Analysis of 985 fire incidents related to oil- and gas production on the Norwegian continental shelf

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ABSTRACT: Fire is a major threat in the petroleum industry. However, little has been published about the fire related incidents that have occurred in the Norwegian petroleum sector. To gain more knowledge, data from 985 incidents in the 1997 - 2014 period has been analysed. Examples of factors studied are type of facility involved, involved area or system, consequences and severity level. The analysis of the fire incidents reveals that even though many incidents are reported, the large majority of these have not imposed risks for severe fire accidents. It has also provided valuable information regarding possible dangerous situations, commonly involved areas, types of equipment as well as types of activity that were involved. Twenty-nine percent of the incidents were false alarms, which must be regarded as a high number in an industry where any production stop could be extremely costly.

1 INTRODUCTION

In Petroleum Safety Authority Norway's (Ptil) assessment of the risk level in the petroleum industry on the Norwegian continental shelf, defined situations of hazard and accidents (DFUs) are defined and utilised. A DFU is an unplanned event which has led, or may lead, to loss of life and other values. Also, a DFU must be an observable event which it is feasible to measure accurately (Vinnem et al., 2006). Different DFUs are associated with different risk areas. According to Ptil's annual report on trends in risk level, there has been a declining trend in DFUs occurrences associated with major accident risk from 2004 to 2014 (Petroleum Safety Authority Norway, 2016). In the period there were no hydrocarbon fires, but there were hydrocarbon leakages with ignition potential. However, a fraction of the observed DFUs were fires and explosion not involving hydrocarbons. Even though fire occurrences are few compared with other DFUs, fires have disastrous potential, and a fire preventive focus should be maintained.

The current study has a quantitative approach and look in depth into the fire incident statistics, with false alarms included, to gain more knowledge about the incidents, where they occurred and what their outcomes were, in order to found a basis for future work aiming to improve fire safety, improve detection reliability and prevent false alarms in the petroleum industry.

2 DATASET

The dataset which found the basis for this study is an extract of Ptil's fire incident statistics. RISE Fire Research received authorization from Ptil to analyse this set of data, and gained access to all relevant incidents over the defined period of time. The database contains fire incidents, small and large, which are systematically reported to the authority. The sample comprises 985 reported incidents from all facilities and operators in the areas within Ptil's jurisdiction in the 1997 – 2014 period. The incidents included in our selection were reported as one of the following incident types: ignited hydrocarbon leakage, fire/explosion in other areas, fire/explosion in other areas (not hydrocarbon fire), and fire/explosion in other areas (not hydrocarbon explosion).

The dataset comprise information about time of the event, at which facility and in which area or system it occurred. Furthermore, the severity together with actual and potential consequence of the incidents are classified and registered. Also, there is a free text field where each incident is described in short.

The severity of the incidents is assessed and reported according to a 5-point scale, where the different values are defined as follows: 1–not notifiable, 2–simpler follow-up, 3–potential under minor changes, 4–severe or 5–large potential / serious accident / death.

3 METHOD

In the current study, the analyses are based on fire statistics from Ptil. The study has a quantitative approach, which implies that the individual cases have not been studied in detail, except for information extracted from free text fields in the statistics database. The results from the analyses are presented as descriptive statistics.

4 RESULTS

4.1 *Sample description*

During the 1997 - 2014 period there were 985 reported fire incidents on the Norwegian continental shelf. From 14 incidents the first year of the period, there has been an increase over the period, ending on 66 incidents in 2014. In 2006, there was a peak with 84 reported incidents, see Figure 1.

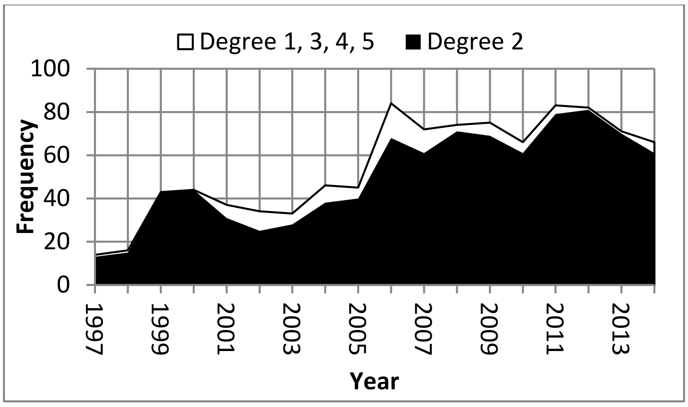

Figure 1 Number of reported incidents, distributed over severity degrees. Degree 2 (n = 898) is presented as one category, whereas degrees 1 (n = 15), 3 (n = 3), 4 (n = 63) and 5 (n = 6) are collapsed into one category for readability, N = 985.

