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NIST presents first real-world test of new smokestack emissions sensor designs

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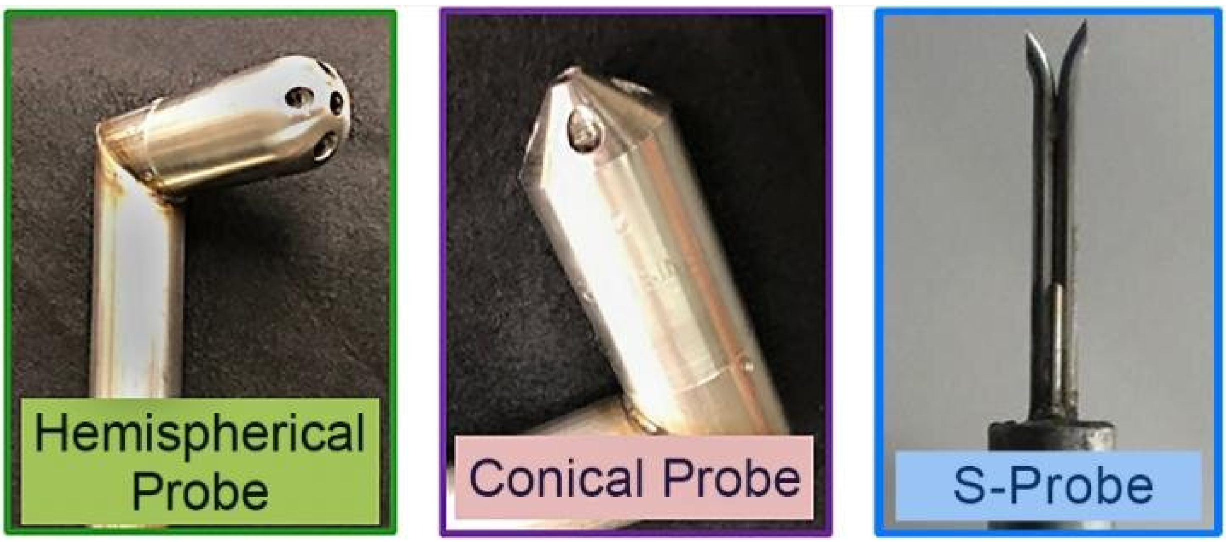


NIST designed two new pitot probes (left and center), one whose sensing surface is cone-shaped and the other whose surface is hemispherical. The probes have five holes, or ports. Comparing pressure readings obtained in each of the five ports allows technicians to calculate the flow rate. An older type of pitot tube, called an S-probe (right), has two ports that face in opposite directions. Credit: NIST

In collaboration with industry, researchers at the National Institute of Standards and Technology (NIST) have completed the first real-world test of a potentially improved way to measure smokestack emissions in coal-fired power plants. The researchers are presenting their work this week at the 2019 International Flow Measurement Conference (FLOMEKO) in Lisbon, Portugal.

Each year, to meet requirements set by the Environmental Protection Agency (EPA), coal-fired power plants must have their smokestack emissions audited, or checked by an independent third party. NIST researchers wanted to make this test quicker to save the plants money during their audits, while also improving accuracy of the sensors. So, a NIST team has designed new probes for sensing emission flow rates and a new measurement method that could potentially speed up on-site audits by a factor of 10, researchers say.

The fieldwork results were "promising," said NIST engineer Aaron Johnson, and were in reasonable agreement with the laboratory findings. "We were surprised; it did quite well compared to what the EPA has on its books as its 'best practices' method."

To monitor emissions from coal-fired power plants, technicians need to measure the rate at which flue gas is emitted from the smokestack. The flow inside the smokestack contains eddies and swirls but generally travels upwards. In the NIST tests, four probes—called pitot tubes—are inserted horizontally into the smokestack.

The four probes each take a flow measurement at four different spots, for a total of 16 measurements. With this information, NIST scientists could test the precision and accuracy of a new pitot tube design and measurement method.

NIST conducted this work as part of a cooperative research and development agreement (CRADA) with the Electric Power Research Institute (EPRI), an independent nonprofit organization whose members include electric utility companies, businesses and government agencies.

