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Volume 1

Leak Testing Errata

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Errata

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Errata: Chapter 2 Tracer Gases in Leak Testing page 37 Table 1

Gas	Chemical Symbols	Molecular Weight	Molecular Diameter (pm)	Viscosity (Pa·s)	Gas Constant, (J·kg ⁻¹ ·K ⁻¹)
Air		29.00		1.80×10^{-7}	287
Ammonia	NH_3	17.03	297.0	9.7 × 10 ⁻⁶	488
Argon	Ar	39.94	288.0	$2.20 imes 10^{-7}$	208
Carbon dioxide	CO ₂	44.01	334.0	$1.45 imes 10^{-7}$	189
Dichlorodifluoromethane	CCI ₂ F ₂	120.93		$1.27 imes 10^{-7}$	68.8
Helium	He	4.00	190.0	$1.92 imes 10^{-7}$	2079
Hydrochloric acid	HCI	36.50		$1.40 imes 10^{-7}$	228
Hydrogen	H_2	2.02	240.0	8.6 × 10 ⁻⁶	4116
Krypton	Kr	83.80		$2.46 imes 10^{-7}$	9.92
Methane	CH_4	16.04		1.07×10^{-7}	518
Neon	Ne	20.18			412
Nitrogen	N_2	28.01	315.0	1.73×10^{-7}	297
Nitrous oxide	N_2O	44.00		1.43×10^{-7}	189
Oxygen	O ₂	31.99	298.0	1.99×10^{-7}	260
Sulfur dioxide	SO ₂	64.00		1.23×10^{-7}	130
Water vapor	H ₂ O	18.02	460.0	9.3 × 10 ⁻⁶	461

TABLE 1. Physical properties of typical gases and vapors at 15 °C (59 °F).

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Gas	Chemical Symbols	Molecular Weight	Molecular Diameter (pm)	Viscosity (µPa·s)	Gas Constant, (J·kg ⁻¹ ·K ⁻¹)
Air		29.00		18.0	287
Ammonia	NH_3	17.03	297.0	9.7	488
Argon	Ar	39.94	288.0	22.0	208
Carbon dioxide	CO ₂	44.01	334.0	14.5	189
Dichlorodifluoromethane	CCI ₂ F ₂	120.93		12.7	68.8
Helium	He	4.00	190.0	19.2	2079
Hydrochloric acid	HCI	36.50		14.0	228
Hydrogen	H_2	2.02	240.0	8.6	4116
Krypton	Kr	83.80		24.6	9.92
Methane	CH_4	16.04		10.7	518
Neon	Ne	20.18		31.0	412
Nitrogen	N_2	28.01	315.0	17.3	297
Nitrous oxide	N_2O	44.00		14.3	189
Oxygen	O ₂	31.99	298.0	19.9	260
Sulfur dioxide	SO ₂	64.00		12.3	130
Water vapor	H ₂ O	18.02	460.0	9.3	461

Errata: Chapter 2, "Tracer Gases in Leak Testing," page 42, Table 5

TABLE 5. Physical properties of common gases used in leak testing.

Gas	Formula	Molecular Mass (g·mol ⁻¹)	Density ^a at 100 kPa (g·L ⁻¹)	Numerical Factor ^b for Mean Free Path (m·Pa)	Viscosity ^c at 20 °C (68 °F) (mPa·s ⁻¹)	Diffusivity ^d in Air at 0 °C (32 °F) and 101 kPa (m ² ·s ⁻¹)	Thermal Conductivity ^e at 20 °C (68 °F) (W·m ⁻¹ ·K ⁻¹)
Air ^f	Mixture	29.0	1.21	68 × 10 ⁻³	18		2.57×10^{-2}
Argon	Ar	40	1.79	72 × 10 ⁻³	22	13.9 × 10 ⁻⁶	1.75×10^{-2}
Carbon dioxide	CO_2	44	1.97	45×10^{-3}	15	15.8 × 10 ⁻⁶	16.0
Refrigerant-12	CCI_2F_2	121	5.25		13		9.8
Helium	He	4.0	0.179	196 × 10 ⁻³	19		149.0
Hydrogen	H ₂	2.0	0.090	125×10^{-3}	9	63.4 × 10 ⁻⁶	183.0
Krypton	Kr	84	3.74	53.6 × 10 ⁻⁶	25		9.4
Neon	Ne	20	0.90	140×10^{-3}	31		48.0
Nitrogen	N ₂	28	1.25	67 × 10 ⁻³	18		25.6
Oxygen	O ₂	32	1.43	72×10^{-3}	20	$17.8 imes 10^{-6}$	26.2
Sulfur hexafluoride	SF_2	146	6.60	25×10^{-3}	15		
Water Vapor ^g	H ₂ O	18	0.83	42×10^{-3}	9	$23.9 imes 10^{-6}$	0.017
Xenon	Xe	131	5.89	38	22		55.0

