Lesson 1: Jet Propulsion
Grades 5 - 8

Objective

- To build a model to demonstrate how thrust is created in a jet engine.

Science Standards

Science as Inquiry
Physical Science
Position and Motion of Objects
Unifying Concepts and Processes
Evidence, Models, and Explanation

Science Process Skills

Observing
Communicating
Collecting Data
Making Models
Controlling Variables

Mathematics Standards

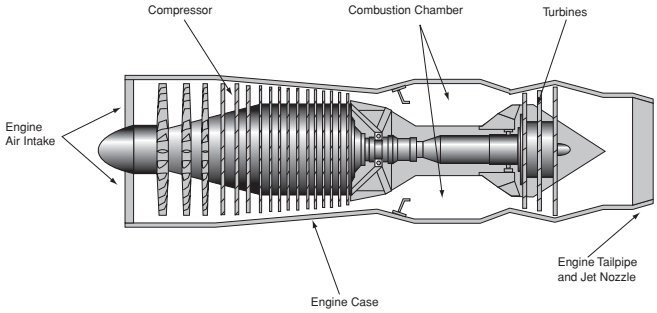
Communicating
Reasoning
Connections

Management

This activity works best if the students work in pairs. Allow approximately 40-45 minutes to complete. This is activity is divided into two parts. In part 1 the students move through the three stations discovering what happens as different forces act on air. Then students process what they observed and compile it into the correct arrangement to describe how a turbojet engine produces thrust. This experiment stresses prediction, observation, data collection, and analysis of results. In part 2 the students construct a model of a jet engine, label each part, and describe what each part does. An optional teacher demonstration may be used to bring the three stages together into a single event.

Background Information

A turbine engine works in four basic stages. Outside, or ambient, air enters the engine through the air inlet. The air then moves into the compression section of the engine. In this section the compressor increases the air pressure, which also increases its temperature. From there the air is forced into the burner section, where the temperature is further increased by fuel combustion. The hot, expanding air then moves into the turbine, which drives the compressor. The air expands through a tailpipe designed to discharge the exhaust gas at high velocity, producing thrust.



Description

Using a series of stations, students discover how an engine takes in air, compresses it, burns fuel to make air expand, and how the air is then forced out the tailpipe, creating thrust. There is also an optional teacher demonstration combining all these components into a single tennis ball–container engine.

Part 2 involves building a static, or non-moving, model of a jet engine. At the end of the lesson, students will use technical writing skills to explain how a jet engine works.

Part 1
Materials and Tools

- **Intake Station**
  - Small desk fan
  - One sheet of paper
  - Intake Station Directions
- **Compression Station**
  - Butcher paper
  - Two desk fans that are the same size
  - Twenty 6-inch lengths of string
  - Twenty 5-by-7-inch index cards
  - Tape
  - Two markers
  - Compression Station Directions
- **Combustion Station**
  - Flask, medium size
  - Balloon
  - Can of Sterno
  - Matches or lighter
  - Tongs
  - Combustion Station Directions

Procedures

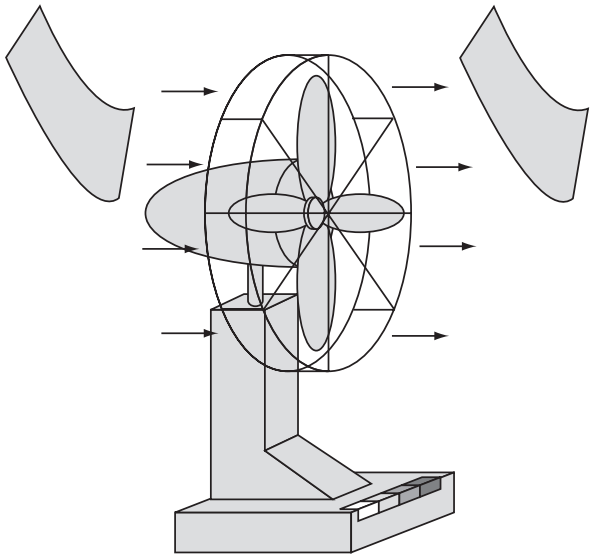
1. Prior to the start of school, set up the equipment at the three stations. If there is room you may want to set up several stations to improve classroom management and increase student participation. Make sure the fans are in good working order.

