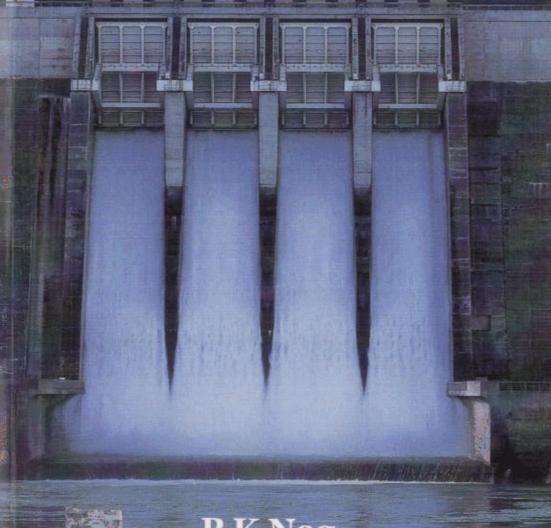
Power Plant Engineering

Third Edition



P K Nag

Contents

Pr	eface		X
1.	INTR	ODUCTION: ECONOMICS OF POWER GENERATION	1
	1.1	Introduction 1	
	1.2	Load-Duration Curves 2	
	1.3	Location of Power Plants 9	
	1.4	Power Plant Economics 10	
	1.5	Indian Energy Scenario 20	
	1.6	Coal-fuelled Electricity Generating Unit 23	
	110	Short-Answer Questions 37	
		Problems 38	
		Bibliography 40	
2.	ANA	LYSIS OF STEAM CYCLES	41
	2.1	Steam Power Plant 41	
	2.2	Rankine Cycle 42	
	2.3	Carnot Cycle 48	
	2.4	Mean Temperature of Heat Addition 48	
	2.5	Effect of Variation of Steam Condition	
		on Thermal Efficiency of Steam Power Plant 51	
	2.6	Reheating of Steam 53	
	2.7	Regeneration 55	
	2.8	Regenerative Feedwater Heating 58	
	2.9	Feedwater Heaters 61	
	2.10	Carnotization of Rankine Cycle 63	
	2.11	Optimum Degree of Regeneration 65	
	2.12	Supercritical Pressure Cycle 70	
	2.13	Steam Power Plant Appraisal 70	
	2.14	Deaerator 72	
	2.15	Typical Layout of Steam Power Plant 74	
	2.16	Efficiencies in a Steam Power Plant 76	
	2.17	Cogeneration of Power and Process Heat 78	
		Short-Answer Questions 96	
		Problems 97	
		Bibliography 102	

3.	COM	BINED CYCLE POWER GENERATION		103
	3.1 3.2	Flaws of Steam as Working Fluid in Power Cycle Characteristics of Ideal Working Fluid for Vapour Power Cycle 104	103	
	3.3 3.4 3.5 3.6	Binary Vapour Cycles 105 Coupled Cycles 107 Combined Cycle Plants 109 Gas Turbine—Steam Turbine Power Plant 110 Short-Answer Questions 154 Problems 155 Bibliography 158	÷	
4.	FUEI	LS AND COMBUSTION		159
	4.1 4.2 4.3 4.4 4.5 4.6 4.7 4.8 4.9 4.10 4.11 4.12 4.13 4.14 4.15 4.16 4.17 4.18 4.20 4.21	Coal 159 Coal Analysis 160 Fuel Oil 164 Natural and Petroleum Gas 165 Emulsion Firing 165 Coal-Oil and Coal-Water Mixtures 166 Industrial Wastes and Byproducts 166 Synthetic Fuels 168 Biomass 173 Thermodynamic View 175 Combustion Reactions 177 Mass Balance of a Steam Generator 186 Energy Balance of a Steam Generator 187 Draught (or Draft) System 189 Fans 197 Heat of Combustion 199 Heating Values: Enthalpy of Combustion 202 Theoretical Flame Temperature 204 Free Energy of Formation 205 Equilibrium Constant K _p 206 Effect of Dissociation 209 Short-Answer Questions 226 Problems 229		
_		Bibliography 233	•	
5.		IBUSTION MECHANISM, COMBUSTION IPMENT AND FIRING METHODS		234
	5.1 5.2 5.3 5.4 5.5 5.6 5.7	Kinetics of Combustion Reactions 235 Mechanism of Solid Fuel Combustion 237 Kinetic and Diffusion Control 238 Combustion Equipment for Burning Coal 241 Fuel Bed Combustion 241 Mechanical Stokers 244 Pulyerized Coal Firing System 248		

Contents	vii

	5.9 5.10 5.11 5.12 5.13	Cyclone Furnace 272 Fluidized Bed Combustion 274 Coal Gasifiers 299 Combustion of Fuel Oil 304 Combustion of Gas 307 Combined Gas Fuel Oil Burners 307 Short-Answer Questions 312 Problems 314 Bibliography 315	
6.	STEA	AM GENERATORS	317
	6.5 6.6 6.7 6.8 6.9 6.10 6.11 6.12 6.13 6.14 6.15 6.16 6.17	Water-Tube Boilers 321 Economisers 356 Superheaters 359 Reheaters 364	
7.	STEA	AM TURBINES	428
		Introduction 428 Flow Through Nozzles 430 Turbine Blading 451 Electrical Energy Generation 508 Short-Answer Questions 553 Problems 555 Bibliography 561	
8.		DENSER, FEEDWATER AND CIRCULATING ER SYSTEMS	562
•	8.1 8.2 8.3	Need of a Condenser 562 Direct Contact Condensers 563 Surface Condensers 565	

