GAS ANALYTICS FOR OPTIMIZED FIREFIGHTING

Hot topic: **Fire research**

Firefighters around the world risk their lives daily to rescue people and protect property and the environment. Training, knowledge, experience and lightning-fast decision making are all essential in firefighting. But how can effective strategies and tactics be developed to mitigate something as highly dynamic as fire? Fortunately for firefighters, fire is rooted in physics, and scientific knowledge of fire behavior and fire dynamics within structures provides an important framework. Fires of all scales are being studied; from small laboratory experiments to define and understand changing material properties, to large-scale building fires to determine the effectiveness of different firefighting tactics. In all of these studies, gas analysis (utilizing Siemens technology) plays an important role in understanding the fire dynamics and potential impact to building occupants that may be exposed and trapped.

SIEMENS

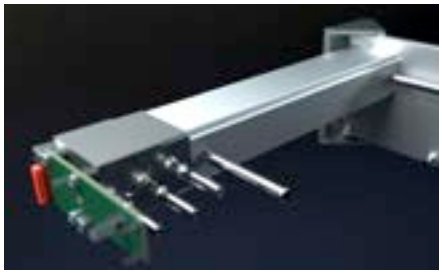
Modern fire research

The Underwriters Laboratories' Fire Safety Research Institute (FSRI) helps answer critical questions about fire safety with a large focus on firefighting strategies and tactics. The U.S. based, non-profit institute conducts highly technical research to help firefighters better protect themselves, improve the efficiency of their operations, and improve their ability to save lives and protect property. This research is conducted in direct collaboration with fire departments and academic research departments around the world. Much of the research highlights the ever-changing fire dynamics in residential, commercial, and industrial fires and the resulting implications for firefighting strategies and tactics. Located between Washington D.C. and Baltimore, Maryland, the institute conducts scientific research on all scales from the laboratory to the field in full-size structures.

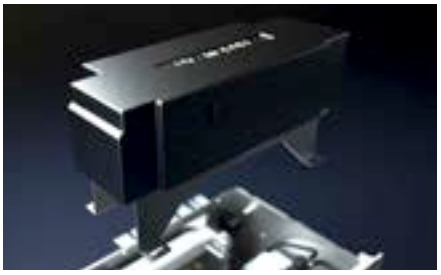
Valuable insights...

The following example illustrates why this work is so important: Over the past few decades, residential fire environment has changed. Fundamentally fire dynamics in residential structures have changed, due not just to the arrival of new construction materials but also to the construction of larger houses, adapted architectures, larger window openings, and increased fuel loads caused by more synthetic materials in the interior. FSRI is constantly conducting experiments to study the impact of these changes on fire behavior. According to its findings, residential fires of today can transition through flashover in under five minutes. Two decades ago, this sudden transition of a fire from its incipient phase to its fully developed phase took over 30 minutes, which provided a significantly longer period of time for firefighters to rescue people and contain the fire in its incipient phase. Other experiments demonstrate that the failure time of wall linings, windows, and interior doors has decreased over the same time period. This also directly impacts fire behavior, which in turn affects firefighter tactics. These and other studies clearly show that fire behavior in residential buildings has changed significantly, and that the change in fire dynamics has a major impact on how the firefighters must engage with and mitigate the fire problem at hand.

A robust device: ULTRAMAT 23



IR-Detector



UV-Photometer

O_2-Sensor

... supported by precise measurement results

But how does the FSRI team arrive at reliable conclusions about fire dynamics? Modern gas analytics makes an important contribution to meeting this challenge. Every fire produces toxic gases like carbon monoxide, hydrogen chloride, hydrogen cyanide, and sulfur dioxide, as well as other dangerous combustion gases that depend on the material burned. To precisely analyze the gas composition of residential fires a fire has to be ignited and observed under test conditions that are as close to reality as possible. For each study, FSRI compiles a list of specific research questions that need to be answered during the test fire. Appropriate test conditions are then created inside a true-to-scale building that is either purpose-built or acquired that provides a safe but realistic environment for the experiment. Robust sensors and instrumentation make it possible to track fire dynamics by providing direct and extrapolated measured variables like gas temperature and the speed and direction in which gases move in a burning room. From this data, FSRI gains valuable knowledge about how fires start and spread. What's important here is that the concentration of gases like carbon monoxide, carbon dioxide, and oxygen in specific locations be precisely recorded at a high resolution between 10 and 100 times per minute throughout the entire fire event. Because every event – a curtain catching fire, a door opening, a window shattering – contributes to fire dynamics, the tests require gas analyzers that can record data quickly and continuously and that are robust enough to deliver precise results in a harsh environment.

Advanced Analytics Made Into A Commodity. The multi-technology analyzer ULTRAMAT 23 fulfills highest standards.

