Helidyne

Helidyne LLC has developed an innovative, positive displacement, rotary TFC expander for use in geothermal and geopressure power generation applications. The expander is intended to replace the turbine currently employed in traditional plants as the prime mover. One major advantage offered by Helidyne technology is the ability to process brine directly as it emerges from the geothermal well. The "total-flow" strategy makes possible the recovery of available thermal energy by flashing the brine entirely within the expander cavity instead of an external flash tank. Direct brine processing potentially doubles the plant overall output for a given resource and significantly decreases plant capital cost.

Geothermal Power Generation

Geothermal Plant Types:

Geothermal electric power production begins thousands of feet below the earth's surface in large underground reservoirs. Water in the reservoir is heated naturally by the earth's core and pumped through a well to a power plant on the surface. After thermal energy is extracted by turbines and converted to electricity, the water returns to the reservoir via a separate well to repeat the cycle again.

Three challenges limit rapid growth and investment in this industry: 1) high drilling cost and risk associated with resource discovery; 2) low plant conversion efficiency; 3) high cost of plant equipment. Helidyne believes its technology can address the latter two.

To understand why such low plant efficiencies are achieved (typically less than 20%), a basic knowledge of key plant components and how they work is necessary. In order to provide dry steam required by the plant turbine, pressurized hot well water is separated from the steam in a flash tank. This "flashing" process introduces a 50% efficiency penalty, because available expansive energy dissipates in the tank rather than performing work in the turbine. In addition, low well temperatures produce relatively low pressure steam that cannot be efficiently utilized by steam turbines, especially for well temperatures below 300°F.

The industry's solution has been to replace water with a low boiling-point refrigerant in a “binary” system, essentially a large air conditioning unit operating in reverse to take advantage of the higher pressures created by the refrigerant fluids. Instead of flashing well water, a heat exchanger is used to boil the refrigerant and provide vapor to the turbine. Another advantage of this design is turbine isolation from the harsh well water chemistry. The two fluids never mix, being fully contained within their respective closed loop heat exchangers.

Despite certain advantages of the binary approach, the boiling process introduces the same inefficiencies as the flashing process mentioned earlier. However, binary systems do make electric power production possible from well temperatures that are too low for steam-driven flash plants.

Helidyne's solution is more direct. Pressurized hot well water flashes directly within the innovative TFC (Trilateral Flash Cycle) “expander”, eliminating the losses associated with flashing or boiling altogether. The "total-flow" strategy of replacing the turbine with an alternative expander has been previously attempted but never commercialized due to the inherent design limitations of prior-art methods.

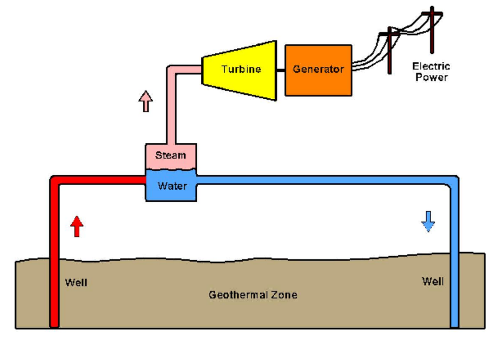
According to extensive research conducted by experts in the field over a period spanning more than 35 years, the total-flow solution can double plant output by raising current efficiencies from 20% to over 40%. In addition, the same researchers have concluded that the total-flow approach would significantly decrease plant capital cost.

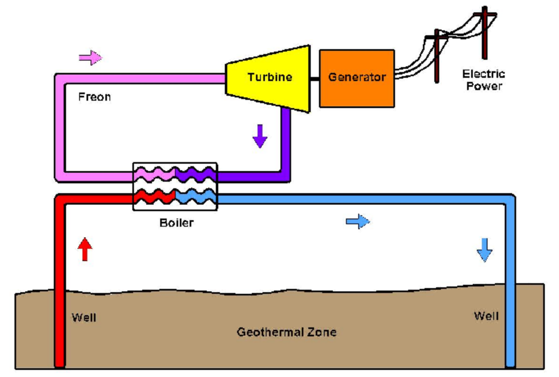
"Basically, the Total-Flow concept offers the potential of maximum recovery of available energy, but achieving this potential depends on the choice of expander." (Austin & Lundberg, A Status Report on the Development of the Total-Flow Concept, 1978)

