

Contents

1	The Combustion of Hydrocarbon Fuels	1
1.1	Introduction	1
1.2	The Combustion Process	2
1.3	The Complete Combustion Reaction	2
1.4	Quantification of the Combustion Reaction	4
2	Stoichiometric Calculations	7
2.1	Applications of the Combustion Equation	7
2.2	Combustion Air Requirements – Gaseous Fuels	7
2.3	Flue Gas Composition – Gaseous Fuels	9
2.4	Combustion Air Requirements – Solid and Liquid Fuels	11
2.5	Combustion Products – Solid and Liquid Fuels	13
2.6	Practical Significance of the Flue Gas Composition	15
2.7	Sub-stoichiometric Combustion	19
2.8	Problems	20
3	Heat Release in Combustion	23
3.1	Introduction	23
3.2	Constant-pressure Combustion	23
3.3	Enthalpy of a Mixture of Gases	24
3.4	Enthalpy of Combustion	25
3.5	Constant-volume Combustion	27
3.6	Internal Energy of Combustion	27
3.7	Relationship between ΔH_{25} and ΔU_{25}	28
3.8	Calorific Values	30
3.9	List of Symbols	34
3.10	Problems	34

4	Flame Temperature	36
4.1	Energy Balance on a System	36
4.2	Adiabatic Flame Temperature	37
4.3	Specific Heats of Gases	38
4.4	Calculation Algorithm	41
4.5	Calculated Adiabatic Flame Temperatures	43
4.6	References	46
4.7	List of Symbols	46
4.8	Problems	46
5	Equilibrium Composition of Flames	48
5.1	Introduction	48
5.2	Chemical Equilibrium	49
5.3	Calculation of the Equilibrium Composition	52
5.4	Dissociated Flame Temperature	54
5.5	Dissociation with Hydrocarbon Fuels	56
5.6	References	59
5.7	List of Symbols	59
6	Efficiency of Combustion Plant	61
6.1	Plant Efficiency	61
6.2	Direct Determination of Efficiency	64
6.3	Inferential Measurement of Efficiency	65
6.4	Efficiency and Flue Gas Temperature	69
6.5	Flue Gas Dew Point	70
6.6	Efficiency of a Condensing Boiler	72
6.7	References	75
6.8	List of Symbols	75
6.9	Problems	76
7	Gaseous Fuels	78
7.1	Introduction	78
7.2	Natural Gas	78
7.3	Town Gas (Coal Gas)	79
7.4	Liquefied Petroleum Gas (LPG)	80
7.5	Combustion of Gaseous Fuels	81
7.5.1	Flammability Limits	81
7.5.2	Burning Velocity	82
7.5.3	Wobbe Number	83
7.6	Gas Burners	86
7.6.1	Diffusion Burners	86
7.6.2	Premixed Burners	86
7.7	References	87

7.8	List of Symbols	88
8	Liquid Fuels	89
8.1	Occurrence and Processing	89
8.2	Properties of Oil Fuels	90
8.3	Combustion of Liquid Fuels	92
8.4	Pressure Jet Burners	93
8.5	Rotary Cup Burners	94
8.6	Twin-fluid Atomisers	94
8.7	Storage of Liquid Fuels	95
8.8	References	95
9	Solid Fuels	96
9.1	Introduction	96
9.2	Coal Classification	97
9.3	Coal Properties	98
9.4	Coal Combustion	99
9.5	Coal Storage and Handling	102
9.6	References	102
10	Emissions from Combustion Plant	103
10.1	Environmental Considerations	103
10.2	The Greenhouse Effect	103
10.3	Carbon Dioxide Emissions	104
10.4	Carbon Monoxide	106
10.5	Oxides of Nitrogen	106
10.5.1	Atmospheric Nitrogen	107
10.5.2	Fuel-bound Nitrogen	108
10.5.3	NO _x Levels	109
10.5.4	Low-NO _x Burner Design	110
10.6	Oxides of Sulphur	112
10.6.1	The SO _x Problem	112
10.6.2	Sulphur Trioxide Formation	112
10.6.3	Flue Gas Desulphurisation	114
10.7	Particulate Emissions	115
10.7.1	Solid Formation in Combustion	115
10.7.2	Soot Formation	115
10.7.3	Cenosphere Formation	116
10.7.4	Acid Smut Formation	116
10.7.5	Ash	116
10.8	List of Symbols	117
10.9	References	117
11	Flues and Chimneys	118

x CONTENTS

11.1 Functions of the Flue System	118
11.2 Chimney Heat Transfer	119
11.2.1 Heat Transfer Mechanism	119
11.2.2 <i>U</i> -value of a Chimney	119
11.2.3 Temperature Distribution in a Chimney	127
11.3 Pressure Loss	130
11.3.1 Chimney Draught	130
11.3.2 Flow Resistance	131
11.4 Chimney Location	134
11.5 List of Symbols	135
11.6 References	136
 Index	 139