APPENDIX 11

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CONTENTS

APPENDIX 11

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QUESTION 11A.1

Provide a Radiation Monitoring System schematic similar to the format of Figure 7.1-2 which indicates location, equipment type, power sources, and interlock functions. The schematic should show the relationship of the area, waste and gas disposal, ventilation, and site monitoring systems. The schematic should be accompanied by adequate description.

ANSWER Refer to 11.2.2

The Radiation Monitoring System will consist of the Process Radiation Monitoring System and the area Radiation Monitoring System. Control room area monitors will be located close to the control console. The system functions are the early detection of an abnormal rise in radiation within the reactor complex and at selected locations on the reactor site perimeter, an audible alarm of the location of the abnormal radiation and the display of the level of the radiation as a visual or printed record. The Process Radiation Monitoring System function is to detect early indication of plant malfunction and the Area Radiation Monitoring System function is to warn personnel of excessive gamma radiation within selected working areas. Except for the waste gas disposal interlock, the signals from the monitoring system are not used for the automatic control of the equipment. Continuity of operation of the monitoring equipment is assured by taking power for the equipment from the Essential Power System. Schematics of the Area Monitoring and Process Systems are shown on Figures 11A.1-1 and 11A.1-2.

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QUESTION 11A.2 What actions are initiated upon receipt of a high radiation alarm.

ANSWER Refer to 11.2.2 Upon receipt of a high radiation alert alarm the following action will be taken:

a. The channel that is alarming will be checked to determine that the alarm is being caused by radiation and not due to equipment malfunction.

b. For process system monitors, a high radiation alarm will alert the operator and the leaking heat exchanger will be isolated.

c. For reactor coolant letdown flow, a high radiation alarm will alert the operator to sample the reactor coolant to assess the proper action to be taken. It is estimated that analysis of the sample will require approximately one hour. 4

d. For plant vent gaseous discharge alarm an interlock will automatically stop the discharge from the waste gas system. 3

e. For area gamma alarms, the area will be monitored with portable instruments to determine the mrem/hr reading. If a high level is found, the area will be cordoned off and properly posted as to dose rate and the necessity of film badges, etc.

