Planning of Efficient Plant-technical Fire Protection - Examples of System Solutions from a Detection Point of View

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**Abstract**

The planning and realization of detection systems for industrial applications represents a challenge for all involved. Notably all parties involved must be aware that a detection system can only be efficient if it optimally helps to prevent or limit damage.

At first these objectives must be clearly described. The risks need to be identified and split into separate branches addressing preventive and mitigation tasks. The detection solution must be able to fulfil these tasks and be technically and economically feasible. Detectors which can be adjusted regarding conditions of the task by optimizable parameterization should be favoured. Suitable detectors for monitoring the facility are ideally based on the source of danger, in many cases over temperature. Detection may be performed directly via thermocouples or infrared detectors (e.g. "HOTSPOT"), or indirectly via smoke detectors or fire gas detectors (e.g. "GSME").

The detection must be followed by an adequate action - from switching off the engine, information to the operating personnel up to (in the last step of intervention) triggering extinguishing systems or a fire fighting attack of the fire department. A suitable method for description and visualization for risk protection is a “bowtie” diagram. Separated into different escalation levels the detection system can or should provide separate information to different recipients with adapted instructions.

The earlier a controlling intervention takes place, the more likely damage is avoided or limited. Examples from industrial practice show identified risks, focus on detection methods and name methods of intervention. Considered are: belt conveyors, shredders and silos in coal, steel or recycling industry.
Introduction

Efficiency:
"Measures are effective and economical"

Plant-technical:
“Technical measures for prevention or mitigation of damages”

Fire protection:
“Preventive measures that allow extinguishing and rescue”

This simplified use of fire protection terminology has to be connected to a target:

Damage has to be avoided or at least minimized. The source of damage may be a fire that affects the plant or a defect in the plant that causes a fire. “Damage” also includes production downtime due to fire or also due to fire protection measures.

For the technical realisation a proper detection system shall initiate optimal measures. The system and the measures strongly depend on the kind of plant.

Risk identification and assessment

To initiate effective fire protection measures, the planners have to be aware of the real risks.

\[ \text{Risk} = \text{Probability} \times \text{Severity} \]

Nevertheless a “risk” first has to be assigned to each individual part of the production facilities.

After categorizing the severity to “catastrophic - significant - minor – insignificant” and the probability to “regularly - frequently - occasionally – rarely” each facility part is assigned in a matrix.

Risk engineers e. g. of insurance companies then demand technical measures to lower the risk: lowering probability by early detection and/or lowering severity by subsequent extinguishing.

After identification of the risks for each facility part, effective technical measures have to be evaluated and described. It is helpful to create an overview with all relevant failure or fire causes and all important consequences. With the help of a "bow tie diagram" [1] (see Fig. 1), it can be investigated how the failure of individual components affects
if protective measures take effect before or after the failure ("blocking elements" are indicated as text boxes).

For clarification, such a bow tie diagram is shown here for the example of a shredder. The failures until the damage "shredder fire" are investigated and the possible effects indicated. Detection measures are highlighted in green letters.

![Bow tie diagram example focusing on shredder protection.](image)

Fig. 1. Bow tie diagram example focusing on shredder protection.

A key method to mitigate the extent of losses bases on proper detection in combination with subsequent actions (alarm organisation).

**Detection**

Detection is the automatic or manual recognition of an “unusual” condition. Different sensors are available for every aspect of the monitoring (“detection purpose”). The following table lists typical detection purposes, sorted by "escalation level" of the damage.
Table 1. Plant technical detection purposes, assorted to ascending severity.

<table>
<thead>
<tr>
<th>Escalation level</th>
<th>Detection purpose</th>
<th>Measurement variable</th>
<th>Industrial application example</th>
</tr>
</thead>
<tbody>
<tr>
<td>short term overload</td>
<td>plant failure</td>
<td>(over-)current, force limit</td>
<td>drive motor</td>
</tr>
<tr>
<td>mechanical damage</td>
<td>mechanical failure</td>
<td>sound / impact sound</td>
<td>Gears, bearings at generators, wind turbines, conveyors ...</td>
</tr>
<tr>
<td>thermal damage</td>
<td>overheating</td>
<td>object temperature</td>
<td>drive motor, crushing cylinder ...</td>
</tr>
<tr>
<td>„thermal runaway“</td>
<td>critical temperature</td>
<td>object temperature</td>
<td>self-igniting bulk material (in silos, lorries; coal, biomass)</td>
</tr>
<tr>
<td>initial fire</td>
<td>smoldering fire smoke, aerosol</td>
<td>obscuration / scattering of light</td>
<td>electric cabinet, control units, cable trays</td>
</tr>
<tr>
<td>initial fire, self-heating</td>
<td>smoldering fire fire gas</td>
<td>gas concentrations and ratios</td>
<td>Bulk storage and conveying – coal, biomass, ignitable powders</td>
</tr>
<tr>
<td>fire</td>
<td>flaming fire</td>
<td>UV or IR radiation</td>
<td>Fuel storage, pipelines</td>
</tr>
</tbody>
</table>

For each detection purposes different detectors are available. Whether these detectors are suitable and can be used efficiently for the application requirement must be described or determined when creating a detection concept.

