Freshman Engineering Clinic
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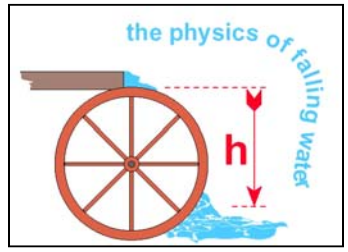
Civil and Environmental Engineering



Hydropower – A Renewable Resource

Introduction

Water power has been used for millennia to perform a variety of useful tasks. For instance, water wheels are commonly associated with grain, textile, and lumber mills. Those types of water wheels created mechanical power to drive millstones, looms, and saws. Today, hydraulic turbines are used to generate electricity, which in turn is used for lighting, computers, stereo systems, and your favorite video games. In all of these examples, energy is converted from one form to another.

Water stored in a reservoir or in a bucket suspended near the ceiling contains ***potential energy***; that is, the water has the *potential* to do useful work. Once the water is allowed to move (through a pipe or over a waterwheel), the potential energy is converted to ***kinetic energy***. This energy is associated with the moving fluid; when the water strikes a turbine and starts that moving, the kinetic energy is transferred to the turbine. Finally, the turbine converts the kinetic energy of its motion to either ***mechanical energy*** (in the case of a mill) or ***electrical energy*** (in the case of a hydroelectric plant).

This concept of ***conservation*** is one of the building blocks all of engineering and science. In engineering systems, properties such as mass or energy are not created or destroyed; they are merely transformed or transported, accumulated or exchanged.

In this lab, students will be exposed to the fundamentals of energy conversion to perform useful work. A turbine will be used to generate mechanical power that will (hopefully!) lift a weight.

Objectives

In this module, you will:

- Learn about energy conversion
- Learn about unit conversions
- Understand the differences between force, work, and power
- Assemble a turbine
- Measure pertinent turbine dimensions
- Test the turbine by measuring the time required to lift different weights
- Document the tests neatly in lab books
- Have fun!

Theory of hydraulic turbines

In general, a turbine is a device that extracts energy from flowing fluid and converts it into mechanical energy. In this case, the turbine will be used to generate mechanical power that will lift a weight a given distance. An impulse turbine (Figure 1) employs a fluid jet to cause the revolving element (usually called a runner) of the machine to rotate. Since the jet is exposed to the atmosphere prior to its impact with the bucket of the rotating element, the only available energy to the turbine is the kinetic energy of the moving fluid.

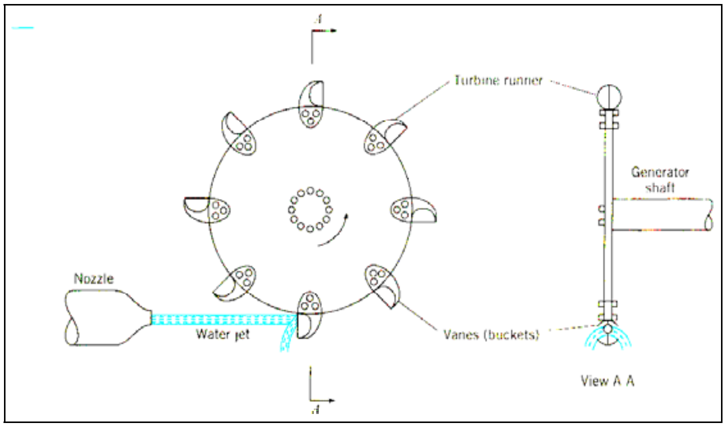


Figure 1: Impulse Turbine

Force, Work, and Power

A **force** is (mathematically speaking) the product of a mass (m) and an acceleration (a):

$$\mathbf{F} = m * \mathbf{a} \tag{1}$$

In the SI system, the unit of mass is the *kilogram (kg)*, and acceleration is expressed in *meters per second per second (m/s²)*. The unit of force is called a *Newton (N)* = $kg*m/s^2$.

