Safety Regulation Group

Civil Aviation Authority

CAA Paper 2008/03

Helideck Design Considerations - Environmental Effects

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Foreword

The production of the guidance material contained in this Paper was commissioned in response to a recommendation (ref. 10.3 (i)) that resulted from earlier research into offshore helideck environmental issues, reported in CAA Paper 99004. The lack of any guidance on good offshore helideck design practice was noted during that study, and the provision of such material identified as an important factor in addressing the underlying safety issues affecting helicopter operations to offshore installations.

The material contained in this Paper was originally published in CAA Paper 2004/02. The material has been updated to take account of progress in several research areas. In particular, a turbulence criterion has been introduced and the original vertical flow criterion removed (see CAA Papers 2004/03 and 2008/02).

The work was jointly funded by the Safety Regulation Group of the UK Civil Aviation Authority (CAA) and the Offshore Safety Division of the Health & Safety Executive (HSE), and was performed by BMT Fluid Mechanics Limited. The content of CAA Paper 2004/02 has been incorporated in the Offshore Helideck Design Guidelines document which the HSE commissioned with the support of the CAA and the endorsement of the Offshore Industry Advisory Committee's Helicopter Liaison Group (OIAC HLG). The content of this paper is to be incorporated in an updated version of that document.

Safety Regulation Group

July 2009

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Executive Summary

This manual covering environmental effects on offshore helideck operations is a revision of a document originally commissioned by the Health & Safety Executive (HSE) and the Civil Aviation Authority (CAA). The original document was published as CAA Paper 2004/02 which is referenced from the 5th Edition of CAP 437, Helicopter Landing Areas - Guidance on Standards. It was also incorporated in a comprehensive helideck design manual, produced under the aegis of the Helicopter Liaison Group of the Health and Safety Commission's Offshore Industry Advisory Committee (OIAC). This new version of the manual has been produced to reflect changes in the guidance since 2003.

It is almost inevitable that helidecks installed on the cramped topsides of offshore structures will suffer to some degree from their proximity to tall and bulky structures, and to gas turbine exhausts and flares. The objective of this manual is to help platform designers to create offshore installation topsides designs, and helideck locations, that are safe and 'friendly' to helicopter operations and, as far as possible, avoid the 'environmental' effects (mainly aerodynamic, thermal and wave motion) which can affect helicopter operations. It is hoped that, if used from 'day one' of the offshore installation design process when facilities are first being laid out, this manual will prevent or minimise many helideck environment problems at little or no cost to design or construction.

Guidance on the design and placement of offshore helidecks has existed for many years in the various editions of CAA document CAP 437, which have contained certain environmental criteria relating to the occurrence of vertical airflows and higher than ambient temperatures due to exhausts and flares. More recently a criterion for turbulence has been validated and added, and the vertical flow criterion has been removed (see CAA Paper 2004/03 and CAA Paper 2008/02). These criteria were set in order to ensure safe helicopter operations by avoiding these hazards. Where these criteria could not be met, or where pilots experienced other environmental phenomena, an entry has been placed in the Helideck Limitation List (HLL). These entries are specific to particular combinations of wind speed and direction, and either restrict helicopter weight, or prevent flying altogether in the conditions.

The HLL system operated by the Helideck Certification Agency (HCA) should ensure that landings on offshore helidecks are properly controlled when adverse environmental effects are present. On poorly designed helidecks, severe restrictions may be placed on operations resulting in reduced payloads or cancelled flights. This can lead to significant commercial penalties for the installation operator or vessel owner. Well-designed and 'helicopter-friendly' platform topsides and helidecks therefore result in efficient operations, and a saving in cost for the platform operator.

This manual, addressing helideck environmental effects, was produced with assistance from, and in consultation with, offshore installation operators/duty holders, helicopter operators, platform designers, marine contractors, drilling contractors, rig owners, trade associations and regulatory bodies.

The manual is split into three main sections. Design issues related to the location of the helideck, and its juxtaposition with other facilities are considered in Section 3. In as many cases as possible, clear guidance is given on the preferred location of the helideck and its relationship with other potentially hazardous facilities or topside design features. The design issues are amplified by means of illustrative examples of good and bad design practice in Section 4. Methods for the qualitative and quantitative assessment of the design in terms of helicopter operability are described in Section 5.

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Report Helideck Design Considerations - Environmental Effects

1 Introduction and Background

1.1 Introduction

This manual covering environmental effects on offshore helideck operations is a revision of a document originally commissioned by the Health & Safety Executive (HSE) and the Civil Aviation Authority (CAA) [1].The original document was published as CAA Paper 2004/02 which is referenced from the 5th Edition of CAP 437, Helicopter Landing Areas - Guidance on Standards. It was also incorporated in a comprehensive helideck design manual, produced under the aegis of the Helicopter Liaison Group of the Health and Safety Commission's Offshore Industry Advisory Committee (OIAC). This new version of the manual has been produced to reflect changes in the guidance since 2003.

The safety of offshore helicopter flight operations can be seriously affected by environmental effects that may be present around installations, vessels and their helidecks. These environmental effects are typified by structural turbulence, the thermal effects caused by gas turbine and diesel exhaust emissions, hot and cold gas streams and vessel motions.

It is vital, in order to ensure the safety of helicopters operating to and from offshore installations and vessels, that the best possible flying environment (minimum turbulence and helideck movement) is maintained.

Where, for operational and/or meteorological reasons, ideal flying conditions do not prevail, then flight crews need to have access to as much information as possible on the anticipated turbulent conditions and helideck movements in order to plan (or abort) flight operations.

This section addresses, in detail, the environmental effects likely to be encountered, and provides information on how to identify problems during the design process and ways that these adverse effects can be minimised and/or mitigated.

1.2 Background

It is almost inevitable that helidecks installed on the cramped topsides of offshore structures will suffer to some degree from their proximity to tall and bulky structures, and to gas turbine exhausts and flares. The objective of this manual is to help platform designers to create offshore installation topsides designs, and helideck locations, that are safe and 'friendly' to helicopter operations and, as far as possible, avoid the 'environmental' effects (mainly aerodynamic, thermal and wave motion) which can affect helicopter operations. It is hoped that, if used from 'day one' of the offshore installation design process when facilities are first being laid out, this manual will prevent or minimise many helideck environment problems at little or no cost to design or construction.

Guidance on the design and placement of offshore helidecks has existed for many years in the various editions of CAA document CAP 437 [2], which have contained certain environmental criteria relating to the occurrence of vertical airflow, turbulence, and higher than ambient temperatures due to exhausts and flares. More recently a criterion for turbulence has been added and the vertical flow criterion has been removed (see [3] and [4]). These criteria were set in order to ensure safe helicopter operations by avoiding these hazards. Where these criteria could not be met, or where pilots experienced other environmental phenomena, an entry has been placed in the Helideck Limitation List (HLL) [5]. These entries are specific to particular combinations of wind speed and direction, and either restrict helicopter weight, or prevent flying altogether in certain weather conditions.

The HLL system operated by the Helideck Certification Agency (HCA) should ensure that landings on offshore helidecks are properly controlled when adverse environmental effects are present. On poorly designed helidecks, severe restrictions may be placed on operations resulting in reduced payloads or cancelled flights. This can lead to significant commercial penalties for the installation operator or vessel owner. Well-designed and 'helicopter-friendly' platform topsides and helidecks therefore result in more efficient operations, and a saving in cost for the platform operator.

A survey based on pilot responses to a questionnaire on workload and safety hazards [6] rated 'turbulence around platforms' as the largest source of workload and presenting the largest safety risk of all aspects of offshore flight operations. A review of offshore helideck environmental issues [8] pointed out that many of the decisions leading to poor helideck performance were made by designers in the very early stages of design, and recommended that it would be easier for designers to get these decisions right if comprehensive helideck design guidance published by industry was available to run in parallel with CAP 437.

This manual, addressing helideck environmental effects, has been produced with assistance from, and in consultation with, offshore installation operators/duty holders, helicopter operators, platform designers, marine contractors, drilling contractors, rig owners, trade associations and regulatory bodies.

2 How To Use This Manual

This manual is intended for use throughout the design life of an offshore installation or vessel. It should be used at the very earliest stages of concept design when the main deck elements are being laid out. It should be used during detailed design, and at any stage in later life when changes to the superstructure are being contemplated.

The main part of the manual, Section 3, is organised in terms of the main design decisions that need to be made when determining the general arrangement of installations and vessels, and in selecting the optimum location for the helideck. It recommends various design features, and clearances from topsides elements that may be sources of turbulence or hot gases. Section 3 also describes how the wave motions of floating installations and vessels can influence helideck availability, and how this can vary significantly depending on the helideck location on the vessel. Examples of good and bad layouts are presented in Section 4. Section 5 describes how assessments of helideck performance can be made at the various stages in the design process.

It is recognised that it will often not be possible to comply with all the aspects of good practice recommended in this design manual. However, the assessment methods outlined in Section 5 make it possible to estimate the likely helideck operability penalty associated with deviations from the ideal, and this knowledge can then be used as a basis for rational decision-making on the best design compromise. Information from helideck flow assessment studies should also be made available to the HCA prior to flight operations in order that any necessary operational limitations can be imposed prior to service to ensure that safety is not compromised.

The material in this manual is intended to help the platform designer with basic layout in the design process. The manual is not a substitute for formal assessment, and compliance with the guidelines cannot guarantee compliance with the various helideck performance criteria. Such compliance can only be assessed on a case-by-case basis by suitably qualified experts using methods such as those described in Section 5.

3 Design Issues

3.1 Introduction

The design guidance in this document applies to all fixed installations (manned and normally unattended installations), floating installations including semi-submersibles (e.g. MODU's, FPU's and specialist barges) and vessel hull based FPSO's, and any other specialist offshore support vessels with a helideck (e.g. seismic, diving support, pipelay).

The environmental effects described in this section fall into two classes;

- aerodynamic effects, and
- wave motion effects.

All offshore installations experience the aerodynamic effects described in Sections 3.2 - 3.7, but it is only floating systems that experience the influences of wave motions on the helideck as described in Section 3.8.

Turbulent airflows and thermal effects are in effect 'invisible' obstructions in flight paths around installations and vessels. They can seriously affect flight operations onto a helideck. These effects must be identified, quantified and taken fully into account when establishing the operability of a helideck.

The environmental issues described in this manual are clearly not the only factors in the selection of the helideck design or location. It is also strongly influenced by other important practical, safety and regulatory factors. For example, on many installations the helicopter will be designated the 'primary means of escape', and so the helideck must be close to the 'temporary refuge'. Selection of the best helideck location is therefore invariably a compromise between a number of potentially conflicting requirements.

3.2 Aerodynamic Issues and Criteria

Helidecks are basically flat plates and so are relatively streamlined structures. In isolation they would present little disturbance to the wind flow, and helicopters would be able to operate to and from them in a more or less undisturbed airflow environment. Difficulties arise because the wind must deviate around the bulk of the offshore installation causing large areas of flow distortion and turbulent wakes, and because the installation is also often a source of hot or cold gas emissions.

The effects fall into three main categories (see Figure 1):

- The flow around the bulk of the offshore installation itself. Platforms are slab-sided, non-streamlined assemblies ('bluff bodies') which create regions of highly distorted and disturbed airflow in their vicinity.
- The flow around large items of superstructure, notably cranes, drilling derricks and exhaust stacks. Like the platform itself, these are bluff bodies, and it is the turbulent wake flows behind these bodies that are important.
- Hot gas flows emanating from exhaust outlets and flare systems.

The current design criteria are based ultimately on achieving two objectives:

- The turbulence, defined as the standard deviation of the vertical airflow velocity, shall not exceed 1.75m/s[1].
- The maximum temperature rise, averaged over a 3 second time interval, in the vicinity of the flight path and over the landing area, shall not exceed 2°C.[2]

1. The 2.4m/s value given in CAP 437 5th Edition was lowered following completion of the validation exercise.
2. The issue arises of how high above the landing area these criteria should be applied. CAP 437 [2] states that this should be "…up to a height above the helideck corresponding to 30 ft plus wheels-to-rotor height plus one rotor diameter".

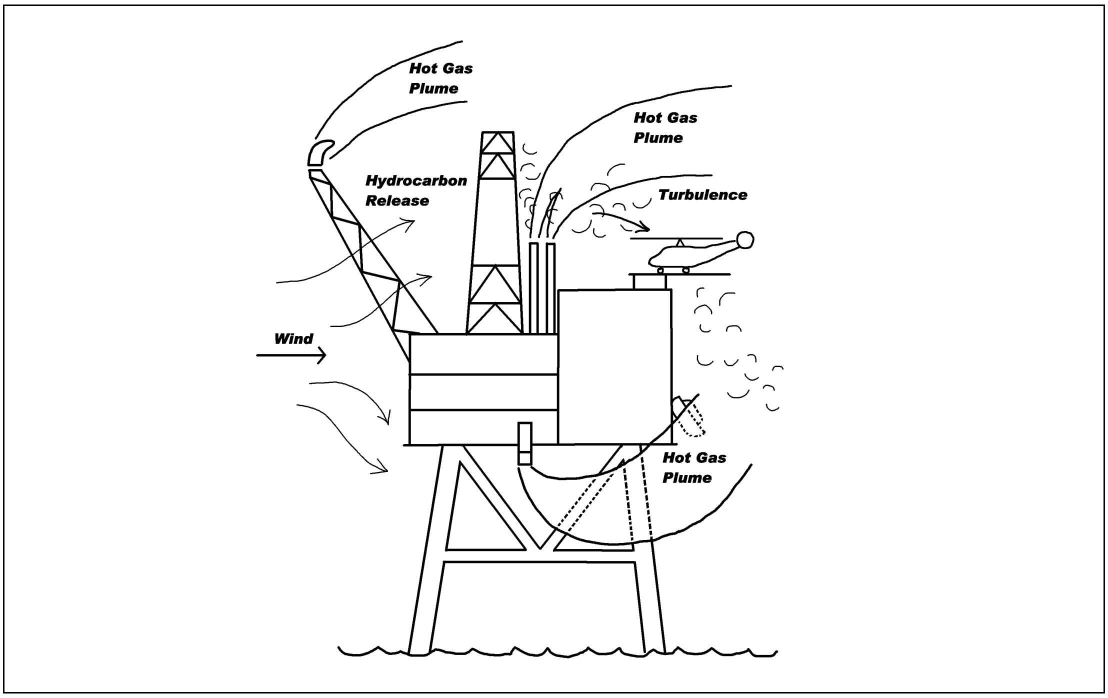


Figure 1 Sketch showing the main elements of aerodynamic flow interaction

These criteria are defined in CAP 437 [2] and are taken to be the limiting conditions for safe helicopter operation. If they are exceeded under any conditions then the helicopter operator is to be advised, and in most circumstances an appropriate flight limitation should be entered into the HLL [5].

3.3 Plan Location of the Helideck

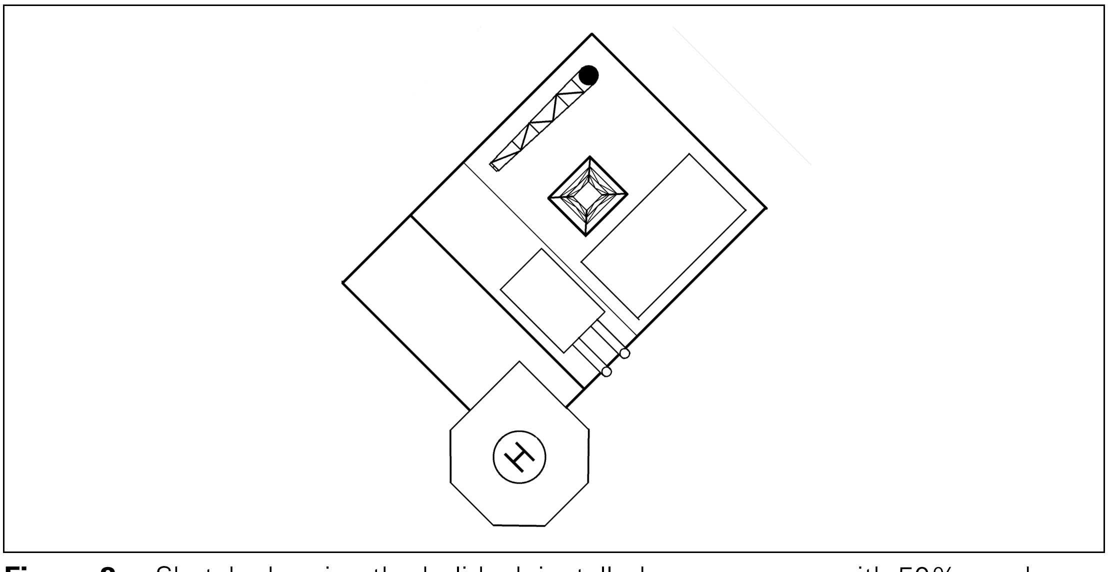


Figure 2 Sketch showing the helideck installed over a corner with 50% overhang

A key driver of the helideck location in [2] is the need to provide a generous sector clear of physical obstructions for the approaching/departing helicopter, and also sufficient vertical clearance for the helicopter to lose altitude after take-off in the event of a single engine failure. This requirement is for a minimum 210° obstacle free sector, with a falling 5:1 gradient below the landing area over at least 180° of this arc.

From an aerodynamic point of view the helideck should be as far away as possible from the disturbed wind flow around the platform. This objective, and the 210° obstacle-free sector, are most readily achieved by locating the helideck on a corner of the platform with as large an overhang as possible. In combination with an appropriate elevation and air gap (see Section 3.4), the overhang will encourage disturbed airflow to pass under the deck leaving a relatively horizontal and clean flow over the top.

It is recommended that the overhang should be such that the centre of the helideck is vertically above, or outboard of, the corner of the installation superstructure (see Figure 2).

3.4 Helideck Height and Air Gap under the Helideck

The height of the helideck, and the presence of an air gap between the helideck and the supporting module are the most important factors in determining wind flow characteristics. The helideck should ideally be located at a height above, or at least equal to, all significant surrounding structures. This will minimise the occurrence of turbulence downwind of adjacent structures.[3]

An air gap, separating the helideck from superstructure beneath it, promotes beneficial wind flow over the helideck. If there is not an air gap under the helideck, then wind conditions immediately above the helideck are likely to be severe, particularly if the helideck is mounted on top of a large multi-story accommodation block. It is the distortion of the wind flow around the bulk of the platform that is the cause.

