Early Fire Detection and Automatic Extinguishing in Waste-to-Energy Power Plants and Waste Treatment Plants

Albert Orglmeister

1. Fire protection challenges – current status quo .................................................................261
1.1. Why are there so many major fire incidents despite existing fire protection measures? ........................................................................................................261
1.2. What are the main causes of these major fires? ..........................................................263
1.3. Industry applications – or: Which fire detection options are available for waste-to-energy plants and recycling companies? ........................................264

2. Infrared detection and thermal imaging technology with automatic extinguishing .................................................................................................266
2.1. Short introduction to thermal imaging ........................................................................266
2.2. Past problems ...............................................................................................................268
2.3. State-of-the-art technology ..........................................................................................268
2.4. Infrared early fire detection .......................................................................................269
2.5. Automatic extinguishing ............................................................................................270
2.6. Application examples ..................................................................................................271
2.7. Summary and outlook ................................................................................................273

1. Fire protection challenges – current status quo

1.1. Why are there so many major fire incidents despite existing fire protection measures?

In the UK, for example, according to a recent Resource Magazine online article, the waste industry has an average of one fire a day.

The UK Government revealed that in the years 2001 to 2012 the average rate of fires at waste and recycling works came in at ‘just under’ one per day (335 fires per year).

Naturally, these statistics vary from country to country, and as can be seen from the International Technical Committee for the Prevention and Extinction of Fire CTIF table below as a sample, some other countries face even more fire incidents in the waste sector.
Table 1: Fire statistics by types

