

# Radioactive Ar-41 Effluents at Research Reactors: Regulatory Requirements and Technical Specifications

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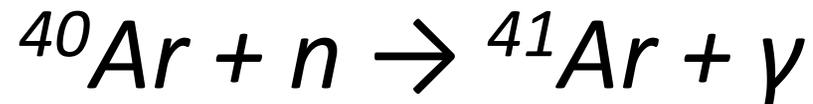
# Overview

- Background on Argon-41 (Ar-41)
- NRC regulations applicable to Ar-41 releases
- Guidance applicable to Ar-41 dose calculations
- Guidance applicable to Ar-41 Technical Specifications (TSs) for RTRs
- Ar-41 TSs at RTRs

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# Introducing Ar-41

Dry air is 0.93% Ar, Ar is 99.6% Ar-40



- Ar-41 generated in rabbit systems, beam ports, reactor pool water
- Half-life = 1.8 hours
- External exposure hazard

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## Regulating Ar-41: 10 CFR Part 20, “Standards for Protection against Radiation”

- 10 CFR 20.1301, “Dose limits for individual members of the public”

100 mrem annual public dose limit

- 10 CFR 20.1302, “Compliance with dose limits for individual members of the public”

Show compliance with 100 mrem limit by:

- 1) Measurement or calculation; or,
- 2) Annual average concentrations of radioactive material at restricted area boundary < 10 CFR 20, App. B., Table 2, and external doses < 50 mrem per year.

# 10 CFR 20, Appendix B

Table 1

Ar-41 Derived Air  
Concentration (DAC):

$3e-6 \mu\text{Ci/mL}$

Table 2

Ar-41 Air Effluent  
Concentration (EC):

$1e-8 \mu\text{Ci/mL}$

Atomic No.	Radionuclide	Class	Table 1 Occupational Values			Table 2 Effluent Concentrations		Table 3 Releases to Sewers
			Col. 1 Oral Ingestion ALI ( $\mu\text{Ci}$ )	Inhalation		Col. 1 Air ( $\mu\text{Ci/mL}$ )	Col. 2 Water ( $\mu\text{Ci/mL}$ )	Monthly Average Concentration ( $\mu\text{Ci/mL}$ )
				Col. 2 ALI ( $\mu\text{Ci}$ )	Col. 3 DAC ( $\mu\text{Ci/mL}$ )			
17	Chlorine-38 <sup>2</sup>	D, see <sup>36</sup> Cl	2E+4 St. wall (3E+4)	4E+4	2E-5	6E-8	-	-
		W, see <sup>36</sup> Cl	-	5E+4	2E-5	6E-8	3E-4	3E-3
17	Chlorine-39 <sup>2</sup>	D, see <sup>36</sup> Cl	2E+4 St. wall (4E+4)	5E+4	2E-5	7E-8	-	-
		W, see <sup>36</sup> Cl	-	6E+4	2E-5	8E-8	5E-4	5E-3
18	Argon-37	Submersion <sup>1</sup>	-	-	1E+0	6E-3	-	-
18	Argon-39	Submersion <sup>1</sup>	-	-	2E-4	8E-7	-	-
18	<b>Argon-41</b>	Submersion <sup>1</sup>	-	-	<b>3E-6</b>	<b>1E-8</b>	-	-
19	Potassium-40	D, all compounds	3E+2	4E+2	2E-7	6E-10	4E-6	4E-5
19	Potassium-42	D, all compounds	5E+3	5E+3	2E-6	7E-9	6E-5	6E-4
19	Potassium-43	D, all compounds	6E+3	9E+3	4E-6	1E-8	9E-5	9E-4
19	Potassium-44 <sup>2</sup>	D, all compounds	2E+4 St. wall (4E+4)	7E+4	3E-5	9E-8	-	-
			-	-	-	-	5E-4	5E-3
19	Potassium-45 <sup>2</sup>	D, all compounds	3E+4 St. wall (5E+4)	1E+5	5E-5	2E-7	-	-
			-	-	-	-	7E-4	7E-3

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# Regulating Ar-41: 10 CFR Part 20, “Standards for Protection against Radiation”

- **10 CFR 20.1101, “Radiation protection programs”**

20.1101(b): Licensees must have ALARA program

20.1101(d): Licensees must establish a constraint on air emissions such that no member of the public will be expected to receive > 10 mrem per year

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# Providing Guidance for Calculation of Doses from Ar-41 Effluents

- **NUREG-1537, Part 1, “Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors: Format and Content,” Chapter 11, “Radiation Protection Program and Waste Management”**
- **U.S. NRC Regulatory Guide 1.109, “Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I”**

