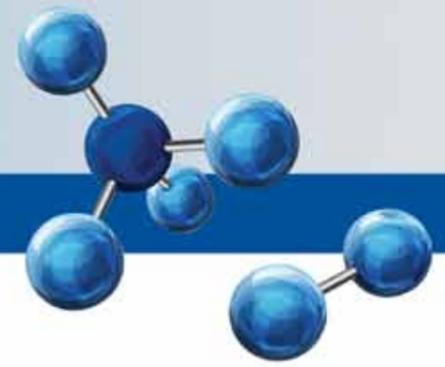




## FREESPIN™ IN-LINE TURBOEXPANDER

for Natural Gas and Hydrogen Applications





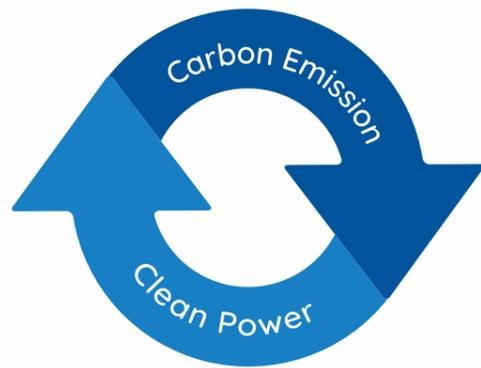
## SUSTAINABLE AND RELIABLE PRESSURE-TO-POWER SYSTEMS ●●●

Sapphire Technologies' FreeSpin™ In-line Turboexpander (FIT) harnesses the power of gas expansion to produce reliable and clean electricity. The FIT uses magnetic technologies that provide a way to capture the energy lost in pressure reduction. Sapphire has the technology and experience to maximize your plant efficiencies, improve productivity, reduce carbon emissions and generate additional revenue.



Sapphire Technologies' FreeSpin™ In-line Turboexpander and Variable Speed Drive

## REDUCED CARBON EMISSIONS ●●●



Carbon emission reduction is the cornerstone of Sapphire Technologies' mission. Sapphire's FreeSpin™ systems convert wasted energy into usable electricity, offsetting CO<sub>2</sub> emissions from the gas distribution network. Each FreeSpin™ system produces 300 kW of clean power and reduces carbon emissions by 1,200 CO<sub>2</sub>e tons per year.

## FREESPIN™ TECHNICAL FEATURES ●●●

The FreeSpin™ In-line Turboexpander system consists of a high-performance, high-speed permanent magnet generator with an integrated radial in-flow expansion turbine and low loss active magnetic bearings (AMBs). The FIT is designed to have the process gas flow through the system, which cools the generator section and eliminates the need for auxiliary cooling equipment. More information about each component is provided below.

**Expander/Turbine Wheel** - High-pressure gas enters through the expander wheel where the kinetic energy is extracted from the gas stream. The gas leaves the expander section at a lower pressure and temperature.

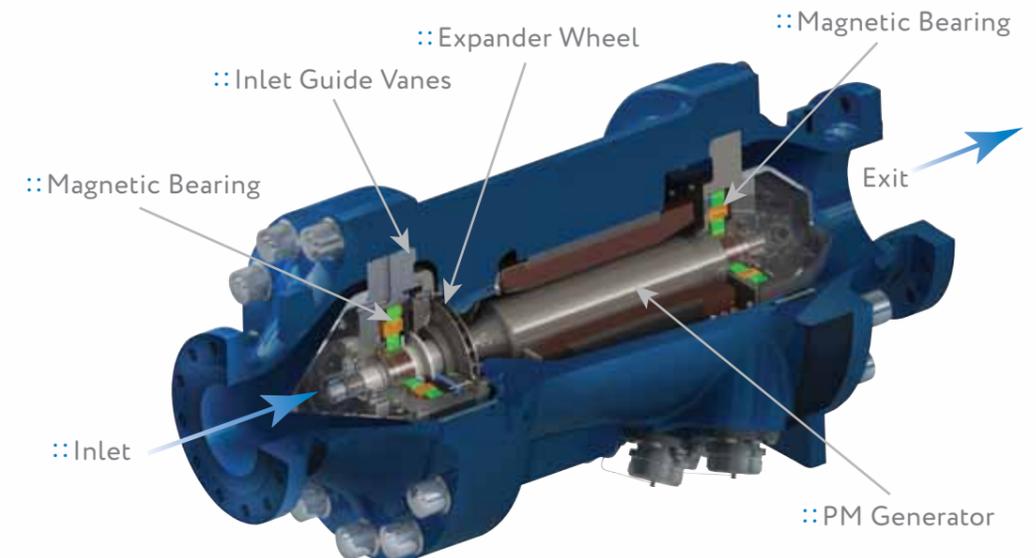
**High-speed Permanent Magnet Generator** - The permanent magnet (PM) generator is directly coupled to the turbine shaft and converts the rotational mechanical energy from the turbine into useable electricity via the variable speed drive.

