POWER

GEOTHERMAL
POWER GENERATION

Demand for renewable energy continues to grow. As a cleaner alternative to fossil fuel combustion, geothermal power utilizes the Earth's thermal energy reserves as a clean, carbon neutral and sustainable source of electricity production. There are hundreds of geothermal plants around the world with many more being built. This fast-growing segment of "green" energy accounts for nearly 15,800 MW of generating capacity worldwide.

Much like traditional power generation companies, geothermal power producers must meet their economic targets. Large capital expenditures focus on the exploration and construction phases of each project. Once constructed, operational efficiency is the key to recovering initial investment costs and delivering future profits. Maximum uptime with sustained operation is the critical component in meeting or exceeding economic projections.

Many geothermal plants are upgrading to REXA Electraulic™ Actuation to achieve high performance and reliability for their toughest, most critical applications!

ELECTRAULIC™ ACTUATION

Geothermal Power Generation

At REXA, we have more than 20 years of experience in the Geothermal Power market. We offer high-quality, low/no maintenance Electraulic™ Actuators that have been field-proven in the most critical and difficult process applications:

- Production Well Control and Emergency Shutoff
- Separator Level Control
- Rock Muffler/Emergency Bypass Valve
- Turbine Governor Control
- Condenser Hotwell Level Control
- Injection Well Control and Isolation

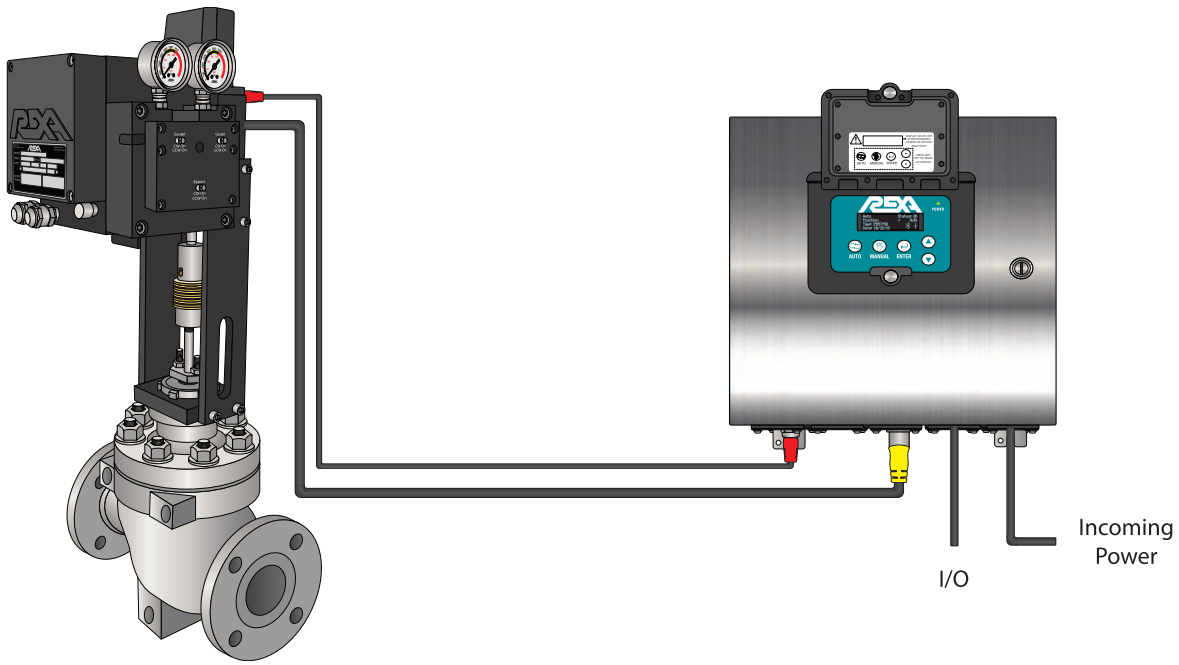
Why REXA?

The REXA Electraulic™ Actuator is a superior positioning device well suited for critical control applications, such as those found in geothermal power plants. It controls severe process conditions in harsh environments and provides high reliability. REXA Electraulic™ Actuators and Drives provide the final control element capabilities to match the most sophisticated instrumentation and distributed control systems.

The system is comprised of the mechanical subassembly and the electrical subassembly. The mechanical subassembly consists of a double acting hydraulic cylinder, position feedback sensor and an Electraulic™ Power Module. The power module is a unique, self-contained, sealed hydraulic pumping system which manages oil pressure and flow to and from the cylinder. The electrical subassembly consists of the power supplies, motor drivers and a dedicated microprocessor.