The figure shows the development in number of incidents, distributed over severity degree over the period. Most incidents (91.2 %) are classified with severity degree 2, which are incidents which require minor follow-up, whereas the remaining incidents are classified as one of the other severity degrees. For readability, the incidents in these categories are presented as one bulk in Figure 1. Most of the incidents in this bulk were incidents with severity degree 4 (n = 63). In addition there were 6 serious accidents (degree 5).

There is a leap in number of incidents from 2005 to 2006. The average number of incidents for the years before the leap, i.e. 1997 – 2005, is 35, whereas the corresponding number for the 2006 – 2014 period is 75. This corresponds to a 216 % increase. As will be demonstrated in section 4.5, this is related to an increase in the number of reported false alarms.

Further, 2006 also stands out because the number of incidents with severity degree 4 is over twice as high as any other year in the period (15 incidents, compared with the year with the second highest number of degree 4 incidents: 7). The median over the period is 4.

A vast majority of the reported incidents occurred on fixed installations (73 %), whereas one out of five incidents was related to movable installations. A minor proportion (6 %) was incidents occurring in onshore facilities.

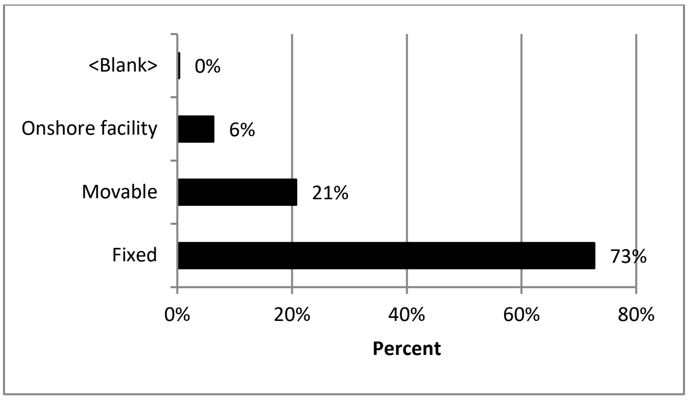

Figure 2 Distribution of incidents between different facility types, N = 985.

Over 70 % of the incidents were real fire and explosion incidents. However, as Figure 3 demonstrates, a vast majority of the incidents were non-hydrocarbon fires, but rather fires in electrical systems, overheated machinery etc. Almost one third of the incidents were classified as false alarms.

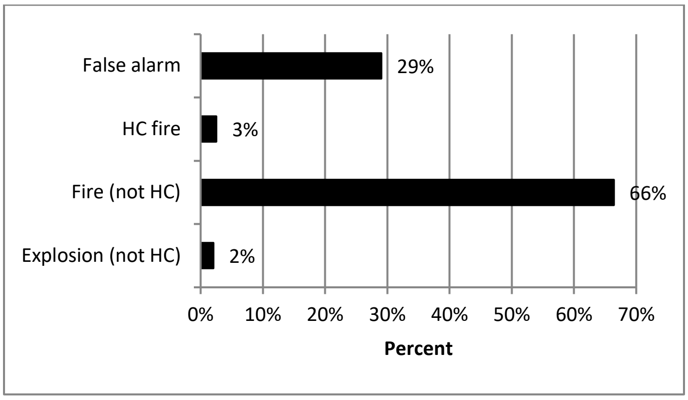

Figure 3 Actual outcome of reported alarms, N = 985.

4.2 *Type of area/system involved*

The incident reporting system on which this analysis is based upon is designed so that there is one variable to register both the area and system involved, i.e. one cannot discriminate between different systems in one specific area. E.g. a fire may start in an electric installation, but it is not specified if the electric installation is in the living quarter, main process or other areas of the facility. In Figure 4, and the figures following, areas and systems have been split into two separate groups, where the first group represent areas and the second group represent systems. The areas and systems are sorted with descending number of reported incidents within each group.

