Explosion of a solvent drum

11th January, 2006

Saint Marcellin (Isère)

France

Methyl ethyl ketone (MEK)
Butyl acetate
Paint booth
Used solvent recovery drum
Explosion
Organisation / procedures
Faulty process execution
Static electricity / "ATEX" zones
Victims

THE FACILITIES INVOLVED

The site:

The company was developing its activities on 2 neighbouring sites, both of which required administrative approvals to operate. The application of paints on plastic parts for the automobile industry was the primary activity at the Saint Marcellin plant. This site was equipped with 2 automated processing lines (UNI2 and UNI3), along with various storage zones (paints and solvents, unfinished parts, painted parts, components, packaging), an assembly and packaging zone, equipment rooms and some office space.

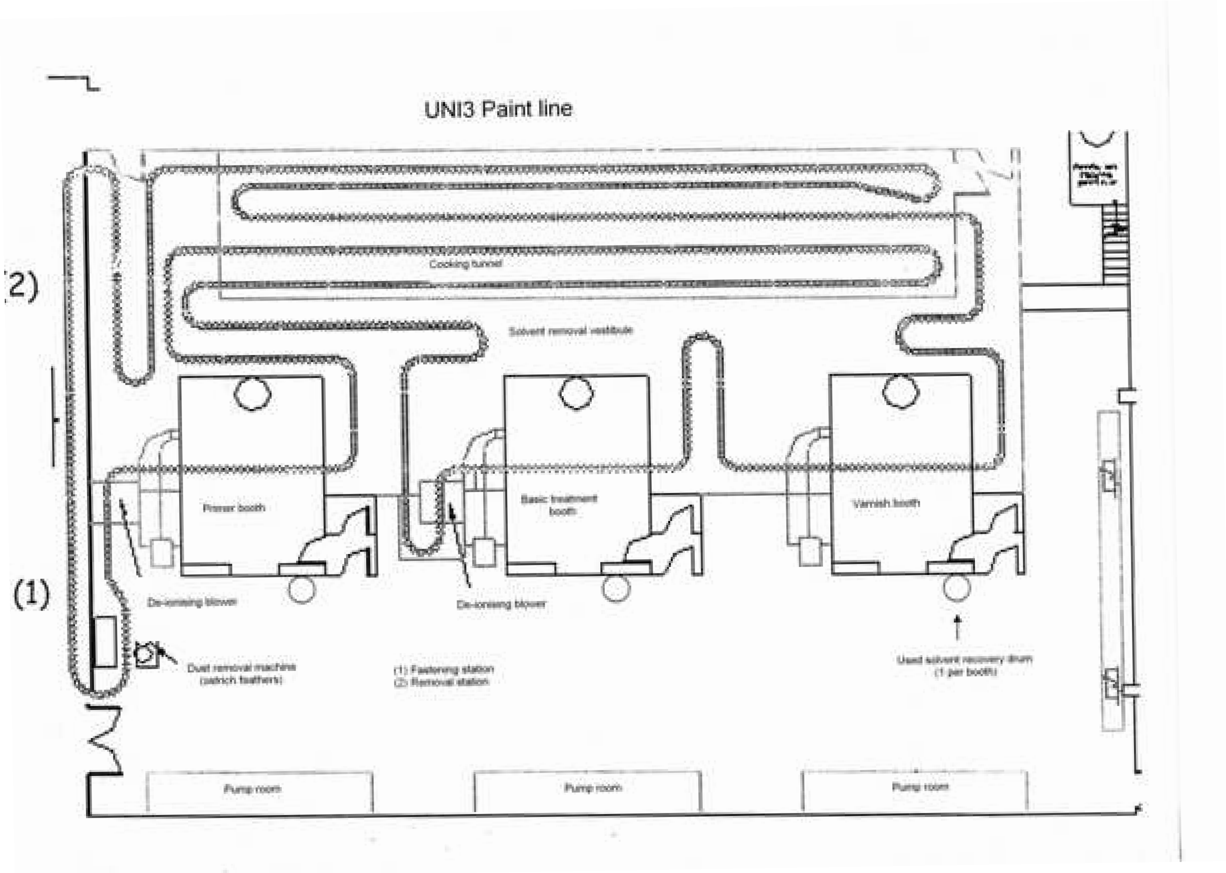
The specific unit involved:

The accident occurred on the UNI3 line, which had been designed to operate according to the following principle:

- Parts are set by technicians onto frames (metal structures fit with fastening systems specific to each type of part).
- The conveyor handling these frames is used to transfer parts among the various stations served by the line.
- The parts are cleaned of dust by means of a suction device that contains ostrich feathers and a de-ionisation ramp.
- The spray booths are equipped with manipulation devices, commonly called "raise/lower" or "back and forth", that perform a vertical translation. Prior to the accident, each booth contained the following equipment:
  - Primer booth: 1 robot handling device fitted with 3 guns capable of accommodating 2 application modes (conventional or electrostatic).
  - Basic treatment booth (affected by the accident): 2 robot handling devices, the 1st equipped with a bowl (running in electrostatic mode, since the conventional mode offered no advantage) while the 2nd one featured 2 spray guns for use in either conventional or electrostatic mode.
  - Varnishing booth: 2 robot handling devices, the 1st of which was equipped with 2 guns for use with either of the two operating modes and the 2nd device contained a bowl.

Photo credit: DRIRE

Solvent extraction steps were carried out in the vestibule separating the various booths. An oven was set up for the purpose of drying parts, which were subsequently removed from the conveyor, inspected and packaged by technicians.



The various stages of booth treatment:

■ *Product input:* The prepared products were set on the booth feeding stations. A series of pumps ensured their transfer to the gun or bowl.

■ *Rinsing*: Upon each product change (e.g. transition from a blue to red shade in the Basic treatment booth), the equipments were rinsed using a cleaning solvent, mixed at 50% butyl acetate and methyl ethyl ketone (MEK), with a flash point of below 21℃. The solvent was pumped i nto a tank, located outside the buildings, to initially supply the guns; used solvent was then sprayed into the water curtains. Afterwards, a 3-channel valve was switched on and the used solvent routed via an insulated plastic pipe to a 200-litre drum for the recovery step. Before the accident, each booth had its own used solvent recovery drum.

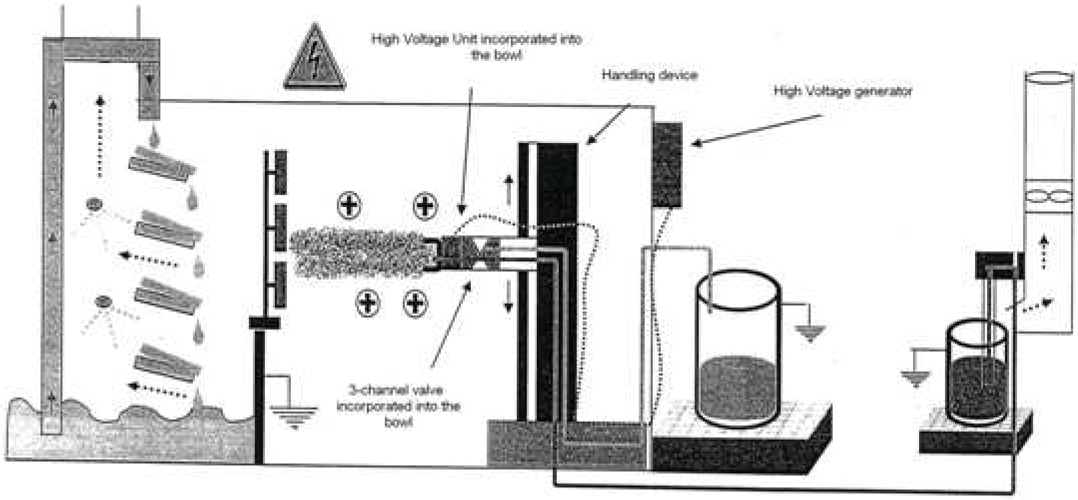
■ *Paint application:* The step of applying paint involved 2 processes. According to the conventional mode, paint was sprayed from a pneumatic gun onto the prepared part surface. The electrostatic mode consisted of loading the paint electrically and then spraying it onto the target surface, which had previously been grounded. The "magnetic" effect was introduced to considerably raise spraying yield (i.e. less paint used, hence smaller quantities of solvent released for an equivalent coverage). The paint was loaded via a high voltage unit controlled by a generator for feeding the guns. In the case of electrostatic application using the bowl, this high voltage unit was sometimes incorporated into the bowl itself. The parts to be painted were grounded by contact with the metal frames, which had already been grounded by contact with the conveyor belt.