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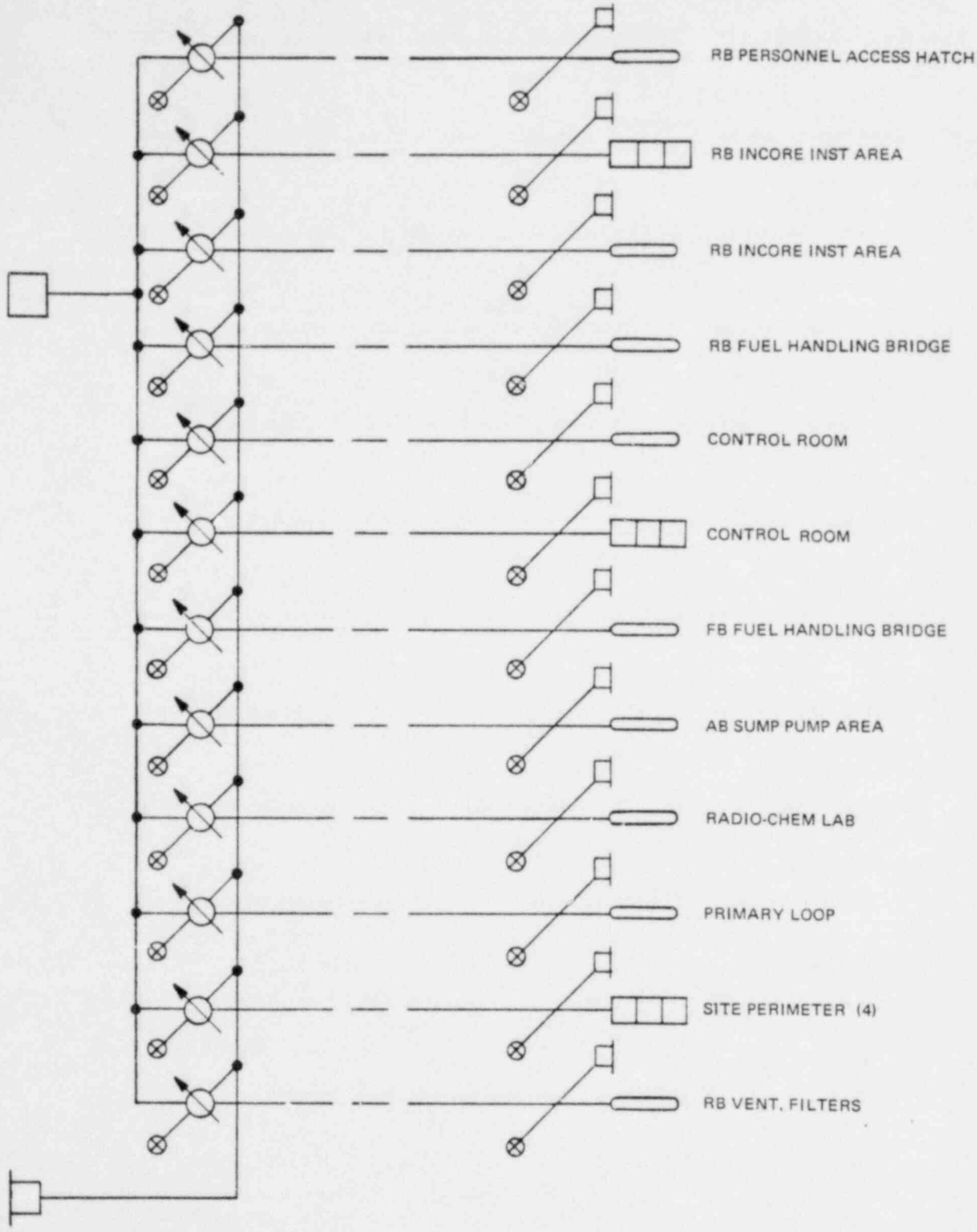