Based on previous research work [8] it is recommended that the air gap on production platforms should be in the range 3m - 5m. Helidecks mounted on very tall accommodation blocks require the largest clearance, while those on smaller blocks and with very large helideck overhangs tend to require less. For shallow superstructures of three stories or less, such as often found on semi-submersible drilling vessels, a 1m gap may be sufficient.

In combination with an appropriate overhang (see Section 3.3), the air gap encourages the disturbed airflow to pass under the deck leaving a relatively linear and clean flow over the top (see Figure 3).

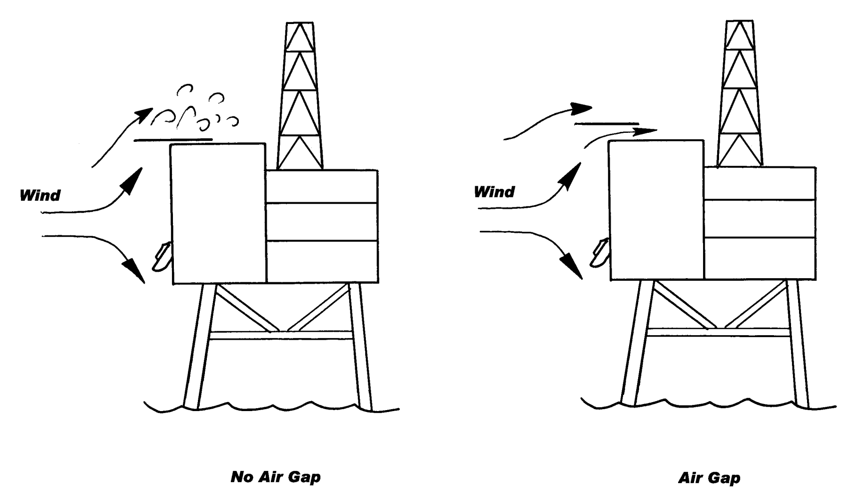


Figure 3 Sketch showing the flow passing under the helideck and clean flow over

3. However, note that CAP 437 recommends that the helideck height should not exceed 60m above sea level. Above this height the regularity of helicopter operations may be affected by low cloud base conditions.

It is essential that the air gap is preserved throughout installation operational life, and does not become a storage area for bulky items that might obstruct the free flow of air through the gap.

3.5 Proximity to Tall Structures

Offshore installation topsides tend to include a number of tall structures (drilling derricks, flare towers, cranes, gas turbine exhaust stacks etc.), and it is usually impractical to mount the helideck at a higher elevation. All such tall structures will cause areas of turbulent or sheared flow downwind that may potentially pose a hazard to the helicopter. The severity of the disturbances is greater the bluffer the shape, and the broader the obstruction to the flow. It is reduced the greater the distance downwind.

It should be noted that the location and configuration of drilling derricks can vary during the field life. The derrick position over the well slots can change, and temporary work-over rigs may be installed from time to time. The assessment of the helideck location should take into account the various derrick configurations that are expected to occur during the life of the installation.

3.5.1 Clad Derricks

A fully clad drilling derrick is a tall and solid structure and generates a correspondingly significant wake. The important flow property of the wake is that it is unsteady and so, if it is upwind of the helideck, it subjects the helideck area to large and random variations in wind speed and direction.

A general guide on wake decay from bluff bodies indicates that wake effects largely dissipate within a downwind distance of 10-20 structure widths. For a clad derrick 10 m wide at helideck level, this would correspond to a decay distance of 100-200 m (see Figure 4).

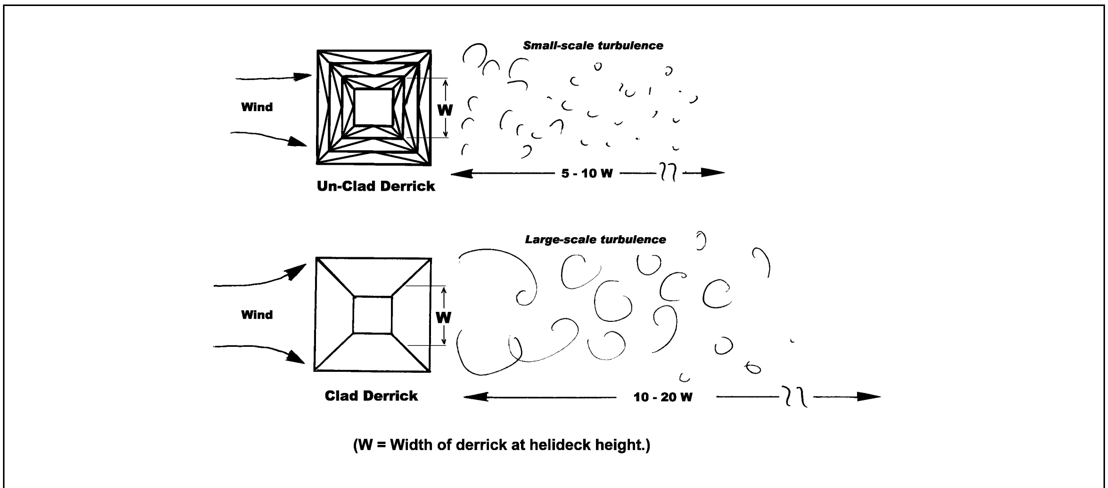


Figure 4 Sketch showing plan view of flow behind a clad and an unclad derrick

Consequently it is best if the helideck is not placed closer than 10 structure widths from a tall solid structure such as a clad derrick. However, few offshore installations will be large enough to permit such a clearance to be included in the design, and so the specification of a clad derrick is almost certain to result in a significant operational limitation for helicopters when the derrick is upwind of the helideck. It will be particularly important to try to ensure that the installation is aligned such that this only happens in rarely occurring wind directions (see Section 5.3).

3.5.2 Unclad Derricks and Cranes

Unclad derricks are relatively porous. A wake still exists, but the turbulence is of a much higher frequency and smaller scale due to the flow being broken by the lattice elements of the structure. A helideck can therefore be safely located closer to an unclad derrick than its clad equivalent. Ideally the separation between the helideck and an unclad open lattice derrick should be at least five times the derrick width at helideck height (see Figure 4). Separations of significantly less than 5 derrick widths may lead to the imposition of operating restrictions in certain wind conditions.

Crane pedestals and crane booms are also usually of lattice construction, and the same approximate rule can be applied as for lattice derricks. Generally the disturbed flow region will be much less due to their smaller dimensions.

3.5.3 Exhaust stacks

Gas turbine and other exhaust stacks, whether operating or not, also represent a physical blockage to the flow and create a turbulent wake (as well as the potential hazard due to the hot exhaust - see Section 3.6).

The same guideline as defined for clad derricks is recommended, namely, a minimum of 10 structure widths between the stacks and the helideck. If there are multiple exhausts and these are located in close proximity to each other, then it is recommended that the structure width be considered to be the overall span of the group of stacks.

3.5.4 Other Enclosed Structures

Some offshore drilling rigs include large enclosed structures in close proximity to the drilling derrick (e.g. shaker houses). If the height of these structures extends to helideck elevation, then they may give rise to large-scale turbulent disturbances downwind, and should be treated similarly to a clad derrick.

3.5.5 Lay-down Areas

A lay-down area in the vicinity of a helideck poses a number of potential problems to helicopter operations. Bulky or tall items placed in a lay-down area close to a helideck may result in turbulence. The temporary nature of such lay-down areas increases the potential hazard because the helicopter pilots, though perhaps familiar with the installation, may not be expecting turbulence.

The platform design should seek to ensure that lay-down areas are significantly below helideck level or sufficiently remote from the helideck to avoid such problems. If this cannot be achieved then it is essential that management procedures are in place to ensure that appropriate limitations are placed on flight operations, or that tall or bulky items are removed from temporary lay-down areas during helicopter operations.

3.6 Temperature Rise due to Hot Exhausts

Increases in ambient air temperature are a potential hazard to helicopters. Increased air temperature means less rotor lift and less engine power margin. Rapid temperature changes can also induce engine surge and even compressor stall or flameout.

It is therefore extremely important that helicopters avoid these conditions, or that the occurrence of higher than ambient conditions is foreseen, and steps taken to reduce payload to provide an appropriate performance margin.

Gas turbine power generation systems are usually the most significant source of hot exhaust gases on offshore production platforms, but diesel propulsion or auxiliary power system exhausts on mobile units may also need to be considered.

For certain wind directions the hot gas plumes from the exhausts will be carried by the wind directly across the helideck. The hot gas plume mixes with the ambient air, and the mixing increases the size of the plume, and reduces the temperature (by dilution).

Evaluations of likely temperature rise, based on a Gaussian dispersion model and supported by wind tunnel tests, indicate that for gas turbine exhausts with release temperatures up to 500°C and flow rates of 50-100 kg/s, the minimum distance required before the temperature rise drops to 2°C rise above ambient is in range 130-190 m (see Figure 5). Some gas turbine power generation systems include waste heat recovery systems that have lower exhaust gas temperatures of about 250°C, resulting in reduced minimum distances in the range 90-130m.

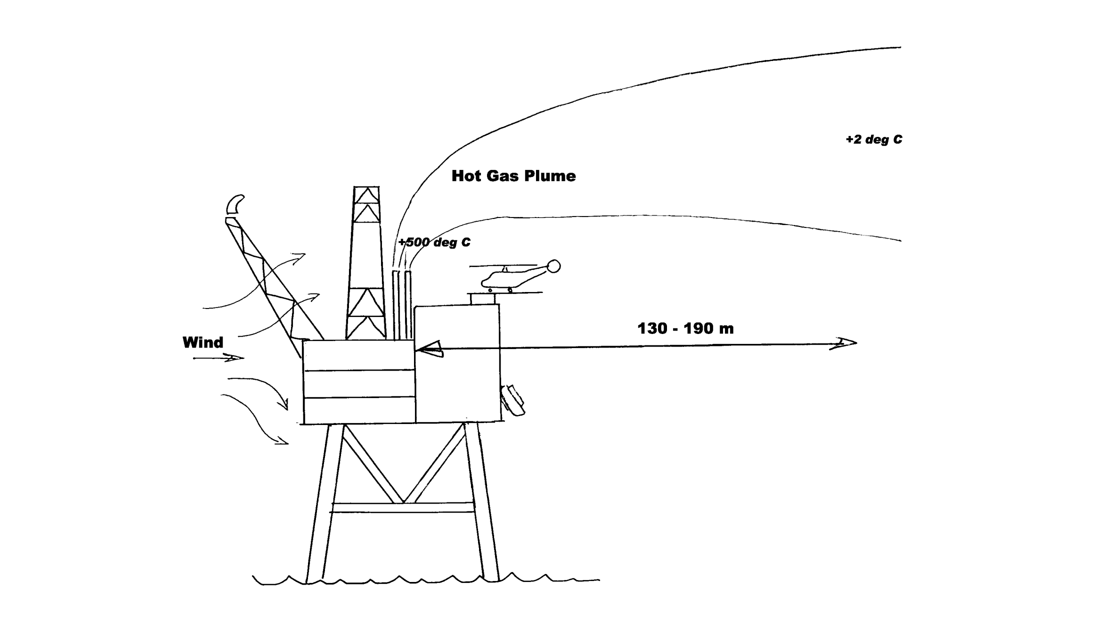


Figure 5 Sketch showing the hot gas plume dispersing, and 2°C rise 130-190m downwind

Except for very large platforms, this implies that regardless of design, there will always be a wind condition where temperature rise above the helideck exceeds 2°C. It is likely to be impossible, therefore, to design a helideck that is compliant with the criteria under all conditions. The design aim becomes one of minimising the occurrence of high temperatures over the helideck rather than eliminating them. This can be achieved by trying to ensure that platform layout and alignment direction are such that these conditions are only experienced rarely (see Section 5.3).

Many offshore installations have the power generation modules and exhausts located close to the accommodation modules and helideck. This is because the power generation is regarded as significantly less hazardous than drilling or production module activities. This can be a good location provided that the stacks are high enough to keep the exhaust gas plume clear of arriving/departing helicopters, are not wide enough to cause large amounts of turbulence, and do not impinge on the 'obstacle protected surfaces'.

The helideck should be located such that winds from the prevailing wind directions carry the plume away from the helicopter approach/departure paths. To minimise the effects for other wind directions, the exhausts should be sufficiently high to ensure that the plumes are above the helicopter approach/departure paths. To achieve this, it is recommended that the exhaust outlets are no less than 20-30 m above the helideck, depending on the gas turbine flow rates and temperatures.[4]

In the past, some platforms were fitted with downward facing exhausts so that the hot exhaust gases were initially directed down towards the sea surface. This arrangement is not recommended because the hot plume can rise and disperse in an unpredictable way, particularly in light wind conditions.

In situations where it is difficult or impractical to reduce the potential interaction between the helicopter and the turbine exhaust plumes to a sufficiently low level, consideration should be given to installing an exhaust plume visualisation system [7]. This will highlight the hazard to pilots and thereby minimise its effects by making it easier to avoid encountering the plume.

3.7 Cold Flaring and Rapid Blow-down Systems

Hydrocarbon gas can be released from the production platform process or from drilling rigs at various times. It is important to ensure that a helicopter cannot fly into a cloud of hydrocarbon gas because [8];

- concentrations above 10% of Lower Flammable Limit (LFL) might cause the helicopter engine to surge or flameout with consequent risk to the helicopter, and
- the helicopter poses a risk to the offshore installation because it is a potential ignition source for the hydrocarbon gas.

Consideration therefore needs to be given to ensuring that gas release points are as remote as possible from the helideck and helicopter flight path, and that any unforeseen gas releases activate the helideck status lights (flashing red). Planned gas releases should only occur when helicopters are not in the area.

The blow-down system on a production platform depressurises the process system releasing the hydrocarbon gas. It will normally be designed to reduce the pressure to half, or to 7 bar, in 15 minutes (the API standard). For a large offshore installation this might require the release of 50 tonnes of gas or more. Once down to this target pressure in 15 minutes or less, the remainder of the gas will continue to be released from the system. A blow-down may be automatically triggered by the detection of a dangerous condition in the production process. Alternatively it may be triggered manually.

The blow-down system should have venting points that are as remote as possible from the helideck and, in prevailing winds, downwind of the helideck. It is common to have this vent on the flare boom, and this will normally be a good location. However, it should be noted that dilution of the gas to 10% LFL may not occur until the plume is a considerable distance from the venting point. This distance could be anywhere between 200m - 500m depending on vent size, venting rate and wind speed.

4. Where it is considered necessary to extend the gas turbine exhaust outlets, it is important for the design project team to consider early on in the project how the installation of extended outlets can reasonably be achieved. Ideally, the engineering requirement should be established before firming up the gas turbine prime mover specification(s). It is important to consider the potential effects on operating performance and extra maintenance requirements caused by extending the gas turbine prime mover exhaust ducts, particularly when they are used in conjunction with some waste heat recovery systems (it may result in an increase in back pressure on the turbine). A complete picture of the exhaust / flare plume and its potential extremities (i.e. under normal operating and maximum output conditions) for a full range of wind conditions is required. Test Houses will require project teams and manufacturers to furnish them with full details for the varying load conditions, mass flows and exhaust temperatures for all possible operating conditions.

Drilling rigs often have 'poor-boy degassers' which are used to release gas while circulating a well, but a drilling rig is unlikely to release any significant quantities of gas without warning, unless there is a sudden major crisis such as a blow-out. As with production platforms it is unlikely to be possible to locate the helideck sufficiently distant from the potential gas sources to guarantee 10% LFL or less, and so the rig should not accept helicopter flights when well circulation activity is going on, or when there are problems down the well. Helideck status lights should be connected to the appropriate gas detection systems and automatically initiated.

3.8 Special Considerations for Floating Systems and Vessels

3.8.1 General

As well as experiencing the aerodynamic effects and potential hazards outlined above, floating installations and vessels experience dynamic motions due to the ocean waves. These motions (see Figure 6) are a potential hazard to the helicopter, and operational motion limits are set in order to avoid unsafe conditions.

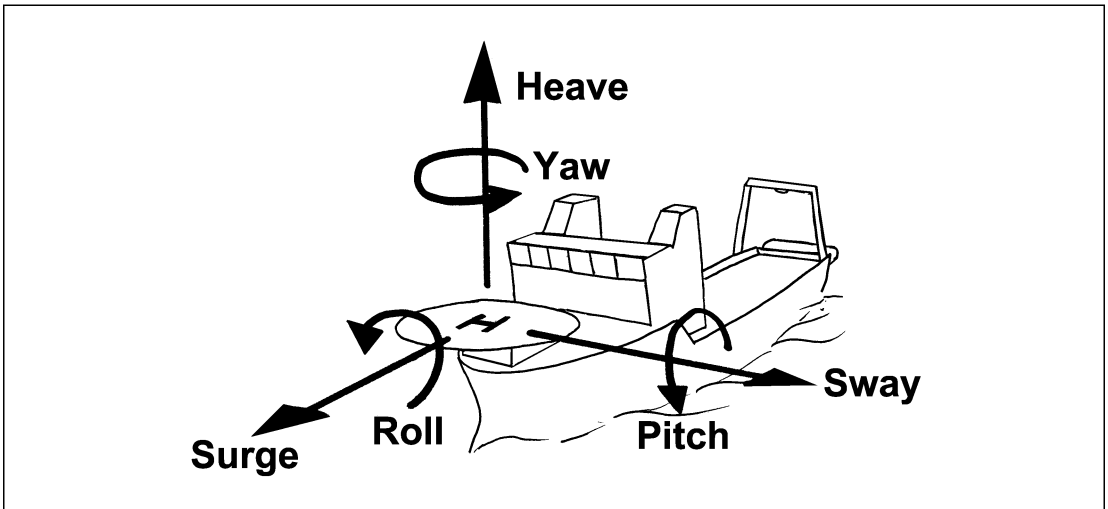


Figure 6 Vessel wave motions definition

The setting of these operating limits should involve consideration of two aspects:

- motion limits for executing a safe landing, and
- limits for safely remaining on the deck for the period necessary to effect passenger and cargo transfer (usually not more than 20 minutes).

