Course Outline

- What is Fire?
- How do we detect Fire?
- Construction Challenges
- Future Detection Technologies
- Application Solutions
- The Saving of Lives
What is Fire?
Fire Principles

For a fire to break out, **combustible material (fuel)** and an **oxidation agent (usually oxygen)** must be available. Our environment is to a large extent made up of combustible materials – and oxygen is virtually always sufficiently available. But another condition must be fulfilled for a fire to break out: The **ignition energy (heat)** must be the driving force to initiate oxidation. Ignition energy sources are manifold: Electrical discharge (e.g. lightning), short-circuits, flying sparks, hot surfaces (light bulbs, heating equipment, etc.), direct exposure to flames or bundled light, to name only the most important ones. If a fire occurs, it provides the necessary energy to maintain the combustion process.
Stages of Fire Development

**Incipient stage:** Little visible smoke occurs, but especially invisible aerosols are generated.

**Smoldering stage:** In this phase, the fire can be extinguished by means of a fire extinguisher or a similar extinguishing agent. Visible, partly dense smoke occurs. Usually, combustion is incomplete, which is why rather a lot of (toxic) CO is produced in this phase.

**Flaming stage:** We are faced with an open fire to be fought by the fire brigade. As enough energy is available, the combustion process is rather complete, resulting in a high production of CO2.

**Heat Stage or Flashover:** This is the explosive fire spread, taking place exactly at the point when the gases and aerosols produced during the previous phases ignite and carry the fire into all rooms already penetrated by the smoke gases.
Throughout the **various stages** of fire development and the **types of fuel loads** consumed it is important to select the most appropriate detection technology for the expected fire.

Frequently the design parameters require different technologies to accomplish the goal of fast and reliable fire detection.

<table>
<thead>
<tr>
<th>Type of Fire</th>
<th>Smoldering fires (non-flaming fires)</th>
<th>Glowing fires</th>
<th>Solid matters (mostly ember-forming fire)</th>
<th>Liquid matters (flame combustion)</th>
<th>Gaseous matters (flame combustion)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion process</td>
<td>Not independent, requires continuous energy supply</td>
<td>Independent after ignition</td>
<td>Independent after ignition</td>
<td>Independent after ignition</td>
<td>Independent after ignition</td>
</tr>
<tr>
<td>Type of smoke (aerosol)</td>
<td>Very light smoke</td>
<td>Light smoke</td>
<td>Dark smoke</td>
<td>Very dark smoke</td>
<td>Depending on the carbon share of the gas, its chemical properties and mixing with oxygen</td>
</tr>
<tr>
<td>Optical properties of smoke</td>
<td>Quickly spreading</td>
<td>Quickly spreading</td>
<td>Strongly absorbing, spreading little</td>
<td>Strongly absorbing, spreading little</td>
<td></td>
</tr>
<tr>
<td>Aerosol volume</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High (except pure alcohol: none)</td>
<td></td>
</tr>
<tr>
<td>UV / IR radiation</td>
<td>Low</td>
<td>Low to medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Heat convection</td>
<td>Low</td>
<td>Low to medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Combustion gases</td>
<td>Much CO, little CO2</td>
<td>Much CO, little CO2</td>
<td>Little to much CO, much CO2</td>
<td>Little CO, much CO2</td>
<td>Little CO, much CO2</td>
</tr>
<tr>
<td>Sound</td>
<td>None</td>
<td>None</td>
<td>None to much</td>
<td>None to much</td>
<td>None to much</td>
</tr>
<tr>
<td>Pressure increase</td>
<td>None</td>
<td>None</td>
<td>Low to medium, depending on the fuel</td>
<td>Low to high, dep. on fire phenomenon</td>
<td>Low</td>
</tr>
</tbody>
</table>
How do we detect Fire?

- Heat Detection
- Spot Smoke Detection
- Beam Smoke Detection
- Duct Smoke Detection
- Aspirating Smoke Detection
- Flame Detection
Heat Detectors – fixed temperature snap disc

Bifurcated leaf
Heat Detectors – Rate of Rise & Fixed Temp.

**Combination detectors** have both fixed and rate-of-rise elements.

- The fixed element is generally a non-restorable type, and when activated, must be replaced.
- The rate-of-rise element is restorable when conditions return to normal.

