The Dairy Industry Problem

Fires and Explosions in the European dairy Industry are becoming an increasing problem: An analysis of 116 incidents in the milk powder processing industry showed that five of these incidents experienced an explosion, with another three explosion like effects without any damage that could be traced to pressure effects of an explosion. The remaining incidents were fires only, with damages ranging from medium to total loss of the drying unit.

More than 90 % of these incidents could be traced directly back to the self-heating processes within the drying installation. The five to eight explosions were found to have been a consequence of the fire not the other way around.

Another analysis looked at 240 incidents that occurred in spray driers in the Food industry from 1953 to 1993. 20 incidents were reported to have experienced an explosion while 210 were fires only. It was believed that fire was the initiator of the explosion.

The result of this statistical analysis defined the next steps of the new approach:

By studying the plant details, internal mechanical and/or outside introduction of ignition sources were ruled out. So the problem can be solved if an appropriate detection method can be found to detect heating before it turns into a fire.

In the Irish Dairy Industry, incidents from 1980–1987 revealed that 12 incidents were reported involving fires in spray drying plants, in five of these cases, explosions were reported.

In the UK Dairy Industry Incidents from 1972 to 1982, 7 explosions were reported in spray drying plants.

From this, the Dairy industry believed they needed a method to prevent the development of fires in their plant. If a fire does develop, they would need a range of explosion protection systems to mitigate its effect.
Prevention

In spray driers it was realised that they cannot remove the fuel (milk powder) and oxygen, but they could control the ignition sources. Operating experience shows, that the primary source of ignition for fires or dust explosions in drying installations for milk, or in secondary installations such as filters and dust precipitators, are smouldering spots or self-igniting milk products.

Up to the present time, early-warning fire detection in such facilities consisted of installed temperature measurement devices or sniffing lines, with which the smell of fires could be detected. The frequency of damaging events however shows that these devices are not sensitive enough to recognize small smouldering spots on time.

Early-Warning fire recognition through CO detection

An early recognition of smouldering fires at an initial stage is possible through inspection of the exhaust air from drying installations for the presence of carbon monoxide, a gas which is the product of the thermic decomposition of milk products. Due to high volumes of air, the CO would be diluted so the system had to be very sensitive. Also it had to use differential readings between the inlet (reference) air which can be excessively CO loaded from boilers, trucks, forklift etc. and the exhaust air (sample) which would add anything burning inside the drying process.

Infrared gas analysis

With NDIR, the non-dispersive infra-red absorber, a measuring principle is made available, which is suitable for detection of traces of carbon monoxide. NDIR CO gas analysers, with a measuring range of 0 to 10 ppm, have been tested in the area of emission control and under harsh conditions, and can be considered as reliable for this type of measuring task.

<table>
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<th>An early-warning fire detection system consists of the following main components:</th>
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<td>1. gas sampling probe</td>
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<td>2. sample gas preparation</td>
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<td>3. analyser</td>
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The use of an early-warning fire detection system, as the primary safety measure in spray drying systems in the milk industry, requires a high degree of reliability and availability. An unambiguous and quick recognition of smouldering fires must be guaranteed, while it must be avoided that a false alarm initiates the corresponding safety measures.

The locations at which gas samples are taken and the place of installation must be carefully selected, at the time of installation. The location for the gas sampling probe in the exhaust gas canal must be chosen in such a way, that the sum of all exhaust gas flows is measured, if at all possible, at the same time. Because the exhaust gases are loaded with dust and have a high dew point temperature, a dust and water removal system is required at the sampling point and over the gas sample line.
The reaction time of the system is a cumulative combination of the time, during which the air is present in the system, the residence time in the gas sampling lines and the response characteristics of the analyser. To avoid a false alarm, caused by a sudden rise in CO content in the intake air (for instance as a result of heavy traffic), the transit time in the sampling lines must be balanced. The gas sampling lines to the analyser should be kept as short as possible, in order to avoid unnecessary delay times. This proved to be an insurmountable task when considering direct fired dryers.

Since infrared gas analysers are very sensitive to contamination, the gas samples must be carefully pre-conditioned, by removing humidity and product residues.