   Intake Station: Plug in the electric fan. Lay a few pieces of paper near the fan. Post the direction sheet on page 39 where it can be seen easily.

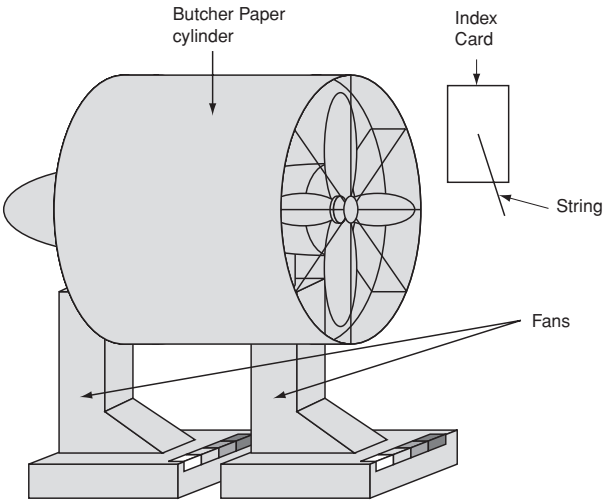
   Compression Station: Line up two fans, one in front of the other, pointing the same direction. Using butcher paper make a cylinder that will fit precisely around the frames of the fans. Tape the ends of the cylinder to the fans. Set out index cards, markers, string, and tape. Post the direction sheet on page 40 where it can be seen easily.

   Combustion Station: Stretch the balloon over the neck of the flask. Set out the Sterno can, matches, and tongs. You will want to monitor this station closely because of the use of heat and matches. Post the direction sheet on page 41 where it can be seen easily.
2. Distribute Student Work Sheet. Tell the students they will be conducting various experiments at the stations situated around the room.
3. Move around the room and read the directions for each station and demonstrate them with the fans turned off and the Sterno can unlit.

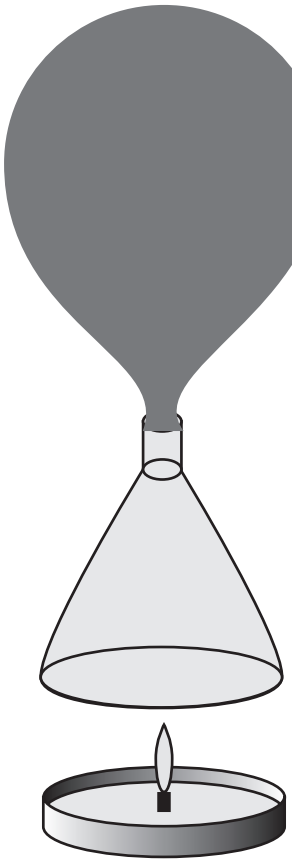
   Intake Station: Tell students to turn on the fan when they get to the station. Hold the piece of paper in front of the fan. Record what you observe. Next hold the paper behind the fan. Record what you observe.



Compression Station: Show the students how to poke a hole in the middle of the index card. Then put one end of the string through the hole and tape it to the index card. About 5 inches of the string should be hanging free. Tell them to turn on the fan. Then they will hold the index card 2 to 3 inches away from the front of the fan. The string should hang free. Using the marker, the students will mark how high the string is blown. Then the back fan will be turned on. With both fans blowing, the students will again hold the index card and string in front of the air stream and mark the height of the string. Record what you observe.



Combustion Station: Carefully light the Sterno can. Using the tongs hold the flask over the Sterno can for a few minutes. Observe what happens to the balloon. Record what you observe. Answer the questions on the student record sheet on page 42.



4. Prior to allowing the students to conduct each experiment, have them write their predictions for each activity. Set a time limit of approximately 15 minutes and allow the students to move around the room and conduct each experiment and answer the questions.

