Beaver Valley Power Station

Radiation Protection Technical Position/Evaluation/Calculation

Subject	No.	PAGE 1 OF
Unit 1 Letdown Radiation Monitor (RM-1CH-101) Alarm Setpoint Calculation and Emergency Action Level (EAL) Value Determination	**ERS-JTL-99-005**	**21**

Reference

HPP_____ EPP _____ T/S _____ CR _____ DCP_____

Category

☐ Technical Position ☒ Technical Evaluation ☐ Calculation

Unit 1 ☒ Unit 2 ☐

Purpose

This technical evaluation documents determination of the High and High-High alarm setpoints for the Unit 1 letdown radiation monitor, including process safety limit and trip setpoint for the high range and low range channels (ref. CR 990281). Also, monitor response to RCS concentrations of 0.1 uCi/g, 0.35 uCi/g, 21 uCi/g and 300 uCi/g are calculated.

☐ **ORIGINAL ISSUE**

☒ **REVISION # 3**

Revision description:

Directly calculated the DE I-131 monitor response by using ratio technique applied to the 1% FF design equivalent concentration (3.69 uCi/g) and the corresponding calculated monitor value. Added the letdown radiation monitor indications that correspond to an RCS concentration equivalent to 21 uCi/g dose equivalent iodine-131 (DE I-131). This is done for both the 843-30 and 843-30R detector types. This value is proposed for use as part of the NEI EAL upgrade project for EAL SU9. Updated references. Corrected 843-30R low range channel I-131 detector efficiency.

by	checker/reviewer	independent review (calculation only)
John T. Lebda 8-9-11 date	Michael Unfried 8/9/11 date	N/A - Not a Calculation date

Checklist

☒ Purpose
☒ Methodology
☒ Input Data
☒ Results
☒ References

Attachments

☒ Data Sheets
☐ Illustrations
☐ Printouts
☐ Code Listings

☒ Transmittal to BVRC
☒ Original RP ERF FILE
☐ MGR, Radiation Protection
☐ Supt, Rad Ops
☐ Supv, RP Services
☐ Supv, Rad Waste/Effluents
☒ Author: John T. Lebda BV-ERF
☒ Hal Szklinski BV-SIM
☐ Michael Unfried SEB-3
☐ _____

PURPOSE

The purpose of this calculation is to determine the alarm setpoints (high-high and high) for the Unit 1 letdown radiation monitor, RM-1CH-101 high range and low range channels.

DISCUSSION

REVISION HISTORY:

Revision 0:

The previous calculation of record, SWEC RP-11700-87, Rev. 0[1], was reviewed during an investigation of an identified setpoint discrepancy (ref. CR 990281[2]). This review discovered that, for the high range channel, the contribution from iodine-135 to the monitor indication was miscalculated, and the necessary correction for fluid density change between the reactor coolant system (RCS) and the monitor sample line was not made. These errors resulted in an overly conservative setpoint. Using such a setpoint could lead to spurious alarms and may have contributed to the condition described in CR 990281. Revision 0 corrected these issues & used updated parameters in the calculation.

Revision 1:

This revision was made to calculate alarm setpoints that correspond to reactor coolant radioactivity concentrations of 0.1 and 0.35 dose equivalent I-131. In addition, monitor indication that corresponds to 300 uCi/g dose equivalent I-131 is provided. Revision 0 was unchanged and this additional information was provided in an Addendum.

Revision 2:

Made the same calculations as the previous revisions using efficiencies for the 843-30R detector type. The most recent RCS design/Technical Specification radioactivity concentrations are used in the calculations. The package text was updated.

Revision 3:

Directly calculated the DE I-131 monitor response by using ratio technique applied to the 1% FF design equivalent concentration (3.69 uCi/g) and the corresponding calculated monitor value. Added the letdown radiation monitor indications that correspond to an RCS concentration equivalent to 21 uCi/g dose equivalent iodine-131 (DE I-131). This is done for both the 843-30 and 843-30R detector types. This value is proposed for use as part of the NEI EAL upgrade project for EAL SU9. Updated references.

ADDITIONAL DISCUSSION:

The Unit 1 UFSAR[3] describes the licensing basis for the Unit 1 letdown process flow radiation monitor (CH-101):

"The gross activity of the reactor coolant is continuously monitored by two detectors. The samples are drawn from the reactor coolant letdown line and delayed to permit sufficient decay of N-16 isotope before they pass by the detectors. In this system, large variations in the activity are possible depending upon the amount of fission products leaked to the coolant. The alarm setpoints can be set to provide graded indications of reactor coolant activity increases. This system cam be flushed with clean water from a flush line inlet upstream of the sample monitor."

The USNRC SER[4] for Unit 1 states:

"The gross activity of the reactor coolant will be monitored by a low range and a high range detector located in the reactor coolant letdown line. We believe that this system is capable of detecting gross failed fuel and is acceptable."

CH-101 is an off-line monitor physically located near the northeast corner of the PAB elevation 722'. It draws sample flow from the letdown piping prior to the system demineralizers and degassifiers. The fluid at this point is cooled to approximately 90 °F. Additional cooling may be expected as the fluid passes thourgh the sample line to the monitor. The sample line is equipped with a temperature control valve that closes if the sample fluid temperature exceeds about 134±3 °F5. This calculation will use 137 °F as a conservative value.

The original monitor configuration included two shielded gamma scintillation detectors. Channel CH-101A was designated as the high range channel, and CH-101B, the low range channel. The detector/sample line geometry between the two channels was identical with the exception that a lead attenuator plug was placed between the high range detector and the sample line. This option was available for the low range channel should letdown fluid radioactivity be high and a redundant high range channel desired. However, in 1981 the channels were noted to read the same, and the alarm setpoints for the two channels were changed to be identical[6].

The basis for the alarm setpoints was established in the SWEC setpoint calculation as the RCS design maximum radioactivity concentrations which would result from operating with 1% failed fuel.

This is considered a reasonable value for "gross failed fuel", however, no specific commitment to this basis could be found. The basis for the Unit 2 letdown radiation monitor[7] is an RCS radioactivity concentration corresponding to the Technical Specification[8] radioactivity limit of 1 μCi/g dose equivalent iodine 131. This difference between the Units is thought to result from the difference in dates that the Units were licensed, and is not researched further here.

SWEC[19] also calculated high alarm setpoint values for the high range channel. The calculation used 0.25% failed fuel as the basis. This is the only place that any high setpoint basis is provided, and no justification is given. During the development of this calculation, Radiological Operations expressed concern that a high setpoint based on 0.25% failed fuel would be too close to the monitor background and requested that setpoint values be based on 0.5% failed fuel. REAP 1.105 recognizes such situations and (Step 5.3.2.3) permits an alternative approach. As such, the high setpoint calculated herein will be based on 0.5% failed fuel.

METHODOLOGY

The methodology used herein remains similar to that used in RP-11700-87-0. The RCS activity concentrations (μCi/g) assumed are those activities which result from operation with 1% failed fuel[9]. The list of isotopes used is identical to that in the original calculation of record with the exception of Mn-54, which was added in Revision 0 of this package. Mn-54, along with the other activation products which are included in this calculation, are present in such low concentrations that they have no influence on the monitor indication.

The activity concentrations (μCi/g) are converted to μCi/cc by applying an appropriate density correction. Because the concentrations are expressed in μCi/g, the only correction needed is to account for the density difference between the fluid in the sample line and the density at standard temperature and pressure. This correction is applied prior to multiplying the monitor efficiency to obtain the individual isotope count rate contribution. The individual contributions are then summed to determine the monitor process safety limit.

The activity concentrations used to calculate this first setpoint are based on a specific set of operating parameter values that influence the concentrations. These are related to processes that remove radioactivity from the RCS and are, letdown flow rate, letdown filtration and demineralization efficiencies and leakage from the RCS. The 1% failed fuel RCS concentration calculation maximizes the activity concentrations by selecting each parameter value, within the design operation range, such that radioactivity removal is minimized (ref. Unit 1 UFSAR Table 14B-5). Because actual operating conditions are different, and these differences will cause the 1% failed fuel RCS concentrations to be lower, adjustments are necessary to avoid using a non-conservatively high setpoint. The adjustment discussed above is made by assuming a typical letdown flow rate of 105 gpm[10]. All activity removed from the system by letdown is assumed not to be returned. This minimizes RCS radioactivity concentrations, and adds a small conservatism to the setpoint calculation. RCS leakage is typically very low, and even when maximized would be low as compared to the radioactivity removal by letdown. Therefore, the influence of RCS leakage is ignored in this calculation. To make the correction for increased letdown flow rate, an equilibrium radioactivity removal rate while operation at 60 gpm is calculated for each radionuclide by summing the radioactive decay removal rate constant with the letdown removal rate constant. This is applied to total RCS activity to obtain the net removal rate (μCi/s) from the system. At equilibrium, the removal rate is assumed to be equal to the release rate form the fuel. The sequence of this calculation is then reversed using 105 gpm in place of 60 gpm to obtain radioactivity concentrations (μCi/g) while operating at the higher flow rate. The setpoint calculation is then repeated to determine the process safety limit when operating with letdown at 105 gpm. The calculations described above are performed for both the high range and low range monitor configurations.

