THE CHALLENGES AND BENEFITS OF COAL GASIFICATION

TECHNICAL WHITE PAPER

The United States has enough coal to provide energy for the next 200 years with a recoverable reserve base of nearly 475 billion tons. With oil prices continuously rising and unrest in the Middle East, utilizing our coal reserves seems a likely option for the United States. But coal is dirty to burn. It emits sulphur dioxide, nitrogen oxides, mercury compounds, and carbon dioxide. Care must be taken to reduce the environmental impact of coal mining and coal energy conversion. Perhaps the solution comes with coal gasification.

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PEPPERL+FUCHS
PROTECTING YOUR PROCESS

Coal: The Good News…

The U.S. has more coal than any other country in the world with 28% of the world's reserves—50% more than Russia, who has the second largest reserves. To quantify the magnitude of this resource, Saudi Arabia has about 18% of the world's total conventional oil reserves. Coal is the United States' most abundant fossil fuel. It's our largest domestically-produced source of energy, and it's used to generate half of the electricity in the United States. With a recoverable reserve base estimated at nearly 475 billion tons, we have enough coal to provide energy for the next 200 years. So, with oil and natural gas prices continuously rising and unrest in the Middle East, utilizing our vast coal reserves seems a most likely option for the United States.

Coal		Oil		Gas	
United States	27.5%	Saudi Arabia	17.7%	Russia	25.2%
Russia	18.3%	Venezuala	14.4%	Iran	15.7%
China	13.3%	Canada	11.9%	Qatar	13.4%
Other Non-OECD Europe and Eurasia	10.7%	Iran	9.3%	Saudi Arabia	4.1%
Australia and New Zealand	8.9%	Iraq	7.8%	United States	4.1%
India	7.0%	Kuwait	6.9%	Turkenistan	4.0%
OECD Europe	6.5%	United Arab Emirates	6.7%	United Arab Emirates	3.4%
Africa	3.7%	Russia	4.1%	Nigeria	2.8%
Other Central and South America	0.9%	Libya	3.2%	Venezuala	2.7%
Rest of World	3.2%	Rest of World	18.2%	Rest of World	24.7%
Total	100.0%	Total	100.0%	Total	100.0%

Source: U.S. Energy Information Administration, *International Energy Outlook*, September 2011, Tables 5, 7, and 10

Figure 1 Estimated world energy reserves of coal, gas, and oil by country. The United States has more coal than Saudi Arabia has oil.

…and the Bad

But while coal-fired plants contribute nearly half of the electricity produced in the United States, they also contribute 80% of the carbon emissions associated with electrical generation. Coal is a dirty fuel to burn. It emits sulphur dioxide, nitrogen oxides, mercury compounds, and many other trace elements that can cause acid rain, ash, and mercury pollution, not to mention the carbon dioxide, a greenhouse gas that is frequently in the news because of its link to climate change. Care must be taken to reduce the environmental impact that coal mining and coal energy conversion can have on our ecosystems, water quality, and even our countryside landscape.

A Potential Solution—Clean Coal

A promising solution comes with coal gasification. Gasification avoids burning coal altogether: it turns coal into gas. One of the major environmental opportunities of this technology is the fact that impurities can be almost entirely filtered out when coal is transformed from a solin into a gas, alleviating many of the environmental concerns of coal-fired power plants. In fact, gasifying coal is one of the best ways to clean pollutants out of coal, and many experts predict that coal gasification will be the heart of clean coal technology for the next several decades.