When we speak of *gravitational forces*, we are usually referring to the *weight* of an object:

$$\mathbf{w} = m * \mathbf{g} \tag{2}$$

Where **w** = weight (in Newtons), and **g** = the acceleration due to earth's gravity ($\mathbf{g} = 9.81\ m/s^2$).

Work is a force carried over a distance:

$$W = \mathbf{F} * d \tag{3}$$

The units of work are Newton-meters ($N\text{-}m = kg*m^2/s^2$). This is the same unit as ***Energy***.

Power is the amount of work done per unit time:

$$P = W / t \tag{4}$$

The units of power are Watts ($W = N\text{-}m/s = kg*m^2/s^3$).

Experimental Setup:

Today's experiments will be conducted on the Turbine Test Stand in Room 151. The test stand is a 5-meter tall tower, designed specifically for evaluating the performance of hydraulic turbines. A reservoir on top of the tower provides water to a turbine via a hose. The flow from the reservoir to the turbine can be turned on and off by means of a ball valve. Water leaving the turbine falls into a lower reservoir, where it is pumped back up to the reservoir on top of the tower. A constant-head overflow tube is attached to the upper reservoir, to maintain a constant water level.

The kinetic energy of the spinning turbine is converted to mechanical energy by lifting a weight. The weight is suspended from a pulley, and can travel roughly 4 meters. The power developed by the turbine will be determined by measuring the time required to lift different weights a fixed distance. A schematic of the test stand is shown in Figure 2.

