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A study on fire design accidental loads for aluminum safety helidecks

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Abstract

The helideck structure must satisfy the safety requirements associated with various environmental and accidental loads. Especially, there have been a number of fire accidents offshore due to helicopter collision (take-off and/or landing) in recent decades. To prevent further accidents, a substantial amount of effort has been directed toward the management of fire in the safety design of offshore helidecks. The aims of this study are to introduce and apply a procedure for quantitative risk assessment and management of fires by defining the fire loads with an applied example. The frequency of helicopter accidents are considered, and design accidental levels are applied. The proposed procedures for determining design fire loads can be efficiently applied in offshore helideck development projects.

Keywords: Fire accidents; Helicopter collision; Safety design of helidecks; Quantitative risk assessment and management; Design fire loads; Applied example

1. Introduction

Helicopters are the primary modes of transport for offshore platforms. They carry people, equipment and necessities to offshore installations. Unlike other transport, such as ships, helicopters take off and land on offshore installations. The offshore structures can therefore be damaged by helicopter accidents.

Many helicopter accidents (referred to as heli-accidents in this paper) have been reported over the last ten years (OGP, 2010a). Fig. 1 shows examples of heli-accidents on offshore platforms.

The frequency of heli-accidents is lower than for other events (explosions, fires, collisions or dropped objects), but they do also have the potential risk factor of fires, as combustibles, in the form of highly volatile fuel in fuel tanks, are always present in helicopters.

If a heli-accident occurs on a helideck, fuel can leak from the tank. Released fuel can cause a pool fire, which can structurally damage the helideck.

API (2006) and DNV (2001) recommend that fire safety facilities such as fire extinguishers, water sprays, fire resistant equipment, etc. are installed to prevent such structural damage. Also, SOLAS (2015) suggests the fire-fighting appliances regarding categories in Regulation 18 (Helicopter facilities).

There are, however, only recommendations for fire suppression facilities in the rules and standards, and the guidelines for structural safety designs to fire fighting and the definition of design fire loads are weak.

In particular, a helideck made from aluminum is sensitive to temperature and heat flux, compared with other materials such as carbon steel, stainless steel, nickel alloy, etc. A structural design for aluminum helidecks that specifically addresses the risk of fires is therefore necessary and should be developed.

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Nomenclature

F_{Fire} Fire frequency
$F_{Release}$ Leak frequency
$P_{Ignition}$ Ignition probability
α Scale factor of Weibull distribution
β Shape factor of Weibull distribution
μ Mean of normal distribution
σ Standard deviation of normal distribution

There has been extensive research into the fire risk assessment and management of topside structures on offshore installations (Spouge, 1999; Vinnem, 2007; Paik and Czujko, 2009, 2010, 2011, 2012; Paik et al., 2013). In addition, structural safety assessment of topside structure considering fire accidents is performed by Yanlin and Jang (2015). In spite of these efforts, different approach for helidecks is needed (Vinnem, 2007).

The aims of this study are to (i) introduce and (ii) apply a procedure for quantitative fire risk assessment and management for helidecks on offshore installations, and to (iii) define the design fire loads for helicopter collisions on helidecks, with applied examples.

In the present study, credible fire scenarios are selected in the procedure, and a reasonable accident acceptance level for helidecks is suggested, to help define design fire loads to ensure the structural safety of aluminum helidecks in case of fires.

2. A procedure for quantitative fire risk assessment and management

Unlike the prescriptive procedures associated with rules, standards or qualitative risk assessment and management (Paik

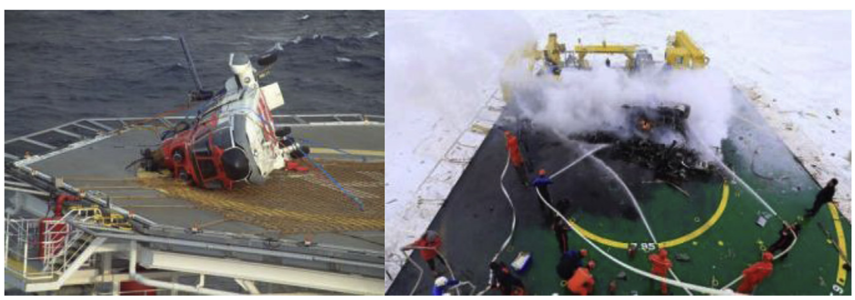


Fig. 1. Heli-accidents on West Navion (left, 2001) and Araon (right, 2013).

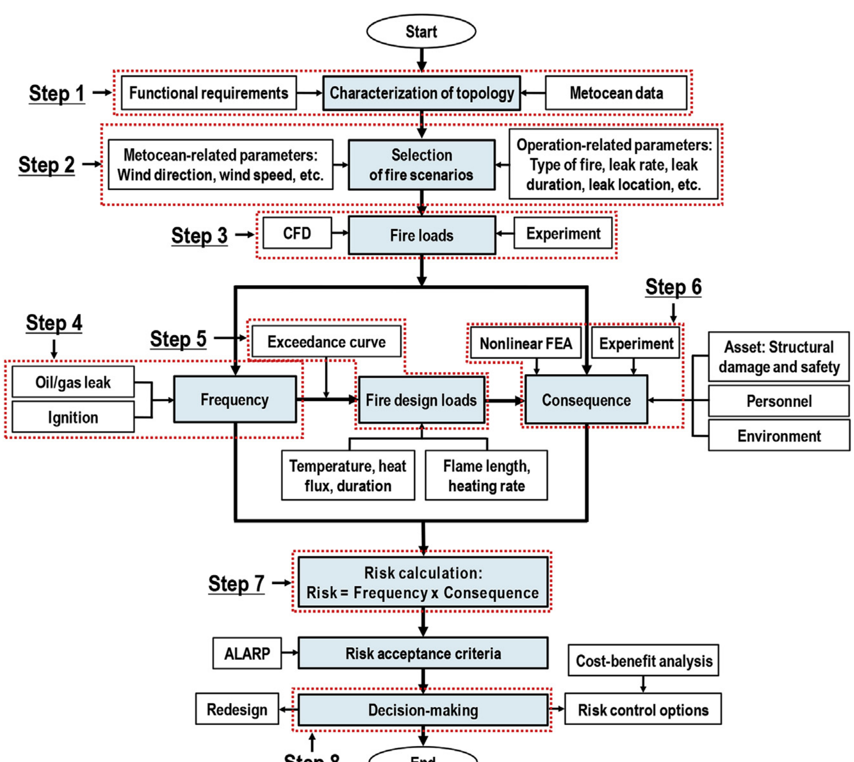


Fig. 2. A procedure for quantitative risk assessment and management for fires.

and Czujko, 2012), the procedure for Quantitative Risk Assessment and Management (QRA&M) for fires on offshore platforms proposed by Paik et al. (2013) efficiently evaluates risks and defines the design loads. Fig. 2 illustrates a procedure for the quantitative risk assessment and management of offshore installations in case of fires. The procedure can be applied to the risk assessment of helidecks, and is used in this study.