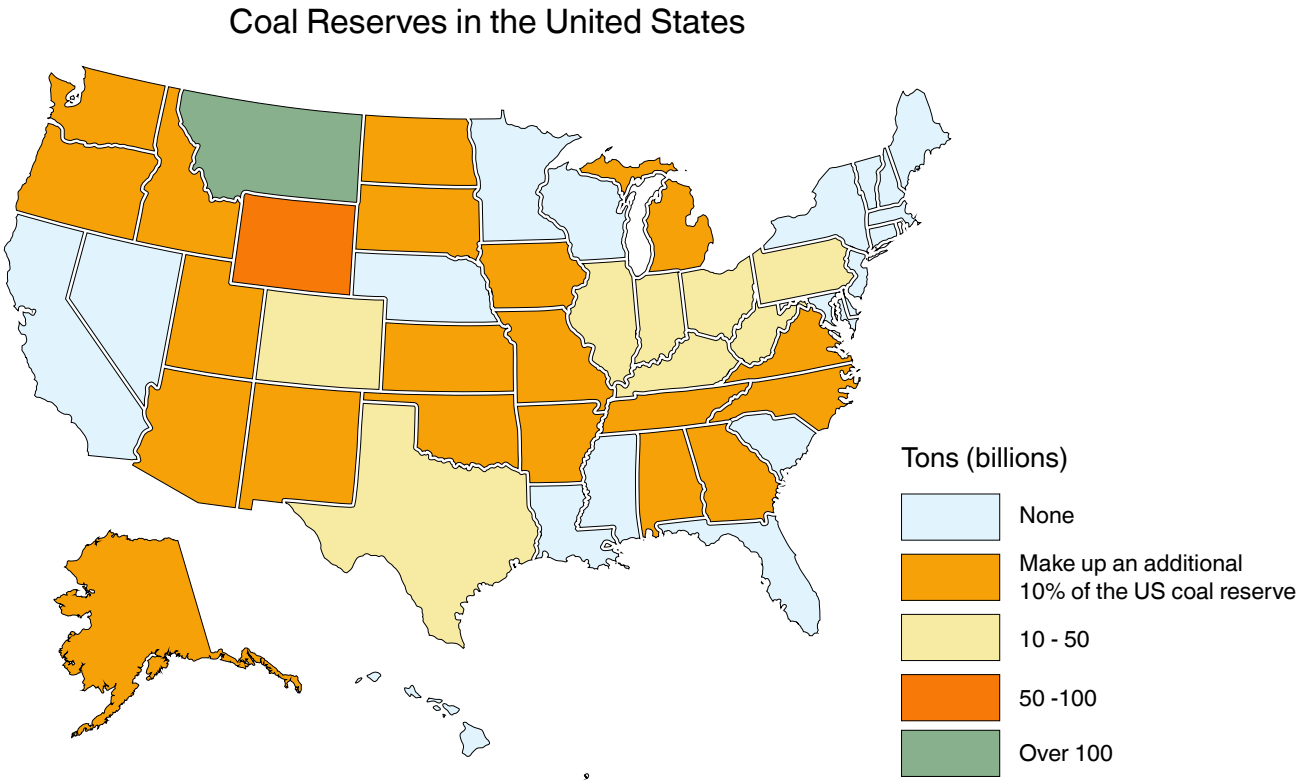

Figure 2 There are more than 30 coal-producing states, with 90% of the country's reserves concentrated in 10 states. According to the United States Geological Survey, the US has 475 billion tons of recoverable coal reserves.

What is Coal Gasification?

Rather than burning coal directly, gasification converts all of the carbon of the coal into electricity, hydrogen, and other forms of energy through partial oxidation. The coal is fed into a high-temperature pressurized container (gasifier) and combined with hot steam and controlled amounts of air or oxygen under high temperatures (up to 2600 °F) and high pressures (up to 1200 psig) to generate synthetic gas or 'syngas.' The composition of the syngas can vary depending upon the conditions in the gasifier and the coal that is used, but typically it is a mixture of carbon dioxide, hydrogen, methane, and nitrogen and carbon monoxide. The gas is cooled, and as much as 99 percent of the pollutant-forming impurities are removed. To increase efficiency even further, the cleaned gas is burned in a conventional gas turbine to produce electrical energy, and the hot exhaust gas is recovered and used to boil water, creating steam for a steam turbine that also produces electrical energy. It can be turned into pipeline quality natural gas and piped directly into people's houses. It can also be used as a building block to manufacture more complex products in refining and petrochemical industries. Syngas burns much cleaner and reduces air pollution; it is renewable and does not depend on fossil fuels. In fact,

"Coal gasification offers one of the most versatile and clean ways to convert coal into electricity, hydrogen, and other valuable energy products.