Discussion Questions

1. What did you observe at station 1 with the paper and the fan? Did this match your prediction? *The paper that is held in front is blown away from the fan. The paper held in the back is sucked in towards the fan.*
2. What was your prediction for what would happen if the air had been moving into the front fan instead of being still? What actually happened? *The air speed increases when the air behind the fan is blown into the fan rather than being still.*
3. What happened to the balloon at station 3? Why do you think this happened? What would happen if the air was enclosed in a tube that didn't expand instead of inside a balloon? *The balloon inflated because the air inside was heated. Heated air expands. If this had taken place in a tube, the air would have been forced out the end of the tube.*
4. All these stations demonstrate the processes that take place inside the various parts of a jet engine. In what order do you think they take place? Why? *The proper order of the stations is intake, compression, and combustion. There is an additional step of using a turbine to move the air out of the engine. This was not demonstrated. According to one NASA engineer, a shorthand way to remember the steps is "suck, squeeze, burn, and blow."*
5. Describe to the class the process an engine uses to produce thrust. A jet engine's compressor turns like the blades of a fan. This causes air to be drawn in from the outside. When the air moves through the compressor, which is a series of fans, it is compressed or squeezed. After moving through the compressor, the air enters the combustion chamber. In the combustion chamber jet fuel is ignited by the igniters, which are similar to spark plugs, which heats the compressed air, forcing it to expand. The rapidly expanding air is forced through a turbine, which causes it to turn and drive the compressor. The turbine is connected to the compressor by a shaft. The air then flows out the tailpipe.

Part 2
Materials and Tools

- One cardboard paper towel core per student
- One flexible straw per student
- One 12-by-12-inch sheet of aluminum foil per student
- Four paper circles 1-1/2 inches in diameter per student
- One small (1-inch) paper clip per student
- One 3-oz. paper cup per student
- One pair of scissors per student
- Tape
- Glue (not glue sticks)
- One copy of the Student Work Sheet Part 2 for each student (see page 44).

Procedures

1. Cut the paper towel core in half lengthwise (figure 1).

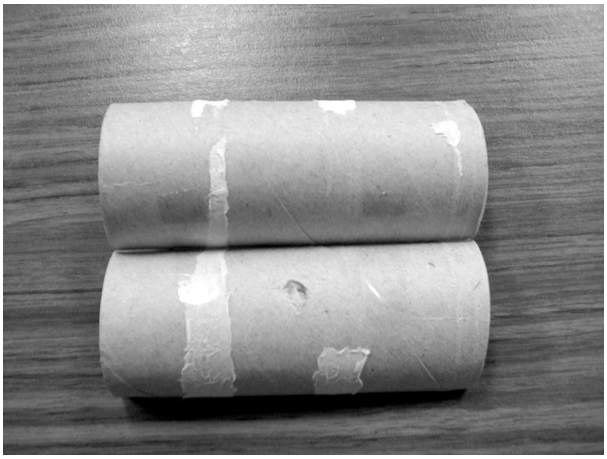


Figure 1

2. Tape the halves together on one side to create a hinge effect. This will make it easier for the students to put the pieces together.
3. Cover the halves with foil. This is strictly for appearance.
4. Using the pencil, poke a hole in one side of the toilet-paper core halfway down the core. Make the hole large enough for the straw to fit into it.

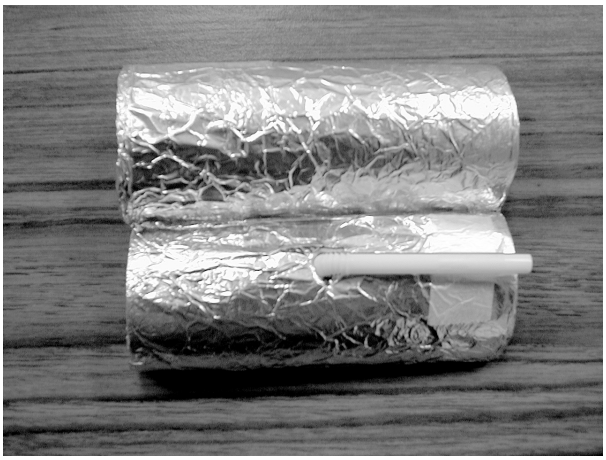


Figure 2

5. Cut the straw down so it is 1/4 inch long on one side of the flexible section and about 1 inch long on the other side.
6. Put the short end of the straw into the hole, bend the straw so the longer end lays flat against the paper towel core. Tape into place. This represents the fuel line (figure 2).
7. Fold the paper circles in half then into quarters. Open the circles.
8. Cut along the folds close to the center but do not cut through the center. Do this on the remaining circles too.