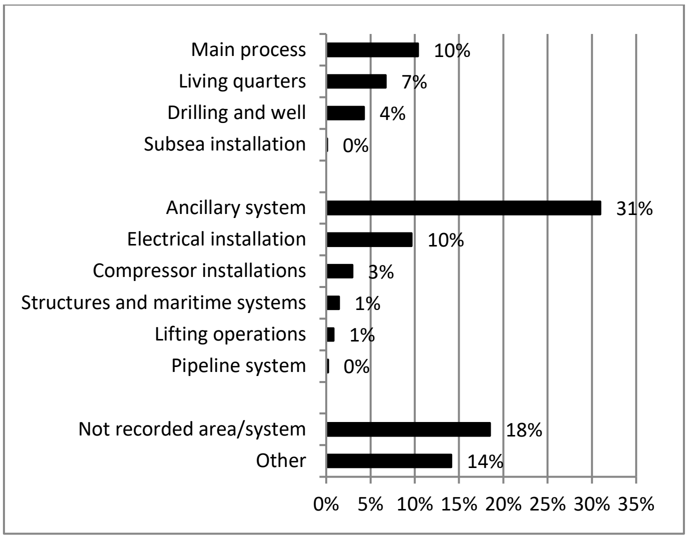

Figure 4 Distribution of incidents between different areas (top group) and systems (middle group). Incidents without recorded area or system is shown in the bottom group, N = 985.

Further, incidents with no area or system recorded, or incidents in other areas or systems constitute a third group. The categories in the latter group are relatively large, with 18 % and 14 % of the incidents, respectively. The majority of the incidents within these categories (88 %) were reported between 1997 and 2002. Also, it is seen that there is a distinction between the categories. While most of the incidents tagged with "Not recorded area/system" were reported before 2002, the main part of the incidents tagged with "Others" was reported after 2004.

With reference to Figure 4, one sees that of all reported incidents, nearly one third occurred in ancillary systems. These systems comprise, among others, communication systems, electrical power supply systems and water treatment facilities. In short, systems not related to separation, production and transport of hydrocarbons. An equal proportion incidents occurred in areas and systems not specified. The remaining incidents were distributed over main process (10 %), electrical installations (10 %), living quarters (7 %) and others (9 %).

4.3 *Consequences*

Of the 985 reported incidents in the period, only 8 % resulted in drilling downtime whereas 23 % caused production stoppage.

Not surprisingly, one fifth of all incidents causing drilling downtime occurred in the drilling and well area, see Figure 5. Of all incidents causing production stoppage, half of them occurred in the main process and one third occurred in the drilling and well area, see Figure 6.

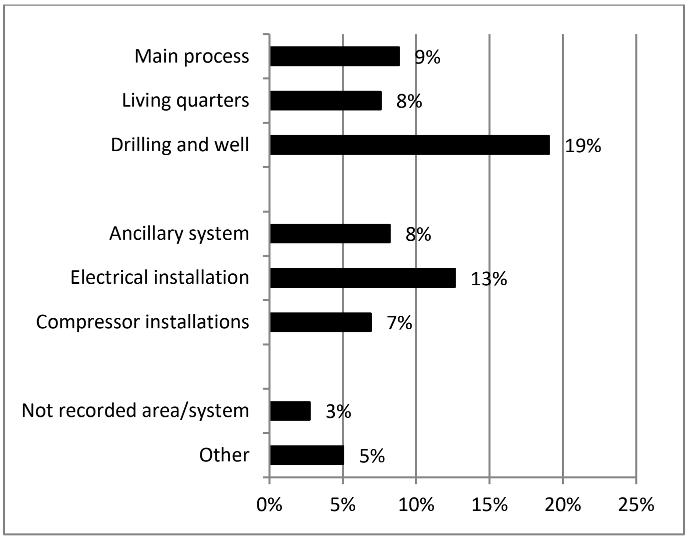

Figure 5 Incidents causing drilling downtime, distributed over the area or system the incident occurred in. Areas and systems with fewer than 20 reported incidents are excluded from the figure, n = 76.