A second set of monitor indication values are provided which correspond to the design radioactivity mix reduced to concentrations equal to a dose equivalent iodine 131 of 0.1 μCi/g, 0.35 μCi/g, 21 uCi/g and 300 uCi/g. These calculations do not require any adjustments associated with changes in letdown flow rate as the measurements are direct (the radiation monitor responds to RCS radioactivity), rather than derived (percent failed fuel inferred by measuring RCS radioactivity). All are calculated by simple ratio technique applied to the 1% FF (3.69 uCi/g) monitor indication. Instrument error is not applied to these values herein. This should be done if these are later used as alarm setpoint values.

Determination of radiation monitor alarm setpoint uncertainty used herein is consistent with previous similar applications for both Unit 1 and Unit 2. Regulatory Guide 1.105[12] provides the basis for instrument setpoints for safety related systems. BVPS Unit 2 is committed to the Regulatory Guide, while Unit 1 is not. Historically established guidelines provide four conditions where it may be prudent to apply uncertainty analysis to a Unit 1 radiation monitor. These are, if the monitor or setpoint, 1) is QA Category 1, 2) initiates an automatic process control function, 3) is specifically referenced by an emergency operating procedure, or 4) initiates manual operator action that results in a change in the configuration of any safety related process systems.

CH-101 is referenced in several EOPs, and the High-High alarm is used to determine if fuel damage may have occurred which, in turn, may affect operator actions. Although other means for detecting failed fuel, such as chemistry sampling and monitoring or in-plant radiation levels are routinely employed, monitor uncertainty analysis is appropriate.

As with older monitors at Unit 1, many of the allowances which are considered in setpoint uncertainty analyses are not provided for the letdown radiation monitor. Historically established appropriate assumptions for some of these. Also, this defines the Total Loop Uncertainty as:

$$TLU = (EA^2 + PA^2 + CA^2 + SA^2 + DA^2 + LA^2 + TA)^{0.5}$$

and, the Trip Setpoint as:

$$TSP = AL / [1 + (\%=TLU) / 100 + (\%-DEADBAND) / 100]$$

Because many of TLU allowances are not available for the Unit 1 monitors, the uncertainty analyses for safety related monitors is assumed to be +100%, -50%. This leads to a value of 2.1 as the divisor for the Analytical Limit (or, Process Safety Limit). This high degree of conservatism is not necessary for the letdown radiation monitor. The assumptions used therein were reviewed against the available vendor documentation and are found to be reasonable and sufficiently conservative for the letdown radiation monitor. The errors and uncertainty allowances are:

Factory calibration allowance (CA_1) = 20%
Onsite calibration allowance (CA_2) = 10%
Sensor allowance for rate meter response (SA_1) = 5%
Sensor allowance for alarm circuitry (SA_2) = 2%
Process allowance (PA) = 0%
Leakage allowance (LA) = 0%
Environmental allowance (EA) = 0%
Administrative tolerance (TA) = 10%
Drift allowance (DA) = 10%
Deadband = 10%

$$TLU = (0.20^2 + 0.10^2 + 0.05^2 + 0.02^2 + 0.10^2 + 0.10^2)^{0.5} = 0.27 = 27\%$$

$$TSP = AL / [1 + (27 / 100) + (10 / 100)] = 1.37$$

See Attachment 1 for additional information concerning alarm setpoint determination methodology.

After the setpoints (Process Safety Limits) are calculated, each will be divided by 1.37 to obtain setpoints having uncertainty analysis applied.

INPUT DATA AND ASSUMPTIONS

1. 1% Failed Fuel RCS Radioactivity Concentrations (high-high setpoint) [9]
   (Refer to Attachment 1)
   0.5% Failed Fuel RCS Radioactivity Concentrations (high setpoint)
   (requested by Radiological Operations as discussed above)

2. Maximum Fluid Temperature at Monitor = 137 °F. [5]

3. Fluid Density at Monitor = 61.43 lbm/ft^3 [13]
   Fluid Density at ST = 62.43 lbm/ft^3

4. CH-101 Channel Efficiencies - 843-30 detector (See calculations) [14]

4. CH-101 Channel Efficiencies - 843-30R detector [Attachment 2]

5. Letdown volume Flow Rates = 60 gpm minimum [10,15,16]
   = 105 gpm normal

6. Letdown Mass Flow Rates (calculated):

$$\frac{60\ \text{gpm} * 3785.3\ \text{cc/gal} * 1\ \text{g/cc} * (61.43\ \text{lbm/ft}^3 / 62.43\ \text{lbm/ft}^3)}{60\ \text{s/min}} = 3.725\text{E3 g/s}$$

$$\frac{105\ \text{gpm} * 3785.3\ \text{cc/gal} * 1\ \text{g/cc} * (61.43\ \text{lbm/ft}^3 / 62.43\ \text{lbm/ft}^3)}{60\ \text{s/min}} = 6.158\text{E3 g/s}$$

7. RCS Mass = 1.8084E8 g [9]
   (Average of mass at 100% power, 0% and 22% S/G tubes plugged)

8. Radionuclide Half-Live Times = (Refer to Attachment 1) [18]

9. RCS Technical Specification and DE I-131 concentrations corresponding to 1% FF [9]

10. Radionuclide Decay Rate Constants

    Calculated: =ln(2) / Radionuclide Half-Live (s)

11. Letdown Flow Rate Removal Constants

    Calculated: = Letdown Mass Flow Rate (g/s) / RCS Mass (g)

12. All radioactivity removed by the letdown system is assumed not to be returned to the system. Returned activity is expected to be small, and this assumption is conservative for the setpoint calculation.

13. RCS leakage is ignored. Leakage is typically very low, and this influence is small as compared to the removal by letdown.

14. When the amount of RCS radioactivity is at equilibrium, the rate of radioactivity removal from the system is equal to the release rate from the fuel.

RESULTS

843-30 detector with updated source term:

1% FF Basis	60 gpm letdown operation (cpm)		105 gpm letdown operation (cpm)	
	High	High-High	High	High-High
CH-101 High Range Channel	3.72E+03	7.44E+03	3.03E+03	6.06E+03
CH-101 Low Range Channel	n/a	1.00E+06 (1.47E+6)	n/a	9.93E+05

843-30R detector with updated source term:

1% FF Basis	60 gpm letdown operation (cpm)		105 gpm letdown operation (cpm)	
	High	High-High	High	High-High
CH-101 High Range Channel	4.78E+03	9.57E+03	3.77E+03	7.54E+03
CH-101 Low Range Channel	n/a	1.00E+06 (2.67E+6)	n/a	1.00E+06 (1.70E+6)

SWEC provided a low range channel, high-high alarm setpoint with 0.05% failed fuel used as the basis. The basis is deemed acceptable and is applied to give the final setpoints (for the low range channel). Because the calculated low range channel setpoints are still above the monitor range, the highest on-scale value of 1.00E6 is provided with the calculated value shown in parenthesis. Consistent with previous calculations, no high setpoint is provided for the low range channel. All values are reduced for instrument error consideration.

RM-CH-101A/B Indication Corresponding to Various DE I-131 RCS Concentrations

Updated design source term basis with 843-30 detector:	Low Range Channel (cpm)	High Range Channel (cpm)
Page 9 monitor indication with 1% FF (3.69 uCi/g DE I-131) =	4.02E+07	1.02E+04
Monitor indication with 0.1 uCi/g DE I-131 =	1.09E+06	2.76E+02
Monitor indication with 0.35 uCi/g DE I-131 =	3.82E+06	9.66E+02
Monitor indication with 21 uCi/g DE I-131 =	2.29E+08	5.80E+04
Monitor indication with 300 uCi/g DE I-131 =	3.27E+09	8.28E+05
Updated design source term basis with 843-30R detector:		
Page 12 monitor indication with 1% FF (3.69 uCi/g DE I-131) =	7.32E+07	1.31E+04
Monitor indication with 0.1 uCi/g DE I-131 =	1.98E+06	3.55E+02
Monitor indication with 0.35 uCi/g DE I-131 =	6.94E+06	1.24E+03
Monitor indication with 21 uCi/g DE I-131 =	4.17E+08	7.46E+04
Monitor indication with 300 uCi/g DE I-131 =	5.95E+09	1.07E+06

Values in the tables above are provided without instrument error consideration. If used for an alarm setpoint, the value(s) should be reduced by dividing by 1.37. High alarm setpoints should be set at 50% of the high-high value, or if too close to background indications, at an appropriate value above background so as to avoid spurious alarms. For values calculated that exceed the monitor range of 1.00E+06, an on-scale value appropriate for the application should be used.

