain a grab sample, transport and analyze for hydrogen.
- (c) Discuss the capabilities to sample and analyze for the accident sample species listed here and in Regulatory Guide 1.97, Rev. 2.
- (d) Provide a discussion of the reliability and maintenance information to demonstrate that the selected on-line instrument is appropriate for this application. (See

(8) and (10) below relative to back-up grab sample capability and instrument range and accuracy).

3.3 Response

3.3.1 Counting Equipment Capabilities

Samples for counting are prepared in the Chemistry Laboratory and then transported to the Counting Room. Background levels in the Counting Room would not be affected since samples brought into the room will have been diluted to allow counting on the equipment. Also, preparation of the samples in the Chemistry Lab places sufficient shielding (walls) and distance between hot samples and the counting equipment. This is shown on the arrangement drawing in Appendix C. A discussion of the counting equipment capabilities is given in Section 10 of this response.

3.3.2 Core Damage Assessment

PSE&G has developed an interim procedure for assessing core damage. Currently, PSE&G is participating with the Westinghouse Owners Group in the development of a more rigorous methodology to assess core damage. Once this methodology is developed, the interim procedure will be revised. PSE&G Report Number NFG-0026, Post Accident Core Assessment Procedure, which details the interim approach, is included with this response in Appendix A.

3.3.3 Containment Air Grab Sample

The Sentry "Model A" Containment Air Sampling Panel (CASP) provides the capability to obtain grab samples of containment air at varying times after an accident. The CASP Control Panel (CCP) is used during accident conditions to sequence the capturing of four representative containment air samples in sampling flasks within mobile casks.

After connecting the shielded cart/cask assemblies to the front of the CASP, the operator uses the remote CCP to select and start CASP sampling exercises. The CASP uses nitrogen gas flow through an eductor to establish a 0.2-acfm containment air sample flow rate through the CASP and cart/casks after an initial backflush of sampling lines to the CASP. The CCP controls isolation of a sample within the cart/cask, removal of residual gas from the CASP, backflushing of internal CASP lines, and backflushing of the connecting lines to the sampling flasks.

After isolation of samples and backflushing of connecting lines, cart/cask assemblies may be disconnected and moved to the Chemistry Laboratory. One of the cart/cask assemblies is supplied by a heat-traced line to minimize iodine plateout and vapor condensation. This sample could be passed through a particulate filter and silver zeolite cartridge for isotopic analysis of particulates and iodines respectively. All sampling flasks can be used to sample for hydrogen analysis and noble gas isotopic analyses.

3.3.4 Sampling and Analysis Capabilities

The following summarizes the capabilities to sample and analyze for the accident species listed in Regulatory Guide 1.97, Rev. 2. The instruments listed are discussed in detail in Sections 10.3 and 11.3 of this response. Procedures listed in Appendix B provide detailed instructions to the technician which ensure that the capabilities of the instruments are utilized under accident conditions.

Accident Capabilities

| <u>Analysis/Species</u> | <u>Sample Type</u> | <u>Instrument</u> | <u>Location</u> |
|---------------------------|--------------------|--|------------------------|
| 1. Gamma Spectrum | Liquid Grab | Canberra 8100 | Counting Rm |
| 2. Gross Activity | Liquid Grab | Packard Tri Carb | Counting Rm. |
| 3. Dissolved Hydrogen | In-Line | Baseline 1030A Gas Chromatograph | Panel 815 |
| 4. Chloride Concentration | In-Line | Dionex Model 10 Ion Chromatograph | Panel 815 |
| 5. Boron Concentration | Liquid Grab | Fluoroborate Selective Ion Electrode | Chemistry Lab |
| 6. Dissolved Oxygen | In-Line | YSI Analyzer | Panel 815 |
| 7. pH | In-Line | Cole-Parmer pH Probe | Panel 815 |
| 8. Hydrogen Content | Air Grab | Carle Gas Chroma- tograph | Primary Sample Room |
| 9. Oxygen Content | Air Grab | Carle Gas Chroma- tograph | Primary Sample Room |
| 10. Gamma Spectrum | Air Grab | Canberra 8100 | Counting Rm. |

3.3.5 Reliability and Maintenance

NUS performed in-depth testing of the Baseline Model 1030A subsequent to the initial studies using the Fisher Model 1200 gas chromatograph. Both gas chromatographs have similar characteristics concerning operational requirements and restrictions in use. However, the Baseline system can perform hydrogen analyses over a wider concentration range than the Fisher system.

The application of the Baseline system for total gas analyses by determining individual concentrations of gases in solution and summing these for a total gas concentration was investigated by NUS. Various GC loop sizes were investigated to determine the optimum loop size for analysis for helium, hydrogen, nitrogen, oxygen, xenon and krypton. Linearity characteristics, need for an on-line integrator, column degradation, sensitivity of detection, and effects of operating temperatures were evaluated.

Testing performed by NUS demonstrated that total gas analyses of reactor coolant stripped gases or analysis of containment air for hydrogen, oxygen and the inert gases are possible over an extended range when using a 0.25 cc sample loop. However, sensitivity of detection is somewhat decreased by using a 0.25 cc loop. NUS developed a single procedure to determine total gas concentration using the Baseline system. The procedure requires modification to loop sizes, operating temperatures, program sequencing, and thermal conductivity detector operation. Details of the testing program are presented in NUS Report R-27-3-1-1A.

The gas chromatographic method for performing dissolved hydrogen analyses was selected based on: 1) its application to routine and accident conditions, 2) simplicity of operation, 3) wide measurement range, 4) accuracy of the technique, 5) limited operator interaction required during analysis sequence, 6) the dependability of GC's, and 7) selective measurement capabilities.

4.0 Criterion 3

4.1 Criterion

Reactor coolant and containment atmosphere sampling during post accident conditions shall not require an isolated auxiliary system (e.g., the letdown system, reactor water cleanup system (RWCUS)) to be placed in operation in order to use the sampling system.

4.2 Clarification

System schematics and discussions should clearly demonstrate that post accident sampling, including recirculation, from each sample source is possible without use of an isolated auxiliary system. It should be verified that valves which are not accessible after an accident are environmentally qualified for the conditions in which they must operate.

4.3 Response

The taking of a reactor coolant or containment air sample does not require an isolated auxiliary system to be placed in operation for sampling. The reactor coolant sample lines are tied directly into the 11 and 13 hot legs on Unit 1 and the 21 and 23 hot legs in Unit 2. The flow diagram for the Liquid Sampling System is included in Appendix C. The diagram shows the flow path from the hot legs, through the Liquid Sampling Panel (LSP) and return to the containment sumps. Operation of this system requires a minimum of 50 psig in the Reactor Coolant System (RCS) in order to obtain a sample. In the event there is no pressure on the RCS, a sample can be taken off the discharge of the Residual Heat Removal (RHR) pumps.

The flow diagram for the Containment Air Sampling System is included in Appendix C. An eductor located in the Containment Air Sampling Panel (CASP) provides the motive force for removing air from containment, to the CASP and returning the air back to containment. No isolated auxiliary system is required to be placed in operation in order to obtain an air sample. The eductor is capable of drawing a sample over a containment pressure range of -0.5 psig to 60 psig and a temperature range of 50°F to 310°F.

The containment and electrical penetration areas are inaccessible under accident conditions. PASS valves located in these areas are, therefore, remotely operated from the PASS Room. The valves and controls were purchased and installed as Nuclear Class 2 and Seismic I components in order to assure operability during and after an accident.

The electrical components for these valves were purchased and installed to meet the environmental requirements of IEEE Standard 323 (1974).

5.0 Criterion 4

5.1 Criterion

Pressurized reactor coolant samples are not required if the licensee can quantify the amount of dissolved gases with unpressurized reactor coolant samples. The measurement of either total dissolved gases or H₂ gas in reactor coolant samples is considered adequate. Measuring the O₂ concentration is recommended, but is not mandatory.

5.2 Clarification

Discuss the method whereby total dissolved gas or hydrogen and oxygen can be measured and related to reactor coolant system concentrations. Additionally, if chlorides exceed

0.15 ppm, verification that dissolved oxygen is less than 0.1 ppm is necessary. Verification that dissolved oxygen is <0.1 ppm by measurement of a dissolved hydrogen residual of > 10 cc/kg is acceptable for up to 30 days after the accident. Within 30 days, consistent with minimizing personnel radiation exposures (ALARA), direct monitoring for dissolved oxygen is recommended.

5.3 Response

The Post Accident Sampling System is equipped with in-line instrumentation to perform both dissolved hydrogen and oxygen analyses of reactor coolant. The analyses involve operator actions at the Liquid Sampling Panel (LSP) and Chemical Analysis/Chemical Monitor Panels (CAP/CMP). Hydrogen analyses are performed using a gas chromatograph (GC) and dissolved oxygen analyses are performed using a dissolved oxygen probe and analyzer. The controller and recorder for the GC and the analyzer and recorder for the dissolved oxygen probe are located in the remote CMP to reduce operator exposure.

5.3.1 Dissolved Hydrogen Analysis

All system components associated with gas stripping operations are initially purged with argon to dry the gas expansion vessel which collects stripped gases. The gas expansion vessel and connecting lines which route the gases from the LSP to the CAP are evacuated as is the gas chromatograph. Reactor coolant is routed through the LSP and a pressurized sample is isolated within a 30 ml sampling flask. The dissolved gases are stripped from the pressurized sample into the previously evacuated expansion vessel. Argon gas is routed through the pressurized sample flask to strip any remaining gases into the expansion vessel. A pressure control valve limits the pressure within the vessel to 24.7 psia.

LSP valving is opened to route the stripped gases to the in-line gas chromatograph within the CAP. The gas chromatograph contains a four-loop sampling selector valve. All four sample loops are loaded with stripped gases by remote operation at the CMP.

After isolating the gas samples, the CMP controller is used to remotely inject a 1 cc sample into the GC. In the automatic mode, the complete analysis is controlled by the CMP microprocessor which has been preprogrammed by entry of a step, time, and command code sequence.

The gas chromatograph in the CAP employs a dual column, thermal conductivity detector system to separate and measure hydrogen (and other gases). Argon is utilized as the carrier gas. Samples are introduced into the gas chromatograph carrier stream from any loop of a 4-loop sampling valve. The injected gas is swept through two chromatographic columns by a continuous flow of argon carrier gas. The gaseous components diffuse through the columns at rates characteristic of the gas. To prevent degradation of the performance of the second column, the water vapor is retained on the first column until the sample gases have eluted and then is backflushed out of the system.

A thermal conductivity detector indicates the presence of each component as it is eluted by sensing the difference in thermal conductivity of the gas of interest relative to that of the carrier gas.