The former is mainly affected by the rate of the heave (vertical) motion, but also by the roll and pitch motions, and is relatively easy for the pilot to judge visually. The pilot can see the movements of the vessel, and can judge whether it is safe to make the landing, and can choose the appropriate moment to set the helicopter down.

The latter is mainly affected by helideck accelerations, which can be generated directly by the motion of the vessel (heave, surge and sway) and indirectly due to the inclination of the helideck (component of gravity due to pitch or roll angle), and aerodynamic loads such as rotor lift and airframe drag. Limits for remaining safely on the deck are also much more difficult to judge because they should involve a prediction of the helideck motions for the period that the helicopter will be on the deck which should include an assessment of the statistical risk of unsafe motions. Furthermore, the options available to the pilot in the event of excessive motions building up while the aircraft is on the helideck are limited.

3.8.2 Wave Motion Characteristics and Criteria

The setting of helideck performance limitations due to vessel motion is the responsibility of the helicopter operator as the AOC holder. Currently in the UK offshore helicopter-operating environment the motion limitations for a variety of vessels have been agreed and set jointly by the helicopter operators, and these are published by HCA in the HLL [5]. It is recommended that vessel owners and designers consult with the Helideck Certification Agency during conceptional design of new vessels or refits to determine the limitations that are likely to be applied to the class of vessel for given helicopter types.

The limitations that currently exist apply to both the vertical linear motion (heave/ heave rate) and the angular motions (roll and pitch). Large accelerations can cause the helicopter to slide across the deck or tip over (though these do not currently form part of the limitations applied[5]).

The angle of roll and pitch experienced is the same for all points on the vessel or structure, but the amount of heave, sway or surge motion experienced can vary considerably depending on the location of the helideck on the vessel.

The severity of the helideck motions will depend on:

- The wave environment (e.g. more severe West of Shetland than in the Southern North Sea).
- The size of the vessel (a small vessel generally tends to exhibit larger and faster wave induced motions than a large vessel).
- The vessel's motion characteristics (certain hull forms exhibit larger wave induced motions than others, or are sensitive to particular sea conditions).
- Whether the vessel is moored, underway or under tow.
- The location of the helideck (vertical motions tend to be greater at the bow and stern of a ship than at midships, and sway motions due to roll tend to increase with helideck height).

Helicopter operational limitations will depend on:

- The design of the helicopter itself (different motion limits apply to different helicopter types [5]).
- Day time / night time (more onerous motion limits are applied to helidecks in the hours of darkness due to the degraded visual cues available to the pilot [5, 9]).
- The size of the vessel (the motion characteristics of large vessels are generally more benign than for small vessels).
- The visual cueing environment (the pilot will often have relatively few visual cues to judge landings on bow-mounted helidecks when landing facing forwards, and on helidecks mounted above the bridge superstructure when landing facing abeam).

  NOTE: The helicopter operating limits associated with the new acceleration-based criterion will also be a function of the 10 minute mean wind speed.

5. Work on a new acceleration-based helideck motion criterion, which also takes account of the exacerbating effect of the wind on the risk of the helicopter sliding or tipping, is nearing completion - see Section 5.7.1 and [15].

3.8.3 **Sea State Characterisation**

Sea states are usually characterised in terms of the significant wave height, an associated wave period (usually either the mean zero up-crossing period or peak spectral period) and a wave energy spectrum. Standard wave spectral formulae, such as the JONSWAP or Pierson-Moskowitz spectrum, are commonly used in design to define the way in which wave energy is distributed across the wave frequency range. Wave spectra may be defined as either uni-directional or multi-directional, the latter describing the proportion of wave energy coming from each direction by means of a directional spreading function.

3.8.4 **Vessel Motions and Helideck Downtime**

The motions of a vessel or floating installation generally become larger as the significant wave height and period increase, but may be especially severe at certain wave periods (e.g. at natural roll or pitch periods), and may be sensitive to the frequency content of the wave spectrum. The motion characteristics of a vessel or floating platform may be reliably predicted by recourse to well-established computer models, or to physical model testing.

Helideck downtime will occur whenever the motions of the vessel exceed the criteria [5]. (See Section 5.8 for an outline of a method to estimate the downtime.)

3.8.5 **Helideck Location Dependence**

The heave motions of the helideck depend on its horizontal location, and on how the vessel's heave, roll and pitch motions combine at that location. The operability of the helideck therefore depends on its location on the vessel or floating installation, both longitudinally and transversely.

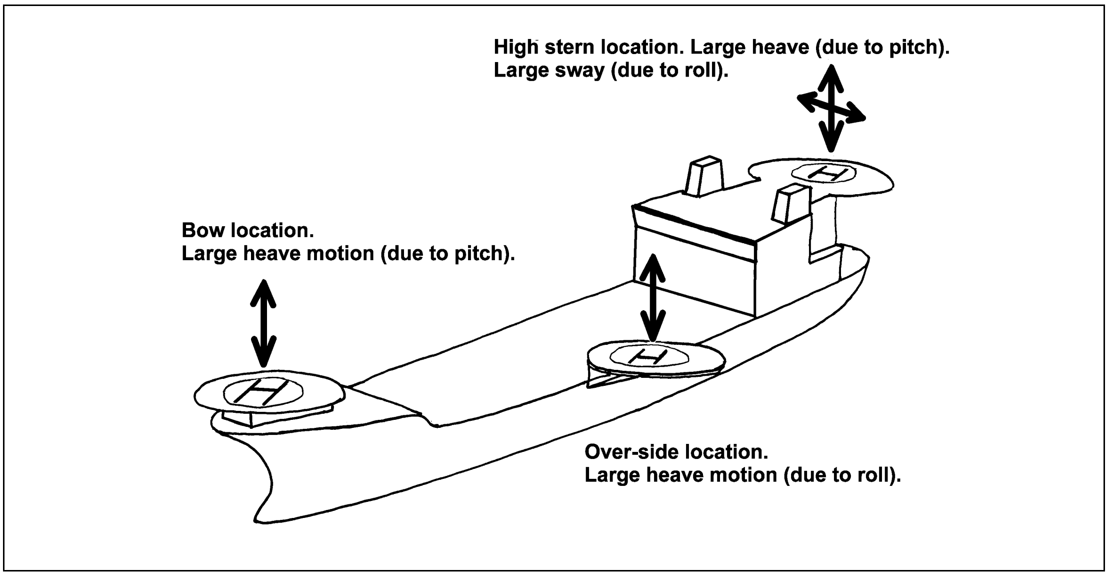


Figure 7 Areas of larger wave motions on a ship-shaped vessel

This location dependence is particularly marked for ships and ship-shaped installations such as FPSOs. The pitching motion of a ship is such that the vertical heave motion experienced at the helideck will generally be much greater if it is located at the bow or stern, and will be least if it can be located amidships. Bow-mounted helidecks can also be particularly vulnerable to damage from green seas unless mounted high above deck level.

Helidecks are also often located off the vessel's centreline. In some cases they are cantilevered over the side (which provides the benefit of an unobstructed falling 5:1 gradient over at least 180°). In this case, downtime due to wave motions will generally tend to increase because of greater helideck heave motions caused by roll.

Semi-submersible drilling or production platforms, tension leg platforms and spar buoys tend to have smaller motions at lower frequencies and, while the helideck location on a spar or semi-submersible will have an effect on performance, this is much less important than for a ship-shaped vessel.

However, the location of the helideck is generally determined by factors other than the need to minimise heave motions. In the case of an FPSO or drillship, for example, the central deck area is generally occupied by processing or drilling equipment. The helideck also has to be conveniently located for access by personnel who are generally accommodated either near the bow or stern. As the helicopter is likely to be the 'primary means of escape' the helideck needs to be close to the 'temporary refuge', which is usually incorporated into the accommodation.

Figure 8 illustrates how wave motion downtime for a helideck typically varies with its location along the length of a large ship (in this case an FPSO) when operating in a reasonably harsh environment. Maximum downtime occurs when the helideck is located at the bow or stern, and minimum downtime when the helideck is amidships. Variations in downtime in this case are a direct consequence of variations in predicted heave motions.

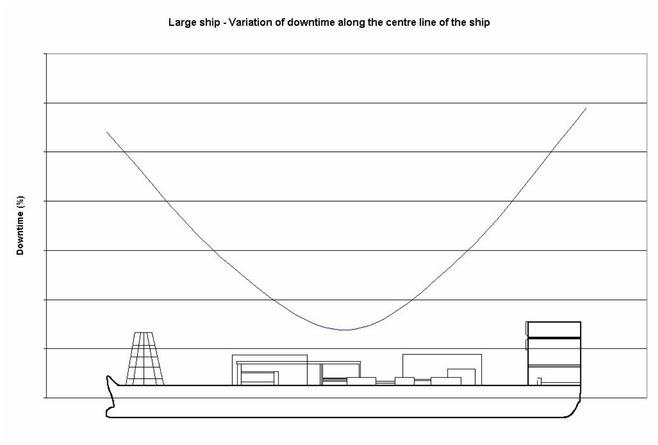


Figure 8 Variation in helideck downtime with location along the length of a large FPSO

Figure 9 illustrates how the helideck location affects wave motion downtime on a small ship (e.g. a diving support vessel) operating in a moderate sea environment. Once again, downtime tends to be greatest at the bow and least amidships, although there is relatively little variation over the aft part of the ship. In this case there is a marked difference between levels of downtime occurring when the helideck is at the vessel's bow and stern. The asymmetry in the downtime curve is not due to any marked difference between the vessel motions at bow and stern, but is rather a direct consequence of the more stringent motion limits for a helideck located at the bow of a small ship than for a helideck at the stern. This is because both helicopter and ship will normally be facing into wind and, consequently, pilots landing on bow helidecks will have poorer visual cues to assist the landing.

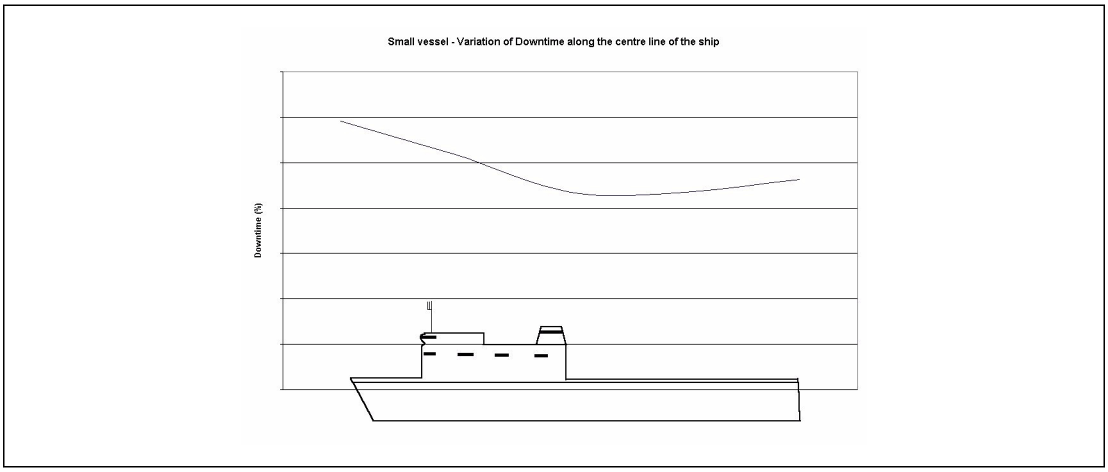


Figure 9 Variation in helideck downtime with location along the length of a small ship

3.8.6 **Special Considerations for FPSOs and Dynamically Positioned Vessels**

Most FPSOs operating in UK waters are turret-moored, and either weathervane naturally with the wind, waves and current, or use thrusters to control the vessel heading. A naturally weathervaning vessel has no control over its heading or motions, whereas a thruster-controlled vessel has the ability to choose its heading (within limits). For the latter, the heading is normally chosen in order to minimise the wave motions, and this normally means heading into the waves.

Dynamically positioned drillships and other offshore construction vessels also often operate with thruster heading control, with the heading invariably selected to minimise the wave induced vessel motions (unless the drilling or construction task demands some other fixed heading).

Whichever heading control strategy is adopted, the vessel's wave induced motions (and therefore helideck downtime) are sensitive to variations in the vessel's heading relative to waves. The heading of a naturally weathervaning vessel depends on the relative strengths and directions of the wind, wind-generated waves, swell and current. Swell and wind-generated waves can come from very different directions, and especially complex heave, roll and pitch motions may occur if swell onto the beam of the vessel occurs at the same time as a wind-generated sea onto the bow. The vessel roll response in head-sea conditions is sensitive to the amount of wave directional spreading, and a multi-directional wave model may have to be used to obtain reliable estimates of maximum roll response in these circumstances. Despite the complexity, all these effects can be taken into account at the helideck design assessment stage (see Section 5.6).

The ability of a thruster-assisted FPSO, or other dynamically positioned vessel, to turn to a desired heading can be used operationally to minimise helideck downtime due to both wave motions and aerodynamic effects. It can be used during flight operations to ensure that:

- wave induced motions at the helideck are minimised, and/or
- relative wind headings leading to turbulence or hot gases over the helideck are avoided.

Consequently, a thruster-assisted FPSO or dynamically positioned vessel with relatively poor inherent wave induced motions and helideck aerodynamic limitations may nevertheless be operated in such a way that good helideck operability is achieved. The benefit of this can also be taken into account at the helideck design assessment stage (see Section 5). However, it should also be recognised that a sudden loss of heading control during helicopter operations is likely to result in a rapid increase in vessel motions (especially roll) and an adverse relative wind direction with potentially catastrophic consequences for a helicopter on the deck. This roll motion problem will be particularly severe for vessels with high-mounted helidecks. Consequently, heading control should not be relied upon unless the heading control system has adequate integrity and capacity to bring the vessel back onto heading, and the risk of loss of heading control has been shown to be appropriately low.

3.9 Multiple Platform Configurations

It is common for offshore installations to consist of more than one platform or vessel. In some cases fixed platforms are bridge-linked and in quite close proximity (e.g. Figure 10), and are close enough for the aerodynamic effects (turbulence, hot gases etc.) of one platform to be experienced at the helideck of the other when the wind is in the appropriate direction.

In these situations the various effects considered in Sections 3.2 - 3.7 must be considered for the platform complex as a whole. It will normally be necessary for the helideck to be located on the platform corners remote from the other platform(s) in order to comply with the 210° obstacle-free sector, and for best aerodynamic performance.

Figure 10 Computer generated visualisation of a hot gas plume from downward facing exhausts enveloping the helideck on an adjacent bridge-linked platform

In some cases the platform complex may include more then one helideck, and it will therefore be necessary to assess the design issues for each of these helidecks. However, operational limitations which have to be placed on an individual deck may cause little helicopter downtime if there is an alternate helideck that can be used under these conditions. All such limitations need to be fully investigated, documented, and communicated to the operators to ensure that the various management procedures to control the use of the helidecks are put into place.

3.10 Combined Operations

Combined operations refer to a temporary arrangement where at least one mobile platform or vessel (e.g. a flotel) is operating in close proximity to another permanent installation. In many cases there may be a gangway in place connecting the two.

While the detailed arrangements for these combined operations may vary considerably from one circumstance to another, there are certain aspects of design and platform topsides layout that, if optimised, can minimise the need for helideck restrictions during combined operations.

Certain types of mobile platforms (e.g. flotels) have gangways and/or gangway landing portals, and clearly this defines the side of the mobile platform that will normally be closest to the fixed platform when combined operations are in progress. Consequently the design of the flotel should have the gangway located as far away from the helideck as practicable in order to maximise the available obstacle-free sector, and also to ensure that turbulence or hot gas plumes caused by the adjacent fixed platform are as distant from the mobile platform helideck as possible.

Whatever considerations and choices were made at the fixed or mobile platform design stage, when combined operations are to be carried out, a helideck assessment should be conducted to evaluate the effect of one platform on the other, and determine any helideck restrictions that should be imposed. Apart from the physical requirements for an unobstructed 210° obstacle free sector and falling 5:1 gradient (over at-least 180°), this assessment should consider the effect of the turbulent wake from one platform impinging on the helideck of the other, and any hot gas exhausts from one platform influencing the approach to the other helideck. The helideck on a mobile unit is likely to be at a much lower level than the bulk of the fixed platform it is alongside, and is therefore likely to experience severe turbulence when downwind.

These considerations are likely to determine that, under certain wind conditions, helideck operations to the mobile unit need to be curtailed. Where the combined operations have more than one helideck available and a gangway platform for personnel, it may be possible to switch from using one helideck to the other depending on the conditions. All such limitations need to be fully investigated, documented, and communicated to the helicopter operators to ensure that the various management procedures to control the use of the helidecks are put into place.

4 Examples of Good and Bad Practice in Platform Helideck Location

This section contains sketches of the main types of offshore installation (fixed jacket, semi-submersible, jack-up, tension leg platform and FPSO) with examples of each, illustrating good and poor practice in helideck location.

4.1 Fixed Installations

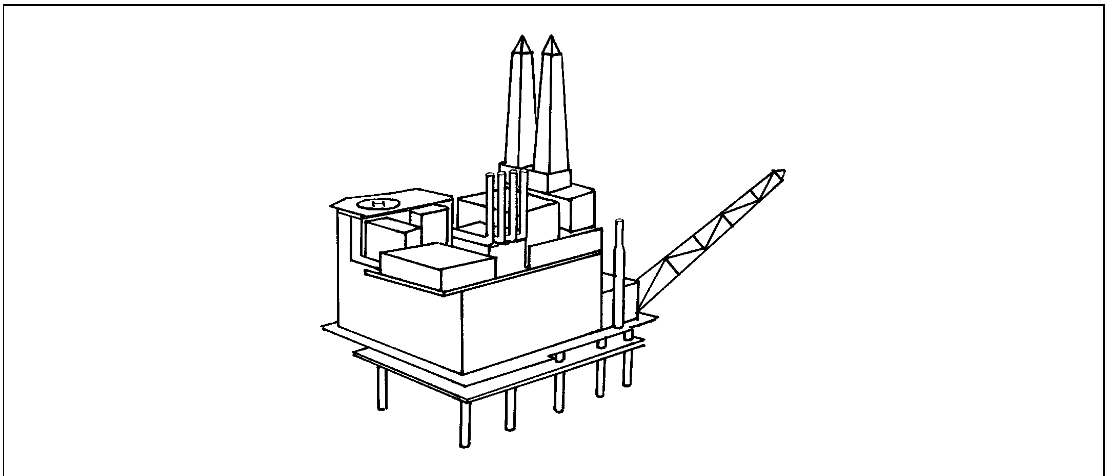


Figure 11

- **Good:** Helideck is above the level of the surrounding main modules.
- **Bad:** Two large clad derricks present a major solid obstruction to the wind flow and the helideck will experience serious turbulence when downwind. A set of four gas turbine exhaust stacks is also located close to the helideck. They are not high enough to prevent problems with hot gas exhausts, and are also a significant obstruction to the wind flow over the helideck at certain wind headings. The helideck has insufficient overhang and air gap.

