Experiences with Fires and Explosions

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This paper compares a historical record of Gexcon's observations and recommendations across a wide range of sites with ignition sources from actual incidents. Some of these incidents are confidential, based on experience with operating companies, but others are in the public domain. Certain ignition sources seem to be very common, despite the fact that they have been well known for many years.

ATEX, DSEAR, Ignition Sources, EN 1127-1:2011, Risk Assessment, Hazardous Area Classification

Introduction

When conducting surveys and assessments under the Dangerous Substances and Explosive Atmospheres Regulations 2012 (DSEAR), many analogous observations come up very frequently across a wide range of sites. Likewise, in incident reports, similar contributing causes and ignition sources are often repeated.

Gexcon has been conducting assessments against DSEAR in the UK for over ten years. This means that we have seen hundreds of sites and, unfortunately, some of these have gone on to have fires or explosions. Because of our relationships with our clients and our involvement with incident investigations, we have developed a good understanding of the factors which may have led to the events.

This paper compares a historical record of Gexcon's observations and recommendations across a wide range of sites with conclusions drawn from actual incidents. Some of these incidents are confidential and based on our real experience with operating companies, but others are in the public domain. Certain ignition sources seem to be very common, despite the fact that they are well known and Gexcon has been identifying them and providing recommendations to control them in DSEAR assessments over the last decade.

This paper aims to present a direct comparison between real experiences of ignition sources in fires and explosions that have occurred in industry with the recommendations that are typically made by Gexcon, with the intention of answering the following questions:

- Are the recommendations made in DSEAR Assessments appropriate?
- Are operators taking into account these recommendations?
- Is the published data on incidents appropriate to allow assessors to make informed decisions?

A statistical analysis of Gexcon survey findings will be presented and reviewed against the literature incident data, and against Gexcon's experiences from smaller incidents.

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- Gary Pilkington, Principal Engineer, Gexcon UK

Methodology for Review

The review consisted of 3 main parts:

1. Review of Gexcon recommendations
2. Review of ignited events in the literature
3. Review of ignited events in Gexcon's experience

Gexcon's database showed 281 DSEAR Assessments since 2016. 50 of these (18%) were randomly selected for review to give a representative sample of the overall population. The recommendations from each report were individually reviewed to identify if they related to control of ignition sources. Where the recommendation related to control of ignition sources (for example, control of static, non-ATEX electrical or mechanical equipment, or hot surfaces), it was categorised in line with the most relevant of the 13 ignition sources presented in EN 1127-1:2011 [1] it was intended to improve safeguarding against. The total number in each category was then summed.

Various literature sources were reviewed by the same method. The US CSB (Chemical Safety Bureau) bulletins proved to be the most detailed sources of info, at least for events in recent years. Where the ignition source could be determined from the source, this was recorded. Where the ignition source was not explicitly stated, but could be identified from context or description, this was also noted. Where the ignition source was not readily identifiable, it was omitted.

Finally, members of Gexcon UK who had experience with incidents involving ignited events were interviewed, noting the type of site and the ignition source. Care was taken to avoid identifying any sites or clients specifically.

The list of potential ignition sources given under EN 1127-1:2011 is as follows:

1. Hot Surfaces
2. Flames and Hot Gases (including hot particles)
3. Mechanically generated sparks
4. Electrical apparatus
5. Stray electric currents, cathodic corrosion protection
6. Static electricity
7. Lightning
8. Radio frequency (RF) electromagnetic waves from 10^4 Hz to 3 x 10^{11} Hz
9. Electromagnetic waves from 3 x 10^{11} Hz to 3 x 10^{15} Hz
10. Ionizing radiation
11. Ultrasonics
12. Adiabatic compression and shockwaves
13. Exothermic reactions, including self-ignition of dusts

Clearly, many of these are not relevant at many typical industrial sites, although Gexcon has performed assessments for many sites with unusual ignition sources such as experimental laboratories.

For the purposes of the assessment, mechanically generated sparks was broken down into non-ATEX mechanical equipment and mechanical sparks arising from the operation. One issue with EN 1127-1 is that it is not necessarily clear how to account for non-ATEX mechanical equipment – the description for "mechanically generated sparks" specifically refers to those from operations (cutting/grinding etc.). The intention seems to be that failed bearings etc. are included with "hot surfaces", which has some logic but reduces the granularity available as it groups it in with all other possible hot surfaces (in the author's opinion).

Analysis

Gexcon DSEAR Assessments

The 50 selected DSEAR assessments can be broken into the following categories based on the principle hazardous materials present at the facility:

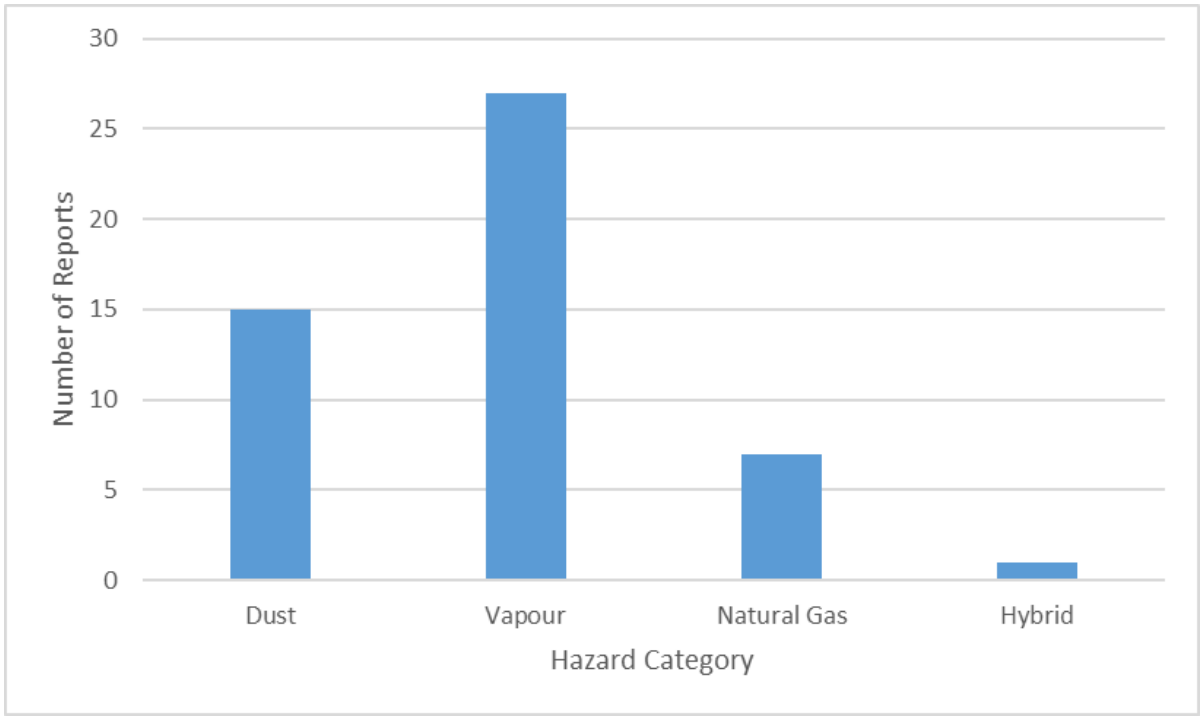

Figure 1: Overview of Gexcon Assessments by primary Hazard Category

Many sites have both dust and gas/vapour hazards, however it is normally possible to determine the "primary" hazard. For example, a manufacturing site using wood would have significant generation of combustible dust, but would likely also have

some possibility for vapour releases in some areas such as flammable cabinets and gas bottle cages etc. In this example, the primary hazard would be considered to be dust. In one case, it was impossible to determine which hazard was the primary hazard as the site had significant issues related to both dusts and vapours. This has been considered as a hybrid hazard.

Over 50% of the assessments were primarily vapour sites, encompassing everything from chemical and petrochemical sites through to automotive sites. Another 30% were primarily combustible dust sites; Gexcon has historically conducted a significant number of dust assessments. These sites are either manufacturing, food and drink, or biomass. Recently, this has included a lot of wood pellet biomass.

Natural Gas-specific sites were drawn out as a separate category because these sites typically represent energy centres or similar facilities using low pressure natural gas, where the aim is to achieve a Zone 2 NE ("Negligible Extent") using IGEM/UP/16 [2] or IGEM/SR/25 [3]. Because the focus for low pressure natural gas installations is on eliminating hazardous atmospheres by achieving a Zone 2 NE, recommendations tend not to be related to ignition source control (as evidenced by Figure 2). Hazardous area classification for vapours is typically conducted using EN 60079-10-1 or Energy Institute Model code of safe practice Part 15: Area classification for installations handling flammable fluids ("EI 15") where the site primarily handles flammable liquids. For dusts, EN 60079-10-2 is used for Hazardous Area Classification.

The average Gexcon report contained 30 recommendations, approximately 8 of which (23%) related to control of ignition sources. The other recommendations could be related to a number of things, including improvements to ventilation, control of dust layers (housekeeping), signage, or any other relevant recommendation. Figure 2 shows the breakdown by hazard category:

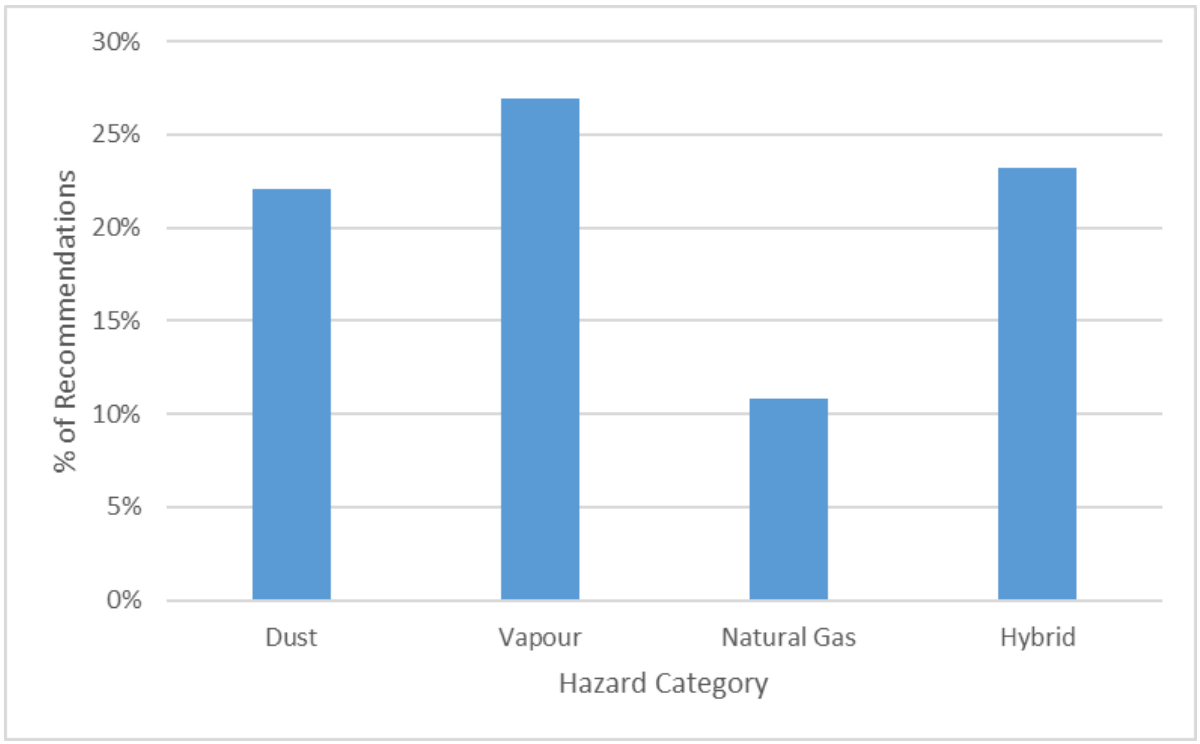

Figure 2: Percentage of Recommendations relating to Ignition Source Control, by Hazard Category

As discussed previously, facilities using natural gas tend to be focused on removing all hazardous zones and therefore ignition control is less of a focus. Facilities with combustible dusts tend to have slightly fewer recommendations relating to ignition control than facilities with flammable vapors, primarily because removal of dust layers and reduction of dust release from the process tends to be quite important.

The overall breakdown of the recommendations by ignition source is given below:

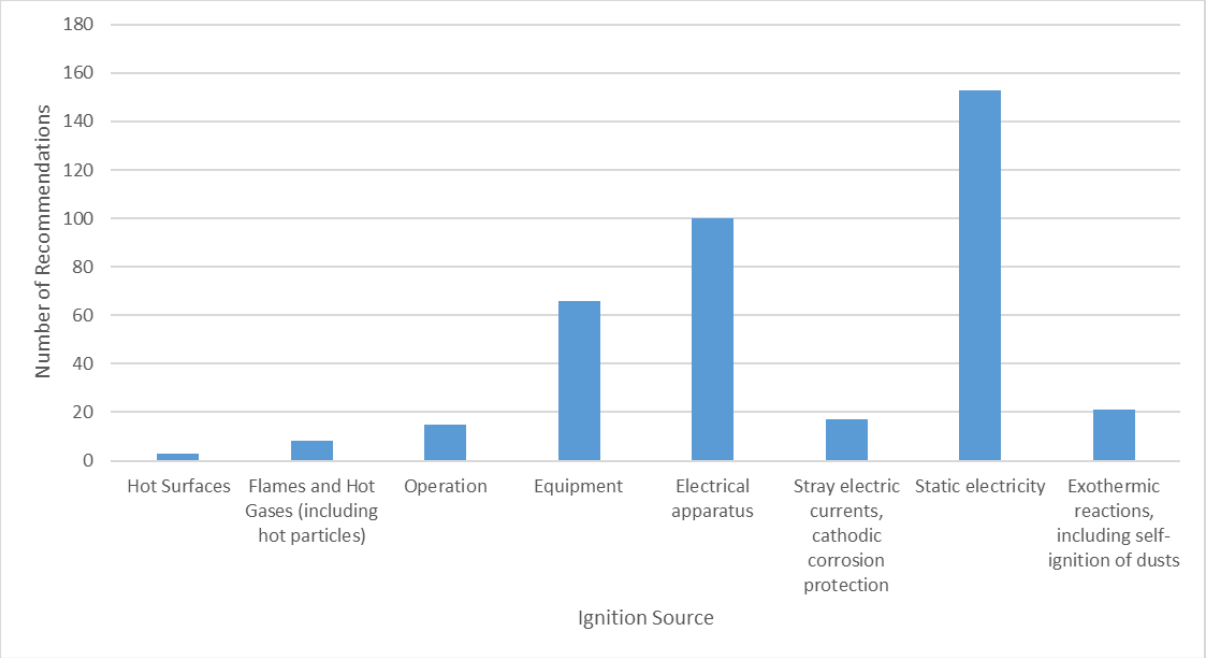

Figure 3: Gexcon Recommendations by EN 1127-1:2015 Ignition Source

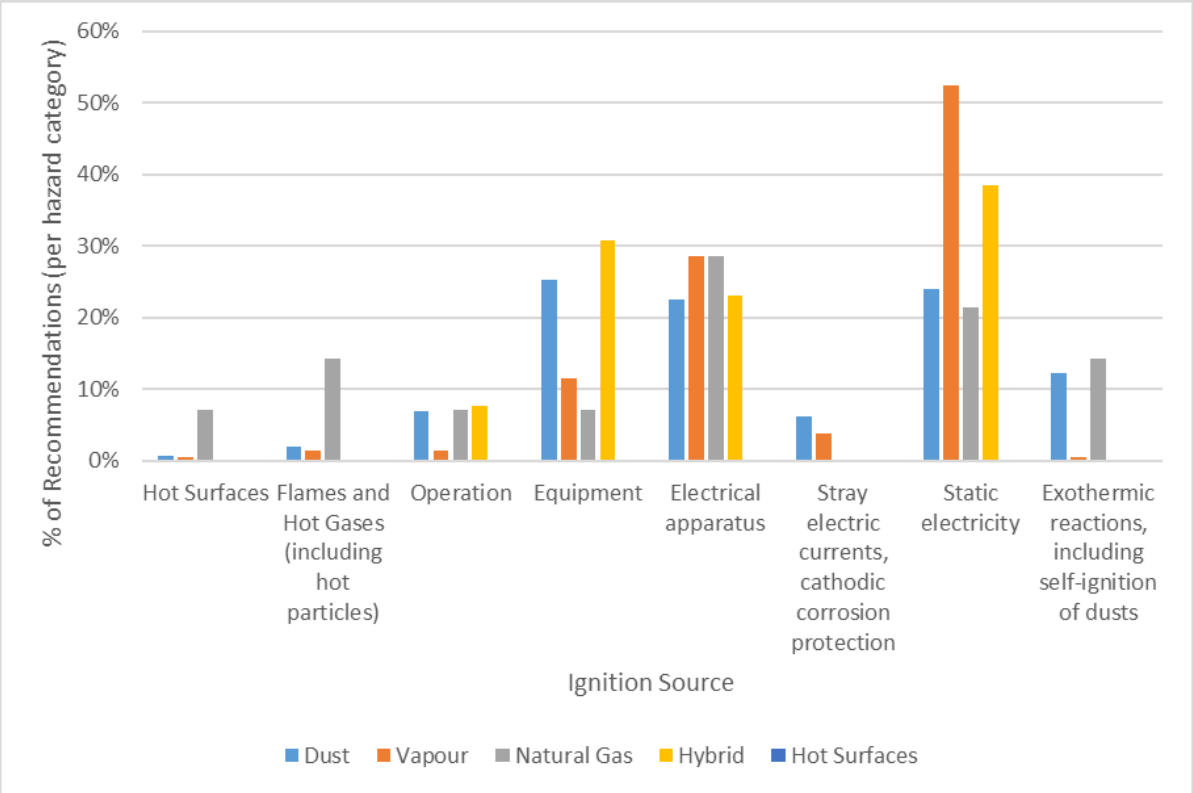

Figure 4: Gexcon Recommendations by Hazard Category

Figure 4 clearly shows that facilities whose main hazard is flammable vapours have significant issues related to static electricity, with over 50% of ignition-related recommendations relating to static electricity. Commonly, this relates to earthing of equipment, static dissipative footwear and flooring. This is followed by non-ATEX electrical equipment and then by non-ATEX mechanical equipment.

For sites handling combustible dusts, the primary ignition-related recommendations are related to non-ATEX mechanical equipment followed by electrical apparatus and static electricity. The last finding is surprising because relatively few dusts are

susceptible to static, although Gexcon deals with a number of clients who do have such dusts. Additionally, it is occasionally assumed dusts are static sensitive before testing has been carried out, although typical practice would just be to recommend testing. Many dusts lack good data, which is a perennial issue – suppliers simply do not conduct the testing that would be required to make this judgement.

Literature Review

Some 51 events were identified from the literature. Some data was available from the IChemE's accident database [7], although appears to no longer be "live", and most ignited event details are now quite old. Additional information came from the US Chemical Safety Board [8], and in particular the Combustible Dust Incident Reports (also from the US). The 2018 [9], 2017 [10] and 2016 [11] reports were used.

RIDDOR (Reporting of Injuries, Diseases and Dangerous Occurrences Regulations) data published by the HSE was also reviewed, however the RIDDOR reporting requirements do not mandate any information regarding ignition sources or much information regarding the nature of the incident. For instance, it is not even possible in many cases to determine whether the event involved dust, gas or vapours.

32 of the events were related to combustible dusts (due to the quality of the Combustible Dust Incident Reports) and 19 were vapour related. No energy centre/natural gas events were present in the literature so this category of events is not included here.

However, with all sources there were often issues determining what the actual cause of ignition was most likely to be. There appears to be no consistent way of recording ignition sources in incident reports. For example, it was often impossible to determine from the incident report whether a "spark" was caused by mechanical impact, failed electrical equipment, or by static. This meant that many incidents could not be included in this numerical assessment.