The detection and measuring system is a thermal conductivity cell consisting of two matched pairs of hot wire filaments; the electric resistance of the filaments changes with small changes of temperature. When exposed to pure carrier gas flow, the filaments reach temperature equilibrium and constant resistance, causing the bridge to be electrically balanced. When a component of the gas sample, such as hydrogen, is carried past the filaments, the increase in thermal conductivity causes the filament to lose heat. As the bridge becomes unbalanced, a signal is sent to the recorder. The result, after a complete sample has passed through the system, is a chromatogram with a peak for each separate component. Concentration of an unknown sample is determined by comparing the peak height of the sample with calibration curves.

Calibration curves relate peak height to concentration (cc/kg) for each attenuation setting selected. Analyses of all four sample for hydrogen can be completed within 15 minutes after loading the sampling loop.

Based on testing data provided by NUS, the Baseline Model 1030A gas chromatograph installed in the CAP/CMP system may be used to accurately determine dissolved hydrogen concentration in the range of 3-2,000 cc/kg (STP) with an accuracy of + 10 percent. Experimental data indicate that it is possible to measure dissolved hydrogen concentrations as low as 0.5 cc/kg (STP).

The CAP is equipped with a dual set of hydrogen standards which are to be used to verify the validity of calibration curves prior to initiating any gas stripping operations. The calibration gases can be routed to the GC for analysis by remote operation from the CMP.

The Baseline system can also be used to determine total gas concentrations with modifications to the sequence program, operating column temperature, and sample loop sizes.

5.3.2 Dissolved Oxygen Analysis

Dissolved oxygen analyses for accident conditions are performed using an in-line dissolved oxygen probe and remote analyzer and recorder manufactured by Yellow Springs Instrument Company. The probe holder is designed to minimize fluid volume and thereby reduce radiation exposure. The probe can be removed easily for replacement or repair.

Calibration of the dissolved oxygen system is completed prior to routing reactor coolant to the CAP. The CAP contains a front-mounted recirculation tank which is filled with demineralized water. The water is recirculated through a spray nozzle for a minimum of one hour to saturate the water with air.

The water is then pumped through the analytical train containing the dissolved oxygen probe. The flow rate is adjusted to 200 ml/min and flow is continued for 5 minutes. The O₂ calibration knob on the CMP YSI analyzer is adjusted until the recorder pen indicates the dissolved oxygen concentration of the calibration solution.

At a given atmospheric pressure, the oxygen concentration is dependent on the water temperature. Since water temperature in the calibration tank is monitored, oxygen concentration can be determined from a solubility chart relating dissolved oxygen concentration to the temperature of the water.

After completion of calibration, reactor coolant is routed through the LSP to the CAP. Flow is routed through the analytical train containing the dissolved oxygen probe. Flow rate is controlled from the LSP, and flow is continued for a minimum of 5 minutes. Dissolved oxygen concentration in ppm is recorded on the remote CMP recorder.

During dissolved oxygen measurements, the oxygen in the sample stream diffuses through the semi-permeable membrane of the CAP probe which contains an electrolyte. The KCl electrolyte surrounds a pair of electrodes. Oxygen which has passed through the membrane reacts at the gold cathode causing a current to flow. The membrane passes oxygen at a rate proportional to the pressure across it. The force causing the oxygen to diffuse through the membrane is proportional to the partial pressure of the oxygen outside the membrane.

Testing performed by NUS demonstrates that the YSI Model 56 analyzer and probe can be used to obtain dissolved oxygen analyses in the range of 0.1-20 ppm with an accuracy of + 10%. The minimum level of detection is approximately 0.1 ppm.

6.0 Criterion 5

6.1 Criterion

The time for a chloride analysis to be performed is dependent upon two factors: (a) if the plant's coolant water is seawater or brackish water and (b) if there is only a single barrier between primary containment systems and the cooling water. Under both of the above conditions the licensee shall provide for a chloride analysis within 24 hours of the sample being taken. For all other cases, the licensee shall provide for the analysis to be completed within 4 days. The chloride analysis does not have to be done onsite.

6.2 Clarification

BWR's on sea or brackish water sites, and plants which use sea or brackish water in essential heat exchangers (e.g. shutdown cooling) that have only single barrier protection between the reactor coolant are required to analyze chloride within 24 hours. All other plants have 96 hours to perform a chloride analysis. Samples diluted by up to a factor of one thousand are acceptable as initial scoping analysis for chloride, provided (1) the results are reported as ppm Cl (the licensee should establish this value; the number in the blank should be no greater than 10.0 ppm Cl) in the reactor coolant system and (2) that dissolved oxygen can be verified

at <0.1 ppm, consistent with the guidelines above in clarificatin no. 4. Additionally, if chloride analysis is performed on a diluted sample, an undiluted sample need also be taken and retained for anlysis within 30 days, consistent with ALARA.

6.3 Response

The Post Accident Sampling System Chemical Analysis Panel (CAP) and Chemical Monitor Panel (CMP) provide the capability to remotely perform in-line analysis of a reactor coolant sample for chlorides within 24 hours (or 96 hours). The Liquid Sampling Panel (LSP) also provides the capability to collect an undiluted reactor coolant sample for back-up analysis.

Chloride analyses are performed by routing a reactor coolant through the LSP to the analytical section of the in-line ion chromatograph (I.C.) within the CAP.

Located on the front of the CAP are: a calibration tank (for a 1 ppm chloride standard), eluent and regenerant pumps, containers for all I.C. reagents, flow indicators, valving, and the I.C. conductivity meter. All components, such as piping, valving, and separator and suppressor columns, sampling loop, and conductivity detector, which contact the reactor coolant, are located behind the panel shield. The controller section for the modified Model 10 Dionex I.C. is located on the CMP. The controller provides for remote operations such as column washing and regeneration and sample injection. The signal from the CAP I.C. conductivity detector is transmitted to the CMP and is recorded on the Speedomax M recorder.

Prior to routing reactor coolant to the CAP, the I.C. is calibrated with a 1 ppm chloride standard in a boric acid matrix of 2000 ppm boron. The chloride standard is routed from the calibration tank to the I.C. sampling loop and remotely injected into the eluent stream. The resultant peak of the chloride standard chromatogram is compared to the previously prepared calibration curve for the range of interest. A change in the total scale divisions (net peak height x micromho setting) for the standard may indicate a need for column regeneration prior to sample analysis.

After completion of calibration operations, reactor coolant is routed from the LSP to the CAP. The CAP valving is aligned to route coolant through the I.C. sampling loop. A 0.2 ml aliquot is injected into the eluent stream by activating a solenoid valve from the CMP controller after purging of the LSP and CAP lines is completed. The chromatogram for a chloride analysis is recorded on the CMP recorder in less than ten minutes after sample injection. The total time required to obtain a chloride analysis and flush components is approximately 45 minutes. Chloride analysis can easily be completed within the 24 hour or 96-hour time requirement using the I.C.

The I.C. can be flushed with demineralized water prior to any required maintenance operations. Demineralized water and a sodium carbonate eluent are used to flush radioactive anions from the separator column while a sulfuric acid solution is used to regenerate the suppressor column and remove any radioactive cations.

Replacement of separator and suppressor columns or I.C. control valves can be accomplished in a short time, if required. Because replacement of components is possible within a limited time frame, the retention of an undiluted sample for chloride analyses at a later date is not anticipated.

If the hydrogen concentration is verified to be greater than 10 cc/kg and the decision is made to delay the chloride analysis, an undiluted sample will be collected within the 24-hour or 96-hour period and retained for chloride analysis within 30 days. The LSP will be used to collect 15 ml of an undiluted sample. The CAP is equipped with a septum port and valve for manual injection of a sample for chloride analysis. A syringe will be used to withdraw a sample from the undiluted sample bottle and inject 10 cc into the sample loop from the rear of the panel. The dose rate from the 10 cc sample is estimated to be 3.8R/hr at 1 foot, 30 days after the accident. Three inches of leadshot shielding reduces the dose rate to 100 mr/hr at 1 foot.

To date, no chloride analysis procedure is available with sufficient sensitivity to permit quantitative analysis of chlorides indicating >10 ppm on a 1-1000 diluted sample. The ion chromatographic technique used provides the

capability to detect chloride concentrations of less than 100 ppb (0.1ppm) on a 0.2 ml undiluted sample which is injected in-line.

The range for I.C. chloride analyses is 0.1ppm-20ppm. The upper range value can be extended by calibrating in this region and varying the micromho setting on the conductivity meter. The system is capable of determining chloride concentrations in the range of 0.1-20.0 ppm with an accuracy of approximately $\pm 10\%$, based on testing performed by NUS.

7.0 Criterion 6

7.1 Criterion

The design basis for plant equipment for reactor coolant and containment atmosphere sampling and analysis must assume that it is possible to obtain and analyze a sample without radiation exposures to any individual exceeding the criteria of GDC 19 (Appendix A, 10 CFR Part 50) (i.e., 5 rem whole body, 75 rem extremities). (Note that the design and operational review criterion was changed from the operational limits of 10 CFR Part 20 (NUREG-0578) to the GDC 19 criterion (October 30, 1979 letter from H.R. Denton to all licensees)).

7.2 Clarification

Consistent with Regulatory Guide 1.3 or 1.4 source terms, provide information on the predicted personnel exposures based on person-motion for sampling, transport and analysis of all required parameters.

7.3 Response

The primary sources of radiation during sampling operations are the Salem Unit 2 safety injection pumps, related piping and pipe chase areas located beneath the Post Accident Sampling room on elevation 84'. Based on these sources, the calculated dose rates in the Post Accident Sampling room are shown in Figure 7-1. The accident dose rates are based on the release of 100 percent of noble gases, 50 percent of halogens and 10 percent of the cesium, barium, and strontium from an equilibrium core operating at a power level of

2561 MWt. Initially, high radiation levels are present in the post Accident Sampling room during the first few hours following a Salem Unit 2 accident. These high radiation levels diminish by a factor of approximately ten (10) within four hours as the short lived radioactive fission products decay.

The times to perform the various sampling steps are based on an NUS/Sentry Equipment Corporation time study performed on a similar production model sampling system and PASS operator training performed at the Salem Station. Actual time motion studies have not yet been performed on the sampling system at Salem. A time motion study of sampling exercises is planned depending on manpower availability. Also, during nuclear accident drills times to perform the various sampling exercises are to be monitored.

The sampling exercises discussed in the following sections represent the most severe cases which subject the operator to the highest radiation levels. The dose rates listed include the dose from equipment beneath the sampling room and the dose contributed from the sampling panels during specific sampling exercises.

7.3.1 Liquid Sampling Panel (LSP)

To evaluate the dose rates obtained from the LSP and associated operations, it is necessary to define the actions involved when obtaining a sample. These actions can be categorized into the following steps.