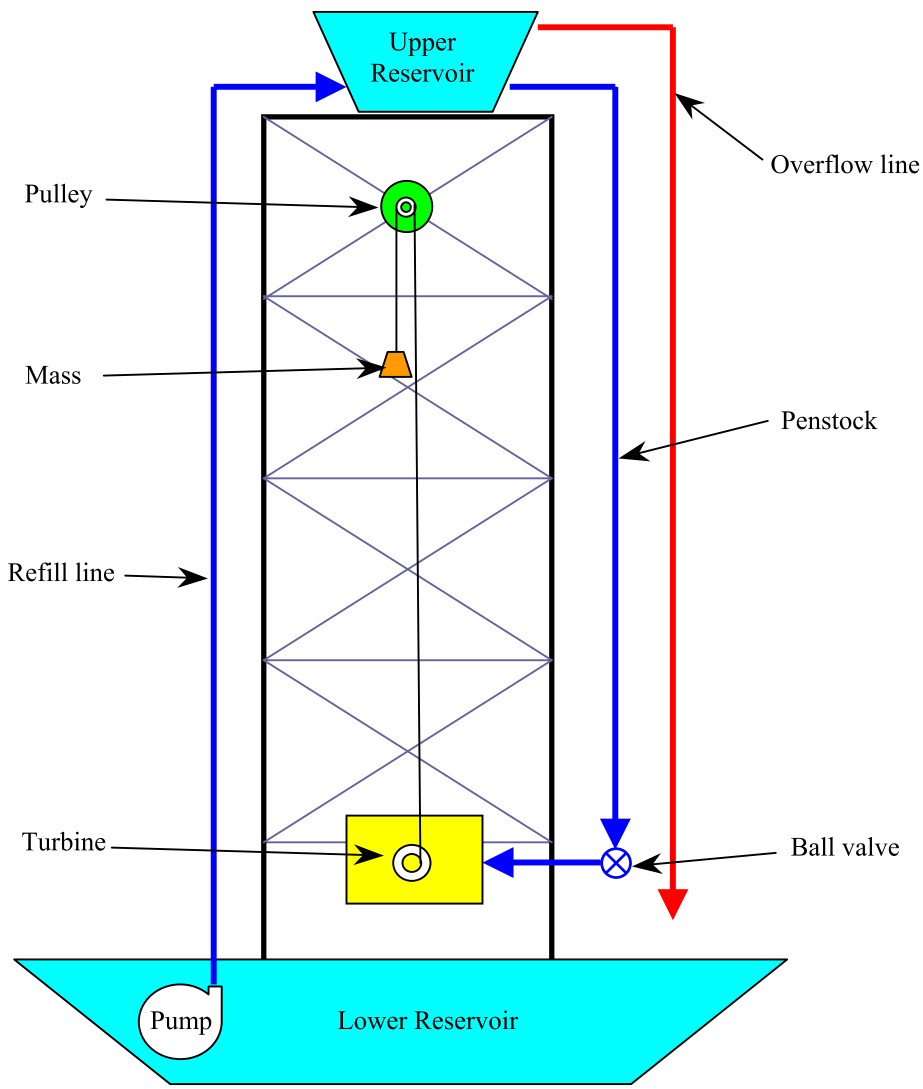


Figure 2: Schematic of Test Stand

Apparatus:

Each group will construct a turbine, using the following parts:

1 mounting board	1 hose connector
1 bearing board	19 segments of Snaplock piping
3 bearing board connecting rods	1 Snaplock 'Y'
2 bearings	6 nozzles (in a variety of sizes and shapes)
2 turbine runners	1 Rectangular nozzle
1 clamp	1 Snaplock pliers

Some of the parts are illustrated in Figure 3; an example of a completed turbine is shown in Figure 4.

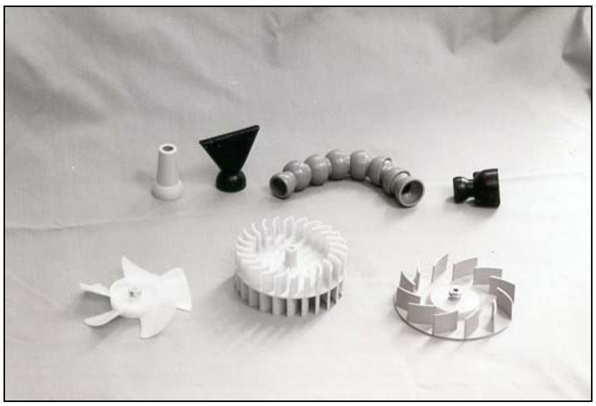


Figure 3: Turbine parts

Figure 4: Sample Turbine

Procedure:

1. Form into groups
2. Designate team members in your group for specific roles:
   a. Team Leader b. Rule Keeper c. Assembler d. Tester
3. Each team member should record all pertinent information in your laboratory book.
4. Build a turbine, using the demonstration turbine as a guide.
5. Use Snaplock pliers to assemble ball-and-socket pieces together.
6. To **separate** Snaplock parts that are stuck together, use the 'separation tool.'
7. Cut 15 feet of ultra-flexible fishing line; wind onto take-up spool.
8. When the turbine is complete, include a **detailed sketch** and **parts list** in your lab book. Be certain to include which type of turbine runner and what nozzles you used.
9. Test the turbine:
   a. Set the turbine up on the turbine test stand.
   b. Select a weight to try lifting
   c. Turn on the pump
   d. When water from the upper reservoir reaches the overflow tube, start the experiment (*i.e.* open the ball valve, start the stopwatch).
   e. Record the time it takes for the weight to travel vertically to the photocell.

Results:

Record and report your results in a tabular form as shown below. Use this format in your lab book:

Class: ______________________________ Section: ________________
Experiment: ______________________ Date: __________________
Group: ___________ (leader), ________ (rule keeper), __________ (assembler),
______ (tester)

Purpose of Lab: *(describe, in your own words, what you are doing & why)*

Procedure: *(describe, in your own words, your how you assembled your turbine.* ***Include a detailed sketch of the completed turbine and parts list****)*

Turbine type: ___________ Nozzle configuration: _________________

(sketch should go here – make it big enough to see!)

