AC 2010-208: A GUIDED INQUIRY APPROACH TO TEACHING FAN SELECTION

Robert Edwards, Penn State Erie, The Behrend College

Gerald Recktenwald, Portland State University

A Guided Inquiry Approach to Teaching Fan Selection

Abstract:

The selection of a fan for sufficient airflow for a particular system involves much more than determining the flow requirements and selecting a fan out of a catalog. A designer must understand that the flow rate of a fan is dependent on the amount of backpressure in the system while the backpressure depends on the flow rate. The characteristic curve for a fan and the impedance curve for a system show these dependencies. The actual amount of flow that a fan will deliver to a given system is determined by the intersection of these two curves.

Students could be taught about this as part of a traditional lecture. The exercise described in this paper is an attempt to enhance their learning experience through a guided inquiry laboratory exercise. The students learn to generate both the fan and system characteristic curves. The curves are used to predict the actual flow rate of a fan in an application. Once the fan is mounted into the device the actual operating flow rate is determined. As part of the exercise the students also plot characteristic curves for fans in series and in parallel to determine what happens in those configurations. The system used for the exercise is a familiar computer power supply.

This exercise has been implemented twice in small groups. The first time the subject was introduced in a lecture which included an in class demonstration. The second time the exercise was used to introduce the topic. A lecture during the next class was used to answer any questions the students had about the topic.

This paper discusses the learning objectives, equipment, procedure and preliminary findings from the two implementations. Also, the optional in-class demonstration is discussed.

Introduction:

The exercise documented in this paper is part of a National Science Foundation funded project being jointly conducted at Penn State Erie, The Behrend College and Portland State University. It is one in a suite of eight exercises being developed by the authors which are intended to help teach core principles in the thermal and fluid sciences through the use of everyday devices. These include a hair dryer, a bicycle pump, a blender, a computer power supply, a toaster, straight and stepped tanks, and a pipe section with a change of area. The project was first introduced at the 2007 ASEE national convention in a paper presented in the DELOS division[1]. Papers are available describing some of the other exercises[2,3,4]. This paper focuses on the computer power supply exercise.

The performance of a fan follows a characteristic curve, known as a fan curve, which is specific to that particular fan design. Coad[5] describes fan curves as “probably the most misunderstood and yet most useful tool in HVAC systems engineering”. It is easy to misinterpret catalog information on fans since they often rate fans by their maximum flow rate and/or maximum pressure output. These specifications do not actually have much value for selecting a fan for a particular application. In fact, neither of these values will ever be realized in a real application

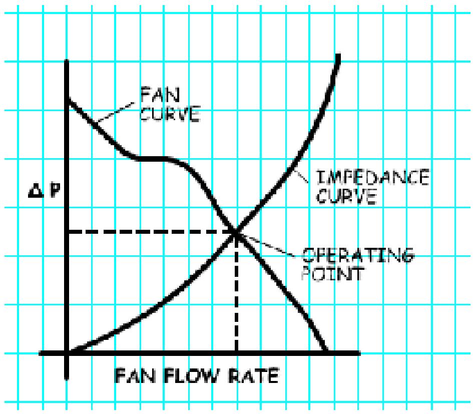

Figure 1 – Operating Point of a Fan

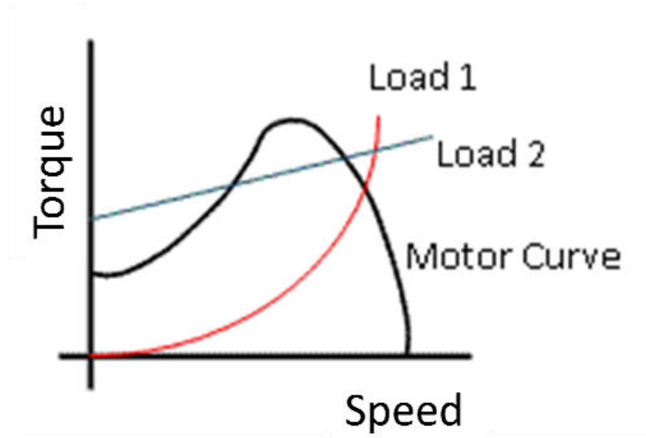

Figure 2 – Operating Point of a Motor

because the maximum flow rate requires zero back pressure and the maximum pressure requires zero flow. The actual operating point lies somewhere between these values, and must fall on the characteristic curve for the fan. Whenever a fan is attached to a system a certain amount of back pressure on the fan will be created. This backpressure depends on the amount of flow going through the system. In order to determine the actual operating point the engineer must know the characteristic curves for both the fan (fan curve) and the system (impedance curve). The operating point is the point at which the two curves intersect (Figure 1). Since it is likely that an engineer will have to select a fan at some point in his/her career it is important to understand this concept.