- Step 1 - Assembly of personnel and entrance and egress from PASS room
- Step 2 - LSP valve alignment and equipment setup
- Step 3 - Purging of all sample lines connecting the hotleg of the reactor coolant system with the LSP
- Step 4 - Performance of sampling procedure (i.e. obtaining a 24 ml diluted reactor coolant sample, 15 ml undiluted reactor coolant sample or diluted stripped gas sampling)
- Step 5 - Transport of sample to analysis area
- Step 6 - Analysis of the sample
- Step 7 - Post sample purge and panel shutdown

The purging steps are common to all liquid sampling or chemical analysis panel operations; however, continual operator presence is not required. The post-accident sampling procedures require a sixty (60) minute minimum flush time to ensure obtaining a representative sample. This estimate is based upon a maximum sample flow rate of 1900 cc/min to yield a threefold volume changeover for the longest piping run between the panel and the most remote hotleg of the reactor coolant system. Since operator presence is not continuously required following establishment of flow, the dose assessment from purging operations is based on partial stay times.

Since it is highly unlikely that any post-accident sampling and analyses will occur within the first four hours, the dose rate estimates in the following tables are for the time range of 4-12 hours following the accident. Sampling and analyzing reactor coolant samples between 4-12 hours following the accident is considered a realistic estimate and allows sufficient time for the short-lived fission products to decay.

Table 7-1 lists the integrated dose for sampling and analyzing a 24 ml diluted reactor coolant sample. Although the procurement of an undiluted liquid sample is probably unlikely to occur in emergency conditions, nevertheless the dose assessment evaluation is being offered in Table 7-2. Justification of this reasoning is based on the premise that sampling undiluted reactor coolant is the "worst case". The total time required by an operator to sample an undiluted sample is 52.4 minutes. If the sample is taken at 4 hours following the accident the maximum dose received would be 1846 mrem.

The total estimated operator dose for sampling and analyzing a 24 ml diluted reactor coolant sample is 2317 mrem at 4 hrs. following the accident and 1054 mrem at t=12 hrs. These estimates are based on sampling and analysis time of 69.4 minutes. Since the diluted reactor coolant sample is diluted by a factor of one thousand (1:1000), the operator dose is primarily dependent on the general surrounding radiation levels while exposure to the diluted sample during laboratory preparation and analysis subjects the operator to approximately 6 mrem. Consequently, a single operator (if necessary) can sample and analyze a diluted reactor coolant sample and remain well below the maximum 5 Rem whole body exposure dose limitation.

The summary of integrated dose calculations of procuring a reactor coolant stripped gas sample and performing a dissolved hydrogen analysis using the on-line Baseline Model 1020A gas chromatograph appear in Table 7-3.

A single operator conceivably could sample and analyze a gas sample and not exceed the maximum whole body exposure limit of 5 Rem. At t=4 hrs., the operator dose is estimated to be 2696-2735 mrem for an exposure time of 86.1 min.

7.3.2 Chemical Analyses Panel (CAP)

The integrated dose from the Chemical Analysis Panel (CAP) includes a dose contribution from the LSP since CAP operation is dependent on the LSP. The total integrated operator dose is 1818-1894 mrem 4 hours following the accident and 876-981 mrem 12 hours following the accident for performing either the pH/conductivity/dissolved oxygen analyses or chloride analyses.

The dose time used in these estimates is 10 minutes, although actual analysis time for the pH/conductivity/dissolved oxygen or chloride analyses are approximately 45 minutes; however, continual operator presence at the panel is not required. Table 7-4 summarizes the integrated operator doses for on-line analyses performed at the Chemical Analysis Panel. The maximum time expected to be required for a chloride analysis is 1.5-2.0 hours if column regenerations for the ion chromatograph are necessary. Using this time estimate, the total operator dose would be 3788 mrem at 4 hours after the accident and 1962 mrem 12 hours after the accident. However, chloride analyses do not have to be completed within the 3-hour time frame stated in Criterion 1, therefore, doses would be lower if chloride analyses were performed later than 12 hours following the accident.

7.3.3 Containment Air Sampling Panel (CASP)

The total operator dose rate calculations are summarized in Table 7-5. These dose rates are calculated for 4 and 12 hours after the accident at one meter from the panel. The total operator dose for sampling and analyzing a containment air sample is estimated to be 2156 mrem at 4 hours

following the accident and 1043 mrem if the exercise is performed 12 hours following the accident. The summarized dose calculations appearing in Table V were based upon the use of the mobile gas containing cart/cask assemblies. Presently, PSE&G is in the process of installing a gas sampling device developed by Radiological Control Technology (RCT) Company, Inc. This device attaches directly to one of the sampling stations in lieu of the cart/cask assembly and functions to partition particulate, noble gas, and iodine constituents of the containment air sample for laboratory analyses. The use of this device should lower the estimated operator dose by approximately 100-400 mrem since smaller volumes of sample are used and laboratory sample preparation is not required. A more thorough dose assessment of the use of the RCT gas partitioner will be conducted once the instrument is installed and operable.

8.0 Criterion 7

8.1 Criterion

The analysis of primary coolant samples for boron is required for PWR's. (Note that Rev. 2 of Regulatory Guide 1.97 specifies the need for primary coolant boron analysis capability at BWR plants).

8.2 Clarification

PWR's need to perform boron analysis. The guidelines for BWR's are to have the capability to perform boron analysis but they do not have to do so unless boron was injected.

8.3 Response

Boron concentration is determined using the Fluoroborate Selective Ion Electrode technique. Selection of this technique for the boron analysis is discussed in Section 11.3.2 of this response. The analysis is performed on a diluted sample of reactor coolant obtained from the Liquid Sampling Panel (LSP). The analysis time is expected to be less than 20 minutes excluding sampling, sample transport and reagent preparation.

FIGURE 7-1

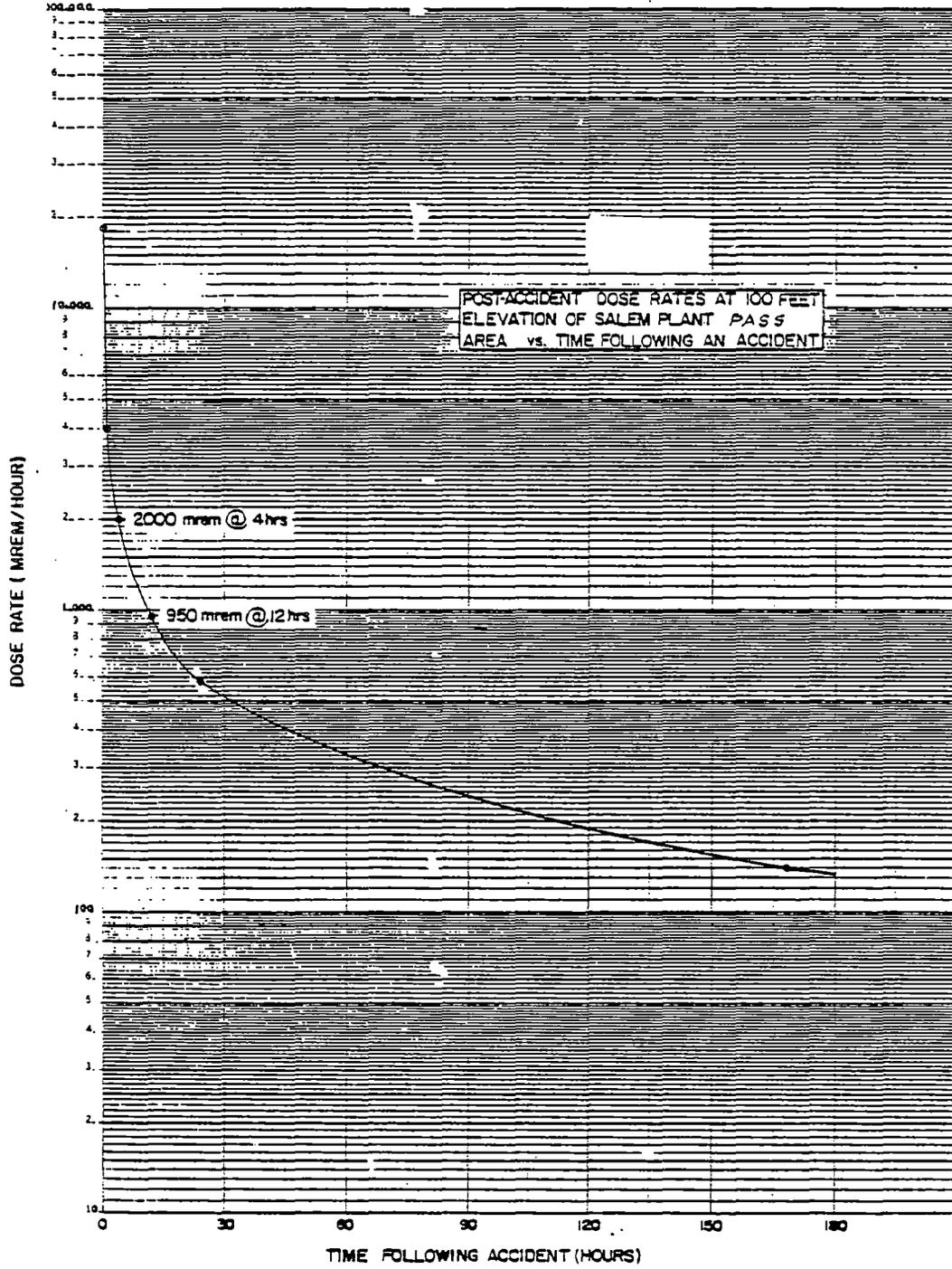


TABLE 7-1

24ml DILUTED REACTOR COOLANT SAMPLING AND ANALYSIS
INTEGRATED DOSE

| <u>STEP</u> | <u>Time in Min.</u> | <u>DOSE RATE*</u> <u>(mrem/hr.)</u> | | <u>INTEGRATED DOSE</u> <u>(mrem)</u> | |
|--|---------------------|--|----------------|---|----------------|
| | | <u>4 Hrs.</u> | <u>12 Hrs.</u> | <u>4 Hrs.</u> | <u>12 Hrs.</u> |
| 1. Assembly of Personnel, Entrance and Egress from PASS Room | 10 | 2000 | 950 | 333 | 158 |
| 2. LSP Valve Alignment | 5 | 2000 | 950 | 167 | 79 |
| 3. Purge Incoming Lines to LSP | 7.9 | 2000 | 950 | 263 | 125 |
| 4. Perform Manipulations on LSP | | | | | |
| a. Purge the LSP Prior to Sampling | 3.7 | 2000 | 950 | 123 | 58 |
| b. Filling the 60 ml Sample Vial | 3.2 | 2000 | 950 | 106 | 50 |
| c. Isolate Sample Vial Within LSP | 0.5 | 2000 | 950 | 17 | 83 |
| 5. Transport Sample to Laboratory | 5 | 2064 | 995 | 172 | 83 |
| 6. Sample Preparation and Analysis | | | | | |
| a. Sample Dilution | 2 | 2000 | 950 | 66 | 32 |
| b. Sample Analysis | 15 | 2000 | 950 | 500 | 190 |
| 7. LSP Final Purge and Panel Shutdown | 17.1 | 2000 | 950 | 570 | 271 |
| TOTAL | 69.4 | | | 2317 | 1054 |

*NOTE: Dose Rate Includes Dose Rate from Panel and General Area Dose Rate.