In fire protection terminology, this concept is called the “fire alarm system concept”:

**Fire alarm system concept**

This term “fire alarm system concept” is in Germany introduced in DIN 14675, which describes the standard, how to do planning and how to install a fire alarm system. Chapter 5 in DIN 14675 deals with: “Erstellung des Brandmelde- und Alarmierungskonzeptes” (preparation of the fire detection and alarm concept).

However, this standard does not give a detailed procedure. Therefore a sketch is provided in the next subchapters.
First step of concept – description of detectors

**Detection Task:** The operator should name and explain scenarios to be prevented and therefore to be detected.

*Example for a shredder:*

“Overheating must not ignite the flammable material”

**Technical description:** The planner has to translate into technical specification:

“Temperature must not exceed 80°C”

**Efficiency:** The planner has to compromise on technical and economic issues: Which amount of detectors covers the requirements?

**Proposal for realisation:** In many cases it is not possible to monitor the point of fire origin. Thus the subsequent step of material processing should be monitored, but less reliable.

“Discharged chopped material must not exceed 80°C”

**Redundancy:** With low reliability, add separate detection methods.

“If shredder operation stops, use smoke- or gas-detection”

**Technical details:** The planner has to decide on detector -accuracies, -thresholds and –speed and to assign to the detector positions.

“An infrared detector array is installed 1 m above the discharge belt, trigger limit 80°C, response time 0.1 s, the message is sent to the plant control unit and the staff”

The planner must have knowledge on the plant and technical details of the production line – especially due to:

**Flow control:** The detection system should intervene in the production process

“If overheated material is discharged, stop the shredder”

**Unpredictable:** Experience of the operators has to be regarded, staff knows best on trouble sources – the detection system should not cause production downtime due to improper configuration.

“During summer the temperature exceeds 80°C anyway…”

All information has to be collected for contribution to engineering of an optimal detection system.

Second step of concept – description of alarm organisation

Detection only makes sense, if an action is triggered, either information to personnel or automatic stop of machines, stop of ventilation, extinguishing, etc. Anyway the possible additional damage due to the action has to be assessed. Efficient actions to be considered are: stop of
the machine, inform the personnel, cooling by means of water and, if
without success, finally call the fire brigade.

**Third step of concept – description of acceptance test**

At handover, a system test has to be performed. To avoid differences of
opinion, a description of the acceptance test has to be part of the
contract, and should cover:

- Formal check: documentation, inspection on site
- Functional test by use of testing tools
- Functional test by use of an effectiveness test, e. g. “real fire test” or
  “simulation of overheating”. This test should be related to the
detection task, described in first step.

**Application Examples**

Besides the standard guideline VdS2095 [2] that covers planning of fire
detection systems in standard buildings, there are many applications
where engineered solutions are necessary. Some examples are given in
the following section.

In the examples the detector types “GSME” representing Fire gas
detectors and “HOTSPOT” representing IR Temperature detectors are
used, as the terms are used in the VdS application recommendations for
power plants and chemical industry [3], [4].

**Monitoring of a shredder in a recycling plant**

During recent years the amount of fires in recycling plants increased
rapidly due to impermissible disposal of Li-ion batteries. Even small
batteries in electronic household devices cause fires inside the stored
piles after thermal runaway if damaged in a shredder. Therefore
monitoring of shredders is an important part of fire protection. But just
installing smoke detection is not efficient, because once if smoke is
released to a certain amount to reach detectors, the fire already spreads
and hardly is to be extinguished.

More effective preventive detection methods have to be considered to
avoid fires (see Table 2 and Fig. 2).