Data Table: ***(leave space for ~10 rows of data)***

Run	Mass (kg)	Weight = Mass * g (N)	Distance raised (m)	Time to raise, t (seconds)	Work = Weight * distance (N-m)	Power = Work / time (Watts)	Volume of Water Used (liters)

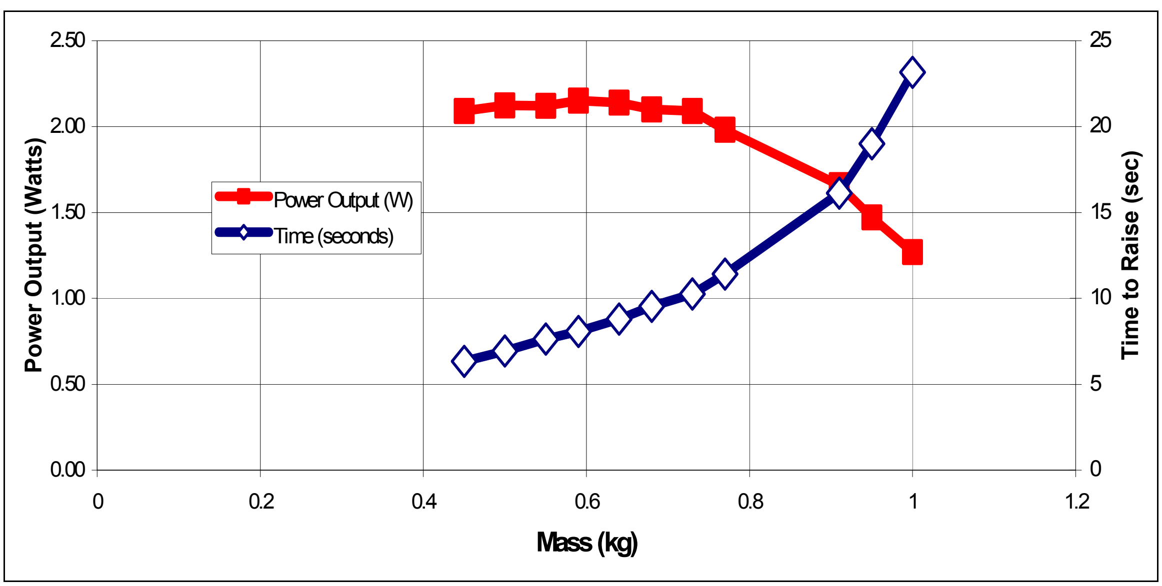


Figure 5: Sample Results – Graph should fill approximately ½ page.

WHAT TO HAND IN:

FOR TODAY: Turn in one set of carbon copies from one team member's lab notebook, showing your raw data and your preliminary analysis. At a **minimum**, your lab notebook should contain:

- Title of Lab Module
- Names of all members in group, along with their role in the lab
- Your section number
- Today's date
- Purpose of lab
- Procedure
- Sketch of your turbine device, including dimensions of nozzles, number of nozzles, snap lock parts, etc.
- Table of raw data
- Hand-drawn plot of data

FOR NEXT WEEK – Laboratory Report:

Work together in the same group as you worked with today to complete a formal laboratory report, using the standard Rowan Freshman Engineering Clinic report format. The report format can be found on the course web page, along with a sample report and grading scheme.

Only ONE report is required for each group. At a minimum, the report must include the following elements:

1. Cover page
    a. Course title
    b. Section number
    c. Module title
    d. Names of group members
    e. Date report is turned in
2. Body of report
    a. Introduction explaining objectives of experiment and some background about energy conversions in general and using waterpower in particular
    b. A brief description of equipment and methods used, including a PHOTOGRAPH of your turbine device (photographs will be available on course web page 1 day after lab)
    c. A results and data analysis section which includes:
        i. A verbal description of your results, with some thoughtful comments about what the results mean (*i.e.,* interpretation, not regurgitation)
        ii. Neatly formatted and labeled table(s) of results
        iii. Neatly formatted plot(s) of Power Output (in Watts) and Time to Raise Mass (in seconds) as a function of the mass lifted (in kg) (similar to Figure 5)
    d. A conclusions and recommendations section that includes discussion on your interpretation of the results, along with suggestions for improvements to the lab
3. An appendix with raw data and sample calculations

In your report, remember to:

- Label figures and tables
- Use headings for different sections
- Number pages using the 'footer' feature