REFERENCES

1. SWEC Calculation RP-11700-087-0, Determination of High and High-High Setpoints for all Process and Area Monitors in the BVPS Unit #1 RMS, 1975
2. BVPS Condition Report 990281, Setpoint Discrepancy for RCS Letdown Gross Activity Radiation monitors, Dated 02/12/99
3. BVPS Unit 1 UFSAR Chapter 11, Section 11.3.3.3.16, Reactor Coolant Monitor
4. Unit 1 USNRC SER, Section 11.6, Process and Area Radiation Monitoring Systems
5. Unit 1 OM Chapter 43, 1OM-7.2.B, Setpoints
6. BVPS Onsite Safety Committee Meeting Minutes, BV-OSC-107-81
7. DLCO Calculation ERS-SFL-88-027 Rev. 1, Process Safety Limits and Alarm Setpoints for 2CHS-RQ-101A/B
8. Unit 2 Technical Specification 3/4-.4.4, Specific Activity
9. SWEC Calculation 10080-UR(B)-484, Primary and Secondary Design/Technical Specification Activity Concentrations Including Pre-Accident Iodine Spike Concentrations and Equilibrium Iodine Appearance Rates Following Power Uprate, 2002
10. Chemistry Database for RCS Radioactivity Determinations, Actual Logged Letdown Flow Rates for Unit 1 Cycles 11, 12 and 13
11. BVBP-RP-0002, Radiation Monitor Alarm Setpoint Determination
12. USNRC Regulatory Guide 1.105, Instrument Setpoints
13. 1967 ASME Steam Tables
14. Victoreen VTI 07.503-0110, Section 6, Tables 8 & 9
15. DLCO NED EM Response, EM 1171, NED Verification of EM 116252 (Design basis accident parameter verification – Unit 1) Response, Dated 11/25/98
16. BVPS Unit 1 UFSAR Chapter 9, Table 9.1-2
17. DLCO NED EM Response, EM 116252, Design basis accident parameter verification – Unit 1, Dated 08-01-98
18. Kocher, D. C., Radioactive Decay Tables, Technical Information Center, U. S. Department of Energy, 1981
19. SWEC letter DLS-12168, Beaver Valley Power Station – Unit No. 1 J.O.NO. 11700-O.F.E.NO. 8700 – C.O.NO. 3468, Radiation Monitor Setpoints, October 21, 1975

CH-101 Setpoint Calculation @60 gpm Letdown flow Rate

Updated design RCS concentrations and for the 843-30 detector type

Nuclide	*1% FF @ 576 F (uCi/g)	**At-monitor Density Correction	*1% FF 60 gpm Density Corrected (uCi/cc)	High Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @60 gpm High Range Channel Indication (cpm)	Low Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @60 gpm Low Range Channel Indication (cpm)
Br-84	3.73E-02		3.67E-02	7.0673E+02	2.59E+01	6.5003E+05	2.39E+04
Rb-88	2.75E+00		2.71E+00	3.3324E+02	9.02E+02	1.8750E+05	5.07E+05
Rb-89	1.57E-01		1.54E-01	1.0125E+03	1.56E+02	8.8684E+05	1.37E+05
Sr-89	3.49E-03		3.43E-03	1.6920E-02	5.81E-05	4.4819E+01	1.54E-01
Sr-90	2.16E-04		2.13E-04	0.0000E+00	0.00E+00	0.0000E+00	0.00E+00
Sr-91	1.45E-03		1.43E-03	1.7804E+02	2.54E-01	6.9789E+05	9.96E+02
Sr-92	1.03E-03		1.01E-03	5.8336E+02	5.91E-01	4.6832E+05	4.75E+02
Y-90	5.94E-05		5.84E-05	2.1300E-01	1.24E-05	9.5400E+01	5.58E-03
Y-91	4.78E-04		4.70E-04	1.3596E+00	6.39E-04	1.4543E+03	6.84E-01
Y-92	8.84E-04		8.70E-04	6.7325E+01	5.86E-02	1.1881E+05	1.03E+02
Zr-95	6.32E-04		6.22E-04	8.8200E+01	5.48E-02	4.9537E+05	3.08E+02
Nb-95	6.41E-04		6.31E-04	1.0250E+02	6.47E-02	5.0437E+05	3.18E+02
Mo-99	7.62E-01		7.50E-01	1.6074E+01	1.21E+01	1.2222E+05	9.16E+04
Tc-99m	4.09E-01		4.02E-01	3.0000E-02	1.21E-02	4.4085E+05	1.77E+05
I-129	1.11E-07		1.09E-07	0.0000E+00	0.00E+00	0.0000E+00	0.00E+00
I-131	2.89E+00		2.84E+00	8.6362E+00	2.46E+01	4.8206E+05	1.37E+06
I-132	1.13E+00		1.11E+00	4.3446E+02	4.83E+02	1.5435E+06	1.72E+06
I-133	4.32E+00		4.25E+00	6.4390E+01	2.74E+02	5.3280E+05	2.26E+06
I-134	6.32E-01		6.22E-01	5.4811E+02	3.41E+02	1.3588E+06	8.45E+05
I-135	2.48E+00		2.44E+00	7.8131E+02	1.91E+03	6.7981E+05	1.66E+06
Co-58	1.38E-02		1.36E-02	1.4106E+02	1.92E+00	6.5859E+05	8.94E+03
Co-60	1.59E-03		1.56E-03	1.0207E+03	1.60E+00	9.6841E+05	1.52E+03
Fe-59	9.00E-04		8.86E-04	4.3408E+02	3.84E-01	5.0432E+05	4.47E+02
Te-129	1.43E-02	0.9840	1.41E-02	7.7144E+00	1.09E-01	9.3730E+04	1.32E+03
Te-132	3.00E-01		2.95E-01	3.4826E-01	1.03E-01	4.4459E+05	1.31E+05
Te-134	2.99E-02		2.94E-02	2.0382E-01	6.00E-03	2.8864E+05	8.49E+03
Cs-134	6.05E+00		5.95E+00	2.0187E+02	1.20E+03	1.1422E+06	6.80E+06
Cs-136	1.50E+00		1.48E+00	4.8303E+02	7.13E+02	1.5456E+06	2.28E+06
Cs-137	3.79E+00		3.73E+00	5.1000E+01	1.90E+02	4.3258E+05	1.61E+06
Cs-138	1.03E+00		1.01E+00	9.9875E+02	1.01E+03	8.1615E+05	8.27E+05
Ba-140	4.10E-03		4.03E-03	1.0006E+01	4.04E-02	2.5622E+05	1.03E+03
La-140	1.41E-03		1.39E-03	9.8104E+02	1.36E+00	9.2029E+05	1.28E+03
Ce-144	4.69E-04		4.61E-04	3.1167E-03	1.44E-06	5.5762E+04	2.57E+01
Pr-144	4.72E-04		4.64E-04	1.3164E+01	6.11E-03	1.2369E+04	5.74E+00
Kr-85	1.25E+02		1.23E+02	9.1200E-02	1.12E+01	2.0185E+03	2.48E+05
Kr-85m	1.42E+00		1.40E+00	2.7263E-01	3.81E-01	4.2749E+05	5.97E+05
Kr-87	9.48E-01		9.33E-01	6.2626E+02	5.84E+02	6.9058E+05	6.44E+05
Kr-88	2.65E+00		2.61E+00	5.0762E+02	1.32E+03	5.3234E+05	1.39E+06
Xe-133	3.11E+02		3.06E+02	0.0000E+00	0.00E+00	3.5335E+04	1.08E+07
Xe-133m	4.20E+00		4.13E+00	5.7826E-02	2.39E-01	6.9178E+04	2.86E+05
Xe-135	9.64E+00		9.49E+00	1.8987E+00	1.80E+01	4.6560E+05	4.42E+06
Xe-135m	9.56E-01		9.41E-01	2.0320E+01	1.91E+01	4.0401E+05	3.80E+05
Xe-138	6.70E-01		6.59E-01	1.4864E+03	9.80E+02	1.4879E+06	9.81E+05
Mn-54	4.80E-03		4.72E-03	1.4208E+02	6.71E-01	5.0129E+05	2.37E+03
					1.02E+04		**4.02E+07**
						0.05% FF >	**2.01E+06**
					7.44E+03	**/1.37 error**	**1.47E+06**
					cpm		**cpm**

*1% FF RCS concentrations from SWEC 10080-UR(B)-484 Table 8a

**Letdown density correction based on 137 F (monitor high temperature isolation) = 61.43 lbm/ft3 / 62.43 lbm/ft3

*** Manufacturer calibration data

RCS Specific Activity Determination With Letdown Flow Rate Increased to 105 gpm

Parameters for correction to 105 gpm letdown flow rate:

RCS mass (average of 0% - 22% S/G tubes plugged) = 1.808E+08 grams
Letdown **mass flow rate at 60 gpm = 3.725E+03 grams/s
Letdown **mass flow rate at 105 gpm = 6.518E+03 grams/s