"Coal-fired electric generating units may benefit from the current NIST work by having improved standards and techniques to measure mass emissions more accurately, with increased confidence that all entities are reporting on a uniform basis," said EPRI program manager Tom Martz. He added that the potential time savings "is not something we can accurately quantify at this time, but this will be a key objective of future work."

The ultimate goal is to provide research that the EPA might someday develop into a new standard for smokestack emissions calibration.

"The advantages for industry are that it will reduce test time and cost and has the potential to be more accurate" than current industry-standard probes, Johnson said.

Even if the EPA does not create a new standard, however, the work could have benefits for industry by providing power plant companies with more choices for managing their emissions tests. "Our goal is to get it written as an EPA standard," Johnson said. "But it's still up to industry members to decide whether they would want to use it."

Go With the Flow

Smokestacks at coal-fired power plants are equipped with monitors that continuously measure the concentration of flue gas emissions, which include carbon dioxide, mercury, sulfur dioxide and nitrogen oxides, as well as the flow rate of the flue gas. By federal law, the built-in flow-rate sensors need to be calibrated—that is, checked for accuracy—during the annual audit.

To conduct the yearly calibration, auditors use small portable devices called pitot tubes. The audit technicians climb the stack—usually several dozen meters (hundreds of feet) tall—and insert their pitot probes horizontally into the gases churning their way up the smokestack. They take several readings of the flow at various points within a cross section of the stack, which is typically 7 or 8 meters (25 feet) in diameter.

By far the most common kind of sensor used for this work is an "S-probe." It has two holes, or ports. One port faces directly into the flow of gas and detects the pressure that builds up in the tube. The other port faces the opposite direction. The faster the flow, the higher the pressure difference between the two ports; measuring this difference in pressure allows auditors to calculate the flow's speed.

S-probes don't require calibration, but each measurement can take several minutes, since the technician has to manually rotate the sensor until one side is facing directly into the flow. This is complicated because the flow is not necessarily traveling directly upward at the point being tested. At the base of the stack, flue gas usually travels around a sharp bend, which creates complicated eddies and swirls that don't go away even in tall smokestacks.

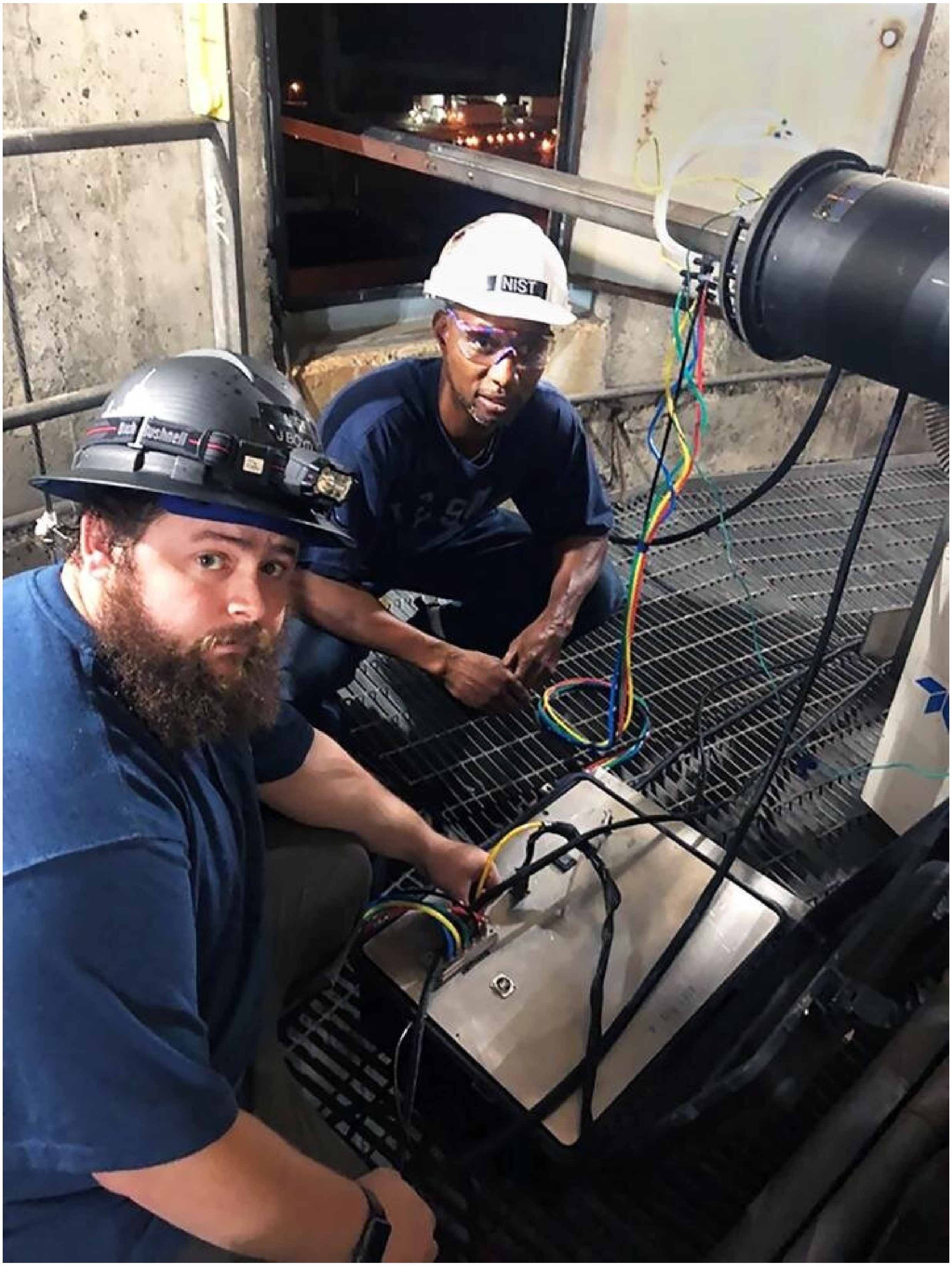
Using S-probes is so labor-intensive that an on-site annual calibration can take a day or more to complete. "And the power plant is losing money all the time the auditors are there, so they want the technicians in and out as fast as possible," Johnson said.

