



Fluid Flow

Course Number: ME-02-104

PDH: 4

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Course Author: Mathew Holstrom

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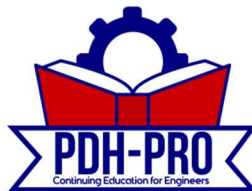
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TERMINAL OBJECTIVE

- 1.0 Given conditions affecting the fluid flow in a system, **EVALUATE** the effects on the operation of the system.

LEARNING OBJECTIVES

- 1.1 **DESCRIBE** how the density of a fluid varies with temperature.
- 1.2 **DEFINE** the term buoyancy.
- 1.3 **DESCRIBE** the relationship between the pressure in a fluid column and the density and depth of the fluid.
- 1.4 **STATE** Pascal's Law.
- 1.5 **DEFINE** the terms mass flow rate and volumetric flow rate.
- 1.6 **CALCULATE** either the mass flow rate or the volumetric flow rate for a fluid system.
- 1.7 **STATE** the principle of conservation of mass.
- 1.8 **CALCULATE** the fluid velocity or flow rate in a specified fluid system using the continuity equation.
- 1.9 **DESCRIBE** the characteristics and flow velocity profiles of laminar flow and turbulent flow.
- 1.10 **DEFINE** the property of viscosity.
- 1.11 **DESCRIBE** how the viscosity of a fluid varies with temperature.
- 1.12 **DESCRIBE** the characteristics of an ideal fluid.
- 1.13 **DESCRIBE** the relationship between the Reynolds number and the degree of turbulence of the flow.
- 1.14 **DESCRIBE** the relationship between Bernoulli's equation and the First Law of Thermodynamics.

ENABLING OBJECTIVES (Cont.)

- 1.15 **DEFINE** the term head with respect to its use in fluid flow.
- 1.16 **EXPLAIN** the energy conversions that take place in a fluid system between the velocity, elevation, and pressure heads as flow continues through a piping system.
- 1.17 Given the initial and final conditions of the system, **CALCULATE** the unknown fluid properties using the simplified Bernoulli equation.
- 1.18 **DESCRIBE** the restrictions applied to Bernoulli's equation when presented in its simplest form.
- 1.19 **EXPLAIN** how to extend the Bernoulli equation to more general applications.
- 1.20 **RELATE** Bernoulli's principle to the operation of a venturi.
- 1.21 **DEFINE** the terms head loss, frictional loss, and minor losses.
- 1.22 **DETERMINE** friction factors for various flow situations using the Moody chart.
- 1.23 **CALCULATE** the head loss in a fluid system due to frictional losses using Darcy's equation.
- 1.24 **CALCULATE** the equivalent length of pipe that would cause the same head loss as the minor losses that occur in individual components.
- 1.25 **DEFINE** natural circulation and forced circulation.
- 1.26 **DEFINE** thermal driving head.
- 1.27 **DESCRIBE** the conditions necessary for natural circulation to exist.
- 1.28 **EXPLAIN** the relationship between flow rate and temperature difference in natural circulation flow.
- 1.29 **DESCRIBE** how the operator can determine whether natural circulation exists in the reactor coolant system and other heat removal systems.
- 1.30 **DESCRIBE** how to enhance natural circulation flow.
- 1.31 **DEFINE** two-phase flow.

ENABLING OBJECTIVES (Cont.)

- 1.32 **DESCRIBE** two-phase flow including such phenomena as bubbly, slug, and annular flow.
- 1.33 **DESCRIBE** the problems associated with core flow oscillations and flow instability.
- 1.34 **DESCRIBE** the conditions that could lead to core flow oscillation and instability.
- 1.35 **DESCRIBE** the phenomenon of pipe whip.
- 1.36 **DESCRIBE** the phenomenon of water hammer.
- 1.37 **DEFINE** the terms net positive suction head and cavitation.
- 1.38 **CALCULATE** the new volumetric flow rate, head, or power for a variable speed centrifugal pump using the pump laws.
- 1.39 **DESCRIBE** the effect on system flow and pump head for the following changes:
 - a. Changing pump speeds
 - b. Adding pumps in parallel
 - c. Adding pumps in series

CONTINUITY EQUATION

Understanding the quantities measured by the volumetric flow rate and mass flow rate is crucial to understanding other fluid flow topics. The continuity equation expresses the relationship between mass flow rates at different points in a fluid system under steady-state flow conditions.

