C O N T E N T S

PREFACE	xiii
Chapter 1. The Vacuum and Surrounding Space	
1.1 The vacuum	1
11.1 Pressure and mean free path	1
11.2 Low, high and ultra-high vacuum	2
11.3 Vacuum systems	3
1.2 Interaction between the surrounding space and the vacuum	5
12.1 Gas flow, throughput and impedance	5
12.2 Gas permeation	6
1.3 Real and virtual leaks	7
13.1 Real leaks and tightness	8
13.2 Virtual leaks and degassing	9
13.3 Leak detection	9
13.31 Pressure rise method	9
13.32 Test gas methods	11
1.4 The seals and their classifications	11
14.1 Vacuum tightness, the essential requirement	12
14.2 Functional requirements	13
14.21 Electric current transmission	13
14.22 Motion transmission	13
14.23 Material transfer	13
14.24 Radiant energy transmission	18
14.3 Special requirements	18 18
14.31 Bakeability for ultra-high vacuum 14.32 Low temperature (cryogenic) seals	10
14.33 Corrosion resistance	21
14.34 Cost requirements	21
Chapter 2. Permanent Seals	
	22
2.1 Prefabricated vessels and pipes 21.1 Selection criteria for vessels and pipes	23 23
21.11 Mechanical strength	23
21.12 Permeability to gases	23
21.12 Degassing	34
21.2 Metal vessels and pipes	43
21.3 Glass (quartz) vessels and pipes	46
21.4 Elastomer and plastic pipes	52
2.2 Metal to metal welding and brazing	57
22.1 Welding	57
22.11 Welding methods	58
22.12 Weldability of metals and alloys	67

CONTENTS

71
73
83
83
88
93
101
101
101
107
112
116
116
119
121
126
128
130
131
131
131
134
134
135
138
142
143
151
151
processes 152
154
154
154
156
156
157
157
162
162
162
162
162
166
167
169
169
170
181
185

vi

	CONTENTS	vii
	24.5 Faults in glass-glass, and glass-metal seals and their detection	189
25	Cerumic to glass and ceramic to metal seals	197
2.0	25.1 Sealing principles and materials	197
	25.11 Sealing principles	197
	25.12 Materials used in ceramic-metal seals	200
	25.2 Sealing techniques	201
	25.21 Ceramic-glass and ceramic-glass-metal seals	201
	a) Glass-ceramic seals	201
	b) Ceramic-glaze-metal seals	203
	c) Ceramic-glass-metal seals	205
	25.22 Ceramic-metal sintered seals	208
	25.23 Active metal processes	211
	a) Hydride process	212
	b) Active metal powders	213
	c) Carbide seals	214
	d) Active metal core seals	214
	e) Massive active metal seals	215 215
	f) Active metal alloy seals 25.24 Compression (diffusion) seals	213 216
	25.25 Various ceramic-metal seals	210
	25.3 Possibility of brazing ceramic-metal seals	210
	25.4 Ceramic-metal seal shapes	222
	25.41 Butt seals	222
	25.42 Cylindrical seals	222
	25.5 Testing of glass-ceramic and ceramic-metal seals	224
2.6	Sealing and sealing-off	225
	26.1 Sealing vacuum devices	225
	26.11 Drop sealing	225
	26.12 Butt sealing	226
	26.13 Diffusion seal	227
	26.2 Sealing-off glass exhaust tubes	228
	26.21 Sealing-off small diameter tubes	228
	26.22 Sealing-off large diameter tubes	230
	26.23 Sealing-off quartz exhaust tubes	230
	26.3 Sealing-off metal exhaust tubes	231
	26.31 Cold sealing-off	231
	26.32 Sealing-off with valves	233
	26.33 Brazed seal-off	234
Снар	ter 3. Semi-permanent and Demountable Seals	
3.1	Waxed seals	236
	31.1 Sealing waxes	236
	31.2 Vacuum sealing technique with waxes	236
3.2	Sealing with paints and plastics	244
	32.1 Irreversible adhesives	244
	32.2 Sealing of plastics and the use of plastics for sealing	247
3.3	Sealing with epoxy resins	248
	33.1 Epoxy adhesives	248
	33.2 Preparing the adhesives and completing the joints	253
	33.21 Mixing	253