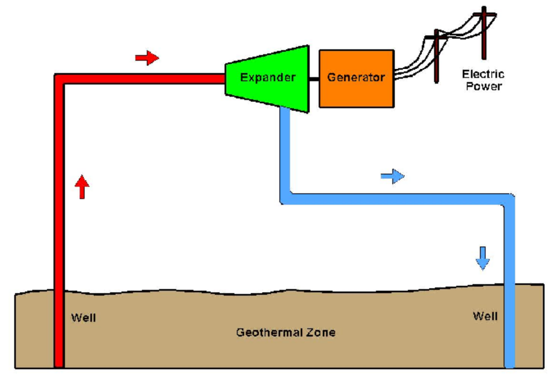
"The notion of a total-flow system arises from a desire to avoid the irreversibilities associated with the flashing process needed for either a single or double-flash plant." (DiPippo, 2008)

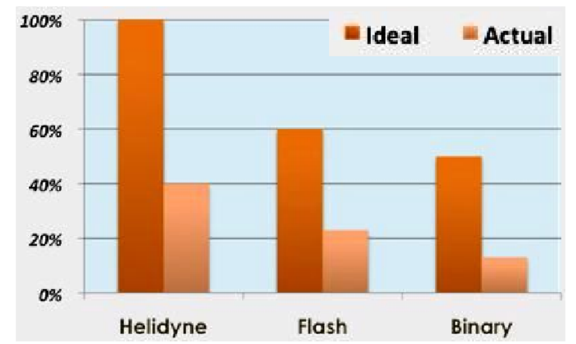
"If a way could be devised to use the geofluid directly as it emerges from the well in the prime mover, be it a turbine or some other specially designed device, significant [cost] savings would be achieved." (DiPippo, 2008)

"Provided that two-phase adiabatic expansion efficiencies of at least 75% could be attained, a (TFC) system using light hydrocarbons as working fluids, could recover almost double the power from a hot liquid stream than was possible from either steam or indirectly heated simple ORC systems." (Smith, Stosic, & Kovacevic, 2005)


Flash Plant


Binary Plant


Total Flow Plant



Plant Conversion Efficiency

Challenges and Solutions:

Other problems engineers face when attempting to develop a total-flow expander: 1) how to handle hard water scale deposits on working parts; 2) how to provide sufficient volume-ratio to allow full expansion of the steam component.

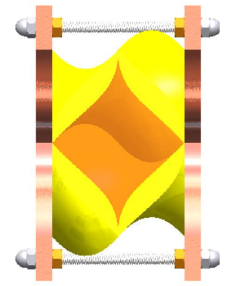
Scale build-up on total-flow devices can cause moving parts to bind and eventually seize up, and in many cases fail catastrophically. Turbines avoid this problem due to separation of steam from liquid water, essentially a distillation process, mentioned earlier.
Sufficient volume-ratio is critical to achieving good efficiency. If steam expansion is cut-off prematurely before starting the next cycle, expansive energy will be lost. Water at low geothermal temperatures requires high ratios to allow full steam expansion. Unfortunately, all prior designs are limited by an inherent built-in ratio -typically about 5:1.

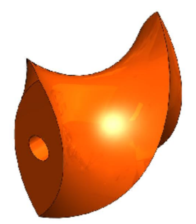
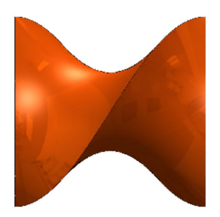
The Helidyne TFC (Trilateral Flash Cycle) expander is an innovative, high flow rate, pure rotary design that addresses both of the design issues mentioned above.

Rotors interact to create a self-cleaning mechanism that removes scale deposits for continuous maintenance free operation. In addition, the rotors are manufactured using non-corrosive materials that withstand exposure to even the harshest well chemistry.
The unique Helidyne design isolates a single chamber to the intake port per cycle, allowing injection of a specific quantity of water. This technique achieves very high volume ratios (up to 1000:1) for efficient steam expansion.