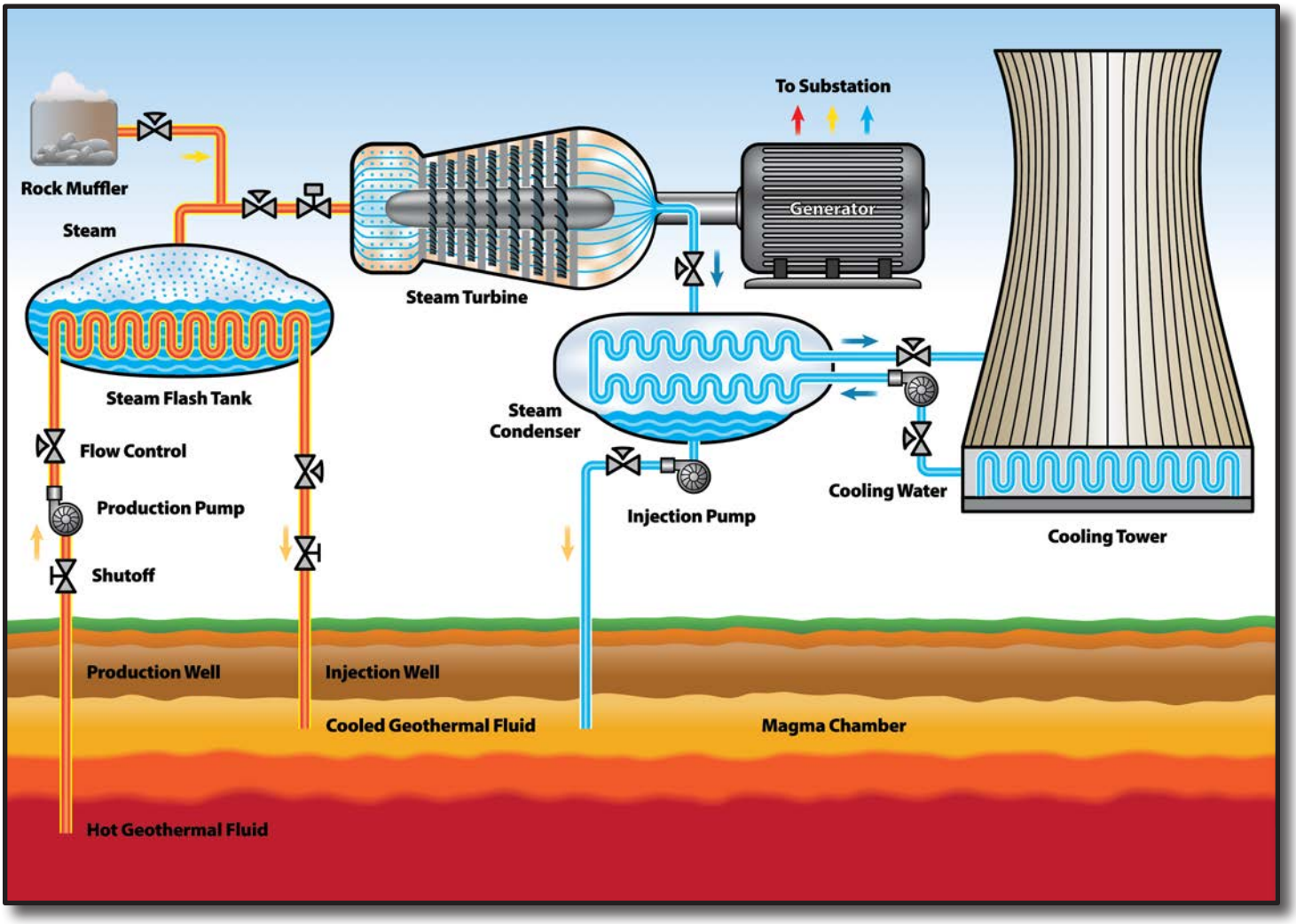
The combination of these mechanical, hydraulic and electronic technologies ensures accurate and repeatable control of geothermal power plant processes.