FIGURE 11A.1-1
AREA MONITORING SYSTEM

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Amendment 1

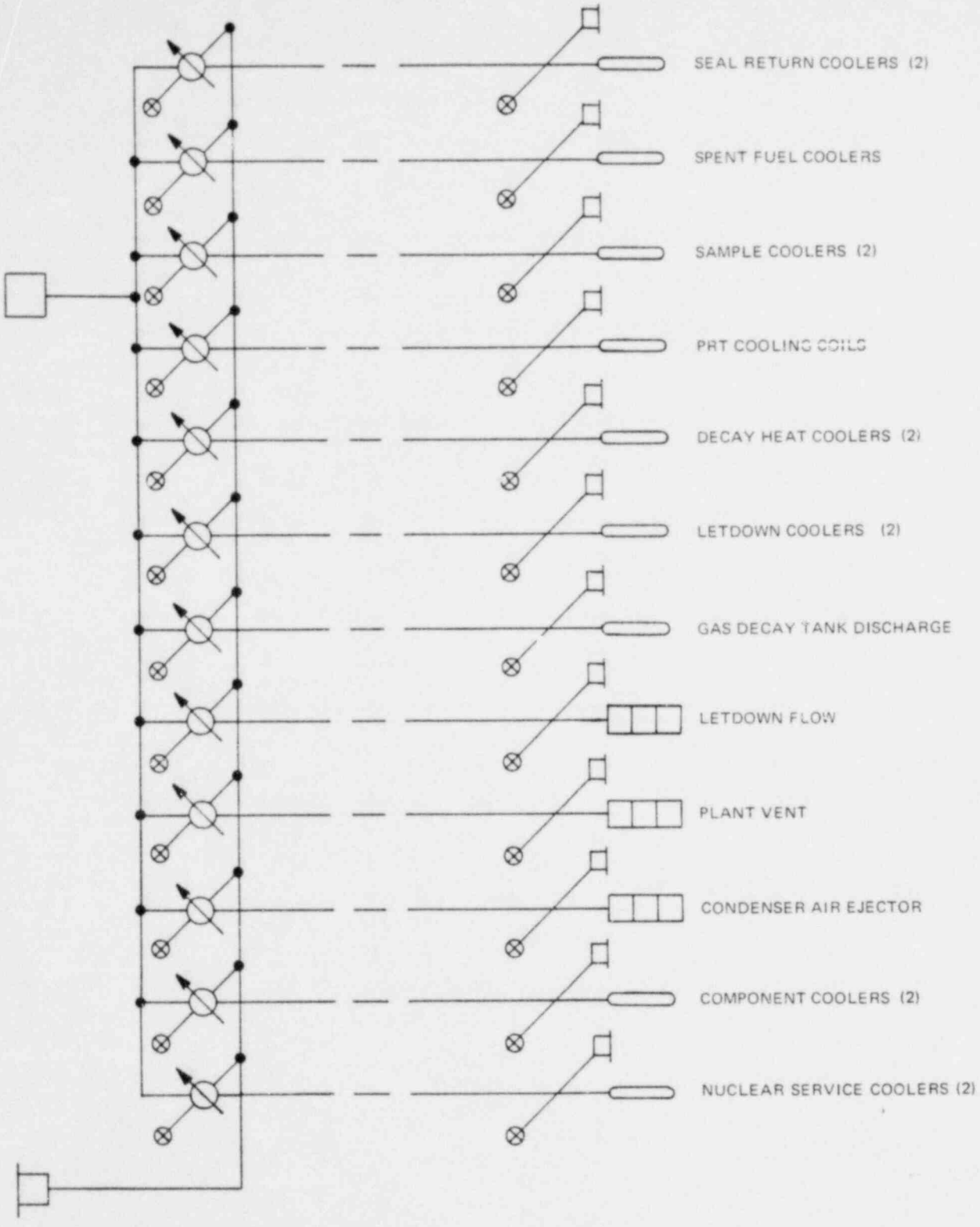

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FIGURE 11A.1-2
PROCESS MONITORING SYSTEM

