CHEMICAL ENGINEERING TRANSACTIONS
VOL. 90, 2022
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Aleš Bernatík, Bruno Fabiano

ISBN 978-88-95608-88-4; **ISSN** 2283-9216
DOI: 10.3303/CET2290106

Evaluation of the Management of Explosive Atmospheres in Milling Companies: the Île-de-France Region Example

Agnès Janès[a,b,*], Olivier Dufaud[b]

[a] Direction Régionale des Risques Professionnels de la Caisse Régionale d'Assurance Maladie d'Ile-de-France, 75019, Paris, France
[b] Université de Lorraine, CNRS, LRGP, F-54000 Nancy, France
agnes.janes@assurance-maladie.fr

Due to its nature, the activity of mills promotes the suspension of fine flour, grain or bran in the air. This can lead to the formation of explosive atmospheres (ATEX) into process equipment (silos, mills, handling equipment or dust collectors), but also in working areas. The objective of this study is to assess the management of this risk by companies in the milling sector. This investigation is mainly carried out in the Île-de-France region, within the framework of a French National Social Insurance prevention program. Two approaches were combined: an accident database managed by the Government was thoroughly examined and additional visits were performed in several companies representative of this sector. More than 600 fires and explosions, that occurred between 1975 and 2021, were investigated through statistical methods.
This study shows that, although regulations have been applicable since 2003, the management of the fire and explosion risks is very disparate, depending on the culture of the company and its organization. In some facilities, the risk associated to ATEX formation and ignition is significant and is greatly underestimated. In such cases, the analysis of accident feedback shows that in more than one third of the cases, similar negligence has led to multiple accidents. Moreover, factors such as the grain nature, the lack of quality control of raw materials or maintenance deficiencies play a significant role on accident likelihood and on the primary failure mode. This work allows the definition of a more targeted actions intending to enhance the milling companies awareness and convince them act on this particular risk.

1. Introduction

Milling plants, industrial bakeries or cereal wholesalers, due to their specific activities, can generate explosive atmospheres (ATEX) into process equipment (silos, mills, conveyors, dryers or dust collectors), but also in working areas. If an ignition source is activated, an explosion may occur. However, while most companies are aware of these risks, many have an insufficient risk prevention policy and do not take into account feedback on incidents/accidents. The objective of this work was to assess the fire and explosion risk related to combustible powders in the milling and grain industries based on a feedback from a large database and from an onsite investigation carried out in the Île-de-France region, within the framework of a French National Social Insurance multi-year prevention program concerning chemical risk.

2. Methods

Onsite observations were performed on six facilities representative of the milling industries, in the Ile-de-France region. This investigation intended to evaluate the exposure of their employees to the inhalation risk of flour dusts and mycotoxins possibly contained, as well as to the risk associated with dust ATEX.
As a parallel work, feedback available in the ARIA accident database, managed by the French Ministry of Ecological Transition, was thoroughly examined (ARIA, 2021). More than 600 fires and explosions, which occurred between 1975 and 2020, were investigated through statistical methods. In a first approach, the facilities considered for this study were selected from the following NAF codes (French nomenclature of activities): C10.61, C10.62, C10.71, C10.72, C10.73 and G46.21, corresponding to the industrial activities described in Table 1. In this work, only accidents related to the combustible powder (grains, flour, etc.) were

Paper Received: 21 November 2021; Revised: 9 March 2022; Accepted: 14 May 2022
Please cite this article as: Janès A., Dufaud O., 2022, Evaluation of the management of explosive atmospheres in milling companies: the Île-de-France region example, Chemical Engineering Transactions, 90, 631-636 DOI:10.3303/CET2290106

considered and, for instance, electric fires, engine fires or gas leaks were not recorded. However, industrial sites having experienced product-related accidents were also the sites of other types of accidents.

Table 1: Correspondence between codes and activities

Codes	C10.61	C10.62	C10.71	C10.72	C10.73	G46.21
Activities	Manufacture of grain mill products	Manufacture of starch products	Manufacture of bread	Manufacture of bakery products	Manufacture of pasta	Wholesale of grain and animal feeds

A second step consisted in reducing the scope of the database accident analysis to the trade in grains, animal feed and flour mill activities (i.e. G46.21, C10.61 and C10.62 codes in the French nomenclature of activities), as they were more specifically concerned by dust explosion risk. There were 527 such accidents.

3. Results and discussion

3.1 Sites and materials involved in the recorded events

602 accidents, including 577 in mainland France, were recorded. Figure 1 shows that facilities involved are mainly located in agricultural and port areas, and that nearly a third is concerned by more than one accident.