The procedure for QRA&M in fire accidents, as shown in Fig. 2, can be divided into eight steps, described in detail in Table 1. In application of risk acceptance criteria, As Low As Reasonably Practicable (ALARP) risks such as fire loads, structural response, etc. can be adopted.

In this study, steps 1–5 (not the entire procedure) are carried out to obtain a fire exceedance curve, which can define the design fire loads of helidecks.

Table 1
Details of the procedure for quantitative fire risk assessment and management.

Steps	Descriptions
1	Investigation of metocean data and functional requirements of target structure
2	Selection of credible fire scenarios with metocean and operation-related parameters using a probabilistic approach
3	Obtaining fire loads (temperature, heat flux, etc.) of each fire scenario by experiment and/or computational fluid dynamics (CFD)
4	Calculation of fire accident frequencies of fire scenarios using historical data
5	Generation of fire (temperature, heat flux, flame length, etc.) exceedance curves with fire loads and frequencies, and determination of design fire loads
6	Conducting structural consequence response analysis by the nonlinear finite element method and/or experiment, and investigating the consequences of fire accidents
7	Calculation of fire risk [risk = frequency × consequence]
8	Decision making (redesign of the structure or adoption of risk control options)

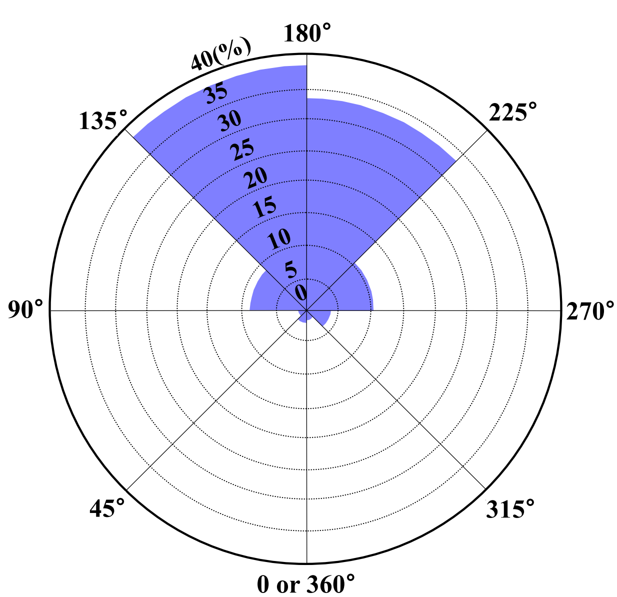


Fig. 3. Probability of wind direction (wind rose) in the ocean of West Africa from the south (Paik and Czujko, 2010).

The partial procedure carried out applies a (i) probabilistic method to select scenarios, (ii) computational fluid dynamics (CFD) to obtain fire loads and (iii) historical data to calculate the fire frequency.

Table 2
Probability of wind direction and speed in the ocean of West Africa.

Wind direction (°)	Probability (%)	Wind speed (m/s)	Probability (%)
0–45	2.137	0–2	9.508
45–90	1.501	2–4	33.831
90–135	8.101	4–6	40.270
135–180	38.775	6–8	14.870
180–225	33.628	8–10	1.446
225–270	10.572	10–12	0.065
270–315	3.420	12–14	0.010
315–360	1.871	14+	0.005
Total	100.005	Total	100.005

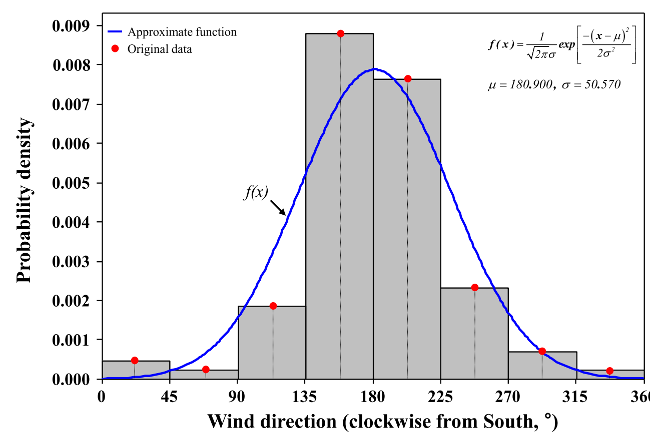


Fig. 4. Probability density distribution of wind direction.

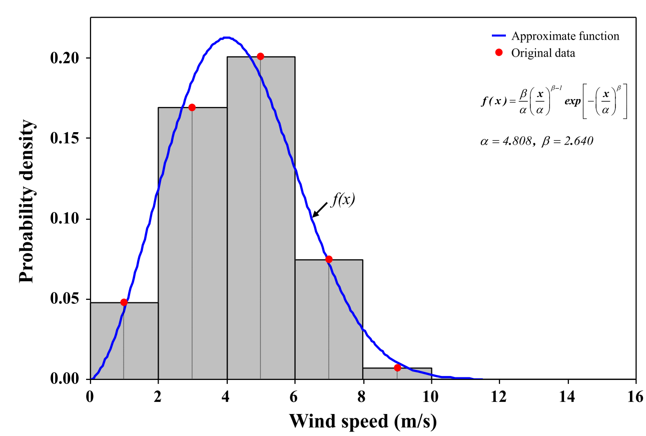


Fig. 5. Probability density distribution of wind speed.

Table 3
Helicopter information used in the examination of offshore installations.