In the initial UNI3 line configuration, the conventional, pneumatic type application mode was used with one robot handling device per booth, each fitted with 3 spray guns. As of 2004, the operator showed a preference for the electrostatic mode, considered more economical, and gradually replaced the conventional guns. The electrostatic bowls were introduced later (during 2005) in both

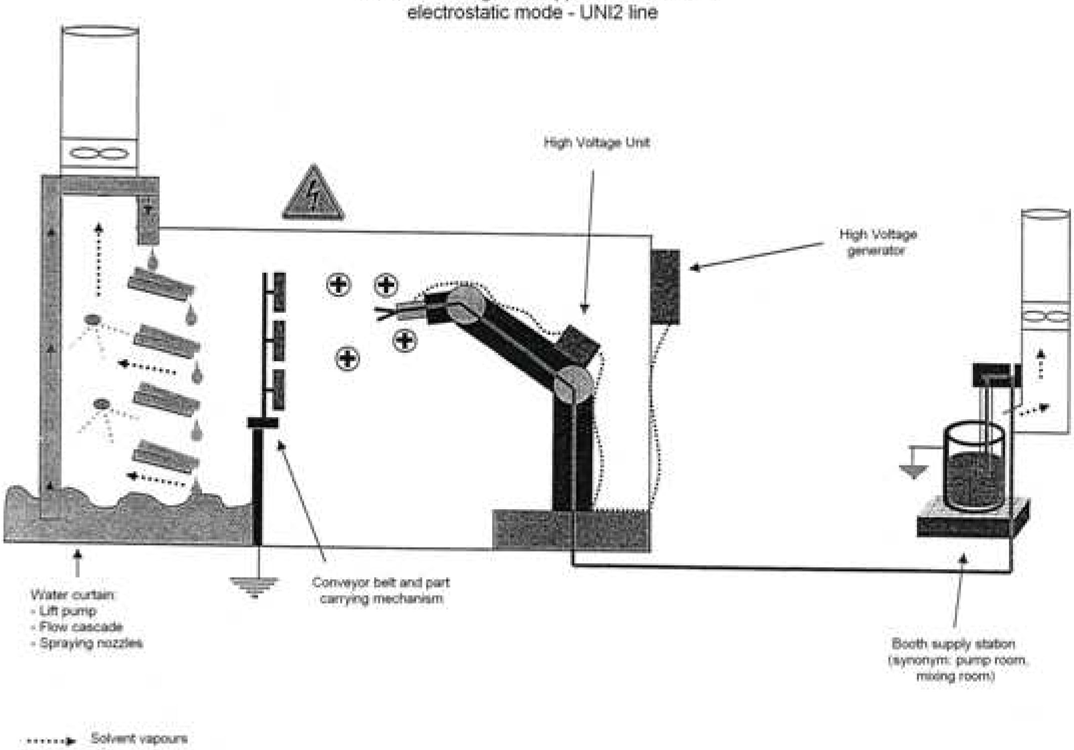
Photo credit: DRIRE: spraying robot

the basic treatment and varnishing booths, leading to modified booth layouts, including: addition of robot handling devices, elimination of guns, expanded number of bowls.