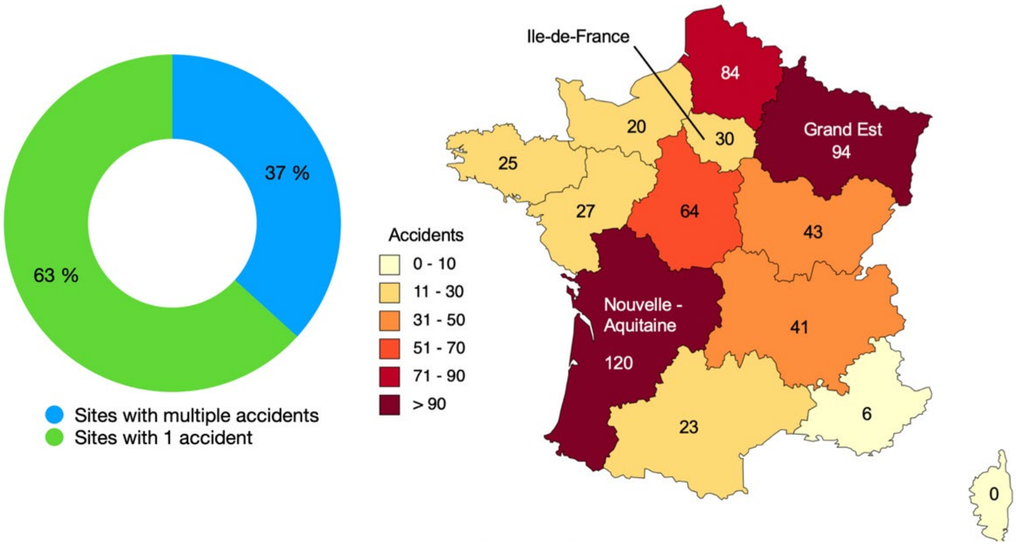

Figure 1: Geographical distribution of establishments concerned by the 577 accidents recorded in mainland France, and proportion of establishments concerned by one or more events (all activity codes)

Figure 2 indicates the frequency of occurrence of materials involved in the recorded accidents. A wide variety of products appear, as all the cereals processed in the factories are combustible. Unsurprisingly, wheat, sunflower and maize are the main cereals related to accidents, whereas barley, alfalfa or rapeseed represent less than 5 % of the materials involved.

3.2 Consequences and equipment involved in the accidents

When the analysis is reduced to trade in grains, animal feed and flour mill, more than 40 accidents over 527 resulted in injuries or fatalities. Almost 91 % of these events are fires (open fires, self-heating) and only 9 % are explosions (Figure 3), but the vast majorities of causalities was caused by them. The process equipment that is very frequently implicated are silos and dryers, and to a lesser extent, grain mills and pellet mills. Similar findings have been established previously (Janès and Chaîneaux, 2010).

3.3 Main causes of accidents

Causes of dust fires and explosions are numerous, but self-heating (21 %), mechanical friction (12 %) and works (12 %) are among the most common causes (Figure 4). They can, of course, be combined and, e.g. the energy supplied by cutting with a grinder can generate a hot spot which will smoulder and cause further self-heating. The significant role of impurities and humidity of the raw materials should also be highlighted.

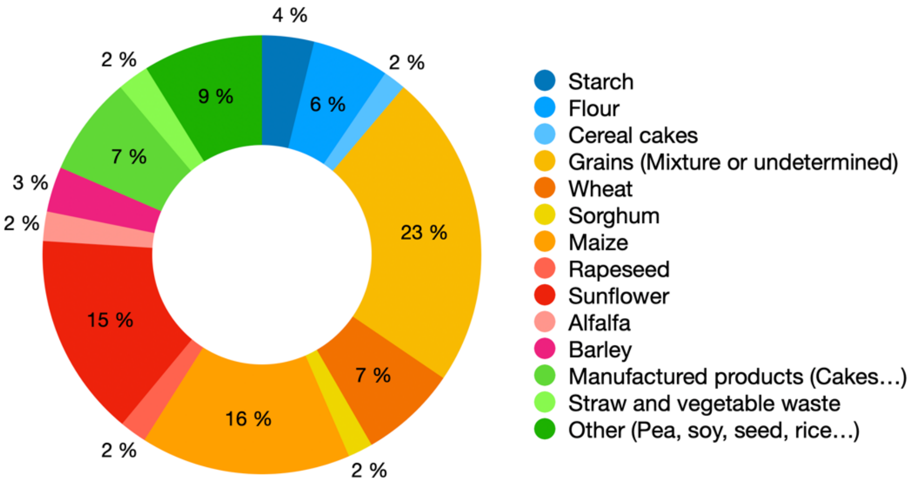

Figure 2: Nature and frequency of occurrence of the materials involved in the 602 accidents recorded (activity codes: C10.61, C10.62, C10.71, C10.72, C10.73, G46.21)