Learning about how to determine the operating point for a fan in a system is enough to make this a worthwhile activity. However, there is a broader reason to teach this concept. There are many other applications for this type of analysis that the students may encounter in school or in industry, and they should be prepared to deal with them. The most obvious is pump selection. Pumps and fans perform very similar functions and the selection process is essentially the same for both of them[6]. Another common device which employs a similar selection method is a motor[7]. Figure 2 shows an example of this. A motor torque vs. speed characteristic curve is shown with two very different load curves. For load 1 the intersection point of the load characteristic curve with the motor characteristic curve shows the operating point. It can be readily seen that load 2 crosses the motor characteristic curve in two places indicating two possible operating points. However, upon closer scrutiny it can be seen that this motor is not suitable for the application. The starting torque of the device is greater than that available from the motor so the motor will be stalled from the beginning. Mechanical devices are not the only ones that use this type of graphical analysis. A similar technique known as load line analysis is commonly used to find operating points for many electronic devices including diodes and transistors[8].

The exercise described in this paper focuses on teaching how to determine the operating point for a fan and how parallel and series configurations affect the fan curve. Biswas, Agarwal, et al[9] discuss several methods that might be used to determine the operating point for small electronic enclosures. These include the graphical technique used here, manual calculations to determine the flow impedance curve and of course CFD analysis. Each of these methods has its' advantages and disadvantages. For small devices that fit on a flow bench it is always nice to have actual test data either to plot and use for fan sizing or for validation of a model. Coad[10] advocates actual testing even for larger systems. He discusses the advantages of testing for flows in something as large and involved as an air conditioning system for a building. This exercise focuses on the empirical method of gathering data and plotting curves, but there are several opportunities during the exercise that allow for brief discussions about some of the other possible methods.

A computer power supply was selected as the test specimen for several reasons (Figure 3 shows the power supply mounted to the inlet of the flow bench).

- It is familiar to the students, so they do not have to spend time figuring it out.
- The contents of the housing are fairly complex. This gives an opportunity to discuss advantages and disadvantages of manual calculations, measurements and computer models.
- It is small enough to easily fit on the available flow bench.
- The operating characteristics of the fan are well within the test capabilities of the flow bench.
- The impedance curve data for the housing is well within the test capabilities of the flow bench.
- The fan can be easily removed from or replaced in the power supply housing which facilitates data collection.
- Mounting hardware is simple.
- Power supplies are readily available and inexpensive. The one used here was salvaged from a computer destined to be scraped.

Figure 3 – Power Supply Mounted on Flow Bench

Pedagogical Basis:

Many laboratory exercises tend to follow a "cookbook" approach in which the equipment functions essentially the same way and the data is similar every time it is run. Little is left to chance, and the exercise is generally successful. Students follow the prescribed procedure, gather data and follow-up with an analysis and/or report. This type of exercise tends to focus on demonstrating a concept or theory. One of the goals of the authors is to use the suite of exercises not only to demonstrate a concept but to teach it.

Research is showing that student learning requires more than lectures and the use of "cookbook" type laboratory experiences[11,12]. One approach is inquiry-based learning. This approach places the responsibility on the students to pose questions, develop experiments to try to answer those questions, analyze information from those experiments, and draw conculusions[13]. A variation of this approach is known as guided inquiry. A guided inquiry exercise poses leading questions to try to keep the students focused on the main concepts. This pedagogical approach is used by the authors for the entire suite of exercises of which this is a part. In addition to the key questions that are posed on the worksheets, students are encouraged to bring up their own questions throughout the exercise. Strategic points throughout the worksheet are built in for discussion periods.

This particular exercise requires that a certain set procedure be used to determine the characteristic curves that are needed. Unfortunately that goes contrary to the guided inquiry approach that is desired. Since the goal of the exercise is to move beyond simply plotting the curves to a better understanding of the entire process, the students need to look at the data collection activity not as the objective of the lab but simply as a tool to get at the concepts. A later section will provide a complete list of the learning objectives for the exercise.

Overview of the Exercise:

The computer power supply exercise is designed to teach students about fan characteristics, fan sizing and parallel and series operation of fans. There are two parts to the exercise, an in-class demonstration and a follow-up lab exercise.

The purpose of the in-class demonstration is to demonstrate to the students that a fan does not produce the rated flow rate when it is installed in a system. Hopefully this will cause the students to think about why that happens. The in-class demonstration uses a simple, inexpensive device which will be described in a later section.

The follow-up lab exercise reinforces and extends this idea of diminished flow performance when the fan is installed in a system. The students learn to measure and plot the necessary characteristic curves and graphically determine the operating point for a common device, in this case a computer power supply. They also learn to experimentally determine the actual operating point. The exercise is extended to teach about parallel and series configurations. The apparatus for this lab exercise is more extensive and expensive than what is used for the in-class demonstration. It will also be described in a later section along with a suggestion for mitigating the cost.

