

Contents

Foreword	V
Authors	VII
1. Combustion	1
1.1 Stoichiometry	1
1.1.1 Reaction elements of technical fuels	1
1.1.2 Characteristic values for the composition of gaseous fuels	2
1.1.2.1 Characteristic amount of atoms for gaseous fuels	2
1.1.3 Combustion calculation	4
1.1.3.1 Calculation of the air requirements	5
1.1.3.2 Calculation of the exhaust gas amount and exhaust gas composition	7
1.2 Energy flux in the furnace	10
1.2.1 Characteristic furnace interfaces	10
1.2.2 Characteristic energies and heat flux	11
1.2.3 Energy balance	13
1.2.4 Efficiency factors	13
1.2.4.1 Combustion efficiency	14
1.2.4.2 Furnace efficiency	16
1.2.4.3 Heating efficiency	16
1.2.5 Saving of fuel with preheating of the air	16
2. Fluid Dynamics	19
2.1 The ideal gas	19
2.2 Equation of continuity	21
2.3 Equation of Bernoulli	22
2.4 Turbulent free jet	25
2.5 Pressure losses in pipings	26
3. Heat Transfer	28
3.1 Mechanisms of heat transfer	28
3.2 Heat radiation	30
3.2.1 Electromagnetic spectrum	30
3.2.2 Stefan-Boltzmann's law	31
3.2.3 Planck's distribution law	31
3.2.4 Reflection, absorption, transmission	32
3.2.5 Kirchhoff's law	33

3.2.6	Radiation from a diffuse surface and direction-dependent radiation	34
3.2.7	Radiation transfer	34
3.2.7.1	Radiation flux	34
3.2.7.2	Radiation transfer between two bodies	34
3.2.8	Gaseous radiation	39
3.3	Heat conduction	39
3.3.1	Differential equations of the temperature field	39
3.3.2	Steady state, one-dimensional heat conduction	40
3.3.2.1	Plane walls with given surface temperatures	40
3.3.2.2	Plane walls with convective heat transfer	41
3.3.3	Unsteady state heat conduction without heat sources	41
3.3.3.1	Bodies with high values of thermal conductivity	41
3.4	Convection	43
3.4.1	Application of the dimensional analysis for heat transfer	44
3.4.2	Cylinders in a flow parallel and perpendicular to their longitudinal axis	45
4.	Burner Technology	49
4.1	Combustion techniques	49
4.1.1	Wood fire	50
4.1.2	Open grate fire	50
4.1.3	Simple furnace	50
4.1.4	Firing with burners	51
4.1.5	Flame formation	51
4.1.6	Flame velocity	53
4.1.7	Subdivision of flames	54
4.2	Classification of burners and flames	55
4.2.1	Air supply	55
4.2.2	Fuel and fuel preparation	55
4.2.3	Way of stabilization	55
4.2.4	Flame colour	56
4.2.5	Air or fuel staging	56
4.2.6	Flame shapes	57
4.2.7	Flow velocity	57
4.2.8	Direct and indirect heating	58
4.2.9	Air preheating	58
4.2.10	Stoichiometry	59
4.2.11	Turndown	60
4.3	Flameless oxidation	60
4.3.1	Principle	61
4.3.2	Computations and experimental results	64
4.3.3	Field measurements	66

Contents	XI
4.3.4 Applications	69
4.3.5 Essential features	70
5. Computer Simulation	71
5.1 Assembly of input data	71
5.1.1 Computational mesh	71
5.1.2 Stationary and non-stationary calculations	73
5.1.3 Material properties	73
5.1.4 Boundary conditions	74
5.1.5 Computing models	75
5.2 Solution of equations	77
5.3 Presentation of the results	78
6. Reduction of Pollutants	81
6.1 NO _x reduction by flame cooling	83
6.2 Lean premixed combustion	84
6.3 Flame staging	84
6.4 Recirculation of combustion products	85
6.5 Oxygen combustion	86
6.6 Limits of air-preheating	86
6.7 Reduction of fuel NO _x	86
6.8 NO _x – removal	87
6.9 NO _x Units	87
6.10 NO _x measurements	87
7. Heat Exchangers	90
7.1 Basic design	91
7.2 Characteristics	94
7.3 Determination of the efficiency	97
7.3.1 Determination of the idle value	97
7.3.2 Measurement of the air preheating temperature	101
7.3.3 Measurement of the flue gas temperature	101
8. Industrial Burners	103
8.1 Cold air burners	103
8.1.1 Premix burners	103
8.1.2 Nozzle mix burners	103
8.1.3 Fan burners	108

