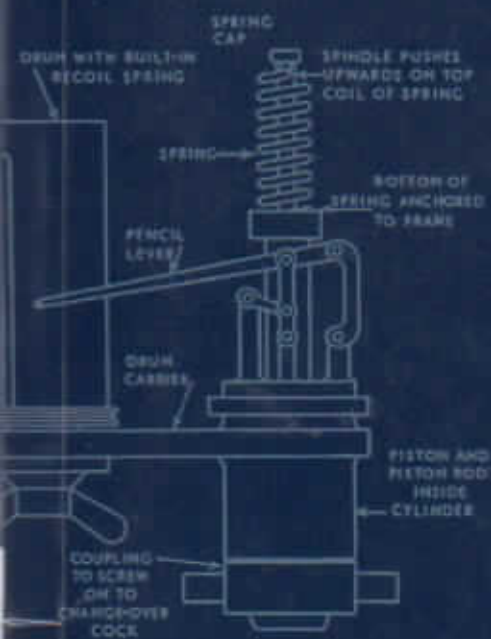


REED'S MARINE ENGINEERING SERIES

3



APPLIED  
HEAT  
FOR  
ENGINEERS

# **REED'S APPLIED HEAT FOR ENGINEERS**

**WILLIAM EMBLETON OBE**

**CEng, FIMarE, MIMechE**

**Extra First Class Engineers' Certificate**

Revised by

**LESLIE JACKSON**

**BSc, MA, CEng, FIMarE, MIMechE**

**Extra First Class Engineers' Certificate**



**ADLARD COLES NAUTICAL**  
London

# CONTENTS

	PAGE
CHAPTER 1 - UNITS AND COMMON TERMS Mass, force, work, power, energy, efficiency. Pressure, gauge, absolute. Volume. Temperature, absolute temperature. Volume - flow and swept (stroke). Mass flow. System - nonflow and steady flow processes. ....	1-11
CHAPTER 2 - HEAT Specific heat. Mechanical equivalent. Water equivalent. Latent heat, fusion, evaporation. Sensible heat. Enthalpy. ....	12-19
CHAPTER 3 - THERMAL EXPANSION Expansion of metals. Linear, superficial, cubical expansion. Expansion of liquids. Apparent cubical expansion. Restricted thermal expansion.....	20-27
CHAPTER 4 - HEAT TRANSFER Conduction. Thermal conductivity. Composite wall. Cylindrical wall. Convection. Radiation, Stefan-Boltzmann law. Combined modes. Fluid, wall, fluid-surface heat transfer coefficient. Overall heat transfer coefficient. Heat exchangers. Logarithmic mean temperature difference.	28-42
CHAPTER 5 - LAWS OF PERFECT GASES Boyle's law. Charles' law. Combination. Characteristic equation. Gas constant. Avogadro's law. Dalton's law of partial pressures. Partial volumes. Specific heats of gases. Energy equation, closed systems. Ratio of specific heats. Enthalpy. Energy equation, open systems. ....	43-61

CHAPTER 6 - EXPANSION AND COMPRESSION OF PERFECT GASES Isothermal, adiabatic, polytropic closed system processes. Relationships between pressure, temperature and volume. Work transfer. A relationship between heat energy supplied and work done .....	62-81
CHAPTER 7 - I.C. ENGINES, ELEMENTARY PRINCIPLES Cycles of operation, four-stroke and two-stroke diesel engines. Timing diagrams. Indicator diagrams. Petrol engines. Engine indicator. Mean effective pressure. Indicated and brake power. Mechanical efficiency. Morse test. Thermal efficiency. Heat balance. Clearance and stroke volume. ....	82-103
CHAPTER 8 - IDEAL CYCLES Constant volume, diesel, dual-combustion, Carnot. Reversed Carnot. Other ideal cycles. Mean effective pressure. Non-ideal cycles. ....	104-122
CHAPTER 9 - RECIPROCATING AIR COMPRESSORS Work done per cycle. Effect of clearance. Multi-stage compression. Free air delivery. Minimum work. ....	123-138
CHAPTER 10 - STEAM Saturated steam, dry, wet. Dryness fraction. Superheated steam. Enthalpy. Steam tables. Mixing steam and water. Effect of throttling. Throttling and separating calorimeters. Air in condensers. Humidity. ....	139-160