Nuclide	*1% FF @ 576 F (uCi/g)	Total RCS Activity (uCi)	(Kocher 1981) $t_{1/2}$ (s)	λ Decay (s^{-1})	@60 gpm λ Letdown (s^{-1})	λ Effective (s^{-1})	1% FF RCS removal rate @60 gpm (uCi/s)	@105 gpm λ Letdown (s^{-1})	@105 gpm λ Effective (s^{-1})	Total RCS Activity (uCi)	1% FF @ 576 F (uCi/g)
Br-84	3.73E-02	6.75E+06	1.91E+03	3.63E-04		3.84E-04	2.59E+03		3.99E-04	6.48E+06	3.59E-02
Rb-88	2.75E+00	4.97E+08	1.07E+03	6.49E-04		6.70E-04	3.33E+05		6.85E-04	4.86E+08	2.69E+00
Rb-89	1.57E-01	2.84E+07	9.26E+02	7.48E-04		7.69E-04	2.18E+04		7.84E-04	2.78E+07	1.54E-01
Sr-89	3.49E-03	6.31E+05	4.37E+06	1.59E-07		2.08E-05	1.31E+01		3.62E-05	3.62E+05	2.00E-03
Sr-90	2.16E-04	3.91E+04	9.02E+08	7.69E-10		2.06E-05	8.05E-01		3.60E-05	2.23E+04	1.23E-04
Sr-91	1.45E-03	2.62E+05	3.42E+04	2.03E-05		4.09E-05	1.07E+01		5.63E-05	1.90E+05	1.05E-03
Sr-92	1.03E-03	1.86E+05	9.76E+03	7.10E-05		9.16E-05	1.71E+01		1.07E-04	1.59E+05	8.81E-04
Y-90	5.94E-05	1.07E+04	2.31E+05	3.00E-06		2.36E-05	2.54E-01		3.90E-05	6.49E+03	3.59E-05
Y-91	4.78E-04	8.64E+04	5.06E+06	1.37E-07		2.07E-05	1.79E+00		3.62E-05	4.95E+04	2.74E-04
Y-92	8.84E-04	1.60E+05	1.27E+04	5.44E-05		7.50E-05	1.20E+01		9.04E-05	1.33E+05	7.33E-04
Zr-95	6.32E-04	1.14E+05	5.53E+06	1.25E-07		2.07E-05	2.37E+00		3.62E-05	6.55E+04	3.62E-04
Nb-95	6.41E-04	1.16E+05	3.03E+06	2.29E-07		2.06E-05	2.41E+00		3.63E-05	6.66E+04	3.68E-04
Mo-99	7.62E-01	1.38E+08	2.38E+05	2.92E-06		2.35E-05	3.24E+03		3.90E-05	8.32E+07	4.60E-01
Tc-99m	4.09E-01	7.40E+07	2.17E+04	3.20E-05		5.26E-05	3.89E+03		6.80E-05	5.72E+07	3.16E-01
I-129	1.11E-07	2.01E+01	4.95E+14	1.40E-15		2.06E-05	4.13E-04		3.60E-05	1.15E+01	6.34E-08
I-131	2.89E+00	5.23E+08	6.95E+05	9.98E-07	2.06E-05	2.16E-05	1.13E+04	3.60E-05	3.70E-05	3.05E+08	1.68E+00
I-132	1.13E+00	2.04E+08	8.28E+03	8.37E-05		1.04E-04	2.13E+04		1.20E-04	1.78E+08	9.84E-01
I-133	4.32E+00	7.81E+08	7.49E+04	9.26E-06		2.99E-05	2.33E+04		4.53E-05	5.15E+08	2.85E+00
I-134	6.32E-01	1.14E+08	3.16E+03	2.20E-04		2.40E-04	2.75E+04		2.56E-04	1.07E+08	5.94E-01
I-135	2.48E+00	4.48E+08	2.38E+04	2.91E-05		4.97E-05	2.23E+04		6.52E-05	3.42E+08	1.89E+00
Co-58	1.38E-02	2.50E+06	6.12E+06	1.13E-07		2.07E-05	5.17E+01		3.62E-05	1.43E+06	7.90E-03
Co-60	1.59E-03	2.88E+05	1.66E+08	4.17E-09		2.06E-05	5.92E+00		3.60E-05	1.64E+05	9.09E-04
Fe-59	9.00E-04	1.63E+05	3.86E+06	1.80E-07		2.08E-05	3.38E+00		3.62E-05	9.33E+04	5.16E-04
Te-129*	1.43E-02	2.59E+06	4.18E+03	1.66E-04		1.87E-04	4.82E+02		2.02E-04	2.39E+06	1.32E-02
Te-132	3.00E-01	5.43E+07	2.82E+05	2.46E-06		2.31E-05	1.25E+03		3.85E-05	3.25E+07	1.80E-01
Te-134	2.99E-02	5.41E+06	2.51E+03	2.76E-04		2.97E-04	1.61E+03		3.12E-04	5.14E+06	2.84E-02
Cs-134	6.05E+00	1.09E+09	6.50E+07	1.07E-08		2.06E-05	2.25E+04		3.61E-05	6.25E+08	3.46E+00
Cs-136	1.50E+00	2.71E+08	1.14E+06	6.10E-07		2.12E-05	5.75E+03		3.67E-05	1.57E+08	8.68E-01
Cs-137	3.79E+00	6.85E+08	9.51E+08	7.29E-10		2.06E-05	1.41E+04		3.60E-05	3.92E+08	2.17E+00
Cs-138	1.03E+00	1.86E+08	1.93E+03	3.59E-04		3.79E-04	7.07E+04		3.95E-04	1.79E+08	9.90E-01
Ba-140	4.10E-03	7.41E+05	1.10E+06	6.27E-07		2.12E-05	1.57E+01		3.67E-05	4.29E+05	2.37E-03
La-140	1.41E-03	2.55E+05	1.45E+05	4.79E-06		2.54E-05	6.47E+00		4.08E-05	1.59E+05	8.77E-04
Ce-144	4.69E-04	8.48E+04	3.48E+07	1.99E-08		2.06E-05	1.75E+00		3.61E-05	4.85E+04	2.68E-04
Pr-144	4.72E-04	8.54E+04	1.04E+03	6.69E-04		6.89E-04	5.88E+01		7.05E-04	8.35E+04	4.62E-04
Kr-85	1.25E+02	2.26E+10	3.38E+08	2.05E-09		2.06E-05	4.66E+05		3.60E-05	1.29E+10	7.14E+01
Kr-85m	1.42E+00	2.57E+08	1.61E+04	4.30E-05		6.36E-05	1.63E+04		7.90E-05	2.07E+08	1.14E+00
Kr-87	9.48E-01	1.71E+08	4.58E+03	1.51E-04		1.72E-04	2.95E+04		1.87E-04	1.57E+08	8.70E-01
Kr-88	2.65E+00	4.79E+08	1.02E+04	6.78E-05	2.06E-05	8.84E-05	4.24E+04	3.60E-05	1.04E-04	4.08E+08	2.26E+00
Xe-133	3.11E+02	5.62E+10	4.53E+05	1.53E-06		2.21E-05	1.24E+06		3.76E-05	3.31E+10	1.83E+02
Xe-133m	4.20E+00	7.60E+08	1.89E+05	3.66E-06		2.43E-05	1.84E+04		3.97E-05	4.64E+08	2.57E+00
Xe-135	9.64E+00	1.74E+09	3.28E+04	2.11E-05		4.17E-05	7.28E+04		5.72E-05	1.27E+09	7.04E+00
Xe-135m	9.56E-01	1.73E+08	9.22E+02	7.52E-04		7.73E-04	1.34E+05		7.88E-04	1.69E+08	9.37E-01
Xe-138	6.70E-01	1.21E+08	8.48E+02	8.18E-04		8.38E-04	1.02E+05		8.54E-04	1.19E+08	6.58E-01
Mn-54	4.80E-03	8.68E+05	2.70E+07	2.57E-08		2.06E-05	1.79E+01		3.61E-05	4.96E+05	2.74E-03

*1% FF RCS concentrations from SWEC 10080-UR(B)-484 Table 8a
**Letdown density correction based on 137 F (monitor high temperature isolation) = 61.43 lbm/ft3 / 62.43 lbm/ft3
*** Effective removal rate constant = decay removal rate constant + letdown removal rate constant