Mechanical Subassembly **Electrical Subassembly**



Geothermal Flash Steam Power Plant

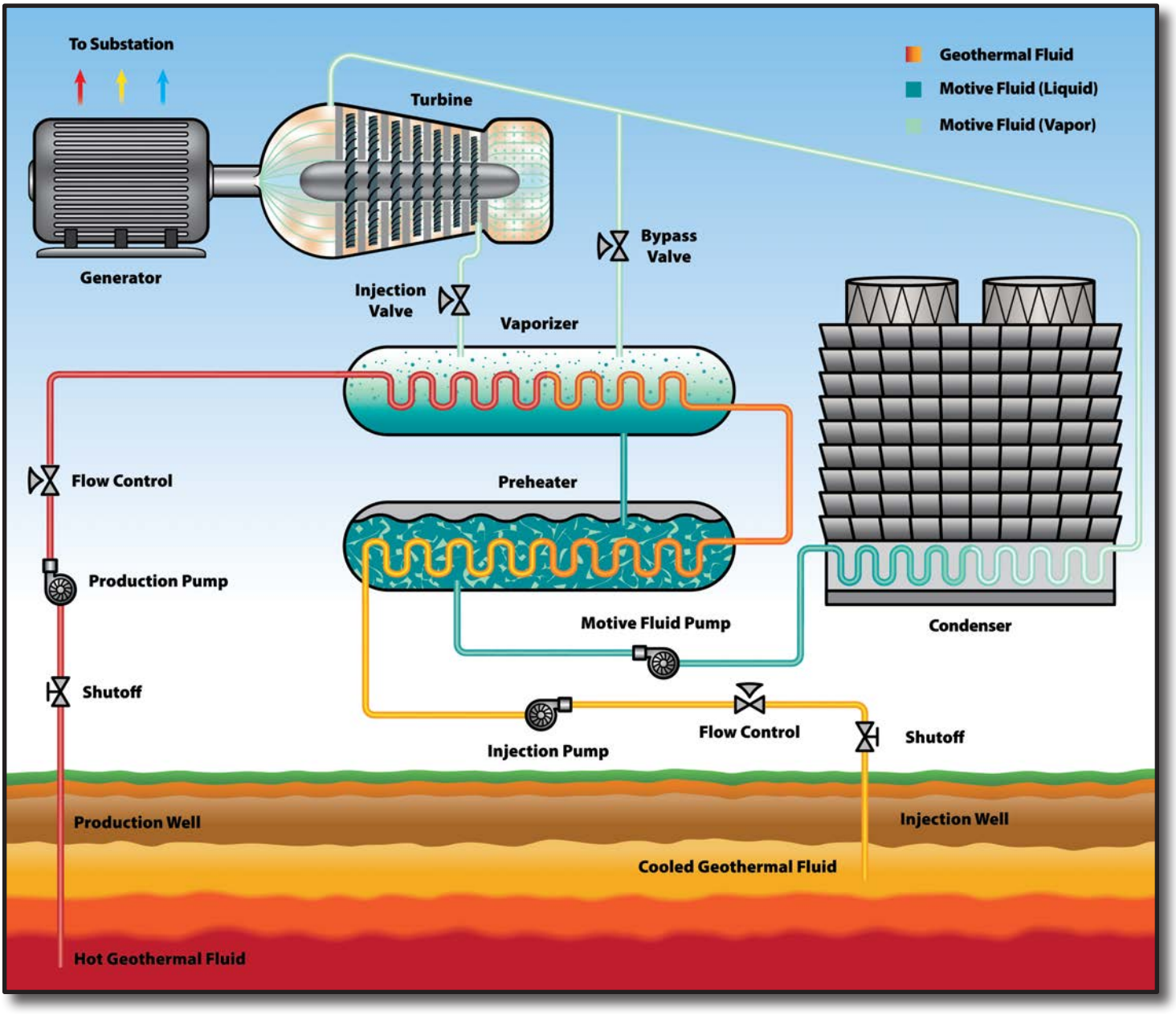
Flash steam power plants utilize geothermal heat resources (also known as hydrothermal resources) deep in the Earth's crust at temperatures greater than 175 ° C (350 ° F). Hot brine flows up from the underground geothermal reservoir to the production wells where the decrease in pressure as it moves towards the surface can cause a partial flash into steam. This heat resource is then extracted and piped as a single or two-phase fluid to the plant. The liquid is piped to a lower pressure separator where it's flashed into high pressure steam (as depicted below). For more complex systems, the remaining fluid is then directed to a second flash tank or crystallizer to produce medium pressure steam. For plants with triple pressure cycles for higher efficiency, the process continues with the brine sent to a low pressure crystallizer to generate LP steam. This multi-pressure flashed steam goes through governor control and stop valves to various stages of the turbine, generating electricity. The remaining brine that isn't flashed moves to a clarifier, then out to the injection well replenishing the reservoir.