Capacity of fuel tank (L)	2877
Mileage (km/L)	0.35
Density of fuel (kg/L)	0.811

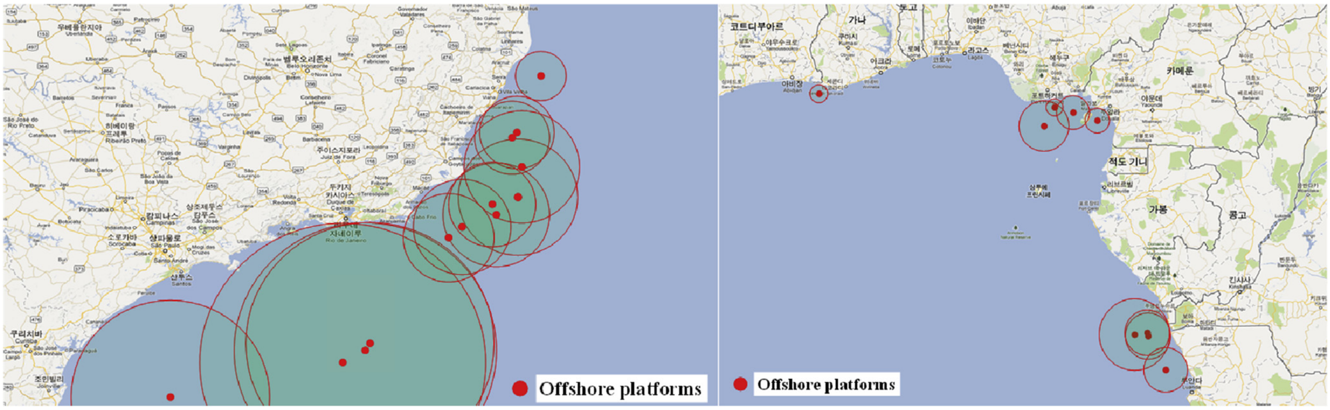


Fig. 6. Location and distance of offshore installations from the nearest land (left: the ocean of Brazil, right: West Africa).

Table 4
Distance of offshore platforms from the nearest land, the minimum required fuel and the remaining fuel.

Offshore no.	Shortest distance from land (km)	Minimum required fuel (L)	Fuel in tank after landing on offshore (L)
1	332.00	948.57	1928.43
2	322.58	921.66	1955.34
3	296.77	847.91	2029.09
4	282.76	807.89	2069.11
5	202.94	579.83	2297.17
6	180.00	514.29	2362.71
7	138.00	394.29	2482.71
8	135.71	387.74	2489.26
9	123.48	352.80	2524.20
10	123.33	352.37	2524.63
11	122.58	350.23	2526.77
12	120.00	342.86	2534.14
13	113.00	322.86	2554.14
14	111.29	317.97	2559.03
15	110.00	314.29	2562.71
16	108.00	308.57	2568.43
17	106.00	302.86	2574.14
18	93.00	265.71	2611.29
19	88.24	252.11	2624.89
20	87.10	248.86	2628.14
21	84.38	241.09	2635.91
22	81.67	233.34	2643.66
23	60.00	171.43	2705.57
24	53.33	152.37	2724.63
25	45.00	128.57	2748.43
26	40.00	114.29	2762.71

Table 5
Probability of practicable leak amount.

Leak amount (L)	Leak amount (kg)	Probability (%)
1849.57—1972.87	1500—1600	7.69
1972.87—2096.18	1600—1700	7.69
2096.18—2219.48	1700—1800	0.00
2219.48—2342.79	1800—1900	3.85
2342.79—2466.09	1900—2000	3.85
2466.09—2589.40	2000—2100	42.31
2589.40—2712.70	2100—2200	23.08
2712.70—2836.00	2200—2300	11.54
Total		100.00

Table 6
Re-categorized index of leak amount for probability density distribution.

Index	Leak amount (kg)	Probability (%)
0—1	1700—1800	0.00
1—2	1800—1900	3.85
2—3	1500—1600	7.69
3—4	2100—2200	23.08
4—5	2000—2100	42.31
5—6	2200—2300	11.54
6—7	1600—1700	7.69
7—8	1900—2000	3.88
Total		100.00

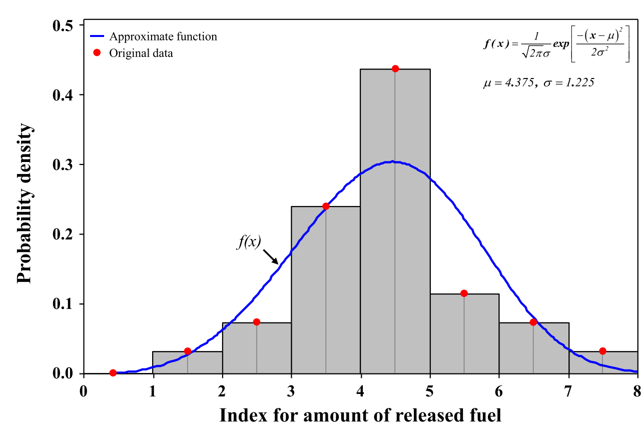


Fig. 7. Probability density distribution of index for amount of released fuel.

3. Selection of credible fire scenarios on helidecks

When selecting credible fire accident scenarios, all possible parameters that can have an effect on fire loads should be considered, such as temperature, heat flux, flame length, etc. Fires can also be affected by wind (direction and speed) and leak (rate, direction, duration and position).

In the case of a jet fire, the scenarios should take into account the leak rate, direction, duration and position associated with the release. The characteristics of a pool fire, however, mean that only the operation parameters of leak amount and position are required.

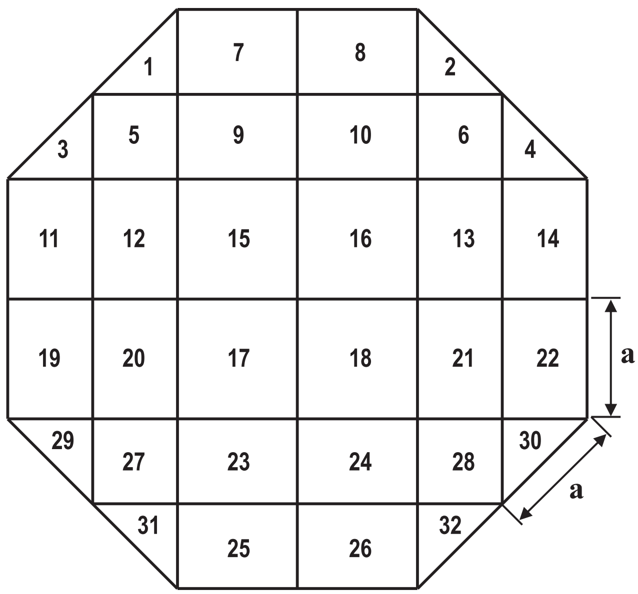


Fig. 8. Divided, numbered sections for selection of the leak position on a regular octagon helideck.

