Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

PROBLEM STATEMENT

The Vallecitos Nuclear Center (VNC) Reactor Facilities Radiological Emergency Plan (REP), Revision 1 (June 2021) contains the Emergency Action Levels (EALs) applicable to the reactors at VNC, including the Nuclear Test Reactor (NTR). Section 5.1 of the REP includes abnormal radiological Conditions that would result in an unusual event or alert declaration. For an unusual event, RU3 states:

> *Radiological effluent level (µCi/cc) meet any of the following for greater than 60 minutes:*
>
> - *≥ 2.4E-5 NTR Noble Gas Stack Monitor*
> - *≥ 2.4E-5 NTR Particulate Stack Monitor*
> - *≥ 2.4E-1 from any reactor facility effluent Noble Gas sample*
> - *≥ 4.7E-3 from any reactor effluent Halogen sample*
> - *≥ 2.4E-7 from any reactor facility effluent α Particulate sample*
> - *≥ 2.4E-5 from any reactor facility effluent β Particulate sample*

For an alert, RA3 states:

> *Radiological effluent level (µCi/cc) meet any of the following for greater than 60 minutes:*
>
> - *≥ 1.2E-4 NTR Noble Gas Stack Monitor*
> - *≥ 1.2E-4 NTR Particulate Stack Monitor*
> - *≥ 1.2E-0 from any reactor facility effluent Noble Gas sample*
> - *≥ 2.4E-2 from any reactor effluent Halogen sample*
> - *≥ 1.2E-6 from any reactor facility effluent α Particulate sample*
> - *≥ 1.2E-4 from any reactor facility effluent β Particulate sample*

The EAL thresholds notwithstanding, the NTR Noble Gas Stack Monitor reads approximately 2.7E-5 to 3.3E-5 µCi/cc during normal operations, which exceeds the RU3 limit for the monitor. Procedure NTR SOP 5.2 currently sets the operational alarm setpoint at 9.5E-5 µCi/cc based on the stack release action level in SAR Table 6-1 of License Amendment 25 dated June 29, 2022. This is approximately 4 times the RU3 EAL threshold (but below the RA3 EAL threshold).

BACKGROUND

The EAL thresholds for RU3 and RA3 were calculated based on the 10CFR20, Appendix B, Table 2 values for the applicable radionuclides. The assumed radionuclides are as follows:

Table 1 - Current REP EAL Threshold Basis

Monitor/Sample	Radionuclide
Noble Gas	Unlisted, non-Alpha and non-spontaneous fission, greater than 2 hour half-life
Particulate Stack Monitor	Unlisted, non-Alpha and non-spontaneous fission, greater than 2 hour half-life
Noble Gas Sample	Ar-41
Halogen Sample	I-131
Alpha Particulate Sample	Np-237

Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

Beta Particulate Sample	Unlisted, non-Alpha and non-spontaneous fission, greater than 2 hour half-life

The EAL thresholds were determined as the activity concentration that, if released from the NTR stack with the assumed X/Q dispersion coefficient (3.48E-11 s/cc), and with a modifier for multiple stack releases, would result in a fraction (either 10% or 20%) of the 10 CFR 20, Appendix B, Table 2 effluent concentrations for members of the public.

For the noble gas monitor, the unlisted, non-alpha, > 2 hour half-life effluent concentration limit of 1E-12 µCi/cc was assumed.

The basis for the RU3 EAL thresholds for RU3 and RA3 is contained in the REP, Att. 3:

Figure 1 - RU3 and RA3 Threshold Setpoints (from REP Att. 3)

		10 CFR 20 Concentration Limit (µCi/cc)	RU3 Site Boundary Release Concentration (µCi/cc)	RU3 NTR Stack Release Rate (µCi/sec)	RU3 NTR Stack Release Concentration (µCi/cc)
10 CFR 20 Unknown*		1.00E-12	7.01E-10	2.02E+01	2.37E-05
Noble Gas**	**Ar-41**	1.00E-08	7.01E-06	2.02E+05	2.37E-01
Halogen**	**I-131**	2.00E-10	1.40E-07	4.03E+03	4.74E-03
Alpha Particulate**	**Np-237**	1.00E-14	7.01E-12	2.02E-01	2.37E-07
Beta-Gamma Particulate**		1.00E-12	7.01E-10	2.02E+01	2.37E-05