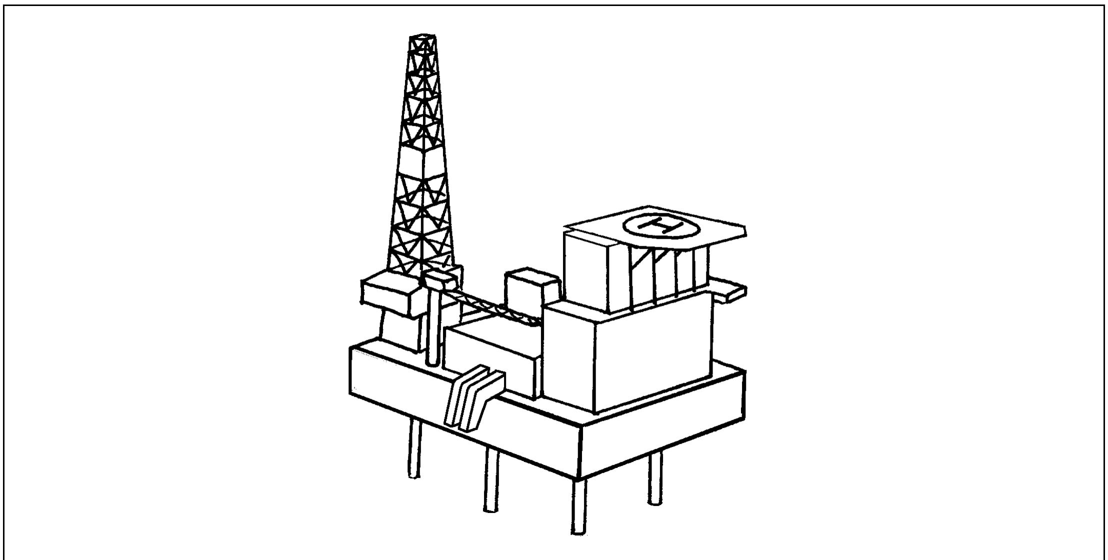


Figure 12

- **Good:** The helideck is mounted significantly above the level of all the platform modules, and with an appropriate air gap beneath. The only structure above helideck level is the derrick, which is unclad, and therefore likely to produce little significant turbulence at the helideck.

- **Bad:** The installation has downward facing gas turbine exhausts, which may cause clouds of rising hot gas to envelop the helideck and helicopter approach path. This is particularly likely to happen in light wind conditions (when helicopter performance is inherently poor).

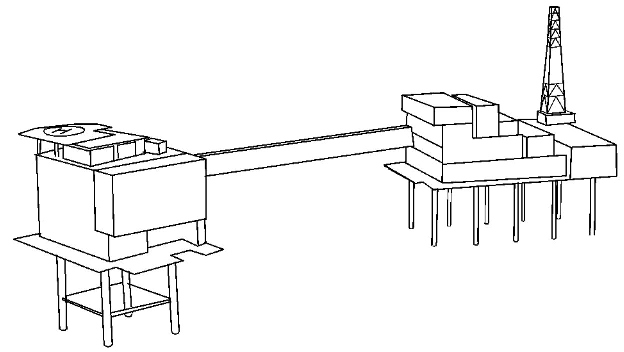


Figure 13

- **Good**: Being mounted on the top of a separate accommodation platform and with a significant air gap and overhang, the helideck is unlikely to suffer from any significant turbulence problems.
- **Bad:** No significant bad features.

4.2 **Semi-submersible and Jack-up Drilling Units**

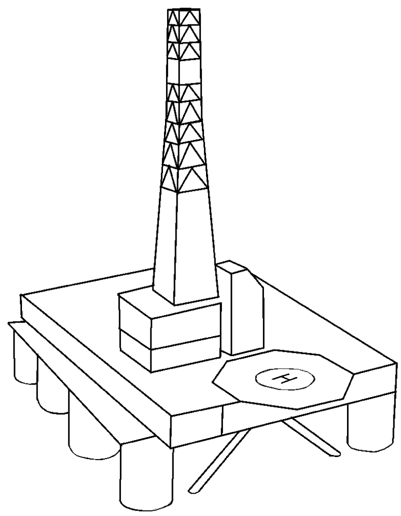


Figure 14

- **Good:** All semi-submersible drilling units are good from a wave motion point of view unless they are floating at a very shallow transit draft. At operating or survival draft, motions are generally of low amplitude and low frequency.
- **Bad:** Helideck is in close proximity to a partially clad drilling derrick and other adjacent solid structures, which all extend to a height significantly above the height of the helideck. The helideck will experience significant shear turbulence when the derrick is upwind. (The lack of an air gap is likely to be less significant due to the relatively shallow deck on which it is mounted.)

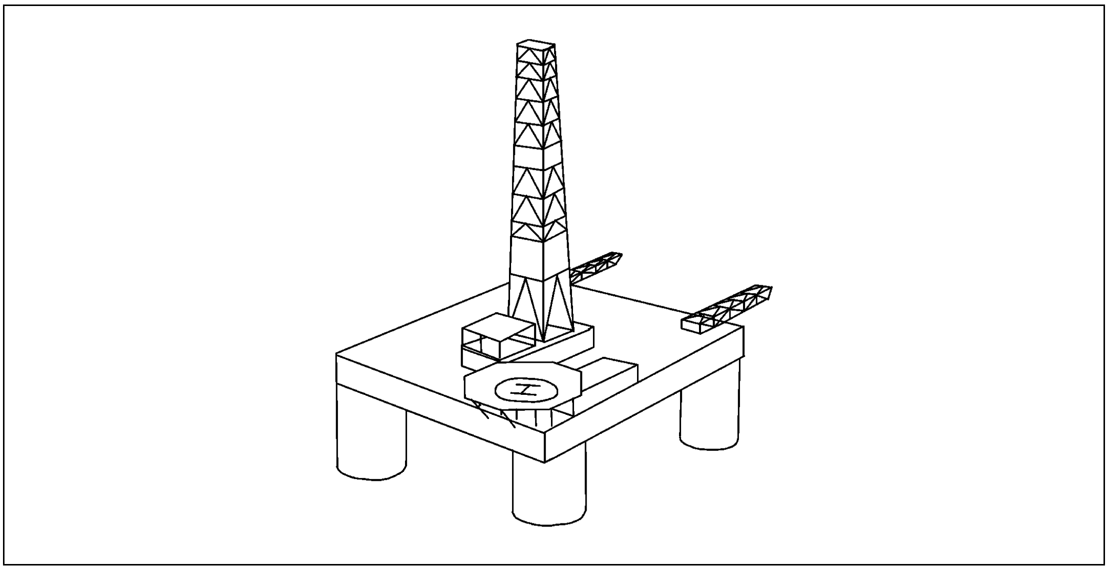


Figure 15

Good: Good corner helideck location with significant overhang and air gap. Structures close to the helideck are mainly open and porous to the wind. Flare booms for well-test operations are both reasonably distant from the helideck and should be visible when in use.

Bad: No significant bad features.

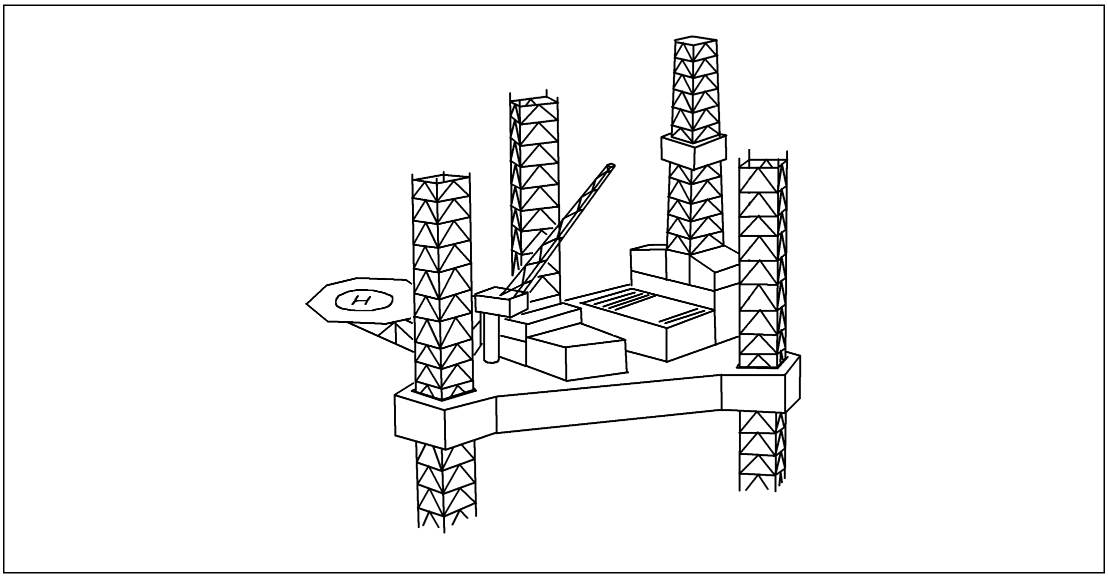


Figure 16

Good: The example jack-up drilling platform shown here has a helideck with large overhang and generous air gap, and it is located higher than most of the solid superstructure. Structures above the level of the helideck are generally porous. (Most jack-up drilling platforms have good helideck locations.)

Bad: No significant bad features

4.3 Tension Leg Platforms

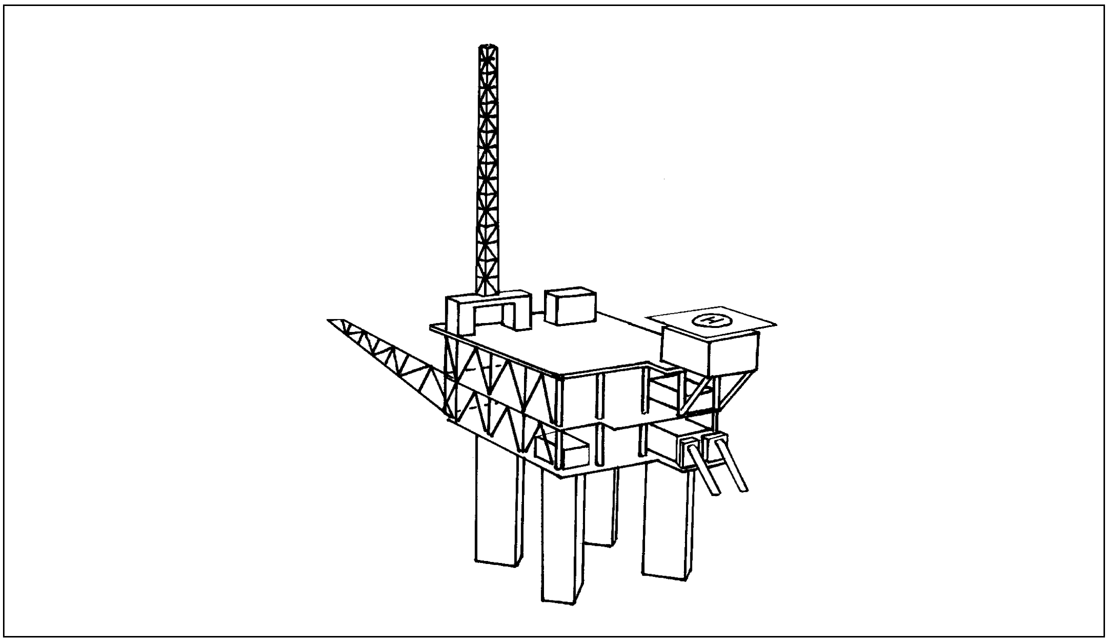


Figure 17

Good: This tension leg platform (TLP) has a high corner location helideck with an air gap. Also the generally open and porous design of the superstructure will reduce wind flow problems. Wave induced motions are generally small for a TLP. They are almost zero in roll, pitch and heave, while the larger surge, sway and yaw motions are normally at very low frequency.

Bad: The downward pointing gas turbine exhausts directly under the helideck are likely to result in a cloud of hot gas enveloping the helideck in light wind conditions when helicopter performance is inherently poor.

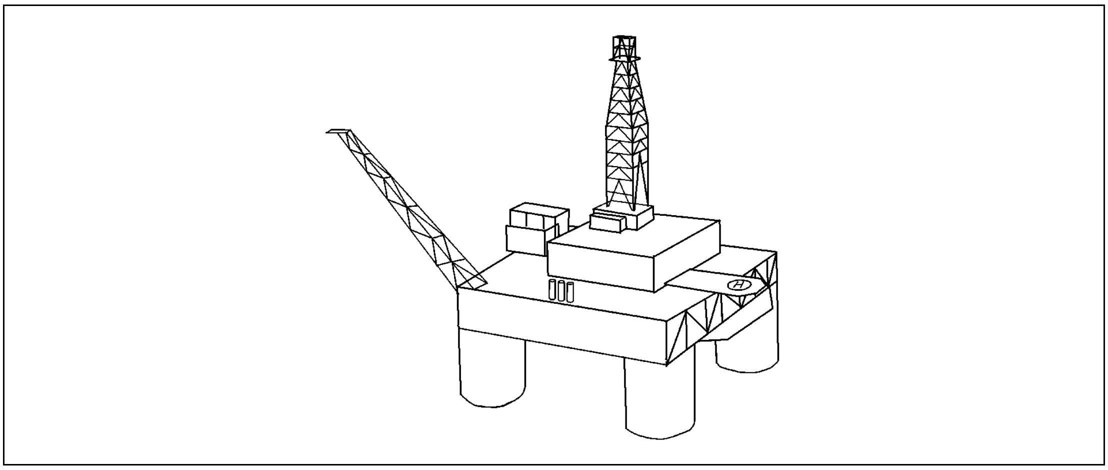


Figure 18

Good: Wave induced motions for this tension leg platform will generally be small. They are almost zero in roll, pitch and heave, while the larger surge, sway and yaw motions are normally at very low frequency.

Bad: The helideck is mounted relatively low on the superstructure and is close to a large solid construction, which will cause significant turbulence when up wind. Upward facing gas turbine exhaust stacks are insufficiently high to ensure that the hot gas plume will pass above the helicopter flight path.

4.4 FPSOs

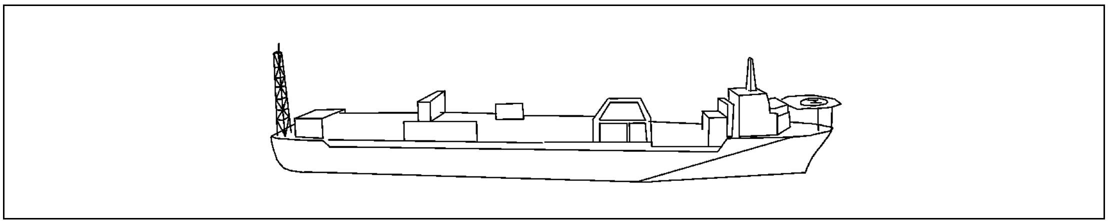


Figure 19

Good: The high location of the helideck and generous air gap mean that it is very unlikely to suffer from any aerodynamic turbulence, particularly as the vessel usually operates heading into wind.

Bad: The extreme forward location of the helideck means that vessel pitch will be experienced at the helideck as heave motion and acceleration. The high location of the helideck means that vessel roll will be experienced at the helideck as sway motion and acceleration. Pilots also dislike bow-mounted helidecks because of the lack of visual cues when landing facing away from the vessel.

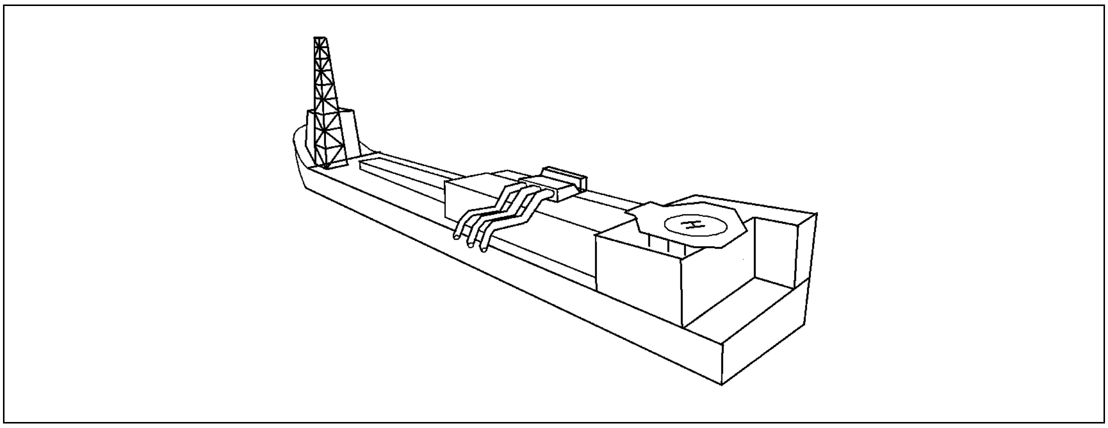


Figure 20

Good: A helideck at the stern will experience lesser wave induced motions than if it were at the bow. It is also reasonably high compared with the bulk of the superstructure, and is unlikely to experience severe turbulence even though it will usually be downwind. Pilots will have good visual cues for approach and landing.

Bad: Gas turbine exhausts pointing down over the side may cause clouds of rising hot gas to envelop the helideck and helicopter approach path. This is particularly likely to happen in light wind conditions when helicopter performance is inherently poor. The aft superstructure violates the 5:1 falling gradient, and if a shuttle tanker can connect to the stern, it is likely to violate the helideck obstacle-free sector when present.