CH-101 Setpoint Calculation @105 gpm Letdown flow Rate

Updated design RCS concentrations and for the 843-30 detector type

Nuclide	1% FF @ 576 F (uCi/g)	**At-monitor Density Correction	*1% FF 105 gpm Density Corrected (uCi/cc)	High Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @105 gpm High Range Channel Indication (cpm)	Low Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @105 gpm Low Range Channel Indication (cpm)
Br-84	3.59E-02		3.53E-02	7.0673E+02	2.49E+01	6.5003E+05	2.29E+04
Rb-88	2.69E+00		2.64E+00	3.3324E+02	8.81E+02	1.8750E+05	4.96E+05
Rb-89	1.54E-01		1.51E-01	1.0125E+03	1.53E+02	8.8684E+05	1.34E+05
Sr-89	2.00E-03		1.97E-03	1.6920E-02	3.33E-05	4.4819E+01	8.82E-02
Sr-90	1.23E-04		1.21E-04	0.0000E+00	0.00E+00	0.0000E+00	0.00E+00
Sr-91	1.05E-03		1.04E-03	1.7804E+02	1.84E-01	6.9789E+05	7.23E+02
Sr-92	8.81E-04		8.67E-04	5.8336E+02	5.06E-01	4.6832E+05	4.06E+02
Y-90	3.59E-05		3.53E-05	2.1300E-01	7.52E-06	9.5400E+01	3.37E-03
Y-91	2.74E-04		2.70E-04	1.3596E+00	3.66E-04	1.4543E+03	3.92E-01
Y-92	7.33E-04		7.21E-04	6.7325E+01	4.86E-02	1.1881E+05	8.57E+01
Zr-95	3.62E-04		3.56E-04	8.8200E+01	3.14E-02	4.9537E+05	1.76E+02
Nb-95	3.68E-04		3.62E-04	1.0250E+02	3.71E-02	5.0437E+05	1.83E+02
Mo-99	4.60E-01		4.53E-01	1.6074E+01	7.27E+00	1.2222E+05	5.53E+04
Tc-99m	3.16E-01		3.11E-01	3.0000E-02	9.33E-03	4.4085E+05	1.37E+05
I-129	6.34E-08		6.24E-08	0.0000E+00	0.00E+00	0.0000E+00	0.00E+00
I-131	1.68E+00		1.66E+00	8.6362E+00	1.43E+01	4.8206E+05	7.99E+05
I-132	9.84E-01		9.68E-01	4.3446E+02	4.21E+02	1.5435E+06	1.49E+06
I-133	2.85E+00		2.80E+00	6.4390E+01	1.80E+02	5.3280E+05	1.49E+06
I-134	5.94E-01		5.84E-01	5.4811E+02	3.20E+02	1.3588E+06	7.94E+05
I-135	1.89E+00		1.86E+00	7.8131E+02	1.45E+03	6.7981E+05	1.27E+06
Co-58	7.90E-03		7.78E-03	1.4106E+02	1.10E+00	6.5859E+05	5.12E+03
Co-60	9.09E-04		8.94E-04	1.0207E+03	9.13E-01	9.6841E+05	8.66E+02
Fe-59	5.16E-04		5.08E-04	4.3408E+02	2.20E-01	5.0432E+05	2.56E+02
Te-129	1.32E-02	0.9840	1.30E-02	7.7144E+00	1.00E-01	9.3730E+04	1.22E+03
Te-132	1.80E-01		1.77E-01	3.4826E-01	6.16E-02	4.4459E+05	7.86E+04
Te-134	2.84E-02		2.80E-02	2.0382E-01	5.70E-03	2.8864E+05	8.07E+03
Cs-134	3.46E+00		3.40E+00	2.0187E+02	6.87E+02	1.1422E+06	3.89E+06
Cs-136	8.68E-01		8.54E-01	4.8303E+02	4.12E+02	1.5456E+06	1.32E+06
Cs-137	2.17E+00		2.13E+00	5.1000E+01	1.09E+02	4.3258E+05	9.22E+05
Cs-138	9.90E-01		9.74E-01	9.9875E+02	9.73E+02	8.1615E+05	7.95E+05
Ba-140	2.37E-03		2.33E-03	1.0006E+01	2.34E-02	2.5622E+05	5.98E+02
La-140	8.77E-04		8.63E-04	9.8104E+02	8.46E-01	9.2029E+05	7.94E+02
Ce-144	2.68E-04		2.64E-04	3.1167E-03	8.22E-07	5.5762E+04	1.47E+01
Pr-144	4.62E-04		4.54E-04	1.3164E+01	5.98E-03	1.2369E+04	5.62E+00
Kr-85	7.14E+01		7.03E+01	9.1200E-02	6.41E+00	2.0185E+03	1.42E+05
Kr-85m	1.14E+00		1.12E+00	2.7263E-01	3.06E-01	4.2749E+05	4.81E+05
Kr-87	8.70E-01		8.56E-01	6.2626E+02	5.36E+02	6.9058E+05	5.91E+05
Kr-88	2.26E+00		2.22E+00	5.0762E+02	1.13E+03	5.3234E+05	1.18E+06
Xe-133	1.83E+02		1.80E+02	0.0000E+00	0.00E+00	3.5335E+04	6.37E+06
Xe-133m	2.57E+00		2.52E+00	5.7826E-02	1.46E-01	6.9178E+04	1.75E+05
Xe-135	7.04E+00		6.92E+00	1.8987E+00	1.31E+01	4.6560E+05	3.22E+06
Xe-135m	9.37E-01		9.22E-01	2.0320E+01	1.87E+01	4.0401E+05	3.73E+05
Xe-138	6.58E-01		6.47E-01	1.4864E+03	9.62E+02	1.4879E+06	9.63E+05
Mn-54	2.74E-03		2.70E-03	1.4208E+02	3.84E-01	5.0129E+05	1.35E+03
					8.31E+03		**2.72E+07**
						0.05% FF >	**1.36E+06**
					6.06E+03	**/1.37 error**	**9.93E+05**
					cpm		**cpm**

*1% FF RCS concentrations from SWEC 10080-UR(B)-484 Table 8a

**Letdown density correction based on 137 F (monitor high temperature isolation) = 61.43 lbm/ft3 / 62.43 lbm/ft3

*** Manufacturer calibration data

CH-101 Setpoint Calculation @60 gpm Letdown flow Rate

Updated design RCS concentrations and for the 843-30R detector type

Nuclide	*1% FF @ 576 F (uCi/g)	**At-monitor Density Correction	*1% FF 60 gpm Density Corrected (uCi/cc)	High Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @60 gpm High Range Channel Indication (cpm)	Low Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @60 gpm Low Range Channel Indication (cpm)
Br-84	3.73E-02		3.67E-02	2.29E+03	8.40E+01	2.11E+06	7.74E+04
Rb-88	2.75E+00		2.71E+00	3.69E+02	9.98E+02	2.08E+05	5.63E+05
Rb-89	1.57E-01		1.54E-01	9.76E+02	1.51E+02	8.57E+05	1.32E+05
Sr-89	3.49E-03		3.43E-03	2.13E-02	7.31E-05	5.62E+01	1.93E-01
Sr-90	2.16E-04		2.13E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.45E-03		1.43E-03	2.08E+02	2.97E-01	8.13E+05	1.16E+03
Sr-92	1.03E-03		1.01E-03	6.27E+02	6.35E-01	5.25E+05	5.32E+02
Y-90	5.94E-05		5.84E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	4.78E-04		4.70E-04	1.33E+00	6.26E-04	1.41E+03	6.63E-01
Y-92	8.84E-04		8.70E-04	7.84E+01	6.82E-02	1.39E+05	1.21E+02
Zr-95	6.32E-04		6.22E-04	1.09E+02	6.78E-02	6.09E+05	3.79E+02
Nb-95	6.41E-04		6.31E-04	1.27E+02	8.01E-02	6.19E+05	3.90E+02
Mo-99	7.62E-01		7.50E-01	7.99E+01	5.99E+01	6.05E+05	4.54E+05
Tc-99m	4.09E-01		4.02E-01	3.73E-02	1.50E-02	5.47E+05	2.20E+05
I-129	1.11E-07		1.09E-07	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	2.89E+00		2.84E+00	9.21E+00	2.62E+01	5.66E+05	1.61E+06
I-132	1.13E+00		1.11E+00	5.16E+02	5.74E+02	1.81E+06	2.01E+06
I-133	4.32E+00		4.25E+00	7.56E+01	3.21E+02	6.57E+05	2.79E+06
I-134	6.32E-01		6.22E-01	6.44E+02	4.00E+02	2.06E+06	1.28E+06
I-135	2.48E+00		2.44E+00	9.62E+02	2.35E+03	7.25E+05	1.77E+06
Co-58	1.38E-02		1.36E-02	1.28E+02	1.74E+00	6.01E+05	8.16E+03
Co-60	1.59E-03		1.56E-03	1.15E+03	1.80E+00	1.08E+06	1.69E+03
Fe-59	9.00E-04		8.86E-04	4.90E+02	4.34E-01	5.69E+05	5.04E+02
Te-129	1.43E-02	0.9840	1.41E-02	1.17E+01	1.65E-01	1.11E+05	1.56E+03
Te-132	3.00E-01		2.95E-01	3.59E-01	1.06E-01	4.59E+05	1.35E+05
Te-134	2.99E-02		2.94E-02	2.34E-01	6.88E-03	3.31E+05	9.74E+03
Cs-134	6.05E+00		5.95E+00	2.46E+02	1.46E+03	1.39E+06	8.27E+06
Cs-136	1.50E+00		1.48E+00	5.50E+02	8.12E+02	1.77E+06	2.61E+06
Cs-137	3.79E+00		3.73E+00	5.92E+01	2.21E+02	5.03E+05	1.88E+06
Cs-138	1.03E+00		1.01E+00	1.29E+03	1.31E+03	1.05E+06	1.06E+06
Ba-140	4.10E-03		4.03E-03	1.09E+01	4.40E-02	2.80E+05	1.13E+03
La-140	1.41E-03		1.39E-03	1.09E+03	1.51E+00	1.02E+06	1.42E+03
Ce-144	4.69E-04		4.61E-04	3.99E-03	1.84E-06	7.16E+04	3.30E+01
Pr-144	4.72E-04		4.64E-04	1.36E+01	6.32E-03	1.28E+04	5.94E+00
Kr-85	1.25E+02		1.23E+02	1.07E+01	1.32E+03	2.37E+05	2.92E+07
Kr-85m	1.42E+00		1.40E+00	3.20E-01	4.47E-01	5.01E+05	7.00E+05
Kr-87	9.48E-01		9.33E-01	6.60E+02	6.16E+02	7.28E+05	6.79E+05
Kr-88	2.65E+00		2.61E+00	5.14E+02	1.34E+03	5.38E+05	1.40E+06
Xe-133	3.11E+02		3.06E+02	0.00E+00	0.00E+00	3.27E+04	1.00E+07
Xe-133m	4.20E+00		4.13E+00	5.98E-02	2.47E-01	7.16E+04	2.96E+05
Xe-135	9.64E+00		9.49E+00	1.97E+00	1.87E+01	4.84E+05	4.59E+06
Xe-135m	9.56E-01		9.41E-01	2.40E+01	2.26E+01	4.78E+05	4.50E+05
Xe-138	6.70E-01		6.59E-01	1.55E+03	1.02E+03	1.55E+06	1.02E+06
Mn-54	4.80E-03		4.72E-03	1.73E+02	8.17E-01	6.10E+05	2.88E+03
					1.31E+04		**7.32E+07**
						0.05% FF >	**3.66E+06**
					9.57E+03	**x1.37 error**	**2.67E+06**
					cpm		**cpm**

