



## Fluid Flow

**Course Number:** ME-02-104

**PDH:** 4

**Approved for:** AK, AL, AR, DE, FL, GA, IA, ID, IL, IN, KS, KY, LA, MD, ME, MI, MN, MO, MS, MT, NC, ND, NE, NH, NJ, NM, NV, NY, OH, OK, OR, PA, SC, SD, TN, TX, UT, VA, VT, WI, WV, and WY

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## Fluid Flow Fundamentals

### Learning Objectives

By the end of this introductory section, you will be able to:

- **Identify** the three primary modules of the thermal science series.
- **Recall** the core engineering principles covered in the Fluid Flow handbook.
- **Navigate** the course structure based on the professional learning objectives.

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*Executive Summary: This course provides the foundational knowledge of thermal sciences—thermodynamics, heat transfer, and fluid flow—necessary for the safe and reliable operation of nuclear and industrial fluid systems. This specific module focuses on the energy relationships within fluid streams and the mechanics of head loss.*

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### Program Overview

This course is designed as a comprehensive resource for engineering professionals. A deep understanding of the thermal sciences is not merely academic; it is a prerequisite for the safe maintenance and operation of complex facility support systems. The content is structured to facilitate the application of engineering concepts to real-world scenarios.

The complete Fundamentals Handbook is divided into three distinct volumes:

- **Volume 1: Thermodynamics**  
Focuses on fluid properties, energy balances, and efficiency calculations.
- **Volume 2: Heat Transfer**  
Covers the three modes of heat transfer: conduction, convection, and radiation.
- **Volume 3: Fluid Flow**  
Analyzes the relationship between different types of energy in a fluid stream and the factors affecting head loss.

### Fluid Flow Scope

This module serves as a deep dive into the mechanics of moving fluids. We will move beyond basic definitions to explore the practical application of:

- **The Continuity Equation:** Mastering mass and volumetric flow relationships.
- **Bernoulli's Equation:** Evaluating energy conversions between velocity, elevation, and pressure.



- **Head Loss Dynamics:** Calculating frictional and minor losses using Darcy's Equation and the Moody Chart.
- **System Components:** Analyzing the performance of centrifugal pumps and the complexities of two-phase flow.

💡 **Design Tip:** While the manual provides a broad overview, focus your attention on the "shall" and "should" statements throughout the modules. These distinguish between absolute physical laws (like Conservation of Mass) and engineering optimizations (like pump curve selection).

## Continuity Equation

### Learning Objectives

By the end of this section, you will be able to:

- **Evaluate** the relationship between fluid density, depth, and pressure in stationary and moving systems.
- **Calculate** mass and volumetric flow rates using cross-sectional area and fluid velocity.
- **Apply** the continuity equation to solve for unknown velocities in single-path and multi-path piping configurations.

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*Executive Summary: The continuity equation is the mathematical application of the Principle of Conservation of Mass to fluid systems. In steady-state flow, the mass entering a control volume must equal the mass leaving it, meaning that any change in pipe area or fluid density must be balanced by a corresponding change in velocity.*

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## Introduction to Fluid Dynamics

Fluid flow is a fundamental component of most industrial processes, particularly those involving heat transfer. Whether you are analyzing cooling water in an engine, airflow through motor windings, or coolant moving through a reactor core, understanding how fluids move is critical for predicting system response. While fluid particles move at varying velocities and accelerations, you can apply simplified concepts and average values to accurately predict system behavior under various operating parameters.

### Fluid Characteristics and Behavior

A fluid is any substance that flows because its particles are not rigidly attached to one another. This definition encompasses liquids, gases, and even materials like glass that lack a repeating crystalline structure.

### Density and Temperature Relationship

Fluid density is the mass of a substance per unit volume, while specific volume is the volume per unit mass. These properties are dependent on temperature:

- As temperature increases, density decreases and specific volume increases.
- Conversely, as temperature decreases, density increases.

## Buoyant Forces and Submerged Bodies

Buoyancy is the tendency of a body to float or rise when submerged in a fluid. This effect is governed by Archimedes' Principle, which states that a body in a fluid is buoyed up by a force equal to the weight of the fluid it displaces.