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![Diagram of Heat Detectors]

- **Rate of Rise Vent**
- **Fixed Heat Collector**
- **Fixed Actuator**
- **Alarm Contacts**
- **Rate of Rise Diaphragm**
- **Eutectic Solder** (thermal lag)
Rate Compensation Detector
Rate Anticipation Detector

Fixed Temperature only
Not Subject to Thermal Lag
Spot Smoke Detection – Ionization

Principle of Detection – Changes in Conductivity

- $^{241}\text{Am}$ – (Americium 241) source of alpha particles
- Half-life of $^{241}\text{Am}$ is 432.2 years
- Alpha particles are emitted to create current flow
- Emitter and collector electrodes measure changes
- Smoke particles absorb alpha particles and reduce current flow to create an alarm

Application Notes

- Detects fire in the incipient stage – small invisible smoke particles
- Detects particles < 3 microns in size
- More unstable at higher airflows
- Requires proper safe disposal procedures
Spot Smoke Detection – Photoelectric

**Principle of Detection – Light Extinction**

- Infrared LED light source – constant signal
- Smoke entering the chamber absorbs and scatters light – signal is reduced
- Suitable for all fires producing visible smoke
- Poor maintenance produces false alarms

**Principle of Detection – Light Scattering**

- Infrared LED light source – blocked by labyrinth
- Smoke entering the chamber and scatters light, hits the receiver and produces a signal
- Forward scatter detectors suitable for suitable for smouldering fires with light smoke
- Backward scatter detectors can be better balanced and made suitable for light or dark smoke

- Poor maintenance produces false alarms or … puts detectors to “Sleep”
Multi-sensor (Element) Detector

- 2 or more sensors in a single package (independent)
- Not true Multicriteria
  - Most commonly optical smoke sensor with a heat detector
  - Smoke sensors (Scattered light, extinction, laser, ionization)
  - Heat sensors (fixed, rate of rise, rate compensated)
  - Gas sensors (CO, CO2)
- Optimize performance of each sensor
Fire Detection Fuzzy Logic

Is this a real fire or a false phenomenon? How do you tell the difference? - When does a boy become a man?
True Multi-Criteria Fire Detection

Consider

What we know about fire
- Products of combustion?

The environment
- POC normally present?
- What will be burning (fuel)?

The signals
- The change in signals
- The rate of change in signals

The history of this situation
Fire Detection Fuzzy Logic

Is this a real fire or a false phenomenon

How do you tell the difference? - When does a boy become a man?
Beam Smoke Detection - Principle

- The emitter sends out a focused light beam. When there is no smoke, this light beam reaches the receiver in its unattenuated intensity. However, if there is smoke between the emitter and the receiver, the light is partly absorbed when impinging the smoke particles and partly scattered by them, meaning that it changes direction. Only a part of the emitted light can reach the receiver. The signal reduction indicates the average smoke density over the measuring section.

- As the linear smoke detector reacts on absorption and scattering, it is suited for light and dark, large and small aerosols. It is characterized by its uniform response behavior and is suited for the early detection of all fires generating visible smoke.

- Systems accommodating the emitter and receiver in the same housing use a remote reflector and have the advantage that they need to be connected to the detector line at one point only, and that maintenance is easier.
Open-area Smoke Imaging Detection  “OSID”

Benefits of OSID
- Fast installation because only the imager is wired
- High tolerance of vibrations and structural movement
- High resistance to reflected sun light
- High resistance to false alarms
- High resistance to intruding objects, banners
- 3-D coverage
Duct Smoke Detector – Typical Application

**Detector Locations**

- Downstream of the air filters and ahead of any branch connections in the air supply systems having a capacity greater than 2000 ft³/min.

- At each story prior to the connection to a common return and prior to any recirculation or fresh air inlet connection in the air return systems having a capacity greater than 15,000 ft³/min and serving more than one story.

**Example Detector Installation**

Note: The sum of the cross sectional area of inlet holes MUST equal cross sectional area of inlet tube!
Aspirating smoke detectors are also known as air sampling smoke detection system or aspiration smoke detection (ASD). In the air sampling smoke detection system, air samples from the monitored area are guided to the detection chamber via a pipe network by means of a powerful suction system. The photoelectric detection principle using a laser providing much less reflected light under normal circumstances which increases sensitivity while maintaining stability.
Air sampling piping network provides inlets which are spaced as smoke detectors.

There is no reduction needed for high air flow as with spot smoke detectors.
Linear Heat Detection

Detection Principle – Direct Shorting of Conductors at Specific Temperatures (350-500 degrees typical)

Manufacturer specific panels can provide approximate locations of wiring faults to provide point annunciation of the location of alarm.

Wiring Construction

- Steel Conductors are used in a twisted pair to form the Inner Core
- Conductors are wrapped in a heat sensitive polymer to insulate them from each other and prevent shorting
- Protective Tape is then used to protect the conductors from physical damage
- Outer jacket is then applied to protect cable from environmental conditions specific to the installation
This system is based on a laser beam being sent through a fiber-optic cable. As the fiber-optic cable reflects a small part of the laser radiation at any point, the backscatter can be measured by a receiver connected at the same end as the laser source.