<table>
<thead>
<tr>
<th>No.</th>
<th>Country</th>
<th>Structure fires</th>
<th>%</th>
<th>Vehicles</th>
<th>%</th>
<th>Forests</th>
<th>%</th>
<th>Grass, brush</th>
<th>%</th>
<th>Rubbish</th>
<th>%</th>
<th>Other</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Austria</td>
<td>19123</td>
<td>77.7</td>
<td>1584</td>
<td>6.4</td>
<td>883</td>
<td>3.6</td>
<td>2744</td>
<td>11.1</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>288</td>
</tr>
<tr>
<td>2</td>
<td>Belarus</td>
<td>5318</td>
<td>72.5</td>
<td>458</td>
<td>6.2</td>
<td>1218</td>
<td>16.6</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>345</td>
</tr>
<tr>
<td>3</td>
<td>Bulgaria</td>
<td>3737</td>
<td>12.3</td>
<td>2262</td>
<td>7.5</td>
<td>156</td>
<td>0.5</td>
<td>10365</td>
<td>34.2</td>
<td>6348</td>
<td>21.0</td>
<td>7411</td>
<td>24.5</td>
</tr>
<tr>
<td>4</td>
<td>Croatia</td>
<td>3430</td>
<td>28.2</td>
<td>716</td>
<td>5.9</td>
<td>304</td>
<td>2.5</td>
<td>4203</td>
<td>34.6</td>
<td>2279</td>
<td>18.7</td>
<td>1224</td>
<td>10.1</td>
</tr>
<tr>
<td>5</td>
<td>Czech Republic</td>
<td>4405</td>
<td>21.9</td>
<td>2101</td>
<td>10.4</td>
<td>1748</td>
<td>8.7</td>
<td>1092</td>
<td>5.4</td>
<td>5266</td>
<td>26.1</td>
<td>5540</td>
<td>27.5</td>
</tr>
<tr>
<td>6</td>
<td>Estonia</td>
<td>1658</td>
<td>29.8</td>
<td>374</td>
<td>6.7</td>
<td>102</td>
<td>1.8</td>
<td>1450</td>
<td>26.1</td>
<td>1722</td>
<td>30.9</td>
<td>258</td>
<td>4.6</td>
</tr>
<tr>
<td>7</td>
<td>Finland</td>
<td>5209</td>
<td>46.4</td>
<td>2200</td>
<td>19.6</td>
<td>746</td>
<td>6.6</td>
<td>704</td>
<td>6.3</td>
<td>730</td>
<td>6.5</td>
<td>1631</td>
<td>14.5</td>
</tr>
<tr>
<td>8</td>
<td>Hungary</td>
<td>8789</td>
<td>41.7</td>
<td>726</td>
<td>3.4</td>
<td>5317</td>
<td>25.3</td>
<td>–</td>
<td>–</td>
<td>1168</td>
<td>5.5</td>
<td>5056</td>
<td>24.0</td>
</tr>
<tr>
<td>9</td>
<td>Latvia</td>
<td>903</td>
<td>8.2</td>
<td>561</td>
<td>5.1</td>
<td>693</td>
<td>6.3</td>
<td>3556</td>
<td>32.3</td>
<td>1473</td>
<td>13.4</td>
<td>3818</td>
<td>34.7</td>
</tr>
<tr>
<td>10</td>
<td>Liechtenstein</td>
<td>17</td>
<td>40.5</td>
<td>2</td>
<td>4.8</td>
<td>0</td>
<td>0.0</td>
<td>6</td>
<td>14.3</td>
<td>6</td>
<td>14.3</td>
<td>11</td>
<td>26.2</td>
</tr>
<tr>
<td>11</td>
<td>Lithuania</td>
<td>676</td>
<td>5.6</td>
<td>1088</td>
<td>9.1</td>
<td>318</td>
<td>2.6</td>
<td>3388</td>
<td>28.2</td>
<td>2614</td>
<td>21.8</td>
<td>3934</td>
<td>32.7</td>
</tr>
<tr>
<td>12</td>
<td>Moldova</td>
<td>1383</td>
<td>76.2</td>
<td>242</td>
<td>13.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>13</td>
<td>New Zealand</td>
<td>5413</td>
<td>35.3</td>
<td>4815</td>
<td>31.4</td>
<td>–</td>
<td>–</td>
<td>5102</td>
<td>33.3</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>14</td>
<td>Poland</td>
<td>29963</td>
<td>16.2</td>
<td>8463</td>
<td>4.6</td>
<td>11367</td>
<td>6.2</td>
<td>34900</td>
<td>18.9</td>
<td>24203</td>
<td>13.1</td>
<td>75921</td>
<td>41.1</td>
</tr>
<tr>
<td>15</td>
<td>Romania</td>
<td>2402</td>
<td>10.8</td>
<td>1744</td>
<td>7.8</td>
<td>489</td>
<td>2.2</td>
<td>6930</td>
<td>31.0</td>
<td>2554</td>
<td>11.4</td>
<td>8207</td>
<td>36.8</td>
</tr>
<tr>
<td>16</td>
<td>Russia</td>
<td>118445</td>
<td>76.8</td>
<td>20817</td>
<td>13.5</td>
<td>12337</td>
<td>8.0</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>2540</td>
</tr>
<tr>
<td>17</td>
<td>Singapore</td>
<td>3403</td>
<td>73.9</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>1201</td>
<td>26.1</td>
</tr>
<tr>
<td>18</td>
<td>Slovenia</td>
<td>3647</td>
<td>52.2</td>
<td>720</td>
<td>10.3</td>
<td>489</td>
<td>7.0</td>
<td>764</td>
<td>10.9</td>
<td>531</td>
<td>7.6</td>
<td>832</td>
<td>11.9</td>
</tr>
<tr>
<td>19</td>
<td>Sweden</td>
<td>9497</td>
<td>41.7</td>
<td>4526</td>
<td>23.5</td>
<td>1243</td>
<td>–</td>
<td>1502</td>
<td>7.8</td>
<td>2305</td>
<td>–</td>
<td>3712</td>
<td>19.3</td>
</tr>
<tr>
<td>20</td>
<td>Ukraine</td>
<td>34235</td>
<td>41.1</td>
<td>3702</td>
<td>4.4</td>
<td>3813</td>
<td>4.6</td>
<td>39444</td>
<td>47.3</td>
<td>–</td>
<td>–</td>
<td>2204</td>
<td>2.6</td>
</tr>
<tr>
<td>21</td>
<td>USA</td>
<td>501500</td>
<td>37.3</td>
<td>204500</td>
<td>15.2</td>
<td>–</td>
<td>–</td>
<td>297000</td>
<td>22.1</td>
<td>163000</td>
<td>12.1</td>
<td>179500</td>
<td>13.3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>763153</td>
<td>38.2</td>
<td>261601</td>
<td>13.1</td>
<td>41223</td>
<td>2.1</td>
<td>413150</td>
<td>20.7</td>
<td>214199</td>
<td>10.7</td>
<td>303824</td>
<td>15.2</td>
</tr>
</tbody>
</table>

Source: CTIF Report 2017
These scenes are familiar to most operators in the industry.

