



# Free Piston Stirling Engines

The story of a novel remote power solution that helps companies improve efficiency, decrease cost and reduce emissions

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## A New Power Solution for Off-the-Grid Pipelines

### **Combining a 19th Century Technology With 21st Century Power Electronics Provides Cost-Effective Power.**

Ever since there have been gas and oil pipelines, there has been a need for a remote power source to provide electricity for off-the-grid remote locations. And since that need first arose, there has been a competition to provide the ideal generator that could deliver the power required that was affordable and reliable.

#### **Off-Grid Solutions?**

Until very recently, the choices available always involved compromises and none provided a totally acceptable solution for pipeline companies. First was the obvious – expanding the grid to reach the pipeline.

It was also the most expensive due to permitting cost and timeline and therefore was quickly replaced, in most instances by internal combustion engines. But they required fuel shipments and frequent maintenance and repair, often causing downtime for the wells and transmission pipelines.



Fortunately, a new solution has recently appeared that gives all indications of solving the most challenging problems of remote power generation. Ironically, it is based on a technology that is more than 200 years old and invented by a clergyman – the Stirling Cycle External Combustion Engine. But before we look at how this old technology has been modernized to fit the needs of the pipeline industry, we'll look briefly at the technologies it can replace and their attendant problems.

Today, the technologies most in use at remote well pads and pipelines are internal combustion engines, solar, microturbines, and various alternative energy systems. They all provide remote electrical power and they all have serious drawbacks.



### **Power Generation Solutions**

Joe Barker is an asset integrity supervisor for Williams in the Rocky Mountains Region. Among other things, he is responsible for power availability for numerous off-the-grid cathodic protection sites.

“We have been primarily using dedicated generators in most of our remote applications,” said Barker. “One of the problems we had was that none of the generators we were using were as cost effective as we would have liked.

One “alternative energy” unit we were using cost me around \$25,000 each. but one unit only gives me 500 Watts of power. The other limiting factor was that it is only capable of producing about 20 Volts. When my ground bed goes high resistivity, which happens more often than I’d like, I can’t increase the voltage to maintain the same current output. I then have to install an additional generator, which only provides temporary help because I still don’t have the voltage to overcome the increasing resistance of the ground bed. That, in turn requires me to install another ground bed that costs around \$60,000.

“They just don’t give me the power and reliability I need. I have a site near Vernal, Utah that has three generators in series, so that’s an \$80,000 investment and I’m still only getting 1,500 Watts where I could easily use 6,000 Watts.”



## Upstream Problems

Tony Ward, a senior measurement foreman for a major upstream producer, agrees with Barker.

“Once we developed our first field some years ago, our automation needs started to grow. We started using remote alternative energy generation at our off-grid well pads,” he said. “They were somewhat satisfactory but were also expensive for the amount of power generated. At the time, they were the obvious choice because they provided power around the clock. But they were also high maintenance because they were susceptible to environmental problems such as high winds and rain. It seemed that our maintenance crews were always working on one or more of them with all the attendant expenses involved. We now have more than 900 wells to service in the Northwest with 400 generating locations. What we needed was a power solution that provides electricity without all the maintenance.”