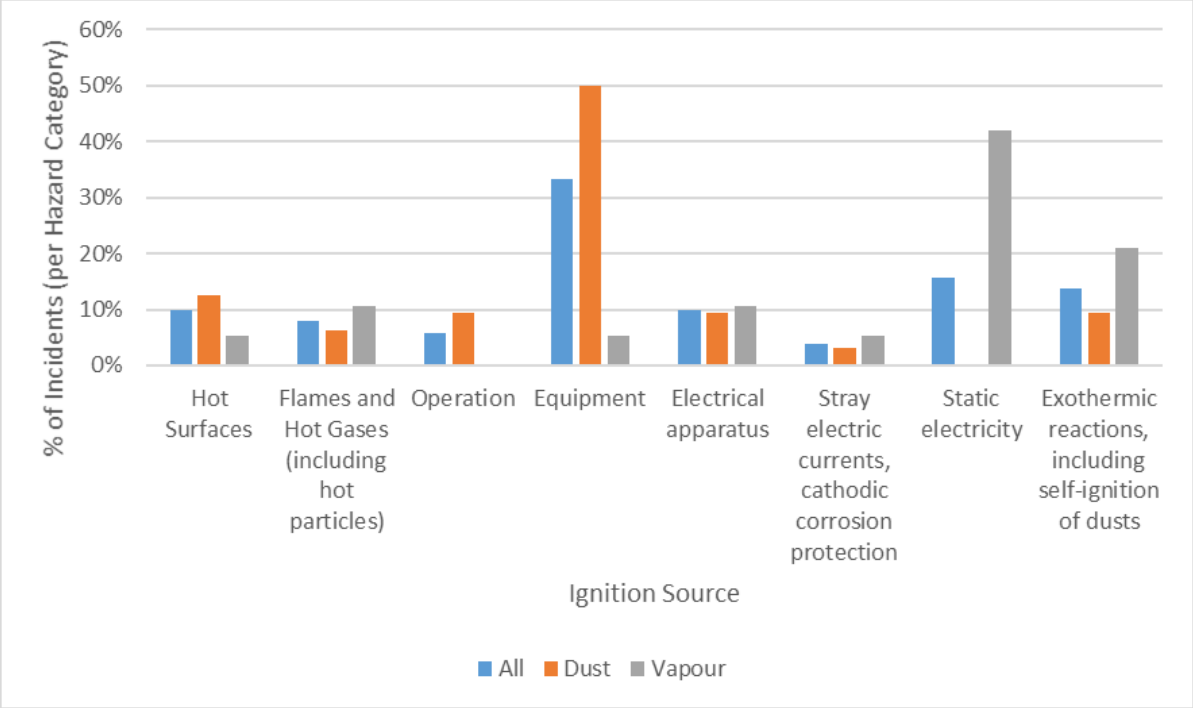

Figure 5 gives the distribution of ignition sources for all events identified in the literature.

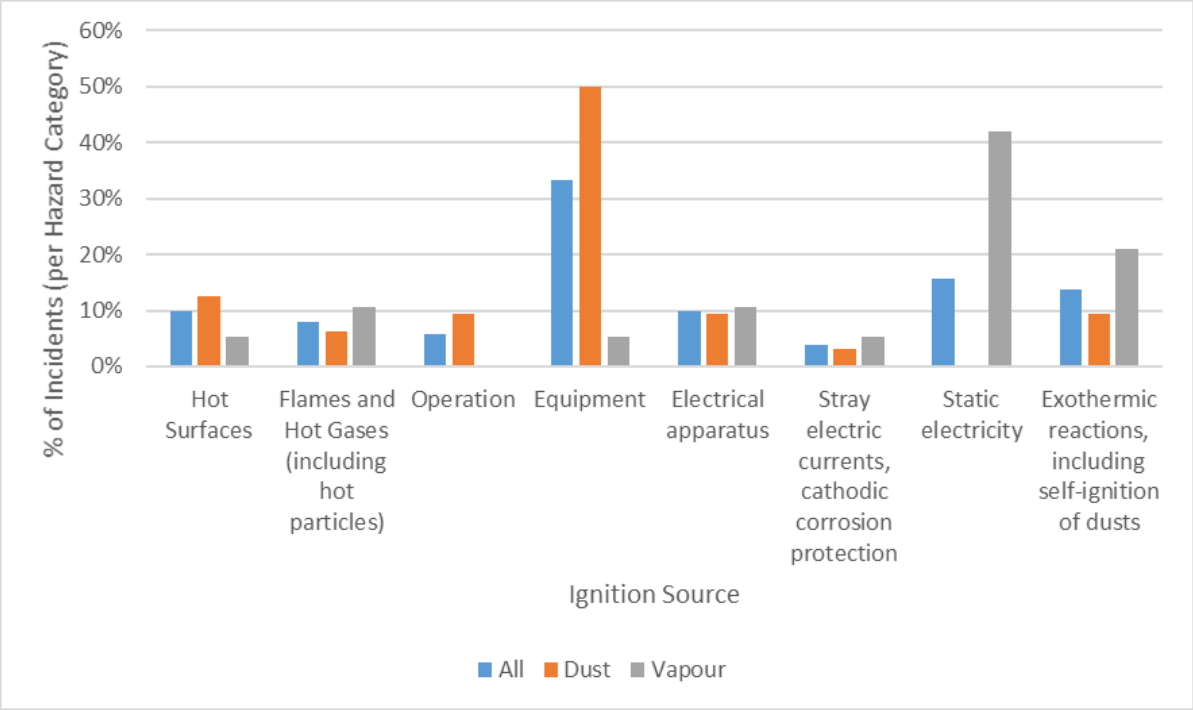

Figure 5: Literature Incidents by Ignition Source

Mechanical equipment was by far the most common cause of ignition for dusts, and static for vapour. The comparison with the Gexcon DSEAR Assessments and engineers' experiences with real events is presented in a later section.

Personal Experiences

For this part of the analysis, engineers from Gexcon UK were asked to provide anonymous information on the ignition sources from various events they were aware of. The engineers surveyed have over a century of combined experience in the industry, which included over 28 ignited events, 11 of which relating to dust and 17 to vapour.

It became clear in this analysis that the vast majority of these smaller events had not been reported outside of the relevant company (and often inconsistently within the company). Only one or two of the events are covered in any independent literature or news sources.