Coal gasification electric power plants are now operating commercially in the United States and in other nations, and many experts predict that coal gasification will be at the heart of future generations of clean coal technology plants."

http://www.fossil.energy.gov/programs/powersystems/gasification/

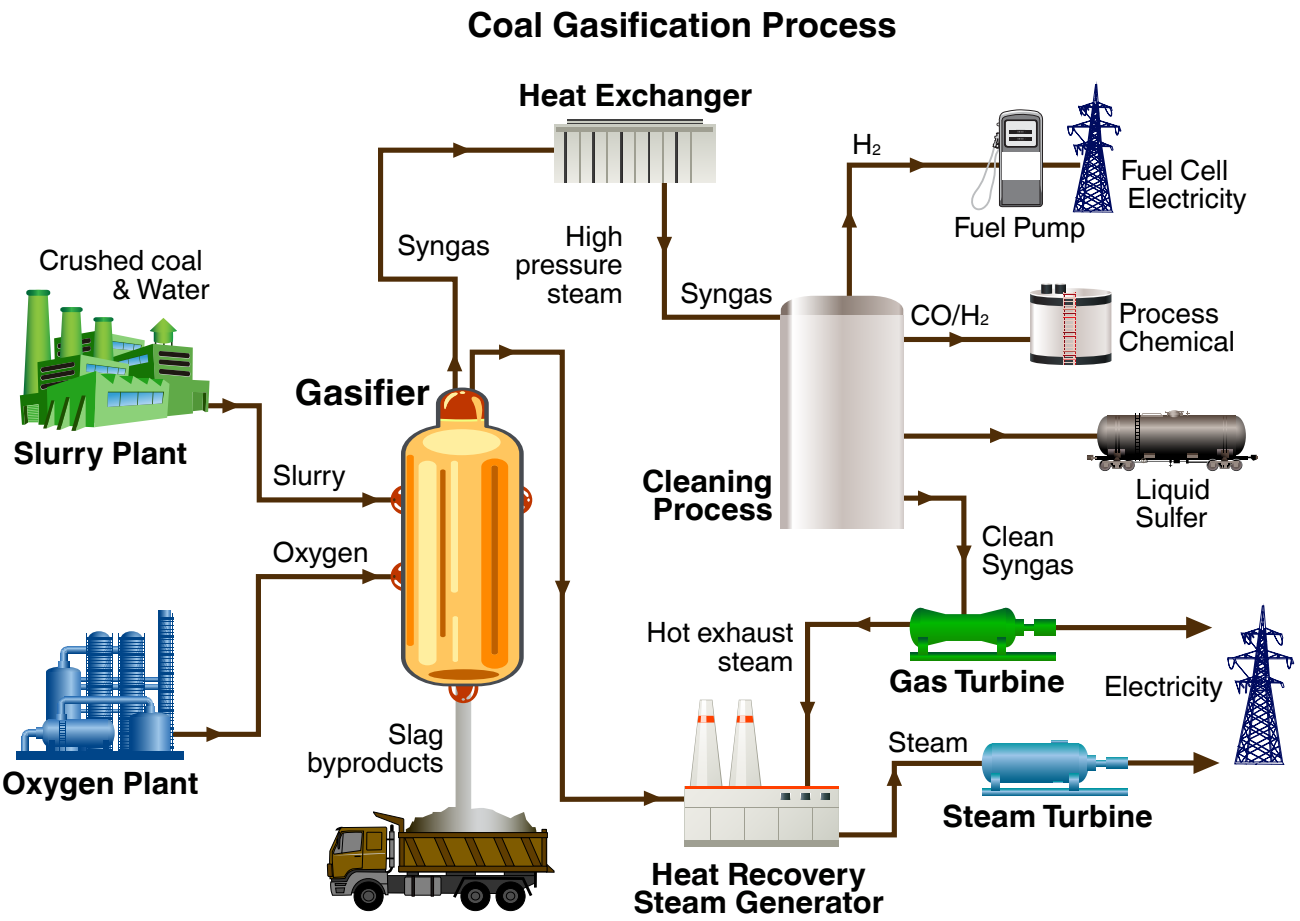

Figure 3 A look inside the gasification process. Gasification converts all of the carbon of the coal into electricity, hydrogen, and other forms of energy through partial oxidation.

syngas may be one of the alternative energy sources that will end our dependence on foreign oil and other resources. It can be produced domestically, and the production plants that produce these alternative energy sources will help local economies. Gasification plants will generate jobs, revenue, and growth for the areas where the plants are built.