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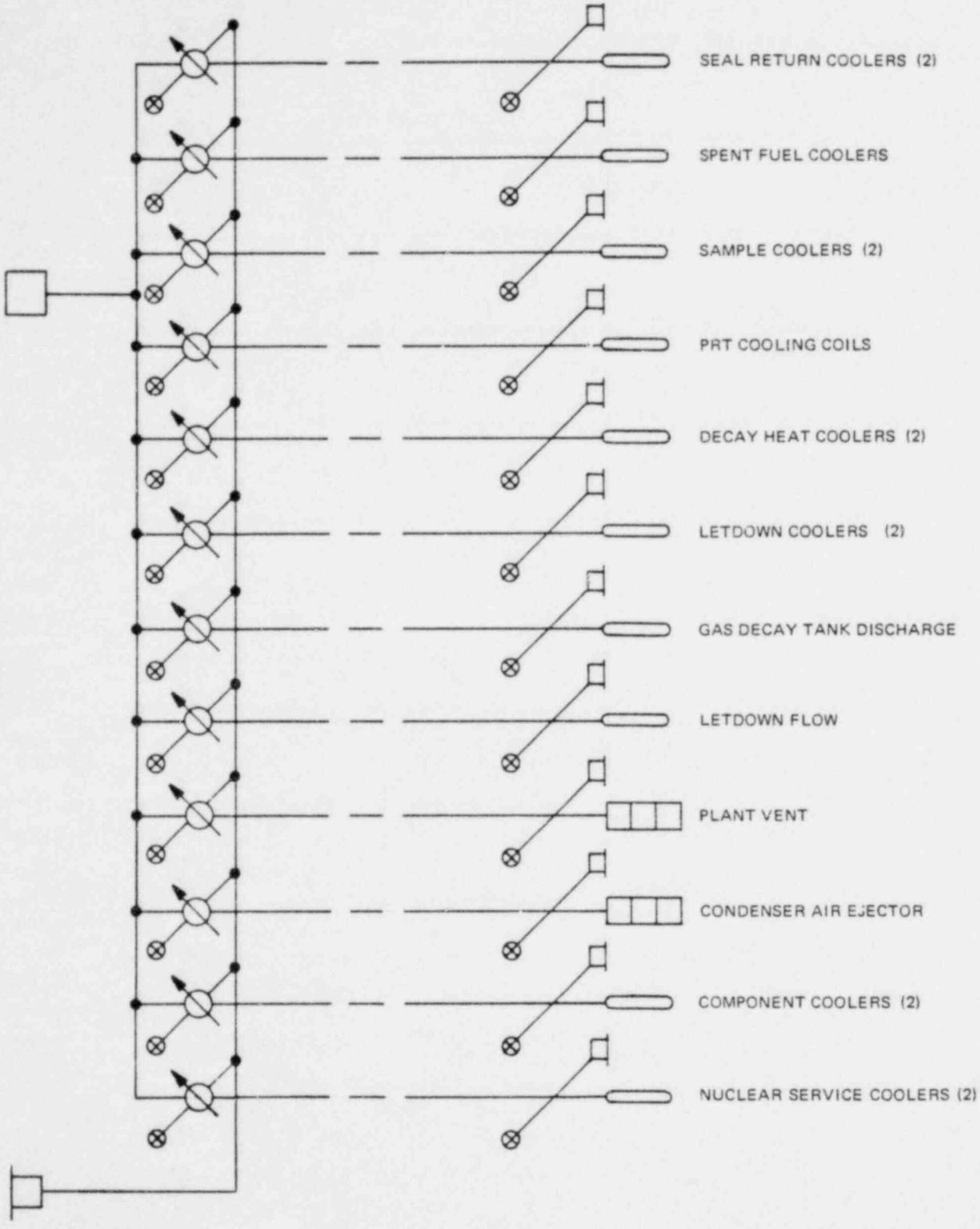

LEGEND

- VISUAL ALARM
- METER READOUT
- G-M SENSOR
- SCINTILLATION SENSOR
- AUDIBLE ALARM
- RECORDERS

FIGURE 11A.1-2
PROCESS MONITORING SYSTEM

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QUESTION 11A.3

FISSION PRODUCT RELEASE FROM FUEL

Provide the details of the method of calculating the primary coolant activity levels for the one percent failed fuel case, including purification cycling of primary system, fission product release assumptions from the failed fuel, effects of burnup and fuel temperature on fission product release from fuel, etc. Provide all formulae, assumptions, and justifications for same. Justify the cleanup system reduction factors stated in the PSAR.

ANSWER Refer to 11.1.1

Activity Levels

Activity levels in the reactor coolant system resulting from fission product leakage through clad defects are determined with the use of escape rate coefficients. These coefficients represent the fraction of the activity in the fuel that is released, per unit time, to the coolant. Values of these coefficients, as derived from experimental data, are reported in the literature.[1-5] These experiments, involving purposely defected fuel elements in pressurized water loops, have been performed for a variety of fuel conditions. For a given isotope, the results yield a wide range of values for the escape rate coefficient even under similar operating conditions. For the calculation of coolant activity levels, values of the escape rate coefficients were determined from these data. In regard to fuel temperature and burnup, no assumptions were made as to the location of clad defects within the core. The coefficients were conservatively chosen from the available data in an effort to account for the worst fuel conditions. The values are shown in Table 11.1-2 of the PSAR.

Calculations of the coolant activity were performed with BURP,[6] a Babcock & Wilcox Company digital computer code. This code solves the differential equations for a five-member radioactive chain for buildup and decay in the fuel, release to the coolant, removal from the coolant by purification or leakage, and collection in a holdup system.