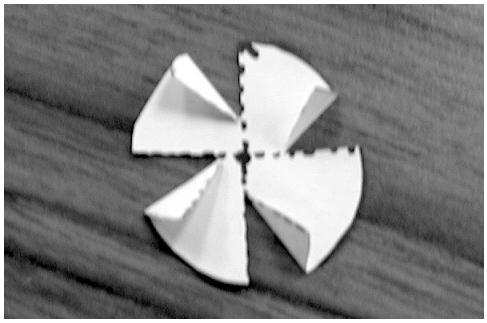


Figure 3

9. Bend one corner from each section so the circles resembles a fan. Do this for two more circles also (figure 3).
10. Straighten the paper clip. Then bend approximately 1/2 inch of the paper clip down on one end. This will keep the paper fans from sliding off the paper clip.
11. Push the end of the paper clip into the center of one fan. Slide the fan back so it is resting against the bent end of the paper clip. Wrap a narrow piece of tape around the paper clip to act as a spacer and to provide stability. Repeat this step with two of the three remaining fans.
12. Wrap a narrow piece of tape 1 inch from the straight end of the paper clip. Place the remaining fan onto the paper clip to serve as the turbine, wrap a final piece of tape around the paper clip to keep the fan in place (figure 4).

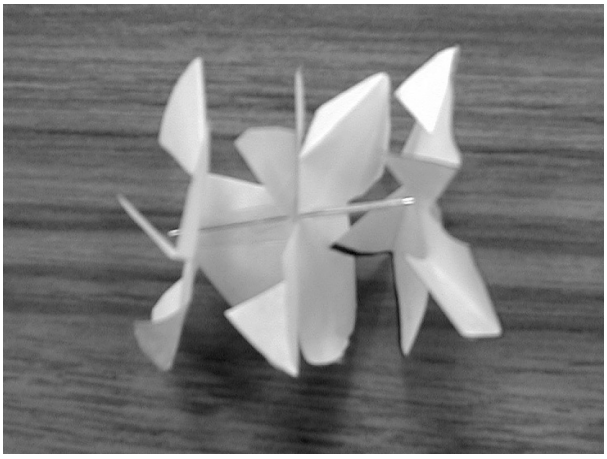


Figure 4

13. Install the compressor and turbine unit into the engine by placing glue inside the tube where the edge of the fans will touch the sides of the tube on the same side as where the hole was made for the fuel line. Hold the fans in until glue is partially dry (figure 5).

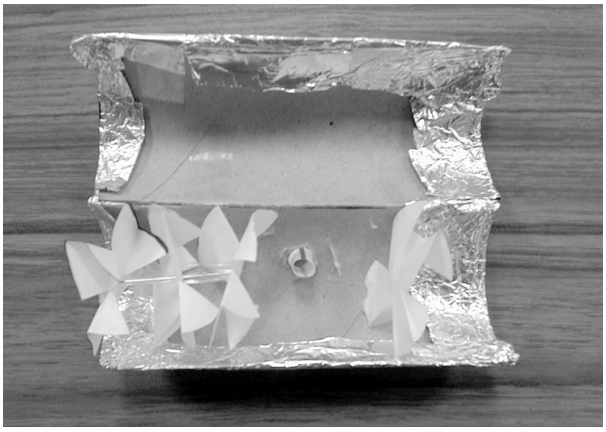


Figure 5

14. Tape the paper towel core shut.
15. Cut down the length of the paper cup and cut the bottom out of it.
16. Put the cup back together overlapping the edges.
17. Insert it into the paper towel roll, large end first. Ease the paper cup open until it snugly fits inside the toilet paper roll. Tape the edge of the cup on the inside to hold its shape. The cup will move easily but should not fall out. This represents the tailpipe and the movement of the tailpipe with thrust vectoring (figure 6).