"After upgrading from pneumatic actuation to REXA Electraulic™ Actuation, we were able to stabilize our condensate system and achieve greater operational efficiency."

Geothermal Binary Cycle Power Plant

Geothermal Binary Cycle Plants are capable of utilizing hydrothermal resources at a much lower temperature range than Flash Plants (160-350°F), making the possibility for use of this technology more widespread. In the binary cycle plant, the hydrothermal resource is used as the heating source for secondary organic fluid, typically isobutane or isopentane, in a heat exchange process. The key to the process is that the organic fluid has a lower boiling temperature than water, allowing the organic fluid to flash to vapor at a lower temperature. There are significant advantages with a binary plant, even beyond the ability to use a lower temperature heating medium. The hydrothermal resources are a closed loop system and are fully re-injected into the geothermal reserve, making the system very efficient with a reduction in environmental impact. Likewise, the organic fluid/vapor is also in a closed loop system, which does not require separation and cleaning to the same level as a comparable flash system. A high level of control is required to maintain the highest level of efficiency in these plants.



Production Well Emergency Shutoff

Often separated from the plant by significant distances, most production wells include emergency shutoff valves (ESV). In the event of a problem at the plant, pipeline or during a major overhaul, the ESVs close, allowing work to be completed safely.

In wells with two-phase flow or high flow rates, vibration can be a major problem. Substantial anchoring and piping supports are normally installed to protect lines and equipment, but considerable vibration still occurs. This risks damage to the on-board electronics of electro-mechanical actuators. The remote-mounted electronics of REXA's system is a key benefit in this scenario.

Reliable valve operation can also be a challenge due to silica and calcite scale buildup on internal parts. The ability to **power through** scaling with the force of hydraulics is extremely important to ensure the well head valves close when required. REXA Electraulic™ Actuation delivers the power and stability necessary to avoid unplanned shutdowns. Vibration, scale build-up and corrosion are no longer concerns for plant operators!

Production Well Flow Control

Improve reliability and fluid flow control of production well(s) with REXA! The wellhead flow control valve is a key process component. Not only does it provide a back pressure to the well of 145-362 psi (10-25 bar) to avoid operating in the silica scaling range, but it maintains downstream pressure to the plant separator of 87-145 psi (6-12 bar) for proper operation. Flow can be adjusted to meet the plant's demand.

It's important the flow control valves modulate with a high level of accuracy. Scale buildup is a constant threat to reliable operation. The ability for valve actuation to continuously provide the required force output without overheating or stalling is a REXA key benefit. Our actuators can be configured for redundant construction to **maximize uptime** and provide continuous well head flow.

Separator Level Control

In areas of the world where steam or two-phase flow are the dominant sources of geothermal energy, it is vital to remove the fluid portion of the mixture from the well. This is to prevent dissolved minerals containing silica and calcite from causing corrosion in the turbine and related equipment. Separators are installed to accomplish this task with a goal of eliminating 99% of the brine.

Fluid level in the bottom of the separator has a large impact on separation efficiency. During operation, tanks quickly fill with contaminants. These contaminants must be removed constantly to maintain proper level. This leads to frequent cycling of control valves, often exceeding the duty cycle of electro-mechanical actuators. With REXA actuators' 100% duty cycle capability and **immediate signal response**, this is no longer a concern!

Rock Muffler/Emergency Bypass Valve

Primarily found in a dry steam system, an emergency dump valve relieves excess pressure in the main steam line to the plant. As units come on and go offline, steam supply pressure can increase, requiring the excess to be vented through a rock muffler or silencer. During transient conditions, separated brine in the reinjection line may also be diverted to a rock muffler or thermal pond. It's important that steam pressure to the plant remain constant to enable the highest conversion efficiency for the turbine.

Silica and calcite build up inside these valves is a major problem and can cause actuator stalls and overheating. Dump/vent valves must have reliable flow control and repeatable positioning when commanded to move, as well as tight shutoff when closed. Ensure tight shutoff and **quick emergency response** with REXA actuators!

Steam Turbine Governor Control

A steam turbine governor system normally includes butterfly valves to modulate steam flow and swing check valves for emergency stops. Turbine speed is controlled by accurately and reliably positioning these butterfly valves with a balanced steam load for stable operation to design conditions. This system is also required to trip the valves closed in less than a second on load shed to prevent turbine overspeed and potential damage.