Schematic diagram - Application booth in electrostatic mode - UNI3 line



Schematic diagram - Application booth in electrostatic mode - UNI2 line



THE ACCIDENT, ITS CHRONOLOGY, EFFECTS AND CONSEQUENCES

The accident:

At 7 pm, a 200-litre metal drum collecting cleaning solvents from the paint booth exploded; 8 employees were injured, 3 seriously, and another 12 employees fell into a state of shock at the sight of their burned colleagues. Installed on a grating and electrically grounded, the drum containing used solvent was projected straight up and hit the ceiling. The fire that broke out after the explosion was extinguished by onsite personnel. A crew of some 100 fire-fighters, along with medical response teams and local gendarme officers, was called to the scene.

Consequences of this accident:

The human toll was severe; the person most seriously injured, an employee burned over 80% of his body, succumbed on 19th January, followed by a second death 3 days later.

Property damage was limited to a 100-m² space in the workshop; all fire extinction water could be recovered. A judicial expert was appointed and the UNI3 line damaged by the explosion was officially sealed off. The UNI2 line did not sustain any direct impact from the accident, yet was still shut down.

The plant closure caused operating losses of between €600,000 and €1 million a month. The UNI3 line started back up on September 12, 2006, resulting in losses estimated to range from €4.8 million to €8 million.

The European scale of industrial accidents

By applying the rating rules applicable to the 18 parameters of the scale officially adopted in February 1994 by the Member States' Competent Authority Committee for implementing the '*SEVESO*' directive on handling hazardous substances, and in light of information available, this accident can be characterised by the four following indices:

The parameters composing these indices and their corresponding rating protocol are available from the following Website: http://www.aria.developpement-durable.gouv.fr.

The drum responsible for the accident contained 50% methyl ethyl ketone (MEK) and 50% butyl acetate, with MEK being qualified as a Seveso substance. Given the absence of data indicating the quantity of substances involved during the accident, the index relative to the quantities of dangerous materials released was rated "1" as a default value (see Parameter Q1). The accident caused the deaths of 2 employees, seriously hurt a 3rd employee and slightly injured 12 others, which accounts for the "3" score on the index relative to human and social consequences (Parameter H3). No environmental consequences could be observed, resulting in a "0" score for the environmental consequences index. The costs ascribed to property damage were not known, though operating losses amounted to between €4.8 and €8 million, thus setting the index relative to economic consequences at a value of "3" (Parameter €16).

THE ORIGIN, CAUSES AND CIRCUMSTANCES SURROUNDING THIS ACCIDENT

Subsequent to this accident, the expert assigned by the plant operator visited site installations on 18th January and proceeded with tests to determine the flash point and resistivity of a sample of the paint / thinner mix stemming from the previous UNI3 line recovery drum. An additional series of tests were intended to measure the resistance of: a dedicated immersion rod, the solvent recovery drum, and hoses conveying cleaning solvent to the recovery drum. On 23rd June, 2006, during an audience consisting of the operator and inspectors from the Labour Office and Classified Facilities Inspectorate, the expert presented an initial set of conclusions from the study, along with the appropriate prevention and protection measures.