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## Providing Guidance for Technical Specifications on Ar-41 Effluents

- **NUREG-1537, Part 1, Appendix 14.1, “Format and Content of Technical Specifications for Non-Power Reactors”**
  - In general, releases should be limited by TSs
  - TSs should address: 1) average/maximum concentration in restricted area, and 2) curies released per year
- **ANSI/ANS-15.1-2007, “The Development of Technical Specifications for Research Reactors”**
  - TSs should ensure public exposure from effluents < 100 mrem/yr, less any external dose
  - TSs should be established at point of release or measurement
  - Basis for TSs may consider diffusion factors

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# Developing TSs on Ar-41 Effluents

“The activity of argon-41 released from the facility **shall not exceed the limits of 10 CFR Part 20, Appendix B, Table 2.**”

“The concentration of argon-41 at ground level below the point of release into the unrestricted area **shall not exceed the unrestricted area effluent concentration limit** (10 CFR 20.1302 and Table 2 of Appendix B to 10 CFR Part 20) when averaged over 1 year or 10 times the effluent concentration limit when averaged over 1 day.”

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# Developing TSs on Ar-41 Effluents

“The annual average concentration of  $^{41}\text{Ar}$  released to the environment **shall not exceed  $1 \times 10^{-8}$  microcuries per milliliter** ( $\mu\text{Ci}/\text{mL}$ ).”

“The annual average concentration of  $^{41}\text{Ar}$  discharged into the unrestricted area **shall not exceed  $1 \times 10^{-8}$   $\mu\text{Ci}/\text{mL}$**  at the point of discharge averaged over one year.”

“The concentration of Ar-41 in the effluent gas from the facility, as diluted by atmospheric air in the lee of the facility as a result of the turbulent wake effect, **shall not exceed  $1 \times 10^{-8}$   $\mu\text{Ci}/\text{mL}$**  averaged over one year.”

“The annual average concentration of Ar-41 discharged into the unrestricted area **shall not exceed  $1 \times 10^{-8}$   $\mu\text{Ci}/\text{mL}$**  at the point of discharge.”

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# Developing TSs on Ar-41 Effluents

“The total exposure from effluents from the reactor facility to a person at the site boundary **shall not exceed 100 mrem per calendar year**, less any external dose from the facility. The limit shall be established at the point of release of measurement using accepted diffusion factors to the boundary. For halogens and particulates with half-lives longer than 8 days, a reconcentration factor shall be included where appropriate.”

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# Developing TSs on Ar-41 Effluents

“The annual average concentration of  $^{41}\text{Ar}$  discharged into the unrestricted area *shall not exceed  $1 \times 10^{-9} \mu\text{Ci/ml}$ .*”

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# Developing TSs on Ar-41 Effluents

“The total annual discharge of  $^{41}\text{Ar}$  into the environment *shall not exceed 30 Ci per year.*”

“Releases of Ar-41 from the reactor bay exhaust plenum to an unrestricted environment *SHALL NOT exceed 30 Ci per year.*”

“The concentration of  $^{41}\text{Ar}$  in the effluent gas discharged from the facility into the unrestricted area, after environmental dilution shall not exceed  $1 \times 10^{-8} \mu\text{Ci/mL}$  averaged over one year. [...] The total annual discharge of  $^{41}\text{Ar}$  into the environment *shall not exceed 20 Ci per year.*”

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Thank you for your attention, any  
questions?

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			Table 1 Occupational Values			Table 2 Effluent Concentration		Table 3 Releases to Sewers
			Col. 1	Col. 2	Col. 3	Col. 1	Col. 2	
			Oral					Monthly
			Ingestion	Inhalation		Air	Water	Average
Atomic No.	Radionuclide	Class	ALI ( $\mu$ Ci)	ALI ( $\mu$ Ci)	DAC ( $\mu$ Ci/ml)	( $\mu$ Ci/ml)	( $\mu$ Ci/ml)	Concentration ( $\mu$ Ci/ml)
1	Hydrogen-3	Water, DAC includes skin absorption	8E+4	8E+4	2E-5	1E-7	1E-3	1E-2
Gas (HT or T <sub>2</sub> ) Submersion <sup>1</sup> : Use above values as HT and T <sub>2</sub> oxidize in air and in the body to HTO								
4	Beryllium-7	W, all compounds except those given for Y	4E+4	2E+4	9E-6	3E-8	6E-4	6E-3
		Y, oxides, halides, and nitrates	-	2E+4	8E-6	3E-8	-	-