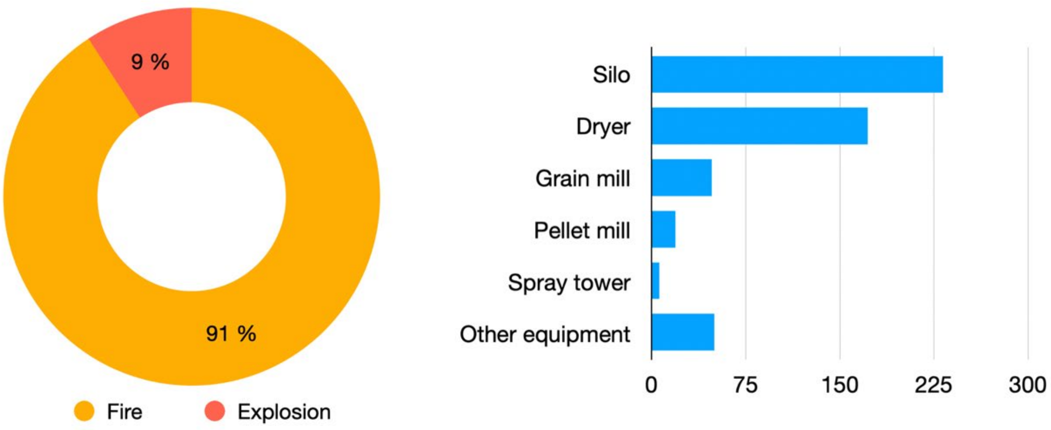

Figure 3: Distribution of events by type of accident and by type of process equipment involved in the 527 accidents considered (activity codes: C10.61, C10.62, G46.21)

3.4 Instance of fault tree for grain dryer fire

A thorough analysis of the accidentology leads to the identification of preferred/common scenarios and to the building of fault trees, which improve the implementation of appropriate preventive actions by revealing the logical chain of events. An example of such fault tree related to grain dryer fires is shown in Figure 6.

3.5 Observation made on the visited facilities

The analysis of the ARIA database was complemented by the visit/audit of six milling companies from the Île-de-France region in 2021. Table 2 summarizes the main information collected. Despite the fact that this region does not have the highest number of accidents (Figure 1), mainly due to the lesser representation of this sector of activity, observations made in the flour mills of this region allow drawing some lessons. All the visited facilities include the processes of unloading grain, crushing, sifting, and then flour conditioning and loading.

Two facilities stand out from the others: site #6, is very small, with a small-scale production and only a few employees in production, whereas site #4, has a significantly larger size than the others. The other four sites are about the same medium size. The largest facility is the only one with specific resources for risk prevention, and is also the only one that operates facilities partially protected against explosion overpressure. The smallest facility is the one that, contrary to what could be expected, has the best control over explosion risks. The visit showed that this is due to the skills and awareness of the company manager on this subject.

Regarding ATEX formation risk, the observations show in general that few dust deposits are present in the work premises, except in sites #2 and #3, for which many deposits are present (Figures 5a and 5b). This is obviously an aggravating factor with regard to the explosion risk. Every visited sites clean up dust deposits with mobile vacuums cleaners but also with broomsticks (Figure 5c), which is not recommended. Site #2 also uses a compressed air blower, which is even worse.

