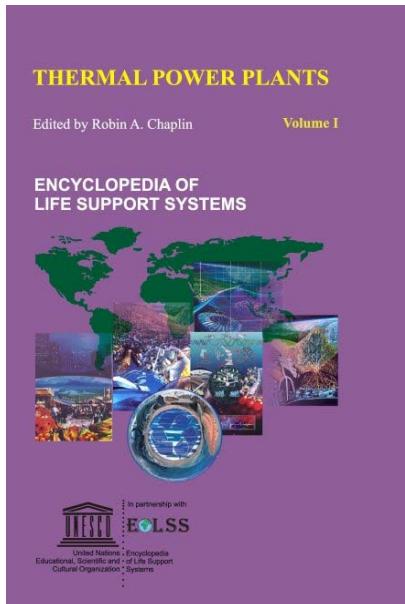


CONTENTS

THERMAL POWER PLANTS



Thermal Power Plants - Volume 1

No. of Pages: 378

ISBN: 978-1-905839-26-1 (eBook)

ISBN: 978-1-84826-926-2 (Print Volume)

Thermal Power Plants - Volume 2

No. of Pages: 380

ISBN: 978-1-905839-27-8 (eBook)

ISBN: 978-1-84826-927-9 (Print Volume)

Thermal Power Plants - Volume 3

No. of Pages: 366

ISBN: 978-1-905839-28-5 (eBook)

ISBN: 978-1-84826-928-6 (Print Volume)

For more information of e-book and Print Volume(s) order, please [click here](#)

Or contact : eolssunesco@gmail.com

CONTENTS

VOLUME I

Thermal Power Plants	1
Robin Anthony Chaplin, <i>University of New Brunswick, Canada</i>	
1. Technology Development	
1.1. Introduction	
1.2. Discovery	
1.3. Development	
1.4. Refinement	
2. Resource Development	
2.1. Resources for Heat Generation	
2.2. Use of Resources	
3. Environmental Effects	
3.1. General	
3.2. Ash Production	
3.3. Gaseous Emissions	
3.4. Nuclear Waste	
3.5. Cooling Water	
3.6. Fuel Supply	
3.7. Health Effects	
4. Power Production Evolution	
4.1. Mechanical Power	
4.2. Electrical Power	
4.3. Limits to Growth	
5. Technical Limitations	
5.1. Efficiency Limits	
5.2. Alternative Sources of Power	
5.3. Combined Cycles	
5.4. Material Limitations	
6. Capital Investment	
6.1. General Characteristics	
6.2. Capital and Operating Costs	
6.3. Financial Implications	
7. Power Plant Operation	
7.1. Operating Costs	
7.2. Load Variation	
7.3. Load Scheduling	
7.4. Operating Constraints	
7.5. Pumped Storage	
7.6. System Operation	
8. Location and Type	
8.1. Choice of Location	
8.2. Choice of Type	
8.3. Environmental Constraints	
9. Safety and Risk	
9.1. Safety Implications	
9.2. Risk of Power Generation	
9.3. Nuclear Safety	
9.4. Engineered Safeguards	
10. Future Prospects	
10.1. Controlling Factors	
10.2. Electricity Demand	
10.3. Fuel Availability	
10.4. Financial Resources	

- 10.5. Environmental Controls
- 10.6. Electrical Grid System
- 10.7. Combined Cycles
- 10.8. Life Extension
- 11. Renewable Resources
 - 11.1. Relative Importance and Feasibility
- 12. Energy Technologies
 - 12.1. Magnetohydrodynamics
 - 12.2. Fuel Cells
 - 12.3. Nuclear Fusion

Power Plant TechnologyRobin Anthony Chaplin, *University of New Brunswick, Canada***45**

- 1. Technological Decisions
 - 1.1. Scope of Topic
 - 1.2. Scientific Knowledge
 - 1.3. Engineering Experience
- 2. Fundamental Requirements
 - 2.1. Common Principles
 - 2.2. Capital Cost
 - 2.3. Fuel Cost
 - 2.4. Efficiency
 - 2.5. Availability
 - 2.6. Reliability
 - 2.7. Unplanned Maintenance
 - 2.8. Planned Maintenance
 - 2.9. Maintenance Costs
- 3. Environmental Considerations
 - 3.1. General Scope
 - 3.2. Plant Safety
 - 3.3. Environmental Safety
 - 3.4. Sustainability
- 4. Thermodynamic Cycles
 - 4.1. Basic Concepts
 - 4.2. Non-Flow Gas Cycles
 - 4.2.1. Otto cycle (Spark Ignition)
 - 4.2.2. Diesel Cycle (Compression Ignition)
 - 4.2.3. Dual Cycle
 - 4.3. Steady-Flow Gas Cycles
 - 4.3.1. Brayton Cycle
 - 4.3.2. Actual and Modified Cycles
 - 4.3.3. Regenerating Cycle
 - 4.3.4. Intercooling Cycle
 - 4.3.5. Reheating Cycle or Afterburning Cycle
 - 4.3.6. Turbojet Cycle
 - 4.4. Steady-Flow Steam Cycles
 - 4.4.1. Saturated Rankine Cycle
 - 4.4.2. Superheated Rankine Cycle
 - 4.4.3. Superheated-Reheated Rankine Cycle
 - 4.4.4. Saturated-Reheated Rankine Cycle
 - 4.4.5. Regenerative Cycle
 - 4.4.6. Actual and Modified Cycles
 - 4.5. Combined and Hybrid Cycles
 - 4.5.1. Combined Cycles
 - 4.5.2. Steam Injected Gas Turbine
 - 4.5.3. Pressurized Fluidized Beds