Table 7
Area and probability of sections.

No.	Area (a^2)	Probability (%)	No.	Area (a^2)	Probability (%)
1	0.250	1.294	17	1.000	5.178
2	0.250	1.294	18	1.000	5.178
3	0.250	1.294	19	0.707	3.661
4	0.250	1.294	20	0.707	3.661
5	0.500	2.589	21	0.707	3.661
6	0.500	2.589	22	0.707	3.661
7	0.707	3.661	23	0.707	3.661
8	0.707	3.661	24	0.707	3.661
9	0.707	3.661	25	0.707	3.661
10	0.707	3.661	26	0.707	3.661
11	0.707	3.661	27	0.500	2.589
12	0.707	3.661	28	0.500	2.589
13	0.707	3.661	29	0.250	1.294
14	0.707	3.661	30	0.250	1.294
15	1.000	5.178	31	0.250	1.294
16	1.000	5.178	32	0.250	1.294
Total				19.314	100.000

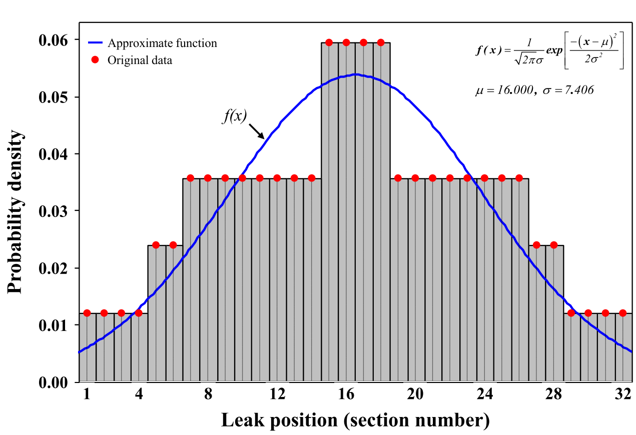


Fig. 9. Probability density distribution of leak position (section number).

In this study, the four parameters (i) wind direction, (ii) wind speed, (iii) leak amount and (iv) leak position are considered when selecting the scenarios, as fires caused by heli-accidents are similar to pool fires.

3.1. Wind direction and speed

Unlike ships that travel around the world, offshore platforms operate in a fixed, specific location. The metocean characteristics of the specific ocean can therefore be used for the risk assessment of offshore helidecks.

Fig. 3 and Table 2 present the wind direction (wind rose) and the metocean data, which in this applied example are the probability of wind direction and speed in the ocean of West Africa.

As the original (raw) data are discontinuous, they must be converted to continuous functions so that a probabilistic approach can be used. Best-fit analysis should be conducted before the probability density function (PDF) is defined.

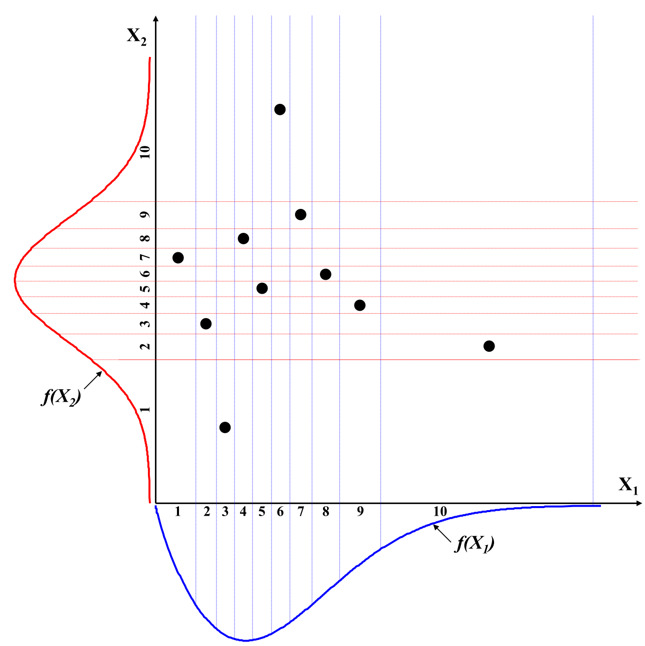


Fig. 10. Scheme of the Latin Hypercube sampling technique (Ye, 1998).

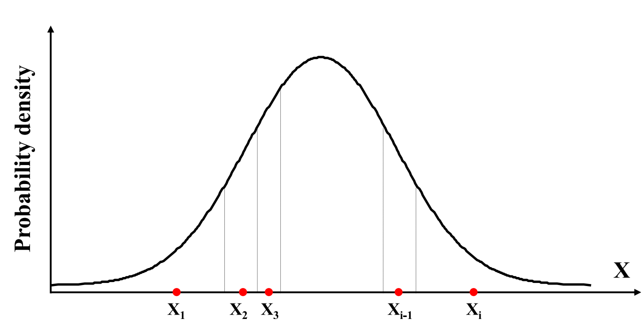


Fig. 11. Method for selecting the representative value of the random variable for each parameter.

Figs. 4–5 show the PDFs of wind direction and speed. The best-fitted function for wind direction is normal distribution, and for speed is Weibull distribution.

3.2. Leak amount

Calculating a leak amount is difficult, as helicopter accidents on offshore platforms are extremely rare, and the capacities of helicopter fuel tanks and engines are all different. Several assumptions (type of helicopter and/or fuel, the location of the offshore platforms, the amount of fuel in the tank, etc.) must therefore be made.

Two assumptions are made in this study: first, that one type of fuel is used in the helicopters, and two, that they have a full fuel condition when they depart from land.

The leak amounts given in the study are calculated using the following steps:

1) Definition of helicopter (type of fuel)
2) Investigation of helicopter characteristics (capacity of fuel tank, mileage, etc.)
3) Definition of fuel condition on the land (a full condition is assumed)
4) Calculation of the distance between the land and the offshore installation
5) Calculation of the minimum required fuel from the land to the offshore installation
6) Calculation of the remaining fuel in the helicopter, which will be the leak amount

To obtain the leak amount, a helicopter with JP-8 fuel type, which is generally used in offshore installations, is assumed. The specifications of the helicopter are given in Table 3.

