

CONTENTS

PREFACE

CHAPTER 1. THE VACUUM AND SURROUNDING SPACE

1.1 <i>The vacuum</i>	
11.1 Pressure and mean free path	
11.2 Low, high and ultra-high vacuum	
11.3 Vacuum systems	3
1.2 <i>Interaction between the surrounding space and the vacuum</i>	
12.1 Gas flow, throughput and impedance	
12.2 Gas permeation	6
1.3 <i>Real and virtual leaks</i>	
13.1 Real leaks and tightness	8
13.2 Virtual leaks and degassing	9
13.3 Leak detection	
13.31 Pressure rise method	
13.32 Test gas methods	
1.4 <i>The seals and their classifications</i>	
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
14.31 Bakeability for ultra-high vacuum	18
14.32 Low temperature (cryogenic) seals	19
14.33 Corrosion resistance	21
14.34 Cost requirements	22

CHAPTER 2. PERMANENT SEALS

2.1 <i>Prefabricated vessels and pipes</i>	23
21.1 Selection criteria for vessels and pipes	23
21.11 Mechanical strength	23
21.12 Permeability to gases	27
21.13 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 <i>Metal to metal welding and brazing</i>	57
22.1 Welding	57
22.11 Welding methods	58
22.12 Weldability of metals and alloys	67

24.5	Faults in glass-glass, and glass-metal seals and their detection	189
2.5	<i>Ceramic to glass and ceramic to metal seals</i>	197
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
f)	Active metal alloy seals	215
25.24	Compression (diffusion) seals	216
25.25	Various ceramic-metal seals	218
25.3	Possibility of brazing ceramic-metal seals	220
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	<i>Sealing and sealing-off</i>	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
CHAPTER 3. SEMI-PERMANENT AND DEMOUNTABLE SEALS		
3.1	<i>Waxed seals</i>	236
31.1	Sealing waxes	236
31.2	Vacuum sealing technique with waxes	236
3.2	<i>Sealing with paints and plastics</i>	244
32.1	Irreversible adhesives	244
*	32.2 Sealing of plastics and the use of plastics for sealing	247
3.3	<i>Sealing with epoxy resins</i>	248
33.1	Epoxy adhesives	248
33.2	Preparing the adhesives and completing the joints	253
33.21	Mixing	253

- 33.22 Applying
- 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 alloys
 - 35.12 Soft soldering of metal parts
 - 35.13 Soft soldering of glass and ceramic parts
 - 35.2 Vacuum sealing with solder glasses
- 3.6 *Ground and lapped 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
- 3.7 *Liquid seals*
 - 37.1 Hydrostatic seals
 - 37.2 Mercury sealed ground and gasket joints
 - 37.21 Cup seals
 - 37.22 Immersion seals
 - 37.23 Guard seals
 - 37.3 Mercury and gallium sealed glass frit
 - 37.4 Oil seals
 - 37.5 Surface tension seals
 - 37.6 Molten metal seals
- 3.8 *Gasket seals*
 - 38.1 Sealing mechanism of gaskets
 - 38.2 Leaking mechanism in gasket seals
 - 38.21 Leak through the seal
 - 38.22 Leak through the gasket.
 - 38.23 Guard vacuum in the seals
 - 38.3 Gaskets; materials and shapes
 - 38.31 Rubbers for gaskets
 - 38.32 Fluorocarbons for gaskets
 - 38.33 Metals for gaskets
 - 38.34 Gasket shapes
 - 38.4 O-ring seals
 - 38.41 O-ring groove seals
 - a) Grooves with rectangular cross section
 - b) Grooves with triangular cross section
 - c) Grooves with trapezium cross section
 - d) Grooves with semi-circular and elliptical cross section
 - e) Grooves for rectangular flanges
 - 38.42 Spacer seals
 - 38.43 Conical seals