**Table 2. Separated detection tasks for protected shredder operation.**

<table>
<thead>
<tr>
<th>Detection task</th>
<th>HOTSPOT</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector positions in sketch</td>
<td>H1</td>
<td>H2</td>
</tr>
<tr>
<td>Overheating parts inside the shredder during operation and standstill (low filling level or empty)</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Overheating in the shredder during operation, indirect by temperature of transported material, hot batteries</td>
<td>✔️</td>
<td></td>
</tr>
<tr>
<td>Smoldering material at standstill (regard airflow!)</td>
<td>✔️</td>
<td>✔️</td>
</tr>
</tbody>
</table>
Alarm actions include in time order:

1) Stop of operation (immediately or after emptying).
2) Information to personnel, including procedure for manual removal of hot parts.
3) Extinguishing by water spray, maybe automatically triggered, maybe using foam additive.
4) Alarm to fire brigade, maybe delayed with personnel present and acknowledgement procedure.

**Monitoring of a silo (e. g. storage of wood chips)**

Protection of a silo is one of the most challenging tasks because of limited accessibility and restrictions to detection. Smoke detection is not applicable due to high dust load – anyway, detectors have to be protected against damages.

Detection has to be separated into certain tasks (see Table 3).

For detection of embers or smoldering material deep inside the pile the speed of spreading of gases or temperature has to be regarded. The time for H\textsubscript{2} gas to travel 1 m inside a pile is about 1 hour; for 5 m a time of 1 day is needed [5]. The delay for detection of temperature increase is comparable. Therefore a continuous monitoring of the intake or surface is recommended to enable a fast reaction.
### Table 3. Separated detection tasks for protected silo operation.

<table>
<thead>
<tr>
<th>Task</th>
<th>HOTSPOT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector position in sketch</td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Monitoring of material intake: embers</td>
<td>✓</td>
</tr>
<tr>
<td>Monitoring of the surface of the pile: over-temperature, self-ignition or embers</td>
<td>✓</td>
</tr>
<tr>
<td>Monitoring of material outtake, embers, over-temperature – only during operation</td>
<td>✓*</td>
</tr>
<tr>
<td>Detection of over-temperature of silo base – only with steel cone</td>
<td>✓*</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detector position in sketch</th>
<th>GSME</th>
<th>T-sensor</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>✓*</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>✓*</td>
<td></td>
</tr>
</tbody>
</table>

Detection of smoldering fires near surface, fire gases in silo headspace – consider breathing!

Detection of smoldering fires near bottom – during operation only

Detection of critical temperatures of silo goods, at selected positions only

* Restrictions to be considered

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![Fig. 3. Achievable positions for detectors inside and outside of a silo. Numbers refer to Table 3.](image-url)
Detection in a conveyor bridge

Conveyors contribute to critical infrastructure like power plants or steel works. Therefore early and sensitive detection helps to avoid production downtime – thus fire detection is closely related to predictive maintenance: Small smoldering situations as well as overheating of rollers or engines are likely during normal operation.

The planner has to be aware, which task is requested by the owner.

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Task</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>very high</strong>, detect even non fire situations</td>
<td>predictive maintenance</td>
<td>call operation personnel – prepare repair work</td>
</tr>
<tr>
<td><strong>low</strong>, only detect harmful fires</td>
<td>fire protection</td>
<td>call fire brigade, extinguish</td>
</tr>
</tbody>
</table>

A detection system that is able to provide at least two separate outputs based on different sensitivities is to be preferred.

Nevertheless, a lot of boundary conditions have to be regarded. Detectors should be located at low height, personnel should be trained to regard airflow when trying to locate the source of smoke or fire gas.

Fig. 4 gives an impression on the situation: Smoke does not exceed the height of the conveyor, thus detectors are installed at that height. Smoke moves up to 100 m along the running belt.

Fig. 4. Conveyor bridge of a coal fired power plant while performing a “real scale” smouldering fire test.
Due to air velocities of up to some m/s, dilution effects have to be considered. Certain areas have to be assigned to detectors which are not necessarily located in this area. The corresponding concept of “detection maps” is described in [6].

**Conclusion and outlook**

Planning of fire detection systems for industrial applications requires profound engineering work. From understanding the protection idea worded by the owner of the plant, preparing a technical description for the detection system (also regarding knowledge on the production process of the plant) up to quantitative specification of detector properties and describing final acceptance tests – the planner has to do a lot of complex work. This paper provides some aspects to be considered, also by means of examples. Hopefully the work of planners will be appreciated and adequately funded as it delivers the basis for an efficient and proper working protection system.

In many cases an efficient protection idea also covers the avoidance of production downtime and strongly is connected to concepts of damage prevention or even predictive maintenance.

**References**


[4] VdS 3824 - Brandschutz in chemischen Anlagen, VdS-Verlag, 201.8