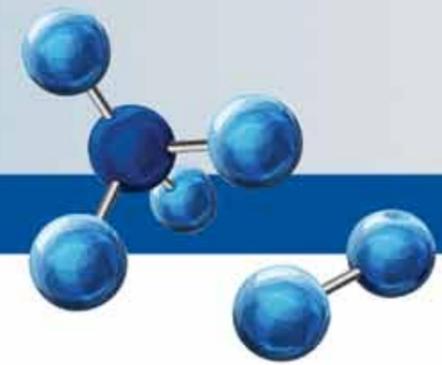
**Active Magnetic Bearings** - The active magnetic bearings (AMBs) are highly reliable and allow the dynamic components of the FIT to operate in a levitated condition, consuming minimal energy and eliminating maintenance as compared to conventional bearing systems.

**Inlet Guide Vanes** - The inlet guide vanes direct gas flow into the expander wheel to optimize aerodynamic efficiency.

**FIT Drive** - The FreeSpin™ power electronics for FIT combines the Variable Speed Drive (VSD) and Magnetic Bearing Controller (MBC) into one cabinet. The VSD allows for a consistent delivery of generated power from the FIT to the grid.

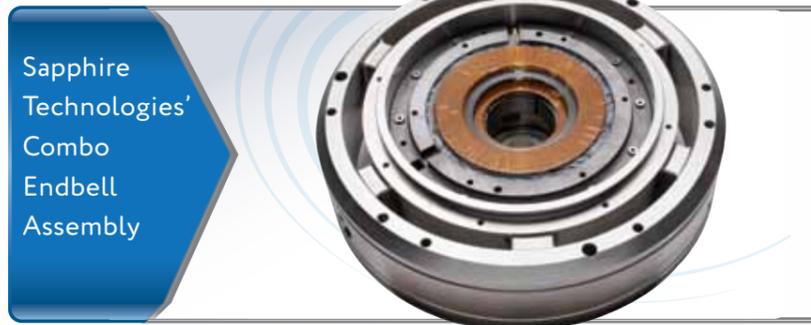
Cutaway model of FreeSpin™ In-line Turboexpander





## COMPETITIVE ADVANTAGES ●●●

- Free Fuel
- Payback 1-3 years
- Proven Technology
  - Millions of operating hours (cumulative)
  - Over 400 fielded units
- Hermetically Sealed Module
  - Eliminates dynamic seal systems
  - No possibility of leaks between rotating parts
- High-Speed Permanent Magnet Generator
  - Up to 30,000 RPM
  - Variable speed and load capabilities
  - 98% generator efficiency
  - No gear box or associated lubrication system
- Low Lifecycle and Capital Costs
- No Carbon Emissions
- No User Serviceable Parts
- Compact Size
- High Power Density
- Magnetic Bearings
  - Non-contact operation
  - Low power consumption
  - No lubrication, lubrication system, or seals
  - No maintenance for the life of the unit
  - Monitors rotor unbalance