	PAGE
CHAPTER 11 – ENTROPY (CLASS ONE ONLY)	
Entropy of water, evaporation, superheated steam. Temperature–entropy ( $T-s$ ) diagram and chart for steam. Isothermal and isentropic processes. $T-s$ diagram for gases. Enthalpy–entropy ( $h-s$ ) chart for steam, etc. ....	161–172
CHAPTER 12 – TURBINES	
Impulse and reaction. Nozzles. Velocity diagrams. Force on blades, power. Ideal cycles, Carnot and Rankine. Superheat and re-heat. Actual steam cycles. Thermal efficiency. Gas turbine cycles.....	173–204
CHAPTER 13 – BOILERS AND COMBUSTION	
Capacity and equivalent evaporation. Efficiency. Feed water. Principles of combustion. Calorific value, higher and lower. Air required for combustion. Composition of flue gases. Orsat apparatus. Conversion of gas analyses. Hydrocarbon fuels. Incomplete combustion.....	205–222
CHAPTER 14 – REFRIGERATION	
Refrigerants. Working cycle vapour-compression system. Capacity and performance. Coefficient of performance. ....	223–234
SOLUTIONS TO TEST EXAMPLES .....	235–310
SELECTION OF EXAMINATION QUESTIONS – CLASS TWO .....	311–319
SOLUTIONS TO EXAMINATION QUESTIONS – CLASS TWO .....	320–344
SELECTION OF EXAMINATION QUESTIONS – CLASS ONE .....	345–355
SOLUTIONS TO EXAMINATION QUESTIONS – CLASS ONE .....	356–396
INDEX.....	397

## INDEX

- A**  
Absolute pressure 5, 43  
Absolute temperature 8, 46  
Absolute zero 8  
Accelerating force 1  
Adiabatic processes 62, 643
- Air composition 210  
Air compressors 123  
Air delivery 135  
Air in condensers 52, 157  
Air standard efficiency 104  
Ammonia 224  
Atmospheric pressure 5  
Atomic weights 211  
Avogadro's law 50
- B**  
Balancing combustion equations 219  
Bar 4  
Barometer 5  
Black body 35  
Blade force 187  
Boiler capacity 205  
Boiler efficiency 206  
Boiling 16  
Boiling points 7, 139  
Boundary 9  
Boyle's law 44  
Brake power 92
- C**  
Calorific value 96, 212  
Calorimeter, combined 156  
Calorimeter, separating 156  
Calorimeter, throttling 154  
Capacity, boiler 205  
Capacity, refrigeration 229  
Carbon 211  
Carbon balance 219  
Carbon dioxide 212, 223  
Carbon monoxide 212  
Carnot cycle 115, 169  
Celsius 7  
Characteristic equation 48  
Charles' law 46  
Chemical equations 212  
Clearance volume 9, 99  
Closed system 9  
Coefficients, heat transfer 36  
Coefficients, expansion 20  
Coefficient, friction 13  
Coefficient, performance 229  
Combined calorimeter 156  
Combined modes, heat transfer 36  
Combustion 210  
Composite wall 30  
Composition flue gases 214  
Compounds 210  
Compression, adiabatic 62  
Compression, ignition 82  
Compression, isothermal 62  
Compression, polytropic 63  
Compression ratio 68, 85, 114  
Compressors, air 124  
Conduction 28  
Conductivity 28  
Constant, gas 48  
Constant-pressure cycle 109, 197  
Constant-volume cycle 105  
Convection 34  
Conversion, gas analyses 216, 218  
Cooling effect 227  
Critical temperature 223  
Cubical expansion 22  
Cycle 10  
Cycle, Carnot 115, 169  
Cycle, constant pressure 109, 197  
Cycle, constant volume 105  
Cycle, diesel 109  
Cycle, dual-combustion 113  
Cycle, four-stroke 82  
Cycle, gas turbine 197  
Cycle, Joule 197  
Cycle, Otto 105  
Cycle, Rankine 191  
Cycle, refrigeration 224  
Cycle, re-heat 193  
Cycle, two-stroke 85  
Cylindrical wall 32

