

An Ingenious Engine

Chris Langenfeld



Courtesy of Chris Langenfeld

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A few years ago, my boss had a vision to create a better wheelchair. After many years and countless prototypes, we finally landed on a great design. The IBOT™ Mobility System, sold by Johnson & Johnson, can climb stairs and balance on its two back wheels to lift the occupant to standing height. We designed the wheelchair with four rear wheels instead of two, so it's kind of like a truck. The extra wheels make it stable but also give it tremendous balance and climbing capability. This design gives users remarkable freedom, helping to restore independence to people who've suffered loss of physical mobility.

This kind of project gives me a lot of satisfaction. I'm Chris Langenfeld, and I'm an engineering manager at Deka Research, a design firm based in Manchester, New Hampshire. Our firm creates new products and technologies that help people.



Courtesy of Chris Langenfeld, Deka
Research and Development Corporation

The IBOT Mobility System

In a **closed system**,
the working fluid
remains within the
system.

In an **open system**,
the working fluid
moves across the
system boundary.

We do research and development for other companies. In other words, we design new products, and then we submit our designs to other companies who manufacture and sell them.

In my opinion, Deka is about the greatest place on Earth to work. Our founder and my boss, Dean Kamen, is a famous inventor who holds over 150 patents for new devices, many of them medical technologies. He firmly believes in the virtues of technology and has made it his mission to educate the world about them. His enthusiasm is contagious. Since I've worked here, I've seen for myself just how much well-designed technologies can improve people's lives.

A Closed-System Engine

Just after we started our wheelchair project, we realized that our design would need a lot of power to make it run. At the time, the best battery available was the ordinary lead-acid storage battery, much like what's used in a car. But because our wheelchair had multiple motors for the wheels and electronics for control and balance, we needed more power than a lead-acid storage battery could supply. Our wheelchair needed an engine.

But what kind of engine would work? We knew that the right engine for our wheelchair had to be quiet. Internal combustion engines make a lot of noise when the fuel combusts in the cylinders. Then we remembered a tiny, very quiet engine invented long ago, the Stirling engine.

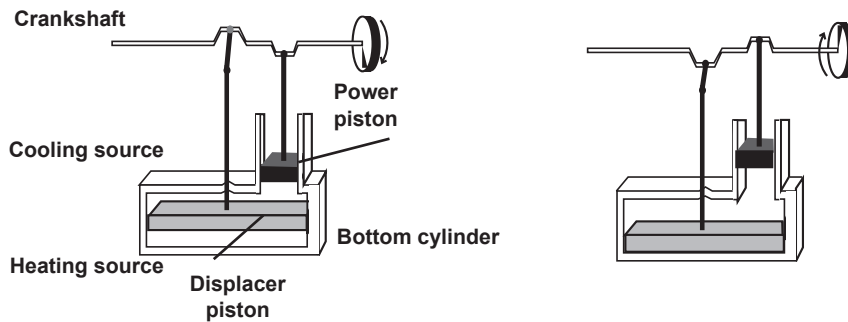
Robert Stirling, a Scottish minister, invented the Stirling engine in 1816. Stirling designed his engine to be a **closed system**—that is, the working fluid stays inside the engine instead of passing through it, as happens in a car engine. The term “working fluid” refers to the fluid—usually a gas—that actually moves inside an engine. In a closed-system engine, only energy moves across the system boundary.

Stirling's design was, and still is, a marvel of technology. The engine works by heating and cooling the working fluid. As you recall, gases expand when heated and contract when cooled. If the gas is in a flexible container, the volume of the container will increase or decrease depending on the change in the gas's temperature.

If you were to look inside one type of Stirling engine, you would see something like the diagram below. A large cylinder full of the working fluid has a displacer in it that can rise and fall easily. At the top of the cylinder, there is a piston, called the “power piston.” The displacer and the power piston are both connected to a crankshaft in such a way that when the power piston rises to maximum height, the displacer piston is nudged down. The up and down movement of the piston turns the crankshaft, which spins a flywheel.



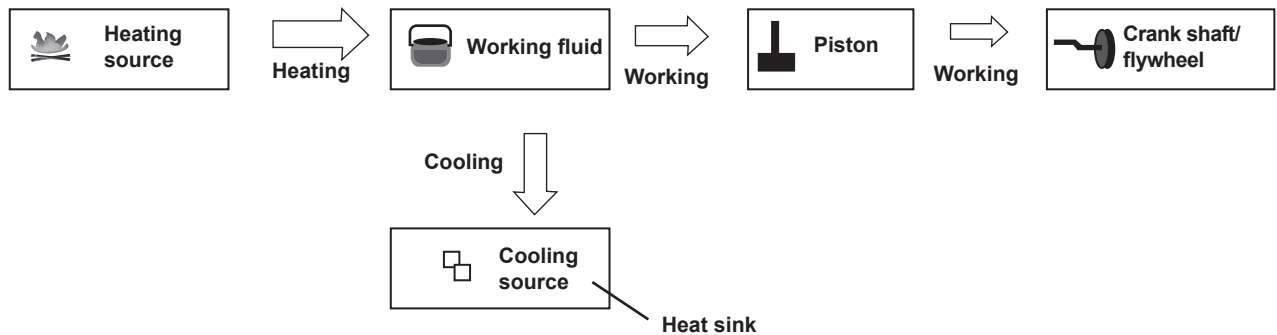
Robert Stirling
(1790–1878)



1. The bottom cylinder is heated. The displacer piston is pushed up.
2. The power piston is pushed up, which causes the crankshaft to turn.