TABLE 7-2

15ml UNDILUTED REACTOR COOLANT SAMPLING AND ANALYSIS
INTEGRATED DOSE

| <u>STEP</u> | <u>Time in Min.</u> | <u>DOSE RATE*</u> <u>(mrem/hr.)</u> | | <u>INTEGRATED DOSE</u> <u>(mrem)</u> | |
|--|---------------------|--|----------------|---|----------------|
| | | <u>4 Hrs.</u> | <u>12 Hrs.</u> | <u>4 Hrs.</u> | <u>12 Hrs.</u> |
| 1. Assembly of Personnel, Entrance and Egress from PASS Room | 10 | 2000 | 950 | 333 | 158 |
| 2. LSP Valve Alignment | 5 | 2000 | 950 | 167 | 79 |
| 3. Purge Incoming Lines to LSP | 7.9 | 2000-2092 | 950-1013 | 263-275 | 125-134 |
| 4. Perform Manipulations on LSP | | | | | |
| a. Purge the LSP Prior to Sampling | 3.7 | 2092-2170 | 1013-1067 | 129-134 | 62-66 |
| b. Filling the 15 ml Sample Vial | 3.2 | 2170-2207 | 1068-1093 | 116-118 | 57-58 |
| c. Isolate Sample Vial Within LSP | 0.5 | 2207 | 1093 | 18 | 9 |
| 5. Transport Sample to Laboratory | 5 | 2064 | 995 | 172 | 83 |
| 6. Sample Preparation and Analysis | N/A | N/A | N/A | N/A | N/A |
| 7. LSP Final Purge and Panel Shutdown | 17.1 | 2000-2207 | 950-1271 | 570-629 | 271-362 |
| TOTAL | 52.4 | | | 1768-1846 | 844-949 |

*NOTE: Dose Rate Includes Dose Rate from Panel and General Area Dose Rate.

TABLE 7-3
REACTOR COOLANT STRIPPED GAS ANALYSIS
INTEGRATED DOSE

| <u>STEP</u> | <u>Time in Min.</u> | <u>DOSE RATE*</u> (mrem/hr.) | | <u>INTEGRATED DOSE</u> (mrem) | |
|--|---------------------|---------------------------------|----------------|----------------------------------|----------------|
| | | <u>4 Hrs.</u> | <u>12 Hrs.</u> | <u>4 Hrs.</u> | <u>12 Hrs.</u> |
| 1. Assembly of Personnel, Entrance and Egress from PASS Room | 10 | 2000 | 950 | 333 | 158 |
| 2. LSP Valve Alignment | 10 | 2000 | 950 | 333 | 158 |
| 3. Purge Incoming Lines to LSP | 7.9 | 2000-2092 | 950-1013 | 263-275 | 125-134 |
| 4. Perform Manipulations on LSP | | | | | |
| a. Purge the LSP Prior to Sampling | 5.0 | 2095-2210 | 1016-1095 | 174-184 | 85-91 |
| b. Commence Initial Flushing of LSP (All Lines and Hard- ware Except 30 ml Sample Vessel) | 10.9 | 2089-2210 | 1011-1095 | 174-184 | 84-91 |
| c. Continue Sampling Operation (Strip Gases from 30 ml con- tainer and Route to 300 ml Container, etc.) | 3.0 | 2089 | 1011 | 104 | 50 |
| d. Flush Remaining Liquid Activity | 5.2 | 2018-2089 | 962-1011 | 174-181 | 83-87 |
| 5. Flush Remaining Gas to Base- line Model 1020A GC for H ₂ Analysis | 4.0 | 2018 | 962 | 134 | 64 |
| 6. Perform Dissolved H ₂ Analysis | 16.0 | 2000 | 950 | 533 | 253 |
| 7. Flush Remaining Gaseous Activity From LSP and Shutdown Panel | 14.1 | 2018 | 962 | 474 | 226 |
| TOTAL | 86.1 | | | 2696-2735 | 1286-1312 |

*NOTE: Dose Rate Ranges Includes Dose Rate from Panel and General Area Dose Rate.

TABLE 7-4

REACTOR COOLANT ON-LINE pH/CONDUCTIVITY/DISSOLVED O₂ ANALYSIS
INTEGRATED DOSE

| <u>STEP</u> | <u>Time in Min.</u> | <u>DOSE RATE*</u> <u>(mrem/hr.)</u> | | <u>INTEGRATED DOSE</u> <u>(mrem)</u> | |
|---|---------------------|--|----------------|---|----------------|
| | | <u>4 Hrs.</u> | <u>12 Hrs.</u> | <u>4 Hrs.</u> | <u>12 Hrs.</u> |
| 1. Assembly of Personnel, Entrance and Egress from PASS Room | 10 | 2000 | 950 | 333 | 158 |
| 2. LSP/CAP Valve Alignment | 5 | 2000 | 950 | 167 | 79 |
| 3. Purge Incoming Lines to LSP/ CAP | 7.9 | 2000-2092 | 950-1013 | 263-275 | 125-134 |
| 4. Perform Manipulations at CAP/ LSP to Purge LSP Prior to Sampling | 3.7 | 2092-2170 | 1013-1067 | 129-134 | 62-66 |
| 5. Transport Sample to Laboratory | N/A | N/A | N/A | N/A | N/A |
| 6. Sample Analysis for pH/Conduc- tivity/Dissolved Oxygen | 10 | 2140 | 1090 | 356 | 182 |
| 7. LSP/CAP Purge and Panel Shutdown | 17.1 | 2000-2207 | 950-1271 | 570-629 | 270-362 |
| TOTAL | 53.7 | | | 1818-1894 | 876-981 |

*NOTE: Dose Rate Ranges Includes Dose Rate from Panel and General Area Dose Rate.

TABLE 7-5

CONTAINMENT AIR SAMPLING AND ANALYSIS
INTEGRATED DOSE

| STEP | Time in Min. | DOSE RATE* (mrem/hr.) | | INTEGRATED DOSE (mrem) | |
|--|--------------|--------------------------|---------|---------------------------|---------|
| | | 4 Hrs. | 12 Hrs. | 4 Hrs. | 12 Hrs. |
| 1. Assembly of Personnel, Entrance and Egress from PASS Room | 10 | 2000 | 950 | 333 | 158 |
| 2. Perform CASP Valve Alignment | 10 | 2000 | 950 | 333 | 158 |
| 3. Perform Manipulations on the CASP | | | | | |
| a. Capture Sample | 8 | 2084 | 1008 | 278 | 134 |
| b. Isolate Cart/Cask | 1 | 2258 | 1128 | 38 | 19 |
| c. Wait for Sequencer Purge Completion | 7 | 2084 | 1008 | 243 | 118 |
| d. Uncouple Cask | 1 | 2084 | 1008 | 35 | 17 |
| 4. Transport Cask/Cart to Laboratory | 5 | 2084 | 994 | 173 | 83 |
| 5. Sample Preparation and Analysis | 10 | 2258 | 1128 | 376 | 188 |
| 6. Line Purge and Panel Shutdown | 10 | 2084 | 1008 | 347 | 168 |
| TOTAL | 62 | | | 2156 | 1043 |

*NOTE: Dose Rate Range Includes Dose Rate from Panel and General Area Dose Rate.

9.0 Criterion 8

9.1 Criterion

If inline monitoring is used for any sampling and analytical capability specified herein, the licensee shall provide backup sampling through grab samples, and shall demonstrate the capability of analyzing the samples. Established planning for analysis at offsite facilities is acceptable. Equipment provided for backup sampling shall be capable of providing at least one sample per day for 7 days following onset of the accident, and at least one sample per week until the accident condition no longer exists.

9.2 Clarification

A capability to obtain both diluted and undiluted backup samples is required. Provisions to flush inline monitors to facilitate access for repair is desirable. If an off-site laboratory is to be relied on for the backup analysis, an explanation of the capability to ship and obtain analysis for one sample per week thereafter until the accident condition no longer exists, should be provided.

9.3 Response

The Post Accident Sampling System provides undiluted and diluted reactor coolant samples and diluted reactor coolant stripped-gas samples in addition to its in-line monitoring capabilities to meet the reactor coolant sampling and analysis requirements. The diluted reactor coolant sample is collected within a shielded cart/cask assembly which interfaces with the Liquid Sampling Panel (LSP). The 1-1000 diluted liquid sample is transported to the Chemistry Laboratory for boron and isotopic analyses. Boron analyses are performed using the fluoroborate selective ion electrode procedure.

Dissolved gases from the reactor coolant are stripped from a 30 ml pressurized reactor coolant sample which is collected in-line behind the LSP shield wall. The stripped gases are routed from a gas expansion vessel through a diluter valve prior to being routed to an in-line gas chromatograph within the Chemical Analysis Panel. The diluter valve is used to

perform a gas dilution of approximately 1:15,000. The diluted gas is collected within a 10 cc glass bottle held in place by an off-gas grip tong. The bottle is removed and transported to the Chemistry Laboratory for isotopic analysis.

Dissolved hydrogen analyses are performed in-line after loading the sampling loops of the gas chromatograph (GC). The advantages of using the GC method are: 1) the wide measurement range, 2) application to normal and post-accident usage, 3) selective measurement capability for hydrogen as well as helium, oxygen, nitrogen, xenon, and krypton, 4) remote analysis capability, 5) rapid analysis time, and 6) redundant analysis capability with four sampling loops. There are no anticipated effects from the radiation field and GC's are very dependable laboratory instruments. Calibration gases are installed in-line to verify the performance of the gas chromatograph prior to analyzing a stripped gas sample.

Analyses of reactor coolant samples for chlorides, pH, conductivity, and dissolved oxygen are performed in-line within the Chemical Analysis Panel (CAP). In-line probes are used for pH, conductivity and dissolved oxygen measurement while an ion chromatograph is used for chloride analysis. Remote monitors for pH and conductivity are installed within the Chemical Monitor Panel (CMP). Strip chart recorders are mounted within the CMP to provide a permanent recording of the chromatogram of the ion chromatograph chloride signal and the dissolved oxygen measurement.

Although the LSP provides the capability to collect undiluted back-up grab samples, the necessity for their collection and development of separate analysis capability is not warranted for the following reasons:

- o If the dissolved hydrogen concentration is verified to exceed 10 cc/kg, the dissolved oxygen, chloride and pH measurements need only be performed within the first 30 days. This is sufficient time to flush all panel lines and remove and replace any probes or components to permit performing analyses in-line.