		10 CFR 20 Concentration Limit (µCi/cc)	RA3 Site Boundary Release Concentration (µCi/cc)	RA3 NTR Stack Release Rate (µCi/sec)	RA3 NTR Stack Release Concentration (µCi/cc)
10 CFR 20 Unknown*		1.00E-12	3.51E-09	1.01E+02	1.19E-04
Noble Gas**	**Ar-41**	1.00E-08	3.51E-05	1.01E+06	1.19E+00
Halogen**	**I-131**	2.00E-10	7.01E-07	2.02E+04	2.37E-02
Alpha Particulate**	**Np-237**	1.00E-14	3.51E-11	1.01E+00	1.19E-06
Beta-Gamma Particulate**		1.00E-12	3.51E-09	1.01E+02	1.19E-04

Calculation Constants

10 CFR 20 Effluent Concentration Dose Basis (mrem/yr):	50
10 CFR 20 Effluent Concentration Dose Basis (mrem/hr):	5.70E-03
EAL RU3 Limit (mr/hr):	4
EAL RA3 Limit (mr/hr):	20
Limiting X/Q* (sec/cc):	3.48E-11
NTR Bldg 105 Stack Flow Rate* (cfm):	1800
Conversion Factor (cc/sec per cfm):	471.95
NTR Bldg 105 Stack Flow Rate (cc/sec):	8.50E+05

* 10 CFR 20 limit for unlisted (unknown) radionuclide with decay mode other than alpha emission or spontaneous fission and with radioactive half-life greater than 2 hours.

** Values taken from NTR SAR Section 6.4

Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

The site boundary release concentrations (above) are determined by adjusting the 10CFR20 Effluent concentration limit (which correspond) to 50 mrem/yr, to a concentration of 4 mR/hr (for the unusual event declaration) or 20 mR/hr (for the alert declaration) The NTR Stack Release Rate (in µCi/s) is that concentration adjusted by the assumed χ/Q (3.48E-11 sec/cc). The NTR Stack Release concentration then accounts for the NTR stack release rate (nominal 1800 cfm).

SYSTEM CONFIGURATION

Effluents from the NTR are released via the NTR stack. The noble gas sample is drawn from the stack at a rate of 1 cfm. The sample is pulled through a particulate filter, then a charcoal filter, and finally into the noble gas (Kanne) detector (See figure below). As such, the sample measured by the noble gas monitor should only contain radioactive noble gases, as the particulates and halogens have been stripped out. The NTR stack exhaust is powered by a 3000 cfm motor, which nominally operates at 1800 cfm.

Figure 2 - NTR Ventilation System (from SAR Figure 6-3)