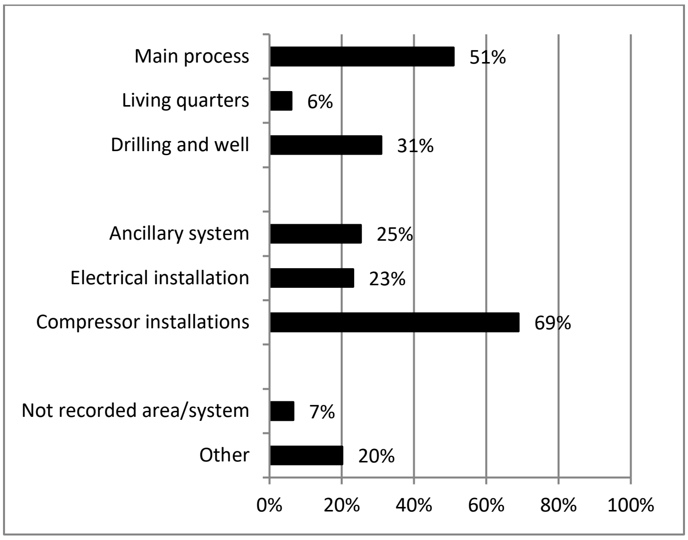

Figure 6 Incidents causing production stoppage distributed over the area or system the incident occurred in. Areas and systems with fewer than 20 reported incidents are excluded from the figure, n = 231.

4.4 *Severity level*

The vast majority (91 %) of the reported incidents were classified as incidents requiring simpler follow-up (severity degree 2), whereas only 3 incidents (≈0 %) had the potential of becoming a severe situation under minor circumstantial changes (degree 3).

Six percent of the incidents were regarded as severe (degree 4) and <1 % (6 incidents) had a large potential or were large accidents, but none resulted in fatalities. Three of these occurred at onshore facilities. In addition, there were 15 incidents (2 %) which had the lowest severity degree (degree 1), even though these incidents are not notifiable.

Examples of incidents on severity level 3 are fires that were extinguished after a short period of time, either by automatic extinguishing systems or by manual effort. A fire in an HVAC module with smoke spread to the living quarter, on the other hand, was classified as severity degree 5.

It is not straight-forward to analyse trends in severity degree over time, since there are few incidents with severity degree other than 2. However, it is seen qualitatively that the proportion of incidents with severity degree 4 is lower in the period 2008 – 2014 (average 3,4 %) than it was between 2001 – 2007 (average 12 %). The same trend is seen when adjusting for the increase in false alarms after 2006 which yields a decrease in degree 4 incidents from an average of 19.5 % in the first period to 5.3 % in the second period. Also, there has not been an incident with severity degree 5, since 2008. It therefore seems that there is a decline in the degree of severity of the incidents in the sample over time.

When studying the distribution of the incidents with severity degree 3 or higher over the different areas and systems, it is seen that most incidents occur in the main process and drilling and well areas, see Figure 7. Correspondingly, one fourth of the incidents with this severity took place in ancillary systems and 15 % in electrical systems.

Even for these degrees of severity, there are around one fifth of the incidents, whereof one incident was classified as *large potential / serious accident / death* (degree 5), where area or system has not been recorded.

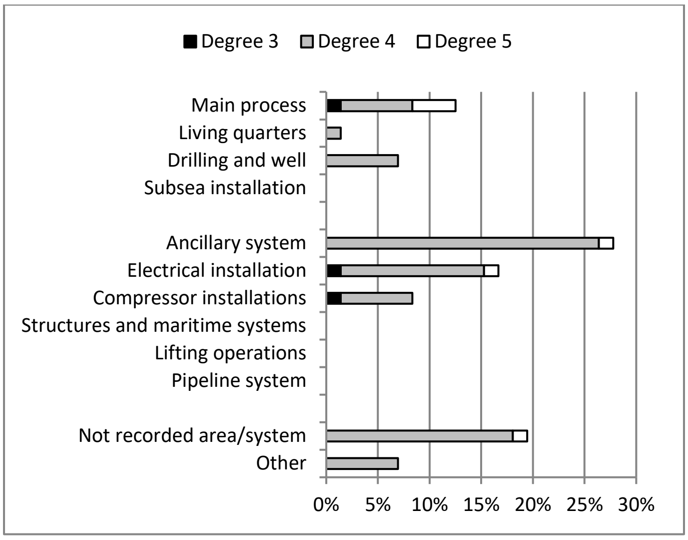

Figure 7 Incidents with severity degree 3 (n=3), 4 (n=63) or 5 (n=6), distributed over different areas and systems, total n = 72.