- If an object weighs more than the displaced liquid, it sinks but loses "apparent weight" equal to the displaced liquid's weight.
- A floating body displaces a volume of liquid exactly equal to its own weight.

## Fluid Compressibility

Compressibility measures the volume change a substance undergoes when subjected to external pressure.

- **Liquids:** Generally considered incompressible. For example, water volume decreases by only 5% even under 16,400 psig of pressure.
- **Gases:** Highly compressible; their volume changes readily with pressure.

## Hydrostatic Pressure Principles

In a stationary liquid, pressure is directly proportional to depth. This pressure is exerted equally in all directions at a given depth and is caused by the weight of the fluid column above that point.

Equation 1-1:

$$P = \frac{\rho h g}{g_c}$$

Where:

- **P** = Pressure (lb/ft<sup>2</sup>)
- **$\rho$**  = Density of fluid (lbm/ft<sup>3</sup>)
- **h** = Height or depth of the column (ft)
- **g** = Acceleration due to gravity (32.17 ft/sec<sup>2</sup>)
- **$g_c$**  = Gravitational constant (32.17 lbm-ft/lbf-sec<sup>2</sup>)

💡 **Design Tip:** The pressure at the bottom of a column depends only on depth and density, not the shape or area of the container. A 30-foot deep pipe exerts the same bottom pressure as a 30-foot deep lake.

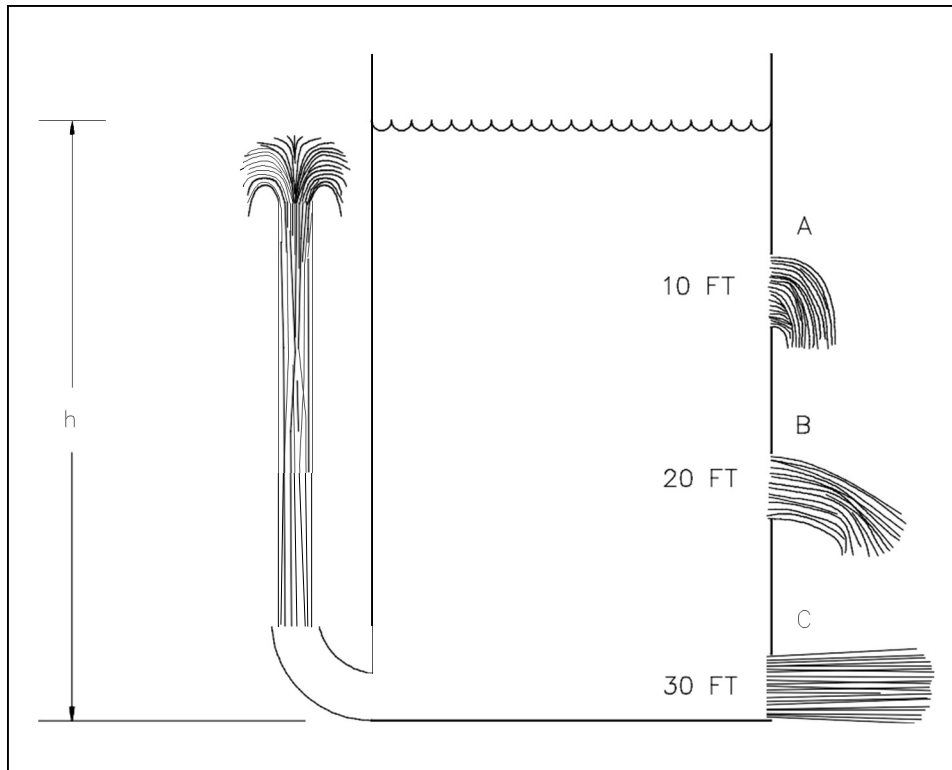


Figure 1: Pressure Versus Depth

### Pascal's Law in Confined Systems

Pascal's Law states that pressure applied to a confined fluid is transmitted undiminished throughout the fluid and to the walls of the containing vessel. In a system with multiple pistons of equal area, an external force applied to one piston increases the pressure at all points by the same amount.



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