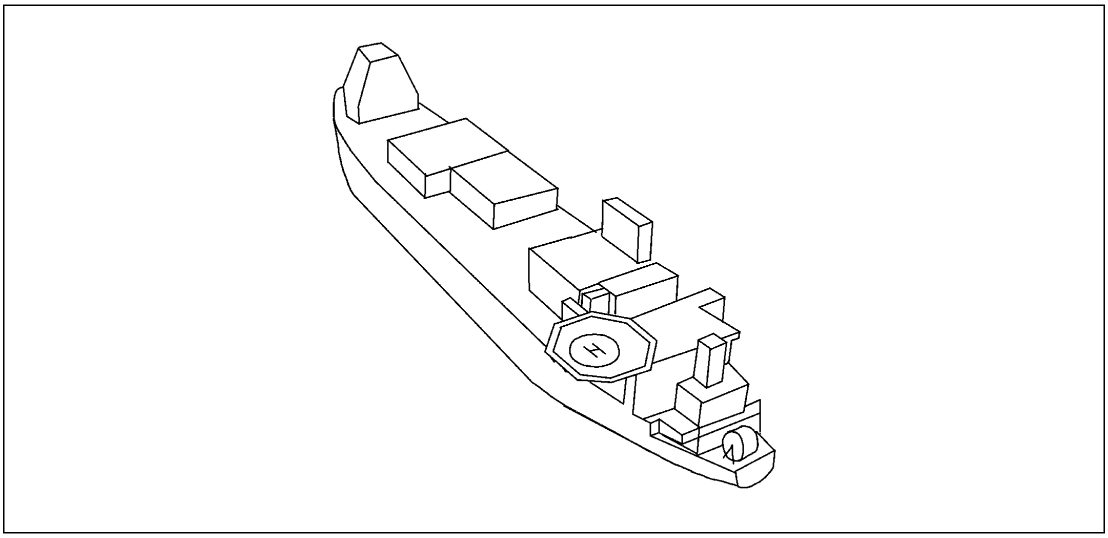


Figure 21

Good: The helideck cantilevered over the port side of the vessel gives a clear approach and overshoot path that is free of obstructions and should be largely clear of turbulence for head winds. There will also be good visual cues for the pilot.

Bad: The highly offset or overhanging helideck location means that vessel roll motion will be manifest at the helideck as heave motion and, depending on the roll characteristics and wave conditions experienced, might severely limit helicopter operability. A shuttle tanker can connect to the stern of the FPSO, and when present is likely to violate the helideck obstacle-free sector and the 5:1 falling gradient.

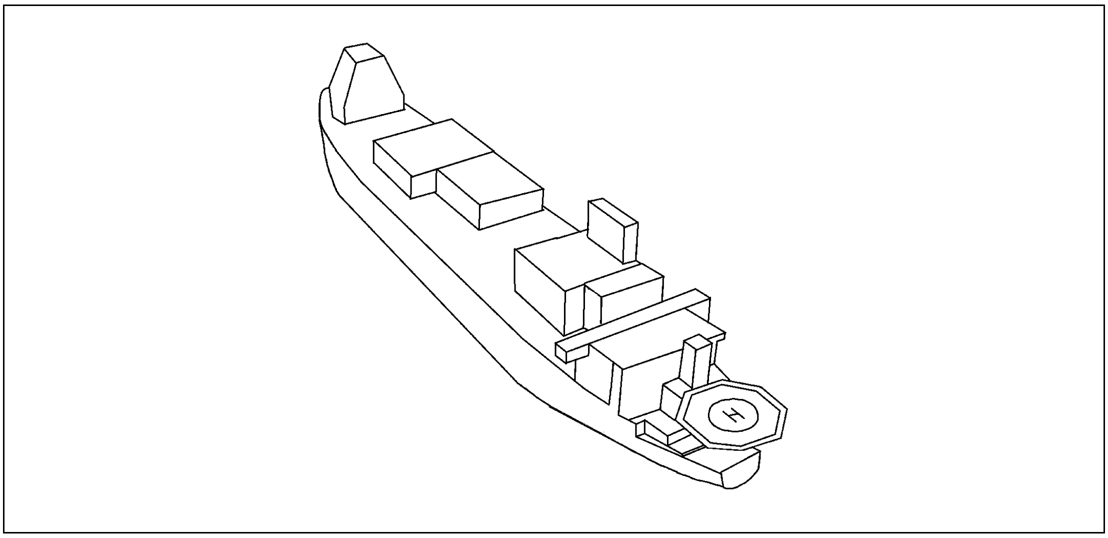


Figure 22

Good: Good visual cues and clear approach path for head winds.

Bad: The helideck is mounted relatively low, and in the wake of the main superstructure. As a result, landing helicopters are likely to experience turbulence, and a sharp reduction in wind speed leading to loss of lift. Any shuttle tanker connected to the stern of the FPSO will violate the helideck obstacle-free sector and the 5:1 falling gradient.

5 Methods of Design Assessment

The environmental effects described in this manual are influenced by the wind and wave conditions experienced by the offshore installation. Clearly these weather conditions vary from day to day in a largely unpredictable way.

However, wind speeds and wave heights are both amenable to statistical analysis, and data can be obtained which describe their statistical properties. These data can be used with information about the flow patterns around the platform, and the platform wave motions to:

- estimate the likely helideck operational downtime,
- locate the helideck in the best location on the installation to minimise helideck downtime, and
- determine the best compromises between conflicting requirements.

The following sections outline methods of assessing the installation properties (from experience, from wind tunnel tests and other modelling methods - see Sections 5.1.1 and 5.1.2), the key statistical properties of the offshore ocean climate (Sections 5.2 and 5.3), and how they can be used together to estimate operability and inform the design process (Section 5.4), and in reporting any likely operating limitations to helicopter operators (Section 5.5).

5.1 Wind Flow Assessment

5.1.1 Expert Visual Inspection

The main factors that influence the wind flow conditions over the helideck are the prevailing wind direction and the location of the helideck on the installation topsides relative to this direction. Ideally, the helideck should be located so that, for the prevailing wind direction, it not downwind of major obstructions such as drilling derricks and gas turbine exhausts. In this way, for the majority of the time, the turbulent wake flows and high temperature gas plumes will be blown away from the helideck and away from the helicopter's flight path.

Assessment can be made in a qualitative manner by expert review of the installation topsides and helideck design in conjunction with information on the prevailing wind directions. This may be appropriate in the very early stages of design, and it may be possible to make an upper estimate of the helideck downtime on this basis. However, in most cases it is preferable to obtain a quantitative measure using flow assessment (Section 5.1.2), the wind climate (Sections 5.2 and 5.3), and a calculation of the helideck downtime (Section 5.4).

5.1.2 Detailed Flow Modelling using Wind Tunnels and/or Computational Fluid Dynamics (CFD)

Wind tunnel testing and CFD are the principal tools available for predicting the flow field around a helideck.

5.1.2.1 Wind Tunnel Tests

The main objectives of wind tunnel tests in the context of helideck design are to predict the mean velocity and turbulence intensity components as well as the mean and peak temperature rises for a range of wind angles and heights above the helideck. A comparison of the results with the design guidance can then be made.

The model scale should be sufficiently large to incorporate an adequate level of geometrical detail to reproduce the correct local flow features around the platform. Typical model scales that can achieve this are in the range of 1:100 to 1:200. At these scales the discrepancies in flow patterns between full-scale and model-scale are generally small.

The model scale should, however, be sufficiently small to minimise the blockage of the wind tunnel flow by the model. A high blockage would result in the airflow over the platform being adversely affected by the walls of the wind tunnel. It is recommended that the frontal area of the model should not exceed 10% of the cross-sectional area of the tunnel working section.

The wind tunnel should accurately simulate boundary layer velocity and turbulence profiles representative of the full-scale marine atmospheric wind flow. Target profiles often used in offshore studies have been defined by a number of regulatory bodies, e.g. NMD [10], API [11], and SNAME [12]. Wind tunnels designed to simulate atmospheric boundary layers tend to have very long working sections to enable the boundary layer to be developed and controlled. Such wind tunnels should also have a reasonable length of working section continuing downstream of the model to enable measurements of decaying temperature or turbulence to be made at least one platform diameter downwind.

In modelling buoyant hot gas plumes, it is necessary to match the ratios of the exhaust density to ambient density, the exhaust velocity to wind speed and the plume inertia force to gravitational force, this to maintain similarity between the model scale and full-scale exhausts. The latter ratio links velocity with buoyancy and implies that the model test velocities have to be scaled as the square root of the model scale (Froude scaling). For example, for a model scale of 1:100, a full-scale wind speed of 10 m/s is represented by a model test wind speed of 1 m/s. This scaling requirement imposes a practical limit on the model scale for a specific wind tunnel facility, and the ability to run at low speeds with good stability is often important.

In circumstances where model scales greater than 1:200 are called for, alternative scaling techniques would be necessary. Such techniques are specific to the particular study and specialist advice would be required.

The correct density ratio can be achieved in two ways. Heated air can be used where the model release temperature is equal to the full-scale temperature. There are practical disadvantages associated with this method in setting the high temperatures of around 500°C in a wind tunnel. A practical alternative is to release a buoyant gas mixture (e.g. helium-air) at ambient temperature with a density equal to that of the full-scale exhaust plume. The local density decay of the gas mixture is used as a direct analogue of the temperature decay. Any gas mixture can be used provided that there is a convenient way to measure its concentration.

The measurement of wind speeds above the helideck should be carried out using instrumentation capable of resolving velocity and turbulence components. Hot wire anemometry is the most widely used technique although laser anemometry is an alternative.

5.1.2.2 Computational Fluid Dynamics

CFD methods allow engineers to model the behaviour of three-dimensional, turbulent, fluid flows by computer. The fundamental aim of CFD is the solution of equations representing the conservation of mass, fluid momentum and energy, throughout a computational domain which contains a geometrical model of the object of interest (e.g. an offshore platform), and is contained within boundaries upon which known values or behaviours of the flow can be defined (boundary conditions).

Solutions are achieved within a defined computational domain using numerical techniques. Among commercially available CFD computer programs, the so-called finite volume method has become the most popular, mainly for reasons of computational speed, versatility and robustness compared to other numerical techniques. As its name suggests, the domain of interest is sub-divided into many smaller volumes or elements to form a three-dimensional grid. Volume-averaged values of fluid variables are located at points within this grid, and local numerical approximations to the conservation equations used to form a very large system of coupled, simultaneous equations. When known boundary conditions are applied, these equations can be solved to obtain averaged quantities for each variable at every grid point in the flow domain.

The extent of the computational domain should be sufficiently large to avoid any numerical influence of the boundaries on the flow around the platform in accordance with best practice guidelines [13]. Typically, this should extend several platform diameters away from the object of interest in all directions with an extended computational domain in the downstream wake region. A marine atmospheric boundary layer profile of velocity and turbulence should be generated at the upstream boundary and maintained throughout the computational domain using suitable roughness properties for the sea.

To obtain good quality CFD solutions, a sufficient number of finite volumes (grid density) must be used, and their quality must be such that the numerical approximations used retain their formal mathematical accuracy. The grid density should be sufficient to fit both geometrical features and flow behaviour (such as shear layers and eddies). The overall aim is to achieve, as closely as practicable, so-called grid-independent solutions of the numerical formulations of the mass, momentum and energy conservation equations. This becomes more difficult, of course, as the Reynolds Number and the range of geometrical scales is increased.

Many engineering flows, including platform aerodynamics, are dominated by the effects of turbulence. There is no single turbulence model that applies universally to all flows. However, there are a number of approaches for engineering applications that have known ranges of validity and can be used with good judgement. It is, nevertheless, best practice to validate CFD results by comparison with physical measurements, or to follow procedures that have been established as valid in this way [13].

Direct Numerical Simulation (DNS) and Large Eddy Simulation (LES) techniques have shown potential to predict turbulence with reasonable accuracy but are not yet practical for helideck design due to the excessive computing power and simulation time required. The most common approach is to use a Reynolds-Averaged Navier-Stokes (RANS) turbulence model in which time-averaged (or occasionally ensemble averaged, for transient flows) values of the flow quantities are solved. The role of the turbulence model is twofold. Firstly, it modifies the mean flow field velocities, pressures and temperatures, and secondly it provides a measure of the turbulence within the flow. Most commonly, this takes the form of the turbulent kinetic energy and the dominant length or time scale of the energy containing eddies. Both can be directly related to simple statistical properties of the turbulence.

5.1.2.3 Strengths and Weaknesses of the Modelling Techniques

Both CFD and wind tunnel testing can provide key information for the design of offshore helidecks. The main strengths and weaknesses of each can be summarised as (assuming best practice in each case):

- On balance, wind tunnel tests can provide reliable turbulent flow data for the safe design of helidecks, whereas CFD is a tool best employed to provide data on hot exhaust gas dispersion and mean flow quantities.
- Wind tunnel testing will give, directly, measured data for turbulent fluctuations, such as peak values, necessary for comparison with helideck design guidance.

- Extracting quality estimates for turbulence data from CFD requires specialist expertise in application and interpretation.
- Wind tunnel tests for helideck wind flows are normally not affected by modelling at small model scale (Reynolds Number effects), but care should be taken to ensure that this is the case and to suitably condition the experiments if necessary.
- CFD can provide results at full-scale flow conditions and hence consistently model buoyancy (Froude Number) and turbulence (Reynolds Number) effects.
- Although some comparisons with full-scale measurements have been made, neither technique can be said to have been fully validated at full scale.
- CFD results are available for the entire flow field. Wind tunnel data is available at the instrumented measurement locations, although a large number of measurements can be obtained in a relatively short period of time.
- When CFD is used without sufficient training and experience of the problem in hand, poor quality spurious results are easy to achieve, and the accessibility of this tool makes this, perhaps, more likely than with wind tunnel testing.

5.1.3 Helideck Environment Report Contents

The helideck environment report should contain the following information as a minimum:

5.1.3.1 Wind Tunnel Report

- Details of model design and construction including reasoning for the choice of model scale and associated scaling parameters for replicating full-scale flow conditions.
- Details of wind tunnel set-up, instrumentation, instrument calibration, model set-up and data acquisition system.
- Details of the atmospheric boundary layer simulation and comparison of mean velocity and turbulence intensity profiles above sea level with standard target marine profiles (e.g. ESDU, NMD [10]). Measurements should be obtained at the model position without the model installed.
- Details of scaling techniques used and experimental conditioning applied to achieve similarity with full-scale, e.g. enhanced model roughness to achieve Reynolds Number similarity.
- Tabular and graphical presentation of measured data in accordance with the recommendations of the helideck design guide (see Section 5.5).
- Conclusions and recommendations to mitigate any adverse conditions that may impact on helicopter operations.

5.1.3.2 Computational Fluid Dynamics Report

- Details of the CFD model with reasoning for the choice of computational domain, geometrical simplifications, computational mesh, modelling assumptions, sub-models (e.g. turbulence model, bulk resistance terms) and range of validity of the sub-models employed.
- Details of boundary conditions including the atmospheric boundary layer at the inlet, heat sources and surface roughness parameters (e.g. sea and platform surfaces).
- Comparison of the atmospheric boundary layer profiles of mean velocity and turbulence intensity above sea level with standard target marine profiles (e.g. ESDU, NMD [10]). The profile should be taken at a location approximately one facility length downstream of the upwind boundary.

- Demonstration of adequate mesh independence through grid resolution sensitivity tests.
- Demonstration of adequate convergence of the final steady-state solution or iterative transient solution at each time step.
- Tabular and graphical presentation of the simulations in accordance with the recommendations of the helideck design guide (see Section 5.5).
- Conclusions and recommendations to mitigate any adverse conditions that may impact on helicopter operations.

5.2 Wind Climate

The wind climate is a description of the probability of experiencing certain wind speeds and directions. It can be used to determine quickly if the wind climate is benign or harsh, and if there are any strongly prevailing wind directions.

The severity of the wind climate is important because, the more severe, then the more likely that turbulence and hot gasses from high exhaust stacks will be a problem. In benign climates turbulence is unlikely to be a problem but hot gases might still be a hazard, especially if downward facing exhausts have been utilised.

An example set of wind speed /direction frequency statistics is shown in Table 1.

Table 1 Example wind speed/direction frequency table

Beaufort number	**Wind direction (from)**									
	N	**NE**	**E**	**SE**	**S**	**SW**	**W**	**NW**	**Var**	**Total**
0	0+	0+	0+	0+	0+	0+	0+	0+	0.3	0.5
1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.5	1.5
2	0.9	0.8	0.7	0.6	0.8	0.6	1.2	1.0	0.2	7.0
3	2.1	1.3	1.3	1.5	2.1	2.3	2.5	2.4	0+	15.5
4	2.8	1.5	1.5	2.0	3.4	3.2	3.0	3.6		21.1
5	2.7	1.0	1.8	2.3	4.2	3.6	3.4	3.5		22.5
6	1.8	0.6	1.6	2.1	3.4	3.3	2.7	2.5		18.0
7	0.9	0.2	1.1	1.3	1.8	2.0	1.4	1.1		9.8
8	0.3	0.1	0.5	0.5	0.6	0.6	0.4	0.4		3.3
9	0+	0+	0.1	0.1	0.1	0.1	0.1	0.1		0.7
10			0+	0+	0+	0+	0+	0+		0.1
11										0+
12										
Total	11.6	5.7	8.8	10.5	16.5	16.1	14.9	14.9	1.0	100

The example is for a Northern European location, and it should be noted that different geographic locations are likely to have very different wind speed and direction distributions. The entries in the table represent percentage annual duration for each wind direction and wind speed interval. In this case, the most probable wind direction is south with a total duration of 16.5%. This means that for 16.5% of the year, or 60 days, the winds will be from the southern sector.

The right hand column also shows that this is a relatively severe wind climate with the wind speed (expressed here as Beaufort number) being at Beaufort 7 or above for about 14% of the time. This information is sometimes presented graphically in the form of a wind rose (see Figure 23).

