



Steady State, Open-System Devices

A Chemical Engineering Lesson
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Overview:

In *Steady State Devices*, students learn about steady-state, open-system devices (such as turbines, pumps, nozzles, etc.) through the cooperative learning exercise *Jigsaw*. Using this method, different students study different aspects of these devices, becoming the “experts” on only their given aspect. The class then comes back together to teach each other about the devices as a whole.

Learning Objectives or Student Outcomes:

By the end of this lesson, students will be able to

1. knowledgeably describe a specific steady-state, open-system device through the completion of both an individual and a group information sheet.

Length of Lesson:

1 to 1.5 hours of in-class time. Follow up review of material in the course textbook will take additional out-of-class time.

Assignment(s) to Ensure Student Preparation:

None of the reading needs to be done before this lesson begins.

Team Size and Composition:

The number of groups will depend on the number of students in the class. For example, if there are only 28 people, there will be 7 groups of 4—one group for each device. If the class has 56 people, it might be better to do 14 groups of 4—two groups for each device. Groups larger than 5 can be difficult for students to manage.

How is *positive interdependence* ensured?

Students are required to work together in groups to synthesize information obtained individually. The group will then have to complete and submit a group *Steady-State, Open-System Device Sheet* for their assigned device.

How is *individual accountability* ensured?

Individual *Steady-State, Open-System Device Sheets* must be turned in along with the *new* group one.

Assessment:

Students will be assessed on both the individual sheet and the group sheet.

Team Skills Needed for Success:

Group members must have the ability to communicate ideas and knowledge and must feel comfortable about sharing and receiving information from other students for the creation of one final product.

How Are These Skills Emphasized?

These skills are emphasized through team processing of the information. The students must be able to come to consensus on what ideas/knowledge needs to be included in the final product.

Materials Needed by Students:

- *Steady-State, Open-System Devices* handout
- Course textbook—*Thermodynamics* (6th ed.) by Wark and Richards, McGraw-Hill

Materials Needed by Instructor:

- A box with numbered slips of paper for the random device selection process
- [Handouts](#)

Instructions to Students:

1	<p>Explanation of the Assignment</p> <p>One way to reduce the work that all of us have to do to learn new material is to divide up the material, each of us learn about a small part in depth, and then share what we've learned with the others. This active learning technique is commonly referred to as <i>Jigsaw</i> because, like a jigsaw puzzle, each of us contributes a small piece of knowledge that helps us understand the big picture. To get the most benefit with the least amount of effort, follow the instructions below carefully. You can obviously do more, but each of us must do the minimum so that we all get the benefit of this tool.</p>
2	<p>Step #1</p> <p>Read the handout Steady-State Open-System Devices.</p>
3	<p>Step #2</p> <p>Skim Sections 5-6-1 through 5-6-5 in <i>Thermodynamics</i> (6th ed.) by Wark and Richards, McGraw-Hill. This is new material.</p>

4	<p>Step #3</p> <p>Each of you will now be randomly selecting a number from a box. This number corresponds to a specific steady-state device. You are to become the expert on this device. The material in parentheses is related reading material in Wark and Richards.</p> <ol style="list-style-type: none"> 1. Turbines (WR 5-6-2) 2. Pumps, compressors and fans (or blowers) (WR5-6-2) 3. Nozzles (WR 5-6-1) 4. Diffusers (WR 5-6-1) 5. Throttling devices (WR 5-6-5) 6. Heat exchangers without mixing (WR 5-6-3) 7. Heat exchangers with mixing (mixing devices) (WR 5-6-4)
5	<p>Step #4</p> <p>Carefully read the assigned reading material (and any other material you care to read) and complete one of the Steady-State, Open-System Device Sheets for your assigned device. Use your reading and your own knowledge to determine the purpose, physical or design factors, and operating conditions or modeling assumptions for your device.</p> <p>On the next class meeting day, you will meet with other people who studied your device, share what you learned, and then create a <i>new</i> Steady-State, Open-System Device Sheet based on your combined knowledge.</p> <p>You will hand in this <i>new</i> form along with your <i>individual</i> sheets as part of your homework for that day.</p>
6	<p>Step #5</p> <p>In addition, you will also be responsible for reviewing the following material in Wark and Richards before the next class date after that.</p> <p><u>Chapter 5: Sections 5-1 to 5-4</u> The following sections are really just review from ES 201:</p> <ul style="list-style-type: none"> • 5-1: Introduction to the concept of open system (control volume) • 5-2: Conservation of Mass Principle (Rate form) • 5-3: Conservation of Energy Principle (Rate form) • 5-4: Steady-state equations • 5-5: Hints on problem-solving <p><u>Chapter 7: Sections –5-1 to 7-5-2</u> These sections are also just review from ES 201.</p>

Handouts:

- [Steady-State, Open-System Devices](#)
- [Steady-State, Open-System Device Sheet](#)

Steady-State, Open-System Devices

Many different technologically important devices can be modeled as steady-state, open systems. Some of the major classes of devices are shown below:

- Turbines
- Pumps, compressors, and fans (or blowers)
- Nozzles
- Diffusers
- Throttling devices,
- Heat exchangers without mixing
- Heat exchangers with mixing (mixing devices)

To help you understand these devices and learn how to model them, we will study each device to identify its **purpose**, essential **design** (or **physical**) **features**, and typical **operating conditions** (or **modeling assumptions**). In addition, you will find that there are common schematic diagrams used to represent devices. Questions that you might ask to identify these things for a specific device are described below:

Purpose	<ul style="list-style-type: none"> • What is this device supposed to do? • Why would you need one? • What happens to the fluid flowing through this device?
Physical or Design Factors	<ul style="list-style-type: none"> • What are the unique physical characteristics of this device, e.g. number of inlets and outlets? • What physical features does <i>every</i> one of these devices have? • What physical features do <i>most</i> of these devices have? • What can you say about the work term in the energy balance for this device, e.g. direction and magnitude?
Operating Conditions or Modeling Assumptions	<ul style="list-style-type: none"> • What are the typical operating conditions for these devices, e.g. changes in kinetic energy negligible, constant pressure, adiabatic, one-dimensional flow, etc.? • What are the typical modeling assumptions that one would make in constructing a mathematical model to predict the performance of this device?

Note that the **physical or design factors** along with a device's **purpose** are essential features of the device. These are characteristics that should spring to your mind each this device is mentioned. **Operating conditions or modeling assumptions** on the other hand are indicative of how the device usually operates. For example, the assumption of an adiabatic system is rarely a physical or design factor; however, it is frequently an operating condition or modeling assumption. One test to help you decide whether some attribute is a design factor or an operating condition is to ask yourself the following question, "Would this device still be a (device name) if this condition was *not* satisfied?" If the condition is not essential, then you are probably considering an operating condition.

Steady-State, Open-System Devices Sheet

Device Name(s)		
Purpose		Symbol (Bare bones Sketch)
Physical or Design Factors		
Operating Conditions or Modeling Assumptions		

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Purpose		Symbol (Bare bones sketch)
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