- o If the dissolved hydrogen is not verified to exceed 10 cc/kg, the dissolved oxygen measurement time requirement is dependent on the chloride analysis. Chloride measurement is required within 96 hours under the above hydrogen condition.

The 96 hour time frame is sufficient to flush all panel and ion chromatograph lines, repair and/or replace components, and recalibrate the system. Calibration of the system can be accomplished in-line or by performing manual injections through a port in the rear of the ion chromatograph (I.C.).

Alternate backup chloride analysis capability is not considered appropriate within the 96 hour period due to known chemical interferences of alternate procedures or the large sample sizes required. To date, the I.C. technique is the only procedure applicable to performing post-accident chloride analyses.

Dissolved oxygen analyses can be performed reliably in-line during the 96 hour period. The CAP provides for in-line calibration of both the Rexnord and YSI dissolved oxygen probes. Calibrations can be accomplished within approximately 1.5 hours. The YSI probe has been demonstrated to be suitable for post-accident use because of its remote operability, accuracy, range, resistance to radiation damage, and simplicity of operation. The YSI probe could be replaced after flushing of CAP lines if it were to fail. If the membrane were to be replaced, a time interval of 1-3 hours may be required for the system to reach equilibrium after the internal portions of the probe are exposed to air.

An alternate approach to replacement of the YSI probe or its membrane is to direct reactor coolant flow through the Rexnord probe which is designed for lower level dissolved oxygen analyses. Although the radiation field would increase slightly in front of the CAP, the availability of a back-up probe is considered preferable to other alternate approaches.

Measurement of reactor coolant pH and conductivity can be determined simultaneously with the dissolved oxygen analyses. In-line measurement of pH and conductivity is

preferable over grab sample analyses. In-line pH and conductivity monitors have been used reliably for a number of years in the nuclear and chemical industries with no apparent disadvantages noted. The in-line probes can be calibrated in-place and provide the advantage of remote operability, sufficient measurement range and accuracy, simplicity, and applicability to normal and post-accident usage. No radiation effects are expected based on past industry experience. Replacement of either probe were failure to occur would not be difficult. All panel lines can be flushed and the probe replaced and recalibrated within an approximate period of two hours.

10.0 Criterion 9

10.1 Criterion

The licensee's radiological and chemical sample analysis capability shall include provisions to:

- (a) Identify and quantify the isotopes of the nuclide categories discussed above to levels corresponding to the source terms given in Regulatory Guide 1.3 or 1.4 and 1.7. Where necessary and practical, the ability to dilute samples to provide capability for measurement and reduction of personnel exposure should be provided. Sensitivity of onsite liquid sample analysis capability should be such as to permit measurement of nuclide concentration in the range from approximately 1 micro Ci/g to 10 Ci/g.
- (b) Restrict background levels of radiation in the radiological and chemical analysis facility from sources such that the sample analysis will provide results with an acceptably small error (approximately a factor of 2). This can be accomplished through the use of sufficient shielding around samples and outside sources, and by the use of a ventilation system design which will control the presence of airborne radioactivity.

10.2 Clarification

- (a) Provide a discussion of the predicted activity in the samples to be taken and the methods of handling/dilution that will be employed to reduce the activity

sufficiently to perform the required analysis. Discuss the range of radionuclide concentration which can be analyzed for, including an assessment of, the amount of overlap between post accident and normal sampling capabilities.

- (b) State the predicted background radiation levels in the counting room, including the contribution from samples which are present. Also provide data demonstrating what the background radiation levels and radiation effect will be on a sample being counted to assure an accuracy within a factor of 2.

10.3 Response

The methods developed for handling a post accident reactor coolant sample are based on a worst case concentration of 10 Ci/gm. The Liquid Sampling Panel (LSP) is capable of diluting a reactor coolant sample by a factor of 1,000. The diluted sample is then transported in the shielded transfer cart to the Chemistry Lab for preparation for counting. Once in the Chemistry Lab, the sample is further diluted by transferring 0.01 ml of the sample into a counting vial containing 10 ml of demineralized water. This further dilutes the sample by a factor of 1,000 for an overall dilution factor of 1,000,000. Thus, reactor coolant with an activity of 10 Ci/gm can be accurately diluted to 10 micro Ci/gm with minimal exposure to personnel. Personnel exposure is discussed in Section 7.3.

10.3.1 Radionuclide Analysis Capabilities

The Counting Room equipment routinely analyzes reactor coolant samples having activities which typically contain .2-.3 micro Ci/ml gross activity. A post accident sample of 10 micro Ci/ml (100 micro Ci total activity) can be analyzed on this same equipment (Canberra 8100's) without impacting the efficiency of the equipment. This has been verified by PSE&G using a 176 micro Ci source to check the response of the counting equipment.

The counting equipment located in the Counting Room is listed below. Also included in the list is all counting equipment which would be available for performing post accident sample counting. The Canberra Series 8100's are considered the primary post accident counting equipment with the portable Canberra Series 85 serving as the backup.

TABLE 10-1
SALEM COUNTING EQUIPMENT

| | <u>Make and Model*</u> | <u>Detector Type*</u> | <u>Analysis</u> | <u>Location</u> |
|----|--|----------------------------|---------------------|----------------------------|
| 1. | Canberra MCA Series 8100(4) PDP 1134A Computer (2) | a. GeLi (2) b. Hp Ge(2) | Gamma Spectrum | Aux. Bldg. Counting Rm. |
| 2. | Packard Tri Carb | Liquid Scin- tillation | Gross Beta Gamma | Aux. Bldg. Counting Rm. |
| 3. | Canberra MCA Series 35 (See Note 1) | HpGe | Gamma Spectrum | Portable |
| 4. | Canberra MCA Series 85(2) PDP 1134 A Computer (1) (See Note 2) | HpGe | Gamma Spectrum | Training Center |
| 5. | Nuclear Data 6700 | Geli | Gamma Spectrum | Service Bldg. |
| 6. | Wide Beta Two | Gas Propor- tional | Gross Beta Gamma | Aux. Bldg. Counting Rm. |

*Number in parenthesis indicates number of units in service.

NOTES: (1) Currently undergoing testing and calibration prior to placement into service.

(2) Used for training purposes only; no routine analytical work done on this equipment.

10.3.2 Background Radiation Levels

Changes to counting equipment background due to accident conditions is currently being evaluated. The primary source of radiation which would cause an increase in background are the Unit 2 safety injection pumps. These pumps are located on Elevation 84' close to the Counting Room. However, current planning assumes that the Counting Room background would preclude its use under certain accident scenarios. The evaluation will document what background levels can be expected. In the event the counting room radiation/background levels become excessive, the following options are available:

- 1) Set up the portable counting equipment in a low background area (i.e., Turbine Bldg., Demin Water Plant, Maintenance Bldg.).
- 2) Move the counting equipment to a low background area.
- 3) Use the counting equipment located in the Service Building.
- 4) Use the counting equipment located at the Salem Training Facility (facility is approximately 10 miles from the station).

Background levels in the Counting Room will not be affected by the samples being collected. All sample handling and dilutions in preparation for counting are done in the Chemistry Lab. The distance from the Chemistry Lab to the Counting Room and the walls between the two areas provide sufficient shielding to preclude an increase in background due to the samples.

The presence of airborne activity in the Counting Room will interfere with the counting of certain isotopes. This problem occasionally arises from routine plant operation. When this occurs, the counting "pigs" are purged with either station air or argon from bottles. Purging is an installed capability which would be used during an accident to reduce airborne background levels. In the event the airborne background is excessive, alternate counting equipment and locations would be utilized as discussed previously.

Transport of samples to alternate counting locations can be done using a shielded container. Preparation of the sample for transport and counting would still be done in the Chemistry Lab.

11.0 Criterion 10

11.1 Criterion

Accuracy, range, and sensitivity shall be adequate to provide pertinent data to the operator in order to describe radiological and chemical status of the reactor coolant systems.

11.2 Clarification

The recommended ranges for the required accident sample analyses are given in Regulatory Guide 1.97, Rev. 2. The necessary accuracy within the recommended ranges are as follows:

- Gross activity, gamma spectrum: measured to estimate core damage, these analyses should be accurate within a factor of two across the entire range.
- Boron: measure to verify shutdown margin.

In general, this analysis should be accurate within +5% of the measured value (i.e. at 6,000 ppm B the tolerance is +300 ppm while at 1,000 ppm B the tolerance is +50 ppm). For concentrations below 1,000 ppm, the tolerance band should remain at +50 ppm.

- Chloride: measured to determine coolant corrosion potential.

For concentrations between 0.5 and 20.0 ppm chloride the analysis should be accurate within +10% of the measured value. At concentrations below 0.5 ppm the tolerance band remains at +0.05 ppm.

- Hydrogen or Total Gas: monitored to estimate core degradation and corrosion potential of the coolant.

An accuracy of +10% is desirable between 50 and 2000 cc/kg but +20% can be acceptable. For concentration below 50 cc/kg the tolerance remains at +5.0 cc/kg.

- Oxygen: monitored to assess coolant corrosion potential.

For concentrations between 0.5 and 20.0 ppm oxygen the analysis should be accurate within $\pm 10\%$ of the measured value. At concentrations below 0.5 ppm the tolerance band remains at ± 0.05 ppm.

- pH: measured to assess coolant corrosion potential.

Between a pH of 5 to 9, the reading should be accurate within ± 0.3 pH units. For all other ranges ± 0.5 pH units is acceptable.

To demonstrate that the selected procedures and instrumentation will achieve the above listed accuracies, it is necessary to provide information demonstrating their applicability in the post accident water chemistry and radiation environment. This can be accomplished by performing tests utilizing the standard test matrix provided below or by providing evidence that the selected procedure or instrument has been used successfully in a similar environment.

STANDARD TEST MATRIX
FOR
UNDILUTED REACTOR COOLANT SAMPLES IN A POST-ACCIDENT ENVIRONMENT

| <u>Constituent</u> | <u>Nominal Concentration (ppm)</u> | <u>Added as (chemical salt)</u> |
|------------------------------------|--|-------------------------------------|
| I- | 40 | Potassium Iodide |
| Cs+ | 250 | Cesium Nitrate |
| Ba+2 | 10 | Barium Nitrate |
| La+3 | 5 | Lanthanum Chloride |
| Ce+4 | 5 | Ammonium Cerium Nitrate |
| Cl- | 10 | - |
| B | 2000 | Boric Acid |
| Li+ | 2 | Lithium Hydroxide |
| NO ₃ | 150 | - |
| NH ₄ | 5 | - |
| K+ | 20 | - |
| Gamma Radiation (Induced Field) | 10 ⁴ Rad/gm of Reactor Coolant | Absorbed Dose |

NOTES:

- (1) Instrumentation and procedures which are applicable to diluted samples only, should be tested with an equally diluted chemical test matrix. The induced radiation environment should be adjusted commensurate with the weight of actual reactor coolant in the sample being tested.
- (2) For PWR's procedures which may be affected by spray additive chemicals must be tested in both the standard test matrix plus appropriate spray additives. Both procedures (with and without spray additives) are required to be available.
- (3) For BWR's, if procedures are verified with boron in the test matrix, they do not have to be tested without boron.
- (4) In lieu of conducting tests utilizing the standard test matrix for instruments and procedures, provide evidence that the selected instrument or procedure has been used successfully in a similar environment.