Learning Objectives:

This exercise has several learning objectives:

- Recognize that the flow rate of fans depends on the flow resistance that the fan must work against.
- Recognize that the flow rate vs. flow resistance relationship for a fan is a well-defined and intrinsic characteristic of the fan, and can be shown graphically as a “fan curve”.
- Plot the “fan curve” for a fan using an air flow bench.
- Recognize that the flow rate vs. flow resistance relationship for a system is a well-defined and intrinsic characteristic of the system, and can be shown graphically as a flow impedance curve.
- Plot the flow impedance curve for a system using an air flow bench.

- Recognize that it is impractical to measure the flow impedance curve for a large system, Calculations or simulations must be used to determine these curves.
- Determine the actual operating point of a fan by superimposing the fan curve on the system impedance curve.
- Recognize the relationships for flow rate and pressure for fans in parallel and fans in series.

In-Class Demonstration:

The apparatus for the in-class exercise is simple and inexpensive. Figure 4 shows a schematic of the overall set-up, and Figure 5 is a picture of the actual device. The flow device consists of a clear plastic tube, a fan and a pitot tube. A perforated plate is attached to one end of the tube to help increase the differential pressure across the device. The fan, with the nameplate data clearly visible, is attached to one end to force air through the tube. The pitot tube is used to measure the air velocity in the tube. The differential pressure across the pitot tube is transmitted to a LabView VI via a low cost USB based data acquisition device. The LabView VI calculates the volumetric flow rate and displays both the velocity and flow rate on the screen.

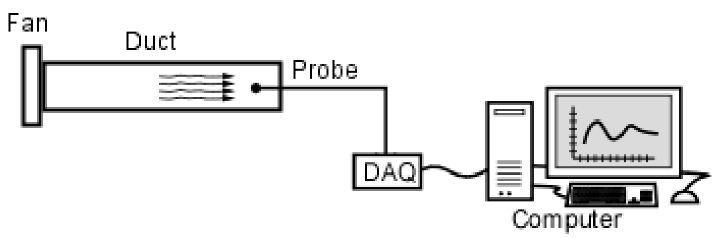

Figure 4 – Schematic of In-Class Exercise

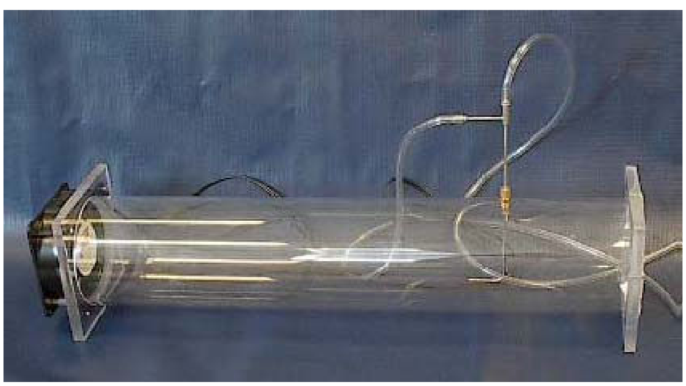

Figure 5 – Photograph of In-Class Set-Up

The primary purposes of the in-class exercise are first to demonstrate that a fan does not generate the rated flow rate when it is in a real system, and then to get the students thinking about how they might approach predicting what the flow rate would be for a particular system. Appendix 1 shows the in-class worksheet. Notice that the final four questions deal with fans in series and parallel. These topics are not addressed during the in-class demonstration. They are included to get the students to start thinking about them prior to testing those configurations during the lab exercise.

A by-product of the demonstration is that it opens up an opportunity to discuss the operation of a pitot tube and the calculations necessary to determine the volumetric flow rate, which is displayed on the screen. The equation for the mass flow rate is shown as equation 1.

$$\dot{m} = \int \rho v dA \qquad \text{Equation 1}$$

Where: $\dot{m} = mass\ flow\ rate$
$\rho = density$

$$v = velocity$$
$$dA = differential\ area$$

The density is assumed to be constant at the density of air at room temperature. This leads to equation 2 for volumetric flow rate.

$$\dot{V} = \int v dA \qquad \text{Equation 2}$$

If an average velocity is used this reduces to equation 3.

$$\boxed{\dot{V} = vA} \qquad \text{Equation 3}$$

The velocity is determined from the pitot tube. The students recognize that the velocity varies across the area because of other experiments they have run. To try to account for that with a simple test device the pitot tube is not located at the center of the tube. It is located at an intermediate location approximating the average velocity. Getting an accurate value is not that critical. The point of the exercise is simply to demonstrate that the fan does not deliver the rated flow rate by using a very basic device. Much more accurate data is collected when the in-lab exercise is run.