Figure 1:
Fire in a paper warehouse

Figure 2:
Fire at a facility for processing and storing recycling material

1.2. What are the main causes of these major fires?

- There is no fire detection system.
- As a result of the technology and installation applied for most fire detection systems they primarily function as flame, smoke or heat detectors. Most importantly, the relevant indicator needs to reach the detector. An alarm is given once a fire has already had time to develop and spread. As this is no real early fire detection, fires often have time to grow.
- This is also the case for sprinklers. Even though they always respond by actively fighting the fire, they are often not powerful enough to extinguish fires with substantial fire loads.
- Early detection is the only way to ensure that small fire sources can be extinguished using limited quantities of extinguishing agents in the initial fire development phase.
• Detectors that respond slowly to fires are not the recommended choice when relying on autonomous, automatic extinguishing systems, either. In such cases, the delay before the fire brigade is notified and arrives on site is far too long. A lot of the damage to the facility has been done by then. Moreover, any large-scale fire-fighting operation is costly in many ways – time, money, public image, energy – and, last but not least, puts firemen at risk.

Conclusion: In order to stop fire from developing at an early stage, a detection system must be able to detect as soon as possible.

1.3. Industry applications – or: Which fire detection options are available for waste-to-energy plants and recycling companies?

The following fire detection systems are predominantly used at present:

Smoke detectors or smoke aspiration systems

These are mainly installed in the ceiling area to monitor waste treatment halls, and are therefore situated very high up. These halls are often open to the sides, which often causes the wind to blow the smoke away from the detectors. In addition, in the summer the hot air accumulates under the roof, and keeps the smoke from reaching the ceiling. It is also not possible for these smoke detectors to clearly distinguish between smoke from a fire and the smoky exhaust gases produced by poorly configured engines on wheel loaders and trucks. As a result, a large amount of smoke needs to rise to the ceiling of the hall before the fire detection system triggers. This creates a delay before firefighting can begin, wasting valuable time. Moreover, in a dusty and moist environment, these detectors are difficult to maintain and clean.

Laser smoke detection

There is a delay in detection when using these systems for the same reasons as smoke detectors and smoke aspiration systems. In addition, they have limited or no ability
to distinguish between dust and smoke, frequently causing false alarms. They are therefore not well suited to fire monitoring of recycling material and processes that generate a large amount of dust.

**Video smoke detection**

These systems only work properly if they are combined with another kind of detection to avoid false alarms triggered by steam and fog – and they also require ideal lighting conditions and only work in an area with low levels of dust.

**Linear heat detectors**

Linear heat detectors are sensor cable detectors, often known as *thermocouples*, and are mainly used to monitor tunnels or garages. These devices detect increases in temperature via changes in resistance. Modern linear fire detectors use fibre-optic cables and use the Raman effect to measure the temperature (fibre-optic temperature measurement). The benefits of these systems are their long range (several kilometres with an evaluating unit) and high degree of flexibility and that they prevent false alarms and are not affected by interference caused by electrical fields. In large halls in waste treatment plants, where linear heat detectors are to be installed on the ceiling, they will only pick up on the temperature change once a sufficient amount of heat builds up at ceiling height. Here again, the fire will already be substantial and large to alert them. Therefore, this technology is less suitable for recycling facilities.

**Sprinklers**

These are triggered when heat causes a liquid to expand in a small glass bulb, which causes the glass tube to burst, releasing extinguishing water. The advantage of this system is that it triggers reliably. However, the disadvantage is that it requires a temperature of at least 70 °C to cause the glass bulb to burst. When installed on the ceiling in waste treatment halls, each sprinkler head normally protects an area of several square meters. Here, too, the heat must reach the detector in order to trigger the extinguishing process. As a result, the fire must already have developed substantially. In open or partly open halls there is also the risk of wind dispersing the heat, delaying detection. Depending on the fire load of the material being stored, the sprinklers may be triggered too late to successfully extinguish the fire.