All equipment and procedures which are used for post accident sampling and analyses should be calibrated or tested at a frequency which will ensure, to a high degree of reliability, that it will be available if required. Operators should receive initial and refresher training in post accident sampling, analysis and transport. A minimum frequency for the above efforts is considered to be every six months if indicated by testing. These provisions should be submitted in revised Technical Specifications in accordance with Enclosure 1 of NUREG-0737. The staff will provide model Technical Specifications at a later date.

11.3 Response

The Sentry Post Accident Sampling System was developed to provide in-line analyses and in-line dilutions for grab sample analyses which would meet the requirements of NUREG 0578, Section 2.1.8a, NUREG 0737 Item II B.3, and Regulatory Guide 1.97 Revision 2. Undiluted coolant and containment air samples can be captured in shielded containers for on-site or off-site analyses. The Sentry equipment can also be used for routine sampling and analyses.

The Rice Division of NUS Corporation developed and tested the methods selected for post-accident boron, chloride, dissolved hydrogen and oxygen, pH and conductivity analyses. The analytical requirements, selected method capabilities, and accuracies achievable based on testing are summarized in Table 11-1. The NUS development and test program considered the following criteria in reviewing the analytical methods available to meet the post-accident requirement.

1. Chemical effect of the post-accident coolant matrix
2. Analysis time and radiological dose limitations
3. Radiation effect on method and/or equipment
4. Application to both normal and post-accident conditions
5. Compliance with sensitivity and range requirements
6. Applicability to in-line or grab sample analysis
7. Sample size requirements

The methods evaluated, testing performed, and reasons for selection of the appropriate method are summarized for each analysis in the following discussion. Complete details of the NUS development and testing program are presented in NUS Report R-27-11-1-3, Final Verification Testing of HRSS Chemical Analysis Panel and NUS Report R-27-4-1-1, Development of Procedures and Analysis Methods for Post Accident Reactor Coolant Samples.

11.3.1 Gross Activity

A 10 Ci/ml reactor coolant sample must be diluted prior to isotopic analysis. Current procedures would have a sample of this concentration diluted by a factor of 10^6 prior to analysis. At a concentration of 10 micro Ci/ml a 10 ml sample can be readily analyzed to an accuracy well within a factor of two. The counting equipment's upper range is approximately 200 micro Ci total activity. Above this activity level the accuracy of the results are suspect but may still be accurate within a factor of 2. A 176 micro Ci source has been used to check the upper limits of the counting equipment.

11.3.2 Boron

NUS evaluated boron analysis methods and selected for further testing the methods best suited for post-accident use. The following methods were included in the evaluation:

Fluoroborate Selective Ion Electrode
Curcumin Spectrophotometric Method
Plasma Spectroscopy Method

Boronometer Neutron Attenuation
Titrimeter Method
Ion Chromatographic Method
Mannitol Titration Method
Carminic Acid Spectrophotometric Method

The fluoroborate selective ion electrode method was selected as the most appropriate method for post-accident applications. Fluoroborate electrode test results confirm that boron can be determined accurately and rapidly on a diluted post-accident sample. The procedure is qualified for 1-1000 diluted samples containing 0.5 to 6.0 ppm boron. This range can be extended by calibration in the region of interest. The boron concentration can be determined within approximately 20 minutes after a diluted sample is available in the chemistry laboratory.

The fluoroborate electrode analysis method was qualified by analyzing post-accident matrix samples containing known concentrations of boron. The specific chemical components and concentrations in the matrix solutions are provided in NUS Report R-27-4-1-1 and are essentially the same as the test matrix identified by the NRC in their post-implementation evaluation criteria guidelines. These samples simulated expected PWR boron concentrations, normal coolant pH additive, post-accident fission product elements, and sump water with containment spray sodium hydroxide. Using the fluoroborate electrode method, shutdown boration levels can be determined rapidly and accurately. The mean absolute bias determined during testing was +3.0 percent at boron levels of 2.0 ppm, and +10 percent at boron levels of 0.5 ppm. Assuming a 1-1000 dilution, the range of procedure is 500-6000 ppm boron in reactor coolant. Thus, the fluoroborate method meets the accuracy and range requirements identified in the NRC post implementation evaluation criteria guidelines.

In addition, NUS modified, tested, and qualified the curcumin spectrophotometric boron method for post-accident application. Testing was performed on 1-1000 dilutions of post-accident matrix solutions. The analysis can be performed in about two hours after the sample is available in the chemistry laboratory. The analysis range is from about 0.2 to 2.0 ppm boron (200 to 2000 ppm boron in the coolant) and the relative standard deviation for multiple analyses is about +13 percent for post-accident matrix solution.

11.3.3 Chloride

NUS evaluated several chloride analysis methods and selected ion chromatography as the method best suited for post-accident use. This method was selected primarily because of the need to analyze undiluted samples to meet the sensitivity required, and the subsequent radiological impact and chemical interferences associated with other methods.

The results of the evaluation and testing performed to qualify the ion chromatographic method are summarized below. The following methods were included in the evaluation:

- Ion Chromatography
- Selective Ion Electrode
- Mercuric Nitrate Titration
- Spectrophotometric Methods

Ion chromatography is a powerful tool for the quantitative analysis of low ionic concentration solutions. The method, applicable to both anions and cations, is based on the elution selectivity of ion exchange media for different ionic species. Sample size, physical size of the ion exchange column, ionic capacity of the resin, eluent concentration, and sample flowrate can all be held constant. The time after sample injection that a conductivity peak appears can be assigned to a specific ionic species. Ion chromatographs can be automated and can be operated remotely, thus optimizing their use for in-line chloride analyses under post-accident conditions.

NUS testing was performed on a Dionex Model 10 ion chromatograph - the same model installed in the Sentry PASS Chemical Analysis Panel. Testing was performed using post-accident matrix solutions containing various concentrations of chloride from 0.1 ppm to 20 ppm. The range of analyses can be extended with additional calibration curves and varying attenuation settings. The test results indicate the absolute mean bias for the ion chromatographic analysis of post-accident matrix samples is 7.6 percent for chlorides in the range of 0.1 to 1 ppm and 5.8 percent for chloride in the range of 1 to 20 ppm.

The test results indicate the ion chromatographic method meets the range and accuracy requirements of the NRC post-implementation evaluation criteria guidelines.

Additional testing of the ion chromatographic method was conducted by NUS to determine if other contaminants, which could exist in the coolant through mixing with sump waters, would effect the chloride analysis. Contaminants tested included morpholine, hydrazine, ammonia, and natural and synthetic oils. No effects of morpholine, hydrazine, and ammonia were observed. Oil contamination increased the chloride results by about 10-30 percent. This result could be due to soluble chlorides present in the oils; however, this was not verified. Fouling of the resin columns was observed by progressive reduction on the time required for the appearance of the chloride peak. Approximately 10 to 15 oil contaminated samples could be analyzed under post-accident conditions without significant resin fouling. Details of the NUS development program and final verification testing are presented NUS Reports R-27-4-1-1 and R-27-11-1-3.

11.3.4 Dissolved Hydrogen

NUS reviewed various methods of measuring dissolved hydrogen concentration in reactor coolant and concluded in-line gas chromatographic techniques were best suited for post-accident applications. Hydrogen concentration in reactor coolant can be determined rapidly (20 to 30 minutes) and accurately by in-line gas chromatographic analyses using the Baseline 1030A which is installed in the PASS Chemistry Analysis Panel. The analytical sections of the gas chromatograph, installed in the rear of the Chemical Analysis Panel, employs a dual column, thermal conductivity detector system to separate and measure hydrogen (as well as other gases). The controller for the gas chromatograph is installed in the Chemical Monitor Panel.

Hydrogen gas is initially stripped from a 30 ml coolant sample captured in an in-line sampling flask in the Liquid Sampling Panel. After collection of the liquid sample, hydrogen and other gases are stripped into a 300cc evacuated flask. The stripped gas is routed to the Chemical Analysis Panel and to four 1 cc sampling loops

of the gas chromatograph. Gas in the sampling loops is injected into the gas chromatograph by continuous flow of argon carrier gas. Residual water vapor is retained on the first column until the sample gases have eluted and then is back-flushed from the system.

Initial testing to establish optimum conditions was performed by NUS using a Fisher Model 1200 gas chromatograph. Both the Fisher and Baseline gas chromatograph have similar operating characteristics. Final calibration and identification testing was performed using a Baseline Model 1030A gas chromatograph as installed in the Sentry PASS. The absolute mean deviation of results are 7.1 percent in a hydrogen range of 3.1 to 28 cc/kg at STP. The absolute mean deviation of results in the 21.7 to 186 cc/kg at STP was 8.8 percent. For the hydrogen range of 186 to 930 cc/kg at STP the absolute mean deviation was 7.6 percent. The absolute mean deviation was 2.8 percent in the hydrogen range of 930 to 1860 cc/kg at STP.

Based on the data, the Baseline gas chromatograph installed in the PASS may be used to determine dissolved hydrogen concentration in the range of 3 to 2000 cc/kg at STP with an accuracy within the requirements of the NRC post-implementation evaluation criteria guidelines. The accuracy statements apply to determinations made using separate calibration curves for each sample loop and for each of the four attenuation settings available. The operator must relate his determined peak height units to the calibration curve corresponding to the loop and attenuation scale used during the analysis.

11.3.5 Dissolved Oxygen

Since accurate dissolved oxygen results require analysis of undiluted samples with minimal exposure to air, on-line analyses methods must be performed.

NUS reviewed the capabilities of various in-line oxygen analyzers and concluded that two analyzers, a Yellow Springs Instrument analyzer and a Rexnord analyzer, were required to meet the objectives of providing monitoring capabilities under both normal plant operating conditions and post-accident conditions.

The Yellow Spring Instrument (YSI) Analyzer, while not as sensitive as the Rexnord analyzer, meets post-accident criteria. The YSI was selected for post-accident use because the response time of the probe was relatively short (i.e., 5 minutes) and the smaller probe holder volume would lower associated radiation levels. The Rexnord analyzer provides the sensitivity required during normal operating conditions. Preliminary testing to determine the effect of variable flow and high dissolved gases were performed. The conclusions drawn from this testing were:

1. The YSI Model 54 oxygen analyzer is relatively insensitive to flow rates from 58 ml/min to 547 ml/min.
2. Hydrogen in solution and microscopic bubbles of hydrogen in the water have no effect on oxygen readouts.
3. The YSI oxygen analyzer has adequate accuracy at 0.10 ppm oxygen.