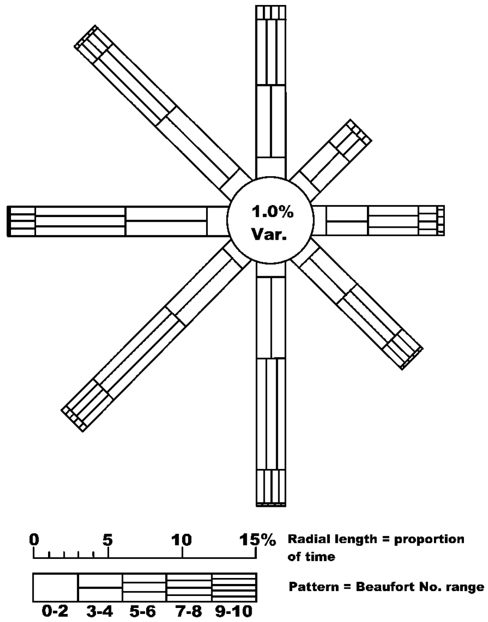


Figure 23 Example wind rose presentation of Table 1

5.3 Prevailing Wind Direction

The wind frequency table or the wind rose can be used to identify the prevailing wind directions. These may be defined as the highest probability directions with a combined probability of occurrence of approximately 50%. For example, taking the data in Table 1, the directional sectors can be ranked as follows:

Table 2 Prevailing wind directions

Wind Direction (from)	Probability	Cumulative
South (157.5° – 202.5°)	16.5%	16.5%
South-West (202.5° – 247.5°)	16.1%	32.6%
West (247.5° – 292.5°)	14.9%	47.5%
North-West (292.5° – 337.5°)	14.9%	62.4%

The prevailing wind directions are therefore defined to be in the range 157.5° to 292.5° with a cumulative probability of 47.5% (or 173 days in the year).[6]

6. It should be noted that wind directions are invariably defined in terms of the direction that the wind blows FROM. However, occasionally such data may be presented as directions TO (often to be consistent with wave direction data which is usually presented in this way). If there is any doubt about the direction definition then it is essential to check with the authority that generated or published it. An error of 180° in determining the prevailing wind directions is likely to be disastrous for helideck operability.

5.3.1 Upwind Helideck Location

When a pilot selects his approach direction to an offshore helideck he will take into account a number of considerations such as:

- direct approach wherever possible,
- clear overshoot available,
- sideways/backwards manoeuvring minimised,
- turbulence effects, and
- right versus left seat pilot.

The balance (or relative weighting) between these considerations will change depending on the wind speed. For example, if the turbulence is low, a pilot could prefer to make a straight-in approach downstream of an obstacle rather than fly a sideways manoeuvre. Hence, there could be a trade-off between turbulence and sideways and backwards manoeuvring, related to wind strength.

However, generally the helideck should be located such that winds from the prevailing directions carry turbulent wakes and exhaust plumes away from the helicopter approach path. To assess if this is likely to be the case, overlay the prevailing wind direction sectors onto the centre of the helideck. Figure 24 to Figure 27 give examples ranging, respectively, from most to least favourable helideck locations for a platform with prevailing winds from the southwest.

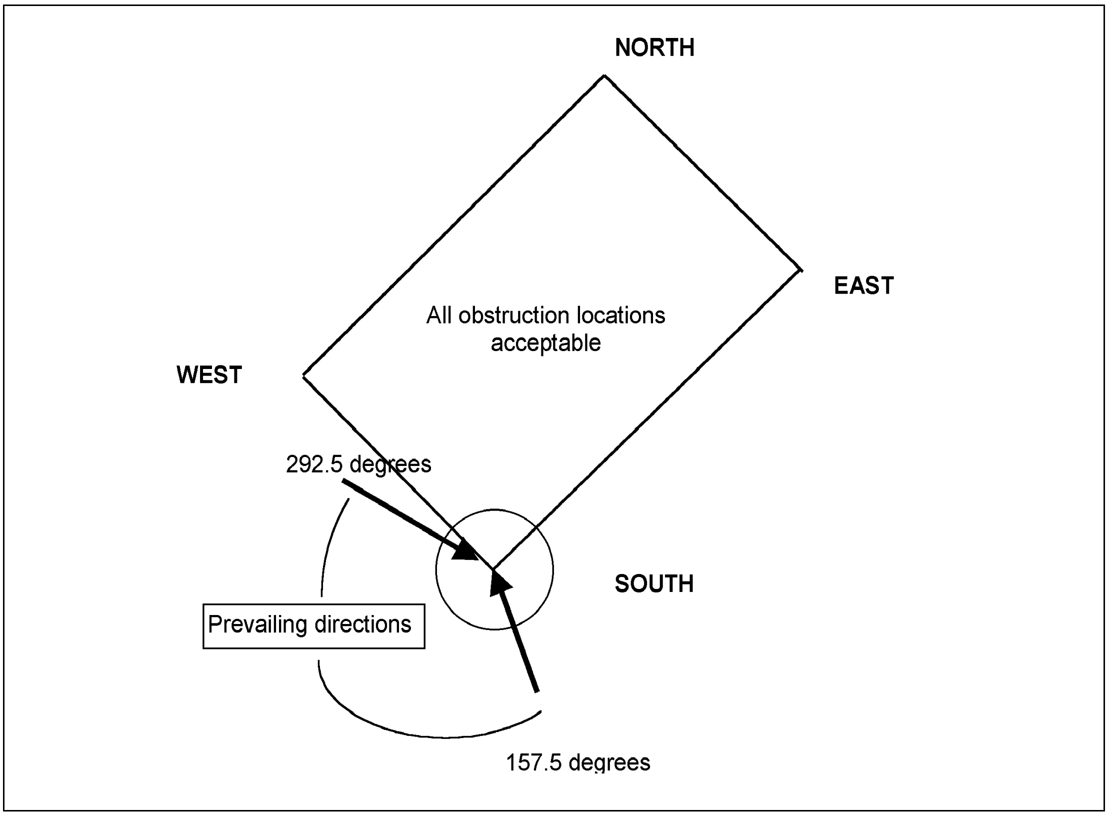


Figure 24 Most favourable helideck location is at the south corner. Regardless of the location of the obstruction, the southwest prevailing winds will carry turbulent wakes and exhaust plumes away from the helideck. The location also allows into-wind approaches to be flown by the Captain for most prevailing wind directions with minimum sideways manoeuvring and a clear overshoot path.

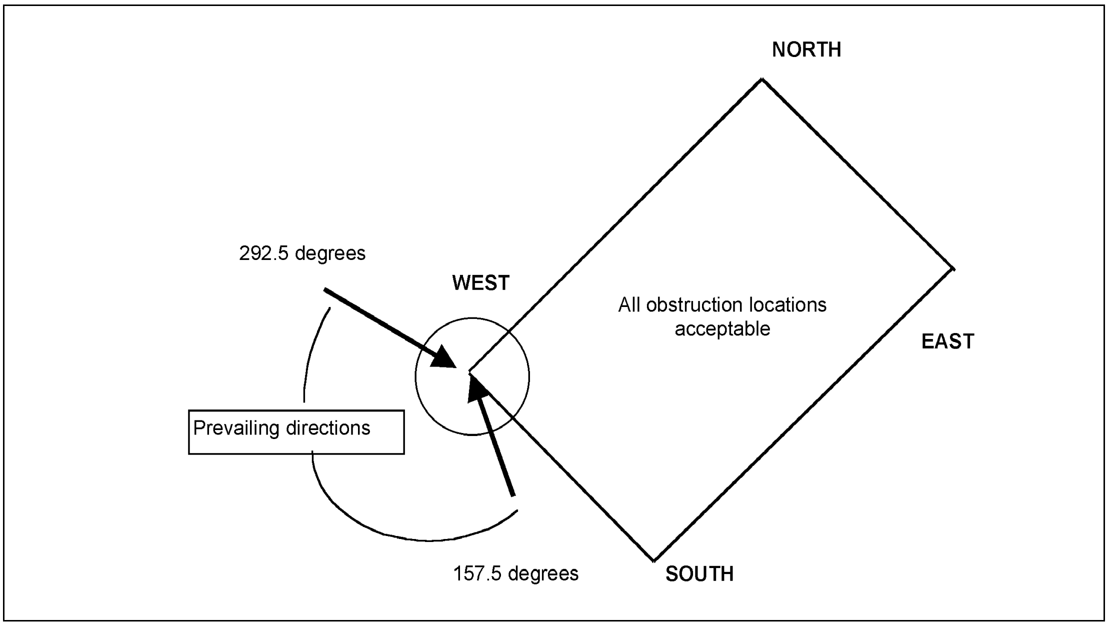


Figure 25 Second most favourable helideck location is at the west corner. Like the south location, prevailing winds will carry turbulent wakes and exhaust plumes away from the helideck. However, the location will require extensive sideways manoeuvring on approach for many prevailing wind directions.

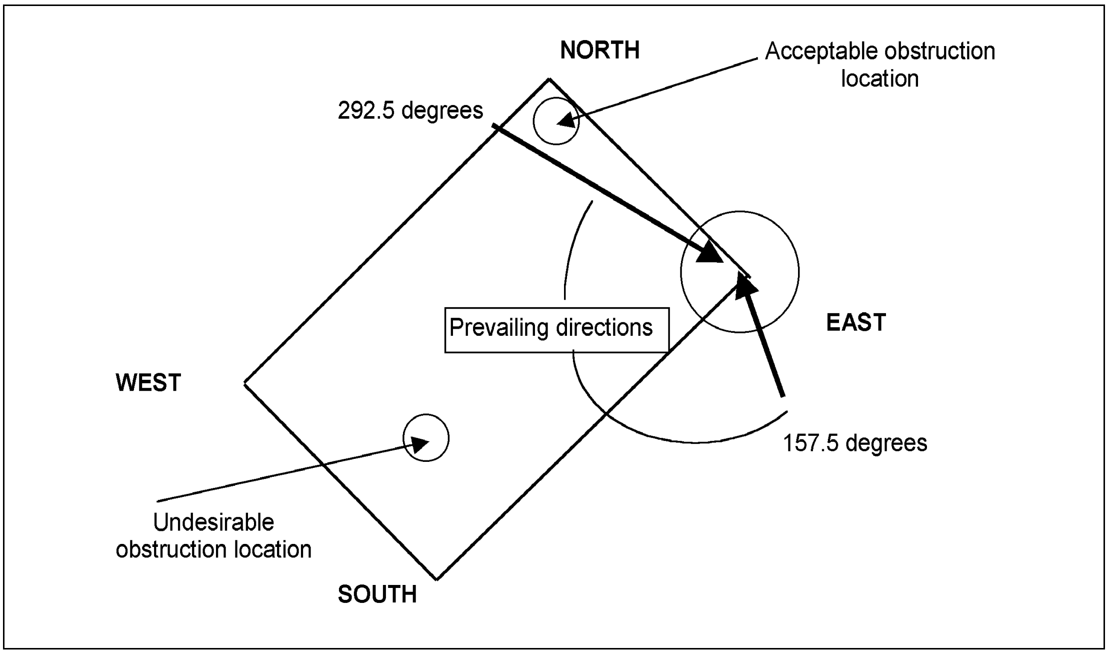


Figure 26 Third most favourable helideck location is at the east corner. About half the prevailing wind directions will carry turbulent wakes towards the helideck. The location permits clear into-wind approaches to be flown but many prevailing wind directions will have an obstructed overshoot path.

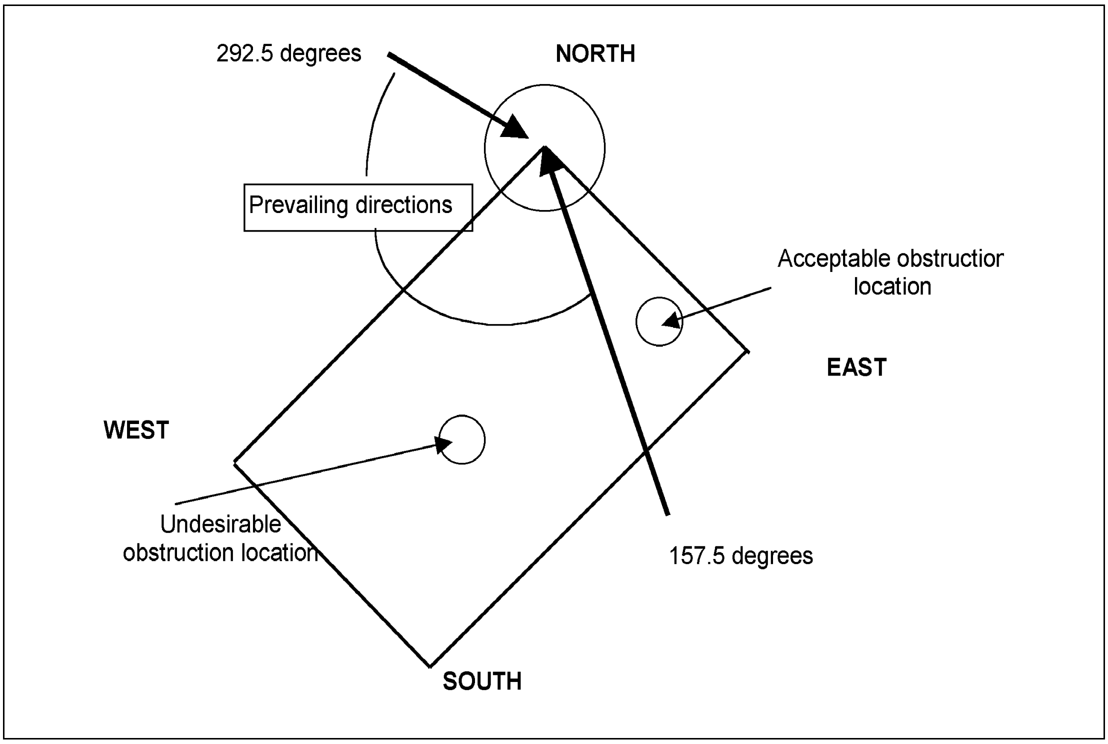


Figure 27 Least favourable helideck location is at the north corner. Like the east location, about half the prevailing wind directions will carry turbulent wakes towards the helideck. The location permits clear into-wind approaches to be flown but many prevailing wind directions will have an obstructed overshoot path.

Major items of obstruction, including drilling derricks and exhaust stacks should be outside the areas embraced by these sectors as shown in the figures. If they are, then conditions at the helideck are likely to be compliant for 50% of the time. If obstructions are located within the prevailing wind sectors, then the following options should be explored:

- rotate the platform to adjust the prevailing wind sectors,
- relocate the obstructions, or
- relocate the helideck.

If none of these are successful, then a more detailed assessment is required and an aerodynamic specialist should be consulted.

To minimise the effects for other wind directions, then obstructions should be located as far away as possible from the helideck. In the case of the exhaust stacks, these should be sufficiently high to ensure that the plumes are above the helicopter approach path. To achieve this, it is recommended that the exhaust outlets be no less than 20-30 m above the helideck.

5.4 Estimating Helideck Downtime due to Wind

The installation flow studies outlined in Section 5.1.2 are likely to identify combinations of wind speed and direction which result in flow conditions over the helideck that do not comply with the guidance requirements (1.75m/s Standard Deviation of the vertical component, 2°C temperature rise). Ultimately the wind speed and direction conditions that lead to non-compliant combinations will need to be communicated to the helicopter operator (see Section 5.5).

However, in these circumstances it is important to estimate the likely severity of the flight limitations. It may be that they will be sufficiently limiting to operations that the cost to the field operator will be too high (this cost being experienced in terms of flights that cannot operate when required, and payloads that are less than maximum). This operating penalty may be avoidable if design changes are made to the helideck, its location or to other installation topside features (e.g. turbine exhausts). These changes may involve additional capital costs that need to be assessed against the operating penalty.

A rational decision can be made about such design changes if a quantitative estimate of the helideck downtime is made and presented to the platform operator. A wind speed and direction frequency table (see example Table 1) can be used to make the estimate of downtime.

On the frequency table highlight all combinations of wind speed and direction that flow studies have indicated will not fulfil the guidance requirements. Adding up all the highlighted values will give the estimate of the total percentage of the time that the helideck will be unavailable for flight operations or where payload limitations may be imposed.

Table 3 Example wind frequency table showing estimation of total downtime

Beaufort number	**Wind direction (from)**								
	n	ne	e	se	s	sw	w	nw	Var	Total
0	0+	0+	0+	0+	0+	0+	0+	0+	0.3	0.5
1	0.2	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.5	1.5
2	0.9	0.8	0.7	0.6	0.8	0.6	1.2	1.0	0.2	7.0
3	2.1	1.3	1.3	1.5	2.1	2.3	2.5	2.4	0+	15.5
4	2.8	1.5	1.5	2.0	3.4	3.2	3.0	3.6		21.1
5	2.7	1.0	1.8	2.3	4.2	3.6	3.4	3.5		22.5
6	1.8	0.6	1.6	2.1	3.4	3.3	2.7	2.5		18.0
7	0.9	0.2	1.1	1.3	1.8	2.0	1.4	1.1		9.8
8	0.3	0.1	0.5	0.5	0.6	0.6	0.4	0.4		3.3
9	0+	0+	0.1	0.1	0.1	0.1	0.1	0.1		0.7
10			0+	0+	0+	0+	0+	0+		0.1
11										0+
12										
Total	11.6	5.7	8.8	10.5	16.5	16.1	14.9	14.9	1.0	100

In the example presented in Table 3 the total of the highlighted cells is 14.3% indicating that, on average, helideck restrictions may apply one day in seven. The direct cost and associated inconvenience of these flight limitations can only be determined by the field operator. If necessary, similar assessments may be made on a seasonal basis.

5.5 Presentation of Wind Flow Assessment Results

5.5.1 General

The results of wind flow assessment are used at two quite distinct stages of the development of an offshore installation design.

Firstly, the results are used in design. They may be used to justify changes to the layout to the installation superstructure and helideck location, and they may be used to estimate the future operability of the helideck. This requires detailed tabulations and plots of the aerodynamic features around the helideck. Section 5.5.2 below contains recommended formats for the presentation of these results, and guidance on the range of different wind conditions and other parameters that should be covered.

Secondly, when the design process is complete, and any changes have been taken into account, there is a need to summarise and present the data to the helicopter operators and pilots through HCA. This ultimately needs to be a concise assessment of the flow modelling results, interpreted in terms of the restrictions that will need to be placed on flight operations. Section 5.5.3 contains recommended formats for the presentation of this summary information to operators and pilots.