- 4.5.4. Nuclear Gas Turbines
- 5. Applications of Thermodynamic Cycles
 - 5.1. Governing Factors
 - 5.1.1. Plant Capacity
 - 5.1.2. Fuel Availability
 - 5.1.3. Plant Duty
 - 6. Heat and Energy Flows
 - 6.1. Thermal Cycle Efficiency
 - 6.2. Heat Transfer
 - 6.3. Energy and Exergy Flows
 - 6.4. Thermo-economic Analysis
 - 7. Fuels and Efficiency
 - 7.1. Calorific Value
 - 7.2. Combustion Calculations
 - 7.3. Efficiency Determination
 - 7.3.1 Input-output Method
 - 7.3.2 Heat Loss Method
 - 7.4. Gaseous Effluents
 - 7.5. Nuclear Fuel
 - 8. Metallurgy and Chemistry
 - 8.1. Material Selection
 - 8.2. Carbon Steel
 - 8.2.1. Carbon
 - 8.2.2. Manganese
 - 8.2.3. Molybdenum
 - 8.2.4. Chromium
 - 8.2.5. Nickel
 - 8.3. Other Metals
 - 8.3.1. Copper
 - 8.3.2. Titanium
 - 8.3.3. Nickel
 - 8.3.4. Zirconium
 - 8.4. Material Damage
 - 8.4.1. Fatigue Failure
 - 8.4.2. Creep Rupture
 - 8.4.3. Thermal Fatigue
 - 8.4.4. Overheating Damage
 - 8.4.5. Corrosion Damage
 - 8.4.6. Erosion Damage
 - 8.4.7. Radiation Damage
 - 8.5. Material Inspection
 - 8.5.1. Liquid Penetrant Testing
 - 8.5.2. Magnetic Particle Inspection
 - 8.5.3. Eddy Current Testing
 - 8.5.4. Ultrasonic Testing
 - 8.5.5. Radiography
 - 8.6. Water Chemistry
 - 8.7. Water Treatment
 - 8.8. Operation and Monitoring

Power Plant Combustion TheoryRobin Anthony Chaplin, *University of New Brunswick, Canada***90**

1. Combustion Fundamentals
 - 1.1 Definitions of combustion
 - 1.2 Principles of Combustion
 - 1.3 Combustion Equations

2. Combustion Calculations
 - 2.1 Concept of the Mole
 - 2.2 Composition of Air
 - 2.3 Excess Air Requirements
3. Energy Balances
 - 3.1 Plant Efficiency
 - 3.2 Boiler Efficiency (Input-Output Method)
 - 3.3 Boiler Efficiency (Heat Loss Method)
4. Air-Fuel Ratios
 - 4.1 Review
 - 4.2 Exhaust Gas Analysis
 - 4.3 Methods of Calculation
 - 4.3.1 The Mole Method
 - 4.3.2 The Joule Method (BTU Method)
5. Heat of Combustion
 - 5.1. Calorific Value
 - 5.2. Higher and Lower Heating Values
 - 5.3. Combustion Temperatures
6. Combustion products
 - 6.1. General
 - 6.2. Nitrogen Oxides
 - 6.3. Sulfur Dioxides

Nuclear Reactor TheoryRobin Anthony Chaplin, *University of New Brunswick, Canada***107**

1. Nuclear Physics
 - 1.1. Atomic Structure
 - 1.2. Atomic Notation
 - 1.3. Atomic Mass Scale
 - 1.4. Mass-Energy Equivalence
 - 1.5. Avogadro's Number
 - 1.6. Atomic Dimensions
2. Energy Levels
 - 2.1. Nuclear Structure
 - 2.2. Radio-Activity
 - 2.3. Binding Energy
3. Nuclear Interactions
 - 3.1. Neutron Interactions
 - 3.2. Fission
 - 3.2.1. Elastic Scattering (Elastic Collision)
 - 3.2.2. Inelastic Scattering (Inelastic Collision)
 - 3.2.3. Radiative Capture
 - 3.2.4. Nuclear Transmutation (Charged Particle Reaction)
 - 3.2.5. Neutron Producing Reaction
 - 3.2.6. Fission
 - 3.3. Neutron Flux
 - 3.4. Microscopic Cross-sections
 - 3.5. Macroscopic Cross-sections
 - 3.6. Reaction Rate
 - 3.7. Absorption Characteristics
4. Radiative Capture Models
 - 4.1. Variation in Neutron Absorption
 - 4.1.1. The $1/v$ Region
 - 4.1.2. The Resonance Region
 - 4.1.3. The Smooth Region
 - 4.2. Cross-sections

- 4.3. Log Mean Energy Decrement
- 4.4. Thermal Neutrons
- 5. Nuclear Energy
 - 5.1. Fission and Fusion
 - 5.2. Fission
 - 5.3. Fission Characteristics
 - 5.4. Fission Products
 - 5.5. Neutron Energy Spectrum
 - 5.6. Delayed Neutrons
 - 5.7. Fission Process Summary
- 6. Nuclear Reactors
 - 6.1. Fission Reaction Rate
 - 6.2. Nuclear Reactor Materials
 - 6.3. Homogeneous and Heterogeneous Arrangements
 - 6.4. Characteristics of Uranium Fuel
 - 6.5. Nuclear Reactor Configuration
 - 6.5.1. Neutron Leakage
 - 6.5.2. Heat Removal
 - 6.6. The Neutron Cycle
 - 6.6.1. The Four Factor Formula
 - 6.6.2. The Six Factor Formula

