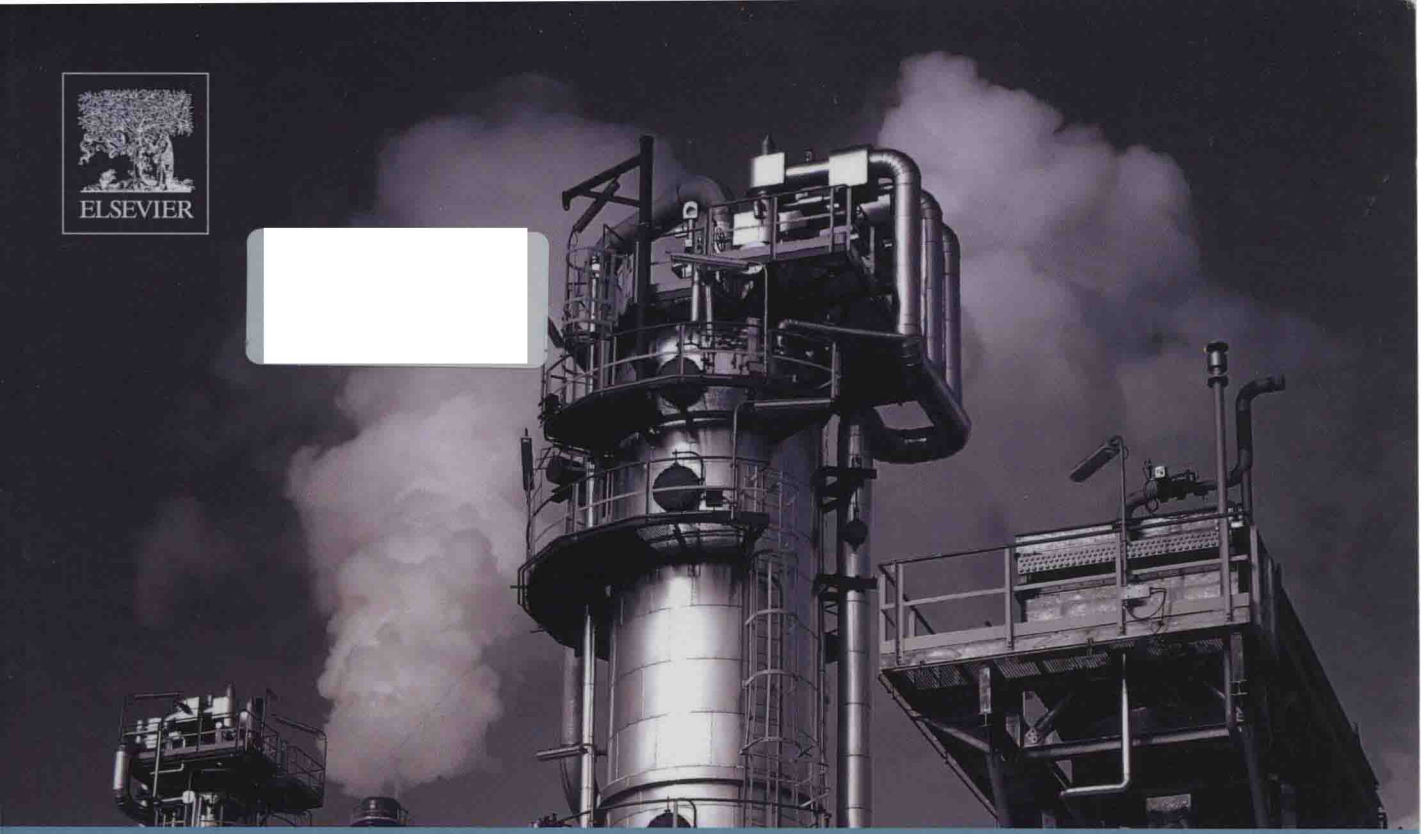
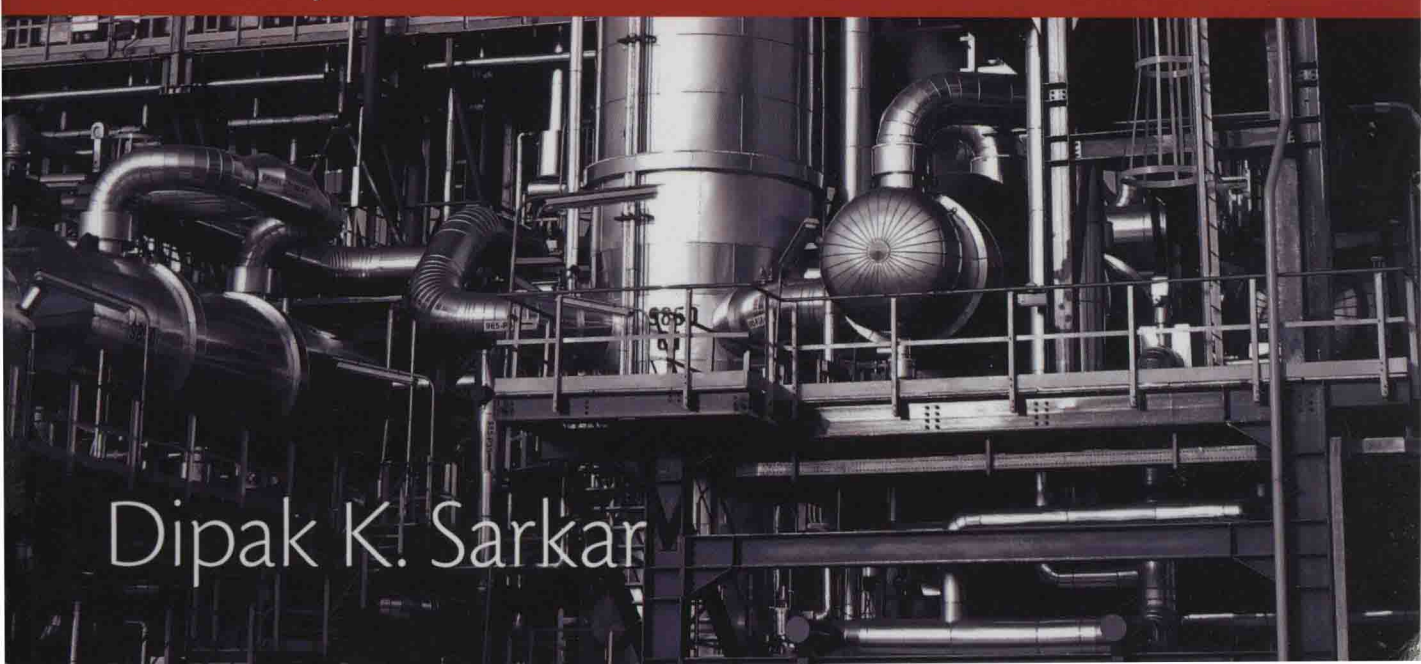