CO	VI'T'	ENI	TC
UU.	×1.	CIN	10

	33.22 Applying	253
	33.23 Curing	255
	33.24 Dismantling	255
	33.25 Strength	255
	33.3 Vacuum sealing with epoxy resins	256
	33.31 Butt joints	256
	33.32 Lap joints	257
3.4	Silver chloride seals	258
3.5	Soft soldering	260
	35.1 Vacuum sealing with soft soldering techniques	260
		260
		261
		266
	35.2 Vacuum sealing with solder glasses	269
3.6	Ground and lapped seals	274
	36.1 Flat seals	275
	36.2 Conical and cylindrical ground seals	277
	36.3 Spherical ground seals	285
	36.4 Assembling and maintenance of ground seals	287
3.7	Liquid seals	293
	37.1 Hydrostatic seals	294
	37.2 Mercury sealed ground and gasket joints	295
	37.21 Cup seals	297
	37.22 Immersion seals	298
	37.23 Guard seals	299
	37.3 Mercury and gallium sealed glass frif	299
	37.4 Oil seals	300
	37.5 Surface tension seals	303
	37.6 Molten metal seals	305
3.8	Gasket seals	306
	38.1 Sealing mechanism of gaskets	306
	38.2 Leaking mechanism in gasket seals	311
	38.21 Leak through the seal	312
	38.22 Leak through the gasket	313
	38.23 Guard vacuum in the seals	314
		319
		319
		323
		328
	•	345
		345
	38.41 O-ring groove seals	347
	a) Grooves with rectangular cross section	348
	b) Grooves with triangular cross section	355
		356
		359
	e) Grooves for rectangular flanges	360
	38.42 Spacer seals	361
	38.43 Conical seals	369
	3.5 3.6 3.7	 33.23 Curing 33.24 Dismantling 33.25 Strength 33.3 Vacuum sealing with epoxy resins 33.31 Butt joints 33.32 Lap joints 3.4 Silver chloride seals 3.5 Soft soldering 35.1 Vacuum sealing with soft soldering techniques 35.11 Soft soldering of metal parts 35.13 Soft soldering of glass and ceramic parts 35.14 Soft soldering of glass and ceramic parts 35.15 Concil and cylindrical ground seals 36.1 Flat seals 36.2 Conical and cylindrical ground seals 36.3 Spherical ground seals 36.4 Assembling and maintenance of ground seals 37.1 Hydrostatic seals 37.2 Immersion seals 37.23 Guard seals 37.3 Guard seals 37.4 Oil seals 37.5 Surface tension seals 37.6 Molten metal seals 38.1 Sealing mechanism of gaskets 38.2 Leak through the gasket 38.2 Leak through the gasket 38.3 Guard vacuum in the seals 38.3 Guard vacuum in the seals 38.3 Guard vacuum in the seals 38.4 Oring gaskets 38.3 Metals for gaskets 38.4 Oring seals 38.4 Space seals 38.42 Space seals 38.42 Space seals

viii

	CONTENTS	ix
	38.44 Corner seals	380
	38.45 Step seals	382
	38.46 Cemented seals	384
	38.47 Standard flanges and unions for O-ring seals	388
-	38.48 Assembling and maintenance of O-ring seals	396
3	8.5 Thick gasket seals	403
	38.51 Plane sealsa) Plane flange seals	403 403
	b) Groove seals	403
	c) Seals with gaskets of special shapes	410
	38.52 Conical seals	413
	38.53 Cylindrical seals	416
	a) Rubber tubing joints	416
	b) Compression gasket seals	418
	c) Lip seals	420
	38.54 Dumbbell seals	421
	38.55 Shear seals	423
	38.56 Ridge seals	425
	a) Tongue seals	426
	b) Knife edge seals38.57 Inflatable gasket seals	427 437
	38.57 Initiatable gasket seals 38.58 Assembly and maintenance of gasket seals	437
3	8.6 Thin gasket seals	440
5	38.61 Plane seals with thin gaskets	440
	38.62 Groove and knife-edge seals	440
	38.63 Surface friction seals	443
Снарте	r 4. Transmission of the Electric Current through Seals	
4.1 S	election criteria for electrical lead-throughs	445
4	1.1 Insulation	445
	41.11 Bulk resistivity	445
	41.12 Surface resistivity	447
	41.13 Dielectric properties	449
1	41.14 Electrolytic effects	451
	1.2 Loading current1.3 Frequency	451 452
	1.4 Temperature	452
	Permanent lead-throughs	452
	2.1 Rod seals	452 453
	2.2 Stem seals	453
	2.3 Pin seals	462
	2.4 Ribbon seals	465
4	2.5 Disc and cup seals	467
	Demountable lead-throughs	471
	3.1 Waxed and resin sealed lead-throughs	471
	3.2 Gasket-sealed lead-throughs	473
4	3.3 Commercially available lead-throughs	481
	r 5. The Transmission of Motion through Seals	
	Aechanical transmission	491
5	1.1 Classification	491