In-Lab Exercise:

The measurements that are required for plotting fan curves or flow impedance curves are taken using an air flow bench. Figure 6 shows a schematic of the flow bench. This is a common device used to plot fan curves and flow impedance curves. Devices such as this are commercially available and can be fairly expensive. The units that are used at both schools were designed and built at the schools according to the ANSI/AMCA 210-99[14] standard for testing fans. Even though they were built for a relatively modest cost the results compare favorably with published fan curves produced using commercial equipment. Contact either of the authors for information about the design of the flow bench. The pressure differential across the nozzle plate is related to the flow rate through the flow bench. A MatLab program is used to make the calculations converting differential pressure to flow rate. The differential pressure across the test specimen is measured directly. Plots are made using an Excel spreadsheet. Since the students must make these measurements several times during the exercise they are given instruction in the use of the machine during a previous lab session, which helps to save time. Also, since the students are already familiar with the flow bench they are free to concentrate more on the concepts than the operation of the equipment. Details of the data collection procedure were previously published[15], and will not be repeated here.

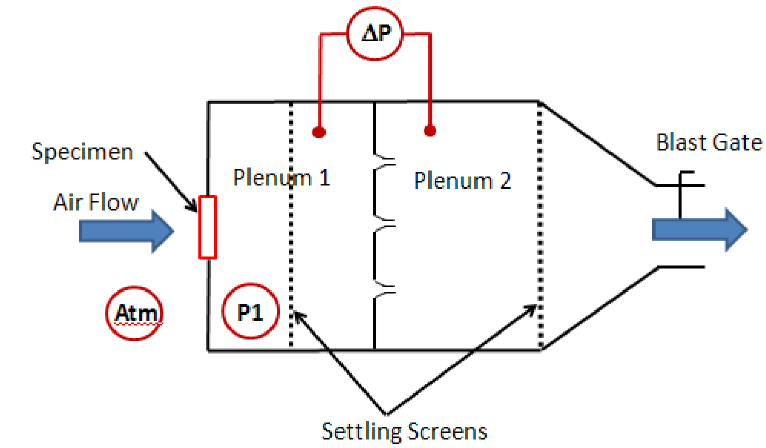

Figure 6 – Schematic of Air Flow Bench

The worksheet, which is shown in appendix 2, begins with some background information for the students to read on fan curves, fans in series and fans in parallel. After reading the background information the students are given an opportunity to ask questions and discuss the material. The worksheet then steps the students through the data collection needed to generate plots of the fan curve and the flow impedance curve for a computer power supply. These curves are then plotted on the same axes and the predicted operating point is determined by the intersection of the two curves (figure 7).

Figure 7 shows actual data taken for the power supply. From the curve it can be seen that the actual air flow through the power supply should be approximately 15 CFM (shown as the operating point). It is interesting to note that the maximum flow rate that is published on the specifcation sheet for this fan is 30 CFM, twice that of the actual delivery in this application. This provides another good opportunity for discussion with the students before they procede with the exercise.

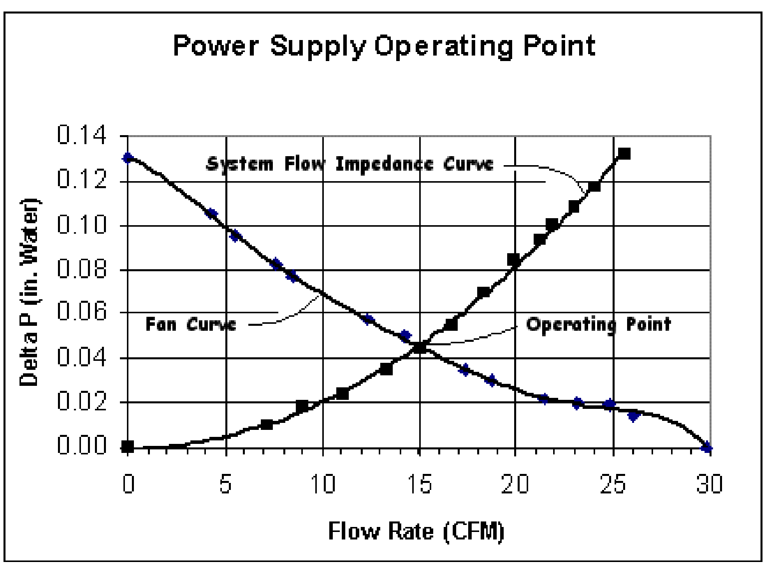

Figure 7 – Plot to Determine Fan Operating Point

Even though the students were given training during a previous lab in how to operate the equipment, they have not been instructed in how to experimentally determine the actual operating point for the assembled power supply. This provides an opportunity to discuss the operation of the system (power supply cooling system) and how the system characteristics lead to a method for determining the actual flow through the device. When the power supply is operated both the inlet and outlet are at atmospheric pressure. The fan in this system is used to pull air through the power supply housing. The fan must reduce the pressure inside the housing to cause the air to flow in. The differential pressure across the fan increases the pressure up to atmospheric pressure at the outlet from the vacuum that is present inside the housing. The actual flow rate can be determined using the fact that the overall differential pressure across the power supply is zero.

The assembled supply is mounted on the air flow bench and the flow is adjusted until the pressure drop across the power supply is zero. The resulting differential pressure across the nozzle plate yields the actual flow rate through the device. This can then be compared with the prediction. To conclude this portion of the exercise the students participate in a brief discussion about the results and possible applications to other areas.