- D  
Dalton's law 51  
Degree of superheat 140  
Density 7, 207  
Diagram, efficiency 188  
Diesel cycle 109  
Dryness fraction 139  
Dry saturated steam 139  
Dual combustion cycle 113
- E  
Efficiency, air standard 104  
Efficiency, boiler 206  
Efficiency, Carnot 115, 169  
Efficiency, constant pressure 197  
Efficiency, constant volume 105  
Efficiency, diesel 109  
Efficiency, dual combustion 113  
Efficiency, Joule 197  
Efficiency, mechanical 92  
Efficiency, Otto 105  
Efficiency, Rankine 192  
Efficiency, thermal 96, 196  
Efficiency, volumetric 127  
Elasticity 25  
Elements 210  
Emissivity 35  
Energy 2  
Energy equations 55, 57  
Energy, internal 55, 140  
Engine cycles 104  
Enthalpy 57  
Enthalpy-entropy chart 171  
Entropy 161  
Equivalent evaporation 205  
Evaporation 16  
Expansion, adiabatic 64  
Expansion, cubical 22  
Expansion, gases 62  
Expansion, isothermal 64  
Expansion, linear 20  
Expansion, liquid 24  
Expansion, polytropic 64  
Expansion ratio 68  
Expansion, superficial 21  
Expansion, volumetric 22
- F  
Feed water 207  
Fixed points 7  
Flue gases 214  
Fluid, heat transfer 36  
Force 1  
Force of gravity 1  
Force on blades 187  
Formation of steam 140  
Four-stroke 82  
Free air delivery 135  
Freon 227  
Friction power 92  
Fuel combustion 210  
Fusion 16
- G  
Gas analyses, conversion 216, 218  
Gas constant 48  
Gas constant universal 50  
Gas laws 43  
Gas power cycles 104  
Gas specific heats 53  
Gas turbine cycles 197  
Gauge pressure 5  
Gravity 1
- H  
Heat 12  
Heat balance 99  
Heat conduction 28  
Heat convection 34  
Heat exchanger 38  
Heat, latent 16  
Heat, mechanical equivalent 13  
Heat pumps 232  
Heat, radiation 35  
Heat, sensible 17  
Heat, specific 12  
Heat transfer 28  
Heat transfer coefficient, overall 37  
Heat transfer coefficient, surface 36  
Heat transfer, combined modes 36  
Heat unit 12  
Higher calorific value 214  
Humidity 158  
Hydrocarbon fuels 218  
Hydrogen 211

- I  
Ice point 7  
Ideal cycles 104, 191  
Ignition 82  
Impulse turbine 173  
Incomplete combustion 219  
Indicated power 89  
Indicator 88  
Indicator diagram 84, 87, 89  
Intercooler 132  
Internal combustion engines 82  
Internal energy 55, 140  
Isentropic efficiency 194  
Isentropic process 167  
Isothermal 62, 64  
Isothermal efficiency 135  
Isothermal process 167
- J  
Joule 2  
Joule cycle 197  
Joule's law 55
- K  
Kelvin 8  
Kilogramme 1  
Kilojoule 2  
Kilowatt 2  
Kilowatt-hour 2
- L  
Latent heat 16  
Law, Avogadro's 50  
Law, Boyle's 44  
Law, Charles' 46  
Law, Dalton's 51  
Law, Joules' 55  
Law, partial pressures 51  
Law, Stefan Boltzmann 35  
Law, thermodynamics 56  
Law of gases 43  
Light oil engines 85  
Linear expansion 20  
Litre 6  
Logarithmic mean temperature difference 38  
Lower calorific value 214  
Lower fixed point 7
- M  
Manometer 4  
Mass 1  
Mass analysis 215  
Mass flow 9  
Mean effective pressure 88  
Mean temperature difference, logarithmic 38  
Mechanical efficiency 92  
Mechanical equivalent 13  
Megagramme 1  
Megajoule 2  
Megawatt 2  
Melting 16  
Mercury thermometer 17  
Millibar 5  
Millilitre 7  
Minimum work 135  
Mixing steam and water 147  
Modulus of elasticity 25  
Mol 50  
Molecular weight 211  
Morse test 94
- N  
Newton 1  
Nitrogen 211  
Non-flow process 9, 55  
Non-ideal cycles 119  
Nozzles 177
- O  
Open system 9  
Orsat apparatus 216  
Other ideal cycles 118  
Otto cycle 105  
Overall heat transfer coefficient 37  
Oxygen 211
- P  
Partial pressures 51, 157  
Partial volumes 52  
Parts per million 208  
Performance coefficient 229  
Petrol engines 85  
Polytropic processes 63, 64  
Power 2, 88, 187  
Power, brake 92  
Power, cycles 104