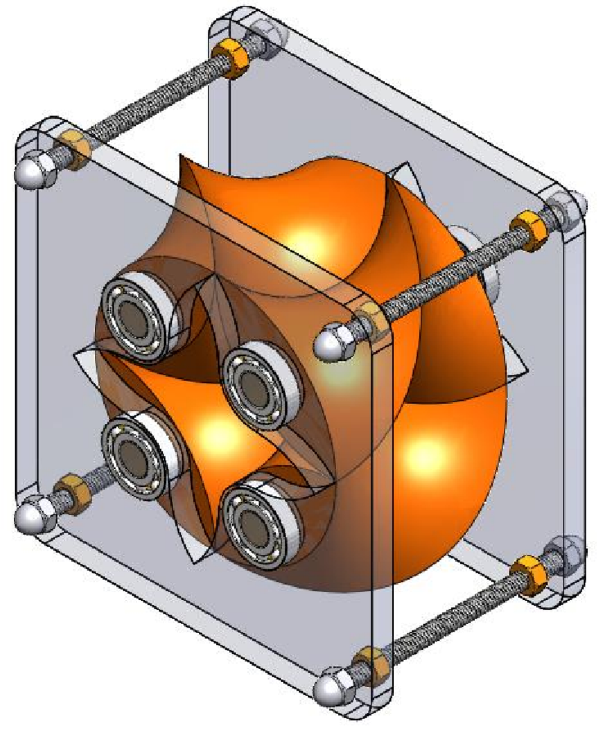
Helidyne LLC offers a novel TFC expander which resolves many issues that have historically plagued total-flow expander technologies. Geothermal, solar thermal, and waste heat energy resources may realize a doubling of electrical output compared to conventional binary or turbine technologies.