To investigate the air-line distance between the land and offshore installations, the ocean regions of Brazil and West Africa, where many platforms are installed, are considered.

Table 8
Selected fire scenarios on helidecks.

Scenario no.	Wind direction (°)	Wind speed (m/s)	Leak amount (kg)	Leak position (section no.)
1	237.975	6.219	2129.880	18
2	255.749	2.636	2084.500	25
3	211.951	4.630	2146.910	3
4	187.294	2.977	2046.570	10
5	118.887	3.083	2065.200	12
6	218.334	2.243	2162.340	23
7	182.203	3.288	1556.610	7
8	140.139	5.263	2071.540	20
9	184.744	2.513	2219.840	14
10	155.847	1.738	1842.790	24
11	123.955	6.056	2077.960	21
12	106.260	0.758	2205.040	10
13	172.008	7.929	2183.510	1
14	189.860	4.832	2021.980	4
15	206.029	3.388	1638.110	14
16	59.249	2.382	2190.190	27
17	97.668	5.904	2091.170	21
18	221.756	4.149	2227.710	19
19	215.074	5.151	1601.130	30
20	158.678	4.339	1587.180	17
21	113.104	3.773	2120.540	8
22	161.440	1.926	1506.490	23
23	174.574	6.399	2028.150	22
24	276.660	6.829	2052.730	17
25	200.436	3.582	2034.290	22
26	195.070	5.380	2287.220	13
27	225.376	2.868	2235.960	20
28	85.563	5.502	2040.420	19
29	169.419	8.991	2169.620	26
30	179.666	4.532	2138.640	12
31	143.556	3.961	2275.010	6
32	197.730	3.867	2196.740	12
33	192.450	4.730	1573.180	13
34	166.800	5.042	1923.560	8
35	264.405	6.599	1666.840	18
36	233.411	1.517	2009.510	9
37	243.060	3.678	2244.690	16
38	208.941	7.101	2098.010	11
39	164.144	4.244	2212.310	15
40	177.124	2.754	1617.560	11
41	146.810	3.187	2254.000	18
42	149.930	1.234	1599.450	15
43	128.505	3.485	2058.940	5
44	203.198	7.443	2110.470	13
45	248.867	4.935	2003.170	19
46	302.975	5.762	2154.790	16
47	152.936	5.628	2264.040	9
48	229.241	4.055	1535.800	16
49	136.523	2.092	2015.770	15
50	132.665	4.435	2176.660	28

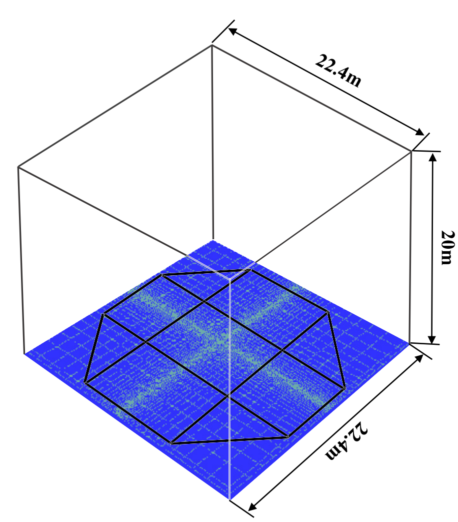


Fig. 12. Target structure, extent of analysis and applied grids in KFX CFD simulations.

Table 9
Gas compositions of the JP-8 fuel type.

Component	Mole fraction (%)
Dodecane ($C_{12}H_{26}$)	31.58
Tetradecane ($C_{14}H_{30}$)	23.64
Decane ($C_{10}H_{22}$)	22.53
Hexadecane ($C_{16}H_{34}$)	17.12
Isooctane (C_8H_{18})	5.13
Total	100.00

Fig. 6 shows offshore platforms in the ocean regions of Brazil and West Africa, and the shortest radius from offshore to land, as the shortest distance is generally preferred.

After investigating the distance from the land in Fig. 6, the minimum amount of fuel required to the platforms, and the remaining amount of fuel when the helicopter arrives at the platforms can be calculated. These are shown in Table 4. The remaining fuel is then considered as the leak amount.

Table 5 shows the probability of the leak amount. It is difficult to make a PDF (normal, Weibull distribution function, etc.), so it is re-categorized, as shown in Table 6, to generate the normal distribution function.

Fig. 7 illustrates the histogram and PDF of the re-categorized leak amount, used to select fire scenarios.

3.3. Leak position

The leak position in the topside structure is relevant to processing units such as pipes, equipment, vessels, etc., and the crash areas are considered as leak positions on the heli-deck. However, this area cannot be exactly defined due to the small amount of historical data available.

It is therefore assumed that helicopter accidents on heli-decks of offshore platforms occur evenly across the entire helideck. Fig. 8 presents a regular octagon helideck, applied as the target structure in this study, and divided into areas so the histogram and PDF can be obtained.

Table 7 and Fig. 9 show the probability of each section, a histogram and the normal distribution function of the leak positions.

3.4. Selection of fire scenarios

Various sampling methods, such as Monte Carlo Simulations (MSC) (Rubinstein, 1981), standard random sampling (Rubinstein, 1981), stratified sampling (Czujko, 2001), Latin Hypercube Sampling (LHS) (Ye, 1998), etc. are used for selecting the scenarios. Of these sampling techniques, LHS can efficiently reduce the number of scenarios and have an accuracy with a number of scenarios less than MSC (Czujko, 2001).

Figs. 10 and 11 present the scheme of the LHS technique and the method for defining the representative value.

In the study, using the Latin Hypercube Sampling (LHS) technique, 50 fire scenarios are selected with PDFs (wind direction, wind speed, leak amount and leak position), as shown in Table 8 for an applied example. The center of each section is defined as a leak position.