### **Solar Difficulties**

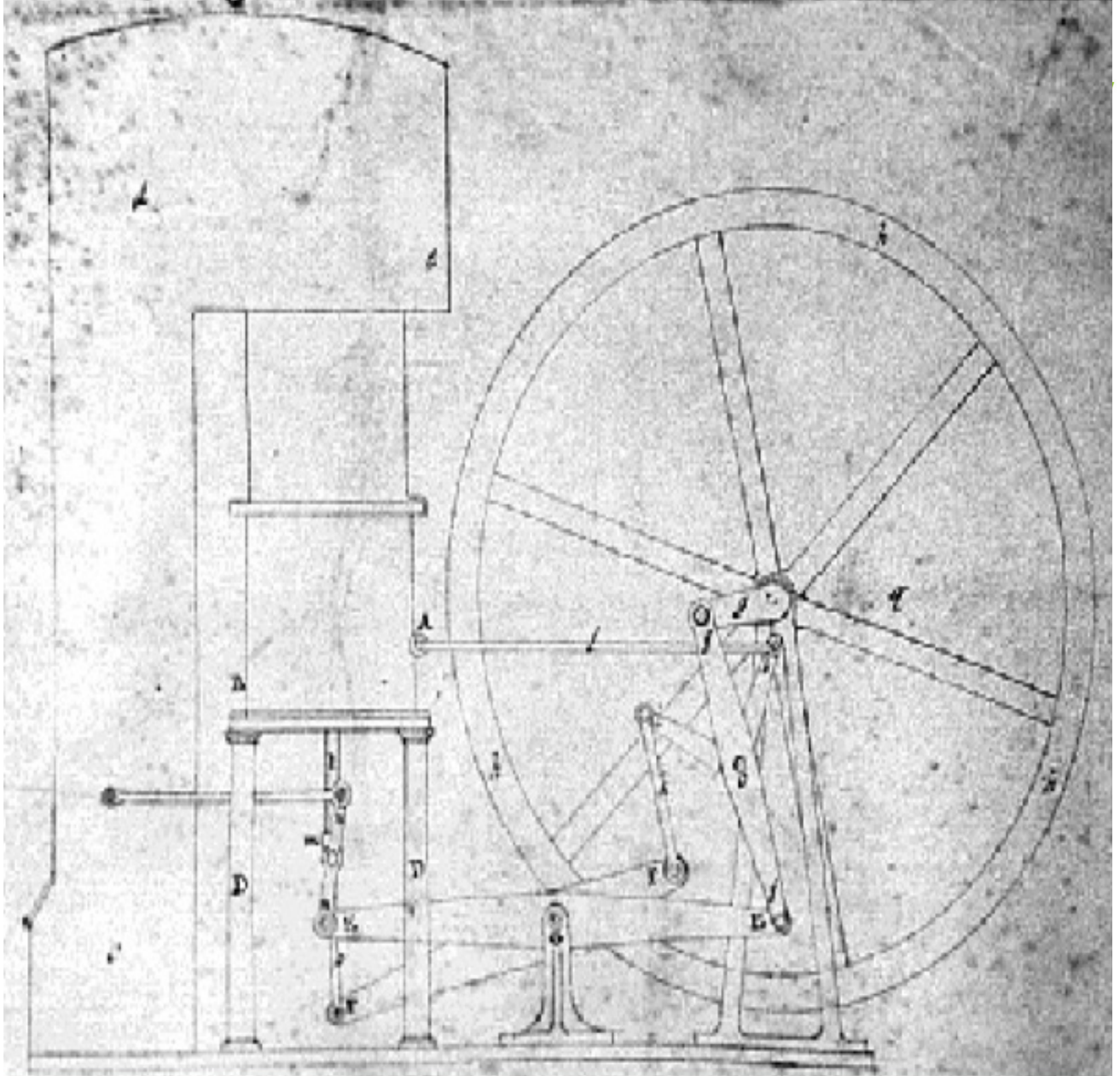
“We also tried solar because it seemed to make sense with no moving parts and battery back-up,” said Barker. “I quickly learned that the batteries weren’t as robust as I needed. Recently, I had to replace batteries for a solar unit and it cost me more than \$8,000 dollars per unit that only puts out six amps of power. We decided to ramp up our search for a better off-grid generating system.”

“The solar generators we tried just didn’t work out for us,” said Ward. “They were passable when the sun shined, but even then, the power was barely adequate. Then from December through April it’s mostly overcast here and when it snows, we had to send crews out to sweep off the panels. Our solar experiment didn’t last long.”