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
38.5	Thick gasket seals	403
38.51	Plane seals	403
	a) Plane flange seals	403
	b) Groove seals	407
	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 seals	427
38.57	Inflatable gasket seals	437
38.58	Assembly and maintenance of gasket seals	438
38.6	Thin gasket seals	440
	38.61 Plane seals with thin gaskets	440
	38.62 Groove and knife-edge seals	440
	38.63 Surface friction seals	443
CHAPTER 4. TRANSMISSION OF THE ELECTRIC CURRENT THROUGH SEALS		
4.1	<i>Selection criteria for electrical lead-throughs</i>	445
41.1	Insulation	445
	41.11 Bulk resistivity	445
	41.12 Surface resistivity	447
	41.13 Dielectric properties	449
	41.14 Electrolytic effects	451
41.2	Loading current	451
41.3	Frequency	452
41.4	Temperature	452
4.2	<i>Permanent lead-throughs</i>	452
	42.1 Rod seals	453
	42.2 Stem seals	458
	42.3 Pin seals	462
	42.4 Ribbon seals	465
	42.5 Disc and cup seals	467
4.3	<i>Demountable lead-throughs</i>	471
	43.1 Waxed and resin sealed lead-throughs	471
	43.2 Gasket-sealed lead-throughs	473
	43.3 Commercially available lead-throughs	481
CHAPTER 5. THE TRANSMISSION OF MOTION THROUGH SEALS		
5.1	<i>Mechanical transmission</i>	491
51.1	Classification	



- 51.2 Transmission of motion by tilting the vacuum device
 - 51.3 Transmission of motion through elastic pipes
 - 51.4 Transmission of motion using bellows
 - 51.5 Transmission of motion using diaphragms
 - 51.6 Transmission of motion using ground seals
 - 51.7 Transmission of motion using gasket seals
 - 51.71 O-ring seals for transmitting motion
 - 51.72 Rim seals for transmitting motion
 - 51.73 Cylindrical and conical seals for transmitting motion
 - 51.74 Lip seals for transmitting motion
 - 51.75 Spring-loaded lip seals for transmitting motion
 - 51.76 Friction seals for transmitting motion
 - 51.77 Commercially available shaft seals
 - 51.78 Seals for angular displacement
 - 51.8 Motion seals using a guard vacuum
 - 5.2 *Magnetic transmission*
 - 52.1 Translation using magnetic fields
 - 52.2 Rotary motion transmitted by magnetic fields
 - 5.3 *Actuation by heat transfer or electric current*
 - 53.1 Motion based on thermal expansion
 - 53.2 Irreversible motion by burning-out
 - 53.3 Actuation with electric current
- CHAPTER 6. SEALS USED IN THE TRANSFER OF MATERIALS**
- 6.1 *Seals for the transfer of gases*
 - 61.1 Cut-offs
 - 61.11 Principles
 - 61.12 Actuating devices in cut-offs
 - a) Raising devices
 - b) Locking devices
 - 61.13 Closing systems in cut-offs
 - a) Cut-offs with simple liquid seals
 - b) Cut-offs with floats
 - c) Cut-offs with sintered glass
 - d) Cut-offs with molten metals
 - 61.2 Stopcocks
 - 61.21 Shapes and dimensions
 - 61.22 Greased stopcocks
 - 61.23 Greaseless stopcocks
 - 61.3 Valves
 - 61.31 Principles and classification
 - 61.32 Closing systems of valves
 - a) Closing systems using liquid seals
 - b) Closing systems using molten metals
 - c) Closing systems using silver chloride
 - d) Closing systems based on fusing glass joints
 - e) Closing systems based on ground joints
 - f) Closing systems using clamped elastomer tubes
 - g) Closing systems using diaphragms

<i>h)</i> Closing systems using gasket seals (plate, flap, plug, nose, gate, plunger, butterfly and ball valves)	583
61.33 Sealing systems of valves	616
<i>a)</i> Packed valves	616
<i>b)</i> Packless valves	617
61.34 Operating systems of valves	619
<i>a)</i> Mechanical movement (manually operated valves)	619
<i>b)</i> Pneumatically operated valves	619
<i>c)</i> Electromagnetically operated valves	624
<i>d)</i> Valves operated by thermal expansion	631
61.35 Valves for specific purposes	632
<i>a)</i> Seal-off valves	633
<i>b)</i> Throttling valves	633
<i>c)</i> Air-admittance valves	633
<i>d)</i> Baffle valves	635
<i>e)</i> Non-return valves	637
<i>f)</i> Bakeable (and ultra-high vacuum) valves (ground joint, fused glass, molten metal and all-metal valves)	638
<i>g)</i> Multi-way valve blocks	653
61.36 Maintenance of valves	659
61.4 Gas-leaks and metering devices	659
61.41 Principles and classification	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
61.51 Opening by striking	688
61.52 Opening by bending	690
61.53 Opening by punching	691
61.54 Opening by squeezing	692
6.2 <i>Transfer of liquids through seals</i>	693
62.1 Continuous transfer	693
62.2 Metered transfer	693
6.3 <i>Transfer of solids through seals</i>	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 <i>Windows</i>	704
71.1 Selection according to the radiation	704
71.11 Windows for light	704
71.12 Windows for ultraviolet	705