Thermal Fluid TheoryRobin Anthony Chaplin, *University of New Brunswick, Canada***145**

- 1. Introduction
 - 1.1. Heat Transfer
 - 1.2. Fluid Flow
- 2. Conduction
 - 2.1. General Conduction Equation
 - 2.2. Heat Generation and Conduction
 - 2.3. Heat Conduction through Cylindrical Walls
 - 2.4. Contact Resistance
 - 2.5. Composite Heat Transfer Paths
- 3. Convection
 - 3.1. General Convection Equation
 - 3.2. Empirical Formulae for Convection
 - 3.2.1. Nusselt Number Nu
 - 3.2.2. Grashof Number Gr
 - 3.2.3. Reynolds Number Re
 - 3.2.4. Prandtl Number Pr
- 4. Radiation
 - 4.1. Radiation Equation for Black Bodies
 - 4.2. Radiation Equation for Grey Bodies
 - 4.3. Radiation from Gases
- 5. Boiling and Condensing
 - 5.1. Phase Change Phenomena
 - 5.2. Pool Boiling
 - 5.3. Flow Boiling
 - 5.4. Boiling Heat Transfer
 - 5.5. Condensing Heat Transfer
- 6. Heat Exchangers
 - 6.1. Classification
 - 6.2. Heat Exchanger Heat Transfer
- 7. Two Phase Flow
 - 7.1. Flow Patterns
 - 7.2. Mass and Volume Fractions

- 7.3. Slip Ratio
- 8. Fluid Friction
 - 8.1. Single Phase Flow
 - 8.2. Two Phase Flow
- 9. Fluid Circulation
 - 9.1. Natural Circulation
 - 9.2. Forced Circulation
 - 9.3. Average Density

Thermodynamic TheoryRobin Anthony Chaplin, *University of New Brunswick, Canada***173**

- 1. Introduction
- 2. Fundamental Equations
 - 2.1. Equation of State
 - 2.2. Continuity Equation
 - 2.3. Energy equation
 - 2.4. Momentum Equation
- 3. Thermodynamic Laws
 - 3.1. The Laws of Thermodynamics
 - 3.2. Heat Engine Efficiency
 - 3.3. Heat Rate
 - 3.4. Carnot Cycle
 - 3.5. Available and Unavailable Energy
- 4. Thermodynamic Cycles
 - 4.1. The Carnot Cycle
 - 4.2. The Rankine Cycle
 - 4.3. The Brayton Cycle
 - 4.4. Entropy Changes
 - 4.5. Thermodynamic Processes
 - 4.5.1. Constant Pressure Process
 - 4.5.2. Constant Temperature Process
 - 4.5.3. Constant Entropy Process
 - 4.5.4. Constant Enthalpy Process
 - 4.6. Thermodynamic Diagrams
- 5. Steam Turbine Applications
 - 5.1. Introduction
 - 5.2. Turbine Processes
 - 5.3. Turbine Efficiency
 - 5.4. Reheating
 - 5.5. Feedwater Heating

Power Plant Steam Cycle TheoryRobin Anthony Chaplin, *University of New Brunswick, Canada***201**

- 1. Cycle Efficiencies
 - 1.1. Introduction
 - 1.2. Carnot Cycle
 - 1.3. Simple Rankine Cycles
 - 1.4. Complex Rankine Cycles
- 2. Turbine Expansion Lines
 - 2.1. T-s and h-s Diagrams
 - 2.2. Turbine Efficiency
 - 2.3. Turbine Configuration

2.4. Part Load Operation

Exergy Analysis

Robin Anthony Chaplin, *University of New Brunswick, Canada*

227

1. Introduction
 - 1.1. Theoretical Thermodynamic Cycle Concepts
 - 1.2. Practical Modifications to Cycle Concepts
 - 1.3. Reversible and Irreversible Processes
 - 1.3.1. Mixing of Fluids of Different Temperatures
 - 1.3.2. Heat Transfer Across a Temperature Difference
 - 1.3.3. Friction in a Flowing Fluid
2. Available Energy and Availability
 - 2.1. Available Energy Principles
 - 2.2. Availability as a Property
3. Heat Exchangers
 - 3.1. Application of Available Energy Principles
 - 3.2. Heat Exchanger Analysis
4. Steam Turbines
 - 4.1. Transfer of Available Energy
 - 4.2. Change of Heat Rejection Temperature
5. Complete Steam Cycle
 - 5.1. Exergy Analysis
 - 5.2. Example of Exergy Analysis
 - 5.3. Energy and Exergy Flow Diagrams
6. Thermo-economic Analysis
 - 6.1. Development of Exergy Concept
 - 6.2. Example of Thermo-economic Analysis
 - 6.3. Application of Thermo-economic Analysis

Power Plant Materials

Derek H. Lister, *University of New Brunswick, Canada*

261

1. Introduction
2. Metals and their Properties
 - 2.1. Steels
 - 2.2. Nickel Alloys
 - 2.3. Zirconium Alloys
 - 2.4. Magnesium Alloys
 - 2.5. Copper Alloys
 - 2.6. Titanium Alloys
3. Conclusion