a. Density in oz·ft⁻³ = g·L⁻¹ = mg·cm⁻³ at 20 °C (68 °F) and 100 kPa (1 atm).
b. Numerical factor for calculating mean free path using Eq. 16. Mean free path in meters at 20 °C (68 °F).
c. Independent of pressure under conditions for viscous flow.
d. Diffusivity in m²·s⁻¹ in air at 0 °C (32 °F) and 101 kPa (1 atm).
e. Thermal conductivity in W·m⁻¹·K⁻¹ at 20 °C (68 °F). Thermal conductivity is independent of pressure under conditions for viscous flow.
f. N₂, 78 percent; O₂, 21 percent; argon, 0.9 percent; others, 0.1 percent.
g. Vapor pressure of H₂O at 20 °C (68 °F) is 2.3 kPa (17.5 torr).

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TABLE 5. Physical properties of common gases used in leak testing.

Gas	Formula	Molecular Mass (g·mol ⁻¹)	Density ^a at 100 kPa (g·L ⁻¹)	Numerical Factor ^b for Mean Free Path (m·Pa)	Dynamic Viscosity ^c at 20 °C (68 °F) (µPa·s)	Diffusivity ^d in Air at 0 °C (32 °F) and 101 kPa (m ² ·s ⁻¹)	Thermal Conductivity ^e at 20 °C (68 °F) (W·m ^{-1.} K ⁻¹)
Air ^f	Mixture	29.0	1.21	6.8 × 10 ⁻³	18		26.2
Argon	Ar	40	1.79	7.2×10^{-3}	22	13.9 × 10 ⁻⁶	17.9
Carbon dioxide	CO_2	44	1.97	$4.5 imes 10^{-3}$	15	15.8 × 10 ⁻⁶	16.0
Refrigerant-12	CCI_2F_2	121	5.25		13		9.8
Helium	He	4.0	0.179	19.6 × 10 ⁻³	19		149.0
Hydrogen	H ₂	2.0	0.090	$12.5 imes 10^{-3}$	9	63.4 × 10 ⁻⁶	183.0
Krypton	Kr	84	3.74	$5.36 imes 10^{-6}$	25		9.4
Neon	Ne	20	0.90	$14.0 imes 10^{-3}$	31		48.0
Nitrogen	N_2	28	1.25	6.7 × 10 ⁻³	18		25.6
Oxygen	O ₂	32	1.43	$7.2 imes 10^{-3}$	20	17.8 × 10 ⁻⁶	26.2
Sulfur hexafluoride	SF_2	146	6.60	$2.5 imes10^{-3}$	15		13.0
Water Vapor ^g	H ₂ O	18	0.83	$4.2 imes 10^{-3}$	9	$23.9 imes10^{-6}$	18.7
Xenon	Xe	131	5.89	$3.8 imes 10^{-3}$	22		5.5

a. Density in oz ft⁻³ = g·L⁻¹ = mg·cm⁻³ at 20 °C (68 °F) and 100 kPa (1 atm).
b. Numerical factor for calculating mean free path using Eq. 16. Mean free path in meters at 20 °C (68 °F).
c. Independent of pressure under conditions for viscous flow.
d. Diffusivity in m²·s⁻¹ in air at 0 °C (32 °F) and 101 kPa (1 atm).
e. Thermal conductivity in W·m⁻¹·K⁻¹ at 20 °C (68 °F). Thermal conductivity is independent of pressure under conditions for viscous flow.
f. N₂, 78 percent; O₂, 21 percent; argon, 0.9 percent; others, 0.1 percent.
g. Vapor pressure of H₂O at 20 °C (68 °F) is 2.3 kPa (17.5 torr).

Errata: Chapter 2, "Tracer Gases in Leak Testing" page 60, Table 11

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TABLE 11. Mean free paths at 25 $^{\circ}$ C (77 $^{\circ}$ F), molecular diameters, and viscosities for gases and vapors used in leak testing.

Gas	Mean Free Path (mm∙Pa)	Molecular Diameter (pm)	Viscosity (µPa∙s)
Acetylene			9.2
Air		16.9	
Ammonia			9.4
Argon	7.23	358	20.8
Benzene	1.53	765	6.9
Carbon dioxide	4.49	465	13.5
Carbon disulfide			8.9
Carbon monoxide			17.1

TABLE 11. Mean free paths at 25 $^{\circ}$ C (77 $^{\circ}$ F), molecular diameters and viscosities for gases and vapors used in leak testing.