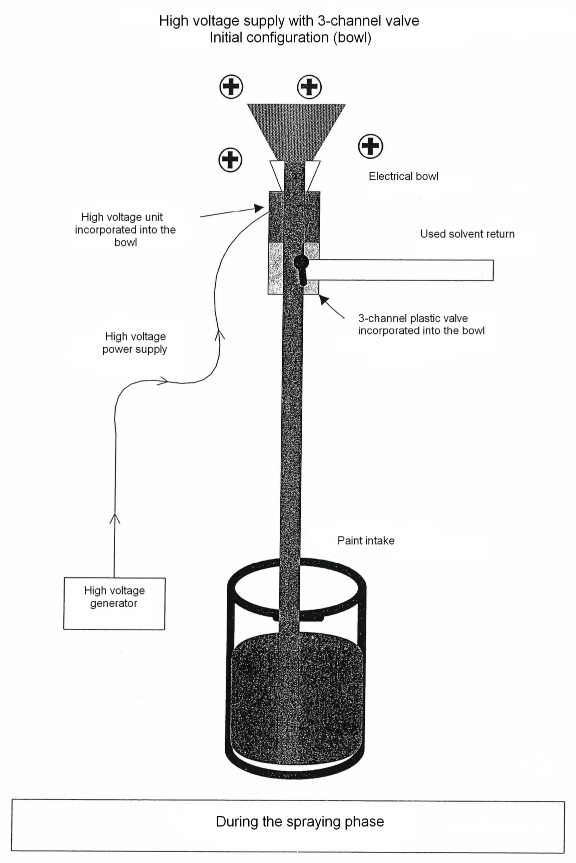
The most plausible scenario adopted focused on an air / solvent explosive atmosphere present in both the drum cap and immersion rod. The spraying bowl's residual electrostatic charge was transferred to the cleaning solvent (with a charge dissipation time, as verbally announced by the supplier, of 7 seconds, which exceeds the lapse in solvent intake). The solvent maintained its charge in passing through the pipe that connected the bowl with the immersion rod (insulated pipe) and caused a spark upon contact with the metal end of the rod. This spark, in turn, triggered ignition of the vapour space of both the rod and drum, ultimately inducing the air / solvent mix to explode.