The final phase is to take a look at series and parallel fan configurations. These are common configurations used in electronics cooling and many other applications. An example of a series configuration is when a fan is used at the inlet to a housing to push air into an enclosure. A fan is series often takes the form of a fan in a secondary device pushing air out of the enclosure. A computer power supply such as the one used in this exercise is an example of a typical secondary device which has its' own fan. An example of fans in parallel is a fan tray used to cool electronic devices. Fan trays are not necessarily used to increase air flow since a single fan could be sized to produce a similar amout. More likely a fan tray would be used to spread out the air delivery to assure it gets to where it has to be to cool the components.

Students are asked to predict how a series or parallel configuration using multiple fans will affect the differential pressure across the fans and the flow rate generated by the fans. Figure 8 shows the theoretical affects of these configurations. The curves shown are for two fans in series and for two fans in parallel. The actual tests are conducted with two fans in series and four fans in parallel. Two fans in series double the differential pressure while keeping the same flow rate, while two fans in parallel double the flow rate while keeping the same differential pressure. Electrical analogies are often used for flow problems, and this is clearly analogous to batteries in these configurations.

By this point the students have become somewhat proficient in the use of the flow bench, so it does not take them long to gather data and plot the fan curves for the new configurations. The fans that are used are the same as the fan that is used in the power supply, so they already have the curve for the individual fan. The resulting curves typically do not match the theoretical curves shown above. The series configuration produces less differential pressure than predicted and the parallel configuration produces less flow than predicted. The question is whether or not this makes sense. Students often write off these kinds of results as experimental error or "human error". Actually, there are reasons for the discrepancies which can be discussed with the students. The devices used for this exercise have the fans closely spaced. This is typical of actual installations since space is often an issue in design. The spacing causes interference in the air flow leading to a drop in performance. In most designs the losses have to be tolerated to stay within size constraints. Designers need to be aware of this to avoid undersizing fans for an application. The complete worksheet used for this exercise is given in appendix 2.

Assessment:

So far this exercise has been used two times with a total of only 20 students. There are pre and post exercise worksheets intended to determine if the students have any learning gains after completing the exercise. With only 20 students there has not been any significant evidence one way or the other on the effectiveness of the exercise. We acknowledge that the assessment aspect of this exercise needs to be significantly strengthened, and will be addressed in the future. Appendix 3 shows the pre and post test questions.

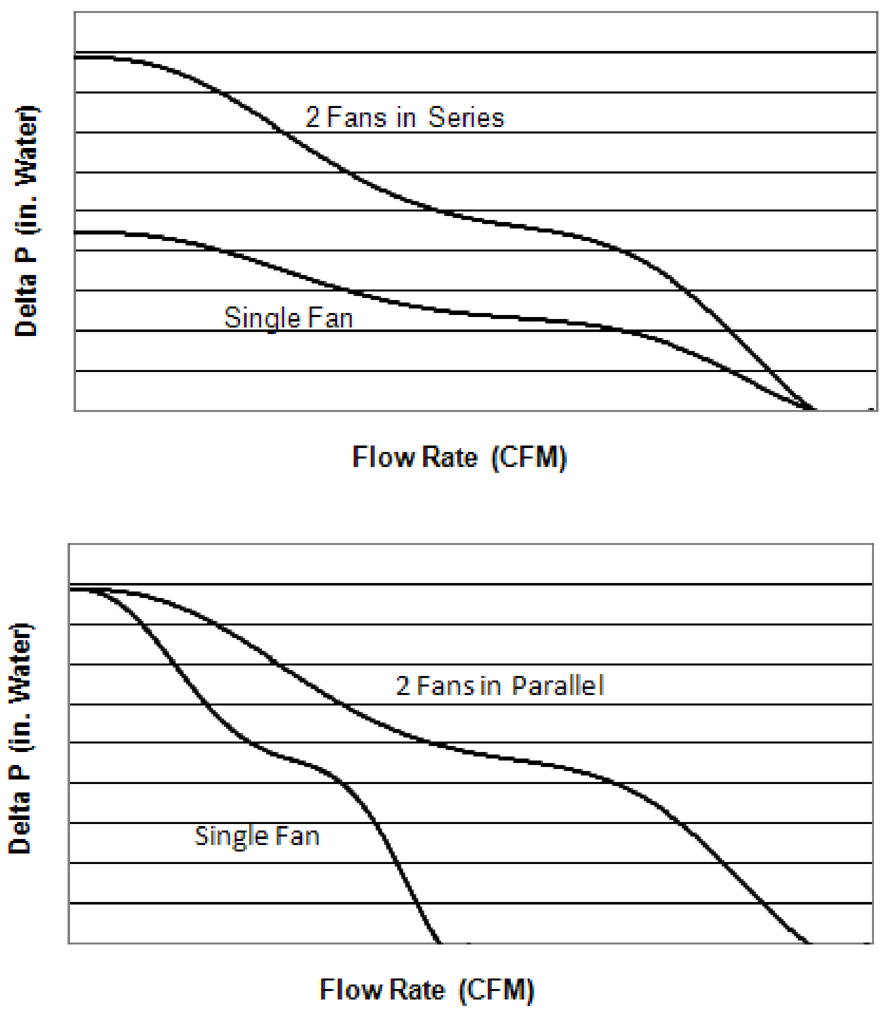

Figure 8 – Fans in Series and Parallel

Future Work:

The exercise described in this paper is part of a suite of exercises aimed at teaching core principles in the fluid and thermal science through the use of guided inquiry. The computer supply exercise is one of the last ones to be developed. It has been used only twice and no significant assessment data is available. It appears that the assessment tool used is insufficient to garner any meaningful data. This exercise needs to be reviewed and improved. Some steps that will be taken to help improve it are:

- Review the assessment instrument to determine how to improve it. This might ultimately be done with the assistance of an outside expert in assessment.
- Revisit the scope of the exercise. Should it include both operating point and series/parallel configurations, or should it be limited to determining the operating point?
- Make improvements to the in lab apparatus to make it easier to operate and gather data. The less the students have to think about operating the equipment the more thought they can put into the concepts.

In addition to the exercise specific steps listed above there are plans for a significant upgrade to the entire suite of exercises. Future work planned for the overall project includes:

1) Researching the feasibility of moving the exercises online making them much more accessible to others without the need for hardware.
2) Rewriting worksheets and protocols to make them compatible with online delivery.
3) Continuing to test and improve the worksheets for using the exercises in a lab environment.
4) Enlisting outside assistance in developing assessment tools.
5) Making the exercises, including the worksheets, LabView VI's, and hardware requirements available to other schools for beta testing.
6) Providing workshops to describe not only the test goals and procedures, but also the overall pedagogy involved.
7) Publishing all of the exercises on the website http://eet.cecs.pdx.edu.

Acknowledgements

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Appendix 1: - In-Class Worksheet

Power Supply Laboratory – The Engineering of Everyday Things

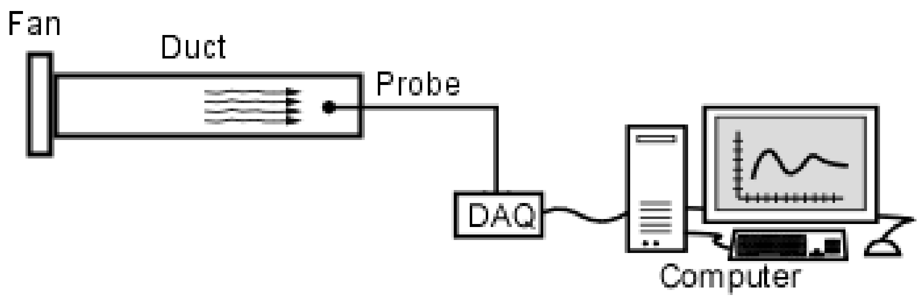

Figure 1: Apparatus for the power supply experiment.

Apparatus

Figure 1 shows the equipment for this laboratory exercise. The key components are:

1. A fan mounted on a round duct.
2. A pitot tube and differential pressure transducer to measure velocity.
3. A data acquisition device (DAQ) for gathering data from the transducer.
4. A computer to record the output of the transducer and to calculate the volumetric flow rate.

Exercise

- The data acquisition software is started.
- The fan is turned on. The data acquisition system is recording the velocity and calculating the volumetric flow rate through the duct.

Questions (Pre-exercise)

1. The nameplate data from the fan is shown below:

    - 115 CFM AC Axial Fan 4WT46
    - RPM 3100 Amps 0.24 Watts 20
    - 115 Volts, 60 Hz

    When the fan is running will the volumetric flow rate be 115 CFM, more than 115 CFM or less than 115 CFM?

2. Why do you think the volumetric flow rate will be as you predicted in #1?

Questions (Post-exercise)

1. Was your prediction for the volumetric flow rate correct?

2. What factors in this exercise do you think influence the actual volumetric flow rate?

3. If two fans are placed in series with each other will the flow rate:

    a. Increase by a factor of 2
    b. Decrease by a factor of 2
    c. Stay the same

4. If two fans are placed in series with each other will the total differential pressure across the fans:

    a. Increase by a factor of 2
    b. Decrease by a factor of 2
    c. Stay the same

5. If two fans are placed in parallel with each other will the flow rate:

    a. Increase by a factor of 2
    b. Decrease by a factor of 2
    c. Stay the same

6. If two fans are placed in parallel with each other will the total differential pressure across the fans:

    a. Increase by a factor of 2
    b. Decrease by a factor of 2
    c. Stay the same

