

Contents

SYMBOLS	7
PREFACE	9
1. INTRODUCTORY CONCEPTS AND DEFINITIONS	11
1.1. INTRODUCTION	11
1.2. FUNDAMENTAL CONCEPTS AND DEFINITIONS	11
1.2.1. Matter	11
1.2.2. Thermodynamic Systems	13
1.2.3. State	14
1.2.4. Equilibrium	15
1.2.5. Process	15
1.3. FUNDAMENTAL PARAMETERS OF STATE – TEMPERATURE AND PRESSURE	16
1.3.1. Concept of Temperature and the Zeroth Law of Thermodynamics	16
1.3.2. Concept of Pressure	16
1.4. CONCEPTS OF HEAT AND WORK AND THEIR RELATIONSHIP WITH ENERGY	17
1.5. CONSERVATION OF AMOUNT OF SUBSTANCE AND BASES OF BALANCING	18
2. THERMODYNAMIC MEDIA AND EQUATION OF STATE	20
2.1. THERMODYNAMIC MEDIA	20
2.2. IDEAL GAS	22
2.3. EQUATION OF STATE OF IDEAL GAS	22
2.4. EQUATIONS OF STATE OF REAL GAS	27
2.4.1. Equation with the Compressibility Factor	27
2.4.2. Van der Waals Equation	29
3. SPECIFIC HEAT AND HEAT CAPACITY	31
3.1. CONCEPTS OF SPECIFIC HEAT AND HEAT CAPACITY	31
3.2. SPECIFIC HEAT OF IDEAL GASES	33
3.3. SPECIFIC HEAT AND MEAN SPECIFIC HEAT	36

4. THE FIRST LAW OF THERMODYNAMICS	41
4.1. CONSERVATION OF ENERGY	41
4.2. THE FIRST LAW OF THERMODYNAMICS, INTERNAL ENERGY, ENTHALPY AND WORK.....	42
4.2.1. Internal Energy – a Thermodynamic Property	43
4.2.2. Formulation of the First Law of Thermodynamics	45
4.2.3. Mechanical Work, External Work and Useful Work	46
4.2.4. The First Law of Thermodynamics for Closed Systems	49
4.2.5. Concepts of Flow Work and Enthalpy	50
4.2.6. The First Law of Thermodynamics for Open Systems.....	54
4.3. INTERNAL ENERGY AND ENTHALPY AS FUNCTIONS OF PARAMETERS OF STATE – CALORIFIC PARAMETERS OF STATE ...	55
4.3.1. Internal Energy.....	55
4.3.2. Enthalpy	57
4.4. KINETIC ENERGY AND POTENTIAL ENERGY IN THE FIRST LAW OF THERMODYNAMICS FOR OPEN SYSTEMS.....	58
5. NONREACTING GAS MIXTURES	61
5.1. DEFINING MIXTURE COMPOSITION.....	61
5.1.1. Mass Fraction – g_i	61
5.1.2. Mole Fraction – z_i	62
5.1.3. Relationships between Fractions.....	62
5.2. IDEAL GAS MIXTURES	63
5.2.1. Dalton’s Law	64
5.2.2. Amagat–Leduc’s Law	64
5.3. EQUATION OF STATE OF MIXTURE OF IDEAL GASES	66
5.4. CALORIFIC PARAMETERS OF STATE AND SPECIFIC HEAT OF MIXTURE OF IDEAL GASES.....	67
6. THERMODYNAMIC PROCESSES (TRANSFORMATIONS)	70
6.1. CHARACTERISTIC PROCESSES (TRANSFORMATIONS) OF IDEAL AND SEMIIDEAL GASES	71
6.1.1. Isothermal Process	71
6.1.2. Isochoric Process.....	74
6.1.3. Isobaric Process.....	76
6.1.4. Isentropic Process – Reversible Adiabatic Process	78
6.1.5. Polytropic Process.....	82
7. THE SECOND LAW OF THERMODYNAMICS	89
7.1. REVERSIBILITY AND IRREVERSIBILITY IN NATURAL PROCESSES.....	89
7.1.1. Irreversible Processes.....	90
7.1.2. Reversible Processes	91
7.2. THERMODYNAMIC CYCLES.....	92
7.3. THERMAL EFFICIENCY OF THERMODYNAMIC CYCLES	95
7.3.1. Thermal Efficiency of the Heat Engine (the Clockwise Cycle)	95

7.3.2. Thermal Efficiency of the Working Machine (the Counter-Clockwise Cycle).....	96
7.4. STATEMENTS OF THE SECOND LAW OF THERMODYNAMICS AND CONCEPT OF THE ENTROPY	97
7.4.1. Concept of Entropy	98
7.5. ENTROPY CHANGE IN THE PROCESSES (TRANSFORMATIONS) OF IDEAL GAS.....	101
7.5.1. Isothermal Process	103
7.5.2. Isochoric Process.....	103
7.5.3. Isobaric Process.....	104
7.5.4. Adiabatic Process.....	105
7.5.5. Polytropic Process.....	105
7.6. CARNOT CYCLE	106
7.7. KELVIN TEMPERATURE SCALE	110
8. WATER STEAM	112
8.1. PHASE TRANSITIONS OF WATER.....	112
8.2. THERMODYNAMIC PROPERTIES OF WATER STEAM.....	118
8.2.1. Specific Volume and Density of Steam	119
8.2.2. Calorific Parameters and Steam Diagrams.....	127
8.3. CLAPEYRON – CLAUSIUS EQUATION.....	132
8.4. THERMODYNAMIC PROCESSES (TRANSFORMATIONS) OF WATER STEAM.....	134
8.4.1. Isochoric Process.....	134
8.4.2. Isobaric Process.....	135
8.4.3. Isothermal Process	136
8.4.4. Isentropic Process.....	138
8.4.5. Irreversible Adiabatic Process.....	140
8.4.6. Throttling Process – Isenthalpic Expansion	141
9. FLOW OF COMPRESSIBLE FLUID	144
9.1. FUNDAMENTAL DEPENDENCIES.....	144
9.1.1. Energy Balance	145
9.1.2. Continuity Equation	145
9.1.3. Bernoulli’s Equation	146
9.1.4. Momentum Equation.....	148
9.2. STAGNATION PROPERTIES.....	149
9.2.1. Stagnation Temperature	150
9.2.2. Stagnation Pressure	150
9.3. VELOCITY OF SOUND AND MACH NUMBER	153
9.4. ONE-DIMENSIONAL STEADY FLOW IN CONVERGING AND DIVERGING DUCTS.....	156
9.4.1. Effects of Area Change of Duct in Subsonic and Supersonic Flows	156
9.4.2. Isentropic Flow of an Ideal Gas in Converging and Converging–Diverging Nozzles	159

9.4.2.1. Outflow Velocity and Mass Flow Rate in Nozzles	159
9.4.2.2. Effect of Back Pressure on Mass Flow Rate and Critical Parameters	162
9.4.2.3. Converging Nozzle (Bendemann Nozzle)	166
9.4.2.4. Converging-Diverging Nozzle (de Laval Nozzle)	169
9.4.3. Flow of a Real Gas throughout the Nozzles	173
BIBLIOGRAPHY	177