4. Fire CFD simulations

4.1. Modeling of fire CFD simulations

To obtain the fire loads, the Kameleon FireEX (KFX, 2014) CFD tool is used. KFX generates control volumes (grids)

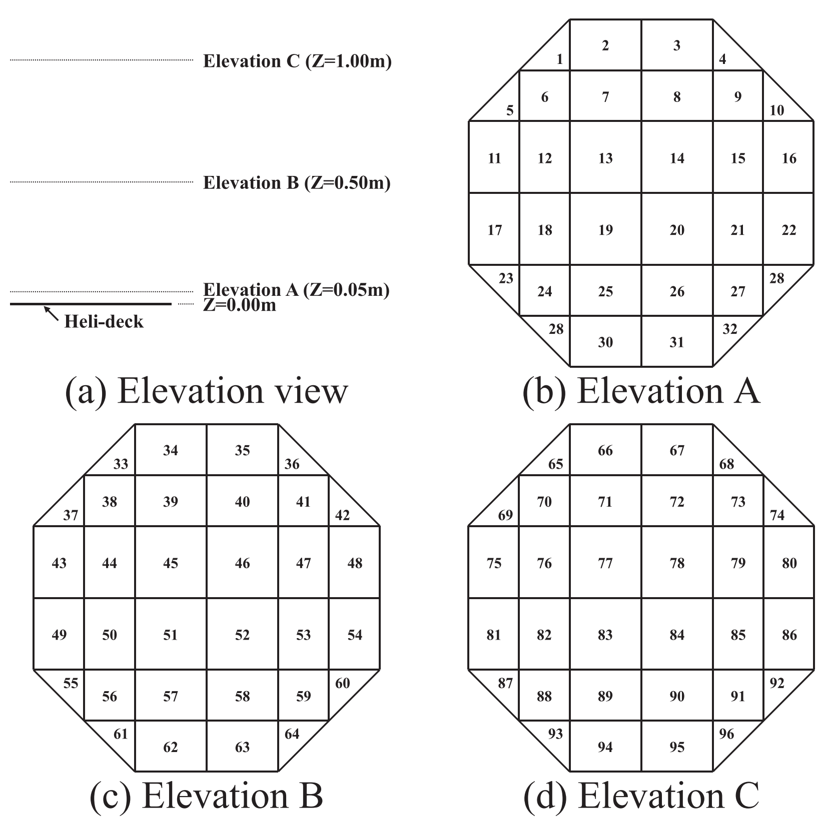


Fig. 13. Location of numbered monitoring points to investigate fire loads.

automatically or by user, in association with the leak amount and/or the leak hole size. Fig. 12 shows the target structure, which is the helideck, the extent of analysis and the applied grids in KFX. The total number of control volumes is 1,800,000.

As mentioned in Section of Leak amount, it is assumed that one type of helicopter fuel (JP-8) is used. Table 9 shows the gas compositions of the JP-8 fuel type.

4.2. Obtaining the fire loads

KFX provides the fire loads at 1000 monitoring points. In this study, 96 points are used to obtain the fire loads.

The fire loads, such as temperature, heat flux, flame length, etc. differ according to the height from the heat source. Three elevations (0.05, 0.50 and 1.00 m from the heat source) are therefore selected to investigate the fire loads.

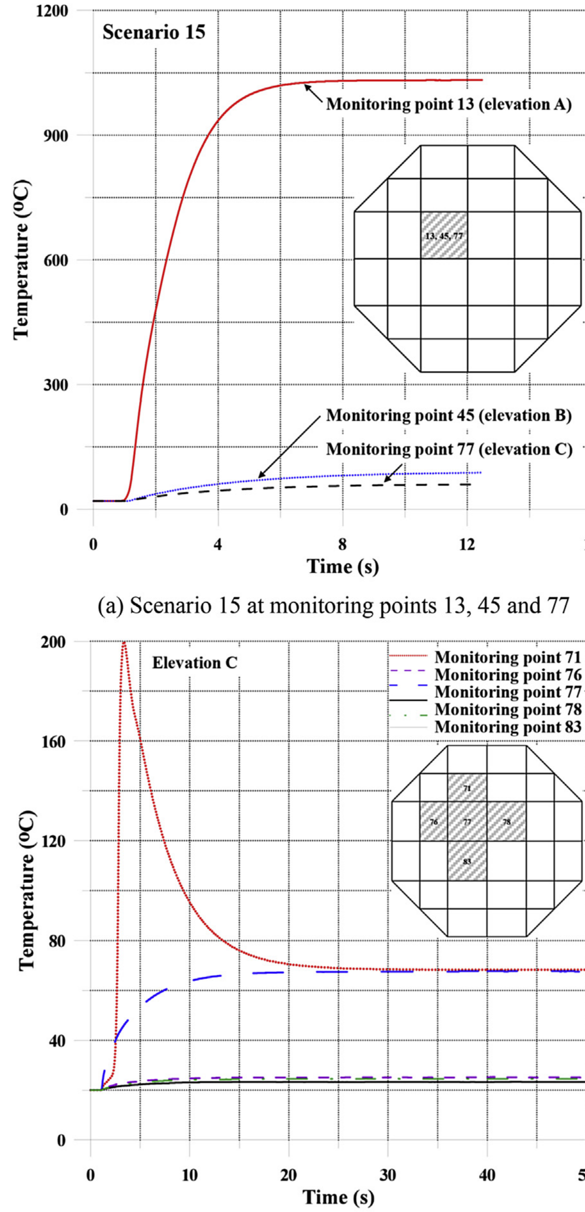
Fig. 13 illustrates the location of monitoring points at three elevations (Fig. 13(a)). A point is located at the geometric center of each section.

4.3. Results of fire CFD simulations

Fig. 14 shows examples of the simulation results. Fig. 14(a) presents the temperature of scenario 15 at three elevations. The temperature at the elevation nearest to the heat source is higher than the others.

Scenario 39, as presented in Fig. 14(b), has a pool fire at section 15 (shown in Fig. 8 and Table 8). In the first 30 s after ignition, the temperature at point 71 is very high compared with the other points, but then reduces and is similar to that at monitoring point 77. This is due to the effect of wind at both points.

Fig. 15 illustrates the effect of the variables wind direction, wind speed, and leak amount on the maximum temperature of the entire monitoring region. It shows that the wind speed has a remarkable effect on the fire loads, compared with other variables. With a wind speed of over 6 m/s, the temperature is similar to room temperature.



(a) Scenario 15 at monitoring points 13, 45 and 77

(b) Scenario 39 at elevation C

Fig. 14. Examples of results of fire simulations.

5. Calculation of fire frequency

To generate a fire exceedance curve, both fire load and fire frequency are required. The fire frequency can be calculated by Eq. (1).

$$F_{Fire} = F_{Release} \times P_{Ignition} \quad (1)$$

where, F_{Fire} = fire frequency, $F_{Release}$ = leak frequency and $P_{Ignition}$ = ignition probability.