Appendix 2: - Lab Exercise

Power Supply Laboratory – The Engineering of Everyday Things

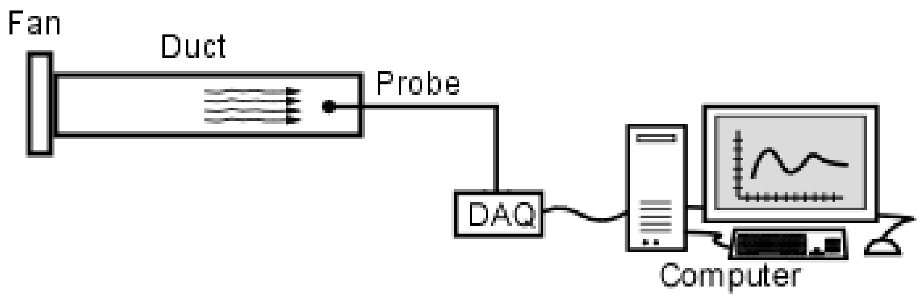

Figure 1: Apparatus for the power supply experiment.

1 Apparatus

Figure 1 shows the equipment for this laboratory exercise. The key components are:

5. A fan mounted on a round duct.
6. A pitot tube and differential pressure transducer to measure velocity.
7. A data acquisition device (DAQ) for gathering data from the transducer.
8. A computer to record the output of the transducer and to calculate the volumetric flow rate.

2 Learning Objectives

As a result of completing this laboratory exercise you will be able to

1. Recognize that the flow rate of fans depends on the flow resistance that the fan must work against.
2. Recognize that the flow rate vs. flow resistance relationship for a fan is a well-defined and intrinsic characteristic of the fan, and can be shown graphically as a "fan curve".
3. Plot the "fan curve" for a fan using an air flow bench.
4. Recognize that the flow rate vs. flow resistance relationship for a system is a well-defined and intrinsic characteristic of the system, and can be shown graphically as a flow impedance curve.
5. Plot the flow impedance curve for a system using an air flow bench.
6. Recognize that it is impractical to measure the flow impedance curve for a large system, Calculations or simulations must be used to determine these curves.
7. Determine the actual operating point of a fan by superimposing the fan curve on the system impedance curve.
8. Recognize the relationships for flow rate and pressure for fans in parallel and fans in series.

3 Lab Preview

3.1 Fan Operating Point

Fan catalogs often rate fans by their maximum flow rate and/or maximum pressure output. These ratings can be very deceiving. The fan will never produce the maximum flow or the maximum pressure output, and will certainly never produce both at the same time. The flow rate produced by a fan varies depending on how much back pressure there is in the system it is attached to. This relationship is shown on what is called a characteristic curve for the fan, or a fan curve.

The back pressure in the system varies by the amount of air flowing through it. This can also be plotted as a system characteristic curve known as a flow impedance curve. Superimposing the two curves will indicate the actual operating point for the fan (Figure 2). This operating point will be at the intersection of the two curves which is the only point at which the component characteristics match.

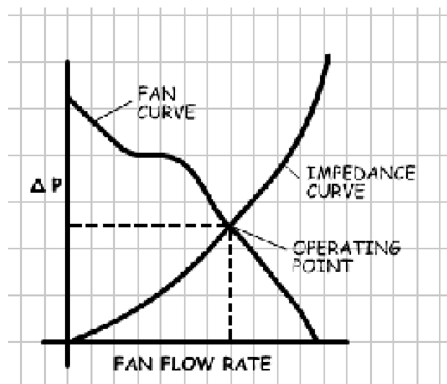

Figure 2: Operating point for a fan

Notice that the operating point is significantly lower than the maximum rated flow rate. Also note that the back pressure is significantly lower than the maximum rated pressure for the fan. This is very important information to have for any system to assure that the system specifications are met.

During this lab exercise you will take all of the measurements needed to predict the actual amount of air that will flow through a typical computer power supply. You will then measure the actual operating point for the same supply.

3.2 Parallel and Series Fans

The theoretical fan curves for fans in parallel and fans in series can be created by knowing the fan curve for an individual fan.

The pressure drop across fans in series is the sum of the pressure drop across each of the individual fans. The flow rate remains the same as for an individual fan (Figure 3). For parallel fans the pressure drop remains the same as for an individual fan, but the flow rate is multiplied by the number of fans in the parallel configuration (Figure 4).

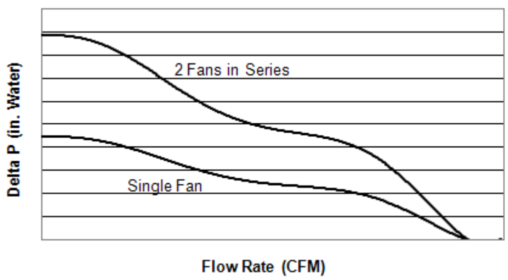

Figure 3: Fans in series

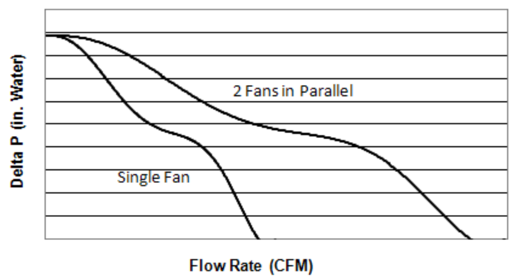

Figure 4: Fans in parallel

In actual operation the series configuration will never reach the theoretical maximum pressure and the parallel configuration will never reach the theoretical maximum flow rate. This is due in large part to flow interference that is set up when the fans are placed too close together, which is common in a real application.