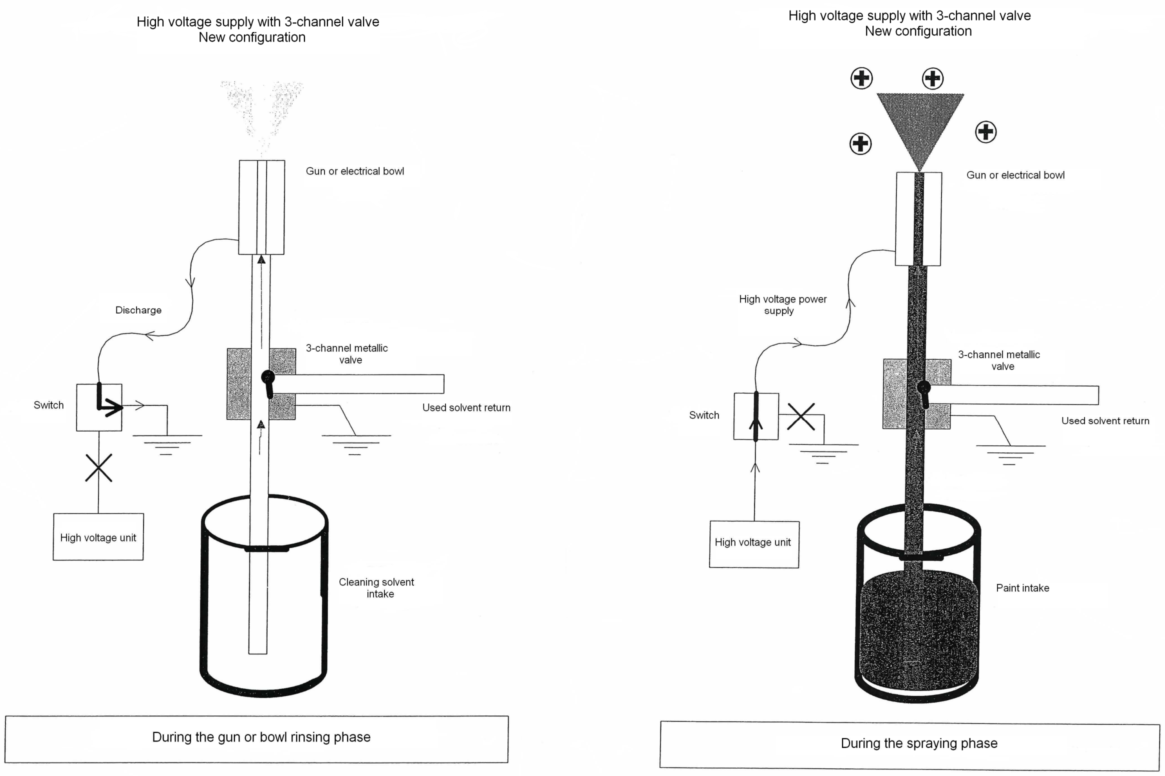
ACTIONS TAKEN

The Classified Facilities Inspectorate collected the first findings as of 12th January, then, after a full site inspection, proposed to the Prefect an additional executive order. The operator was required to submit an accident report describing: installation operations, accident causes, and the human and environmental consequences.

After the expert's visit on 18th January and issuance of inspection findings, the intact line was restarted yet without the 200-litre drums, as the rinsing solvents were being collected solely by means of water curtains installed in the paint booths.

Restarting the damaged line was contingent upon submission of the expert's report containing a specific study on the electrostatic risk relative to the line's future configuration (as the most plausible accident scenario). This study was conducted by a certified body recognised for its competence in the field of static electricity. The expert appraisal was mandated to include the set of recommendations issued by the expert, i.e.: spraying robot ventilation, fire detectors in all spraying booths, sealed ductwork for running the robot's electrical cables, estimation of the maximum energy released by the robot, shutoff of solvent rinsing and drum recovery circuit while awaiting conclusions of the accident evaluation. On 25th August, a fire had previously broken out at the site (ARIA 30491), prompting preventive action to be undertaken on the very same day to improve drum grounding by the insertion of 3 cable clips.





A meeting held on 7th September, 2006 in the company's offices provided the opportunity to reconcile and synthesise the reports submitted by the site operator and expert, in addition to better assessing the risks related to paint recovery and sequencing of the switch controlling "paint spraying / grounding of bowls or gun / solvent rinsing".

Moreover, a number of compensatory measures were adopted with the intention of restarting the UNI3 line with, among other features:

- removal of the solvent recovery drums from operations while awaiting a more secure solution. The rinsing solvents were thus routed directly into the water curtain inside the booth;
- installation of a 3-channel grounded metal valve (or an equivalent device in the case of the UNI3 basic treatment booth) upstream of the bowls and guns;
- introduction of a switch that guarantees grounding between the spraying and cleaning phases.

The UNI3 line was placed back into service on 12th September, 2006.

LESSONS LEARNT

Supervision of modifications, process management, organisation and controls

The use of electrostatic guns and bowls began in 2004 and gradually replaced the conventional mode of operations. The supplier offered an initial training session to the heads of the various lines. During this replacement strategy, the company did not notice the presence of any special risk. This change in favour of electrostatic over conventional mode was accompanied by an optimisation of the paint volumes used thanks to a rapid shade change programme. It was also decided to modify the rinsing procedure by means of collecting used solvents and channelling them to the drum, compared to the former practice of routing them to the water curtain (Problem of cleaning parts once the rinsing intervals between successive sets of parts to be painted had shortened). These measures led to an increase of production rates. The last adjustments were made at the end of December 2005, and the UNI3 line was restarted on 3rd January, 2006.

The modifications intended to optimise a process required review relative to associated potential hazards. The risk of electrostatic charge accumulation was definitely present as the process was built around this phenomenon and given that the rinsing solvent was capable of accumulating charges. More specifically, bowl discharge time had become greater than the rinse cycle, thereby allowing the solvent to accumulate residual charges. Grounding discontinuity would be enough to potentially trigger a spark and the ensuing accident.