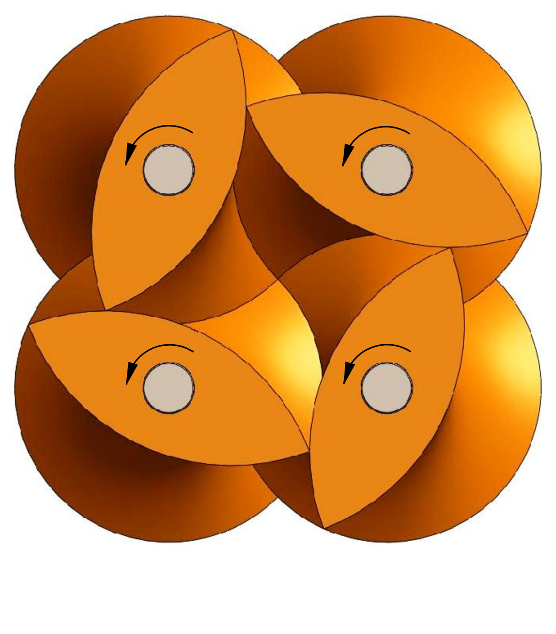

Large Volume Ratio and Flow Rate -Two Volumes Per Rev


Cross Section -Volume in Orange



General Rotor Shape


Scale Buildup

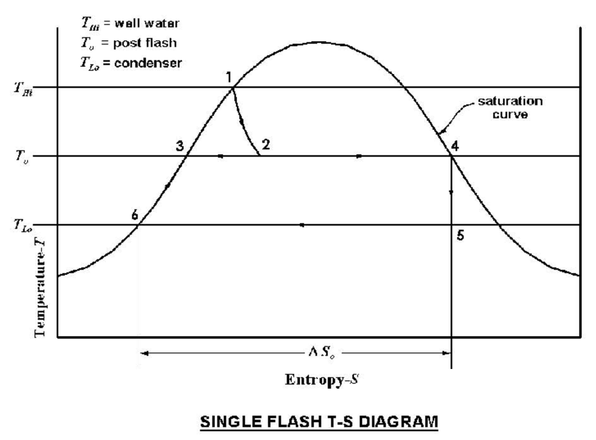

Conceptual Model


Self Cleaning Rotors

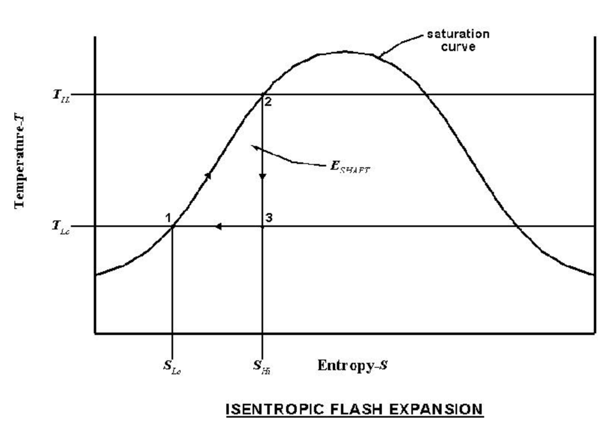
The Total Flow Advantage:

Conventional flash plants utilize throttled flashing, a "constant enthalpy" (isenthalpic) process in which half the resource delta-T is lost. Optimum flashing temperature lies at the midpoint between the source and sink, as depicted below, leaving only half the original geothermal energy remaining to produce shaft energy. In short, a single-stage flash plant re-injects 50% of the available geothermal energy back underground without performing useful work simply because of the isenthalpic flashing process. Serial flashing in 2 or 3 serial stages somewhat reduces this loss.

By contrast, flashing under controlled "constant entropy" (isentropic) conditions inside the expander cavity converts the theoretical maximum available thermal energy to useful shaft work. By replacing steam-driven devices with a total-flow expander, the otherwise wasted energy can be harnessed as shaft energy rather than lost in the flash tank.



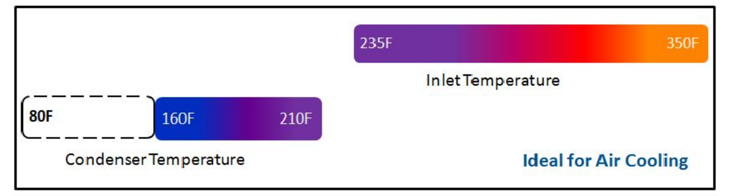
Rankine Cycle



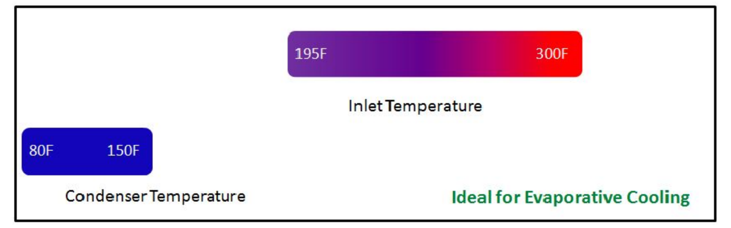
TFC - Trilateral Flash Cycle

TFC Operation Temperature Range:

Water Based TFC



Organic Based TFC



Advantage of Eliminating Heat Exchangers:

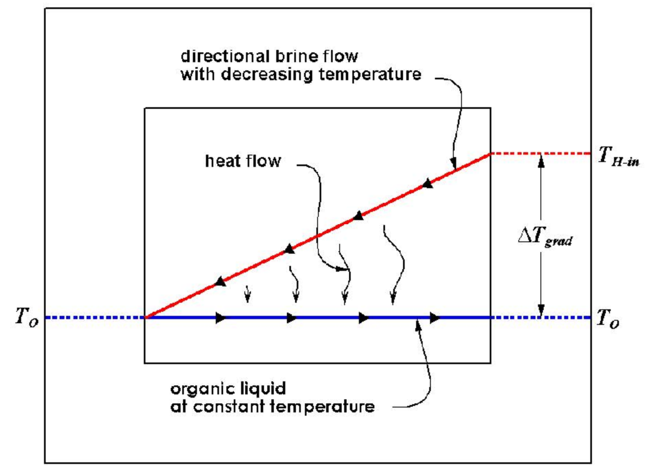
Utilizing an organic working fluid in an ORC plant provides several other key advantages in addition to reduction in plant size and friendly turbine environment: maintaining brine in the liquid state throughout the entire loop prevents scale formation in the water circuit, especially important in the boiler where scale deposits on exchanger walls reduce heat transfer and further compromise efficiency.