One common denominator of all of these detection systems is the fact that they require heavy smoke or a large fire in order to trigger the alarm. Some of these systems are prone to false alarms caused by dust or steam. These detectors will only detect fires in waste treatment halls or waste bunkers with high ceilings at a rather late stage.

Figure 4 shows the time delay for detecting a large fire for the detection systems listed above.
2. Infrared detection and thermal imaging technology with automatic extinguishing

2.1. Short introduction to thermal imaging

Unlike the fire detection systems that have been listed so far, all of which react to smoke or fire, depending on the system type, fire monitoring with infrared (thermal) systems is not fire detection, but temperature monitoring instead.

An infrared detection system sees heat almost immediately.

An infrared early fire-detection system is primarily used to monitor waste processing halls full of stored recycling material. It measures the surface temperature of the recycling material without contact.

Should unusual surface temperatures of around 80 °C be detected it and usually indicates the preliminary stage of a fire. Such detection is effected within one tenth of a second.

Fire monitoring of an object with an infrared early fire-detection system therefore means a fire is identified in its formation phase.
Deep seated fires

Even pockets of fire deep within a stack of recycling material can be detected.

This is what happens: fire requires oxygen. Once a fire breaks out in a heap of recycling material it can only grow and spread as a result of further kindling. Convection guides air away to the surface through gaps in the pile once the oxygen has been consumed, enabling fresh air with more oxygen to flow in. This heat transfer brings the heat of an underlying fire to the surface. When the infrared detector registers a rapid rise in temperature or if a temperature threshold unusual for the stored material (like 80 °C) is reached, a fire alarm is triggered.

Moreover, the infrared technology allows us to see through smoke. This is very beneficial for crane operators in waste bunkers to eliminate fires or hotspots directly into the incineration.

Also, the fire brigade can use the thermal images for orientation and the coordination of their operation. Usually, the smoke would obstruct the operation. Based on the thermal image the hot zones can easily be identified and the core of the fire can be attacked strategically.
2.2. Past problems

Infrared early fire detection has been available for many years, but it was often problematic to operate.

Challenges of previous systems:

- They were not suitable for continuous operation.
- There were many mechanical faults. Pan-/tiltheadswerenotlaidoutfor24/7 operation.
- The only cameras available were those that required cooling, and the Stirling coolers for these cameras needed to be replaced after 600 operating hours.
- There were problems with moving cables.
- The computer capacity required for evaluation and managing disturbances did not exist.

2.3. State-of-the-art technology

Modern infrared early fire detection systems, however, are reliable and can operate continuously without faults.

For cost effectiveness, and to achieve a high local resolution, scanning systems are used in place of large numbers of individual camera systems. Today, monitoring areas can be displayed in a hemispherical fashion, providing 360° vision.

Operational reliability over many years is now ensured via encapsulated and air-cooled housing.

Systems with high-precision pan and tilt drives designed for continuous operation (ten years or more) are available. These systems provide an unbroken infrared panoramic image, which enables complex objects to be evaluated in great detail.

Figure 6: PYROsmart by Orglmeister Infrarot-Systeme GmbH & Co. KG

Figure 7: Detection of a disturbance (exhaust). The temperature threshold for early fire detection is 85 °C. The exhaust (at 114 °C here) does not trigger an alarm
Some systems also provide panoramic video images alongside infrared images. Integated cleaning systems ensure continuous cleaning of the lens in moist and dusty environments. Modern systems in recycling plants typically trigger fire alarms at approximately 85 °C.

Disturbances such as hot exhausts of delivery vehicles and wheel loaders, hot engines, lighting, etc., are recognised as such by intelligent infrared fire detection systems. This feature prevents false alarms, and is therefore crucial for the smooth operation of the recycling facility. A simple thermal camera is not able to distinguish between friend or foe.

2.4. Infrared early fire detection

An intelligent infrared detection system creates unbroken high-resolution video and panoramic thermal images, uses these panoramic images to identify hotspots, and calculates 3D target coordinates to control extinguishing systems.