During this lab exercise you will measure and plot the results for actual series and parallel fan configurations.

4 Flow rate through a computer power supply – Fan operating point

- Using the air flow bench gather data to plot a fan curve for the fan used in the computer power supply. Place these values on the table below. Include units.

Δ P fan	Δ P nozzle	Flow rate

- Use the MatLab program "nozzle" to calculate the flow rates based on the pressure drop across the nozzle. Place these values on the table above.
- Use Excel to plot the fan curve.
- Using the air flow bench gather data to plot a flow impedance curve for the power supply housing. Place these values on the table below. Include units.

Δ P housing	Δ P nozzle	Flow rate

- Use the MatLab program "nozzle" to calculate the flow rates based on the pressure drop across the nozzle. Place these values on the table above.

- Use Excel to plot the flow impedance curve on the same graph as the fan curve. Make a hand sketch of the Excel graph in the space below.

- Determine the flow rate at the intersection of the two curves. Insert the value in the box below. Be sure to include units.

- Re-install the fan inside the power supply housing. Mount the device on the air flow bench. Turn on the flow bench and adjust the blast gate until the pressure drop across the power supply is zero. Measure the pressure drop across the nozzle. The flow rate determined by this pressure drop is the operating point for the device.

- Use the MatLab program "nozzle" to calculate the flow rate for the actual operating point based on the pressure drop across the nozzle. Insert the value in the box below. Be sure to include units.

- Compare the operating point flow rate determined by the intersection of the curves with the operating point determined by direct measurement. Use the measured flow rate as the basis for calculating a percent difference:

$$Percent\ Difference = \frac{|Measured\ value - Predicted\ value|}{Measured\ value} x100$$

5 Fans in series

- Using the air flow bench gather data to plot a fan curve for the individual fan used in the series configuration. Place these values on the table below. Include units.

Δ P fan	Δ P nozzle	Flow rate

- Use the MatLab program "nozzle" to calculate the flow rates based on the pressure drop across the nozzle. Place these values on the table above.

- Using the air flow bench gather data to plot a fan curve for the series fan configuration. Place these values on the table below. Include units.

Δ P fan	Δ P nozzle	Flow rate

- Use the MatLab program "nozzle" to calculate the flow rates based on the pressure drop across the fans in series. Place these values on the table above.

- Compare the data for the maximum flow rate and the maximum differential pressure from the tables above.

	Single Fan	Series Fans
Maximum Flow		
Maximum ΔP		

- Based on the results for the individual fan, what should the maximum flow be for the series configuration?

- Based on the results for the individual fan, what should the maximum ΔP be for the series configuration?

- Does the data shown in the table above make sense based on your knowledge of actual fan systems? Explain.

6 **Fans in parallel**

- Using the air flow bench gather data to plot a fan curve for the parallel fan configuration. Place these values on the table below. Include units.

Δ P fan	Δ P nozzle	Flow rate

- Use the MatLab program "nozzle" to calculate the flow rates based on the pressure drop across the fans in series. Place these values on the table above.

- Compare the data for the maximum flow rate and the maximum differential pressure from the tables above.

	Single Fan	Parallel Fans
Maximum Flow		
Maximum ΔP		

- Based on the results for the individual fan, what should the maximum flow be for the parallel configuration?

- Based on the results for the individual fan, what should the maximum ΔP be for the parallel configuration?

- Do the differences shown in the table above make sense based on your knowledge of actual fan systems? Explain.

Appendix 3: - Pre/Post Lab Exercise Questions

Power Supply Laboratory – The Engineering of Everyday Things

1. If the nameplate data for the fan indicates that it is rated at 100 CFM, which of the following choices is the most likely indication for the actual volumetric flow rate?
   a) 100 CFM.
   b) 110 CFM.
   c) 80 CFM.
   d) Could be any of the above.

2. Briefly explain why made your selection.

3. For a given fan operating at a given speed, what can be done to alter the characteristic curve for the fan (fan curve)?
   a) Increase the back pressure.
   b) Decrease the back pressure.
   c) Either a or b.
   d) Nothing.

4. If two fans are placed in series with each other will the flow rate:
   d. Increase by a factor of 2
   e. Decrease by a factor of 2
   f. Stay the same

5. If two fans are placed in parallel with each other will the flow rate
   a) Increase by a factor of 2
   b) Decrease by a factor of 2
   c) Stay the same

6. Sketch a fan curve for a single fan and one for two fans in series on the same set of axes.

7. Make a sketch illustrating how you might determine the actual operating point for a fan when it is attached to a system.