Carbon Capture and Storage

In addition to syngas, another advantage of coal gasification is the fact that it lets you separate the good parts from the bad, and select the parts you want to keep. (See Figure 4.) For example, mercury, sulphur, ammonia and other compounds can be separated and sold. Separating and capturing carbon dioxide is easier and less expensive when oxygen is used in the gasifier (rather than air), and it does more than lessen the amount of greenhouse gases that are emitted into our atmosphere. Carbon dioxide can actually be useful. It can be pumped deep underground and stored in a storage field. From there, the carbon dioxide can then be piped to older oilfields to help recover oil that was previously left unused.

Protecting the Gasifier Unit

Each gasifier has a refractory lining that protects and insulates the thin outer steel shell of the gasification unit from the harsh environment (See Figure 5.) created by the gasification process—extremely high temperatures (up to 2600 °F) and pressures (up to 1200 psig), reactive gases, thermal shock, and corrosive slags that liquefy during the gasification process. But it's this extremely harsh environment that causes the refractory lining to significantly break down over time and fail. The first signs of deterioration

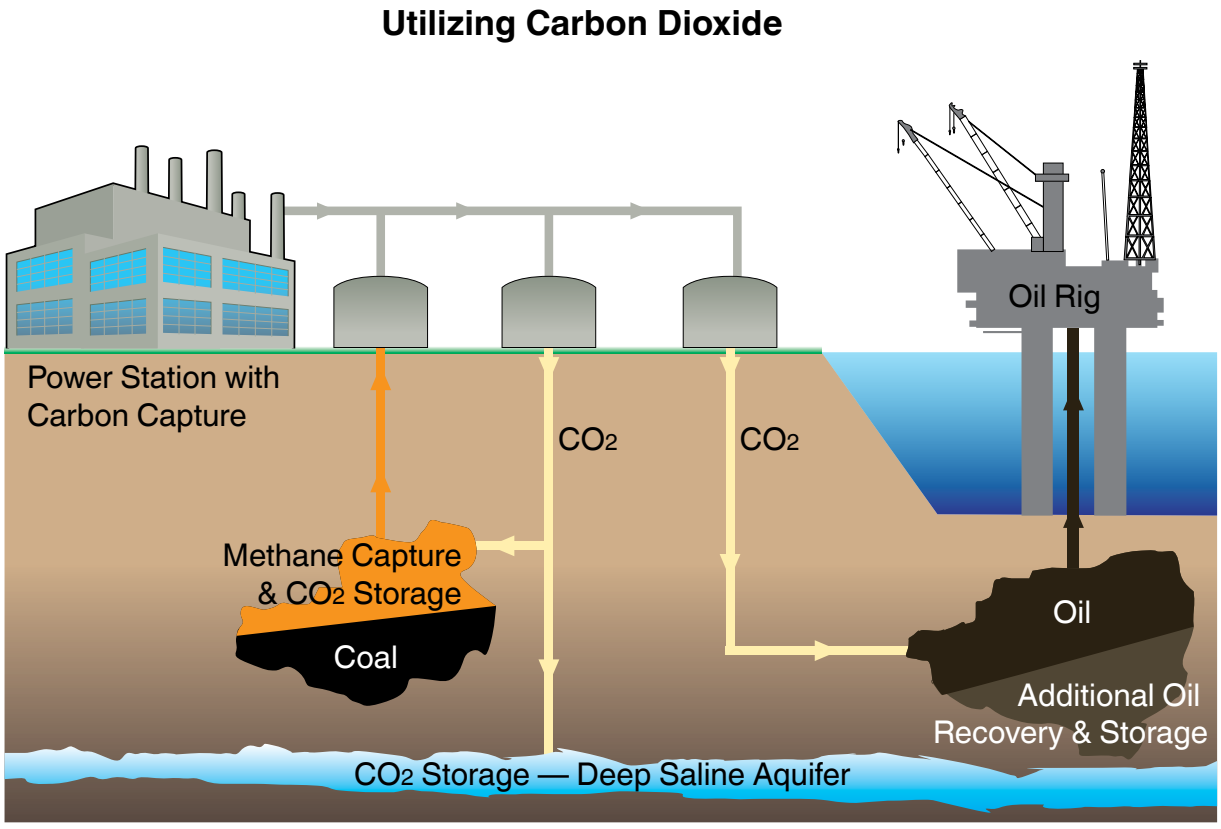

Figure 4 Gasification lets you separate the good parts from the bad, and select the parts you want to keep. Carbon dioxide can be pumped deep underground and stored in a storage field. It can be piped to older oilfields to help recover oil that was previously left unused.