In a unit capable of generating electrostatic currents, a zoning pattern was laid out according to which a number of precautions were adopted ("ADF" fire prevention equipment, grounding of all equipments, etc.). The operator, who had failed to delimit the zones capable of producing these currents, claimed to have circumscribed the explosion risk zones, yet had not laid out any boundaries on the installation nor had any kind of map ever been produced showing:

- the enclosure created by the paint booths,
- the booth supply zone for primer, basic treatment and varnish booth,
- the paint storage room,
- the paint preparation room.

These zones were all equipped with ADF fire prevention equipment, while for the UNI3 line, used solvent recovery drums were placed outside the zone containing all such equipment.

These measures taken as a whole, including zone delimitation, use of ADF fire prevention equipment and grounding of devices (which gave rise to a set of written procedures), plus carefully devised plans accompanied by appropriate training sessions devoted to technicians, had contributed to the proper functioning of the company, as production constraints were no longer considered the sole target criterion during process modifications and improvements.

Feedback management

The measures adopted following the accident were designed to avoid a repeat occurrence. All paint line equipments were permanently grounded, with controls on both grounding and equipment equipotential for facilitating the flow of electrostatic charges between line connections being performed at least once a month by the operator and once a year by an external certified body.

While awaiting a secure solution, to be validated by an expert, the practice of used solvent recovery drums was discontinued. Guns and bowls were only supplied with cleaning solvent when they showed zero potential; the rates were significantly reduced, so as to allow for charge dissipation at the bowl level.

The modifications planned for the solvent supply circuits, such as replacement of the plastic valve by a 3-channel metal valve connected to ground and positioned upstream of the bowl or gun as well as installation of a switch guaranteeing grounding between the paint spraying and solvent cleaning phases, were among the measures intended to avoid an accumulation of charges capable of triggering an accident.

Moreover, technicians, as a potential accident source, were equipped to ensure that their grounding was effective during operations involving the handling of inflammable liquids.

The cataloguing and identification of zones by the operator, on the basis of risk exposure, has also served to improve site safety. This operator has committed to determining the type of risk (fire, explosive atmosphere) for so-called secure zones and moreover maintains an up-to-date layout map of all these zones, whereby the entrance to each zone is properly indicated along with the type of risk exposed and any special instructions to be respected. More specifically, in zones displaying fire and explosive atmosphere risks, the permanent ban on smoking and open flames in proximity has been clearly posted.

These safety zones are to be equipped with detection systems whose sensitivity threshold depends on the type of risk prevention measure required. Regular maintenance of these detectors has been scheduled. Spaces containing fire risk zones are to be equipped with a fire detection network, that when triggered will trip a sound alarm.

The equipments located in explosion risk zones are to be compliant with the "ATEX" Directive for explosive atmospheres, specifically as regards the construction of facilities intended for use in an explosive atmosphere, with the proviso that no device be added to installations without ensuring its full compliance and protection relative to explosion risks.

Various complementary measures were also adopted, namely:

- Scheduled preventive maintenance for all power transmission devices (conveyor drive mechanism, etc.) in order to limit mechanical ignition sources;
- Completion of a hot work permit as part of a written procedure for all work involving grinding, cutting and welding undertaken in any of the designated high-risk zones;

- Circulation of inflammable liquids at velocities less than 1 m / s;
- Fire detection system installed in the paint booths, capable of automatically triggering: deactivation of the spraying robot supply pump, activation of a sound alarm, and shutdown of the paint injection device.
- Temperature probe set on a high alarm level (temperature < 300℃) and servo-controlled to the shutoff of gas burners for each oven.
- Efficient ventilation system for paint booths and ovens, as well as inside the spraying robot and along the robot axis of translation; sealed ductwork to prevent against solvent leaks in the robot's electrical cables.