- Power, friction 92  
Power, indicated 89  
Power, shaft 92  
Pressure 4  
Pressure, absolute 5  
Pressure, atmospheric 6  
Pressure, mean effective 88  
Pressures, partial 51, 157  
Pressure ratio, critical 180  
Products of combustion 215
- Q  
Quality of steam 139
- R  
Radiation 35  
Rankine cycle 191  
Rankine efficiency 192  
Ratio of compression 68, 85, 114  
Reaction turbine 177  
Reciprocating engines 82  
Reciprocating air compressors 123  
Reducing valve 151  
Refrigerating effect 227  
Refrigeration 223  
Refrigeration circuit 225  
Re-heat cycle 193  
Relationship  $pVT$  69  
Relationship spec. heats 56  
Relationship work heat 78  
Reversed Carnot cycle 117, 229  
Rope brake 93
- S  
Saturated steam 140  
Sensible heat 17  
Separating calorimeter 156  
Shaft power 92  
Specific fuel consumption 96  
Specific heat 16  
Specific heat relationship 56  
Specific volume 7  
Steady-flow process 9, 58  
Steam 140  
Steam, dryness fraction 139  
Steam, entropy of 161  
Steam point 7  
Steam tables 141  
Steam throttling 151  
Stefan-Boltzmann law 35  
Stoichiometry 211  
Strain 25  
Stress 24  
Stroke volume 9  
Sulphur 211  
Superficial expansion 21  
Superheated steam 144  
Surface heat transfer coefficient 36  
Surroundings 9  
Swept volume 9  
System 9
- T  
Tables, entropy 162  
Tables, steam 141  
Temperature 7  
Temperature absolute 8  
Temperature conversion 8  
Temperature-entropy chart 165  
Temperature-entropy diagram 163  
Temperature thermodynamic 8  
Test, Morse 94  
Thermal conductivity 28  
Thermal efficiency 96  
Thermal expansion 20  
Thermometer 7  
Throttling calorimeter 154  
Throttling steam 151  
Timing diagram 84, 87  
Transfer of heat 28  
Transfer of work 72  
 $T-s$  diagrams 163  
Turbines, impulse 173  
Turbines, reaction 177  
Two-stroke 85
- U  
Units 1  
Universal gas constant 50  
Upper fixed point 7
- V  
Vacuum gauge 6  
Valve, reducing 151  
Vapour-compression 224  
Vapour power cycles 104  
Velocity compounding 174, 185  
Velocity diagrams 182, 189

- Volume 6  
Volume, clearance 9, 99  
Volume, flow 8  
Volume, stroke 9  
Volumes, partial 52  
Volumetric analysis 216  
Volumetric efficiency 127  
Volumetric expansion 22
- W  
Water, entropy of 161  
Water equivalent 14  
Watt 2  
Weight 1  
Weight, atomic 211  
Weight, molecular 211  
Wet steam 139  
Work 2  
Work transfer 72