

CASE STUDY

GLOBAL WARMING

VISION RESEARCH
HIGH-SPEED DIGITAL CAMERAS
ENABLE REVOLUTIONARY
RESEARCH INTO SOLVING
GLOBAL WARMING THROUGH
CLEAN USE OF FOSSIL FUELS



Phantom v7.1 high-speed camera applied to a cold flow gasification experiment at the NETL.

WHEN IT'S TOO FAST TO SEE, AND TOO IMPORTANT NOT TO®

Here's a shocking fact: according to the United States Department of Energy (DOE), the average U.S. household uses several tons of coal each year without ever seeing it! As the most abundant fossil fuel available in the United States, there is more energy available in the coal in this country than in the world's entire oil reserves.

The use of coal and other fossil fuels can be traced back to the era of the cave man; however, it was the Industrial Revolution that brought fossil fuels center stage as the country's go-to energy source. With the advent of the steam engine, coal was the driving force behind powering the nation's transportation sector, namely locomotives and ships. Using coal to produce electricity didn't come into the picture until the 1880s, but it's currently burned by power plants to produce more than half of the electricity used in the U.S.

Unfortunately, the burning of fossil fuels releases significant amounts of carbon dioxide (CO₂) into the atmosphere. One of the major greenhouse gases contributing to the escalating global warming crisis, CO₂ has long been the focus of scientists looking to develop more efficient and advanced technologies to reduce and hopefully eliminate the gas as a byproduct from the use of fossil fuels. Significant strides have been made over the past 20 years and new technologies are now available which can remove up to 90 percent of CO₂ and

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- Franklin Shaffer
Research Engineer at NETL

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About NETL

The National Energy Technology Laboratory (NETL), one of DOE's 17 national laboratories, is owned and operated by the U.S. Department of Energy (DOE). NETL supports DOE's mission to advance the national, economic, and energy security of the United States.

NETL implements a broad spectrum of energy and environmental research and development (R&D) programs that will return benefits for generations to come:

- Enabling domestic coal, natural gas, and oil to economically power our nation's homes, industries, businesses, and transportation
- Protecting our environment and enhancing our energy independence

NETL has expertise in coal, natural gas, and oil technologies, contract and project management, analysis of energy systems, and international energy issues.

In addition to research conducted onsite, NETL's project portfolio includes R&D conducted through partnerships, cooperative R&D agreements, financial assistance, and contractual arrangements with universities and the private sector. Together, these efforts focus a wealth of scientific and engineering talent on creating commercially viable solutions to national energy and environmental problems.

99 percent of other harmful pollutants that previously would have been released into the air. Revolutionary methods of using coal as an energy source for power plants, including those which don't directly involve burning the fuel to produce heat, are also now being developed and used.

One of these methods, known as advanced coal gasification or Integrated Combined Cycle Gasification (IGCC), is a unique process that ultimately turns coal into a clean gas which can be used to produce electricity. Perhaps the greatest advantage offered by IGCC is the possibility to completely remove carbon dioxide and other pollutants without releasing them into the air as byproducts.

The basics of coal gasification are well understood and coal gasification has been in use for more than 100 years; however, the National Energy Technology Laboratory (NETL), part of DOE's national laboratory system, has been taking a closer look at the technology with hopes of further enhancing its reliability and overall performance in advanced IGCC power plants. With the help of Vision Research, a leading manufacturer of advanced high-speed digital imaging systems, NETL is now able to study the high-speed dynamics of coal particles during the gasification process. Particle dynamics are of critical importance because they are one of the primary determinants of the reaction rate and efficiency of the gasification process. Conducting research on the microscopic level and using a Vision Research Phantom v7.1 high-speed digital camera to record the high-speed particle motion, NETL researchers made significant breakthroughs in the research of coal gasification where, for the first time, they were able to record in ultra-slow motion and high-resolution, the fundamental dynamics of coal particle motion during the gasification process.

Coal Gasification

Coal gasification is a clean and versatile way to generate electricity and other energy products from coal as an alternative to traditional generation methods. Coal, together with oxygen, steam and other chemicals, are reacted at high temperatures and pressure to produce a gaseous mixture, known as syngas, which can be cleaned and used in a gas/steam turbine combined cycle system to either generate power or continue being processed to produce hydrogen, transportation fuels, or chemicals. Advancing year after year, coal gasification is turning coal into a nearly pollutant-free combustible gas that can rival natural gas in terms of environmental performance.