4.5 *False alarms*

False alarms are alarms caused by other circumstances than fire and explosion. According to ISO/DIS 17755-2, a false alarm is an alarm for which no fire occurred or […] due to accidental operation of fire alarm devices (ISO, 2010). The most frequent causes observed in the sample were detectors malfunctioning, misinterpretation of the situation by the detection system, technical and human errors. Examples of misinterpretations are sandblasting dust being detected as smoke, heat from sauna detected as heat from fire, heated leakage of lubricating oil detected as smoke and steam from cleaning detected as smoke.

The number of false alarms was quite low in the first half of the focus period, see Figure 8. Up until 2005, there were only a few cases, whereas in 2006 there is a leap, and in the years following the average number of false alarms per year is 29. This is probably not a real increase in false alarms, but rather an effect of a new reporting scheme, where more incidents are included than before.

From 2006 towards the end of the period, there is a seemingly decrease in the number of false alarms. However, the trend has not been checked statistically or adjusted for changes in the petroleum activity on the continental shelf.

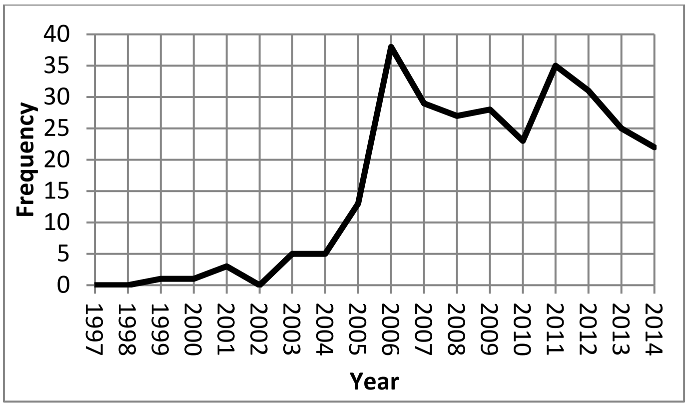

Figure 8 Number of reported false alarms each year, n = 286.

One third of all false alarms occurs in relation to ancillary systems, and one fifth occurs in the main process, see Figure 9. In fact, when taking into account the number of incidents in each area or system, it is seen that 60 % of all reported incidents in the main process are false (Figure 10). This is almost twice as large proportion of false alarms than any other area or system (disregarded the incidents categorised as “other”, as this category most likely constitutes numerous sub-categories).

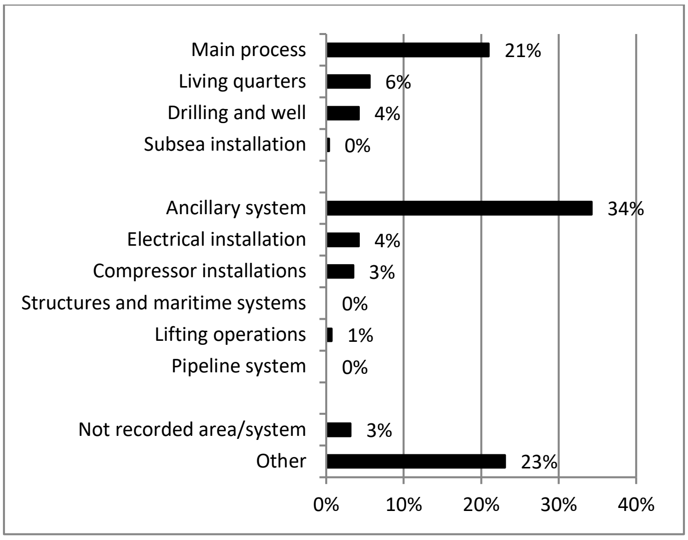

Figure 9 False alarms reported, distributed over areas and systems, n = 286.