By contrast, the Helidyne expander operates directly on well water without a boiler or organic fluid at very low pressures (<15 psi). It can achieve high volume ratios, large mass flow rates, and can be manufactured in large MW sizes with lightweight rotors approaching 5 ft in diameter. The device is truly a low pressure, large volume energy converter. This unique capability, along with the self-cleaning feature, proves extremely valuable in low temperature waste heat recovery, solar thermal, and solar ponds applications in addition to geothermal.

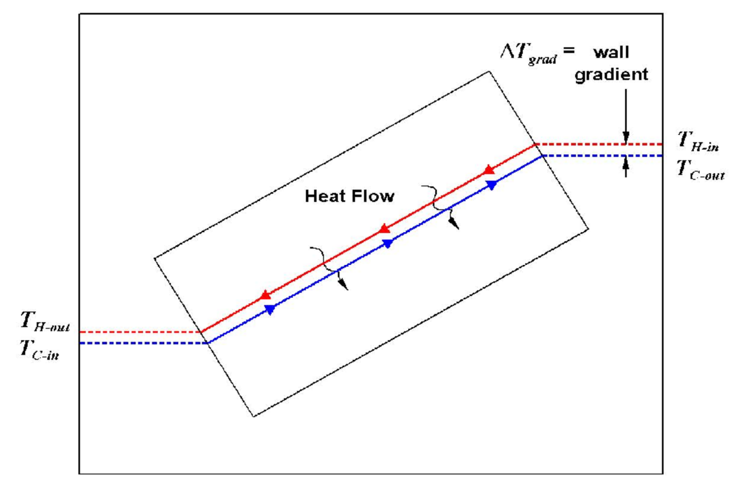
Despite the advantages of using an organic working fluid, binary plants suffer an efficiency penalty similar to flash plants. Binary boiler losses are theoretically analogous to flash tank losses, each representing a 50% loss of available thermal energy.The diagram below represents a binary plant boiler. Organic fluid boils at constant temperature by absorbing heat across a large temperature gradient from the brine. Miss-matched sensible-to-latent heat transfer accounts for a 50% loss of the thermal energy, equivalent in magnitude to single-stage flashing as revealed in the thermodynamic analysis (PDF avaliable on website).

To highlight the inefficiency associated with the ORC boiler heat transfer process, consider the more desirable sensible-to-sensible counter-flow heat exchanger shown below. A very small temperature gradient under this scenario indicates excellent "temperature matching " between the two fluids for efficient heat transfer. Unfortunately, this efficient sensible-to-sensible heat transfer process cannot be achieved in a Rankine cycle ORC binary plant which intrinsically relies on sensible-to-latent heat transfer.

In conclusion, a binary system provides practical solutions to problems engineers face when generating power from a low temperature geothermal resource, notably by increasing power output for a given plant size. It nevertheless suffers the same tremendous loss of available thermal energy as a flash plant.