Condition Assessment and Life Extension

Robin Anthony Chaplin, *University of New Brunswick, Canada*

275

1. Refurbishment versus Replacement
 - 1.1. General Economic Factors
 - 1.2. Development and Evolution
 - 1.3. Factors Affecting Refurbishment
2. Material Characteristics
 - 2.1. Aging Considerations
 - 2.2. Properties of Materials
 - 2.3. Selection of Materials
3. Plant Operational Conditions

- 3.1. General Plant Operation
- 3.2. Life Expectancy
- 4. Component Inspection and Testing
 - 4.1. Material Deterioration and Failure
 - 4.2. Non-destructive Testing Methods
 - 4.3. Applications of Testing Methods
- 5. Life Assessment
 - 5.1. Remaining Life of Components
 - 5.2. Fracture Mechanics
 - 5.3. Life Fraction Analysis
 - 5.4. Environmental Conditions
- 6. Inspection and Reassessment
 - 6.1. Periodic Inspection and Maintenance
 - 6.2. Life Extension Criteria
 - 6.3. General Philosophy

Index		303
--------------	--	------------

About EOLSS		311
--------------------	--	------------

VOLUME II

Production of Steam Robin Anthony Chaplin, <i>University of New Brunswick, Canada</i>	1
---	---

- 1. Introduction
- 2. Coal Gasification
 - 2.1. Fuel Characteristics
 - 2.2. Gasification Process
 - 2.3. Gasification Methods
 - 2.3.1. Moving Bed
 - 2.3.2. Fluidized Bed
 - 2.3.3. Entrained Flow
 - 2.4. Gas Utilization
- 3. Fuel Combustion
 - 3.1. General
 - 3.2. Stoker Firing
 - 3.3. Suspension Firing
 - 3.4. Fluidized Bed Combustion
 - 3.5. Pressurized Fluidized Bed Combustion
 - 3.6. Hybrid Combustion Systems
 - 3.7. Combustion Systems
- 4. Exhaust Gas Treatment
 - 4.1. Fuel Pretreatment
 - 4.2. Fuel Combustion
 - 4.3. Particulate Removal
 - 4.4. Sulfur Dioxide Removal
 - 4.5. Nitrogen Oxide Removal
- 5. Natural Heat Sources
 - 5.1. Non-Fuel Thermal Power
 - 5.2. Geothermal Energy
 - 5.2.1. Hydrothermal Systems
 - 5.2.2. Geopressurized Systems
 - 5.2.3. Petrothermal Systems
 - 5.3. Hydrothermal Systems

- 5.3.1. Vapor-dominated Systems
- 5.3.2. Liquid-dominated Systems
- 5.4. Solar Energy
 - 5.4.1. Parabolic Reflectors
 - 5.4.2. Central Receiver with Heliostats
- 6. Nuclear Heat Sources
 - 6.1. Nuclear Energy
 - 6.1.1. Fission Energy
 - 6.1.2. Fusion Energy
 - 6.2. Nuclear Fuel
 - 6.3. Breeder Reactors
- 7. Nuclear Reactor Developments
 - 7.1. Future Prospects
 - 7.2. Safety Features
 - 7.3. Construction Time
 - 7.4. Licensing Procedures
- 8. Advanced Reactor Designs
 - 8.1. New Reactors
 - 8.2. Design Features
 - 8.3. Advanced Reactor Design Features
 - 8.4. Advanced Passive Reactor Features
 - 8.5. New Breeder Reactor Features

Fossil Fuel Fired Boiler Plant Configuration

35

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Introduction
- 2. Basic Design
 - 2.1. Fundamentals
 - 2.2. Thermodynamic Guidelines
 - 2.3. Physical Arrangement
- 3. Boiler Structure
 - 3.1. Housing and Support
 - 3.2. Boiler Drum
 - 3.3. Water Walls
 - 3.4. Superheaters and Reheaters
 - 3.5. Economiser
 - 3.6. Boiler Burners
- 4. Boiler Auxiliaries
 - 4.1. Fuel Supply
 - 4.2. Ash Removal
 - 4.3. Air Heaters
 - 4.4. Inlet and Exhaust Fans
- 5. Boiler Back-end Components
 - 5.1. Environmental Protection
 - 5.2. Exhaust Gas Stack
 - 5.3. Particulate Collectors
 - 5.4. Desulfurization Equipment
 - 5.5. Nitrogen Oxide Reduction Equipment
 - 5.6. Carbon Dioxide Removal Equipment

Fossil Fuel Handling

54

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Liquid and Gaseous Fuel Handling
 - 1.1. General Characteristics

- 1.2. Transport and Storage
- 1.3. Environmental Considerations
- 2. Solid Fuel Handling
 - 2.1. General Characteristics
 - 2.2. Transport and Storage
 - 2.3. Environmental Considerations
- 3. Pulverising Mills
 - 3.1. Pulverising Principles
 - 3.2. Types of Pulverisers
 - 3.2.1. *Impact Mill*
 - 3.2.2. *Ring-roll Mill*
 - 3.2.3. *Ball-race Mill*
 - 3.2.4. *Tube Mill*
 - 3.3. Systems and Operation
 - 3.3.1. *Pulveriser Air Systems*
 - 3.3.2. *Pulveriser Operation*

Fossil Fuel Combustion SystemsRobin Anthony Chaplin, *University of New Brunswick, Canada***71**