Gas	Mean Free Path (mm∙Pa)	Molecular Diameter (pm)	Viscosity (µPa∙s)
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Carbon dioxide	4.49	465	13.5
Carbon disulfide			8.9
Carbon monoxide			17.1

Errata: Chapter 14, "Leak Testing of Hermetic Seals," page 576, Eqs. 4 and 5

accordance with an inverse exponential relationship:

(4)
$$R_{1} = \frac{P_{E}}{P_{o}} \sqrt{\frac{M_{A}}{M}} \times \left(1 - e^{-\frac{Qt_{1}}{VP_{o}}\sqrt{\frac{M_{A}}{M}}}\right)$$

During the dwell time following bombing, the rate of leakage of helium tracer gas from leaking devices is assumed to follow a typical exponential decay transient:

(5)
$$R_{1} = \frac{QP_{E}}{P_{0}} \sqrt{\frac{M_{A}}{M}} \times \left(1 - e^{-\frac{Qt_{1}}{VP_{0}}\sqrt{\frac{M_{A}}{M}}}\right) \times e^{-\frac{Qt_{1}}{VP_{0}}\sqrt{\frac{M_{A}}{M}}}$$

where R_1 is measured leakage rate of tracer gas, helium, through the leak (Pa·m³·s⁻¹); Q is equivalent standard leakage rate in

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accordance with an inverse exponential relationship:

(4)
$$P = P_{\rm E}\left(1 - e^{\frac{-Qt_1}{VP_0}\sqrt{\frac{M_A}{M}}}\right)$$

During the dwell time following bombing, the rate of leakage of helium tracer gas from leaking devices is assumed to follow a typical exponential decay transient:

(5)
$$R_{1} = \frac{QP_{E}}{P_{0}} \sqrt{\frac{M_{A}}{M}} \\ \times \left(1 - e^{\frac{-Qt_{1}}{VP_{0}}} \sqrt{\frac{M_{A}}{M}}\right) \\ \times e^{\frac{-Qt_{2}}{VP_{0}}} \sqrt{\frac{M_{A}}{M}}$$

where R_1 is measured leakage rate of tracer gas, helium, through the leak (Pa·m³·s⁻¹); Q is equivalent standard leakage rate in

Errata:

Chapter 14, "Leak Testing of Hermetic Seals," page 577, Equations 6 and 7

Devices with an internal volume greater than 0.4 cm³ (0.024 in.³) may be rejected if the leakage rate *Q* exceeds 1×10^{-7} Pa·m³·s⁻¹ (1×10^{-6} std cm³·s⁻¹).

Simplified Equation for Calculation of Leakage Rates after Helium Bombing

Equation 5 can be simplified to the form of Eq. 6:

(6)
$$R_{1} = \frac{QP_{E}}{P_{o}} \sqrt{\frac{M_{A}}{M}} \times \left(1 - e^{-t_{1}}\right) e^{\left(-\frac{Q}{V}t_{2}\right)}$$

The symbols used in Eq. 6 are the same as those identified previously under Eq. 5.

In a similar way, the actual leakage rate for a device that has been filled with helium to the pressure *P* during manufacture can be found from the simplified Eq. 7:

(7)
$$R_1 = Q e^{\left(-\frac{L}{V}t_2\right)}$$

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Devices with an internal volume greater than 0.4 cm³ (0.024 in.³) may be rejected if the leakage rate *Q* exceeds 1×10^{-7} Pa·m³·s⁻¹ (1×10^{-6} std cm³·s⁻¹).

Simplified Equation for Calculation of Leakage Rates after Helium Bombing

The quantity $\sqrt{(M_{\rm A} \cdot M^{-1})} = \sqrt{(28.7/4)} = 2.7$, so Eq. 5 can be simplified as Eq. 6:

(6)
$$R = 2.7 \frac{QP_E}{P_0} \left(1 - e^{-2.7 \frac{Qt_1}{V}} \right) \times e^{-2.7 \frac{Qt_2}{V}}$$

In a similar way, the actual leakage rate for a device that has been filled with helium to the pressure *P* during manufacture can be found from the simplified Eq. 7:

(7)
$$R_1 = 2.7 \frac{QP_E}{P_0} e^{-2.7 \frac{Qt_2}{V}}$$

This errata document was compiled by the Leak Testing Committee of ASNT's Technical and Education Council; Charles N. Jackson, Handbook Coordinator.