The fiber-optic cable is a doted quartz glass, i.e. a form of silicon oxide (SiO\textsubscript{2}). The infrared electromagnetic laser radiation emitted is reflected in different ways by the fiber-optic cable:
- Rayleigh scattering – same frequency
- Raman scattering – Stokes + frequency
- Raman scattering – Antistokes - frequency

The **temperature** of the fiber-optic cable thus results from the intensity **ratio between Stokes and Antistokes scattering**.
By means of runtime measurements, it is possible to measure the associated Raman scattering for each cable spot.
Flame Detector

Principle of Detection – Changes in Radiant Energy

- Detects IR, UV and Flicker Rate of 0.5-15Hz to verify flame
- Calibrated for a 1 sq. ft gasoline pan fire (60, 30, 15 ft selectable)
- Wired and supervised as a 4-wire initiating device (24vdc required)

Safe for Class I. Div 1 Hazardous areas

Line of Sight
The selection of the **optimum fire detector** is based on the expected fire phenomena, generated by the incipient fire. For an office building, smoke detectors will preferably be selected, as in this case fires will produce clearly visible smoke both in the incipient phase and later. In a storage area where combustible liquids are stored, flame detectors and / or heat detectors would be the right choice.

To be able to reliably detect all expected incipient fires, it may be necessary to combine different fire detector types.
Construction Challenges
Construction Challenges

Considerations in product and technology selection

- Accessibility for Maintenance
- Atriums
- Extreme Environments (Temperature, Humidity, Dust, Corrosive)
- Data Centers (High Airflow, Early Warning, Limited Access)
- Hazardous Environments (Class 1 Division 1) Explosion Proof
Future Technologies
RED & BLUE light scattering ASD technology

Distinguishes between large particles that are typical dirt and the small smoke particles typical in incipient fires better than red infrared based technology alone.

Discriminates between Smoke & Dust /Steam
Future Technologies – Wireless Detection

Principle – Radio Frequency Transmission

- Utilizing mesh technology wireless smoke detectors can become integrated into a network whereby the more detectors exist the stronger the network becomes. By acting as a transmitter and a repeater, more detectors create a more robust network that is more resilient than single detectors alone.

- The detection technology remains unchanged and can therefore utilize photoelectric or ionization detection within the same unit.

- This technology is approved for use in the European market today and will be accepted by both the NFPA and UL/ULC in the future.
Future Technologies – Video Smoke Detection

**Principle**
The system concept is to utilize advanced video analytics to identify smoke or flame utilizing either existing CCTV cameras or specialized devices.

The video signals are run through a software program that processes the change in pixels to determine alarm status.

This technology is recognized by NFPA 72 as an alternative provided the specific devices are listed for the purpose.

No ULC standards for this yet.
Gas Sensors come into their own

The original smoke detector was a failed gas detector

1970’s Cerberus developed a CO sensor, did not catch on in the market

2003 studies by industry researchers explored the use of gas sensors (CO and CO$_2$) in the fire detectors. Initial feasibility studies indicated a substantial reduction in nuisance alarms were possible while maintaining a good response time to fires as compared to smoke detection

Today several manufactures including System Sensor, Bosch, Siemens and Simplex have commercially available multi criteria smoke detectors where one of the sensors is a CO gas sensor

Including an array of gas sensors within a smoke detector begins to approximate an “artificial nose”.

We are just seeing the beginning of the “gases”…
The Future –
To go where Smoke Detection has not gone before

Likely path

Further development to improve the intelligence of smoke detectors, primarily to discriminate between fire and nuisance sources, but also perhaps to discriminate between fire sources.

Intelligence can also bring information from an array of smoke detectors to feed a panel to chart the recent course of the fire and direct people to exits away from the fire or heavy concentrations of smoke … maybe this could be called “Intelligent Response” to an emergency situation.
The Future –
To go were Smoke Detection has not gone before

Going further into the future

Having a recent history of fire conditions within a space may enable future conditions to be predicted through the use of a reverse algorithm. This would involve using the detector measurements to infer the characteristics of a fire source, e.g. heat release rate, location, fuel etc. These characteristics can then be used as input to enable the use of a computer fire model to predict the future course of the fire.

Audio Analytics?
Application Solutions
Application Solutions

- Spot Smoke Detection
- Duct Smoke Detection
- Aspirating Smoke Detection
  - High Airflow Data Rooms
  - High Humidity and Condensation
  - Amusement Park Rides (limited access)
  - Atriums
- Spot Heat Detection – Rate of Rise w/ Fixed Temp
- Linear Heat Detection – Thermal / Optical Fibre
  - Long runs
  - Limited access
  - Extreme environments
  - Multiple applications
- Flame Detection – IR & UV with Flicker verification
- Beam Detection – Open-area Imaging Smoke Detection
Challenging Environments for Fire Detection

Finding the right solution may require multiple technologies

Select a vendor who can apply the best solution to meet the challenge
The Saving of Lives
The Saving of Lives

Since 1970 Smoke Detection has contributed to saving an estimated 90,000 lives

Early 1900’s 15,000 people per year die in FIRES

1960’s 8,500 people per year die in FIRES

2010 3,300 people per year die in FIRES
Thank you

bill.lane@siemens.com

don.boynowowski@siemens.com