5.1. Leak (accidental) frequency

OGP (2010a) provides historical data of heli-accidents on offshore platforms. Table 10 presents the frequency of heli-accidents according to areas. In the present study, frequencies of phase in take-off and landing are considered, as a leak from a heli-accident can occur during either. A fuel release is assumed for all accidents.

For comparison, frequencies in the North Sea and in the Gulf of Mexico (GOM) are applied. Therefore, the resulting frequencies of 8.6E-9/yr (4.3E-7/(yr·50), North Sea) and 5.4E-8/yr (2.7E-6/(yr·50), GOM) are equally used for leak (accidental) frequency in each fire scenario.

5.2. Ignition probability

The probability of ignition for fires from helicopter accidents has not been sufficiently investigated, but in this study it must be taken into account, so the 'offshore FPSO liquid model' suggested by OGP (2010b) is adopted. This model

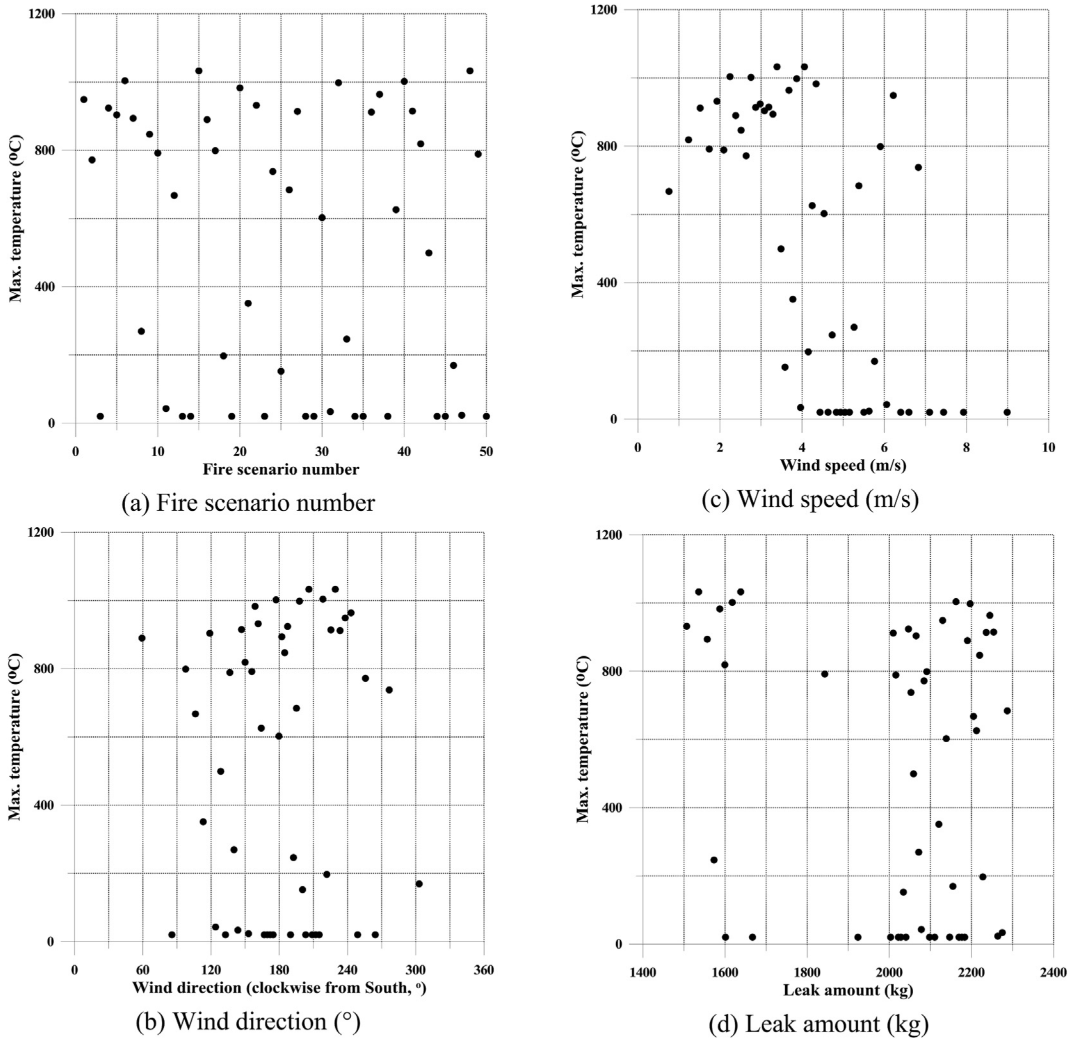


Fig. 15. Effect of variables for fire on maximum temperatures.

Table 10
Offshore helicopter transport flight accident frequency for the risk estimation model (OGP, 2010a).

Region	Flight phase	Frequency (/yr)	Unit
North sea	In-flight	8.5E-6	per flight hour
	Take-off & landing	4.3E-7	per flight stage
Gulf of Mexico	In-flight	8.5E-6	per flight hour
(GOM)	Take-off & landing	2.7E-6	per flight stage
Rest of world	In-flight	8.5E-6	per flight hour
	Take-off & landing	2.7E-6	per flight stage

can be applied to the release of flammable liquids that do not have any significant flash fraction (10% or less) within offshore process modules or decks on FPSOs (OGP, 2010b). Fig. 16 presents the ignition probability according to the leak rate.

If an accident occurs, the fuel spills out of the tank in a very short time, so the total leak amount is considered as the release rate, shown in Fig. 16, to calculate the ignition probability. From Fig. 16, 0.028 of initiation probability is used for all 50 fire scenarios.

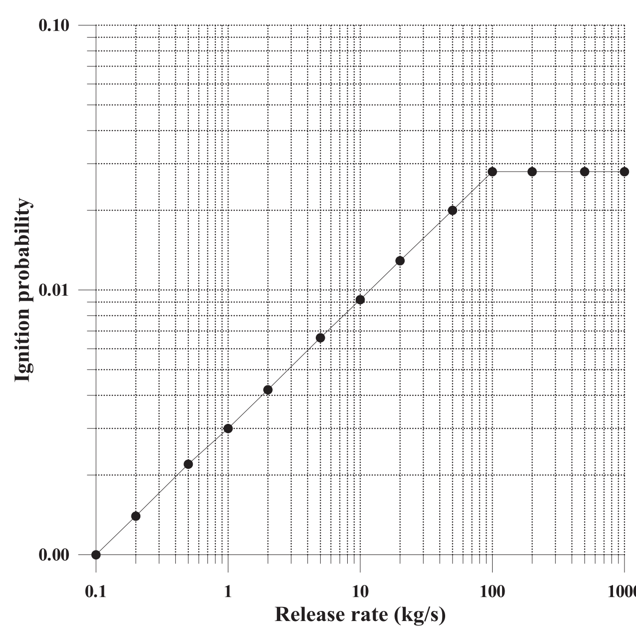


Fig. 16. Ignition probability relevant to release rate (OGP, 2010b).

