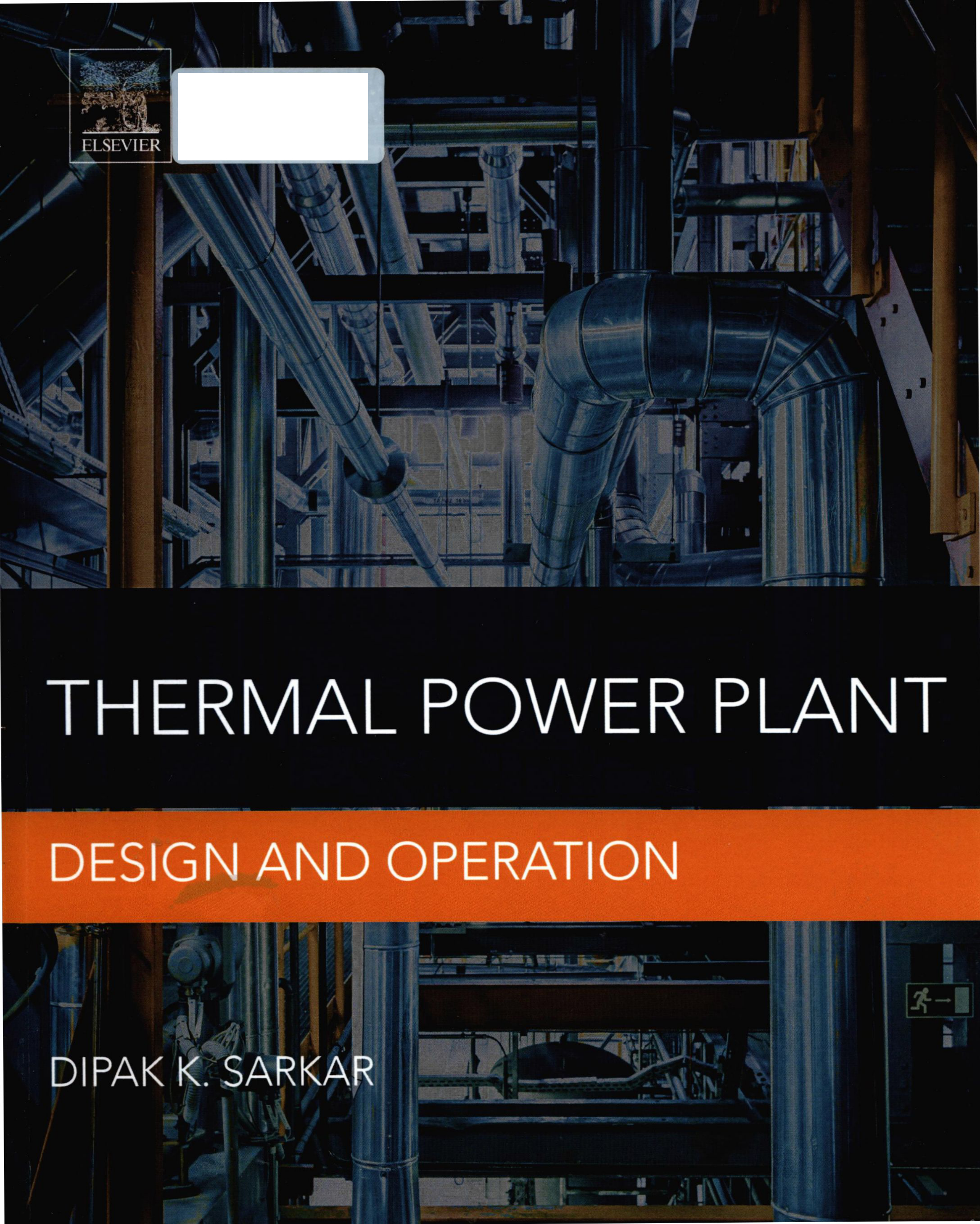

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THERMAL POWER PLANT

DESIGN AND OPERATION

DIPAK K. SARKAR

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THERMAL POWER PLANT

Dedicated to my parents

MANORAMA & SISIR KUMAR

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Dipak K. Sarkar
July 03, 2015

PREFACE

This book on **THERMAL POWER PLANT – Design and Operation** deals with various aspects of a thermal power plant starting from fundamentals leading in depth to technical treatment. The book is aimed at providing new dimension to the subject and thrust of the book is focused on technology and design aspect with special treatment on plant operating practices and troubleshooting. Certain chapters also deal with numerical problems along with some worked out examples.

This book is prepared based on author's long association with thermal power plants for more than 40 years in design as well as in field engineering. During this long carrier, author has shared his knowledge and experience with students of various technical institutes as visiting faculty in the under graduate level and found that students are very attentive to his lectures because they found contents of these lectures would be beneficial to their professional carrier. The author also shared his experience with professional engineers under various training schemes, viz. graduate engineers training programme, refreshers training programme, operating personnel training programme. Against the back drop of feedback received during interaction with engineers at various forums, this book aims at sharing author's experience with much wider group of engineers.