### **Microturbines Expense**

“I also have ten microturbines that I use for remote power for our off-grid cathodic protection sites,” said Barker. “Another experiment that didn’t pan out. They cost me \$100,000 and produce 30,000 Watts each and I usually end up using only 3,000 Watts. It’s a lot of money for power I don’t need.”



### Enter the Stirling Cycle Generator with a Bit of History

The Stirling Cycle External Combustion Engine was invented and patented in 1816 by the Reverend **Robert Stirling**. The concept at the time wasn't new. It utilized steam boilers with external combustion and the heat source outside of the power generation area.

In the early 1800s, those boilers were also the problem Stirling and several other engineers were trying to solve. The reason? The boilers of the time, with their high-pressure steam tanks, poor quality materials, and imperfect welding technology, had a propensity to explode. Several companies tried to find safer replacements that didn't rely on the then- dangerous steam technology. A variety of generator manufactures tried to offer alternatives, but none could provide a functioning system.

Robert Stirling tried to learn from the failures of his colleagues and, in 1818, introduced an external combustion engine that successfully pumped water from a quarry and completely drained it. Unfortunately, the power produced still wasn't sufficient enough to replace the steam generators. For Stirling and those who followed him, that was one of the rare victories for the Stirling engine which never became commercially viable.

**Not until nearly 200 years later, that is.**

### How the Stirling Engine Works

The Stirling engine operates on what is now called the Stirling Cycle. When it was discovered by the good Reverend, no one realized that the cycle was actually a new contribution to thermodynamics. Stirling, unfortunately died before he knew what he had discovered. The unique aspect of the Stirling Cycle is that it is reversible, meaning that it can function as a heat pump for heating and also for cryogenic cooling.

The cycle is defined as a closed regenerative cycle with a gaseous working fluid. "Closed cycle" means the working fluid is permanently contained within the thermodynamic system. This also categorizes the engine device as an external heat engine. "Regenerative" refers to the use of an internal heat exchanger called a regenerator which increases the device's thermal efficiency.



### Pipeline Applications

"In the case of oil and natural gas pipelines, only the heat generation aspect of the Stirling Cycle is applied," said Dan Midea, Vice President of Qnergy, one of the world leaders in remote power generation. The electricity created is identical to the typical AC and DC power available from the grid and, therefore, ideal for off-grid pipeline applications. "But generating electricity wasn't the only change that was needed to prepare the Stirling Cycle technology for remote power generation," said Isaac Garaway, PhD, Chief Technology Officer for Qnergy. "That entailed eliminating much of the design that made it impractical for nineteenth century factories and useless for electrical generation. Since it was designed to replace steam boilers, much of the original Stirling engine was a complex collection of fly wheels, mechanical linkages, and valves – all of them were maintenance problems and none of them were needed for electrical generation."

### **The High-Tech Spring Solution**

“Getting rid of the extraneous mechanical parts was easy, but we needed something to replace them with that would enable the engine to produce reliable energy over the long term,” said Garaway. “To the engineering mind, the answer was obvious – springs. But not just off-the-shelf springs. We needed springs that would last as long as the simple mechanical operation of the Stirling Engine. So, we set about inventing a new, extremely durable spring which was eventually patented. This, along with robust, state-of-the-art power electronics is what separates the Qnergy PowerGen, from all others.

### **Enter NASA**

As Qnergy engineers were refining their new spring technology, NASA was entering the early stages of planning for their proposed Deep Space Missions. There were many needs to be addressed, not least of which was that of a highly reliable power source.

“The Deep Space Programs involved, of course, leaving the solar system,” said Garaway. “And that meant losing access to the sun which some NASA equipment relied upon to produce electricity during near-solar exploration. Ideally, they wanted their equipment to be maintenance free for 20 years running time.