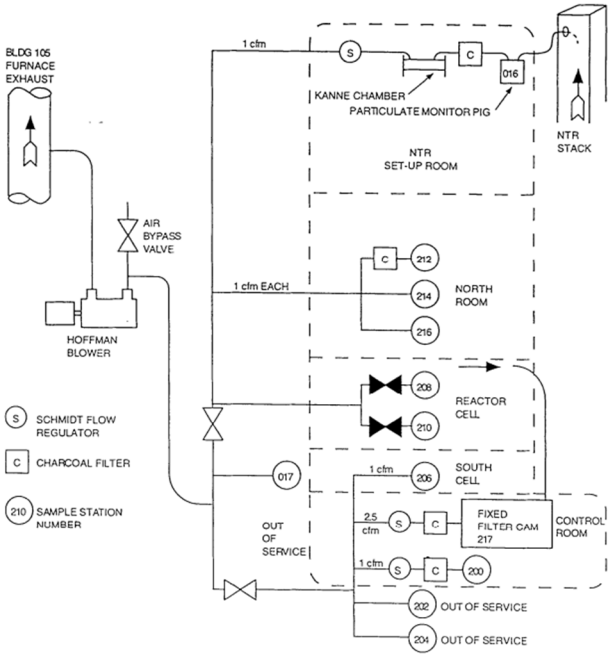

Figure 6-3. Line Diagram of System

EVALUATION

The basis for the noble gas monitor EAL threshold is that the applicable 10CFR20 effluent concentration is based on the "Unlisted, non-alpha radionuclides with > 2hour half-life". That value, however, assumes that the unlisted, or unknown radionuclides may include particulates. However, based on the system configuration no particulates nor halogens are present. The effluent concentration limits for particulates and halogens are generally much lower than those for noble gases. A lower effluent concentration limit will result in a correspondingly lower EAL threshold.

Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

For an accident (or operating) scenario, the radionuclides that will be seen by the noble gas monitor will be radioactive noble gases. Under normal operations, that is predominantly Ar-41. Under accident scenarios, the radionuclides will be the various isotopes of fission noble gases, namely Krypton and Xenon. The 10CFR20 Appendix B, Table 2 Effluent Concentrations for pertinent radionuclides are as follows:

Table 2 - 10 CFR 20 Appendix B, Table 2 Effluent Concentrations

Nuclide	10CFR20 Appendix B Table 2 Effluent Concentration Limit (uCi/cc)
Unlisted alpha	1.00E-15
Unlisted > 2 hour	1.00E-12
Unlisted <2 hour	1.00E-09
Kr-88	9.00E-09
Ar-41	1.00E-08
Kr-74	1.00E-08
Xe-121	1.00E-08
Kr-77	2.00E-08
Kr-87	2.00E-08
Xe-138	2.00E-08
Xe-123	3.00E-08
Kr-76	4.00E-08
Xe-120	4.00E-08
Xe-135m	4.00E-08
Xe-127	6.00E-08
Kr-79	7.00E-08
Xe-125	7.00E-08
Xe-135	7.00E-08
Kr-85m	1.00E-07
Xe-122	3.00E-07
Xe-133	5.00E-07
Xe-133m	6.00E-07
Kr-85	7.00E-07
Xe-129m	9.00E-07
Xe-131m	2.00E-06
Kr-81	3.00E-06
Kr-83m	5.00E-05

As shown above, the smallest and most conservative effluent concentration that would be seen by the noble gas monitor is 9E-09 µCi/cc for Kr-88.

However, the effluent concentration limits (ECL) in 10CFR20 Appendix B, Table 2 do not have consistent dose basis. Per Reg. Guide 4.20, radionuclides with a stochastic based Annual Limit of Intake (ALI) have an ECL based on a 50 mrem/yr dose basis. For purposes of this evaluation, that is any particulate or halogen radionuclide. Conversely, for radionuclides with a submersion based ALI (i.e., noble gases) the ECL is based on a 100 mrem/yr dose basis. As a result, the noble gas monitor EAL thresholds must be calculated assuming that the 10 CFR 20 ECL results in a 100 mrem/yr dose rate.

The REP Att. 3 calculations for the noble gas monitor EAL thresholds for RU3 and RA3 should be 1.07E-01 µCi/cc and 5.34E-01 µCi/cc. respectively.

CONCLUSION AND RECOMMENDATION

The RU3 EAL threshold for the noble gas monitor as contained in the Vallecitos Radiological Emergency Plan is incorrect and overly conservative, because it is based on an overly conservative 10 CFR 20 effluent concentration value. The most conservative, but reasonable, effluent concentration value for a radionuclide that will be detected by the noble gas monitor under accident conditions is Kr-88. Conservatively assuming all fission gasses released during an accident are Kr-88, the RU3 and RA3 EAL threshold for the noble gas monitor should be revised to 2.13E-01 µCi/cc and 1.07E+00 µCi/cc.