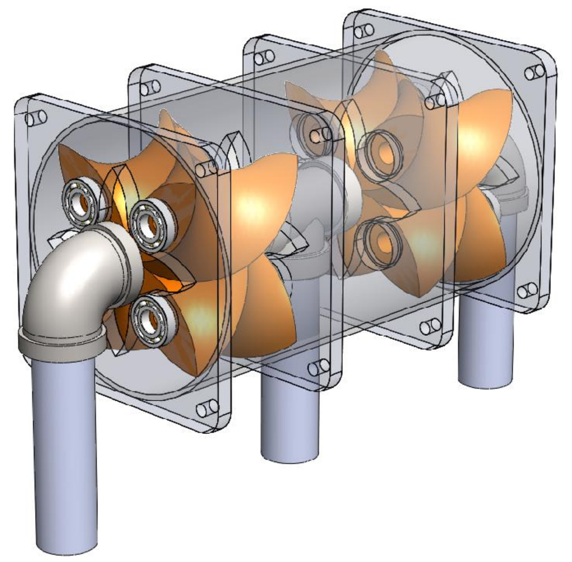
Sensible-to-Latent Heat Transfer

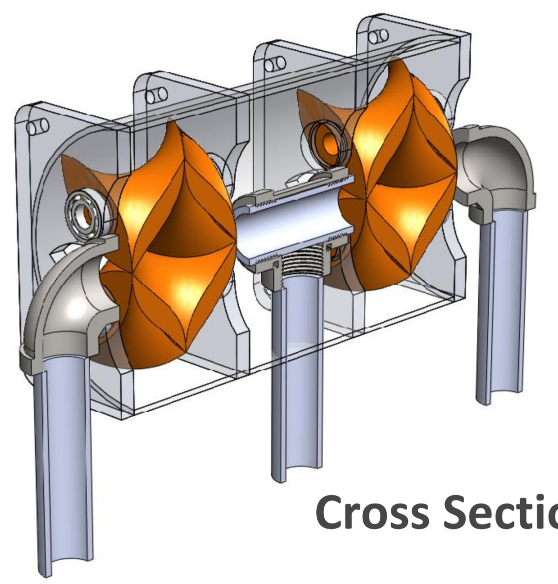


Sensible-to-Sensible Heat Transfer

Geopressure Power Generation


200 Foot Oil Gusher


Dual Rotor Sets Cancel Thrust Forces


Cross Section View

A New Energy Market:

Oil wells located in the Gulf Coast region contain an untapped and relatively unknown form of renewable energy called geopressure. Fluids from these types of wells rise to the surface naturally under extreme hydraulic pressures (4,000 -12,000psi) as evidenced by large gushers that ocassionally accompanying new oil discovery. Presently, this form of energy is but a nuisance to well operators, being reduced through a series of pressure letdown valves.

Helidyne's geopressure reduction generator (PRG) converts this hydraulic form of energy into emission free electricity. It's patent pending helical rotor design enables direct processing of the geofluids in a self-cleaning manner. Scale and other containments that tend to build-up on part surfaces are removed with the novel rotor sweeping action. In addition, fluid pressure is fully contained within the rotor cavity itself, allowing critical shaft seals and bearings to be completely isolated and protected from the harsh high pressure operating environment.

Helidyne is the only company offering a design to harness this form of energy. Owners of abandoned wells would be able to re-tap the original resource and reap additional revenue. In addition, on and off-shore oil wells currently in production can satisfy their remote power needs from the well itself.

Geopressure advantages vs. geothermal:
- no heat exchangers
- no refrigerants
- no cooling tower or cooling water required
- no re-injection if the well is producing oil

Problematic Past:

Absence of suitable equipment has resulted in the capping of most pressurized non-oil producing wells. Producing wells blow-off the excess hydraulic pressure that could otherwise be converted into emission-free electricity using Helidyne's PRG and generate revenue. In 1991 the DOE published a feasibility study on harnessing geopressure to produce electricity and found no commercial off-the-shelf equipment available to meet the need. The market situation remains the same 20 years later, with only one other company developing reciprocating prototypes with limited success.

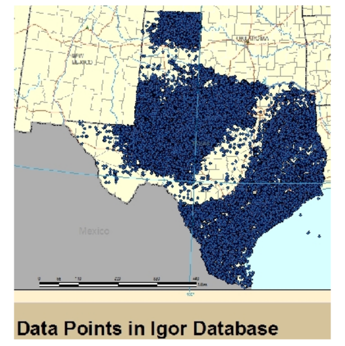
Conclusions from DOE report:
- No commercial "off-the-shelf" equipment for geopressure applications
- The “Pelton wheel” turbine suggested as best choice with the following problems:
  - Shafts seals are problematic at high pressure
  - 2,000 psi is the upper limit for Pelton wheel buckets
  - Nozzle and bucket erosion is a major concern not mentioned in the DOE report as fluid streams approach sonic velocity. Bi-phase turbines use expensive titanium impulse wheels for this reason.
  - Would not work with more viscous fluids, like oil, due to prohibitive shear losses
- No successful geopressure installation known in operation

Promising Future:

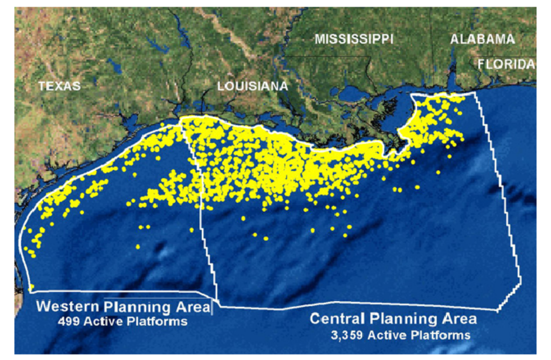
The Gulf Coast contains approximately 5,000MW of geopressure energy worth $2.1 billion in annual wholesale electricity sales. The region has over 1.5 million wells in the ground with over 150,000 exhibiting geopressure, making it unnecessary to ever drill another expensive new well again. Helidyne equipment retails at about $1.0 million per MW for the developer to purchase, resulting in a heretofore untapped multi-billion market created with the technology.

Any pressurized well, either producing oil (like BP's blown out Gulf well) or abandoned wells delivering mostly water, can generate electricity regardless of temperature so long as sufficient pressure is present. The DOE report mentions a minimum of 700 psi at the wellhead, but we believe electricity generation can be economical at pressures down to 100 psi using our technology.

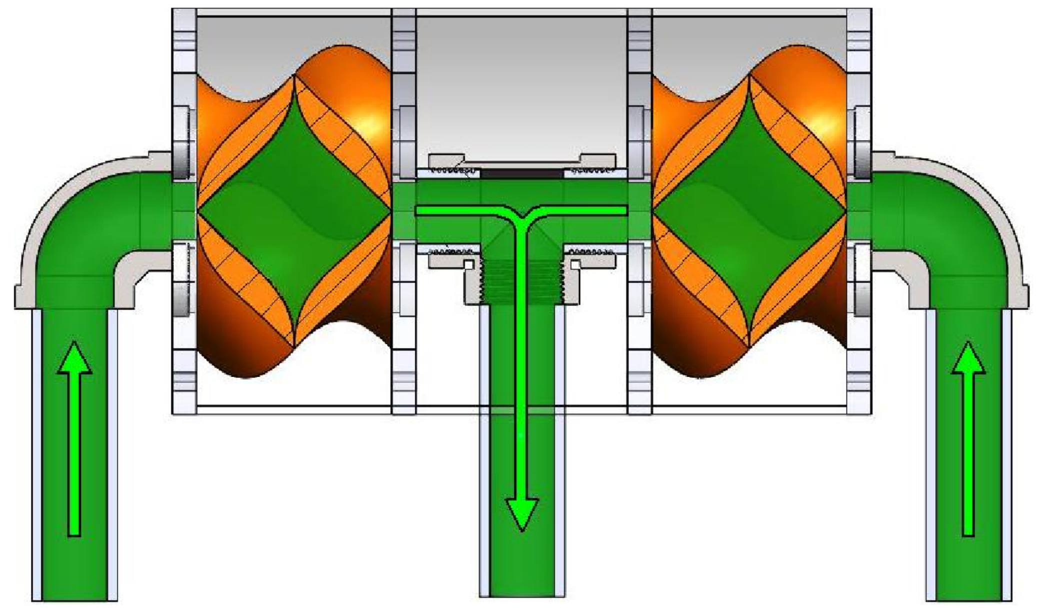
Helidyne Pressure Reduction Generator:
- Can accommodate up to 5,000psi per stage and be placed in series to utilize wellhead pressures over 15,000psi
- Shaft seals exposed to atmospheric pressure only
- Oil in geofluid helps lubricate and seal rotors
- High flow-rate, self-cleaning design
- Dual rotor sets cancel shaft thrust forces and reduce bearing loading



Total Recorded Wells




Off and On Shore Geopressure Wells


Direction of Flow and Pressure Confinement

	Pelton Wheel	Twin Screw	Reciprocating	Helidyne
Shaft seals	✗	✗	✓	✓
Scale removal	✓	✗	✗	✓
Flow-rate	✓	✓	✗	✓
Oil-free	✓	✗	✗	✓

Geopressure Design Options