**Detection of a smoldering fire**

During the test phase of the early-warning fire detection system, deposits were noted between the atomizer plate and the drier ceiling. These deposits, probably caused by problems with the atomizer plate, ignited. A comparison between the progression of CO content in the exhaust gas and the concentration noted from an artificially introduced smouldering spot is made.

An increase from 0 to 1 ppm CO developed within 7 minutes, within a further 16 minutes the CO content rose from 1 to 5 ppm, and thereafter the value rose within 15 seconds to 8 ppm. Four minutes later water was introduced, and after 3 hours of shut-down the installation could be used again. The test installation was not equipped with a dedicated alarm system at that time.

If we assume that clear signs for a smouldering fire were already available below 1 ppm CO, then the operator lost 15 minutes of time, during which he could have initiated safety measures. The alarm threshold for the initiation of safety measures, such as switching to feed water, must be individually definable, in accordance with the requirements of the end-user and the size of the installation.

From the experience gained with the test installation, it can be concluded that an unusually steep increase in CO content in the exhaust air can best be used to trigger a pre-alarm. With such an advance warning, the operator would have sufficient time to localize and remove the smouldering spot, without having to accept long-term shutdowns. The initiation of a forced shutdown, or the activation of fire extinguishing installations, should occur automatically, after a certain individually determined threshold has been exceeded.

**First Generation ACOM early-warning fire detection system**

With the ACOM early warning fire detection system, a complete system of safety measures is available, which can be operated industrially on a long-term basis and with minimum maintenance. This system is an expanded and improved version of the test installation, which was set up by the "BG Nahrungsmittel und Gaststatten".

The introduction of a microcomputer, with an interface to the control systems of the drying installation, has significantly reduced the detection delay. Also, it helped reducing the threshold values for initiating alarms, while at the same time it guarded against false alarms and assured that the associated safety measures will not be actuated in such cases.
The ATEX CO Monitoring detection system ACOM consists of an IP 54 housing, in which the sample gas pumps, the cleaning and conditioning units, the gas analyser and the evaluation unit are protected from the harsh operating conditions of the installation. The evaluation unit is connected to a display unit in the control room. The NDIR gas analyser functions according to the tested cross-flow principle, in which the intake air of the spray drier is used as a reference gas.

The unit calculates the differential value of the CO concentration, between the exhaust and the intake air of the drier. In this way, only the CO value actually created within the spray drying unit is used.

The ACOM detection system makes use of two parallel microcomputers, which permits a permanent supervision, as well as a gradient-oriented definition of the alarm threshold values. To determine the level at which the alarm is actuated, both the steepness and the elapsed time of the increase in CO concentration can be individually set. In addition, it is possible to set absolute threshold values, at which the alarm will be initiated.

By means of a chain of relays, it is possible to set malfunction messages, two pre-alarms and a main alarm. The alarm thresholds, and the safety measures to be taken, can be defined individually and in consultation with the end-user.

The ACOM system is capable of recognizing the operating mode of the installation by means of an interface and can automatically activate a different set of threshold values, so as to prevent false alarms, for instance while taking the installation into operation or during ventilator shutdown.

All parameters, which are essential to the availability of the ACOM system, are monitored for correct functioning. The electronics of the evaluation unit is self-monitoring and goes into a malfunction mode, if any faulty functioning is detected. As an option, the unit can be equipped with the possibilities for automatic calibration.

The system can be extended and, through the individual adjustment of several software parameters, optimized system solutions can be offered to the end-users, which meet their requirements. It is possible to monitor several installations, or to introduce further sampling points within complex drying systems, through an optionally available sampling point switcher.

**Next Generation CO Early Fire Prevention Systems**

In the past while effective CO systems had false signal potentials based on environmental conditions outside of the dryer. Various methods were used in CO to compensate for these environmental CO changes. But while offering a degree of effectiveness they did not prove to work for the wide range of applications required. In addition signal fluctuations could be observed when CO entered the inlet sample. Based on sampling delays a false differential might be indicated. Also various separate inputs caused a flow ratio problem.