While this change results in a non-conservative adjustment in both EALs, the existing basis currently yields a calculated RU3 level of 2.4E-5 µCi/cc. This is not discernible from normal Ar-41 effluent releases which range from 2.7E-5 µCi/cc to 3.3E-5 µCi/cc. Further, it is below the effluent alarm setpoint for the NTR stack monitor of 9.5E-5 µCi/cc and, as a result, provides no prompt for the operators to suspect they may be entering into an EAL. This change does not constitute a reduction in effectiveness. It does result in an overall improvement to the emergency planning function of classifying emergencies by providing a discernible yet conservative RU3 setpoint. This change does not reduce the capability to perform any emergency function in the event of a radiological emergency as per 10 CFR 50.54(q)(1)(iv).

A revised REP Appendix 3 EAL Technical Bases is shown below:

Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

Appendix 3 – EAL Technical Bases for Effluent Releases

Method: 10 CFR 20 effluent concentration limits, representative of a 50 mrem/yr dose, are adjusted to an equivalent concentration limit for the EAL site boundary threshold value in mr/hr. The site boundary EAL concentration limit is back-calculated to an effluent stack release rate using the limiting SAR X/Q dispersion factor and stack flow rate.

		10 CFR 20 Concentration Limit (µCi/cc)	RU3 Site Boundary Release Concentration (µCi/cc)	RU3 NTR Stack Release Rate (µCi/sec)	RU3 NTR Stack Release Concentration (µCi/cc)
Noble Gas*	Kr-88	9.00E-09	7.01E-10	2.02E+01	1.07E-01
Noble Gas**	Ar-41	1.00E-08	7.01E-06	2.02E+05	2.37E-01
Halogen**	I-131	2.00E-10	1.40E-07	4.03E+03	4.74E-03
Alpha Particulate**	Np-237	1.00E-14	7.01E-12	2.02E-01	2.37E-07
Beta-Gamma Particulate**		1.00E-12	7.01E-10	2.02E+01	2.37E-05

		10 CFR 20 Concentration Limit (µCi/cc)	RA3 Site Boundary Release Concentration (µCi/cc)	RA3 NTR Stack Release Rate (µCi/sec)	RA3 NTR Stack Release Concentration (µCi/cc)
Noble Gas*	Kr-88	9.00E-09	3.51E-09	1.01E+02	5.34E-01
Noble Gas**	Ar-41	1.00E-08	3.51E-05	1.01E+06	1.19E+00
Halogen**	I-131	2.00E-10	7.01E-07	2.02E+04	2.37E-02
Alpha Particulate**	Np-237	1.00E-14	3.51E-11	1.01E-00	1.19E-06
Beta-Gamma Particulate**		1.00E-12	3.51E-09	1.01E+02	1.19E-04

Calculations Constants

10 CFR 20 Effluent Concentration Dose Basis – Stochastic (mrem/yr):	50
10 CFR 20 Effluent Concentration Dose Basis - Stochastic (mrem/hr):	5.70E-03
10 CFR 20 Effluent Concentration Dose Basis – Submersion, noble gas (mrem/yr):	100
10 CFR 20 Effluent Concentration Dose Basis – Submersion, noble gas (mrem/hr):	1.14E-02
EAL RU3 Limt (mR/hr):	4
EAL RU3 Limt (mR/hr):	20
Limiting X/Q* (sec/cc):	3.48E-11
NTR Bldg 105 Stack Flow Rate* (cfm):	1800
Conversion Factor (cc/sec per cfm):	471.95
NTR Bldg 105 Stack Flow Rate (cc/sec):	8.50E+05

Evaluation of Vallecitos Nuclear Center NTR Effluent Abnormal Radiological Conditions Emergency Action Level Thresholds

* 10 CFR 20 effluent concentration limit for Kr-88, the most conservative value for fission noble gases.
** Based on NTR SAR Section 6.4 for normal operations

Completed By:	Duane M. DeMore CHP, VNC RSO	10/6/2022 Date
Reviewed By:	David Heckman Digitally signed by David Heckman Date: 2022.10.07 08:00:55 -07'00'	10/7/2022
	Dave Heckman	Date