A robust all-rounder in action

First of all sampling points known as taps are positioned at different locations in the test house as a function of the data parameters and fire physics that the test is intended to study. For years, FSRI has been using process gas analytics from Siemens. ULTRAMAT 23 is an innovative multi-component gas analyzer that can be equipped with the following sensors: IR detectors for IR-active gases, UV photometers for UV-active gases, H_2S sensors (electrochemical), and O_2 sensors (electrochemical and paramagnetic). This makes the continuous measurement of four gas components possible and enables an analyzer to take precise, high-resolution measurements of the most important gases contributing to fire events. FSRI deploys over 20 ULTRAMAT 23 gas analyzers in order to obtain precise results despite high temperatures and the volatile characteristics of fire, and to optimize data analysis in an extremely complex test setup.

No fire without smoke (gas)

As soon as the test fire starts, gas is drawn to the appropriately positioned stainless-steel taps. Before the gas mixture reaches the analysis units, it has to be cooled and cleaned. That's why it's put through a five-micron filter that removes soot particles, followed by a cooling coil condenser that's submerged in ice water. This rapid cooling draws most of the moisture out of the mixture. A series of finer filters removes the last remaining moisture and ensures that only processed gas flows through the analyzers' valves. Depending on the application, the gas is transported a total distance of six to 30 meters before it reaches the ULTRAMAT 23 gas analyzers. The various transport times are taken into account by a series of time tests before the fire is started and a mathematical adjustment is based on the difference between the two values. All this data – plus the ambient air temperatures recorded by separate thermoelements – is managed by a SCADA system that visualizes the results on a monitor in real time. The customized system is linked to over 300 sensors per test setup. A simple and straightforward plug-and-play technology ensures efficient installation. The analyzers are connected by a single power cable and have a 4–20 mA output that allows operators to control and configure the analyzers via the SCADA system. At the press of a button, post-processing scripts developed by FSRI staff generate diagrams of carbon dioxide, carbon monoxide, and oxygen concentrations at a specific location every second. This enables the experts at FSRI to use timestamps to correlate specific fire events – like the collapse of a door or the opening of a window – with the behavior of the fire based on gas concentrations.

Optimal performance

For FSRI, the knowledge that can be derived from precise measurements isn't all that matters. The Siemens devices also have to satisfy the non-profit research institute in terms of maintenance. The robust and corrosion-resistant measuring cell is easy to clean and can withstand the harsh conditions of high temperatures caused by fires, resulting in minimal repairs and the associated reduction in costs. The processing systems and analyzers don't just have to withstand harsh operating conditions: FSRI also values the ULTRAMAT 23 devices' outstanding measurement drift performance. The autocalibration feature of the low-maintenance Siemens gas analyzers serves to lengthen the intervals between calibrations while also preventing drift. This means that the devices deliver results at an accuracy within one percent of the measurement range over a long period of time. And when it comes to fires, accuracy can make the difference between a rescue and a loss of life!

Rack of ULTRAMAT 23 with sample conditioning system in real-life scenario.

Interview with Keith and Joakim

Bio Keith: Keith Stakes is a Research Engineer with UL's Fire Safety Research Institute (FSRI). He is a Fire Protection Engineer and has expertise in the study of fire service tactics, firefighter safety, and fireground operations. Keith holds a Bachelor of Science Degree and a Master of Engineering Degree in Fire Protection Engineering from the University of Maryland. He currently serves with the Bethesda-Chevy Chase Rescue Squad in Bethesda, Maryland where he holds the rank of Fire/Rescue Battalion Chief. Keith also serves on the NFPA Technical Committee for Fire Service Training and the Editorial Advisory Board for FireRescue1 and Fire Chief.

Q: UL's Fire Safety Research Institute (FSRI) helps answer critical questions around fire safety and fire management. Why is that so important?

Keith: Fire has evolved dramatically in the past few decades. Before, we filled our homes with natural materials, such as wood, cotton, natural fibers. Now, the vast majority of our homes are made up of petroleum-based products. That drastically changes how fire will burn and in turn, changes how the fire department needs to respond.

Q: Could you describe the main objective of your research and why it's so important?

Keith: Let's have a look at a typical fire in an environment we are all well familiar with: a living room. Whereas 20 to 30 years ago it took a good half hour for this fire to flashover and consume the room, today, this can take less than five minutes as evident by our studies!

Q: And what is this based on?

Keith: The sum of a multitude of changes: Shifting conditions due to different building materials, but also more spacious homes, adapted architectures, larger window areas, and increased fuel loads through increased synthetic materials found in interior finishings are drastically increasing the challenges for us firefighters – both in terms of the time we have left to extinguish fires and in terms of our own safety. Such studies and others clearly demonstrate that fire behavior in residential buildings is changing significantly and that this change in fire dynamics has a significant impact on the ability of the firefighters to respond and choose tactics to best preserve life and property.