Figure 6

Discussion

1. Based on the experiments and the follow-up discussion, what is the purpose of each part of the engine? *The air intake brings ambient, or outside,air into the engine. The compression section moves the air through a series of fans that compress, or squeeze, the air causing it to increase in speed. The combustion section heats the air by burning fuel. This causes the air to expand very rapidly and significantly increases its speed again. Finally, the turbine forces the heated, expanding air out the back of the engine, creating thrust.*

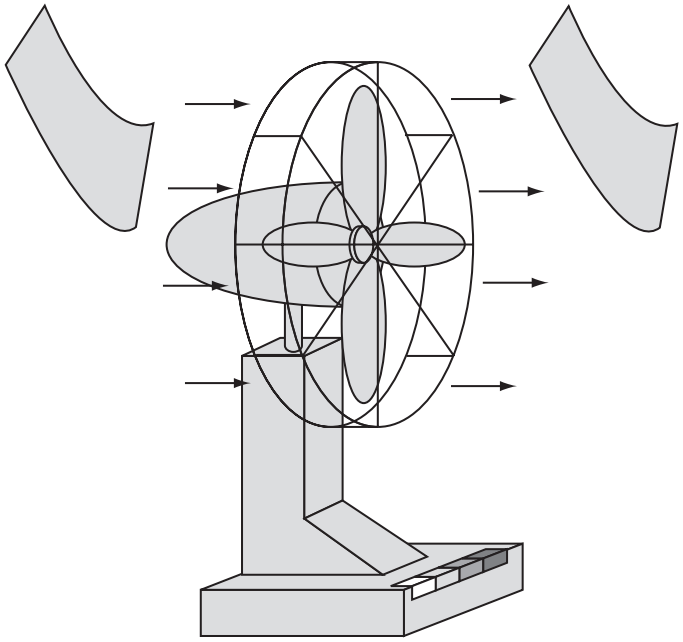
Assessment

Conduct a class discussion where students share their findings about how a jet engine works. Have them complete the jet engine work sheet by describing the function of each part of the jet engine. As an optional activity, instead of the Student Work Sheet, the students could be given a blank sheet of paper and instructed to draw a jet engine cross section using their model and then describe the function of each part. Collect and review completed student worksheets.

Intake Station Directions

Make sure to fill in the description and prediction sections on your Jet Propulsion Work Sheet *before* doing the experiment.

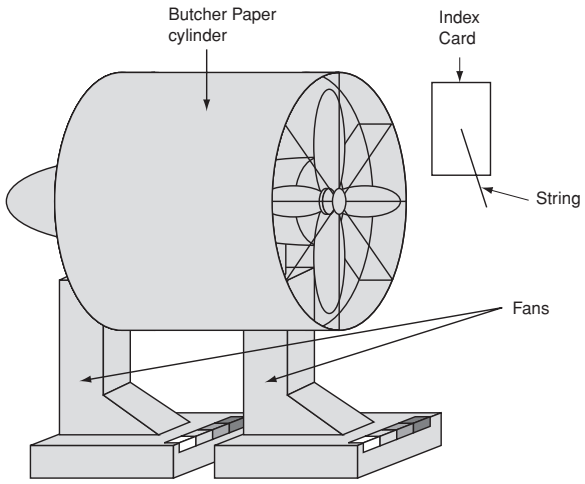
1. Turn on the fan.
2. Hold a piece of paper in front of the fan. Observe what happens.
3. Next, hold the paper behind the fan. Observe what happens.
4. Record your observations on your Student Work Sheet. Make sure to explain not only what happened but also why you think it happened.



Compression Station Directions

Make sure to fill in the description and prediction sections on your Jet Propulsion Work Sheet *before* doing the experiment.

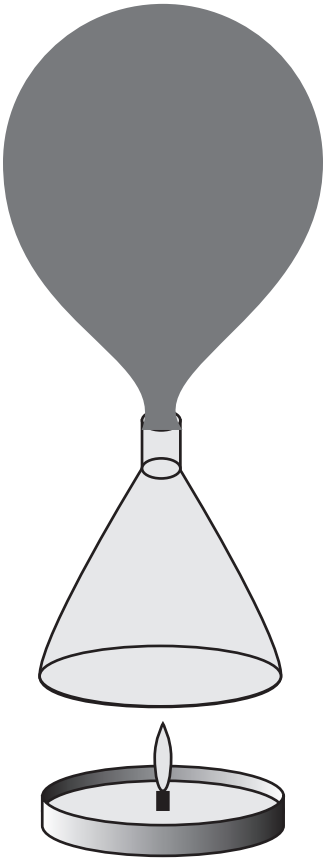
1. Take one of the index cards and poke a hole in the center of it using your pencil.
2. Thread about an inch of the string through the hole. Tape the inch of string to the index card. The free end of the string will move in the air current to help determine the relative speed of the air coming out of the fan.
3. Turn on only the front fan.
4. Hold the card in front of the fan so the long edge of the index card is about three inches from the front of the fan. Angle the card so that the string is blown by the air current coming from the fan.
5. Use a marker to mark how high on the card the string moved.
6. Leave the front fan on and turn on the rear fan.
7. Hold the card in front of the fan again.
8. Again, mark how high on the card the string moved.
9. Record your observations on your Student Work Sheet. Make sure to explain not only what happened but also why you think it happened.