Final verification testing was performed on both the YSI and Rexnord dissolved oxygen analysis systems as installed in the PASS. Testing results in the YSI probe lead to the specified flow time of five minutes at 200 ml/min for obtaining probe equilibrium. Testing with the Rexnord probe indicated that 15 minutes was required to reach equilibrium.

Testing was performed using a PWR post-accident matrix and comparing the dissolved oxygen concentration indicated by the probes with results obtained using the modified Winkler method. The absolute mean bias for YSI probe results on samples varying from 0.38 to 8.0 ppm dissolved oxygen was 8.2 percent. The mean absolute bias for the Rexnord probe was 5.7 percent on samples varying from 0.1 to 10 ppm oxygen.

Based on the final verification testing, the YSI probe can be used during post-accident conditions to determine dissolved oxygen concentrations with an accuracy of at least ± 10 percent in the test range of 0.1 to 10 ppm.

The Rexnord probe data supports the value of +10 percent accuracy for dissolved oxygen in the test range of 0.1 to 20 ppm. Testing at oxygen concentrations up to 20 ppm was not performed, but the linear response obtained indicates measurements at the higher concentration is achievable. The data indicate the requirements established by the NRC in the post implementation evaluation criteria guidelines can be met.

11.3.6 pH

pH analyses are performed in-line using a Cole-Parmer combination pH probe mounted within a probe holder. Calibration of the probe is conducted in-place using pH 7 and pH 4 or 10 buffer solutions. Readout indication is provided by a Beckman pH monitor mounted within the Chemical Monitor Panel.

During final verification testing, two calibration tests were performed. Initially a pH 7 buffer was flowed through the probe holder and the pH monitor adjusted to read 7.0. Then the probe was removed from the probe holder and immersed in a pH 10 buffer; the reading obtained was 9.8. The probe was rinsed and immersed in a pH 4 buffer and a reading of 3.8 obtained. The second calibration involved flowing calibration buffers of pH 7 and 10 from the calibration tanks. Readings of 9.7 were obtained for the pH 10 buffer.

Testing of the pH probe included flowing of PWR matrix fluids through the Chemical Analysis Panel, recording readings and comparing these readings with open grab sample measurements of the stream effluent. The data obtained indicates an absolute mean bias of +0.3 pH units over a pH range of 5 to 8.

11.3.7 Radiation Effects

A study made to determine the effect of radiation on equipment in the PASS analysis system indicates that the radiation levels anticipated will have no effect on accuracy of measurement and very little, if any, effect on operating lifetime of the individual components within the system. The study included a survey of personnel who

have performed similar analysis under high radiation levels in hot cell conditions and a review of the literature concerning irradiation effects on materials of construction. In addition, laboratory experiments were performed to determine the effect of concentrations of hydrogen peroxide on the conductivity of the reference solution. No effect was noted. The laboratory work was performed because there could be trace concentrations of peroxide in the coolant under zero or near zero hydrogen concentrations in the primary coolant.

In performing the survey, personnel were contacted at Battelle-Northwest and Oak Ridge Laboratories. In addition, a former employee of the naval test facility in Idaho was contacted concerning his hot cell experience with radiation chemistry at this location. Operational experience exists within the three laboratories concerning all phases of the analyses performed by the subject system. Results from these laboratories are consistent as all indicate the analytical measurements in question can be made at much higher radiation levels than will be experienced under post-accident conditions in the automated analysis system. One general conclusion that can be made from this survey is that analytical instruments can be operated in a hot cell without loss in accuracy of results. There will be some reduction in operating lifetime of the system where continuing exposure at very high radiation levels is involved. Results of this survey as it applies to the individual analytical components within the system are discussed below:

a. Boron Determination

Since the boron determination is made on a 1:1000 dilution of reactor water, the 5 ml sample radiation level is on the order of 30 R/hr at 1 cm two hours after the accident. The total dose to the fluoroborate electrode during the analyses sequence will be on the order of tens to hundreds of rads. The level of exposure is not anticipated to have any significant effect on the accuracy of measurement or operating lifetime of the probe.

b. Chloride Determination

Radiation levels for the chloride analysis equipment (ion chromatograph) will be lower than is the case for the other equipment in the analytical system. The reasons for this are as follows: (1) the maximum primary coolant volume contained within the ion chromatograph will be on the order of 1 ml, and (2) the system will be located further away from the radiation source than are other components in the system. Components in the ion chromatograph receiving relatively high radiation exposure include the following:

Cation resin
Anion resin
Conductivity cell
Transistors
Capacitors
Wire-wound pots
Circuit board

No radiation damage is anticipated with resins based on experience developed at Battelle. Resins are conventionally used to separate various isotopes at Battelle without problems. Damage occurs after extended exposure; however, the degradation process is slow. Anion resin will start to degrade at about 10^8 rads and cation resin at 5×10^8 rads. This is several orders of magnitude higher than will be encountered for the resins in the ion chromatograph. It is anticipated that electronic components of the type included in the ion chromatograph will be resistant to cumulative exposure well above 10^5 rads.

In the absence of dissolved hydrogen, it is possible the primary coolant will contain low ppm concentrations of hydrogen peroxide from radiolysis of water. The effect of this peroxide on readout of the conductivity cell in the ion chromatograph was investigated by adding peroxide to a solution containing 2 ppm HCl and measuring conductivity before and after the addition of peroxide. The

justification for using a 2 ppm HCl solution is noted below. Essentially, no effect was observed on conductivity within the limits of the accuracy of the instrumentation.

Chloride determinations on an ion chromatograph are obtained by processing the water through resin columns and monitoring the conductivity of the effluent. The chloride (or other anions) will pass through the resin column in wave form at known time intervals after injection of the solution to be analyzed. Cations are removed by the suppressor column resulting in the formation of the corresponding acids such as HCl, H₂SO₄, etc., passing through the conductivity cell in wave form, each at a different though known time interval, after the injection of the solution to be analyzed. Conductivity of the solution at a specific time interval is then related to acid concentration for the anionic species which passes through at that time.

Information developed in testing performed by NUS indicates that 5-10 ppm chloride in the sample size used will result in a maximum HCl concentration of about 2 ppm after it is separated in peaks as it passes through ion exchange columns in the ion chromatograph. The 2 ppm HCl concentration used in the peroxide test is based on the reasonable assumption that chloride level in the primary coolant will generally be below 10 ppm.

c. Dissolved Hydrogen

A review and evaluation of the components of the gas chromatograph i.e., molecular sieves, thermal conductivity cell, etc., indicate they are relatively insensitive to radiation damage. There are no radiation effects anticipated.

d. Dissolved Oxygen Determination

Readout equipment for this system is located remotely. The equipment exposed to radiation contained in the oxygen and temperature detection probe includes the following:

Gold cathode and silver anode
Membrane made of 2 mil Teflon
Electrolyte - saturated KCl
Two metal oxide thermistors
Connecting wires to anodes
Synthetic rubber O-ring seals
Stainless steel probe holder
PVC block and Hysol Epoxy cement

The most sensitive component to radiation damage in the above list is the two-mil thick Teflon membrane. Unpublished data from Oak Ridge indicate that Teflon is resistant to radiation damage to about 10^6 rads. This data is supported by irradiation tests performed in connection with the nuclear plane development effort. Results of this work indicate that high pressure (1400 psi) Teflon hoses would show incipient leakage at 10^6 rads exposure levels. Cumulative exposure levels for the Teflon membrane during post-accident conditions would be less than 10,000 rads. Thus, there is a safety factor of at least 100X associated with this component. It should be noted that the probe or the membrane itself can be easily replaced with very minimal exposure after the system is flushed, drained and blown dry.

The two anodes and stainless probe holder are not sensitive to radiation other than perhaps high-intensity neutron irradiation. There will be no neutrons present in the analytical system. The two metal-oxide thermistors are not expected to be affected by radiation; however, no problem would result if damage occurred. The temperature indication provided by the thermistors is not a critical measurement.

No radiation damage is anticipated to the PVC block below 10^6 rads based on data concerning the general resistance of organics to radiation. The Hysol epoxy cement is stable to radiation at exposure levels to 10^7 rads. Concerning other components (O-ring seals, insulation), the cumulative exposure levels anticipated are far below the area where damage will occur.

e. pH Determination

Readout equipment for this system is located remotely. The equipment exposed to radiation includes the following:

Glass pH probe - Gel type with internal reference cell
Connecting wires to probe
Synthetic rubber O-ring seals
Stainless steel probe holder

Experimental work reported in literature indicates that pH electrodes of the type used in this system are stable at cumulative dosages up to $10^7 - 10^8$ rads. These results are in agreement with data presented in other references and experience reported by Battelle and the naval test facility in Idaho. Concerning selective ion electrodes, it was observed that the potential response of a fluoride electrode shifted with time at very high cumulative exposures; however, the affected electrode did not lose its effectiveness as long as calibrations were made periodically with standard solutions. A nitrate electrode began to give erratic readings as the cumulative dose approached 10^7 rad.

Cumulative exposure levels to the pH probe in the automated analysis panel during post-accident conditions will be less than 10,000 rads. Thus, there is a factor of at least 1000X below the point where incipient radiation damage can be anticipated. It is worthy to note that the data reported in the literature indicate that valid pH readings can be obtained where a radiation effect was noted provided that the system is calibrated periodically. Operating instructions to be included with the automated analysis equipment will specify daily calibration when the system is in regular use. Calibration prior to use will be specified for intermittent operation. Other components within the pH probe assembly will not be affected by the radiation exposure levels involved.

f. Conductivity Determination

Readout equipment for this system is located remotely, thus, will not be exposed to significant radiation levels. The equipment exposed to radiation includes the following:

Platinum electrodes enclosed in a glass holder
Connecting wires to the electrodes
Stainless steel probe holder
Synthetic rubber O-ring seals

Operating experience at Oak Ridge and the naval test facility indicate that conductivity measurements can be made in hot cell conditions under very high radiation levels without problem. Battelle-Northwest could not recall an experience in measuring conductivity under hot cell conditions. Oak Ridge has noted that ruthenium in solution can result in a problem since it will ultimately plate out and thus poison the electrodes. This is a very slow process occurring only in solutions having a much higher radiation level than would be present under post-accident conditions.

Incipient damage to the insulation on the connecting wires to the platinum electrodes could be anticipated at about 10^7 rads based on information presented in the literature. Total radiation exposure to this insulation during post-accident conditions would probably not exceed 1000 rads and would be less than 10,000 rads. Thus, the insulation on the wire has a 1000X factor of safety.

The synthetic rubber O-ring seals could suffer incipient damage at about 10^6 rads based on data listed in literature. Total radiation exposure for these O-ring seals during post-accident conditions would be less than 10,000 rads resulting in a 100X safety factor. The glass and stainless steel would not be affected by the radiation. Glass will darken with time on exposure to radiation; however, this would not affect its performance in this application.