- 1. Pulverized Coal Burners
 - 1.1. Pulverized Coal Supply
 - 1.2. Burner Arrangement
 - 1.2.1. Downshot Firing
 - 1.2.2. Horizontal Firing
 - 1.2.3. Tangential Firing
 - 1.3. Burner Types
 - 1.3.1. Wall Burners
 - 1.3.2. Corner Burners
 - 1.3.3. Low NO_x Burners
 - 1.4. Ignition Equipment
- 2. Cyclone Furnaces
 - 2.1. Principles
 - 2.1.1. Configuration
 - 2.1.2. Operation
- 3. Stokers
 - 3.1. Principles
 - 3.2. Retort Stokers
 - 3.3. Mass Feed Stokers
 - 3.4. Spreader Stokers
- 4. Fluidized Beds
 - 4.1. Principles
 - 4.2. Bubbling Fluidized Bed
 - 4.3. Circulating Fluidized Bed
- 5. Coal Gasification
 - 5.1. Principles
 - 5.2. Gas Turbine Systems
- 6. Gas and Oil
 - 6.1. General
 - 6.2. Gas Burners
 - 6.3. Oil Burners
 - 6.3.1. Pressure Atomized Burners
 - 6.3.2. Steam Atomizing Burners
 - 6.3.3. Air Atomized Burners
 - 6.4. Bitumen Emulsion and Coal Slurry Burners
- 7. Environmental Considerations
 - 7.1. Fuel Life Cycle and Alternative Fuels

- 7.2. Control of Emissions
- 7.3. Carbon versus Hydrogen

Fossil Fuel Fired Boiler Water-Steam System

94

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Furnace Design
 - 1.1. General Principles
 - 1.2. Ash Characteristics
- 2. Water Circulation
 - 2.1. Water Wall Configuration
 - 2.2. General Principles
 - 2.2.1. Natural Circulation
 - 2.2.2. Forced Circulation
 - 2.2.3. Once-Through Flow
 - 2.2.4. Once-Through Flow with Superimposed Recirculation
- 3. Boiler Drum
 - 3.1. General Principles
 - 3.2. Drum Internals
 - 3.3. Chemical Impurities
- 4. Superheaters and Reheaters
 - 4.1. Function
 - 4.2. Configuration
 - 4.3. Superheater Characteristics
 - 4.3.1. Convective Superheater
 - 4.3.2. Radiant Superheater
 - 4.4. Superheater Location
 - 4.5. Steam Temperature Control
 - 4.5.1. Firing System Manipulation
 - 4.5.2. Steam Desuperheating
 - 4.5.3. Gas Recirculation
 - 4.5.4. Gas Flow Variation
- 5. Economizers
 - 5.1. Configuration
 - 5.2. Design Principles

Fossil Fuel Fired Boiler Air and Gas Path

121

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. General Principles
 - 1.1. Combustion Requirements
 - 1.2. Primary and Secondary Air
 - 1.3. Air Ducting Arrangement
- 2. Fan Characteristics
 - 2.1. System Fans
 - 2.1.1. Forced Draught Fans
 - 2.1.2. Primary Air Fans
 - 2.1.3. Induced Draught Fans
 - 2.1.4. Gas Recirculating Fans
 - 2.2. Fan Design
 - 2.2.1. Radial Flow Fans
 - 2.2.2. Axial Flow Fans
 - 2.3. System Curves
 - 2.4. Operational Conditions
 - 2.5. Series and Parallel Arrangements
 - 2.5.1. Parallel Arrangement

- 2.5.2. Series Arrangement
- 2.6. Fan Operation
- 2.7. Furnace Explosions
- 2.8. Furnace Implosions
 - 2.8.1. No Change in Control Dampers
 - 2.8.2. Fast Response of Induced Draught Dampers
 - 2.8.3. Fast Response of Forced Draught Dampers
- 3. Air Heaters
 - 3.1. General
 - 3.2. Recuperative Air Heaters
 - 3.2.1. Tubular Air Heaters
 - 3.2.2. Plate Air Heaters
 - 3.2.3. Heat Pipe Air Heaters
 - 3.3. Regenerative Air Heaters
 - 3.3.1. Ljungstrom-type
 - 3.3.2. Rothemuhle-Type
 - 3.4. Exhaust Temperature Control
 - 3.4.1. Recirculation
 - 3.4.2. Bypassing
 - 3.4.3. Preheating
- 4. Sootblowers
 - 4.1. Ash and Slag
 - 4.2. Sootblowing Media
 - 4.3. Sootblower Types
 - 4.3.1. Short Retractable Furnace Wall Blowers
 - 4.3.2. Long Retractable Convection Surface Blowers
 - 4.3.3. Non-retractable Air Heater Blowers
- 5. Gas Cleanup Facilities
 - 5.1. Particulate Collection
 - 5.1.1. Electrostatic Precipitators
 - 5.1.2. Fabric Filters
 - 5.2. Gaseous Product Collection
 - 5.2.1. Desulphurization Equipment
 - 5.2.2. Nitrogen Oxide Removal Equipment
 - 5.3. Future Trends

Fossil Fuel Waste Product HandlingRobin Anthony Chaplin, *University of New Brunswick, Canada***158**