*1% FF RCS concentrations from SWEC 10080-UR(B)-484 Table 8a

**Letdown density correction based on 137 F (monitor high temperature isolation) = 61.43 lbm/ft3 / 62.43 lbm/ft3

*** Manufacturer calibration data

CH-101 Setpoint Calculation @105 gpm Letdown flow Rate

Updated design RCS concentrations and for the 843-30R detector type

Nuclide	1% FF @ 576 F (uCi/g)	**At-monitor Density Correction	*1% FF 105 gpm Density Corrected (uCi/cc)	High Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @105 gpm High Range Channel Indication (cpm)	Low Range ***Channel Efficiency (cpm-cc/uCi)	1% FF @105 gpm Low Range Channel Indication (cpm)
Br-84	3.59E-02		3.53E-02	2.29E+03	8.08E+01	2.11E+06	7.44E+04
Rb-88	2.69E+00		2.64E+00	3.69E+02	9.76E+02	2.08E+05	5.50E+05
Rb-89	1.54E-01		1.51E-01	9.76E+02	1.48E+02	8.57E+05	1.30E+05
Sr-89	2.00E-03		1.97E-03	2.13E-02	4.19E-05	5.62E+01	1.11E-01
Sr-90	1.23E-04		1.21E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Sr-91	1.05E-03		1.04E-03	2.08E+02	2.15E-01	8.13E+05	8.42E+02
Sr-92	8.81E-04		8.67E-04	6.27E+02	5.44E-01	5.25E+05	4.55E+02
Y-90	3.59E-05		3.53E-05	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Y-91	2.74E-04		2.70E-04	1.33E+00	3.58E-04	1.41E+03	3.80E-01
Y-92	7.33E-04		7.21E-04	7.84E+01	5.65E-02	1.39E+05	1.00E+02
Zr-95	3.62E-04		3.56E-04	1.09E+02	3.88E-02	6.09E+05	2.17E+02
Nb-95	3.68E-04		3.62E-04	1.27E+02	4.60E-02	6.19E+05	2.24E+02
Mo-99	4.60E-01		4.53E-01	7.99E+01	3.62E+01	6.05E+05	2.74E+05
Tc-99m	3.16E-01		3.11E-01	3.73E-02	1.16E-02	5.47E+05	1.70E+05
I-129	6.34E-08		6.24E-08	0.00E+00	0.00E+00	0.00E+00	0.00E+00
I-131	1.68E+00		1.66E+00	9.21E+00	1.53E+01	5.66E+05	9.38E+05
I-132	9.84E-01		9.68E-01	5.16E+02	5.00E+02	1.81E+06	1.75E+06
I-133	2.85E+00		2.80E+00	7.56E+01	2.12E+02	6.57E+05	1.84E+06
I-134	5.94E-01		5.84E-01	6.44E+02	3.76E+02	2.06E+06	1.20E+06
I-135	1.89E+00		1.86E+00	9.62E+02	1.79E+03	7.25E+05	1.35E+06
Co-58	7.90E-03		7.78E-03	1.28E+02	9.96E-01	6.01E+05	4.67E+03
Co-60	9.09E-04		8.94E-04	1.15E+03	1.03E+00	1.08E+06	9.66E+02
Fe-59	5.16E-04		5.08E-04	4.90E+02	2.49E-01	5.69E+05	2.89E+02
Te-129	1.32E-02	0.9840	1.30E-02	1.17E+01	1.52E-01	1.11E+05	1.44E+03
Te-132	1.80E-01		1.77E-01	3.59E-01	6.35E-02	4.59E+05	8.11E+04
Te-134	2.84E-02		2.80E-02	2.34E-01	6.54E-03	3.31E+05	9.26E+03
Cs-134	3.46E+00		3.40E+00	2.46E+02	8.37E+02	1.39E+06	4.73E+06
Cs-136	8.68E-01		8.54E-01	5.50E+02	4.70E+02	1.77E+06	1.51E+06
Cs-137	2.17E+00		2.13E+00	5.92E+01	1.26E+02	5.03E+05	1.07E+06
Cs-138	9.90E-01		9.74E-01	1.29E+03	1.26E+03	1.05E+06	1.02E+06
Ba-140	2.37E-03		2.33E-03	1.09E+01	2.55E-02	2.80E+05	6.54E+02
La-140	8.77E-04		8.63E-04	1.09E+03	9.40E-01	1.02E+06	8.80E+02
Ce-144	2.68E-04		2.64E-04	3.99E-03	1.05E-06	7.16E+04	1.89E+01
Pr-144	4.62E-04		4.54E-04	1.36E+01	6.18E-03	1.28E+04	5.81E+00
Kr-85	7.14E+01		7.03E+01	1.07E+01	7.52E+02	2.37E+05	1.67E+07
Kr-85m	1.14E+00		1.12E+00	3.20E-01	3.60E-01	5.01E+05	5.63E+05
Kr-87	8.70E-01		8.56E-01	6.60E+02	5.65E+02	7.28E+05	6.23E+05
Kr-88	2.26E+00		2.22E+00	5.14E+02	1.14E+03	5.38E+05	1.19E+06
Xe-133	1.83E+02		1.80E+02	0.00E+00	0.00E+00	3.27E+04	5.89E+06
Xe-133m	2.57E+00		2.52E+00	5.98E-02	1.51E-01	7.16E+04	1.81E+05
Xe-135	7.04E+00		6.92E+00	1.97E+00	1.36E+01	4.84E+05	3.35E+06
Xe-135m	9.37E-01		9.22E-01	2.40E+01	2.21E+01	4.78E+05	4.41E+05
Xe-138	6.58E-01		6.47E-01	1.55E+03	1.00E+03	1.55E+06	1.00E+06
Mn-54	2.74E-03		2.70E-03	1.73E+02	4.67E-01	6.10E+05	1.65E+03
					1.03E+04		**4.66E+07**
						0.05% FF >	**2.33E+06**
					7.54E+03	**x1.37 error**	**1.70E+06**
					cpm		**cpm**

*1% FF RCS concentrations from SWEC 10080-UR(B)-484 Table 8a

**Letdown density correction based on 137 F (monitor high temperature isolation) = 61.43 lbm/ft3 / 62.43 lbm/ft3

*** Manufacturer calibration data

Alarm Setpoint Methodology

DISCUSSION

This appendix describes the bases for the alarm setpoint methodology. Only increasing value alarm setpoints are addressed. A similar methodology could be described for decreasing value alarm setpoints, but these are not applicable to radiation monitoring.