8.1.4	Surface burners	108
8.1.5	Porous burners	109
8.1.6	Flat flame burners	110
8.1.7	Burners for low calorific and special fuel gases	111
8.1.8	Multi-fuel burners	111
8.1.9	Burners for oxygen-enriched air	113
8.2	Hot air burners	114
8.2.1	Proportionally controlled hot air burners with central recuperator	117
8.2.2	Pulse-fired hot air burners with central recuperator	118
8.2.3	Hot air burners with central regenerator	124
8.2.4	Steady controlled hot air burner with zone recuperator or regenerator	124
8.3	Recuperative burners	126
8.3.1	Recuperative burners with eductor	129
8.3.2	Recuperative burner with flue gas valve	132
8.4	Regenerative burners	132
8.4.1	Regenerative burners pair	133
8.4.2	Regenerative burner	136
8.5	Radiant tubes	137



ECOTHAL®

The Efficient Gas Solution

ECOTHAL SER-burner (Single-Ended Recuperative) is designed for high efficiency, reliability and low emissions. This gives you the possibility to increase your productivity due to higher power and efficiency based on a favourable air/gas and exhaust flow.

So start saving money by taking advantage of the higher efficiency, power and productivity as well as the reduced maintenance and operation costs.

Kanthal – a Sandvik brand
 Aschaffenburg Str. 7 a.
 64546 Moerfelden-Walldorf
 Tel +49 6105 40010 • www.kanthal.com

KANTHAL

8.5.1	Types of radiant tubes	137
8.5.2	Heat recovery with radiant tubes	140
8.5.3	Temperature uniformity	143
8.5.4	Control of radiant tubes	144
8.5.5	Arrangement of radiant tubes	145
9.	Standardization for Industrial Burners	148
9.1	Introduction and principle	148
9.2	Standards organizations and designations of standards	148
9.3	Standards and their domain	149
9.4	Fundamentals about European standardization work	150
9.4.1	New approach	150
9.4.2	Connection between directives and standardization	151
9.4.3	Application of European harmonized standards	152
9.5	Machinery Directive (MD)	152
9.5.1	EU declaration of conformity for machinery	153
9.5.2	Declaration by the manufacturer	154
9.5.3	CE-Marking	154
9.5.4	New Machinery Directive dated 26 Feb 2009	155
9.6	Additional EU - Directives	157
9.6.1	Pressure Equipment Directive (PED)	157
9.6.2	Gas Appliance Directive (GAD)	157
9.7	Operation of plants and accident prevention regulations	158
9.8	Standardizations structure for the machine directive	158
9.9	Important standards for Type A and Type B standards for industrial burners	160
9.9.1	Important Type A standards for thermoprocessing equipments and industrial burners	160
9.9.1.1	EN ISO 14121-1	160
9.9.1.2	EN 60204 - 1	160
9.9.1.3	EN ISO 12100 - 1	160
9.9.1.4	EN ISO 12100 - 2	161
9.9.2	Important Type A standards for thermoprocessing equipment and industrial burners	161
9.9.2.1	EN ISO 13850	161
9.9.2.2	EN ISO 13732 - 1	162
9.9.2.3	EN 953	162
9.9.2.4	EN 61496 - 1	163
9.10	Important Type C standards for industrial burner	163
9.10.1	EN 746 - 1	163
9.10.2	EN 746 - 2	164
9.11	Standards for components of industrial burners	165

9.11.1	EN 161	165
9.11.2	EN 225 - 1	165
9.11.3	EN 225 - 2	165
9.11.4	EN 230	165
9.11.5	EN 264	166
9.11.6	EN 298	166
9.11.7	EN 1643	167
9.11.8	EN 1854	167
9.11.9	EN 12067 - 1	167
9.11.10	EN 12067 - 2	168
9.12	Standard for package burner	168
9.12.1	EN 267	168
9.12.2	EN 676	168
9.13	Standards for thermoprocessing equipment	169
9.13.1	EN 746 - 3	169
9.13.2	EN 746 - 4	170
9.13.3	EN 746 - 5	170
9.13.4	prEN 746 - 6	171
9.13.5	prEN 746 - 7	172
9.13.6	EN 746 - 8	173
9.13.7	EN 1547	173
9.13.8	EN 1539	174
9.14	Principles for the design of a standard	175
9.14.1	How does one read a standard	175
9.14.2	Structure of a type C standard according to the machinery directive	176
Appendix		178
	Heat table	178
	Heat processing keywords	193
	Further technical information	196
Index		199
Index of Advertisers		203