Combustion Station Directions

Make sure to fill in the description and prediction sections on your Jet Propulsion Work Sheet *before* doing the experiment.

1. Pick up the flask using the tongs.
2. Hold the flask one to two inches above the flame from the Sterno can.
3. Wait and watch the balloon.
4. Record your observations on your Student Work Sheet. Make sure to explain not only what happened but also why you think it happened.



Student Work Sheet Part 1

Name:_____

Date:_____

Jet Propulsion

You may do the experiments in any order you choose. Complete these steps at each station:

1. Describe the experiment in your own words.
2. Predict what will happen during the experiment. Do this BEFORE conducting the experiment.
3. Conduct the experiment.
4. Record your observations and give your opinion as to why the experiment worked as it did.

_____

Intake Station

Describe the experiment: _____

_____

_____

Make your prediction: _____

_____

_____

Record your observations: _____

_____

_____

Compression Station

Describe the experiment: _____

_____

_____

Make your prediction: _____

_____

_____

Record your observations: _____

_____

Combustion Station

Describe the experiment: _____
_____
_____

Make your prediction: _____
_____
_____

Record your observations: _____
_____
_____

These three stations demonstrate different parts of a jet engine and how it works. Based on your observations, describe how you think a jet engine works.
NOTE: One of the stations has to be used twice.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____

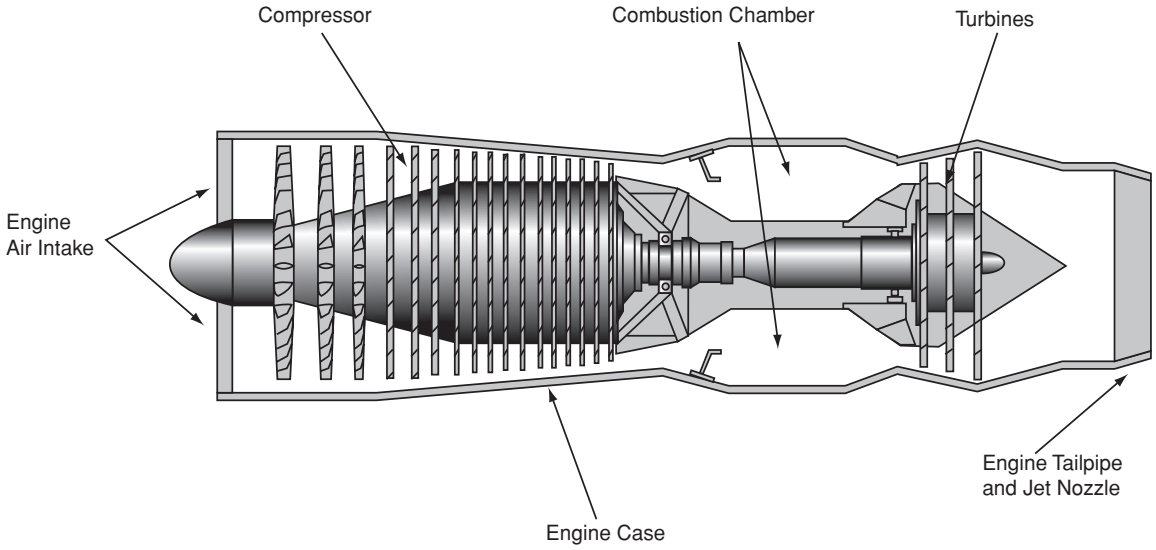
Student Work Sheet Part 2

Name:_____

Date:_____

Jet Propulsion Work Sheet

Describe the function of each part of the jet engine pictured below and state the scientific concepts that occur.



Air inlet (also intake)

_____

_____

Compressor

_____

_____

Fuel line

_____

_____

Turbine

_____

_____

Jet nozzle

_____

_____