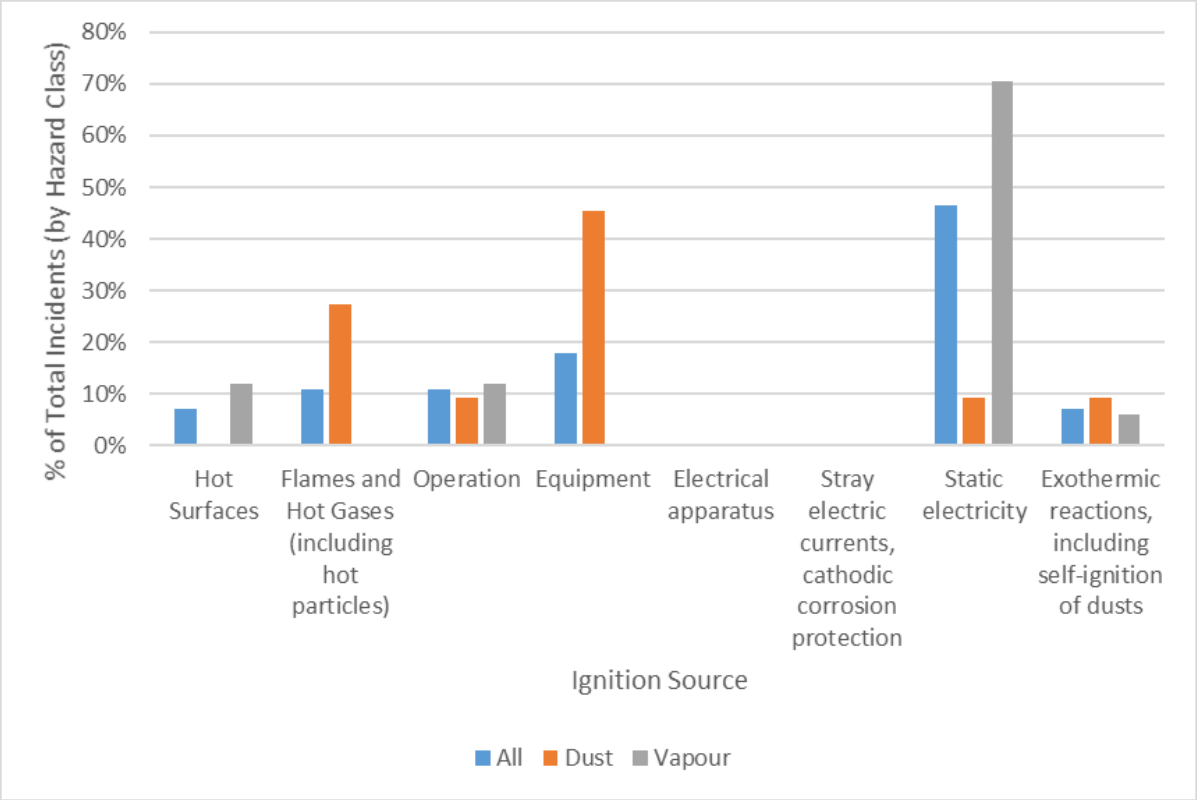

Figure 6: Gexcon Incidents by Ignition Source

Comparison

The following figures present a summary of the findings from the three sources discussed in the previous sections (Gexcon reports, Gexcon experiences of real events and literature). Figure 7 covers all facility types, Figure 8 covers facilities primarily handling dust and dust events, and Figure 9 covers facilities primarily dealing with flammable vapours and vapour events.