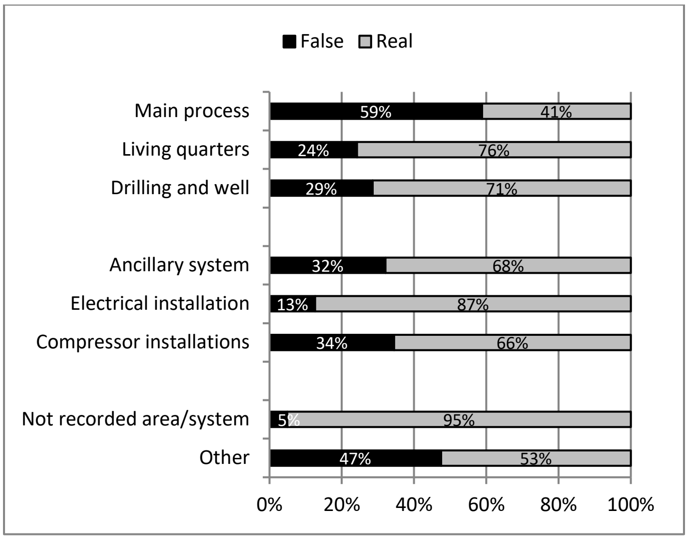

Figure 10 Proportion of real and false alarms for each area and system. Areas and systems with fewer than 20 reported incidents are excluded from the figure. Main process n = 102, living quarters n = 66, drilling and well n = 42, ancillary system n = 305, electrical installations n = 95, compressor installations n = 29, not recorded n = 182, other n = 139, total n = 960.

Table 1 The number of false alarms which caused either drilling downtime or production stoppage.

Area / system	Caused drilling downtime [freq.]	[%]	Caused production stoppage [freq.]	[%]	n
Main process	6	10 %	39	65 %	60
Living quarters	2	13 %	1	6 %	16
Drilling and well	1	8 %	4	33 %	12
Subsea installation	0	0 %	1	100 %	1
Ancillary system	6	6 %	30	31 %	98
Electrical installation	0	0 %	1	8 %	12
Compressor installations	0	0 %	7	70 %	10
Structures and maritime systems	-	-	-	-	0
Lifting operations	0	0 %	0	0 %	2
Pipeline systems	-	-	-	-	0
Not recorded area/system	0	0 %	3	33 %	9
Other	5	8 %	23	35 %	66
All	20	7 %	109	38 %	286

Table 1 presents an overview of how many of the false alarm incidents, in each area or system, which caused either drilling downtime or production stoppage. The table should be read with caution, as some of the areas or systems have very few incidents, which may yield large percentages.

Nonetheless, 7 % of the false alarms resulted in drilling downtime and 38 % caused production stoppage. In addition, a total of 129 false alarm incidents (45 %) resulted in personnel mustering to life boats.

Furthermore, 65 % of the false alarms occurring in the main process caused production stoppage. Similarly, 31 % of the false alarms caused by ancillary systems had the same consequence.

Fewer false alarm incidents caused drilling downtime. Again, false alarms occurring in the main process or ancillary systems are the main cause for drilling downtime.

5 DISCUSSION

5.1 *Incidents*

Over the 18 year period there were almost 1000 reported fire incidents on the Norwegian continental shelf, and it is seen that there was almost twice as many incidents in the second half of the period compared to the first half. The increase is probably an effect of a shift in reporting regime, where more incidents (mostly false alarms) than before were included. There is therefore reason to believe that there were even more incidents in the first half of the period than what has been reported, but that most of the unreported incidents were false alarms incidents.

The analysis of the fire incidents reveals that even though many incidents are reported, the large majority of these have not imposed risks for severe fire accidents. There also seems to be a positive trend regarding the severity degree of the fire incidents, as there is a decline in the number of severe incidents and major accidents. However, the current analysis has not adjusted for the activity level in the Norwegian sector or other possible covariates. Also, in general one should be careful to draw any conclusions based upon the trend of a single indicator, as there may be other indicators not investigated in the current study which may affect the fire safety level negatively (Vinnem, 2010; Vinnem et al., 2006).

Also, since the current study is retrospective in nature, it is important to emphasize that a possible change in the conditions which may affect the fire safety level will not be observed in the incident statistics until later, and that the apparent trend is only valid for the focus period (Vinnem et al., 2006).