- 1. Exhaust Gas
 - 1.1. Exhaust Gas Constituents
- 2. Electrostatic Precipitators
 - 2.1. General Principles
 - 2.2. Design Aspects
 - 2.2.1. Ash Resistivity
 - 2.2.2. Drift Velocity
 - 2.2.3. Specific Collection Area
 - 2.2.4. Flow Area
 - 2.2.5. Treatment Time
 - 2.2.6. Aspect Ratio
 - 2.2.7. Plate Spacing
 - 2.3. Charging Wires
 - 2.4. Collecting Plates
 - 2.5. Wet Electrostatic Precipitators
- 3. Baghouses
 - 3.1. General Principles
 - 3.2. Configuration

- 3.3. Baghouse Types
 - 3.3.1. Reverse Air Fabric Filters
 - 3.3.2. Shaker Type Fabric Filters
 - 3.3.3. Shake–Deflate Fabric Filters
 - 3.3.4. Pulse Jet Fabric Filters
- 3.4. Filter Fabrics
- 3.5. Comparison with Electrostatic Precipitators
- 4. Flue Gas Desulfurization
 - 4.1. General
 - 4.2. Wet Limestone Scrubbers
 - 4.3. Dry Limestone Scrubbers
- 5. Nitrogen Oxides Removal
 - 5.1. General
 - 5.2. Selective Non-catalytic Reduction (SNCR)
 - 5.3. Selective Catalytic Reduction (SCR)
- 6. Carbon Dioxide
 - 6.1. Background
 - 6.2. Removal of Carbon Dioxide
 - 6.3. Disposal of Carbon Dioxide
 - 6.3.1. Underground Storage
 - 6.3.2. Undersea Disposal
- 7. Exhaust Gas Stacks
 - 7.1. General Requirements
- 8. Ash
 - 8.1. Ash Formation
 - 8.2. Types of Ash
 - 8.3. Ash Distribution
- 9. Ash Handling Systems
 - 9.1. Methods of Ash Removal
 - 9.1.1. Mechanical Systems
 - 9.1.2. Pneumatic Systems
 - 9.1.3. Hydraulic Systems
 - 9.2. Bottom Ash Removal
 - 9.3. Clinker Grinders
 - 9.4. Pneumatic Vacuum System
 - 9.5. Pneumatic Pressure System
- 10. Ash Disposal Systems
 - 10.1. Transport Methods
 - 10.2. Dry Ash Disposal
 - 10.3. Wet Ash Disposal
- 11. Environmental Considerations
 - 11.1. Choice of Fuel
 - 11.2. Choice of Clean-up System
 - 11.3. Role of Regulatory Requirements

Fossil Fuel Plant Materials and ChemistryDerek H. Lister, *University of New Brunswick, Canada***192**

- 1. Introduction: A Typical Plant
- 2. Materials Applications
 - 2.1. Boiler Plant
 - 2.2. Turbine Plant
- 3. Chemistry Considerations
 - 3.1. Fire/Combustion Side
 - 3.2. Steam/Water Side
 - 3.2.1. System Makeup Water Treatment
 - 3.2.2. Boiler Feedwater Treatment

4. Conclusion

Nuclear Reactor ConfigurationRobin Anthony Chaplin, *University of New Brunswick, Canada***212**

1. General Principles
 - 1.1. Fission Energy
 - 1.2. Nuclear Reactor Principles
 - 1.3. Fuel Burnup
2. Reactor Types
 - 2.1. Reactor Development
 - 2.2. Commercial Reactors in Service
3. The Pressurized Water Reactor (PWR)
 - 3.1. Reactor Core Arrangement
 - 3.2. Pressure Vessel Arrangement
 - 3.3. Coolant Loop Arrangement
 - 3.4. Steam Generators
4. The Boiling Water Reactor (BWR)
 - 4.1. Reactor Core Arrangement
 - 4.2. Pressure Vessel Arrangement
 - 4.3. Coolant Loop Arrangement
 - 4.4. Steam System
5. The Pressurized Heavy Water Reactor (PHWR) or CANDU
 - 5.1. Reactor Core Arrangement
 - 5.2. Coolant Loop Arrangement
 - 5.3. Steam Generators
6. The Advanced Gas Cooled Reactor (AGR)
 - 6.1. Reactor Core Arrangement
 - 6.2. Pressure Vessel Arrangement
 - 6.3. Coolant Loop Arrangement
 - 6.4. Steam Generators
7. The Light Water Graphite Reactor (LGR) or RMBK
 - 7.1. Reactor Core Configuration
 - 7.2. Coolant Loop Arrangement

Nuclear Reactor Heat RemovalRobin Anthony Chaplin, *University of New Brunswick, Canada***238**

1. Thermodynamic Considerations
 - 1.1. Gas Cooled Reactors
 - 1.2. Thermodynamic Cycle Efficiency
 - 1.3. Water Cooled Reactors
 - 1.4. Steam Cycle Efficiency
 - 1.5. Steam Conditions
 - 1.6. Nuclear Steam Cycles
 - 1.7. Heat Rejection
2. Reactor Heat Transfer
 - 2.1. Heat Generation
 - 2.2. Neutron Flux Variation
 - 2.2.1. Reduction of Neutron Leakage at the Periphery
 - 2.2.2. Variation in Fissile Fuel Density within the Core
 - 2.3. Nuclear Fuel Characteristics
 - 2.4. Heat Removal from Fuel
 - 2.5. Heat Transfer through Cladding
 - 2.6. Heat Transfer to Coolant
 - 2.7. Fuel Channel Conditions