**Benefits of panoramic thermal imaging**

- Extremely high-resolution thermal images. This makes it possible to detect the smallest temperature changes.
- Immediate overview of hot spots and orientation with the monitored area.
- Much better elimination of disturbances thanks to unbroken image analysis of all adjoining areas.

Infrared detection systems usually provide a user interface.
This is typically a terminal contained in a control room, crane cabin or held by the plant fire brigade.

Any hotspots are displayed on the terminal. The user interface for the infrared fire detection system (Figure 9) shows that a hotspot has been detected in a deep level of a heap of recycling material in Hall 2. The maximum temperature (180 °C) is displayed as well. The alarm is also signalled by an audio alert.

At the same time, the potential fire is reported to the central fire alarm system, which immediately notifies the fire brigade. If the fire detection system is connected to an optional extinguishing system, the automatic extinguishing process begins immediately.

![Figure 9: Example of a user interface of an infrared fire detection system](image)

2.5. Automatic extinguishing

Infrared systems can precisely control the extinguishing of fires before or as they break out by attacking the hotspot.

The overall goal is an early detection and prevention of major fires with limited use of extinguishing medium.

Depending on the qualities of the stored material, a specific extinguishing procedure is chosen, one of which is described here.

Once the hotspot is detected the infrared system activates the water cannon, and initiates the first extinguishing cycle lasting one minute. The infrared system then immediately checks on the hotspot again to check on temperature changes. If there is a further increase in temperature, it is assumed that the hotspot/fire has not yet been completely cooled down/extinguished. In such cases, the second extinguishing cycle begins automatically. This process continues until the detected temperatures fall below the alarm threshold.
2.6. Application examples

Waste bunkers in waste-to-energy plants

Benefits of this extinguishing procedure:

- damage caused by large quantities of regular extinguishing agent by standard procedure is prevented,
- reduced environmental impact and cost,
- interruptions in operation due to damage caused by the extinguishing process are avoided, as only a comparatively small area is affected.
Storage and processing: tyres, waste, coal, wood, etc.

Figure 14: Panoramic video image showing outdoor storage of tyres at HeidelbergCement

Figure 15: Panoramic infrared image showing outdoor storage of tyres at HeidelbergCement

Figure 16: Combined detection and extinguishing (IR system and water cannon) outdoor application at a recycling facility

Figure 17: A ceiling-mounted IR system in a waste input hall

Figure 18: Panoramic infrared image created by an early fire-detection system in the input hall of a recycling plant showing storage areas with higher temperatures – weekend operation

Figure 13:
Thermal panoramic image of waste bunker surface at AVA Velsen GmbH
2.7. Summary and outlook

The earlier a fire source can be detected and extinguished, the better. It is not difficult to agree on that.

Any new technology, however, needs time to prove it can replace the old solutions reliably, offering progress and improvement. It must withstand the opposition and rejection of established methods and procedures. This is and has been the case for the application of thermal imaging and automatic extinguishing in the field of fire protection, too. By now, a multitude of successfully implemented projects and satisfied users show that what once was regarded as suspiciously innovative is becoming an industry standard.

Since 2015, this is especially reflected by the fact that the VdS’s (VdS Schadenverhütung GmbH, known as Verein der Sachversicherer – German Insurance Association) guideline 3189 on infrared camera units used for monitoring temperatures for fire protection purposes has been available and applied.

The new standard offers improved and approved fire protection along with more peace of mind for the waste industry.
Figure 7: Rough scheme dry hydration

CaO
Dosing balance
H₂O
Dry hydrator
CaO
Silo
Ca(OH)₂
Silo
towards lime dosing
TIC

Several plants in Germany have been provided with this technology. Figure 8 shows a plant, realised with a dry hydrator for a Ca(OH)₂ production capacity of approximately 3 t/h.

Figure 8: RDF incineration plant EEW Premnitz / Germany

As alternative there is the possibility to install the dry hydrator close to the additive 2 can now be injected directly into the reactor without temporary storage in a silo. Figure 9 shows such a dry hydrator as well as the corresponding WtE plant.