Q: Can you describe how the research is done in practice?

Keith: To get answers, there is no other way to accurately analyze the changing fire dynamics than to conduct and observe an actual inferno. Partnering with a technical panel of fire service members from different backgrounds around the world, FSRI compiles a list of specific research questions that are to be answered during a test fire. A multitude of sensors and instruments are then designed within a full-scale house model that provides a safe yet realistic environment to analyze. Fire is extremely dynamic, so the more we know about it, the more we can do to improve our approach in managing it. Gas concentrations are a very critical piece to that.

Q: What parameters are these analyses based on? What can you specifically measure and compare in such a test setup?

Keith: We are primarily interested in the concentrations of carbon monoxide, carbon dioxide and oxygen. Of particular interest are the gases emitted as synthetic materials burn. Nowadays, when a couch is involved in fire, it actually melts into a pool of burning plastic liquid that accelerates the growth of the fire, and those products of combustion are a lot more toxic and lethal compared to those furnishings of years past. It changes how the fire reacts to new sources of oxygen from say, opening a door. In order to be able to track these very dynamic changes, we rely on modern gas analytics technology and continuously take gas samples for analysis at certain points.

Q: Where and how are these gas samples extracted?

Keith: First, sample points, known as taps, are placed in different locations of the test house according to what data parameters and physics of the fire are being captured in the test. If we want to answer, say, an

exposure question, sample points are placed in areas that simulate human exposure points, such as on a bed or at the end of the hallway or near a doorway.

Q: And then these samples are analyzed?

Keith: Yes, but Joakim can explain that for you much better. He is a specialist for gas analyzers at Siemens.

Joakim: Thanks, Keith. FSRI uses our Continuous Gas Analyzers ULTRAMAT 23, an extractive gas analytics system to analyze the key gases that play a critical role in fires – carbon monoxide, carbon dioxide and oxygen. Extractive measuring methods are characterized by the fact that the sample to be analyzed is taken from the origin source and fed to the analyzer in conditioned form using a sample line and sample preparation – continuously and in a matter of seconds.

Q: And such a device is then able to determine these three mentioned gas components simultaneously?

Joakim: Yes, and even a fourth component is possible at the same time. But first, the gas mixture must reach our analyzers: Depending on the application, the gas must be pulled anywhere from 20 to 100 feet to reach the ULTRAMAT 23 gas analyzers, facilitated by pump boxes that help draw the gas into the analyzers. A series of finer filters remove any last remaining moisture and ensure that the only thing passing through the valves of the analyzers is the gas itself. Then the individual gas concentrations are determined via various measuring methods in corresponding measuring cells of the devices. All of this data – plus ambient air temperatures taken by a separate thermocouple – are managed by a supervisory control and data acquisition system (SCADA) connected to an HMI display that visualizes the data in real time.

Keith: And at that point it's of great importance that the concentrations are available in high resolution. Due to how dynamic the environment is – a curtain starts to catch fire, a door opens, the fire finds a window cracked – the tests need gas analyzers that can capture data quickly and are durable enough to withstand the burning environment itself.

Q: Then, after the actual experiment, you still need to process the data to get answers to your questions, right?

Keith: Exactly, but this is a fairly simple matter thanks to the SCADA system: With a click of a button, post-processing scripts developed by our FSRI staff generate graphs of the carbon dioxide, carbon monoxide and oxygen concentrations at every second in a given location. We are able to time stamp events as they happen. Right away, we can see how an action such as breaking a window or opening a door changes the fire's behavior or affects its gas concentrations.

Q: And what do you think makes the Siemens equipment particularly special?

Keith: In my opinion, there are two main points to mention here: Ease of use and low purchase and operating costs. Despite being double or triple in cost, a lot of the analyzers I've used in the past weren't very user friendly unless you have a technical background. The fact that these are truly robust, both physically and digitally, and are also compact and easy to use is a tremendous help when performing tests with so many moving pieces.

Q: And what's the deal with operating costs?

Keith: Such analyzers must be regularly calibrated and professionally maintained to ensure accurate measurements over time. To prolong calibrations and prevent drift, we use the autocalibration function on the Siemens UTRAMAT 23 Gas Analyzers. Other than sending them out for general maintenance every year and a half, we don't do much more than simple calibrations. Frankly, we abuse the heck out of them in these testing environments, yet we've never had an issue. These analyzers are built like tanks.

Q: So, you are satisfied with the equipment?

Keith: Absolutely, key public safety insights came directly out of the research conducted with these analyzers. They help us answer questions with a lot more data, support, and understanding behind why things happen the way they do in a fire and what the firefighters' response needs to be as a result. With more analyzers in house, we are able to expand our breadth of research and partner with other entities or institutions and dive into deeper into complex issues to gain a greater understanding of fire as a whole.

Keith, Joakim, thank you very much for talking with us.

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