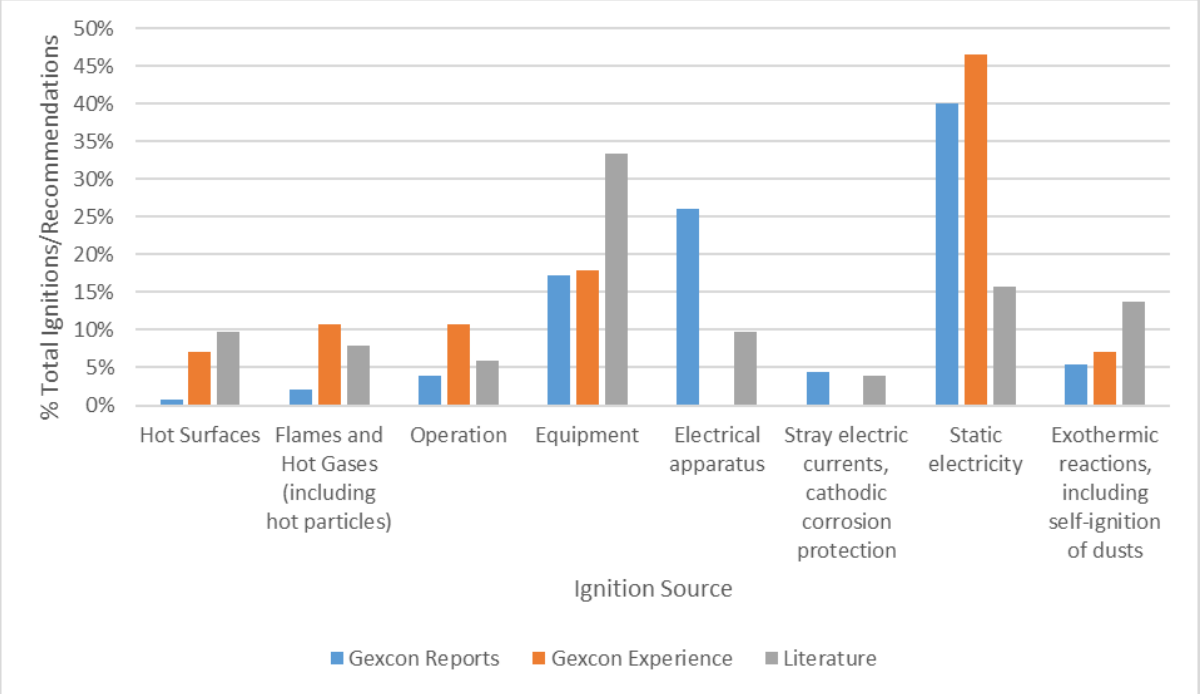

Figure 7: Comparison of Ignition Sources, All Hazard Categories

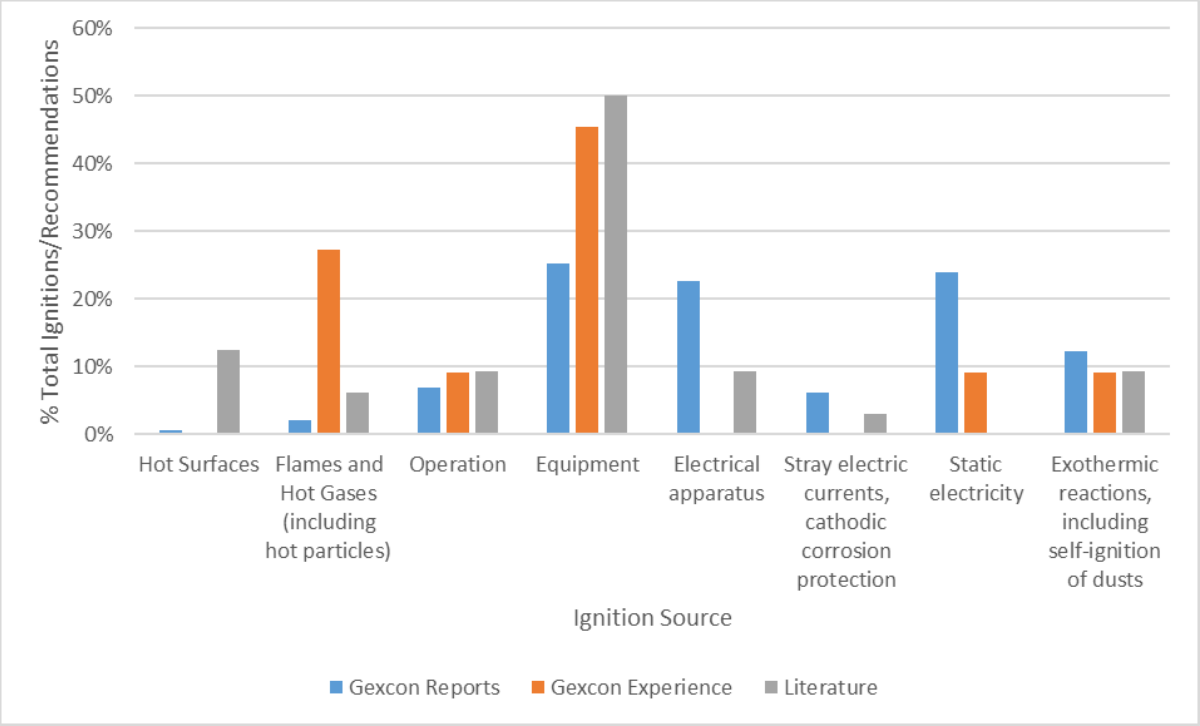

Figure 8: Comparison of Ignition Sources, Dust Events

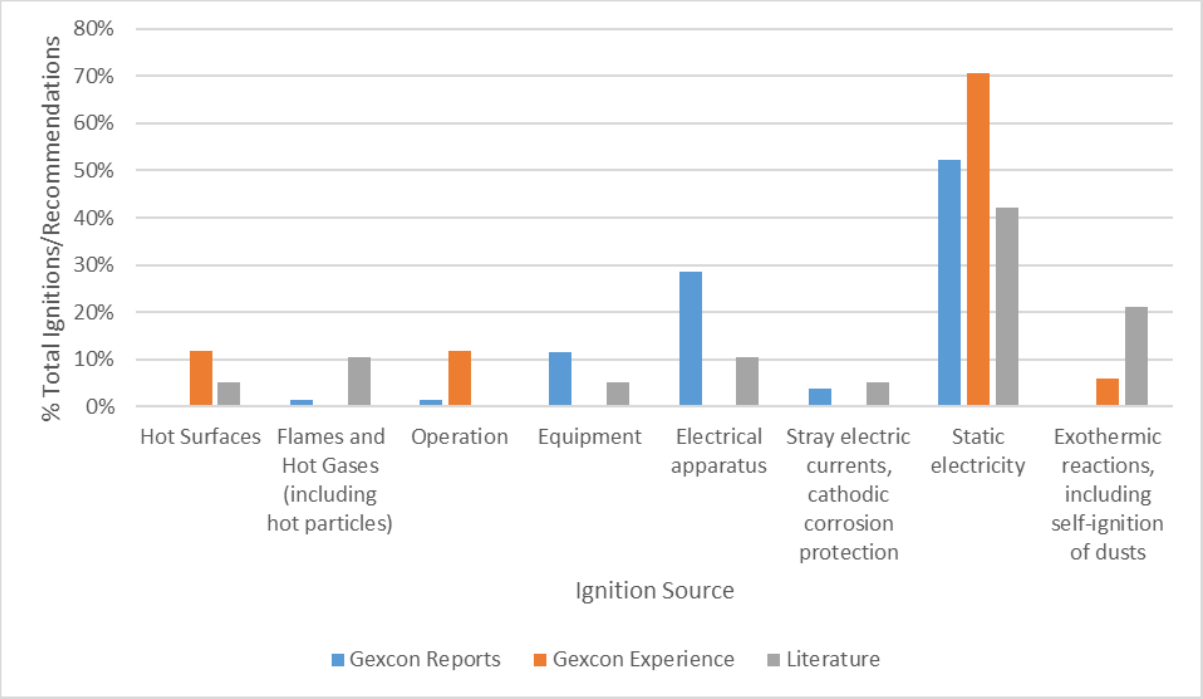

Figure 9: Comparison of Ignition Sources, Vapour Events

Figure 7 shows that static electricity is the key ignition source which Gexcon recommendations focus on and are present in Gexcon's experience of incidents. Figure 9 shows that this is the key ignition source in all 3 categories with regards to vapour incidents. The elevated percentage of static ignitions in Gexcon's event experience compared to the literature may possibly relate to the fact that smaller events tend to be underreported in the literature, and many static ignitions Gexcon has dealt with have been relatively small (flash fires etc.).

For dust events, ignition sources related to mechanical equipment are the most common.

Gexcon assessments tend not to have specific recommendations on hot surfaces, a general recommendation is typically included to the effect that hot works will be controlled using an adequate Permit to Work process. It is very difficult to make

a judgement on the effectiveness of hot works controls during a site survey which is of short duration, as we may not see any hot works being carried out on that day. Potentially, Gexcon should be making more specific recommendations relating to hot surfaces. This warrants further review.

Key Assumptions and Limitations

The assessment rests on the following key assumptions:

- That the reported ignition sources are broadly accurate
- That events in the US are comparable with those in the UK. This seems appropriate given the processes are no different.

The assessment also has several limitations.

Initially the intention was to conduct some temporal analysis of recommendations versus real ignition sources. However, due to limitations with literature evidence, especially recent literature evidence, it was very difficult to develop any trends over the past 10 years without devoting significantly more time to researching individual events.

Secondly, it became apparent that many smaller events simply are not reported and disseminated widely, which means the analysis of frequent smaller events relies entirely on Gexcon staff members personal experiences. These may not be representative of all sites (although Gexcon works across a very wide range of industries and companies which should minimize this issue).

Thirdly, the sample size of events which Gexcon has experience with is quite small (27 incidents vs. 50 Gexcon reports reviewed and 51 from the literature). For example, it appears from these incidents that static electricity is a more common ignition source in smaller events than in the larger events that are typically reported in the literature, however this can only be a qualitative conclusion because the sample size is fairly small.

Conclusions

It is clear from the comparison between incidents in the literature and Gexcon's experience with clients that there is a significant incidence of ignited events which do not get reported, generally because there were, fortunately, no injuries. Gexcon also has knowledge of relatively serious incidents involving explosions which were misreported in the media as "fires", and others which may have only made local news.

