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DOE FUNDAMENTALS HANDBOOK

THERMODYNAMICS, HEAT TRANSFER, AND FLUID FLOW

 Volume 2 of 3



U.S. Department of Energy
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ABSTRACT

The *Thermodynamics, Heat Transfer, and Fluid Flow Fundamentals Handbook* was developed to assist nuclear facility operating contractors provide operators, maintenance personnel, and the technical staff with the necessary fundamentals training to ensure a basic understanding of the thermal sciences. The handbook includes information on thermodynamics and the properties of fluids; the three modes of heat transfer - conduction, convection, and radiation; and fluid flow, and the energy relationships in fluid systems. This information will provide personnel with a foundation for understanding the basic operation of various types of DOE nuclear facility fluid systems.

Key Words: Training Material, Thermodynamics, Heat Transfer, Fluid Flow, Bernoulli's Equation

FOREWORD

The *Department of Energy (DOE) Fundamentals Handbooks* consist of ten academic subjects, which include Mathematics; Classical Physics; Thermodynamics, Heat Transfer, and Fluid Flow; Instrumentation and Control; Electrical Science; Material Science; Mechanical Science; Chemistry; Engineering Symbology, Prints, and Drawings; and Nuclear Physics and Reactor Theory. The handbooks are provided as an aid to DOE nuclear facility contractors.

These handbooks were first published as Reactor Operator Fundamentals Manuals in 1985 for use by DOE Category A reactors. The subject areas, subject matter content, and level of detail of the Reactor Operator Fundamentals Manuals was determined from several sources. DOE Category A reactor training managers determined which materials should be included, and served as a primary reference in the initial development phase. Training guidelines from the commercial nuclear power industry, results of job and task analyses, and independent input from contractors and operations-oriented personnel were all considered and included to some degree in developing the text material and learning objectives.

The *DOE Fundamentals Handbooks* represent the needs of various DOE nuclear facilities' fundamentals training requirements. To increase their applicability to nonreactor nuclear facilities, the Reactor Operator Fundamentals Manual learning objectives were distributed to the Nuclear Facility Training Coordination Program Steering Committee for review and comment. To update their reactor-specific content, DOE Category A reactor training managers also reviewed and commented on the content. On the basis of feedback from these sources, information that applied to two or more DOE nuclear facilities was considered generic and was included. The final draft of each of these handbooks was then reviewed by these two groups. This approach has resulted in revised modular handbooks that contain sufficient detail such that each facility may adjust the content to fit their specific needs.

Each handbook contains an abstract, a foreword, an overview, learning objectives, and text material, and is divided into modules so that content and order may be modified by individual DOE contractors to suit their specific training needs. Each subject area is supported by a separate examination bank with an answer key.

The *DOE Fundamentals Handbooks* have been prepared for the Assistant Secretary for Nuclear Energy, Office of Nuclear Safety Policy and Standards, by the DOE Training Coordination Program. This program is managed by EG&G Idaho, Inc.

OVERVIEW

The *Department of Energy Fundamentals Handbook* entitled *Thermodynamics, Heat Transfer, and Fluid Flow* was prepared as an information resource for personnel who are responsible for the operation of the Department's nuclear facilities. A basic understanding of the thermal sciences is necessary for DOE nuclear facility operators, maintenance personnel, and the technical staff to safely operate and maintain the facility and facility support systems. The information in the handbook is presented to provide a foundation for applying engineering concepts to the job. This knowledge will help personnel more fully understand the impact that their actions may have on the safe and reliable operation of facility components and systems.

The *Thermodynamics, Heat Transfer, and Fluid Flow* handbook consists of three modules that are contained in three volumes. The following is a brief description of the information presented in each module of the handbook.

Volume 1 of 3

Module 1 - Thermodynamics

This module explains the properties of fluids and how those properties are affected by various processes. The module also explains how energy balances can be performed on facility systems or components and how efficiency can be calculated.

Volume 2 of 3

Module 2 - Heat Transfer

This module describes conduction, convection, and radiation heat transfer. The module also explains how specific parameters can affect the rate of heat transfer.

Volume 3 of 3

Module 3 - Fluid Flow

This module describes the relationship between the different types of energy in a fluid stream through the use of Bernoulli's equation. The module also discusses the causes of head loss in fluid systems and what factors affect head loss.

The information contained in this handbook is by no means all encompassing. An attempt to present the entire subject of thermodynamics, heat transfer, and fluid flow would be impractical. However, the *Thermodynamics, Heat Transfer, and Fluid Flow* handbook does present enough information to provide the reader with a fundamental knowledge level sufficient to understand the advanced theoretical concepts presented in other subject areas, and to better understand basic system and equipment operations.

**Department of Energy
Fundamentals Handbook**

**THERMODYNAMICS, HEAT TRANSFER,
AND FLUID FLOW,
Module 2
Heat Transfer**

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TERMINAL OBJECTIVE

- 1.0 Given the operating conditions of a thermodynamic system and the necessary formulas, **EVALUATE** the heat transfer processes which are occurring.

ENABLING OBJECTIVES

- 1.1 **DESCRIBE** the difference between heat and temperature.
- 1.2 **DESCRIBE** the difference between heat and work.
- 1.3 **DESCRIBE** the Second Law of Thermodynamics and how it relates to heat transfer.
- 1.4 **DESCRIBE** the three modes of heat transfer.
- 1.5 **DEFINE** the following terms as they relate to heat transfer:
- Heat flux
 - Thermal conductivity
 - Log mean temperature difference
 - Convective heat transfer coefficient
 - Overall heat transfer coefficient
 - Bulk temperature
- 1.6 Given Fourier's Law of Conduction, **CALCULATE** the conduction heat flux in a rectangular coordinate system.
- 1.7 Given the formula and the necessary values, **CALCULATE** the equivalent thermal resistance.
- 1.8 Given Fourier's Law of Conduction, **CALCULATE** the conduction heat flux in a cylindrical coordinate system.
- 1.9 Given the formula for heat transfer and the operating conditions of the system, **CALCULATE** the rate of heat transfer by convection.
- 1.10 **DESCRIBE** how the following terms relate to radiant heat transfer:
- Black body radiation
 - Emissivity
 - Radiation configuration factor

ENABLING OBJECTIVES (Cont.)

- 1.11 **DESCRIBE** the difference in the temperature profiles for counter-flow and parallel flow heat exchangers.
- 1.12 **DESCRIBE** the differences between regenerative and non-regenerative heat exchangers.
- 1.13 Given the temperature changes across a heat exchanger, **CALCULATE** the log mean temperature difference for the heat exchanger.
- 1.14 Given the formulas for calculating the conduction and convection heat transfer coefficients, **CALCULATE** the overall heat transfer coefficient of a system.
- 1.15 **DESCRIBE** the process that occurs in the following regions of the boiling heat transfer curve:
- a. Nucleate boiling
 - b. Partial film boiling
 - c. Film boiling
 - d. Departure from nucleate boiling (DNB)
 - e. Critical heat flux