To meet our customers’ requirements ATEX developed a new generation of CO monitoring designed to compensate for internal and external environmental and flow conditions. To do this it required that all CO fluctuations measured are at the same point in time so the effects of the dryer process on the sample are taken into account. And if they could solve these problems they should also be able to protect most Direct Fired Burners.
The key to the effective implementation of the new compensation methods, was the basic principle of the ATEX system, that allowed them to have superior speeds of system functioning. This principle is unique and up to now the only one available on the market and can only be done by using “Cross Flow Modulation Type NDIR- Analysers” for Delta CO measurement.

While the ACOM fire prevention system provided the fastest system response available it could not compensate for delays caused by system volumes and flow delays resulting in an inlet signal being out of time phase with the analysis of the outlet signal. The engineers were certain that if the inlet and outlet signals were analysed simultaneously this problem would be eliminated.

The developers start with the advantage of the Cross Flow Analysis which makes a measurement in seconds while other systems are measured in minutes. To gain a further advantage for signal processing the engineers went to the analyser manufacturer and with their assistance, lowered the detection time significantly further. Unlike other systems that were too slow to offer anything other than token processing control the super-fast ATEX ACOM system enabled ATEX design engineers to develop a new analysis method.

The first of these systems performed a volumetric correlation of vessel flows. The engineers using an ATEX calculation algorithm were able to develop a new buffer system to adjust the real time system flows to allow the inlet sample and outlet sample to be analysed at the same relative point in time. This unique ACOM system development reduces significantly the potential of a stray CO signal entering the inlet and causing the indication of a CO rise because of the Spray Dryer Volumes effect on the flow.

As the systems became more and more accepted, new challenges presented themselves. Customers wanted protection for multi input systems. This presented the possibility that the different sources had different ambient CO levels. By performing a ratio calculation it was able to determine the flows required to compensate for this abnormality. To perform this, ATEX augmented their standard flow controls with additional inlet controls to balance the inlet between two devices with potential CO differentials, not to compensate for flow timing as in the original flow gauges, but to compensate for flow rate differentials in the level of CO.

ATEX engineers were not yet done with their improvements, with the increased time they looked for another advantage. On reviewing the system controller they determined a very large amount of power was still available, especially considering other systems that needed the controller to make system decisions. With the knowledge of the algorithms and detection methods used in their advanced explosion detection system, they were able to develop a Running Average Function. This function evened out the signal changes to create a more sloped output, eliminating the rapid change signal fluctuations from causing unwanted signals. By adding systems to decrease timing factors, compensate for signal delays, compensate for flow imbalances and Average Signal Outputs, the result was an extremely stable system still functioning in half the time of any other system available.

ATEX systems are now able to compensate for CO peaks generated by external sources, for example, from other industrial activities, coffee roasters or burning agricultural waste. And with this new increased filtering power they have a system that can deal efficiently with the effects of most direct fired dryers.
Advantages ACOM Atex-CO-Monitoring

- **Reference and exhaust are measured at the same time.**
  Continues information of delta CO value and the possibility to do additional averaging if we encounter strong CO fluctuations on the inlet of the dryer.

- **Analyser with T90 time of 20 seconds.**
  Faster response and shorter change over time from one stream to another. This means that if we have 80 seconds to measure each stream, we only need 20 seconds rinsing time and still have 60 seconds for continuous monitoring (and averaging if needed).

- **Sample preparation/conditioning system is integrated in the analyser cabinet.**
  Installation cost reduced to a minimum and less impact in process area.

- **Automatic Leak Test System for all exhaust sample probes.**
  Safety issue.

- **Semi-automatic calibration system, with key switch.**
  Reliable, safe and maintenance friendly.

- **No consumption of instrument air.**
  Cost issue.

- **Customer specific solutions (Different filter types available).**
  Depends on the application.
  Re-usable filter elements
  Process filters easy to change

- **CIP option available.**

- **Internal Data logging.**

- **Remote diagnostics (via modem or World Wide Web)**

- **Low cost of ownership.**

- **Easy on maintenance.**

- **Automatic analyser safety test before start-up.**

- **Bag filter monitoring even if the plant is not in production.**
**Other Application areas for the CO detection System**

Because of the Millard reaction in stored milk products, CO concentrations continually build up in the air space of storage bins. Through its gradient dependent analysis functions, the ACOM system can spot trend changes in the rate of CO emissions within stored milk products. In this way, it can detect unacceptable thermic conditions in the storage of milk products at an early stage.