vi	ii Con	ntents	
_	8.4	Feedwater Heaters 575	
	8.5	Circulating Water System 579	
	8.6	Cooling Towers 580	
	8.7		
	7	Short-Answer Questions 598	
		Problems 600	
		Bibliography 601	
9.	NUC	LEAR POWER PLANTS	602
	9.1	Structure of the Atom 602	
	9.2	Chemical and Nuclear Reactions 604	
	9.3	Nuclear Stability and Binding Energy 604	
	9.4	Radioactive Decay and Half Life 606	
	9.5	Nuclear Fission 610	
	9.6	Chain Reaction 612	
	9.7		
	9.8	Nuclear Cross-Sections 616	
	9.9	Neutron Flux and Reaction Rates 618	
	9.10	Moderating Power and Moderating Ratio 619	
	9.11	Variation of Neutron Cross-Sections with	
	0.10	Neutron Energy 620	
		Neutron Life Cycle 622	
		Reflectors 624	
		Heat Transfer and Fluid Flow in Nuclear Reactors 625	
	9.15 9.16	Types of Reactors 632 Procuping Water Reactor (PWP) 633	
	9.10	Pressurized Water Reactor (PWR) 633 Boiling Water Reactor (BWR) 637	
	9.17	Gas-Cooled Reactors 640	
	9.19	Liquid Metal Fast Breeder Reactor 641	
	9.20	Heavy Water Reactors 643	
	9.22	Fusion Power Reactors 647	
	J.22	Short-Answer Questions 653	
		Problems 655	
		Bibliography 656	
10	. HYl	DROELECTRIC POWER PLANT	657
	10.1	Introduction 657	
	10.2	Advantages and Disadvantages of Water Power 658	
	10.3	B Optimization of Hydro-Thermal Mix 659	
	10.4	Selection of Site for a Hydroelectric Plant 660	
	10.5	• •	
	10.6	· · · · · · · · · · · · · · · · · · ·	
	10.7		
	10.8	Essential Elements of a Hydroelectric Power Plant 667	

Classification of Hydroelectric Power Plants 676 Hydraulic Turbines 679 Turbine Size 682

10.9 10.10 10.11

	10.12	Pelton Wheel 682	
	10.13	Degree of Reaction 688	
	10.14	Francis Turbines 689	
	10.15	Propeller and Kaplan Turbines 691	
	10.16	Deriaz Turbine 694	
	10.17	Bulb Turbine 695	
	10.18	Specific Speed 695	
	10.19	Comparison of Turbines 698	
	10.20	Cavitation 698	
	10.21	Governing of Hydraulic Turbines 699	
	10.22	Governing of Reaction Turbines 701	
	10.23	Surge Tanks 702	
	10.24	Performance of Turbines 704	
	10.25	Selection of Turbines 708	
		Short-Answer Questions 728	
		Problems 730	
		Bibliography 734	
11.	DIESE	L ENGINE AND GAS TURBINE POWER PLANTS	735
	11.1	Applications of Diesel Engines in Power Field 735	
	11.2	Advantages and Disadvantages of Diesel Engine	
		Power Plant 736	
	11.3	Types of Diesel Plants 736	
	11.4	General Layout 737	
	11.5	Combustion in a CI Engine 751	
	11.6	Performance Characteristics 754	
	11.7	Supercharging 761	
•	11.8	Layout of a Diesel Engine Power Plant 765	
	11.9	Gas Turbine Power Plant 772	
	11.10	Components of Gas Turbine Plant 785	
	11.11 11.12	Gas Turbine Fuels 792 Gas Turbine Materials 793	
	11.12	Free Piston Engine Plant 794	
	11.13	Short-Answer Questions 805	
		Problems 806	
		Bibliography 811	
10	ENER		010
12.		GY STORAGE	813
	12.1	Pumped Hydro 816	
	12.2	Compressed Air Energy Storage (CAES) 818	
	12.3	Flywheel Energy Storage 822	
	12.4	Electrochemical Energy Storage 826	
	12.5 12.6	Magnetic Energy Storage 835 Thermal Energy Storage 837	
	12.6	Thermal Energy Storage 837 Chemical Energy Storage 844	
	12.7	Hudrogen Energy 846	

Short-Answer Questions	852
Problems 854	
Bibliography 855	

13.		CONVENTIONAL POWER GENERATION: CT ENERGY CONVERSION		856
	13.1	Magnetohydrodynamic (MHD) Power Generation	856	050
	13.2	Thermiconic Power Generation 863	050	
	13.3	Thermoelectric Power Generation 869		
	13.4	Fuel Cells 879		
	13.5	Geothermal Energy 888		
	13.6	Hydrogen Energy System 889		
		Short-Answer Questions 893		
		Problems 894		
		Bibliography 895		
14.		RONMENTAL DEGRADATION AND USE ENEWABLE ENERGY		896
	14.1	Greenhouse Effect 897		0,0
	14.1	Acid Rain 898		
	14.3	Smog 899		
	14.3	Nuclear Radiation 899		
	14.5	Solar Energy 899		
	14.6	Wind Energy 912		
	14.7	Ocean Energy Systems 917		
	14.8	Geothermal Energy 929		
	14.9	Small Hydro 934		
	14.10	Energy From Biomass 935		
		Short-Answer Questions 939		
		Bibliography 941		
	Append			942
	Appena			961
	Appena			963
	Index			966