The basic equation for the buildup of a radioactive nuclide, N_f, in the fuel is

$$\frac{dN_f}{dt} = RY + F\lambda' N_f' - \sigma\phi - \lambda N_f - \alpha N_f$$

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where

N_f = concentration of a radioactive nuclide
R = fission rate, fissions per sec
Y = independent fission yield of N_f
$\lambda' N_f'$ = activity of precursor in fuel, dis/sec
F = fraction of precursor which decays to N_f
$\sigma\Phi$ = neutron capture rate in N_f, sec^{-1}
λ = decay constant of N_f, sec^{-1}
α = escape rate coefficient of N_f, sec^{-1}

The equation for a radioactive nuclide in the coolant, N_c, is given by

$$\frac{dN_c}{dt} = \alpha N_f + F\lambda' N_c' - \lambda N_c - \beta N_c - \gamma N_c$$

where

$\lambda' N_c'$ = activity of precursor in coolant, dis/sec
β = removal of N_c by purification, sec^{-1}
γ = removal of N_c by leakage of plate-out, sec^{-1}

In the purification or holdup system the activity of a nuclide, N_p, is given by

$$\frac{dN_p}{dt} = \beta N_c + F\lambda' N_p' - \lambda N_p - \alpha N_p$$

where

$\lambda' N_p'$ = activity of precursor in purification or holdup system, dis/sec
α = removal of N_p from purification or holdup system, sec^{-1}

Using the above equations, activities can be computed for more than 200 radioactive fission products with as many as 100 consecutive reactor operating and shutdown periods. The activity of each nuclide in the fuel, coolant, and holdup or purification systems is computed at each time step.

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In the coolant activity calculations, the assumptions regarding operating times, purification flow, and activity removal are given on page 11.1-1 of the PSAR. Activity concentrations in the coolant are shown in Table 11.1-3 of the PSAR.

ANSWER Cleanup System Reduction Factors

As stated in Section 11.1.1.3 (page 11.1-1) the activity concentration in the coolant, shown in Table 11.1-3 were based on the continuous purification or cleanup of one reactor coolant system volume per day with zero removal efficiency for krypton, cesium, and xenon, and 99 percent removal efficiency for all other nuclides. Krypton and xenon, being noble gases, are not removed by ion exchange. The mixed resin bed in the purification demineralizer will normally operate in the potassium-borate form since potassium hydroxide is used for coolant pH control and since boric acid is used for chemical shim control. Laboratory experiments[7] and operating experience[8] indicate that potassium-saturated resins will not effectively remove cesium. The referenced laboratory experiments also indicate that significant removal efficiencies can be obtained for strontium and barium, and it appears that a removal efficiency of 99 percent should be reasonable for these nuclides.

The referenced experiments further show that yttrium has low removal efficiencies in potassium-saturated resins, and there is additional evidence that molybdenum has low removal efficiencies. Removal efficiencies of 99 percent were assumed to establish the activity levels for yttrium and molybdenum in the reactor coolant activities listed in Table 11.1-3 of the PSAR. If no removal of yttrium and molybdenum is assumed, the activities in Table 11.1-3 will increase. However, the effect on activity concentrations released in the circulating water discharge will be only a small increase in these values. The referenced operating experience shows that borated resin is very effective in removing iodine.

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1 Frank, P. W., et al., Radiochemistry of Third PWR Fuel Material Test - X-1 Loop NRX Reactor, WAPD-TM-29, February 1957.

2 Eichenberg, J. D., et al., Effects of Irradiation on Bulk UO_2, WAPD-183, October 1957.

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6 Perry, J. B. and Alcorn, J. M., BURP - A Computer Program for Calculating Buildup and Decay of Radioactive Fission Products, BAW-TM-444, November 1966.

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8 Weisman, J. and Bartnoff, B., The Saxton Chemical Shim Experiment, WCAP-2599, August 1964.

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