2.8. Fuel Channel Pressure Drop

Nuclear Reactor Steam GenerationRobin Anthony Chaplin, *University of New Brunswick, Canada***261**

1. Steam Generation
 - 1.1. General Characteristics
 - 1.2. Circulation in Boiling Water Reactors
 - 1.3. Steam Generation in CANDU Reactors
 - 1.4. Steam Generators
 - 1.5. Steam Generator for PWR and CANDU Systems
 - 1.6. Heat Transfer
2. Steam Generator Operation
 - 2.1. Swelling and Shrinking
 - 2.1.1. Steady State Swelling and Shrinking
 - 2.1.2. Transient Swelling and Shrinking
 - 2.2. Level Control
 - 2.3. Carryover
 - 2.4. Steam Generator Boiler Tube Leak
3. Steam System
 - 3.1. Characteristics and Function
 - 3.2. Atmospheric Reject and Condenser Discharge Valves

Nuclear Reactor Materials and ChemistryDerek H. Lister, *University of New Brunswick, Canada***280**

1. Introduction - Reactor Types
2. Boiling Water Reactors
 - 2.1. General Description
 - 2.2. Materials and Chemistry Considerations
3. Pressurised Water Reactors
 - 3.1. General Description
 - 3.2. Materials and Chemistry Considerations
4. CANDU Reactors
 - 4.1. General Description
 - 4.2. Materials and Chemistry Considerations
5. Conclusion

Index**307****About EOLSS****313****VOLUME III****Production of Power**Robin Anthony Chaplin, *University of New Brunswick, Canada***1**

1. Introduction
 - 1.1. Prime Movers
 - 1.2. Scope of Topic
 - 1.3. Current Trends
2. Turbine Fundamentals
 - 2.1. Thermodynamic Cycle

- 2.2. Internal Efficiency
- 2.3. Momentum Principles
- 2.4. Energy principles
- 3. Turbine Types
 - 3.1. Turbines for Power Production
 - 3.2. Hydro Turbines
 - 3.3. Steam Turbines
 - 3.4. Gas Turbines
 - 3.5. Wind Turbines
- 4. Energy Storage
 - 4.1. General Considerations
 - 4.2. Pumped Storage
 - 4.3. Pump Turbines
 - 4.4. Compressed Air Storage
- 5. Combined Cycles
 - 5.1. General Principles
 - 5.2. Gas and Steam Turbine Matching
 - 5.3. Fuel Heating Value
- 6. Heat Rejection
 - 6.1. Importance of Heat Rejection
 - 6.2. Waste Heat and Cooling
 - 6.2.1. Waste Heat Dumping
 - 6.2.2. Cooling Systems
- 7. Heat Rejection Systems
 - 7.1. Basic Principles
 - 7.1.1. Steam-Boundary-Water System (Once-through Water-cooled Condenser System)
 - 7.1.2. Steam-Boundary-Water-Air System (Wet-cooled Cooling Tower System)
 - 7.1.3. Steam-Boundary-Water-Boundary-Air System (Indirect Dry-cooled Cooling Tower System)
 - 7.1.4. Steam-Water-Boundary-Air System (Heller System)
 - 7.1.5. Steam-Boundary-Air System (Direct Dry-cooled System)
 - 7.2. Dry Cooling Systems
- 8. Future Developments
 - 8.1. General Considerations
 - 8.2. Life Extension
 - 8.3. Major Modifications
 - 8.3.1. Upgrading
 - 8.3.2. Fuel Switching
 - 8.3.3. Repowering
 - 8.4. Future Outlook

Steam Turbine Configuration

37

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Design Principles
 - 1.1. Introduction
 - 1.2. Configuration
- 2. Design Features
 - 2.1. Large Steam Turbine Examples
 - 2.2. Erection and Maintenance
 - 2.3. Steam Path Components

Steam Turbine Impulse and Reaction Blading

57

Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Turbine Classification

- 1.1. Blade Profiles
- 1.2. Impulse and Reaction
- 2. Velocity Diagrams
 - 2.1. General Relationships
 - 2.2. Momentum Principle
 - 2.2.1. Impulse Blading
 - 2.2.2. Reaction Blading
 - 2.3. Blade Efficiency
 - 2.4. Energy Principle
 - 2.4.1. Impulse Blading
 - 2.4.2. Reaction Blading
 - 2.5. Impulse Blading
 - 2.6. Reaction Blading
 - 2.7. Whirl Velocity
- 3. Stage Design
 - 3.1. Number of Stages
 - 3.1.1. Impulse Blading
 - 3.1.2. Reaction Blading
 - 3.1.3. Impulse Blading
 - 3.1.4. Reaction Blading
 - 3.2. Stage Efficiency

Steam Turbine Components and Systems**89**Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Turbine Cylinder Configuration
 - 1.1. Introduction
 - 1.2. Turbine Cylinders
 - 1.3. Turbine Rotors
 - 1.4. Turbine Blading
- 2. Turbine Seals
 - 2.1. General Principles
 - 2.2. Gland Sealing
 - 2.3. Gland Steam System
- 3. Turbine Bearings
 - 3.1. General Requirements
 - 3.2. Bearing Lubrication
 - 3.3. Fire Resisting Fluid