THERMAL POWER PLANT:

Pre-Operational Activities



Dipak K. Sarkar

Thermal Power Plant

Pre-Operational Activities

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Thermal Power Plant

Dedicated to my grandparents
Nalini Prabha-Rajani Kanta
and
Surabala-Surendra Nath

Preface

I worked in the premier engineering consultancy firm of India, M/S Development Consultants Private Limited (DCPL), for more than four decades. During this long tenure I had the opportunity to work in innumerable thermal power plants of various sizes and configurations. The most important part of this association was my exposure to chronological development in power plant technology, both within and outside India. Against this backdrop, when I was executing various projects I observed that there is a dearth of published books wherein various aspects of preoperational activities are consolidated. This was the starting point in getting motivated to write this book, *Thermal Power Plant—Preoperational Activities*, in which I tried my utmost to incorporate the state-of-the-art technology applicable to these activities.

Design of a thermal power plant is a desktop study, while operation of the plant falls exclusively within the purview of field engineering. In between design and operation there are certain areas, generally known in the industry as preoperational activities. The procedure for execution of these activities is developed during desktop study, but is executed in field only. So these activities act as a go-between for design and operation to ensure unruffled power generation as far as the end user is concerned. Thus, this book may be construed as complemental to my previous book, *Thermal Power Plant—Design and Operation*, published by Elsevier.

This book aims to address some of the essential preoperational activities which are extremely important to carry out in line with the practice followed in the industry globally. Smooth, trouble-free, and economic operation of thermal power plants can be ensured if preoperational activities are carried out with the utmost care in order to establish that prior to the start-up of various systems, equipment, and/or the plant as a whole, they would be ready in all respects in accordance with manufacturers' recommendations, and at the same time fulfill all requirements of applicable statutory guidelines. The main purpose of addressing the essential features of preoperational activities is to ensure economic generation from a plant. Hence, the primary focus of this book is on professional engineers.

The contents of the book are such that the book should not be treated as a conventional textbook used in technical institutes. For design engineers, this book would act as a reference to help them develop project-specific precommissioning manuals of a new plant. It would also fulfill the needs of commissioning engineers, suppliers, and utility operators during the execution

period of new plants. While successful completion of preoperational activities is essentially to be accomplished and certified prior to the start-up of new plants, areas addressed in this work are applicable to running plants as well. In running plants, this book would be a tool to help operation and maintenance engineers/suppliers (contractors) execute cleaning/testing activities (eg, overhaul, critical inspection, major repair) successfully to comply with regulatory requirements.