Normally driven by a hydraulic power unit, these systems are susceptible to oil contamination through the sump and directly from the steam driving the turbine. Separators cannot remove all contaminants, which eventually end up in the turbine lubricating oil. Eliminating the use of control oil systems ensures reliable turbine operation and improves performance. REXA's closed-loop, non-vented system eliminates oil maintenance, provides **accurate turbine speed control and stable operation**.

Steam Turbine Governor Shut-Off

Often a large swing check, a stop or trip valve automatically shuts off steam to the turbine in less than one second during an emergency condition. Potential causes of this typically include turbine overspeed or excessive vibration. A spring fail-safe configuration is used as reliable stored energy to close the valve.

An electro-hydraulic solenoid valve using HPU oil is a common activating device for the shutoff valve. Contamination in the oil system greatly affects solenoid valve operation, causing slow response or no movement at all. Upgrading this arrangement to REXA's self-contained system eliminates these problems and **increases reliability** for critical components.

Vapor Turbine Governor Control

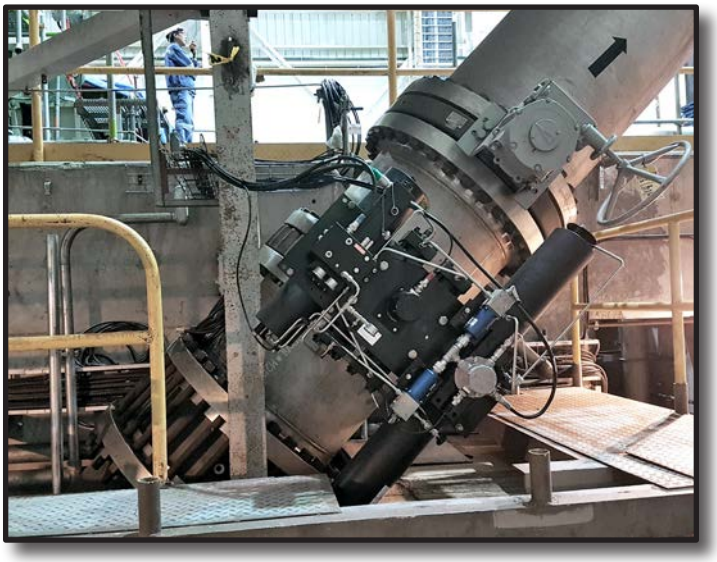
Most binary plant turbines operate using a secondary clean organic fluid (usually isobutane or isopentane), that is vaporized by the heat of geothermal brine as it flows through a heat exchanger. These organic compounds are non-corrosive and compatible with oil, allowing the use of internal bearings and a more rugged, lower cost turbine.

Bringing a vapor turbine online is easier with REXA actuators! This critical process involves ramping from idle speed to rated RPM at a preset rate. The injection valve is used to synchronize the turbine to the grid and must track the PLC control signal precisely for a smooth, fast startup. Erratic valve movement or overshooting setpoint by standard OEM pneumatic actuation can increase ramp times, and if severe, trip the unit. The main governor valve is then opened wide for maximum load. REXA's **immediate response to signal change** and accurate control allows plant operators to reliably ramp up the vapor turbine, quickly connecting to the grid.

Condenser Hotwell Level Control

A steam turbine plant uses a hotwell to collect cooling water in direct contact condenser designs. To maintain proper level control, accurate positioning of the large discharge butterfly valve is key during startup and normal operation. This requires immediate response to signal change with no overshoot and a high degree of repeatability. A stable process is important to **maximize turbine efficiency and plant uptime**.

Startup delays caused by the condenser hotwell level control valve are a major concern for operators. Instability caused by actuation dead time and internal scale buildup can quickly result in a startup sequence balancing act where fill/discharge valves and the hotwell pump must be manually operated. Eliminate startup delays, stabilize your process and maximize uptime by upgrading to REXA actuators!



Injection Wells

Rely on REXA for efficient injection well control! Fluid injection is one of the most important processes in geothermal power. It eliminates environmental impact of surface disposal and provides pressure support for the well. Injection sites are carefully selected to ensure reservoir replenishment and reduce adverse effects on production well fluid, such as cooling and chemistry change.

Fluid velocities must be kept high enough to prevent settling of suspended solids and allow multiple units to feed a reduced number of injection wells. Injection valves play a key role in maintaining system back pressure and proper separator level. Poor valve actuator reliability due to vibration and conductive heat leads to loss of control for brine injection and instability in various plant systems. REXA's reliable operation and rugged design protects against vibration and conductive heat, allowing plant operators to **maintain system back pressure**.

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