How a Vacuum Cleaner Works

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Introduction

A vacuum cleaner is a household appliance that uses suction to collect dust, dirt and other small particles on a variety of surfaces. Vacuum cleaners are an essential appliance for homeowners due to their efficiency. Despite their widespread appeal, very few people know how vacuum cleaners work. There are many different types of vacuum cleaners and this document focuses on describing how a bagged vacuum cleaner works.

Process Overview

A vacuum cleaner uses a fan to create the suction necessary to pick up dirt and dust. Conceptually, a vacuum can be thought of as a reversed blower. The fan blows air towards the outlet, which forces air to enter the vacuum from the inlet. This can be thought of as air from the inlet "replacing" the air blown away by the fan. Since the fan spins at a constant speed, it creates a constant stream of air that travels from the inlet, through the vacuum's internal piping, and eventually to the outlet. The airstream is powerful enough such that it picks up and carries any dust or dirt near the vacuum's inlet. This dusty air eventually reaches the vacuum's bag where the air and dust are separated. The general process can be seen in Figure 1[1]. Overall, every vacuum cleaner involves three main components: an intake port, a fan, and a filter.

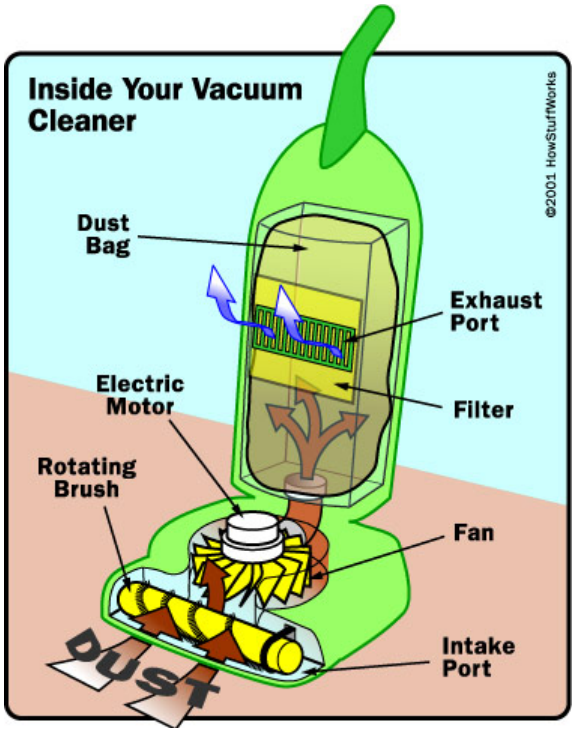

Figure 1: General Process

The Intake Port

Engineers have optimized the intake port's size to maximize the vacuum cleaner's suction. The intake port functions primarily as a nozzle. The inlet's opening size is fairly small relative to the rest of the piping in the vacuum cleaner. This design takes advantage of a physical law called *conservation of mass* which states that matter cannot be destroyed. Since air does not accumulate in the vacuum, all air that enters the vacuum cleaner must leave the vacuum cleaner. This implies that the amount of air traveling through the vacuum must be the same at any point in the vacuum. Therefore, as piping becomes smaller, the stream's velocity must increase. The vacuum cleaner's inlet has a small opening to increase the initial airstream velocity, which helps the vacuum pickup dust and dirt stuck to the floor.

A rotating brush at the intake port also increases the vacuum cleaner's efficiency. When the tiny fibers brush against the floor, they kick the dirt and dust up into the air. This forces the dust and dirt into the air stream that will carry it into the vacuum itself. While rotating brushes

[1] Image from http://s.hswstatic.com/gif/vacuum-cleaner-diagram.jpg

are not present in every vacuum cleaner, they are essential for cleaning carpets and other surfaces that particles can easily stick to.

The Fan

A vacuum cleaner's fan creates a pressure difference that generates the suction. Directly after the fan, the air particles become denser, which leads to a high pressure area. Since gasses travel from areas of high pressure to low pressure, the air travels from the fan to the exhaust port. Just as a high pressure area is created after the fan, a low pressure area is created before the fan. Therefore, an airstream will travel from the relatively high pressure inlet to the low pressure area before the fan. Overall, this creates a stream of air that travels from the inlet to the exhaust.

Figure 2: Typical Vacuum Cleaner Fan

Most vacuum cleaners use a centrifugal fan to generate the pressure difference instead of an axial fan. In a centrifugal fan, the air enters the fan axially (perpendicular to the fan) and flows out radially (parallel to the fan). For axial fans, the air enters and flows out perpendicular to the fan. Table and pedestal fans usually use axial fans while pumps and vacuums usually use centrifugal fans. A typical vacuum cleaner fan can be seen in Figure 2[2]. The fan in the image would push air to the sides by rotating counterclockwise. There are many reasons most vacuum cleaners use centrifugal fans instead of axial fans. For example, they help create a more compact design and they can maintain higher pressures at higher flowrates.

It may be useful to think about a vacuum cleaner's fan not in terms of suction but in terms of flowrate. A vacuum cleaner is no different than a blower put on reverse. As the saying goes, science does not suck; it blows.

The Filter

The vacuum cleaner's bag acts as the process's storage container and air filter. The bag is made with cloth or paper with microscopic holes large enough such that air particles can pass through but dust and dirt cannot. Therefore, while the air passes through the bag and out the exhaust port, the dust and dirt stay behind. Since the filter also acts as the vacuum's collection container, it is placed after the fan but before the exhaust port. The greatest issue with these filters is that vacuums lose suction as the containers become filled. As dust collects in the vacuum bag, the small holes in these filters become clogged. The air faces more resistance in these sections, which decreases the vacuum cleaner's suction.

There are some cases where an air filter is located before the fan. In these cases, the dust will collect in a canister instead of a bag. This is important if the designers do not want dust and other vacuumed materials to come in contact with the actual fan. For example, these designs are prevalent in handheld vacuum cleaners where the fans are cheaper and not as durable.

[2] Image from http://www.thepartsbiz.com/thumbnail.asp?file=assets/images/38755030.jpg&maxx=300&maxy=0

Conclusion

Overall, a vacuum cleaner creates suction through a few simple steps. Every home vacuum cleaner uses a fan to create a pressure difference which generates the suction needed to clean a variety of surfaces. This fan creates a constant stream of air that travels from the intake port, through the fan, and to the exhaust port. All vacuum cleaners also separate the air particles from the dust particles using an air filter. Over the past century, there have been many technological advancements that have improved the vacuum cleaners efficiency, particularly related to the filtering system. Despite these advancements, all vacuum cleaners still operate under the same general principals. These simple components contribute to one of the most important innovations of the 20th century.