## APPLICATIONS ●●●

### Natural Gas Pressure Letdown

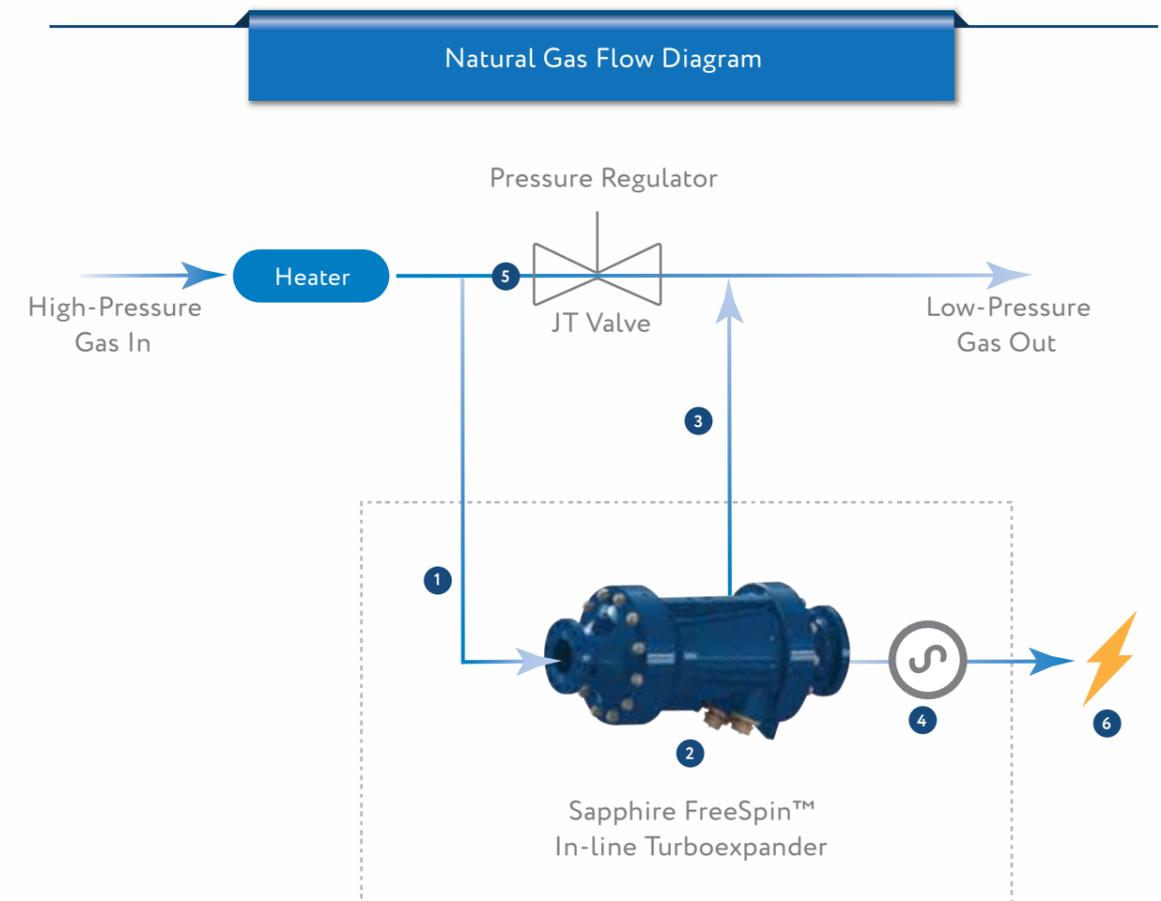
Sapphire's FIT is an innovative and economically viable solution to increase the energy efficiency of a natural gas processing plant or distribution facility.

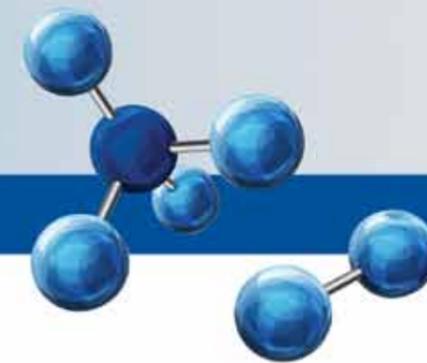


Natural gas is pressurized to facilitate transportation across long distances through pipelines. The pressure is stepped down at pressure letdown (PLD) stations for delivery to industrial, commercial and residential end users. The PLD stations use regulating valves to achieve the required pressure drop, but also waste significant amounts energy in the process. A turboexpander generator, such as the FIT, can be installed in parallel to the regulating valve to recover the wasted energy from pressure reduction and produce electricity.

## How Application Works

- 1 - The pre-heated high-pressure gas flows into the FreeSpin™ In-line Turboexpander.
- 2 - The gas expands through the radial turbine wheel.
- 3 - The low-pressure gas exits the FIT and is ready for further distribution.
- 4 - The energy wasted during the pressure reduction process is recovered by the FIT and converted to electrical power.
- 5 - Any excess high-pressure gas not directed through the FIT is expanded by the conventional pressure regulator, which is installed in parallel to the FIT.
- 6 - The produced electricity enters the Power Electronics Unit, which can be programmed to specific power requirements.





## Hydrogen Power Generation and Distribution

Hydrogen is a rapidly growing global energy storage market and is used in many manufacturing processes from petroleum refining to food processing. There are several instances of pressure letdown in the hydrogen distribution and consumption network where Sapphire's FIT can be used to harness wasted energy, such as the following applications:



### Liquefaction / Gasification

Liquefaction allows hydrogen to be stored in its densest state and transported with highest efficiency. Hydrogen liquefaction is achieved through a series of compression, cooling and expansion processes.



### Pipeline Pressure Letdown

Plans are being created to implement a hydrogen distribution network via pipelines. Hydrogen will be produced, compressed then distributed through high-capacity pipelines and delivered to city gates for further low-pressure distribution and consumption.



### Transport / Consumer Dispensing

Hydrogen is currently being transported in liquid and gaseous form via tanker trucks. In liquid form, hydrogen is kept and dispensed at cryogenic temperatures. In gaseous form, hydrogen is dispensed from the trailer's high-pressure tank to another high-pressure tank at the dispensing site.