The book is so developed as to be used as a core text by Mechanical/Power Engineering students at the undergraduate level and as a special paper on Heat & Work in the Postgraduate level. Diploma engineering students who intend to specialize in Thermal/Power Engineering can use this as a text book. This book can also be used as a reference book in Power Plant Training Institutes and in Graduate Engineers Training Programme on power plants. To Utility Operators and Design Engineers this book would be of immense help as reference book and to execute day-to-day activities. This book on one side addresses basic design aspects of thermal power plants to make it attractive to students pursuing mechanical/power engineering courses, on the other side it discusses how safely to run these plants so that utility operators find it handy as an useful guide book.

Design of a thermal power plant is based on the science of thermodynamics. Chapter 1 deals with treatment on fundamentals of thermodynamics, and comprises vapour cycles, their evolution, merits-demerits and their applications.

Chapter 2 discusses on steam generator covers boiling, circulation, classification, design of heat transfer areas. The intricacies of supercritical boiler are addressed separately.

Fuels and combustion are covered in Chapter 3 elaborating sources, availability, characteristics of fuel, combustion calculation, and design aspects of fuel handling.

From global trend the International Energy Agency (IEA) forecast that coal will remain a dominant fuel worldwide through 2035 for the purpose of power generation. Hence, pulverized coal fired boiler is discussed separately in Chapter 4 in view of large global coal reserves and its acceptance as major power producer in many countries.

Chapter 5 covers fluidized bed boiler that can burn lower grade of coal and other low grade combustible material for the generation of steam.

Steam turbine is the prime mover of steam power plant, and Chapter 6 deals with introduction, type, governing and speed control, losses, performance of steam turbine.

For quick start-up and peak load generation, gas turbine is ideal. Chapter 7 covers introduction, combustion system, and performance of gas turbine. This chapter also covers design, benefits, and use of heat recovery steam generator (HRSG) that facilitates improvement of the efficiency of a gas turbine power plant.

Chapter 8 deals with diesel power plant. Its design, equipment, and associated systems are addressed in this chapter.

A thermal power plant comprises miscellaneous systems comprising electric power supply and distribution systems, as well as solid (coal, ash), liquid (water, oil, acid, alkali) and gaseous (steam, air, flue gas, natural gas, hydrogen) matter supply and distribution systems. Description and purpose of these systems of a steam power plant are covered in Chapter 9.

Operation of modern large power plants is very complex in nature. It requires lot of activities to be executed simultaneously in order to ensure safety of equipment and personnel, as well as stable operation of the unit efficiently. Although discussion on whole gamut of such activities is difficult to be accommodated in this book, an attempt is made to address key aspects of these issues. Thus, Chapter 10 covers automatic control of key parameters of steam generator, steam turbine, and regenerative system. Chapter 11 is developed to address interlock & protection system of steam generator, steam turbine, gas turbine, diesel engine, and generator (alternator). While Chapter 12 covers start-up and shut down of steam generator, steam turbine, gas turbine, and diesel engine; their abnormal operating conditions are discussed in Chapter 13.

Air pollution control is addressed in Chapter 14. This chapter covers emission control of SPM, GHG, SO_x, and NO_x generated from a coal-fired steam generator.

More often than not design engineers get confused and search blindly which code and/or standard are to be followed to design a particular equipment or system. Chapter 15 presents purpose, benefits, and a list of commonly used codes and standards for design and operation of thermal power plants.

Fossil fuels are basically polluting in nature and are major producer of greenhouse gases causing global warming. Hence, to make these fuels environmentally acceptable cost intensive different types of treatment plants are essential to be installed.

To mitigate such complexities and investments, a viable alternative is to adopt renewable energy sources. These sources do not produce greenhouse gases and are free from emitting toxic wastes. So in continuation to aforementioned chapters, a brief discussion on Power from Renewable Energy is addressed under Appendix A. It is more so since renewable energy provides about 16% of global energy consumption.

It is of major concern that on one hand global supply of fossil fuels is depleting; on the other hand world's demand of electricity is rising sharply. As a result, utilities look at nuclear energy as a savior source of bulk power producer. This energy does not produce any air pollution, hence is an attractive alternative in the arena of electricity production even though the reactor area is a potential source of radioactivity and needs special safeguard devices. Appendix B discusses briefly Power from Nuclear Energy.

In accordance with current global practice, SI units have been used all through the book. Nevertheless, for the convenience of readers Conversion Factors from SI units to Metric System of units to Imperial & US System of units are addressed under Appendix C.

Author would earnestly welcome any suggestion for the improvement of the contents of this book both by supplementing with additional information in existing chapters and/or by addressing other areas in consonance with the present intention of this book. These suggestions would be acknowledged gratefully by the author.