Additionally, the precise cause of ignition given in published reports in some incidents can be ambiguous and difficult to group according to EN 1127 [1], which makes the risk assessment process more difficult because the guidance for risk assessments cannot easily be compared with real events..

The combination of these two factors mean that effective assessments are heavily reliant on experience (or possibly high quality training of assessors).

From this it is possible to identify clear gaps in certain areas, especially around the typical sources of ignition:

- Non-ATEX Electrical Equipment is a common recommendation in Gexcon reports, and a common ignition source in the (typically larger) literature incidents
- Poor earthing and static control leading to static ignitions is very common (particularly with sites handling solvents)
- Failed mechanical equipment (especially failed bearings), particularly for sites handling combustible dusts. This has been a particular issue in recent years with the increase in the biomass industry in the UK.

It is promising that the DSEAR assessments reviewed also identified these factors, but equally it is concerning that despite the long experience we have with these incidents (some of the literature data reviewed here was 30+ years old), assessments conducted by Gexcon very recently still identify the same problems. There could be several reasons for this:

- Gexcon recommendations may be unclear or difficult to implement. Discussion with clients indicates that this is probably not the case (for example, a recommendation to use anti-static PPE and install static dissipative flooring is quite clear)
- Sites may underestimate the likelihood or potential severity of these incidents. This could be exacerbated by the poor availability of detail on smaller and more recent incidents.
- Some sites conduct DSEAR assessments as a pure compliance, "check box" exercise. This is particularly concerning and is (unfortunately) fairly common anecdotally. Further review of Gexcon reports may be able to add some further classification here, although it would be impossible to compare this with the attitudes of site operators who have experienced events.
- Certain ignition prevention measures (especially ATEX mechanical equipment) can be difficult and/or expensive to purchase and install. This can be compounded

The issue around reporting of incidents has some serious implications:

- It is hard to get a realistic idea of the severity and likelihood of potential events just by reading the literature, therefore accurate assessments rely on the experience of assessors.

- Industry reporting of smaller events could be significantly improved. Recent, UK experience is hard to find. The HSE has a significant role to play in this, as do industry bodies including the IChemE. It was particularly disappointing to find the lack of detail in the RIDDOR data and in the IChemE's event database. Any improvements which can be made here could have significant positive benefits, as site operators and managers would have more concrete information regarding the potential accidents which could occur.
- Professionals reporting on incidents should use a consistent method for identifying ignition sources. Qualitative descriptions which vary between authors and publications. EN 1127-1 is suggested to be a sensible starting point.

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