This procedure can of course also be used, for the detection of deterioration processes or smouldering spots in other production areas.
Protection

**Hot Water Explosion Suppression**

The UK and Ireland Dairy industry was looking for a better Explosion protection solution to those existing, for their Milk Drying plant.

They determined the following needs for a Protection System:

1. Keep Deflagration Overpressure to a safe non-destructive level
2. It must be suitable for large volumes
3. Considering the Hygiene hazard it could not be a contaminant?
4. An explosive actuator would be a contaminant so it could not be used
5. Easily maintained
6. Low Cost maintenance

The first step was to review existing protection systems to determine if any were suitable or could be modified to be suitable for use. They reviewed Dry Chemical Powder Isolation. It did not meet the large volume requirement without very high pressures, using an explosive actuator that in itself was a contaminant (especially lead particles) and finally in most cases, required expensive factory maintenance. The Halons and Gas systems presented cost and distribution problems that resulted in high maintenance and operational costs.

Finally cold water was reviewed. While meeting most of the requirements above it did not have a delivery system to allow the smaller droplet size required. In addition, water cooling effect on Hot Dryers could be just as problematic as the deflagration itself!

Through research, they understood that if water could be released in a droplet size (below 50 micron) an explosion could be effectively suppressed. Limitations in pressure, energy cost and flow, presented major road blocks to success. In addition, the small diameter orifices required to reduce the droplet size were problematic and unreliable.

They then turned their attention to Pressurized Hot Water Explosion Suppression but it too had its development concerns. First it had to be shown to be reliable and efficient for the application. The operational parameters had to be defined and finally they had to be tested for the required range of Kst and Pmax values.

To evaluate these parameters a test program was developed and performed. To evaluate the system tests were performed using two different sized test vessels with different geometrical characteristics. The first vessel was a 2.8 m³ ISO test rig. The second was a 28 m³ test vessel with a 7:1 aspect ratio to mimic a typical tower dryer.

The results from the tests determined that droplets less than 50 microns performed the best deflagration suppression properties. Further analysis using the REMP (Required Extinguishing Media Portion to fuel gas) or REMP value, me/mg determined in a comparison to other agents, water droplets under 20 micron could function as a total flooding system with extinguishing values twice that of the Halons and equal to or better than, the dry Chemical agents used for explosion protection.
Testing was complete and a suitable suppressant was found, water droplets less than 50 micron. A review of Pressure Heated Water found that water heated to its boiling point increases its liquid heat content, temperature and pressure. This surplus energy increase the amount of flash steam produced. In addition when stored and discharged from a storage cylinder the Pressurized Hot Water has a much more constant discharge flow rate than similar Nitrogen pressurized cylinders.

The major problem with dry chemical systems was that they released like a shot gun. They only hit what they were aimed at and were decelerating as they discharge their volume. The result was a system requiring more release points and a limited discharge distance, limiting the size of vessel they can handle. Pressurized Hot Water has an advantage, that when released into the protected vessel near ambient pressure, it flashed, exploding it droplets to a vapour thus accelerating and expanding in all directions, providing the ideal agent for a large volume applications like a spray dryer.

Using Industry available explosion detection and control equipment the only thing required was a Hot Water Storage and deployment System. Earlier systems produced a dual lined Stainless Steel bottle with a Hot Water Heating element up the centre, which produced approximately 180 C water, resulting in 10 bar pressure. This was released by a pyrotechnic actuated valve that dropped a seal puck type valve when activated.

So a Pressurized Hot Water system provided the following industry required protection needs:

1 – Reduced Pressures ($P_{\text{red}}$) which were acceptable for the Protected Vessel
2 – It was effective for all vessel volume ranges
3 – Hot water is a food safe substance
4 – An actuator was used out of the product stream eliminating contamination
5 – The system was designed to be easily maintained
6 – By using water, the maintenance was expected to be lower in cost.