of the lining are hot spots on the outer shell of the gasifier, and if they are not detected in time, the outer shell, with a melting temperature of approximately 1700 °F, will melt instantly.

Early gasifiers used cables that were wrapped around the gasifier to measure the resistance change in the cable if there were hot spots. But, it was awkward, cumbersome, and it wasn't very accurate.

Thermocouples have also been used to measure the temperature inside the gasification unit. But, like the refractory lining, the thermocouples typically fail because of corrosion from the slag, mechanical shear, or installation errors leaving no real method to measure the temperature while the gasifier is operating. Additionally, the typical life of a thermocouple is <120 days, and they drift. Consequently, long-term reliable temperature measurement within a gasifier using cables and thermocouples is not the method of choice; it makes process control difficult, increases maintenance downtime, and it puts both the gasifier and personnel at risk.

A Better Method

Obviously, a reliable temperature monitoring technique is imperative for the success and proliferation of gasification technology. Enter Mikron Infrared Inc., Oakland, NJ and Pepperl+Fuchs, Inc., Twinsburg, OH who have partnered on a project to provide an innovative solution: remote monitoring of the outer shell of the gasifier using several infrared cameras that provide real-time, color-coded temperature readings at user-defined "areas of interest" (AOIs) on the unit.

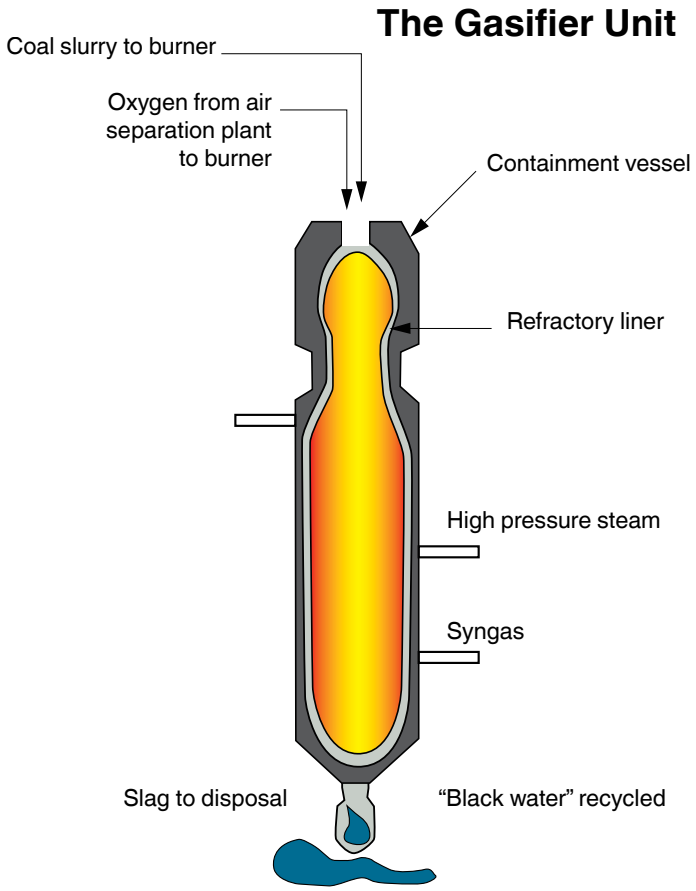

Figure 5 Each gasifier has a refractory lining that protects and insulates the thin outer steel shell of the gasification unit from the harsh environment created by the gasification process.

Mikron Infrared has developed an infrared, noncontact camera that can be mounted a short distance away from the gasifier. Different lens options are available to enable the camera to be mounted at different distances to enable full coverage. The cameras can be aligned and specifically focused on particular sections, providing up to 100% coverage of the gasifier's outer shell.