5.5.2 Presentation of Flow Assessment Results for Design

Data on helideck flow assessment takes a number of different forms, those with defined limiting criteria being:

- Air temperature data, compared with the 2°C above ambient recommended limiting temperature criterion.
- Turbulence intensity, compared with the recommended turbulence criterion defined as the standard deviation of the vertical airflow velocity, which shall not exceed 1.75m/s.

Although no formal criteria currently exist, it is also sometimes helpful to present:

- Longitudinal velocity data at 25m/s free stream velocity (an indication of the extent of shear in the flow).

There are a number of key issues that should be appreciated when this data is presented, and is plotted or tabulated in terms of wind heading:

- The convention is that wind headings are always presented in terms of the heading FROM which the wind is blowing. Nevertheless, labelling of tabulations and plots should always include the words “wind direction (from)” in order to remove any chance of misunderstanding.
- The heading reference being used (e.g. true, magnetic or platform north) should always be explicit on every tabulation and plot.
- For fixed platforms in the early phases of design it may be convenient and useful to present results in terms of headings relative to Platform North. However, in later stages when data is being used in operability assessments, or is being prepared for the production of a summary for operations (see Section 5.5.3), then it is likely to be much more useful if presented in terms of True North.
- Installations such as mobile drilling rigs and FPSOs that can change their heading as a result of the weather conditions or for operational purposes, should have their wind heading data presented relative to their primary axis. Again the direction of this primary axis should be explicit.
- In all the above, a small annotated plan view sketch alongside the table or plot should be used to avoid any possibility of misunderstanding by the reader.

It is recommended that data is presented at two levels: firstly, a detailed level which shows quantitatively the parameters of interest in relation to the acceptance criteria (see Table 4, Table 5 and Figure 28 below); secondly, at a simpler summary level which illustrates the extent of non-compliance with the limiting criteria as a function of wind speed and direction (see Figure 29 and Figure 30).

The tabular presentation of the data should comprise results from a polar survey taken above the landing spot together with results from lateral surveys. The lateral surveys should correspond to the worst-case wind directions identified in the polar surveys. Typical examples of a tabular presentation are shown in Table 4 and Table 5.

The tables show results for peak temperature rise at a wind speed of 5 m/s but a similar format should be used for other parameters. Empty cells evident in the Table 4 indicate where it was judged that measurements were not required. This is often an easy judgement to make for temperature assessments but less so for turbulence. Consequently for turbulence measurements, a full range of wind directions should be tested.

For temperature rise measurements, results should be presented for a range of reference wind speeds e.g. 5, 10, 15 and 20 m/s. This is because temperature rise has an unpredictable dependence on reference wind speed. In contrast, turbulence can be re-scaled for any wind speed. For this re-scaling, a reference wind speed of 25 m/s, taken to be a practical upper limit for helicopter operation, is suggested.

To supplement the tables, it is recommended that the lateral survey results are presented also as a contour plot as shown in Figure 28.

To highlight the wind conditions in which design criteria are exceeded it is recommended that summary data is presented to provide an immediate visual indication. Examples of such presentations for temperature rise and turbulence data are shown respectively in Figure 29 and Figure 30. In these figures, the radial axis is the reference wind speed and the circumference axis denotes wind direction (from), with respect to Platform North. The absence of shading indicates compliance with the criteria.

Table 4 Polar scan of 3-second peak temperature rise above landing spot

Wind speed at 10 m = 5 m/s

Wind direction (from)	**z (m) 5**	**z (m) 10**	**z (m) 15**	**z (m) 20**	**z (m) 25**	**z (m) 30**	**MAX**
(Degrees from Platform N)	**3-second peak temperature ^{o}C**						
0							
15							
30	**5.2**	**4.3**	**8.6**	**5.9**	0.1	0.1	**8.6**
45	**11.8**	**8.3**	**9.3**	**4.1**	0.1	0.1	**11.8**
60	**9.7**	**8.3**	**8.8**	**5.5**	0.3	0.4	**9.7**
75	**3.4**	**2.2**	**5.1**	**2.2**	0.3	0.2	**5.1**
90							
105							
120							
135							
150							
165	0.5	0.4	0.3	0.0	0.0	0.0	0.5
180	1.9	1.5	1.6	0.2	0.0	0.0	1.9
195	1.1	1.1	1.0	0.0	0.0	0.0	1.1
210	0.9	0.9	0.7	0.0	0.0	0.0	0.9
225	0.0	0.0	0.0	0.0	0.0	0.0	0.0
240							
255							
270							
285							
300							
315							
330							
345							

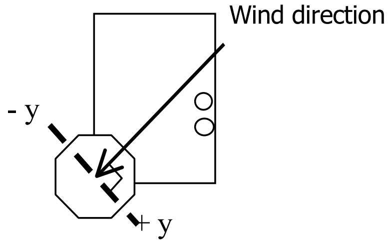
NOTE: Empty cells denote where measurements were judged to be unnecessary.

For temperature rise data, similar tables would be included for other wind speeds e.g. 10, 15 and 20 m/s

Table 5 Lateral scan of temperature rise across the landing spot

Wind speed at 10 m = 5 m/s

Wind direction from (degrees from Platform N) = 45



	z (m) 0	**z (m) 5**	**z (m) 10**	**z (m) 15**	**z (m) 20**	**z (m) 25**	**z (m) 30**
y (m)	**3-second peak temperature rise ^{o}C**						
-25	0.5	1.5	0.2	0.2	0.1	0.2	0.2
-20	0.5	1.0	0.8	0.2	0.1	0.3	0.2
-15	0.7	1.3	**3.2**	**3.9**	0.2	0.4	0.2
-10	2.2	**4.6**	**6.7**	**5.9**	**3.5**	0.3	0.4
-5	4.1	**7.9**	**7.4**	**8.7**	**5.2**	0.3	0.3
0	5.8	**11.8**	**8.3**	**9.3**	**4.1**	0.1	0.1
5	2.3	**6.5**	**9.1**	**8.5**	**8.3**	2.0	0.3
10	1.9	**5.0**	**7.7**	**10.0**	**5.4**	0.4	0.2
15	0.7	**3.4**	**5.2**	**6.8**	**2.7**	0.3	0.2
20	0	0.5	**3.8**	**2.3**	0.7	0.3	0.2
25	0	0.5	0.5	0.2	0.2	0.2	0.3

NOTE: For temperature rise data, similar tables would be included covering the other wind speeds and wind directions where any further local peaks were identified.

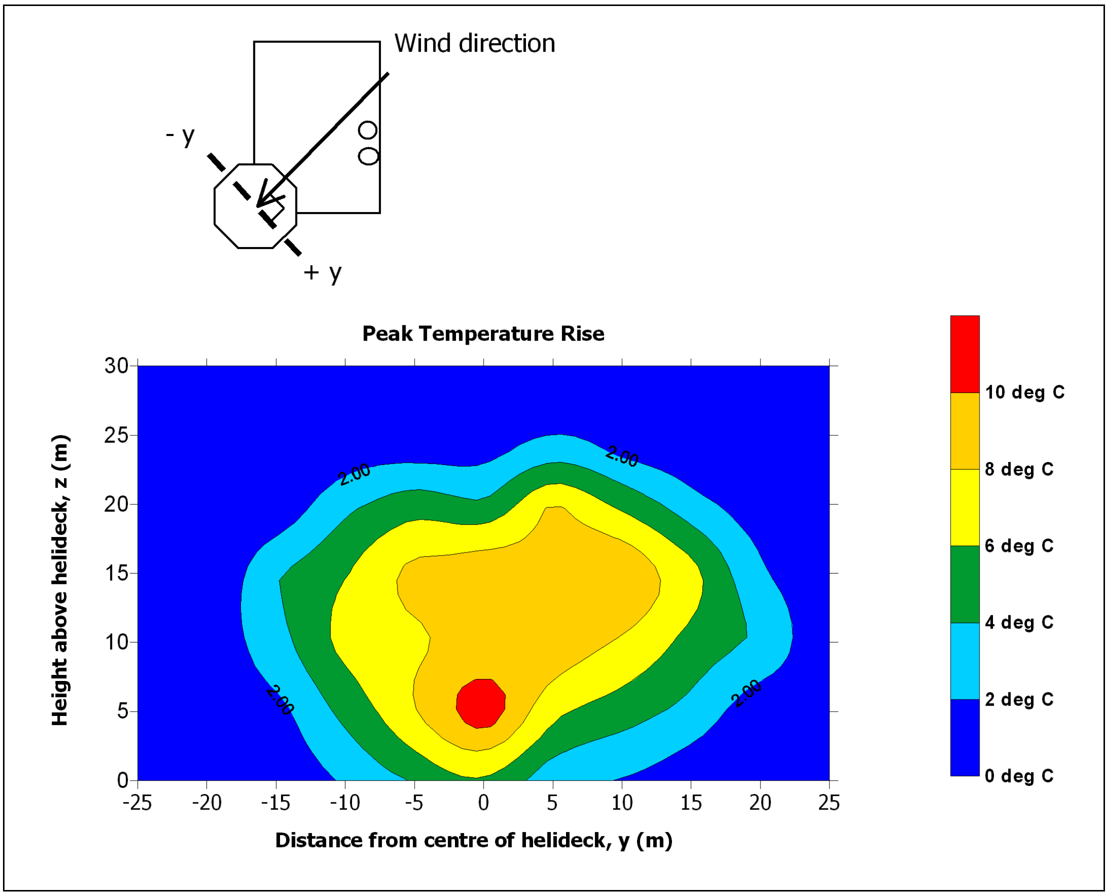


Figure 28 Plot of 3 second peak temperature rise above landing spot; wind speed at 10 m = 5 m/s; wind direction from (degrees from Platform N) = 45. For temperature rise data, similar charts would be included covering the other wind speeds and wind directions where any further local peaks were identified.

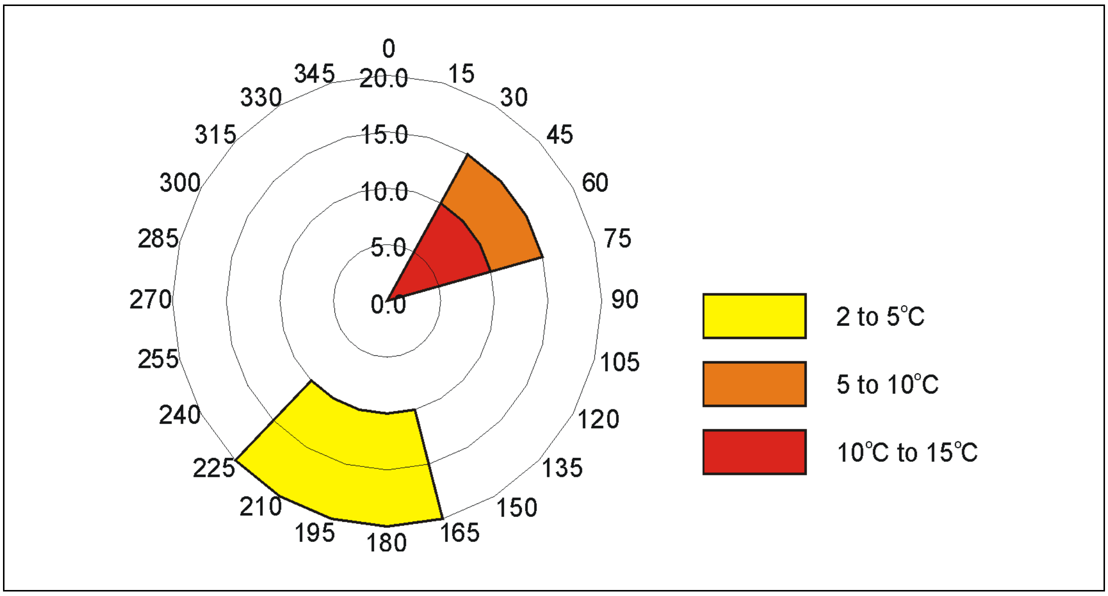


Figure 29 Recommended presentation of temperature data. The radial axis denotes reference wind speed in m/s. The circumference axis denotes wind direction (from), with respect to True North.

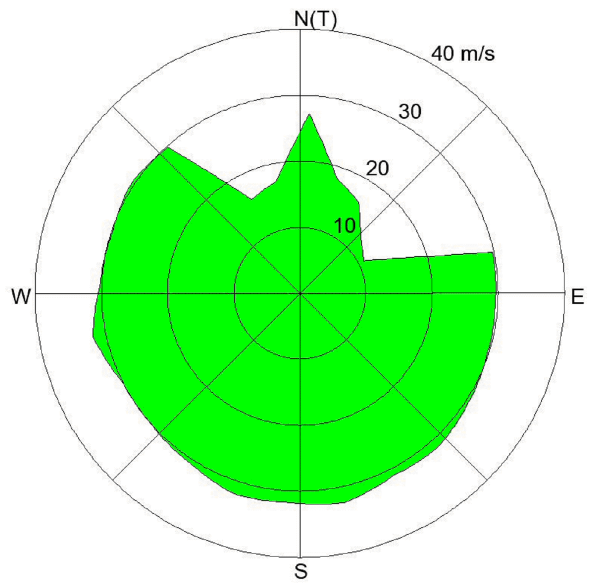


Figure 30 Recommended presentation of turbulence data. The radial axis denotes reference wind speed in m/s. The green shaded area denotes the reference wind speed at which compliance with the critical value is maintained. The circumferential axis denotes wind direction (from), with respect to True North.

5.5.3 Presentation of Flow Assessment Results for Operations

This section contains recommended formats for the presentation of a summary of the helideck flow assessment interpreted in terms of the operational restrictions that will need to be placed on flight operations.

This presentation should be prepared for each installation by a person competent in the interpretation of the wind flow data in terms of helicopter operations. It should then be submitted to HCA, together with the supporting detailed flow assessment results (presented as in Section 5.5.2). It is anticipated that HCA will then review the information, make any changes deemed necessary to the summary presentation, and then issue this summary to the helicopter operators.

It is intended that the presentation should be complementary to the 'Aerad Plate', which currently provides the pilot with concise information on the physical layout of the installation, together with navigational and radio frequency information.

The requirements for this information are somewhat different if the installation is fixed at a particular heading, as is the case for fixed jacket platforms, semi-submersible production or drilling platforms, tension leg platforms etc., or if the installation is an FPSO or mobile drilling unit which changes its heading according to the weather and/or operational needs. Consequently two examples are provided. In Figure 31 an example is given of a presentation for a fixed platform, while Figure 32 contains an example for an FPSO.

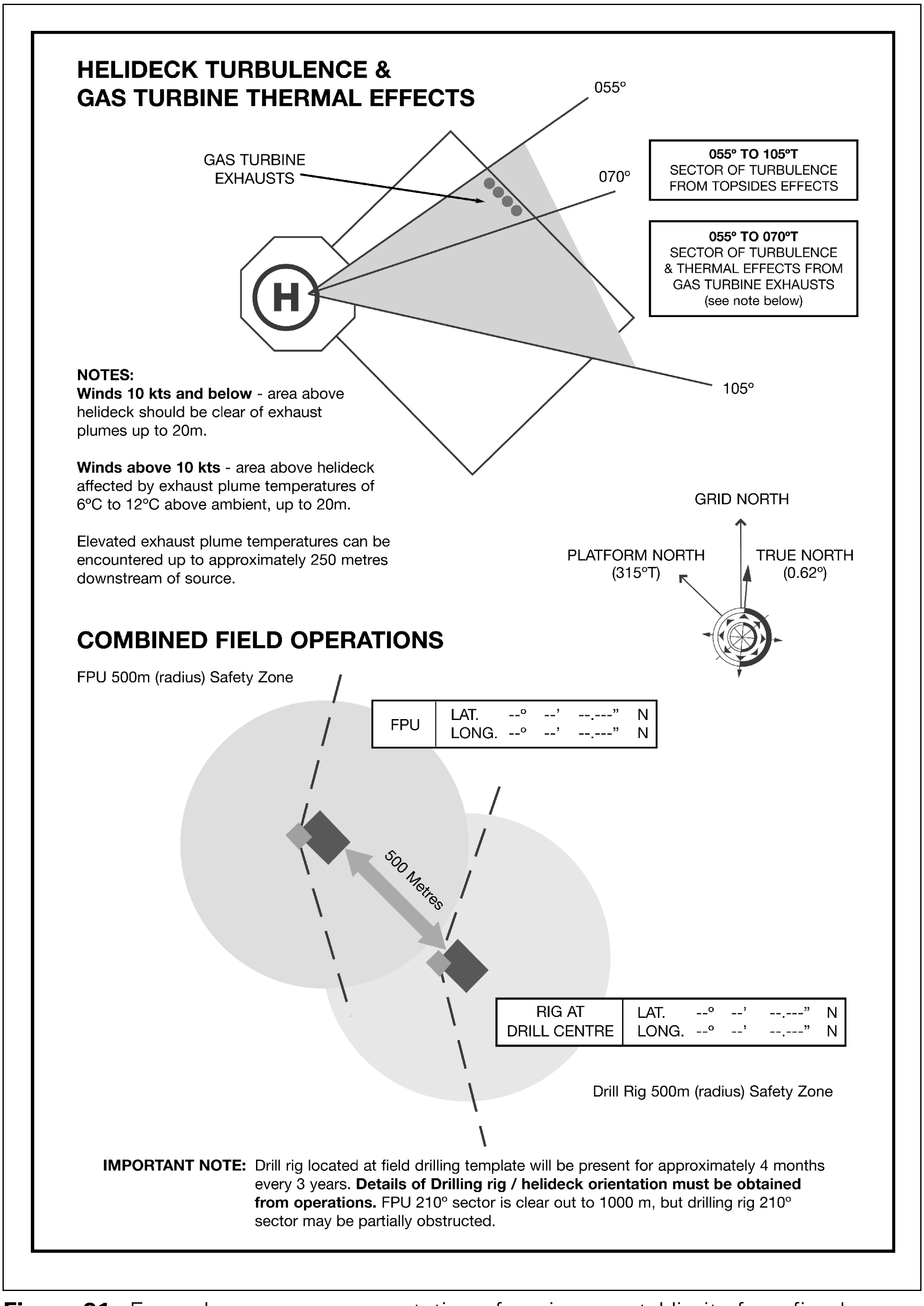


Figure 31 Example summary presentation of environmental limits for a fixed platform