Degradation in the performance of major prime-movers—namely steam turbines, gas turbines, and diesel engines—of running units is a common phenomenon in the industry. In order to arrest the severity of degradation, it is generally recommended to undertake a major overhaul of these prime-movers following a specified period of operating hours. In the case of steam turbines, this period is usually 6 years, while for gas turbines and diesel engines, permissible operating hours that are usually recommended by manufacturers are 48,000 and 8000, respectively. Steam generators are generally inspected after about 12–24 months of operation to meet the statutory requirements of the boiler inspectorate. Any defect observed during inspection needs to be attended to before the boiler inspectorate extends permission to restart the steam generator.

In many countries initiatives have been undertaken to improve the efficiency and environmental performance of their existing thermal power plants through refurbishment, upgradation, rehabilitation, and modernization activities. Before putting these old plants into service on completion of routine overhauls, on completion of renovation and modernization, following a major repair, or after long shutdown of critical equipment or of the plant, it is compulsory to carry out preoperational activities to meet statutory requirements; otherwise, these plants would not be in a position to supply uninterrupted power.

Before discussing details of these activities, it is essential that readers are conversant with an outline of a thermal power plant or that readers' knowledge of a thermal power plant is refreshed for the convenience of understanding various systems and equipment. Hence, Chapter 1 addresses "General Description of Thermal Power Plants." In addition, a generic description of systems and equipment pertaining to specific types of preoperational activities or thermal power plants is discussed substantially in various chapters.

Successful completion of a preoperational cleaning activity or a prestart-up activity depends on how consciously each activity is carried out, such that a plant does not face any untoward incident during normal running, lest generation gets perturbed. This is ensured by adhering to the guidelines laid down by an internationally recognized quality management system (eg, ISO 9000). For the convenience of readers to adopt a foolproof quality management system, guidelines on "Quality Assurance (QA) and Quality Control (QC) (Applicable to Preoperational Activities)" are discussed in Chapter 2. Prior to conducting any preoperational activity it is extremely essential to observe certain precautionary measures, and also to ensure that certain activities/items are completed beforehand. These two aspects are addressed under "Precautions" and "Prerequisites" in Chapters 3–17. The QA team must be responsible for

fulfilling these aspects. Thereafter the QC team takes over to ensure successful completion of each preoperational activity, following the steps of developing preparatory arrangements, operating procedures to be followed, availability of required materials (chemicals/water/any special gadgets), availability of safety equipment, and so on.

Looking toward commissioning of a new plant or recommissioning of a running plant from availability of electric power to commercial operation, the effective order of preoperational activities that are generally followed in the industry are presented here:

1. Hydraulic test of steam generator
2. Airtightness/leakage test of the furnace, air, and flue gas paths of steam generator
3. Alkali flushing of preboiler system
4. Flushing of fuel oil piping system
5. Blowing of fuel gas piping system
6. Steam generator initial firing and drying out of insulation
7. Chemical cleaning of steam generator
8. Flushing of lube oil piping system
9. Steam/air blowing of main steam, cold reheat, hot reheat, and other steam pipe lines
10. Floating of steam generator safety valves
11. Clean airflow test of pulverizers
12. Condenser flood test and vacuum-tightness test
13. Generator drying out and airtightness test
14. Filling of generator with hydrogen and protection stability test of generator
15. Completion test of the power station

While some of the aforementioned activities pertain to the preoperational cleaning of piping systems, the remaining activities are conducted to ensure the integrity of critical equipment. Hence, preoperational activities, as laid down in this book, are addressed under Part 1 and Part 2, as categorized here:

Part 1: Preoperational Cleaning of Various Sub-Systems

Preoperational cleaning of various piping systems of modern thermal power plants assumes considerable importance because of the high-quality demand of flowing fluid, be it steam, water, oil, or gas, through different pipe lines. During the process of manufacturing, transportation, storing, and erection of various piping systems, in spite of taking the best precautionary measures, a certain amount of dirt, mill scale, oil, grease, and so on finds its way into these systems. These unwanted constituents need to be cleaned prior to putting into service "erected new piping" or "replaced old piping."

In running units, deposits may grow inside pipe lines due to improper water treatment or from process contamination. Corrosion inside the pipe lines of operating units may take place either

from an improperly controlled pH of demineralized makeup water or from concentration of boiler water salts.