In the absence of dissolved hydrogen in the primary coolant, it is possible that there will be low concentrations of peroxide present from radiolysis of the water. Testing was performed to determine if this peroxide would have an effect on the conductivity of boron-containing waters. No effect was noted on boric acid solutions with peroxide concentrations of 100 and 200 ppm. A 1 percent increase in conductivity was observed for basic boron solutions containing 100 and 200 ppm peroxide.

g. Pressure Indicator

A pressure transducer incorporating a strain gauge is used to sense pressure and transmit this pressure to the readout equipment which is located remotely. Only the transducer is exposed to radiation. This contains the following material:

Diaphragm made of 17-4 pH stainless steel
A strain gauge made of silicon doped with phosphorous
Synthetic rubber O-ring seal
Circuit board with resistors, capacitors and transistors
Die-cast aluminum housing for electronic components
Insulation on lead-in wire

The most sensitive component to radiation damage in the pressure transducer is probably the transistors. These should be resistant to cumulative exposure above 10^5 rads based on data presented in the literature. Maximum cumulative exposure for the transistors will be below 10,000 rads. There are no data available concerning radiation resistance of the strain gauge. The principle of operation for a strain gauge involves a change in resistivity that is proportional to the deflection in the gauge. It is very unlikely that resistivity of an element will be affected by radiation exposures that will be experienced in the pressure transducer during a post-accident condition.

All other components in the pressure transducer can withstand cumulative exposure on the order of 10^6 rads or more.

h. Valves

All valves in the Sentry PASS use Teflon packing. The use of Teflon packing is specified because of its good sealing characteristics. Oak Ridge prefers Teflon-packed valves for handling radioactive solutions containing high levels of radioactive iodine. Some radiation damage to the Teflon may be anticipated at 10^6 rads cumulative exposure; however, it is unlikely these valves will ever have 10,000 rads exposure. It is recognized that there are packing materials available that are more resistant to radiation than is Teflon. These were not specified because the primary concern is to maintain leaktightness.

11.3.8 Testing and Calibration

In order to maintain good mechanical integrity and operability of the PASS, operational tests will be completed on regularly scheduled intervals. Testing will ensure that all components function properly under post accident conditions. In addition, the equipment tests will provide the operators with hands-on experience to enforce their formal training. The following schedule will be followed for the various operations listed. Adherence to the schedule will be based on availability of manpower.

| <u>Operation</u> | <u>Frequency</u> |
|--|------------------|
| 1. Undiluted Reactor Coolant Sample | Every 4 wks. |
| 2. Diluted Reactor Coolant Sample | Every 4 wks. |
| 3. Reactor Coolant Stripped Gas | Every 4 wks. |
| 4. pH, Conductivity & Dissolved Oxygen | Weekly |
| 5. Ion Chromatograph | Weekly |
| 6. Gas Chromatograph | Weekly |

11.3.9 Training

NUS has developed and implemented a formal training program on the operation of the Post Accident Sampling System for PSE&G. The course is one

week in duration and consists of lectures followed by walkthroughs of all the PASS procedures. Successful completion of this course is documented by a written examination. To date, a majority of the chemistry technicians have successfully completed the training program. Retraining is presently scheduled for every 6 months.

NUS is currently developing a management training program on PASS. This program will cover the design basis and the capabilities of the PASS. It is anticipated that this program will be completed by August, 1983 and implemented by September, 1983.

TABLE 11-1

| ANALYSIS | REQUIREMENT | | Method Selected | RESPONSE | | |
|--------------------|----------------------------|--|---|-------------------------|---|----------------|
| | Range | Accuracy | | Range | Accuracy | Testing Method |
| Boron | 0-2000 | $\pm 5\%$ > 1000 ppm | Diluted Grab Sample | 500-6000 (1) | 3.0% B >2000 ppm (2)(3) | matrix |
| Chloride | 0-20 ppm | $\pm 10\%$ 0.5-20 ppm ± 0.05 ppm < 0.5 ppm | Ion Chromatography | 0.1-20 5.8% 1-20 ppm | 7.6% 0.1-1 ppm (3) | matrix |
| Hydrogen | 0-2000 cm ³ /kg | $\pm 10\%$ 50-2000 cc/kg ± 5 cc/kg < 50 cc/kg | Gas Chromatography | 0.5-2000 cc/kg | 7.1% 3.1-28 cc/kg 8.8% 21.7-186 cc/kg 7.6% 186-930 cc/kg 2.8% 930-1860 cc/kg | non-matrix |
| Oxygen | 0-20 ppm | $\pm 10\%$ > 0.5 ppm ± 0.05 ppm < 0.5 ppm | YSI in-line probe Rexnord in-line probe (4) | 0.1-20 ppm | 8.2% 0.38-8.0 ppm 5.7% 0.1-10 ppm | matrix |
| pH | 1-13 | ± 0.3 pH > 5 < 9 ± 0.5 pH < 5 > 9 | in-line probe | 1-13 | $\pm 0.3, 5.0$ < pH < 8.0 | matrix |
| Conductivity ----- | ----- | ----- | in-line probe | 0.1-500 umho/cm | $\pm 5.4\%$ at 29.6 umho/cm | matrix |

- (1) The range is based on a 1 to 1000 dilution if the applicable range can be lowered by utilizing a small dilution, i.e., 1 to 1000 dilution lowers the range to 50 ppm.
- (2) The accuracy stated is achievable if a boron standard is run immediately before the analysis and if the pH meter readout is adjusted to the correct response based on the calibration curve.
- (3) % error is the mean absolute bias
- (4) The Rexnord probe for routine (non-accident use) is installed parallel to the YSI probe.

12.0 Criterion 11

12.1 Criterion

In the design of the post accident sampling and analysis capability, consideration should be given to the following items:

- (a) Provisions for purging sample lines, for reducing plateout in sample lines, for minimizing sample loss or distortion, for preventing blockage of sample lines by loose material in the RCS or containment, for appropriate disposal of the samples, and for flow restrictions to limit reactor coolant loss from a rupture of the sample line. The post accident reactor coolant and containment atmosphere samples should be representative of the reactor coolant in the core area and the containment atmosphere following a transient or accident. The sample lines should be as short as possible to minimize the volume of fluid to be taken from containment. The residues of sample collection should be returned to containment or to a closed system.
- (b) The ventilation exhaust from the sampling station should be filtered with charcoal absorbers and high-efficiency particulate air (HEPA) filters.

12.2 Clarification

- (a) A description of the provisions which address each of the items in clarification 11.a should be provided. Such items, as heat tracing and purge velocities, should be addressed. To demonstrate that samples are representative of core conditions a discussion of mixing, both short and long term, is needed. If a given sample location can be rendered inaccurate due to the accident (i.e. sampling from a hot or cold leg loop which may have a steam or gas pocket) describe the backup sampling capabilities or address the maximum time that this condition can exist.

BWR's should specifically address samples which are taken from the core shroud area and demonstrate how they are representative of core conditions.

Passive flow restrictors in the sample lines may be replaced by redundant, environmentally qualified, remotely operated isolation valves to limit potential leakage from sampling lines. The automatic containment isolation valves should close on containment isolation or safety injection signals.

- (b) A dedicated sample station filtration system is not required, provided a positive exhaust exists which is subsequently routed through charcoal absorbers and HEPA filters.

12.3 Response

12.3.1 Liquid Sampling Design

Reactor coolant samples can be drawn from the 11 or 13 hot leg on Unit 1 and the 21 or 23 hot leg on Unit 2. The sample lines tee into the main coolant piping near (within 30") the RHR and Safety Injection tie-ins to the same main coolant piping. From the hot legs the reactor coolant is purged at 1900 cc/min. (0.5 gpm) to the Liquid Sampling Panel and discharged to either the Unit 1 or 2 containment sump. Purging at this rate for 1 hour allows for 3 volume turnovers of the longest sample line run (11 hot leg on Unit 1). Sampling and purging from these points assures that the sample is representative of the reactor coolant. Representativeness of the sample has been verified by actual sampling and analysis using the PASS.

Two separate sample lines are provided in the event that one of the lines should become blocked or damaged. In the event that both of the sample lines are blocked, a sample could be drawing using the existing sampling system. Use of this sampling facility would result in increased personnel exposure since this system was never designed to handle high activity reactor coolant. However, procedures have been written for this eventuality which minimize personnel exposure. The existing system also has the capability to sample the discharge of the RHR (Residual Heat Removal) pumps. Sampling from the discharge of the RHR pumps provides a means to sample should the hot legs become vapor bound.

Each reactor coolant sample line is provided with redundant isolation valves. The isolation valves are located on either side of the sample line containment penetrations. The valves are remotely operated from Panel 814 which is located in the PASS Room. The isolation valves are environmentally qualified to meet the anticipated conditions during and following an accident. The valves are designed as normally closed/fail close. During routine operation of the plant the valves are normally closed and therefore, do not receive a containment isolation signal to close.

12.3.2 Containment Air Sampling Design

Containment air is sampled from a point 15' above the 130' elevation (Operating Deck) of the containment building. The sample lines are routed from this point inside containment to the Containment Air Sampling Panel (CASP) and back to containment. The sample lines are heat traced from where the lines penetrate containment up to the CASP. The heat trace can maintain a temperature of 300°F on the sample lines. Heating the lines at 300°F prevents plateout of iodine and prevents condensation from forming in the sample lines.

Units 1 and 2 each have redundant sampling lines. This provides backup capabilities in the event one of the lines should become clogged or damaged. Also, to prevent blockage of the lines, the sample line inlets have 180° bend at their ends. This is to prevent airborne debris or water from entering the open ends of the lines during an accident.

12.3.3 Ventilation System

The PASS sampling panels have their own ventilation system. The ventilation system consists of a booster fan and associated duct work. The duct work ties the sampling panels into the Unit 2 Auxiliary Building ventilation system. The Auxiliary Building ventilation system is equipped with charcoal absorbers and HEPA filters for the removal radioactive particulates and noble gases.

The booster fan is used to maintain a negative pressure inside the Liquid Sampling Panel, Chemical Analysis Panel, and Containment Air Sampling Panel. In the event of any leakage within these panels, airborne activity would be drawn into the ventilation system preventing the accumulation of airborne activity within the PASS Room.

APPENDIX A

Reports

1. NUS Report R-27-3-1-1A, "An Evaluation of the Baseline System for Determination of Total Gas Concentration During Normal or Post-Accident Conditions".*
2. NUS Report R-27-11-1-3, "Final Verification Testing of HRSS Chemical Analysis Panel".*
3. NUS Report R-27-4-1-1, "Development of Procedures and Analysis Methods for Post-Accident Reactor Coolant Samples".
4. PSE&G Report Number NFG-0026, "Post-Accident Core Assessment Procedure."

*Copies of the reports available upon request from PSE&G.