USNRC Regulatory Guide 1.105, Instrument Setpoints [1], provides a regulatory position on setpoints on systems important to safety. The guide provides the following definition of "systems important to safety":

> *"...those systems that are necessary to ensure (1) the integrity of the reactor coolant pressure boundary, (2) the capability to shutdown the reactor and maintain it in a safe condition, or (3) the capability to prevent or mitigate the consequences of accidents that could result in potential offsite exposures comparable to the guideline exposures of 10 CFR Part 100, Reactor Site Criteria...."*

The BVPS Unit 2 UFSAR [2] contains a commitment to this regulatory guide, but the referenced discussion in section 7 of the UFSAR does not specifically address radiation monitors. SWEC addressed RG 1.105 in the development of Unit 2 category 1 radiation monitor setpoints. This issue was addressed by the Radiation Safety Committee in meeting 25-87[3] and a position paper was prepared on this issue [4]. While recognizing the need to consider instrument errors in determining alarm setpoints, this position paper concluded that the regulatory guide was (1) applicable to a subset of the Unit 2 monitors, (2) applicable to only those Unit 1 monitors installed in response to a Unit 2 licensing commitment, and (3) not applicable to effluent monitors (ODCM). This position paper was accepted by the RSC (BV-RSC-27-87) and approved by the OSC (BV-OSC-48-87).

Regulatory Guide 1.105 provides, in part:

> *"...The setpoints should be established with sufficient margin between the technical specification limits for the process variable and the nominal trip setpoint to allow for (a) the inaccuracy of the instrument; (b) uncertainties in the calibration, and (c) the instrument drift that could occur during the interval between calibrations...."*

The methodology employed by SWEC was, as was this appendix, based on ANSI/ISA-S67.04-1988, Setpoints for Nuclear Safety-Related Instrumentation [5], which provides a means to accomplish the above.

DEFINITIONS

Safety Limit [SL] — A limit on an important process variable that is necessary to reasonably protect the integrity of the physical barriers that guard against uncontrolled release of radioactivity [5]. Safety limits are documented in the UFSAR, in technical specification bases, and in other design basis documentation.

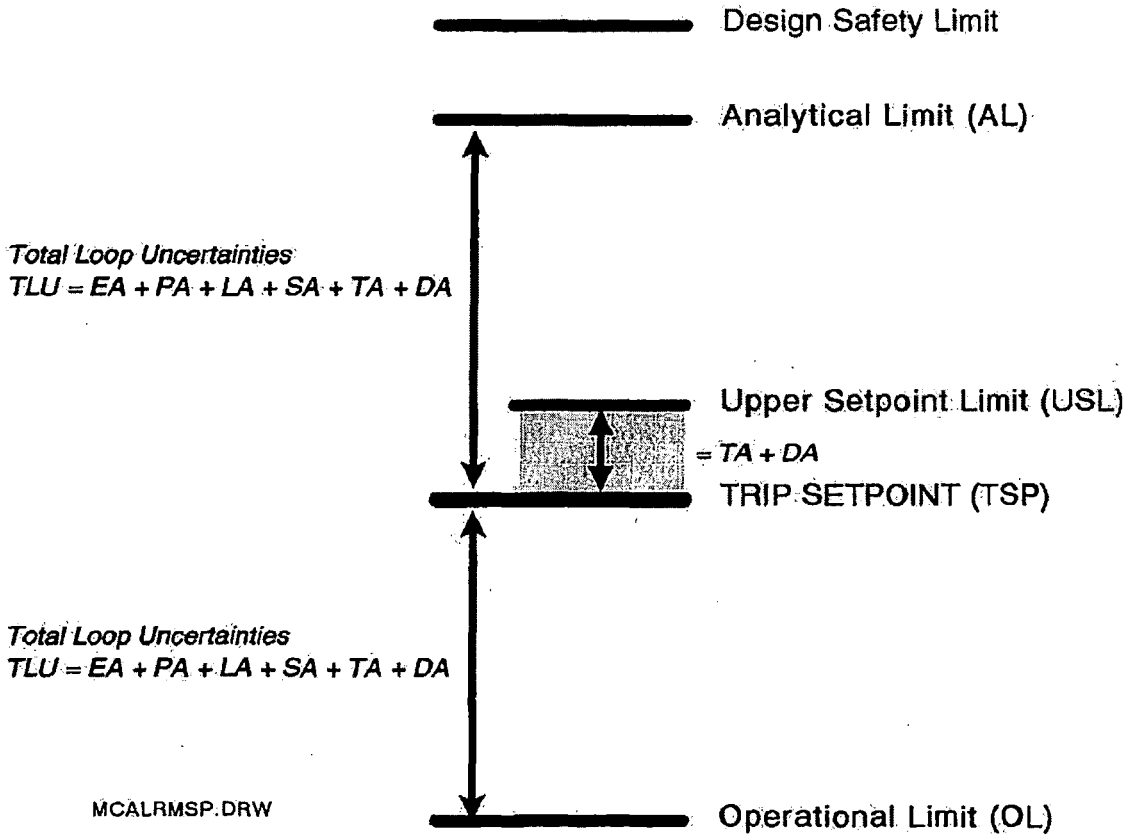
Analytical Limit [AL] — Limit of a measured or calculated variable established by safety analyses to ensure that a safety limit is not exceeded [5]. The difference between a safety limit and an analytical limit provides margin to account for process dependent effects such as (but not limited to) process delays, emergency diesel generator sequencing, valve or damper closure times, and instrument response times.

Trip Setpoint [TSP] — A predetermined value [of the monitored parameter] at which a bistable device changes state to indicate that the quantity under surveillance has reached the selected value [5]. The difference between a trip setpoint and an analytical limit is the allowance provided to account for instrument uncertainty, instrument calibration uncertainty (and, if not addressed in the determination of analytical limit, process dependent effects).

Upper Setpoint Limit [USL] A predetermined value of the monitored parameter above the trip setpoint that, if exceeded during periodic surveillance testing, indicates unsatisfactory instrument performance. The band defined between the trip setpoint and the upper setpoint limit is the allowance provided to account for instrument uncertainties such as setpoint drift, power supply drift, random response variation, deadband, etc.

Operational Limit [OL] The maximum value that the monitored parameter may attain during normal operations, based on administrative controls, that will not result in the occurrence of an alarm.

These quantities are illustrated on the figure below.



Normal Operation

DETERMINATION OF ALLOWANCES

Environmental Allowance [EA] Includes the effects of radiation, temperature, pressure, humidity, chemical sprays on the instrumentation. EA should be determined for all safety related monitors expected to operate under accident conditions if the instrument vendor has indicated an accuracy under these conditions that differs from the accuracy expressed for operation under normal conditions. Applies only to QA Category 1 monitors.

Leakage Allowance [LA]	Includes instrument signal losses due to cable or penetration leakage or impedence. Applies only to QA Category 1 monitors.
Process Allowance [PA]	Includes effects associated with the measurement of the process parameter (e.g., sample line plateout, isokinetic sampling), errors associated with calculation of the process parameter by indirect measurements (e.g., determining flow from Dp measurements).
Calibration Allowance [CA]	Includes errors associated with calibrations of the sensor and the readout rack, such as those related to the calibration standard, equipment, and method.
Sensor Allowance [SA]	Includes errors associated with the sensor and readout accuracy. Considerations include: linearity; deadtime; energy response linearity; repeatability; power supply stability; temperature, pressure, and humidity changes; ADC/DAC errors, etc.
Drift Allowance [DA]	Includes errors due to undesired changes in instrument response, over a period of time, that are independent of the instrument input or use environment. The period of time is normalized to the period between instrument calibrations or surveillance testing.
Tolerance Allowance [TA]	Includes administrative tolerances allowed for calibration and/or setpoint adjustment (e.g., adjust to within ± xx% of xxxx cpm).

The errors addressed by these allowances may be dependent or independent. Dependent errors are summed algebraically. Independent errors are summed using the root-of-squared-sums method. Prior to summing, all errors are normalized to a common base (e.g., percent of span, percent of full scale). Unit 1 calibration MSPs provide a tolerance of ±10%. Unit 2 calibration MSPs provide a tolerance of ±15%.

Not all of these allowances are applicable to a particular monitor -- only those applicable are considered. Dependent errors (e.g., LA, CP), are not addressed explicitly if it is reasonable to conclude that sensor-to-readout (end-to-end) calibrations adequately compensate for these effects. In cases where one allowance envelopes a related allowance, only the most restrictive allowance is summed. For example, an instrument setpoint accuracy (i.e., SA) of ±1% is considered enveloped by a tolerance allowance (TA) of ±10%.