"NETL is constantly seeking ways to improve the energy efficiency and the environmental performance of coal and other fossil fuels," said Franklin Shaffer, a research engineer at NETL. "During the gasification process, coal is pulverized into microscopic particles, typically around 100 microns in diameter. Rather than simply burning the coal to produce heat and electricity, the particles are

Click the following link to view high-speed video clips of random motion and collisions of coal particles in a gasification system, recorded with a Phantom v7.1:

www.visionresearch.com/go/NETL

chemically processed in a large gasifier chamber, sometimes more than a meter in diameter and 20 meters high. The microscopic coal particles are reacted with other chemicals to produce a gas commonly referred to as syngas. Syngas is very much like natural gas in the fact that it can easily be cleaned and directly burned by turbines to generate electricity for the power grid. Also, with the skyrocketing prices of petroleum, gasified and liquefied forms of coal are now economical as a replacement for gasoline and other petroleum products. By using gasified and liquefied coal from the U.S., we can greatly reduce our dependence on foreign oil.”

Improving the Gasification Process

Using the Vision Research Phantom v7.1 high-speed digital camera, NETL scientists were able to view, record and (more importantly) measure the precise motion of microscopic coal particles within a gasification chamber. Thanks to an array of specially designed high-magnification optics developed by NETL and the ultra-fast frame rates and impressive resolution of the Phantom v7.1, the NETL research team was able to achieve insights never before available. The study of particle behavior in gasses and liquids is known as particle image velocimetry or PIV. PIV is a common application for high-speed cameras.

The Phantom v7.1, used by NETL, boasts an impressive frame rate of 4,800 pictures-per-second (pps) at its maximum resolution of 800 x 600 pixels, and for faster speeds, users can scale down the resolution and achieve a maximum frame rate of 160,000 pps. Of significance, the camera's high sensitivity and 12-bits of gray scale bit-depth provide users with increased flexibility and information, especially in low-light environments and where detail is paramount.

“NETL researchers develop computer models, such as the MFIX model¹, to simulate the motion and chemical reaction of microscopic coal particles during the coal gasification process,” said Shaffer. “These models are used to design energy conversion processes like IGCC with higher efficiency, minimal pollution and high reliability; however, to improve these computer models, NETL needs to better understand the fundamental dynamics of particle motion within gasifiers. Because this is one of the most challenging environments to record video in, we needed the best high-speed imaging technology available, one with the highest frame rates, resolution, and light sensitivity. The Vision Research v7.1 met those requirements on paper and in practice.”

Since the completion of this project, Vision Research has introduced the Phantom v7.3 - the next generation of the v7.1. Even more advanced than its sibling, the v7.3 takes speed and sensitivity to the next level. At the same

¹ For more information on the NETL's Multiphase Flow with Interphase Exchanges (MFIX) model, see www.mfix.org

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resolution of 800 x 600 pixels, the Phantom v7.3 can record at a frame rate of 6,688 pps, and thanks to a unique turbo mode, users can configure the camera to record at 500,000 pps. Besides offering incredible speed, the v7.3's specially designed CMOS sensor also yields increased sensitivity and detail with 14-bit pixel depth (monochrome). Faster communication with a computer running Vision Research's Phantom Software is also an added benefit of the v7.3 as the camera boasts Gigabit Ethernet connectivity.

"With the data captured by the v7.1, our research team can now build even more accurate computer models to help design energy systems with higher efficiency, reliability, and pollution control. The ultimate results from the NETL's research could be the ability to use coal without emitting the greenhouse gases that cause global warming," added Shaffer.

Large scale IGCC demonstration projects are already underway around the world, and the U.S. government is considering more large scale IGCC demonstration plants. The clean use of coal through IGCC, other advanced energy technologies like solar energy, and the prudent conservation of energy, are significant steps towards alleviating the problem of global warming and leaving a better world for future generations.



Phantom v7.1 high-speed digital cameras enable revolutionary research into solving global warming through clean use of fossil fuels.



About Vision Research:

Vision Research designs and manufactures high-speed digital imaging systems used in applications including defense, automotive, engineering, science, medical research, industrial manufacturing and packaging, sports and entertainment, and digital cinematography for television and movie production.

The Wayne, N.J.-based company prides itself on the sensitivity, high-resolution and image quality produced by its systems, robust software interfaces, and reliability and versatility of its camera family – all which continue to stand as benchmarks for the high speed digital imaging industry.

Vision Research digital high-speed cameras add a new dimension to the sense of sight, allowing the user to see details of an event *when it's too fast to see, and too important not to*®. For additional information regarding Vision Research, please visit www.visionresearch.com.

Vision Research is a business unit of the Materials Analysis Division of AMETEK Inc., a leading global manufacturer of electronic instruments and electromechanical devices.

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