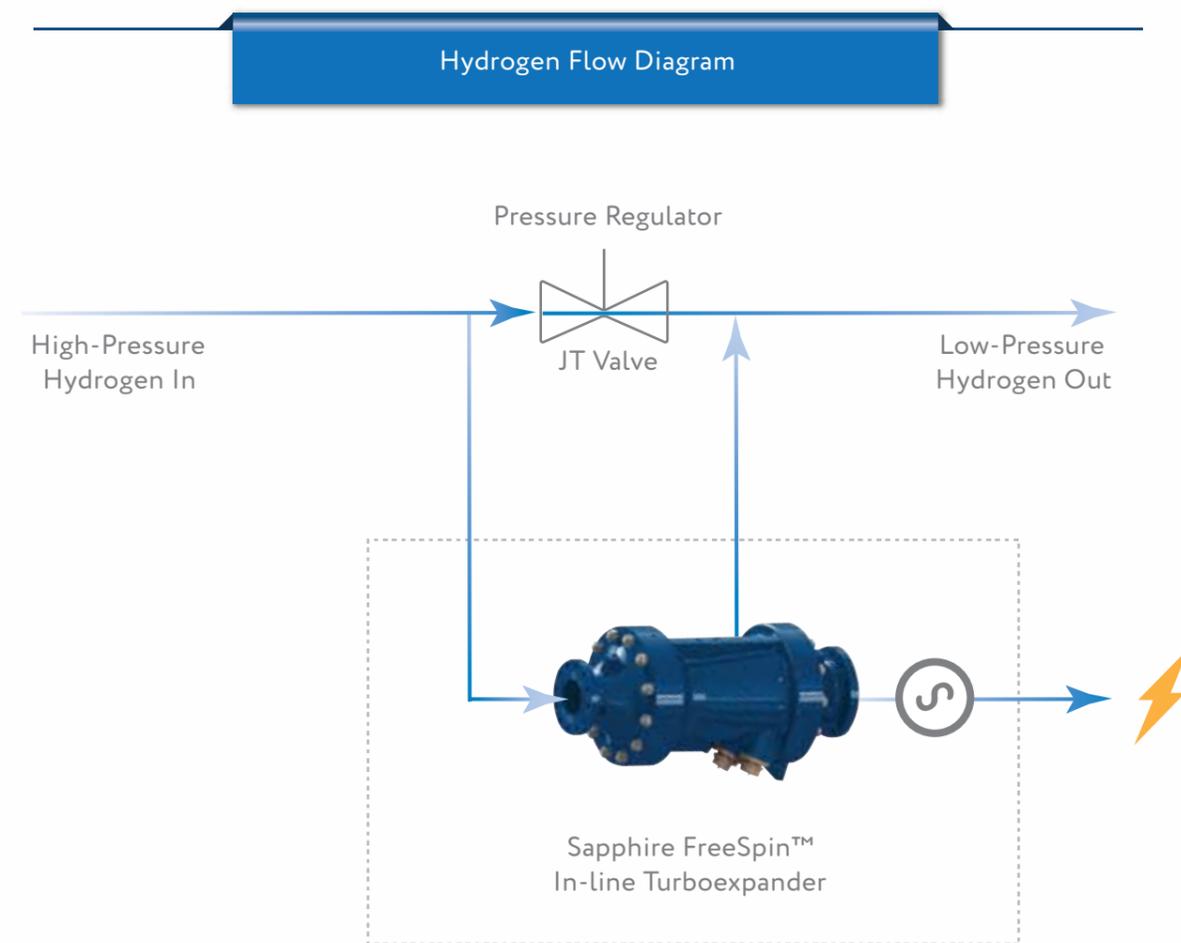


### Fuel Gas (Gas Turbines / Fuel Cells)

Hydrogen fuel cell technology has allowed hydrogen production and electricity generation to be a reversible reaction with electricity acting as the catalyst. With this concept in mind, hydrogen serves as an energy storage medium. Upon energy demand, the hydrogen must be converted into electricity through a fuel gas application, such as a gas turbine or a fuel cell.

## How Application Works

In each of the applications mentioned, the process of recovering energy from high-pressure gas works the same. High-pressure gas flows into the FIT, the FIT expands the gas and generates electricity. Unlike natural gas, pure hydrogen applications do not require pre-heating of the gas to maintain a minimum temperature. Instead, the gas can be expanded to cryogenic temperatures. No pre-heating means no consumed fuels, which makes hydrogen expansion a decarbonization process. Hydrogen, having an incredibly small mass, is prone to leak when stored and transported in pressurized equipment. The FIT eliminates potential leaks by providing a hermetically sealed environment with no dynamic seals.





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