5.3. Fire frequency

As shown in Eq. (1), fire frequency is calculated by leak frequency and ignition probability. Table 11 shows the leak frequency, ignition probability and fire frequency of heli-accidents in the North Sea and the GOM.

6. Design accidental loads for fires on helidecks of offshore installations

The fire load exceedance curve can be generated from the fire frequency and fire loads, and design accidental loads are obtained from this curve. The maximum temperature exceedance curve is adopted to define the design accidental load. Figs. 17–19 present the maximum temperature exceedance curves at elevations A, B and C, which are derived from the study.

As shown in Fig. 14(a), the temperature exceedance curve at elevation A has the highest value, compared with that of the air (B and C). This means that the structure, which is the helideck, is exposed to the highest temperature in the accidents. The structure should have sufficient strength to withstand the fire loads.

Table 11
Leak frequency, ignition probability and fire frequency.

Leak frequency (/yr)		Ignition probability	Fire frequency (/yr)	
North Sea	GOM		North Sea	GOM
8.6E-9	5.4E-08	2.8E-2	2.4E-10	1.5E-9

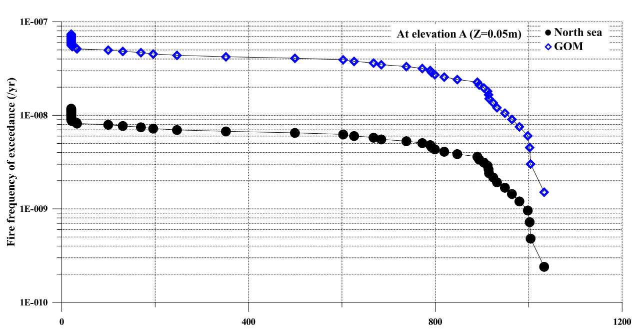


Fig. 17. Probability exceedance curves of maximum temperature at elevation A.

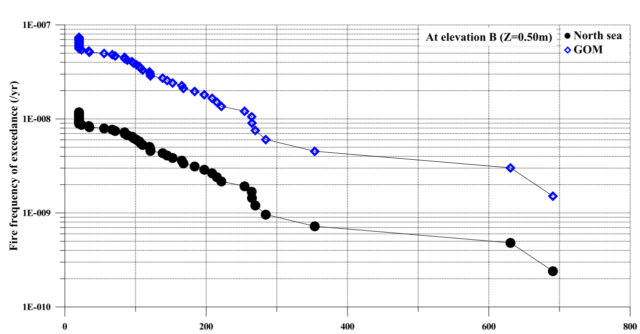


Fig. 18. Probability exceedance curves of maximum temperature at elevation B.

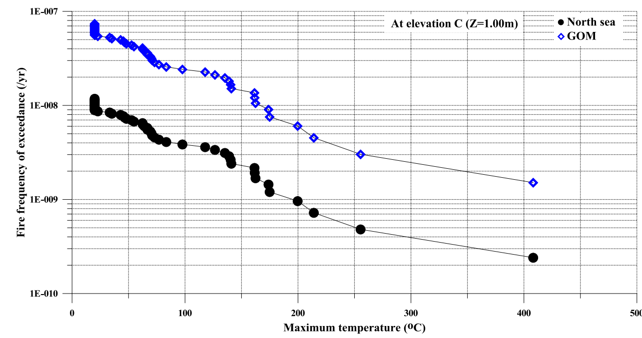


Fig. 19. Probability exceedance curves of maximum temperature at elevation C.

Table 12
Defined design fire loads for helideck with 10^{-8}/yr risk accepted level (°C).

	Elevation A	Elevation B	Elevation C
North Sea	20.3	20.1	20.0
GOM	954.8	264.6	166.8

Helicopter accidents in the Gulf of Mexico are more frequent than in the North Sea. Consequently, the exceedance level in the GOM is almost 10 times that of the North Sea. This suggests that a design for an offshore helideck in a specific ocean area cannot be applied to one in a different area, and that offshore helidecks installed in the GOM need to be stronger for safety.

Helicopter crashes on offshore platforms are rare, so the exceedance level is very much lower than for other accidents, such as explosions, fires, collisions, groundings, etc. (Vinnem, 2007). Different design accidental levels should therefore be adopted for the structural designs of helidecks regarding fires.

Table 12 shows examples of the defined design fire loads for helideck. 10^{-8}/yr of risk accepted load level proposed by Vinnem (2007) is adopted. It can be seen that the 10^{-8}/yr of risk level is practical for risk assessment against the heli-accident.

7. Conclusions

Helicopter crashes on helidecks are rare events, but there is still a risk of helidecks being exposed to fire loads from pool fires that result from heli-accidents. Defining design fire loads is therefore important for safety, and structural design should take into account design loads obtained through risk assessment.

Defining design fire loads for the safe design of helidecks on offshore platforms is not easy, as there is insufficient historical data of heli-accidents.

The aims of this study are to suggest a procedure for defining the design fire accidental loads for aluminum helideck safety, and to carry out a procedure with an applied example.

In the study, it is inevitable that assumptions were needed in the selection of scenarios, and 50 credible accidental fire (pool fire) scenarios were selected, with several assumptions, using the Latin Hypercube sampling technique. The characteristics of fire loads and temperature exceedance curves were investigated.

The conclusions of this study are as follows:

- The temperature at elevation A (structure), the nearest elevation to the heat source, is higher than at the other elevations.
- Helidecks of offshore platform located in the Gulf of Mexico require stronger designs than those located in the North Sea.
- Less than 10^{-8}/yr (at the GOM) and/or 10^{-9}/yr (at the North Sea) of risk accepted load levels should be considered when determining fire accidental loads for aluminum safety helidecks on offshore platforms, in the rare event of a heli-accident.

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