- EO 1.1** **DESCRIBE** how the density of a fluid varies with temperature.
 - EO 1.2** **DEFINE** the term buoyancy.
 - EO 1.3** **DESCRIBE** the relationship between the pressure in a fluid column and the density and depth of the fluid.
 - EO 1.4** **STATE** Pascal's Law.
 - EO 1.5** **DEFINE** the terms mass flow rate and volumetric flow rate.
 - EO 1.6** **CALCULATE** either the mass flow rate or the volumetric flow rate for a fluid system.
 - EO 1.7** **STATE** the principle of conservation of mass.
 - EO 1.8** **CALCULATE** the fluid velocity or flow rate in a specified fluid system using the continuity equation.
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Introduction

Fluid flow is an important part of most industrial processes; especially those involving the transfer of heat. Frequently, when it is desired to remove heat from the point at which it is generated, some type of fluid is involved in the heat transfer process. Examples of this are the cooling water circulated through a gasoline or diesel engine, the air flow past the windings of a motor, and the flow of water through the core of a nuclear reactor. Fluid flow systems are also commonly used to provide lubrication.

Fluid flow in the nuclear field can be complex and is not always subject to rigorous mathematical analysis. Unlike solids, the particles of fluids move through piping and components at different velocities and are often subjected to different accelerations.

Even though a detailed analysis of fluid flow can be extremely difficult, the basic concepts involved in fluid flow problems are fairly straightforward. These basic concepts can be applied in solving fluid flow problems through the use of simplifying assumptions and average values, where appropriate. Even though this type of analysis would not be sufficient in the engineering design of systems, it is very useful in understanding the operation of systems and predicting the approximate response of fluid systems to changes in operating parameters.

The basic principles of fluid flow include three concepts or principles; the first two of which the student has been exposed to in previous manuals. The first is the principle of momentum (leading to equations of fluid forces) which was covered in the manual on Classical Physics. The second is the conservation of energy (leading to the First Law of Thermodynamics) which was studied in thermodynamics. The third is the conservation of mass (leading to the continuity equation) which will be explained in this module.

Properties of Fluids

A *fluid* is any substance which flows because its particles are not rigidly attached to one another. This includes liquids, gases and even some materials which are normally considered solids, such as glass. Essentially, fluids are materials which have no repeating crystalline structure.

Several properties of fluids were discussed in the Thermodynamics section of this text. These included temperature, pressure, mass, specific volume and density. *Temperature* was defined as the relative measure of how hot or cold a material is. It can be used to predict the direction that heat will be transferred. *Pressure* was defined as the force per unit area. Common units for pressure are pounds force per square inch (psi). *Mass* was defined as the quantity of matter contained in a body and is to be distinguished from weight, which is measured by the pull of gravity on a body. The *specific volume* of a substance is the volume per unit mass of the substance. Typical units are ft^3/lbm . *Density*, on the other hand, is the mass of a substance per unit volume. Typical units are lbm/ft^3 . Density and specific volume are the inverse of one another. Both density and specific volume are dependent on the temperature and somewhat on the pressure of the fluid. As the temperature of the fluid increases, the density decreases and the specific volume increases. Since liquids are considered incompressible, an increase in pressure will result in no change in density or specific volume of the liquid. In actuality, liquids can be slightly compressed at high pressures, resulting in a slight increase in density and a slight decrease in specific volume of the liquid.

Buoyancy

Buoyancy is defined as the tendency of a body to float or rise when submerged in a fluid. We all have had numerous opportunities of observing the buoyant effects of a liquid. When we go swimming, our bodies are held up almost entirely by the water. Wood, ice, and cork float on water. When we lift a rock from a stream bed, it suddenly seems heavier on emerging from the water. Boats rely on this buoyant force to stay afloat. The amount of this buoyant effect was first computed and stated by the Greek philosopher Archimedes. When a body is placed in a fluid, it is buoyed up by a force equal to the weight of the water that it displaces.



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