The system was implemented with great application success. As time went on though problems with service and maintenance developed. It was obvious that while a great product in theory the final products engineering left a lot to be desired.

ATEX GmbH had been reviewing the Hot Water solution themselves. They decided to re-engineer the Hot Water System to eliminate the early problems. The cylinder was re-designed to eliminate the effects of its own heat on the life of system components required for system functioning. Control methods were simplified to lower problem potentials and make user servicing simpler.

ATEX also used the basic design of their highly successful Dry chemical system to totally redesign the release valve itself. Providing a reusable valve lowered the cost of system reconditioning and therefore the total operational cost.
The first generation system discharged through a flanged membrane in an open orifice, which did not provide the best hygienic seal required in Dairy Systems. ATEX again went to their proven Dry Chemical T -System Spreader. By enlarging the diameter, to handle the hot water flows the system provided a reusable nozzle for system release. The design with flush seal provided a food grade nozzle for the industry it served.

As for the controls system, ATEX had already developed a Suppression based system for system control and maintenance. Using ATEX Log Modules the entire system became field addressable with the ability to monitor not only system components but also the subcomponents of each suppressor. It no longer took a factory trained technician days to find a wiring fault or damaged component. Components and wiring problems could be pinpointed to the individual component or wire length. The system could be restored to proper service, with ATEX assistance before a manufacturers Engineer could get to the airport!

As for the sensors, ATEX PXD (Pressure Explosion Detector) analog/static sensors replace the old static sensors. These sensors provide an unsurpassed detection principle performed by an ATEX exclusive calculation algorithm. Each sensors data is stored, so if an actuation occurs the activating sensor signals can be compared, to determine the cause of an event. While some manufactures of systems wire in parallel for reliability some wire in series for false signal protection. With ATEX you don't have to choose reliability verses false release protection. With ATEX the sensors are programmed in a series type confirmation mode, to prevent false release. If the system determines that the sensor is not responding, it will automatically reprogram itself to a single sensor response providing the higher degree of reliability without compromising the false alarm signal processing.

All ATEX Systems offer ANSI SIS SIL approvals for reliability. By designing all components with total functional supervision and providing redundancy where a component cannot be supervised as required, the system has been independently certified as providing SIL 2 level protection.
Advantages of ATEX AIS Hot Water Suppression System

- **Detection**
  - PSD Sensors provide Analogue and Static adjustments to meet all system conditions.
  - ATEX Algorithms provide analogue response while eliminating short duration spikes from electrical noise.
  - Direct Sensor communications and heartbeat check provides the first truly performance based sensor supervision.
  - Independent sensor response curves allows for signal verification and diagnostics.
  - Additional ancillary components allow temperature controls to meet the most demanding System Temperatures.

- **Controller**
  - Integrated modular controller allows for unlimited expansion and system configurations.
  - History Function provides a time date stamped indication of all Sensor and System status changes.
  - Reliability “Plus” Logic Control to provide false release protection with redundant sensors but the reliability of independent sensor release for reliability.
  - Three stage signal levels provides varied data to meet user needs.
  - Control Panel Self diagnostics pinpoints system signals to the individual sensor and suppressor.
  - Computer aided software allows diagnostics to individual cables, sensors and sub component suppressor status conditions.

- **Suppressor**
  - Provides simplified High Voltage Controls away for dryer and suppressor heat extending the systems life cycle significantly.
  - Provides OSHA required integral Lock-Out Tag-Out feature with a turn of the locking rod. This does not require unsafe loosening of system bolts etc.
  - Low voltage Control box with plug in connector, does not require working with explosives to disconnect the unit.
  - Redundant Gas Generators and other components for increased reliability for devices that cannot be supervised.

- **Spreader System**
  - T System provides dairy industry required sanitary design.
  - Flush design does not require the use of contaminating and costly blow off caps.
  - The only system to meet the latest NFPA codes before they were released.
  - Our system did not require changing to meet the code.
  - Our features are even superior to today's latest version.
Explosion Protection for the Dairy Industry

White Paper brought to you by

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