Steam Turbine Steam System**122**Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Main Steam System
 - 1.1. General
 - 1.2. Fossil Fuel Fired Units
 - 1.3. Nuclear Reactor Units
 - 1.4. Steam System Operation
 - 1.5. Condenser Steam Discharge Valves
- 2. Reheating and Feedheating
 - 2.1. Reheaters
 - 2.2. Deaerator
 - 2.3. Feedwater Heaters
- 3. Condenser
 - 3.1. Introduction
 - 3.2. Thermodynamics and Heat Transfer
 - 3.3. Turbine Limitations

- 3.4. Environmental Limitations
- 3.5. Condenser Tube Fouling
- 4. Condenser Operation
 - 4.1. Cooling Water Circuit
 - 4.2. Flow Transients
 - 4.3. Variation in Condenser Vacuum
 - 4.4. Causes of Poor Condenser Vacuum
 - 4.4.1. Increased Cooling Water Temperature
 - 4.4.2. Reduced Cooling Water Flowrate
 - 4.4.3. Abnormally Large Thermal Load on Condenser
 - 4.4.4. Tube Fouling
 - 4.4.5. Tube Flooding
 - 4.4.6. Tube Draining
 - 4.4.7. Accumulation of Gases in the Steam Space
 - 4.5. Condenser Vacuum Raising
 - 4.6. Condenser Vacuum Breaking
 - 4.7. Condenser Leaks

Steam Turbine Operational Aspects**145**Robin Anthony Chaplin, *University of New Brunswick, Canada*

- 1. Turbine Losses
 - 1.1. Categorization of Losses
- 2. Supersaturation
 - 2.1. Metastable Conditions
- 3. Turbine Expansion Line
 - 3.1. Steam Conditions
- 4. Moisture in Turbine
 - 4.1. Water Formation
 - 4.2. Erosion Damage
 - 4.3. Water Extraction
- 5. Part Load Operation
 - 5.1. Turbine Load Variation
- 6. Turbine Back Pressure
 - 6.1. Condenser Pressure
 - 6.2. Air Extraction
- 7. Thermal Effects
 - 7.1. Thermal Stress
 - 7.2. Differential Expansion
 - 7.3. Shaft Catenary
- 8. Turbine Governing
 - 8.1. Purpose and Operation
 - 8.2. Turbine Responses
 - 8.3. Reactor or Boiler Trip
 - 8.4. Turbine Trip
 - 8.4.1. Non-sequential Trip
 - 8.4.2. Sequential Trip
 - 8.5. Steam Flow Control
 - 8.6. Load Rejection
 - 8.7. Turbine Overspeed Protection
 - 8.8. Steam Bypass Operation

Air-Cooled Heat Exchangers and Cooling Towers**181**Detlev G. Kroger, *University of Stellenbosch, South Africa*

- 1. Introduction

2. Cooling Towers
 - 2.1. Mechanical Draft
 - 2.2. Natural Draft
3. Air-cooled Heat Exchangers
 - 3.1. Mechanical Draft
 - 3.2. Natural Draft
4. Dry/wet and wet/dry Cooling Systems

Gas Turbine FundamentalsH.I.H. Saravanamuttoo, *Carleton University, Canada***223**

1. Gas Turbines for Electric Power Generation : Introduction
2. Basics of gas turbine operation
3. Ideal Cycles
 - 3.1. Simple Gas Turbine Cycle
 - 3.2. Modifications to the Simple Cycle
 - 3.2.1. Heat Exchange Cycle
 - 3.2.2. Reheat Cycle
 - 3.2.3. Intercooling
 - 3.2.4. Heat Exchange, Reheat and Intercooling
4. Real Cycles
 - 4.1. Typical Performance Results
5. Combined Cycles
6. Cogeneration Plant
7. Off-design Performance

Gas Turbines for Electric Power GenerationH.I.H. Saravanamuttoo, *Carleton University, Canada***246**

1. Introduction
 - 1.1. Large Scale Base Load
 - 1.2. Peak-Load and Emergency Systems
 - 1.3. Co-generation or Combined Heat and Power
 - 1.4. Off-Shore Power Generation
 - 1.5. Distributed Small Scale Base Load
 - 1.6. Repowering
2. Current gas turbines
 - 2.1. Heavy Frame Gas Turbines
 - 2.2. Light Industrial Gas Turbines
 - 2.3. Aero-derivative Gas Turbines
3. Combined cycles
 - 3.1. Korea Electric (Seoinchon)
 - 3.2. Portugal (Tapado do Outeiro)
 - 3.3. Germany (Rheinhafen)
4. Cogeneration
 - 4.1. Canada (Ottawa)
 - 4.2. Netherlands (Hertogenbosch)

Fundamentals of Electric Power GenerationRobin Anthony Chaplin, *University of New Brunswick, Canada***262**

1. Electrical Power Theory
 - 1.1. Electrical Energy
 - 1.2. Direct and Alternating Current
 - 1.3. Three-Phase Systems

- 1.4. Star and Delta Connections
- 1.5. Phasor Representation
- 2. Electrical Generators
 - 2.1. General Theory
- 3. Electrical Transformers
 - 3.1. General Theory
 - 3.2. Transformer Connections
- 4. Electrical Generator Configuration
 - 4.1. Generator Rotor
 - 4.2. Generator Stator
 - 4.3. Excitation System
 - 4.4. Generator Systems
- 5. Power Transmission Components
 - 5.1. Generator Main Connections
 - 5.2. Generator Circuit Breakers
 - 5.3. Generator Transformer
 - 5.4. Switching Station
 - 5.5. Transmission Lines
 - 5.6. Grid System

Index **295**

About EOLSS **299**