For this particular project, a Skin Temperature Sensing System (STSS) is used to monitor two gasifiers that are installed side-by-side. The system consists of a total of 26 infrared cameras, 13 cameras at fixed locations looking at each gasifier. Each camera can be set up to look at different AOIs; as many as 32 AOIs and feed that information back to a computer. The cameras are set up so that there is 100% coverage of the entire gasifier vessel. (See Figure 6.) There will be no spots that are undetected. They will monitor the shell temperature in real time and feed the information back to a computer. If a hot spot occurs due to a failure in the lining, it will be immediately detected and trigger a prompt shut down to avoid serious damage to the gasifier.

Unique to Mikron's camera is its ability to provide a thermal image. It provides a very high degree of resolution, and it's extremely accurate—to 0.1 °C at 2000 °C. And, unlike a thermal imager, the camera is radiometric; the pixels are actually calibrated to read temperature. Each single pixel can be individually calibrated providing exceptional accuracy.

The camera operates best when it is in a controlled environment, around 36 °C. So, it constantly needs to be heated and cooled. The area around the gasifier is an explosive atmosphere, so the camera needs to be in an enclosure and purged. That's where Pepperl+Fuchs comes into the partnership.

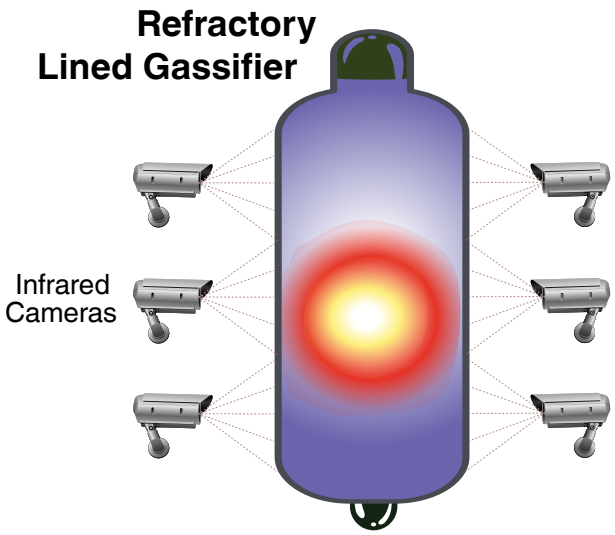

Figure 6 Thermal monitoring for vessel lining integrity. The cameras can be aligned and specifically focused on particular sections, providing up to 100% coverage of the gasifier's outer shell on this project.

Systems & Solutions

Pepperl+Fuchs mounts the cameras in sealed environmental enclosures with infrared transparent windows and continuous purging and cooling by instrument air from a Type X Pepperl+Fuchs Bebco EPS 6000 series purge system. Positive pressure inside the enclosure prevents dirt or dust from entering, even in the harshest conditions, and protects against explosion hazard in areas where volatile gases may be present.

Mikron and the Pepperl+Fuchs' System & Solutions design team created a custom solution for redundant power and safe operation of the IR camera system on the gas separation unit.

Each gasification separator uses 10 to 14 cameras per unit. The units are all supplied with N+1 redundant power from the Pepperl+Fuchs PS3500 power supply system. This type of redundancy is affordable and extremely reliable for continuous processes like gasification.

Gasification—Tremendous Opportunities for the United States and the World!

Gasification offers the United States a plethora of opportunities: it's proven, it's safe, environmentally friendly, it reduces pollutants and our reliance on foreign oil, enables carbon capture and storage, uses our abundant materials, provides American jobs, and it can only get better in the future. The ability to produce electricity, hydrogen, and chemicals and eliminate nearly all air pollutants and greenhouse gas emissions makes coal gasification one of the most promising technologies for the energy plants of tomorrow. And Pepperl+Fuchs together with Mikron Infrared are working to make it a reality. ◙

"Higher efficiencies translate into more economical electric power and potential savings for ratepayers. A more efficient plant also uses less fuel to generate power, meaning that less carbon dioxide is produced. In fact, coal gasification power processes under development by the Energy Department could cut the formation of carbon dioxide by 40 percent or more, per unit of output, compared to today's conventional coal-burning plant."