The current study does not conclude on the underlying causes of fires offshore. Future studies should therefore focus on revealing such causes in addition to triggering factors for the fire incidents. This can be done by examining investigation reports from the different incidents and by performing interviews with key personnel with the operators. A study with such a design, investigating the underlying causes for 35 fires in electrical equipment on offshore platforms in the Norwegian sector, is reported in (Storesund et al., 2012). The study categorised the causes according to the Human–Technology–Organisation perspective, which may be helpful when trying to sort and reveal patterns in causes and find suitable and targeted measures.

5.2 *False alarms*

A great proportion of the reported incidents in the period were false alarms, and a relatively large fraction of these have been shown to cause production downtime and consequently economical losses. The classic ever-returning dilemma of smoke and fire detection is that increasing the detectors' sensitivity to detect fires as early as possible also causes an increase in number of false alarms. Correspondingly, decreasing the sensitivity to eliminate false alarms affects fire detection time negatively.

One of the main reasons for false alarms is that the detection system misinterprets the situation, and for instance takes steam or dust as smoke. However, detection systems have become smarter and there are several technologies available that contribute to reduce the number of false alarms caused by misinterpretation of the situation.

E.g. studies have shown that multi-sensor detectors with CO sensor can both decrease detection time for certain types of fires in addition to reducing the number of false alarms (Cestari et al., 2005; Sesseng et al., 2016; Sesseng and Reitan, 2016). The mentioned studies have only investigated the residential case, and there may be areas where such detectors are not suitable. Still, there is reason to believe that many areas may take advantage of this technology, e.g. living quarter, workshops etc.

The next main causes for false alarms are technical errors and malfunctioning detection systems. At the same time, compared to other barrier elements, fire detection systems have the lowest failure rate when tested. Each year, some 50,000 tests of fire detectors are performed on offshore facilities in the Norwegian sector, and since the beginning of the reporting of these tests in 2002 the mean fail rate has been declining. In 2002, around 0.9 % of the tested detectors failed the tests, whereas only 0.1 % failed in 2015 (Petroleum Safety Authority Norway, 2016, 2015, 2010; Vinnem, 2010). The trend is positive, and it should therefore be a continued focus on maintenance and testing.

The last main cause for false alarms is human errors. This could be due to work made in the proximity of a sensor, work during service and testing of the system or failure to comply with procedures. This is most likely best managed by improved routines for work and risk assessment as well as focusing on procedural compliance.

Obviously, if the number of false alarms can be reduced there will be great economic benefits. The majority of installations on the Norwegian shelf is ageing, and anecdotal evidence suggests that some having old or outdated detection systems. It should be investigated whether an upgrade of the fire detection systems could reduce the number of false alarms and, consequently the number of false alarms resulting in production stoppage and mustering.

5.3 *Reporting*

The current reporting scheme has certain shortcomings. By registering information concerning system and area in the same variable, information is lost. The obvious consequence is that one would have to choose to register either area or system, which would be at the reporter's discretion. Besides, a specific type of system, e.g. ancillary systems, could be found in several areas, but may constitute different risks in different areas, which makes the available information of limited value. The reporting scheme ought therefore to be changed such that more details regarding involved area and system are recorded.

A large number of incidents categorised as "Not recorded area/system" was reported before 2002. Almost half of the incidents categorised as "Other" were false alarms and could, through the free text description, be derived to specific areas / systems. This shows that in some ways the procedure and culture of reporting seems to have improved over the years. At the same time it appears that it may be difficult to categorise false alarms.

6 CONCLUSIONS

The numbers show that there is room for improvement regarding fire safety in the petroleum production on the Norwegian shelf. There are many incidents, although with low degree of severity. Future work should focus on investigating the underlying causes and triggering factors of the fire incidents, to be able to find focused fire preventive measures.

There is also a large number of false alarms, which may be quite costly if they cause production downtime. A more thorough investigation would be informative concerning what types of equipment are causing false alarms. This could found the basis for targeted measures decreasing the occurrence of false alarms and downtime and thus increasing the economic profit of the installations.

The numbers also show that severe incidents do not occur often, something that may be explained by good control of barriers. However, there are still some incidents that occur that have the potential of developing into a severe incident. Hence, there must still be a focus on barriers preventing the consequences of an escalating incident.

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