The bottom of the cylinder is heated to start the engine. The working fluid expands, increasing the pressure underneath the displacer piston and pushing the piston up. As the displacer rises, the working fluid at the top of the chamber pushes the power piston up. The power piston pushes on the crankshaft, causing it to turn. When the power piston reaches the top of its stroke, the crankshaft nudges the displacer down. Fluid flows around the displacer to the top of the cylinder, where the gas is cooled by ice or cold water. As the gas is cooled, the pressure in the cylinder decreases and the displacer piston falls. At the bottom of the piston’s stroke, the crankshaft nudges the displacer up. Fluid flows around the displacer to the bottom of the cylinder, where it is heated, and the cycle begins again. If you were to diagram how the energy moves through the system, you’d see that it flows from the energy source through the engine to the spinning crankshaft. Any energy that is not transferred to the spinning crankshaft is transferred to the cooling “source.” The cooling “source” is not really a source at all. It’s an object with lower temperature (less energy) than the heat source. Energy always flows from the higher-energy object to the lower-energy object. In fact, it may be more appropriate to refer to the cooling “source” as a “heat sink.”

The greater the temperature difference between the top and bottom of the engine, the greater the amount of energy transferred to move the pistons and spin the flywheel. The energy source could be anything hot—burning fossil fuel, wood, or dry sugar cane, hot water from a solar collector, or steam from a geothermal well. Likewise, the heat sink could be any lower-temperature object—water, ice, even a cool breeze. In a Stirling engine, the working gas never leaves the engine the way it does in an internal combustion engine. There are no explosions, and there are no exhaust valves. The Stirling engine is very quiet.



Our plan for the wheelchair was to use a small propane tank as a fuel source to heat up one side of the Stirling engine. Water is used as the heat sink. Propane gas cylinders are cheap and they're available at most hardware stores or home centers.

While it's possible to use room air as the working fluid, a Stirling engine works much better with helium gas. Helium transfers energy very effectively. But helium tends to escape easily from containers. Our engineering team put the Stirling engine inside another sealed container filled with helium. And, of course, we have small pipes that allow us to circulate hot gasses from the burning propane around the "hot" side, and a cold liquid, such as cold water, around the "cold" side. The high-pressure working fluid stays safely sealed inside, and the engine can run for years and years without worry.

Now we had an excellent power source for the wheelchair. During the time it took to develop the wheelchair and the generating engine, however, battery technology improved radically. In a few short years, batteries became so improved that we decided to develop the IBOT using the new type of batteries instead of our power-generating engine. We put our engine on the shelf for a while.

Recently, we've discovered some great alternative uses for our engine. We're working on a water purification system that can provide clean drinking water for a few families or a small village. Our vision is to use this purification system in poor, third-world countries where babies and children become sick and die every day from polluted water. The Deka purification system would be a small-scale machine that, hopefully, we can make available to millions of people who have never had clean water for safe cooking and washing.

We're also looking into the possibility that our generator could provide supplemental power in the big diesel trucks that drive coast to coast. Often the drivers stop for the night and stay in their sleeper cabs. They allow their diesel engines to idle all night to provide power for their TVs, microwaves, air conditioners, heaters, and so on. But these diesel engines pollute, particularly when idling. We envision that our Stirling engine could run on a much smaller amount of fuel to provide the electrical power the truckers need for their sleeper cabs.

In my view, the Stirling engine offers society advantages for producing electricity in an environmentally friendly way, particularly when it draws energy from the sun or geothermal wells. And whether run by external combustion, such as burning wood, or pollution-free sources, such as solar or geothermal energy, the Stirling engine can generate electricity reliably, cleanly, and quietly. I always find it amazing how technologies invented long ago can, with a few improvements, suit our modern needs very well. The best designs are truly timeless. I often wonder if, one hundred years from now, people will still use the IBOT or some other technology that I helped to develop. Regardless, I have complete faith that the work we are doing today at Deka will influence inventors of the future. That's how it is in engineering. In the same way that scientific knowledge accumulates over time, each new technology builds on the ones that came before it—and every engineer draws inspiration from his or her predecessors.



What's the Story?

1. Why is the Stirling engine considered a closed system?
2. What were the design requirements for the wheelchair engine? Why did the Stirling engine seem like it might meet the criteria?
3. Why wasn't the engine that Chris's team redesigned used in the wheelchair? How might it be used?



Designing with Math and Science

4. Chris describes the "cooling source" as an "energy sink." Why is the term "energy sink" more appropriate?
5. Chris says that the greater the temperature difference between the top and bottom of the Stirling engine, the greater the amount of energy transferred to move the pistons and spin the flywheel. Explain.



Connecting the Dots

6. In a Stirling engine, the working gas never leaves the engine. Describe how this is different than a combustion engine.
7. Given what you know about renewable energy sources, explain how the Stirling engine may be used in a way that is beneficial to the environment.



What Do You Think?

8. If you were to manually turn the crankshaft of a Stirling engine, the engine would work in reverse. It would pump energy from one side of the engine to the other. Over time, one side of the engine would become cool and the other side hot. What might be some practical applications of this?
9. Be creative and think of a way that a closed-system engine like the Stirling engine might be applied.