## **“The Longest Running Heat Engine in History” According to NASA, the Free-Piston Stirling has “Unparalleled Reliability”**

Years back, the Qnergy engineering team developed a generator specifically for NASA Deep Space Missions. We bench tested our units against the competitor’s generators at the NASA labs and, when last we checked our generators had recorded the longest time of any dynamic thermal generators ever recorded – 110,000 hours and counting,” said Garaway. “That’s a world record of more than 12 years of constant operation without maintenance.”



**"It keeps going and going: Stirling engine  
test sets long-duration record at NASA glenn"**

July 30TH 2018 | by Michaell Cole



### **The Qnergy Free Piston Stirling Generator on the Pipeline**

Both pipeline professionals we quoted earlier discovered the Qnergy Stirling generator while looking for alternatives to their existing off-grid electrical sources.

"I heard about what Qnergy was doing and made an appointment to see a demo at their Ogden, Utah headquarters," said Barker. "Needless to say, I was skeptical."

"When I first started in Oil and Gas, I was a journeyman electrician and senior instrumentation/controls technician and had an extensive background in electrical generation and instrumentation. I was familiar with the Stirling generator concept; I just never heard of it being practical."

"As they started explaining what they had done to adapt it, I started to get excited. It made so much sense, I decided to give one a try. We installed it at a site outside of Arches National Park." "In the first four months it experienced heat up to 115 degrees Fahrenheit and worked flawlessly with no maintenance. At that point, one of our older generators went down in Wyoming because the ground bed resistance had increased to two Ohms, which was too high for the generator we had. We decided instead of replacing the generator with another like it, to install a Qnergy PowerGen. We set it on the site, put a rectifier on it, and started getting 24 amps where we were only getting eight before. And because the Qnergy PowerGen is capable of delivering the higher voltage, I can push the bed harder."

"But that's not the end of it," he said. "Half a mile away I had a solar generator that had batteries that were ready to go bad. That's about \$8,000 in batteries for a solar unit that is only capable of producing less than 20 volts and 6 amps of current. We dug a trench and ran an AC cable from the Qnergy generator to the solar site and set up another rectifier and now we're running two sites off one Stirling generator."





"Next year we're budgeting for another one at a remote meter station in the Idaho high desert. There, the pipeline feeds into a custody transfer unit in Nevada where we're still running an engine generator with a battery bank and everything else. It needs to have its oil changed every 30 days. The Qnergy PowerGen will pay for itself pretty quickly."

"I asked some of the Qnergy techs what the failure rate is on the springs they used on the generator and they said they didn't know, they have one generator with more than 100,000 hours on it and they've never had a failure."



### **The Qnergy Glycol Circuits and Well Head Power**

“While we were wrestling with the high maintenance costs for our older generators, I received a call from a rep who used to sell them to us,” said Tony Ward. “He, too, had become tired of dealing with the maintenance nuisances and had begun representing the Qnergy Stirling products. He did some demos for us and we were intrigued. Then he mentioned a side benefit of the Stirling generators – that the waste heat is easily usable. We had been using stand-alone heat trace units to keep our water dump lines from freezing in cold weather. But they had the same maintenance problems as our old generators and when a dump line freezes, it shuts down the well. I asked if the company he represented did anything with glycol heating loops and he said not yet, but he was sure they would be interested. He put us in touch with the engineering team from his supplier, Qnergy, and in very short order they developed a means to harness the waste energy and channel it into a glycol loop.”

“That was our first Qnergy generator purchase and it is still running today with no maintenance problems.

“We went on from there to add Qnergy generators for our AC well pad needs and for our straight-up well head applications including DC power for automated valves, controls, analyzers, emergency shut-down switches, air compressors, and motors. Thanks to what was once a nearly forgotten technology, we are now as close to maintenance free and still off-grid.”

**It seems as if the solution to modern pipeline off-grid power issues may well be a 200- year-old concept.**



For more information on the Qnergy,  
Free Piston Stirling engine remote power systems:  
**[www.qnergy.com](http://www.qnergy.com)**