To speed up this process, the NIST scientists have made three innovations. First, they have created two new models of pitot tubes, with five holes instead of two, which perform better than S-probes and may offer advantages over other five-hole models of pitot tubes currently in use.

The probes, designed by NIST physicist Iosif Shinder, come in two shapes: hemispherical and conical.

Second, the scientists have developed a calibration scheme for their new sensors that does not require a technician to rotate the probe inside a smokestack to find the true direction of the flow for each measurement. So, although the sensors would have to be calibrated before use, they would take much less time to use during an actual audit.

Third, NIST's Jim Filla developed software that is compatible with a commercially available automated system to measure flow in real time.


NIST
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NIST's Joey Boyd (left) and Aaron Johnson conducting a test of the new sensors at a power plant. The platform, which gives them access to the smokestack, is about 45 meters above the ground. Credit: Tom Martz/EPRI

The Real Deal

Until now, the new probes' performance had been measured only at NIST's test facility, which includes a scale-model smokestack simulator and a wind tunnel. But NIST's laboratories cannot replicate all aspects of a real power plant, such as the presence of soot in the smokestack's flow.

"It's one thing to test it in our wind tunnel," Johnson said. "It's another to prepare to test it in a stack that's 120 degrees F."

The first field run, in July 2018, took place at a natural gas plant, where flow is relatively straightforward to measure.

The second, in September 2018, was conducted at a coal-fired power plant with a particularly complicated flow.

The coal-fired plant had an enclosed platform where the pitot tubes were inserted into the smokestack. But the natural gas plant's platform was open to the elements. And at roughly 45 meters (145 feet) in the air, "things shake," said NIST technician Joey Boyd. "While you're working, the stack is swaying, and the floor beneath you is moving."

When NIST researchers analyzed the data, their results were promising, agreeing to within 2% with their laboratory findings.

"The probes performed equally well in the smokestack as they did at NIST's test facility," Johnson said.

Future field tests will help the researchers solve the biggest problem they had: sensor clogging, in which the pitot tubes' ports get gummed up with water and particulate matter and have to be flushed before a test can continue.

Also, the work taught them they needed to write special software signaling to their equipment every time there was a "purge—a high-pressure blast of air through the pitot probe that could damage a key part of the apparatus if certain valves were not closed in time.

Provided by National Institute of Standards and Technology

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