The total instrument loop uncertainty (TLU) is the sum of the individual allowances. Assuming LA, to be dependent, and the remainder to be independent:

$$TLU = LA \pm SQRT(EA2 + PA2 + CA2 + SA2 + DA 2+ TA 2)$$

The trip setpoint equals:

NOTE: In the following, %+TLU refers to the total loop uncertainty in the under-response direction expressed in percent. %-TLU refers to the total loop uncertainty in the over-response direction expressed in percent.

$$TSP = AL - (TLU \times TSP)$$

$$TSP = AL / [1 + (\%\text{-}TLU) /100]$$

The upper setpoint limit (USL) (NOTE: See definition above.):

USL = TSP + (TSPxDA) + (TSPxTA)

USL = TSP[1 + SQRT(DA2 + TA2)]

The operational limit (OL):

OL = TSP - (TLUxTSP)

OL = TSP[1- (%-TLU/100)]

1. USNRC, Instrument Setpoints, Regulatory Guide 1.105, USGPO ,11/76
2. DLC, BVPS Unit 2 Updated Safety Analysis Report, 1990
3. DLC, Minutes of Radiation Safety Committee Meeting 25-87
4. DLC, Applicability of RG1.105 to BVPS Radiation Monitors, ERS-SFL-87-036, 1987
5. ISA, Setpoints for Nuclear Safety-Related Instrumentation, ANSI/ISA-S67.04-1988
6. Ficke, R, Instrument Setpoint Calculations, presentation at Sorrento Electronics DRMS User's Group Meeting, Fall, 1990

FLUKE Biomedical

FLUKE Biomedical
Radiation Management Services
6045 Cochran Road
Cleveland, OH 44139-3303

To: Pravin Vakharia
Beaver Valley 1
Tephone: 724-682-7615
Telefax: 724-682-4743

From: Andy Lasko
Project Manager,
e-mail: Andrew.Lasko@flukebiomedical.com
Telephone: (440)542-3611
Telefax: (440)349-8059

Date: April 19, 2006

Page: 1 of 7 Pages

Subject: Revised Model 843-30R Efficiencies

Mr. Vakharia

Enclosed are revised isotopic efficiencies for the Model 843-30R Gamma Scintillation detector used in your liquid and gaseous effluent radiation monitors. Four (4) sets of efficiency tables are enclosed. Each table reflects the efficiency for each of the sampling geometries used in your plant.

The source of the efficiency data is our primary isotopic calibration report 958.402. This report documents the primary isotopic calibration performed on the Model 843-30R detector in our Model 841-334 three (3) Liter Off-line liquid sampling geometry. The Model 841-334 is our current version of your Model 841-3N three (3) liter Off-line sampling geometry. The sample volume and detector location in both sampling geometries is the same, and the data taken with our Model 841-334 will apply directly to your Model 841-3N.

To obtain revised efficiencies for your Letdown monitor and Gaseous effluent monitors, the ratio between your original liquid monitor efficiency and the new efficiency was calculated for each isotope. The efficiency ratio was then applied to the previous letdown monitor and gaseous effluent monitor isotopic efficiencies, and a new efficiency was calculated. We believe this approach is valid because the detector response has been validated in report 958.402. What changes in the letdown and gaseous effluent monitors is the sampling geometry. By knowing the response difference of the detector from the primary liquid isotopic calibration, and the previous response of the letdown and gaseous monitor sampling geometries, a new efficiency for the letdown and gaseous geometries may be obtained by multiplying the original efficiencies by the difference in detector efficiencies.

The results of this analysis are provided on the four (4) tables enclosed.

Please feel free to contact us should you have any questions or comments on the above.

Sincerely Yours,

Andrew Lasko
Project Manager
FLUKE Biomedical
Radiation Management Services
E-Mail: Andrew.Lasko@flukebiomedical.com

Note: Only the portions of the letter attachment that pertain to CH-101 are provided below.

BVPS Unit 1 Reactor Coolant System Letdown Radiation Monitors 4/17/2006

Gamma Sensitivities of the 903664 Sampler & 843-30 High Channel to Liquids

Monitors: RM-1CH-101A **Used as a High Range Instrument**
RM-1CH-101B **Used as a High Range Instrument**

	Nuclide	(1) 843-30 Detection Efficiency (cpm/uCi/ml)	(2) 843-30-R Detection Efficiency (cpm/uCi/ml)
1	Br-84	7.07E+02	2.29E+03
2	Rb-88	3.33E+02	3.69E+02
3	Rb-89	1.01E+03	9.76E+02
4	Sr-89	1.70E-02	2.13E-02
5	Sr-90	0.00E+00	0.00E+00
6	Y-90	2.13E-01	0.00E+00
7	Sr-91	1.78E+02	2.08E+02
8	Y-91	1.36E+00	1.33E+00
9	Sr-92	5.58E+02	6.27E+02
10	Y-92	6.73E+01	7.84E+01
11	Zr-95	8.82E+01	1.09E+02
12	Nb-95	1.03E+02	1.27E+02
13	Mo-99	1.61E+01	7.99E+01
14	Tc-99m	3.00E-02	3.73E-02
15	I-132	4.34E+02	5.16E+02
16	I-133	6.44E+01	7.56E+01
17	I-134	5.48E+02	6.44E+02
18	I-135	7.81E+02	9.62E+02
19	Te-129	7.71E+00	1.17E+01
20	I-131	8.64E+00	9.21E+00
21	Te-132	3.48E-01	3.59E-01
22	Te-134	2.04E-01	2.34E-01
23	Cs-134	2.02E+02	2.46E+02
24	Cs-136	4.83E+02	5.50E+02
25	Cs-137	5.10E+01	5.92E+01
26	Cs-138	9.99E+02	1.29E+03
27	Ba-140	1.00E+01	1.09E+01
28	La-140	9.81E+02	1.09E+03
29	Ce-144	3.11E-03	3.99E-03
30	Pr-144	1.32E+01	1.36E+01
31	Kr-85	9.12E-02	1.07E+01
32	Kr-85m	2.73E-01	3.20E-01
33	Kr-87	6.26E+02	6.60E+02
34	Kr-88	5.08E+02	5.14E+02
35	Xe-133	0.00E+00	0.00E+00
36	Xe-133m	5.78E-02	5.98E-02
37	Xe-135	1.90E+00	1.97E+00
38	Xe-135m	2.03E+01	2.40E+01
39	Xe-138	1.49E+03	1.55E+03
40	Mn-54	1.42E+02	1.73E+02
41	Mn-56	6.74E+02	8.47E+02
42	Co-58	1.41E+02	1.28E+02
43	Co-60	1.03E+03	1.15E+03
44	Fe-59	4.34E+02	4.90E+02

(1) Original Gamma Sensitivities from Addendum to BVPS Spec No. BVS-414, Table V, 10-7-
(2) Gamma Sensitivities from Fluke Biomedical for Replacement Detector

BVPS Unit 1 Reactor Coolant System Letdown Radiation Monitors 4/17/2006

Gamma Sensitivities of the 903664 Sampler & 843-30 Low Channel to Liquids

Monitors: RM-1CH-101A **Used as a Low Range Instrument**
RM-1CH-101B **Used as a Low Range Instrument**

	Nuclide	(1) 843-30 Detection Efficiency (cpm/uCi/ml)	(2) 843-30-R Detection Efficiency (cpm/uCi/ml)
1	Br-84	6.50E+05	2.11E+06
2	Rb-88	1.88E+05	2.08E+05
3	Rb-89	8.87E+05	8.57E+05
4	Sr-89	4.48E+01	5.62E+01
5	Sr-90	0.00E+00	0.00E+00
6	Y-90	9.54E+01	0.00E+00
7	Sr-91	6.97E+05	8.13E+05
8	Y-91	1.45E+03	1.41E+03
9	Sr-92	4.68E+05	5.25E+05
10	Y-92	1.19E+05	1.39E+05
11	Zr-95	4.95E+05	6.09E+05
12	Nb-95	5.04E+05	6.19E+05
13	Mo-99	1.22E+05	6.05E+05
14	Tc-99m	4.40E+05	5.47E+05
15	Te-129	9.37E+04	1.11E+05
16	I-131	~~4.82E+00~~	~~5.66E+00~~ → 4.82E+5 5.66E+5
17	I-132	1.54E+06	1.81E+06
18	I-133	5.33E+05	6.57E+05
19	I-134	1.36E+06	2.06E+06
20	I-135	6.80E+05	7.25E+05
21	Te-132	4.45E+05	4.59E+05
22	Te-134	2.89E+05	3.31E+05
23	Cs-134	1.14E+06	1.39E+06
24	Cs-136	1.55E+06	1.77E+06
25	Cs-137	4.33E+05	5.03E+05
26	Cs-138	8.16E+05	1.05E+06
27	Ba-140	2.56E+05	2.80E+05
28	La-140	9.20E+05	1.02E+06
29	Ce-144	5.58E+04	7.16E+04
30	Pr-144	1.24E+04	1.28E+04
31	Kr-85	2.02E+03	2.37E+05
32	Kr-85m	4.27E+05	5.01E+05
33	Kr-87	6.91E+05	7.28E+05
34	Kr-88	5.32E+05	5.38E+05
35	Xe-133	3.53E+04	3.27E+04
36	Xe-133m	6.92E+04	7.16E+04
37	Xe-135	4.66E+05	4.84E+05
38	Xe-135m	4.04E+05	4.78E+05
39	Xe-138	1.49E+06	1.55E+06
40	Mn-54	5.01E+05	6.10E+05
41	Mn-56	7.05E+05	8.86E+05
42	Co-58	6.59E+05	6.01E+05
43	Co-60	9.68E+05	1.08E+06
44	Fe-59	5.04E+05	5.69E+05

Corrected values jtl 8/8/11

(1) Original Gamma Sensitivities from Addendum to BVPS Spec No. BVS-414, Table V, 10-7-

(2) Gamma Sensitivities from Fluke Biomedical for Replacement Detector