In order to get rid of these undesirable elements from the piping systems of both new units and running units, as far as practicable, preoperational cleaning of piping systems is carried out. Based on the type of flowing fluids through various piping systems, different types of cleaning activities, as adopted in the industry, are discussed in the following chapters:

i. Chapter 3: Alkali flushing of preboiler system
ii. Chapter 4: Flushing of fuel oil piping system
iii. Chapter 5: Blowing of fuel gas piping system
iv. Chapter 6: Chemical cleaning of boiler
v. Chapter 7: Flushing of lube oil piping system
vi. Chapter 8: Steam/air blowing of main steam, cold reheat, hot reheat, and other steam pipe lines

Part 2: Activities that Make Critical Equipment Ready to Put Them in Service

This section addresses activities which are carried out to make critical equipment ready prior to putting it in service and to establish the integrity of this equipment, along with its associated systems. Activities covered in this section are:

i. Chapter 9: Hydraulic test of steam generator
ii. Chapter 10: Airtightness/leakage test of the furnace, air, and flue gas paths of steam generator
iii. Chapter 11: Steam generator initial firing and drying out of insulation
iv. Chapter 12: Floating of steam generator safety valves
v. Chapter 13: Clean airflow test of pulverizers
vi. Chapter 14: Condenser flood test and vacuum-tightness test
vii. Chapter 15: Generator drying out and air-tightness test
viii. Chapter 16: Filling of generator with hydrogen and protection stability test of generator
ix. Chapter 17: Completion test of the power station

As a prequel to Chapter 17, "Brief Description of Performance Guarantee Tests" is addressed in Appendix A.

Safety is a fundamental necessity for operating any plant. Hence, Appendix B lays down "General Safety Guidelines."

When a plant is in operation, under maintenance, or kept under mothballed condition, certain valves/areas/systems purposefully need to be kept isolated. Any attempt to violate such

isolation, even inadvertently, may lead to harm, injury, or major disaster of the plant and personnel. In order to obviate such an inadvertent attempt of violation, warning tags of various types are applied on isolated valves/areas/systems. Typical "Tagging Procedures" delineating various warning content are therefore presented in Appendix C of this book.

In accordance with current global practice, SI units have been used throughout the book. Nevertheless, for the convenience of readers, conversion factors from SI units to the metric system of units to the imperial and US system of units are addressed in Appendix D.

Reader suggestions for the improvement of the contents of this book are welcome, and would be acknowledged gratefully by the author.

Dipak K. Sarkar
June 30, 2016

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The overwhelming response I received from power engineers for my book *Thermal Power Plant—Design and Operation* prompted me to write this book. I am sincerely thankful to the power engineering community for motivating me in this regard. I also am indebted to my colleagues and friends in the industry for their advice on bridging the gap between the design and operation of a thermal power plant in the form of a book on preoperational activities. I am particularly grateful to Mr. Samiran Chakraboty, retired chief engineer, erstwhile M/S ACC Babcock Limited (ABL), currently M/S Alstom India Limited, who firmly expressed the necessity of a book on preoperational activities of a thermal power plant for the benefit of members of start-up, commissioning, and operation engineering departments.

I also am indebted to M/S Development Consultants Private Limited (DCPL) because while working in this organization I received exposure to a variety of technologies chosen by different manufacturers adopted in different countries, the benefits of which were reaped while writing this book.

Mr. S.K. Saha, general manager DCPL, an outstanding operation engineer, shared his long experience that helped me in preparing the manuscript. I gratefully acknowledge Mr. Saha's support.

While I was in DCPL I learnt many aspects of electrical system and electrical protection system from my the then colleagues Mr. P.S. Bhattacharya and Mr. S.K. Bhattacharya. Knowledge gathered thus was subsequently honed at the field. Chapters 15 and 16 might not have been developed by me without my interaction with both the Bhattacharyas. I am specially indebted to them.

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I am grateful to Elsevier for allowing me to borrow materials on system description from my previous book, *Thermal Power Plant—Design and Operation*. I also am indebted to the publishing and editorial team at Elsevier—Sarah Hughes, Joe Hayton, Cari Owen, Alex White, Lucy Beg, Poulouse Joseph and Victoria Pearson—for their support and guidance.

Dipak K. Sarkar
May 27, 2016

List of Acronyms/Abbreviations

μS	Microsiemens
a, abs	Absolute
A	Ash (content in coal)/ampere
ABMA	American Boiler Manufacturers Association
A/C	Air/cloth
AC	Alternating current/air conditioning
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
a.k.a.	Also known as
ANSI	American National Standards Institute
APC	Auxiliary power consumption
API	American Petroleum Institute
APS	Automatic plant start-up and shutdown system
AQC	Air quality control (ESP/bag filter and FGD)
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/citric acid
CAA	Clean Air Act, U.S.A.
CAAA	Clean air act amendments
CBD	Continuous blow down
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	(ComitéEuropéen de Normalisation)-European Committee for Standardization
CEP	Condensate extraction pump
CFBC	Circulating fluidized bed combustion
cfm	Cubic feet per minute
CFR	Cleaning force ratio
CHF	Critical heat flux
CHP	Combined heat and power