CONTENTS

51.2 Transmission of motion by tilting the vacuum device	494
51.3 Transmission of motion through elastic pipes	494
51.4 Transmission of motion using bellows	498
51.5 Transmission of motion using diaphragms	505
51.6 Transmission of motion using ground seals	508
51.7 Transmission of motion using gasket seals	510
51.71 O-ring seals for transmitting motion	511
51.72 Rim seals for transmitting motion	514
51.73 Cylindrical and conical seals for transmitting motion	515
51.74 Lip seals for transmitting motion	517
51.75 Spring-loaded lip seals for transmitting motion	520
51.76 Friction seals for transmitting motion	522
51.77 Commercially available shaft seals	525
51.78 Seals for angular displacement	529
51.8 Motion seals using a guard vacuum	537
5.2 Magnetic transmission	539
52.1 Translation using magnetic fields	539
52.2 Rotary motion transmitted by magnetic fields	541
5.3 Actuation by heat transfer or electric current	543
53.1 Motion based on thermal expansion	543
53.2 Irreversible motion by burning-out	544
53.3 Actuation with electric current	545
Chapter 6. Seals Used in the Transfer of Materials	
6.1 Seals for the transfer of gases	546
61.1 Cut-offs	546
61.11 Principles	546
61.12 Actuating devices in cut-offs	547
a) Raising devices	547
b) Locking devices	549
61.13 Closing systems in cut-offs	552
a) Cut-offs with simple liquid seals	552
b) Cut-offs with floats	552
c) Cut-offs with sintered glass	556
d) Cut-offs with molten metals	557
61.2 Stopcocks	558
61.21 Shapes and dimensions	558
61.22 Greased stopcocks	562
61.23 Greaseless stopcocks	565
61.3 Valves	566
61.31 Principles and classification	566
61.32 Closing systems of valves	500 571
a) Closing systems using liquid seals	571
b) Closing systems using molten metals	572
c) Closing systems using invited metals	575
d) Closing systems based on fusing glass joints	576
e) Closing systems based on ground joints	576
f) Closing systems using clamped elastomer tubes	580
g) Closing systems using diaphragms	581
6/ Crossing allowing anapirraging	201

x

CONTENTS	xi
h) Closing systems using gasket seals (plate, flap, plug, nose,	
gate, plunger, butterfly and ball valves)	583
61.33 Sealing systems of valves	616
a) Packed valves	616
b) Packless valves	617
61.34 Operating systems of valves <i>a)</i> Mechanical movement (manually operated valves)	619 619
b) Pneumatically operated valves	619
c) Electromagnetically operated valves	624
d) Valves operated by thermal expansion	631
61.35 Valves for specific purposes	632
a) Seal-off valves	633
b) Throttling valves	633
c) Air-admittance valves	633
d) Baffle valves	635
e) Non-return valves	637
f) Bakeable (and ultra-high vacuum) valves (ground joint, fused glass, molten metal and all-metal valves)	638
g) Multi-way valve blocks	653
61.36 Maintenance of valves	659
61.4 Gas-leaks and metering devices 61.41 Principles and classification	659 659
61.42 Pinholes, orifices and cracks used as leaks	664
61.43 Capillaries and flattened tubes used as leaks	668
61.44 Porous plugs used as leaks	671
61.45 Annular impedances used as leaks	673
61.46 Needle valves	676
61.47 Temperature-actuated leaks	679
61.48 Diffusion leaks	682
61.49 Pulsed leaks	685
61.5 Techniques for opening sealed gas container	687 688
61.51 Opening by striking 61.52 Opening by bending	690
	690 691
	692
6.2 Transfer of liquids through seals	693
62.1 Continuous transfer	693
62.2 Metered transfer	693
6.3 Transfer of solids through seals	697
63.1 Vacuum locks	697
63.11 Vacuum locks using sliding rods	698
63.12 Vacuum locks using rotating plugs	698
63.13 Vacuum locks using chambers with double ports	700
63.2 Electrolytic transfer through glass walls	702
Chapter 7. Seals Used in Transmitting Radiation	
7.1 Windows	704
71.1 Selection according to the radiation	704
71.11 Windows for light	704
71.12 Windows for ultraviolet	705

CONTENTS

71.13 Windows for infrared	705
71.14 Windows for alpha particles	705
71.15 Windows for beta particles	700 707
71.16 Windows for gamma and X rays	708
71.17 Windows for neutrons	709
71.2 Chambers made of transmitting materials	709
71.3 Attached windows	709
71.31 Glass and quartz windows	710
a) Thick windows	710
b) Thin windows	711
71.32 Ceramic windows	714
71.33 Salt windows	715
71.34 Mica windows	715
71.35 Self-supporting windows	716
a) Plastic films	716
b) Metal (carbon) foils	719
c) Oxide films	721
7.2 Window sealing techniques	725
72.1 Welded and fusion seals	725
72.2 Brazed and soldered windows	726
72.3 Waxed windows	728
72.4 Solder glass sealed windows	729
72.5 Epoxy resin sealed windows	732
72.6 Silver chloride sealed windows	734
72.7 Windows joined with compression seals	737
72.8 Windows sealed with elastomer gaskets	738
72.9 Windows sealed with metal gaskets	741
Appendix A. Formulae and Conversion Factors	
A.1. Pressure units	746
A.2. Conductance and pumping speed units	747
A.3. Throughput and leak rate units	748
A.4. Permeability units	749
A.5. Conductance formulae	750
Appendix B. Physical Constants of Sealing Materials	5
B.1. Mechanical properties	Between pages 750-751
B.2. Thermal properties	752
B.3. Thermal points of glasses	754
B.4. Vapour pressure and degassing properties	756
B.5. Vapour pressure of water (ice) and mercury	758
B.6. Electrical properties	759
References	761
Additional References	813
Index	817

xii