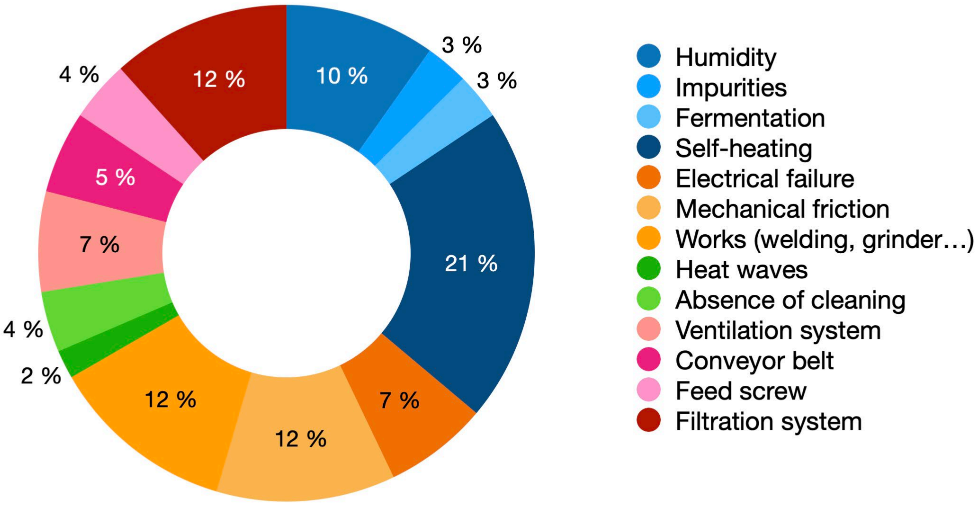

Figure 4: Main causes of the 41 accidents recorded with casualties (activity codes: C10.61, C10.62, G46.21)

In addition, an ATEX is present in normal operation, permanently or not, in the internal volume of process equipment such as mills, screens, dust collectors, and product transport equipment such as redlers, chain, belt and pneumatic conveyors. This justifies a classification of these locations in zone 21 or 20, as required by regulations (EC, 1999), depending on whether the formation of ATEX is permanent or occasional.
Concerning ATEX ignition risks, companies must ensure that all equipment installed in classified locations within the process and product transport equipment comply with regulations (EU, 2014), i.e. choose the appropriate category of materials for each classified zone. Particular attention should be paid to the electrical continuity between the conductive parts of the process or transport equipment, especially when a vibratory decoupling is used, and their connection to the ground potential. This must also be checked after maintenance operations which remove equipotential bonds or during painting operations, as it constitutes an insulating layer. In some facilities, the lighting systems of the premises are certified ATEX 3G. This is suitable if there are dust deposits on the floor and surfaces. However, it would be better to eliminate the dust deposits.
On #3 facility, equipment used for spark-producing work is observed in the vicinity of deposits (Figure 5d), which causes a significant fire and explosion risk. With regard to installations protection against explosion overpressure, it would be necessary to provide venting equipment installation with discharge of the explosion energy outside the buildings. Only two facilities, namely sites #4 and #5, have already trained their employees on the specific risks associated with ATEX explosion.

a) Wheat deposit on the floor | *b) Flour deposit on the floor* | *c) Broom for floor cleaning* | *d) Electrical equipment close to dust deposits*