Dipak K. Sarkar
March 26, 2015

LIST OF ACRONYMS/ABBREVIATIONS

a, abs	Absolute
A	Ash (content in coal)/Ampere
ABMA	American Boiler Manufacturers Association
A/C	Air/Cloth
AC	Alternating Current
ACF	Activated Carbon Filter
ACW	Auxiliary Cooling Water
ad	Air Dried
AFBC	Atmospheric Fluidized Bed Combustion
AFR	Air-Fuel Ratio
AH	Air Heater
AHS	Ash Handling System
ANSI	American National Standards Institute
APC	Auxiliary Power Consumption
API	American Petroleum Institute
APS	Automatic Plant Start-up & Shutdown System
ar	As Received
AS	Auxiliary Steam
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing & Materials
atm	Atmosphere
AVR	Automatic Voltage Regulator
AVT	All Volatile Treatment
AWWA	American Water Works Association
b	Bar
B	Billion
BA	Bottom Ash
B&W	The Babcock & Wilcox Company
BDC	Bottom Dead Center
BEI	British Electricity Institute
BF	Base Factor
BFBC	Bubbling Fluidized Bed Combustion
BFP	Boiler Feed Pump
BHRA	British Hydraulic Research Association
BIS	Bureau of Indian Standards
BMCR	Boiler Maximum Continuous Rating

BMS	Burner Management System
BOOS	Burner Out Of Service
BOP	Balance Of Plant
BP	Booster Pump
BPVC	Boiler and Pressure Vessel Code
BSI	British Standards Institution
Btu	British Thermal Unit
BWR	Boiling Water Reactor
C	Carbon/Celsius/Centegrade
Ca	Calcium
CA	Compressed Air
CAA	Clean Air Act, U.S.A.
CAAA	Clean Air Act Amendments
cc	Cubic Centimeter
CC	Combined Cycle
CCCW	Closed Cycle Cooling Water
CCGT	Combined Cycle Gas Turbine
CCPP	Combined Cycle Power Plant
CE	Combustion Engineering Inc./Collecting Electrode
CEA	Central Electricity Authority, India
CEGB	Central Electricity Generating Board
CEN	(Comité Européen de Normalisation)-European Committee for Standardization
CEP	Condensate Extraction Pump
CFBC	Circulating Fluidized Bed Combustion
cfm	Cubic Feet Per Minute
CHF	Critical Heat Flux
CHP	Combined Heat And Power
CHS	Coal Handling System
CI	Combustion Inspection of Gas Turbine
C.I.	Compression Ignition
cm	Centimeter
CO	Carbon Monoxide
CO_2	Carbon Dioxide
cP	Centipoise
CPCB	Central Pollution Control Board, India
CR	Compression Ratio
CRH	Cold Reheat
CSA	Canadian Standards Association
CV	Calorific Value/Control Valve

CW	Circulating (Condenser Cooling) Water
cwt	Hundredweight
D	Drain/Diameter
D, d	Day
DAF	Dry Ash Free
dB	Decibel
DAS	Data Acquisition System
DC	Direct Current
DCA	Drain Cooler Approach
DCS	Distributed Control System
DE	Discharge Electrode
deg	Degree
DIN	Deutsches Institut für Normung
DM	De-mineralized
dmmf	Dry Mineral Matter Free
DMW	De-mineralized Water
DNB	Departure From Nucleate Boiling
DO	Dissolved Oxygen
DSI	Duct Sorbent Injection
EA	Excess Air
ECS	Environmental Control Systems
EDI	Electrical De-ionization Unit
eff/EFF	Efficiency
EHS	Environmental, Health and Safety
EIA	Environmental Impact Assessment
emf	Electromotive Force
EMV	Effective Migration Velocity
EPA	Environmental Protection Agency, U.S.A
EPRI	Electric Power Research Institute, U.S.A
EPRS	Effective Projected Radiant Surface
ESI	Economizer Sorbent Injection
ESP	Electrostatic Precipitator
ESV	Emergency Stop Valve
EU	European Union
EX	Extraction
F	Fahrenheit
FA	Fly Ash
FAC	Flow Accelerated Corrosion

FBC	Fluidized Bed Combustion
FBR	Fast Breeder Reactor
FC	Fixed Carbon (in coal)
FD	Forced Draft
FEGT	Furnace Exit Gas Temperature
FGD	Flue Gas Desulfurization
FGR	Flue Gas Recirculation
FIG	Figure
FFH	Factored Fired Hours
FO	Furnace Oil
FSI	Furnace Sorbent Injection
ft	Foot/Feet
FW	Feed Water
FWH	Feed Water Heater
fpm	Feet Per Minute
g	Gram/Gauge/Acceleration Due to Gravity (1 kg.m/Ns^2)
G	Gallon/Giga
GB	Guojia Biaozhun, China National Standard
GCB	Generator Circuit Breaker
GCR	Gas Cooled Reactor
GCS	Gas Conditioning Skid
GCV	Gross Calorific Value
GE	General Electric Company
GGH	Gas to Gas Heater
GHG	Greenhouse Gas
GJ	Giga Joule
GLR	Generator Lock-out Relay
GOST	Gosudartsvennye Standarty, Russian National Standards
GPHR	Gross Plant Heat Rate
gpm	Gallons Per Minute
gr	Grain
GT	Gas Turbine/Generator Transformer
h	Hour
H	Hydrogen
H, h	Enthalpy
HAP	Hazardous Air Pollutants
HAZ	Heat Affected Zone
HCSD	High Concentration Slurry Disposal System
HEI	Heat Exchange Institute, U.S.A.