http://www.fossil.energy.gov/programs/powersystems/gasification/

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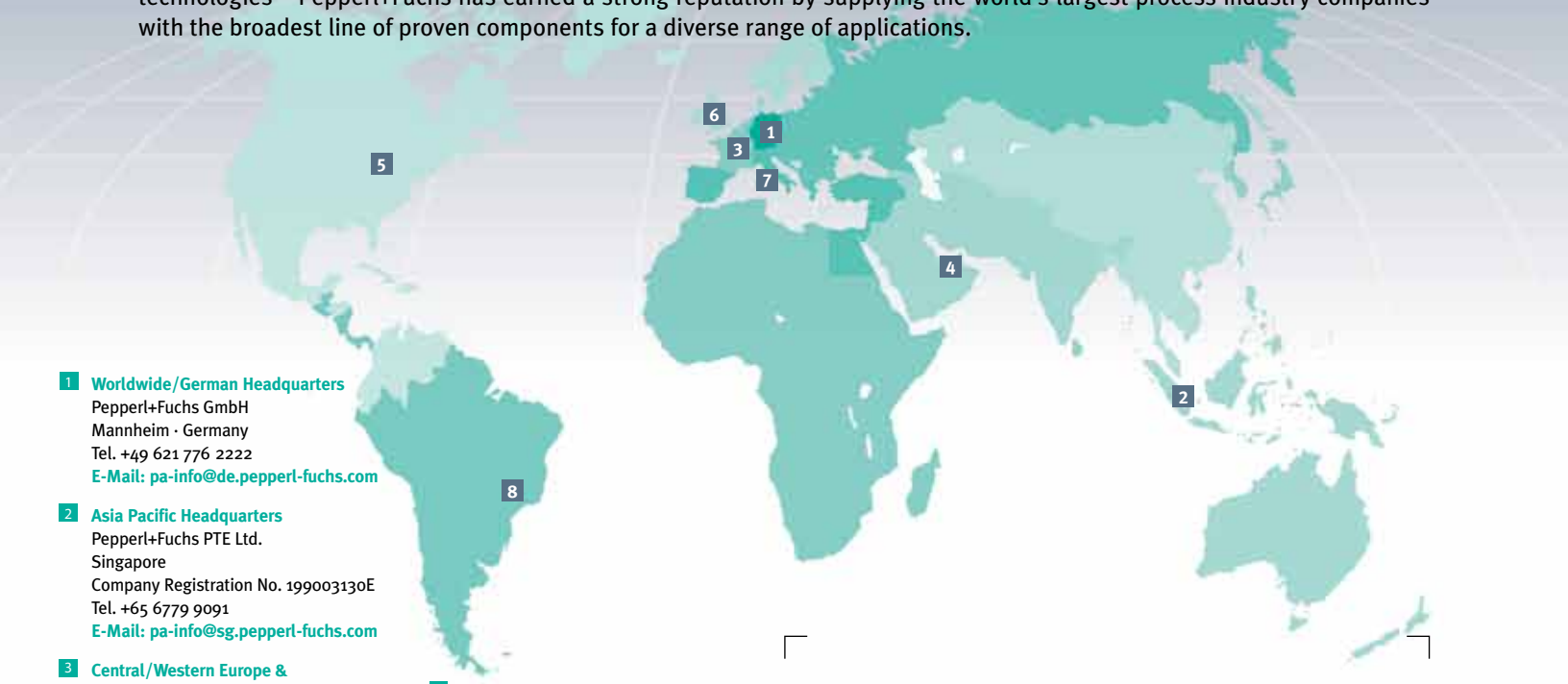
For over a half century, Pepperl+Fuchs has provided new concepts for the world of process automation. Our company sets standards in quality and innovative technology. We develop, produce and distribute electronic interface modules, Human-Machine Interfaces and hazardous location protection equipment on a global scale, meeting the most demanding needs of industry. Resulting from our world-wide presence and our high flexibility in production and customer service, we are able to offer complete individual solutions – wherever and whenever you need us. We are the recognized experts in our technologies – Pepperl+Fuchs has earned a strong reputation by supplying the world's largest process industry companies with the broadest line of proven components for a diverse range of applications.



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