Figure 5: Some views of facility #3

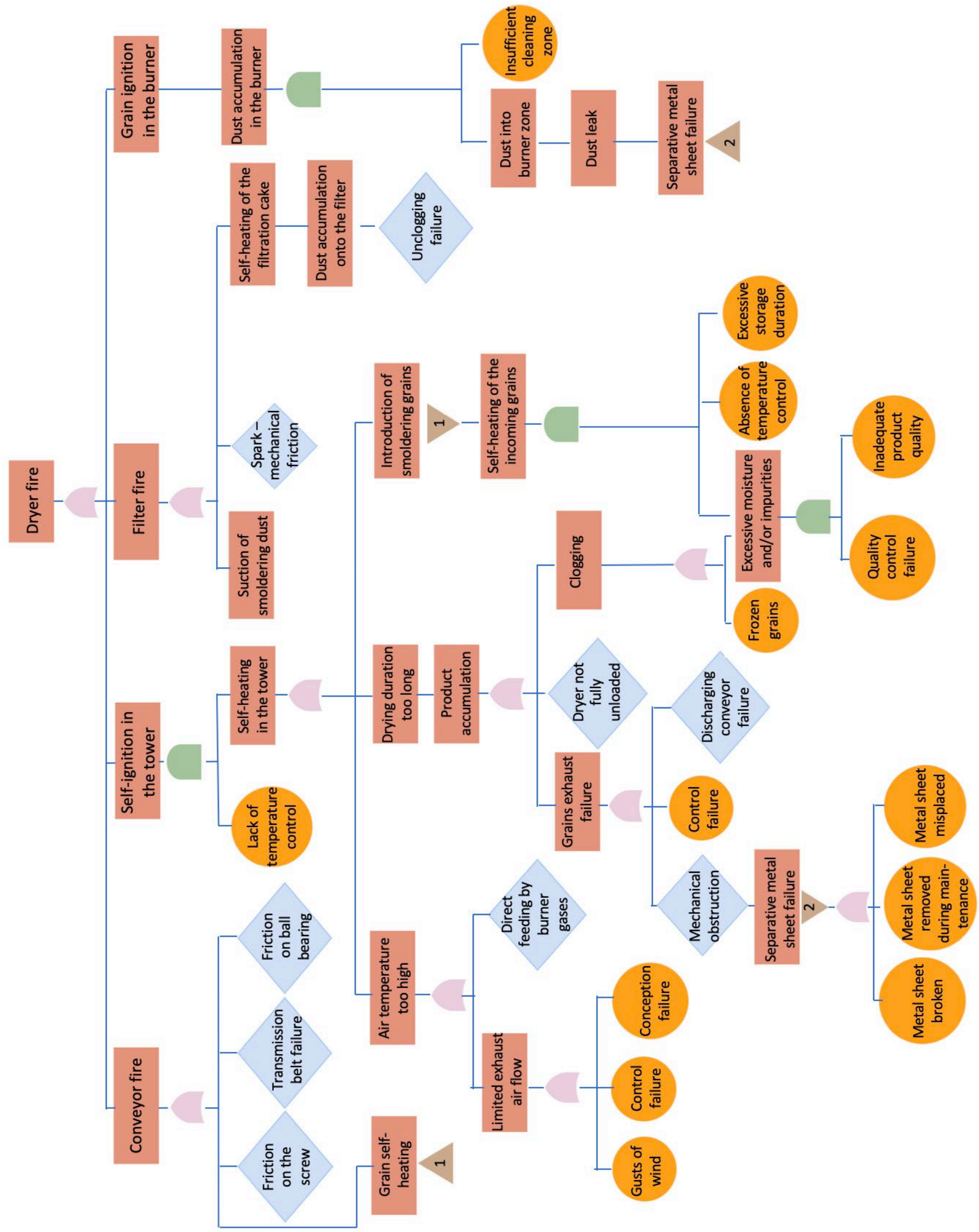

Figure 6: Instance of fault tree for grain dryer fire

4. Conclusions

This study shows that, although regulations are applicable since 2003, the level of control of the risk of ATEX explosion in the milling companies varies greatly as a function of the culture of the company and its organization. In some facilities, this risk is very well assessed and prevention is effective. On the contrary, in others, the risk associated to ATEX formation and ignition is still significant and is greatly underestimated. Consideration of accident feedback, whether internal or external, can make the company aware of the risks involved and help it to choose the most adequate preventive or protective measures.

Table 2: Main information collected during onsite visits

Facility identification	#1	#2	#3	#4	#5	#6
Operated product	Wheat	Wheat, rye, sponge	Wheat	Wheat	Wheat	Wheat, corn, chickpea
Number of facilities in the industrial group	6	2	3	8	4	1
Number of employees engaged in production tasks	10	8	9	30	6	3
Specific resources/skills for workers/process safety	No	No	No	Yes	No	No
Production	Large industrial production	25 t/day	Large industrial production	Very large industrial production	9 000 t/year	Artisanal production
Process equipt. protected against explosion pressure	No	No	No	Partially	No	No
Facility cleaning processes	Mobile vacuum cleaner & broomstick	Centralized vacuum system not used, mobile vacuum cleaner, broomstick & blowpipe	Mobile vacuum cleaner & broomstick	Mobile vacuum cleaner & broomstick; annual cleaning by rope access technicians of non-accessible areas	Centralized vacuum sys., mobile vacuum cleaner & broomstick; annual cleaning by rope access techn. of non acces. areas	Mobile vacuum cleaner & broomstick
Workers training about ATEX issues	No	No	No	Yes	Yes	No
Dust deposits on the floor in the work areas	Slight	Sometimes > 1 mm	Sometimes > 10 cm	Slight	Slight	Slight
Overall control of ATEX explosion risk	Almost well controlled	Poorly controlled	Very poorly controlled	Almost well controlled	Almost well controlled	Well controlled

As showed by the exploitation of the ARIA accident database, about 90% of the recorded events are fires and 10% are explosions, however, they often have much more serious consequences for employees and facilities. The process equipment most affected is silos and dryers, which must be carefully considered. Main causes of accidents are diverse and include maintenance works, environmental conditions or the product quality (water content or/and impurities; however, some common or frequently encountered scenarios can be highlighted.
Prevention messages still need to be carried and these companies need to be trained to risk assessment and to apply safety measures in order to prevent ATEX formation and ignition, and to protect their people and assets against explosions consequences. This work allows the definition of a more systematic targeted action, which will have to be conducted in the next regional prevention program intended to make milling companies aware of this specific risk and convince them act quickly and sustainably.

Acknowledgments

This work was supported financially by the French Ministry for Solidarity and Health.

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