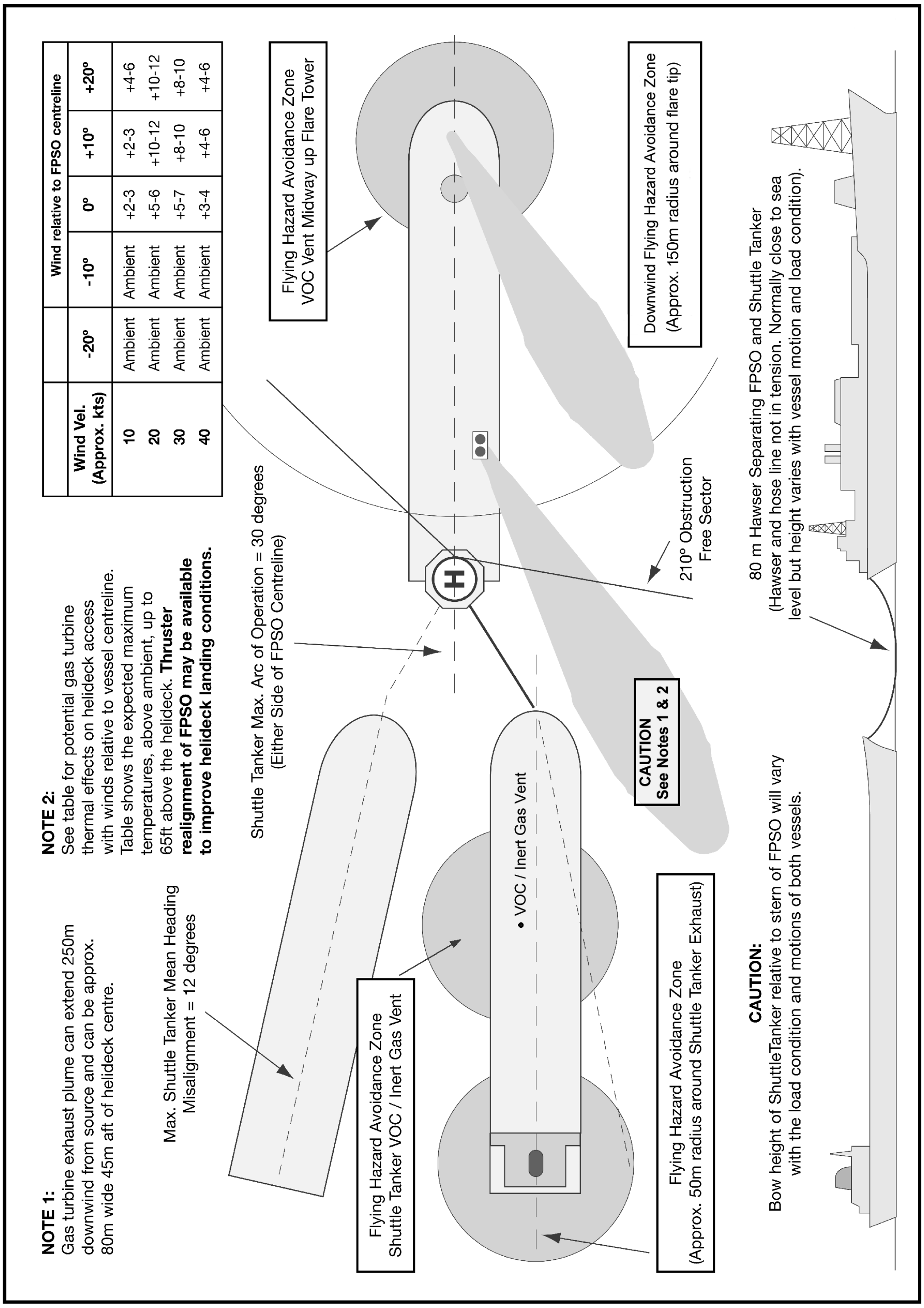


Figure 32 Example summary presentation of environmental limits for an FPSO

5.6 Wave Motion Assessment

5.6.1 Wave Induced Motion Estimates

The motion characteristics of a vessel or floating platform may be reliably predicted by recourse to well-established computer models, or to physical model testing. In either case the results are invariably presented in terms of linear transfer functions. The transfer function contains an amplitude and phase component, and the amplitude is often referred to as a Response Amplitude Operator (RAO). An example RAO is given in Figure 33.

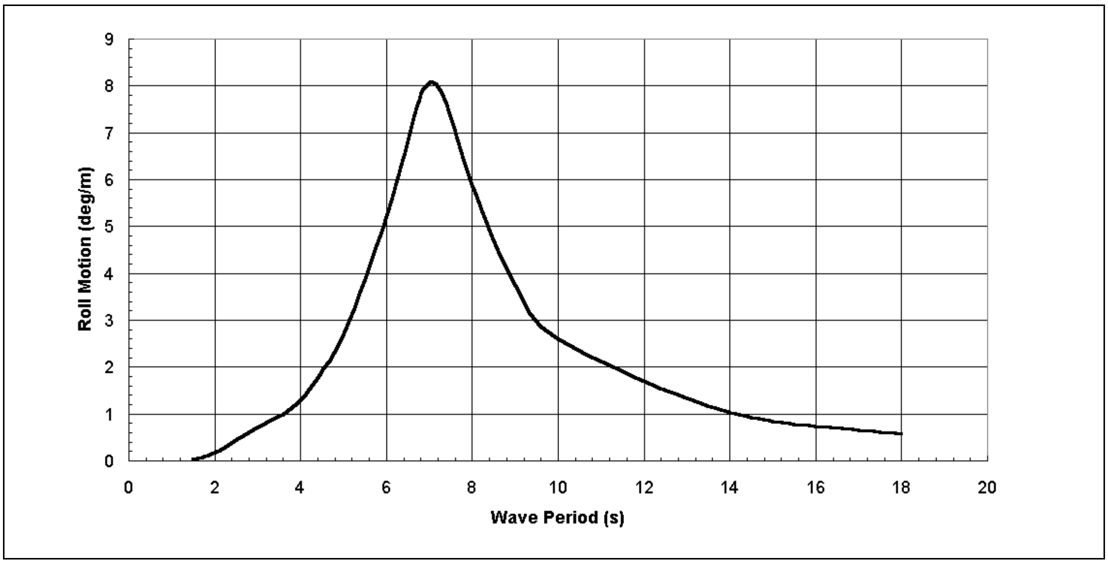


Figure 33 Example RAO

Provided that transfer functions have been derived for all six motion components (roll, pitch, yaw, sway, surge and heave) for a vessel at a defined reference point (often at the centre of gravity, or amidships at the waterline), then RAOs can be readily calculated for any helideck location on the vessel.

Using specialist software this data can be combined with wave climate data (see Section 5.7) and limiting motion criteria (see Section 5.7.1) to derive quantitative helideck downtime estimates (see Section 5.8).

5.7 Wave Climate

The probability of encountering a given combination of significant wave height and period is defined using a 'wave scatter table', which describes the proportion of time when the significant wave height and period lie within specified ranges. Wave scatter tables for open-water sea areas may be obtained from standard reference texts or computer databases (see example in Table 6). Wave scatter tables for specific locations (especially local in-shore conditions) should be obtained from specialist metocean sources.

Wave scatter tables defined on an 'all-year', 'all-directions' basis may be adequate for vessels that are to operate at all times of year and whose motions are relatively insensitive to heading (e.g. semi-submersible drilling vessels). Wave scatter tables for directional sectors are needed in cases where vessel motions vary with relative wave heading (e.g. ships), but the manner of analysis will vary depending on whether the vessel heading is fixed or varies with the direction of the weather. The vessel heading relative to waves should be considered in cases where the vessel weathervanes, or operates under heading control (see Section 3.8.6).

Table 6 Example wave scatter table (from [14])

Worldwide Database, Sea Area 25, Jan - Dec, East

Sig Hgt (m)	28	167	323	278	140	49	13	3	1			OBS 1000
>14												
13 to 14												
12 to 13												
11 to 12												
10 to 11												
9 to 10												
8 to 9												1
7 to 8				1	1							2
6 to 7			1	1	2	1						5
5 to 6			2	4	4	2	1					14
4 to 5		1	7	12	10	5	2					37
3 to 4		5	22	33	24	10	3	1				98
2 to 3	1	19	66	77	44	15	4	1				226
1 to 2	5	62	140	112	46	12	2					381
0 to 1	21	80	85	38	9	2						235
	<4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	>13	
	Zero Crossing Period (s)											

5.7.1 Limiting Motion Criteria

5.7.1.1 General

Limiting motion criteria for landing a helicopter on a floating installation or vessel are at present usually defined in terms of maximum heave, roll and pitch motions. Large heave motions can make it difficult for the pilot to control the final stages of landing and rate of descent at touchdown, and large accelerations can cause tipping or sliding across the deck. The motions used in this analysis must represent the motions of the helideck (rather than the motions of the vessel at its centre of gravity).

The maximum motion experienced during a given time interval depends not only on the sea state, but also on the particular sequence of waves that occurs, and on the length of the time interval. Significant variations in maximum motions often occur between one sample time interval and another. The limiting motion criteria are therefore normally interpreted as specifying 'most probable' or 'expected' maximum values occurring in a 20-minute time interval (i.e. the most likely or average value of all maxima that can occur in different randomly-sampled 20-minute intervals). Standard formulae for estimating the most probable and expected maximum motion in a given sea state are available, and are often incorporated into standard vessel motion prediction programs. Motion time series obtained from time-domain simulation programs or model tests should be processed statistically to obtain estimates of the most probable or expected maximum values.

Special care should be taken to determine whether maximum motions represent 'single-amplitude' (i.e. from the mean value to the maximum) or 'double-amplitude' (i.e. from minimum to maximum) values. Standard helicopter landing criteria are usually defined in terms of maximum double-amplitude heave motions (i.e. measured from trough to peak), but maximum single-amplitude roll and pitch motions (i.e. measured from the true vertical[7]).

5.7.1.2 **Heave Criterion**

The industry is presently moving from a heave limit to a heave rate limit. Heave rate is considered a more appropriate parameter in the context of the helicopter touchdown on the helideck, and its implementation will be facilitated by the provision of electronic motion sensing systems needed to provide the new scheme for assuring on-deck stability described below. It is therefore likely that the switch to heave rate will coincide with the introduction of the new scheme.

Currently, heave rate is calculated by estimating the Maximum average Heave Rate MHR (in m/s) based on measurements of the (peak-to-trough or double amplitude) maximum heave, h_{max}, and the associated heave period, T_h. Calculation of the heave period, however, can be problematic at low values of heave. This measure is therefore to be replaced with the Significant Heave Rate (SHR in m/s) defined as the average of the highest one-third of heave rate amplitudes recorded during the previous 20 minutes. The calculation of the new SHR does not rely on the measurement of heave period and produces very similar numerical results to the original MHR.

SHR = significant heave rate amplitude, defined as the average of the highest one-third of heave rate amplitudes recorded during the previous 20 minutes

NOTE: No change to an existing MHR limit is required when switching to SHR.

5.7.1.3 **Helicopter On Deck Stability**

A new approach to regulating the safety of helicopter operations to moving helidecks is currently being developed [15]. In the new scheme the existing pitch, roll and heave / heave rate measurements are retained to determine whether the helideck motions are acceptable for the helicopter to safely alight on the helideck. Helideck acceleration (motion severity index or MSI) and wind criteria (wind severity index or WSI) have been added, however, to ensure the stability of the helicopter once landed on the helideck.

The acceleration criterion (MSI) is based on a measure of motion severity (MMS), which is simply the acceleration in the plane of the helideck divided by the acceleration normal to the helideck. It can be stated mathematically as:

$$\mathrm{MMS} = \frac{\left|\overrightarrow{x_{ddot}} + \overrightarrow{y_{ddot}}\right|}{\left|\overrightarrow{z_{ddot}}\right|} = \frac{\sqrt{\left(\left|x_{ddot}\right|\right)^2 + \left(\left|y_{ddot}\right|\right)^2}}{\left|z_{ddot}\right|}$$

where: x_{ddot} is the total surge acceleration (including gravitational component due to pitch), in the plane of the deck

y_{ddot} is the total sway acceleration (including gravitational component due to roll), in the plane of the deck

z_{ddot} is the total acceleration (including gravity) normal to the deck

This measure is monitored on a continuous basis over a 20-minute period and factored to produce a prediction of the most likely maximum value during the next 20 minutes:

$MSI(t) = MMS_{max}(t - 20min, t).R$

where R is a constant ≥1. Guidance on the choice of value for R is to be provided by the CAA.

7. Note that the single-amplitude roll and pitch motions must be measured from the true vertical in order that any vessel list or trim is properly accounted for.

The Motion Severity Index or MSI is then given by[8]:

MSI = 10 · $\tan^{-1}$(MSI(t))

When the new criterion is introduced the height of the helideck above the vessel centre of gravity will be of greater concern since the greater this distance, the greater the horizontal acceleration generated by a given roll motion.

The limits of operability for the new scheme are defined in terms of a wind severity index (WSI) as well as the MSI. Both the wind drag forces acting on the helicopter and the main rotor lift are functions of the wind speed, the wind direction in the plane of the deck and the angle of the wind relative to the plane of the rotor disc. Although there are many wind-related parameters that affect the stability of the helicopter, it is not practical to use more than one parameter to describe the effect of the wind. For this reason, all the effects of wind are accounted for in the calculation of the operating limits as a function of the mean wind speed. No forecasting factor (such as R used for the MSI) is needed.

The WSI is simply the 10-minute mean wind speed at 3m above helideck level.

$$\mathrm{WSI(t)} = \mathrm{mean}_{t-10\mathrm{min}}(\mathrm{U}_{\mathrm{meas}}) \cdot \left(\frac{\mathrm{H_d} + 3\mathrm{m}}{\mathrm{H}_{\mathrm{meas}}} \right)^{0.13}$$

where H_d is the helideck height, and U_{meas} corresponds to the measured wind speed at a height H_{meas}.

The WSI is to be measured in knots, but displayed as a unit-less number.

Helicopter operating limits are then to be defined in terms of a plot of maximum permitted MSI value as a function of the WSI value. A generic limits plot is shown in Figure 34 below.

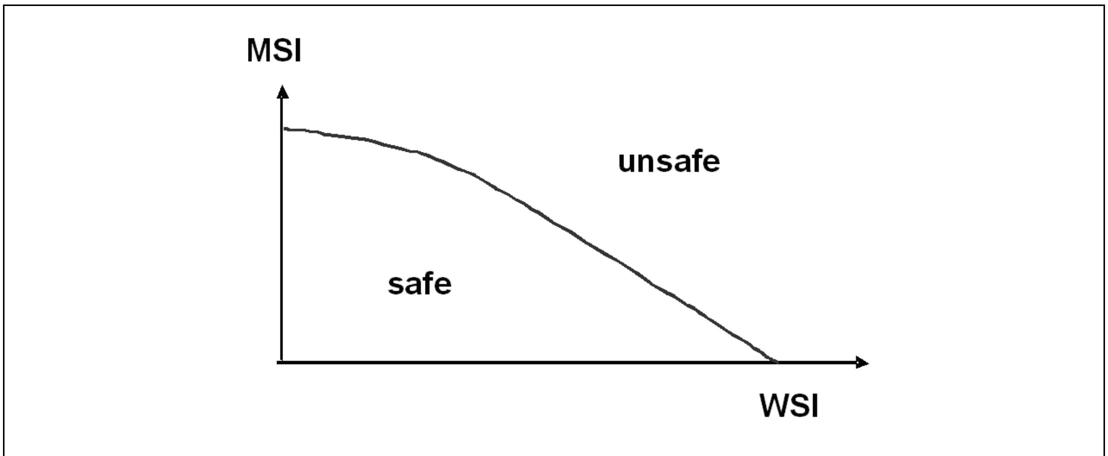


Figure 34 Generic form of a MSI/WSI helicopter operating limit

Maximum MSI values may be calculated and analysed using vessel motion models and procedures similar to those used to determine maximum heave, roll and pitch, together with the published MSI algorithms.

5.8 Estimating Helideck Downtime due to Waves

Estimates of the likely helideck downtime can be made by combining the information about the helideck motion characteristics (RAOs) (see Section 5.6.1) with the

8. The inverse tangent should be calculated in degrees.

expected operating wave climate in the scatter table (see Section 5.7) and wind climate (see Section 5.2), and the helideck limiting motion criteria (see section 5.7.1).

The processes are broadly similar to that described for wind in Section 5.4, but estimating the frequency of non-compliance with the new MSI/WSI criteria is significantly more complex because it involves five parameters (wave height, period and direction, and wind speed and direction). A rigorous downtime estimation for the new criteria needs to include the appropriate joint probabilities of wave and wind conditions and, unless the vessel heading is fixed, some model describing the operating policy for the vessel with regard to wind and wave directions. Methods involving the use of hindcast wind/wave data and time domain or event domain simulation are probably most convenient.

A simpler, less rigorous approach would be to assume a unique wind speed/wave height relationship and base a statistical estimate on the wave scatter data for the operating area. In either case the process should be performed by a competent naval architect using the appropriate specialised software.

Once the helideck downtime has been estimated, the vessel operator can decide whether it is at an acceptable level or not. Helideck downtime will lead to disruption of vessel operations, and these will have a cost. Relocating the helideck to a vessel location with lesser motions and thus lower downtime may be appropriate, but it should be borne in mind that for smaller ships the limiting motion criteria may vary depending on the helideck location on the vessel. Lesser motions are permitted for bow mounted helidecks, for example, owing to the poorer visual cues available to the pilot.

6 Abbreviations

AOC	Air Operator's Certificate
BMT	BMT Fluid Mechanics Limited
CAA	Civil Aviation Authority, UK
CAP	Civil Aviation Publication
CFD	Computational Fluid Dynamics
DNS	Direct Numerical Simulation
FPSO	Floating Production Storage and Offloading
FPU	Floating Production Unit
HCA	Helideck Certification Agency
HLG	Helicopter Liaison Group of the Offshore Industry Advisory Committee
HLL	Helideck Limitation List (previously known as IVLL)
HSE	Health & Safety Executive
IVLL	Installation/Vessel Limitation List (now HLL)
LES	Large Eddy Simulation
LFL	Lower Flammable Limit
MHR	Maximum average Heave Rate
MMS	Measure of deck Motion Severity
MODU	Mobile Offshore Drilling Unit
MSI	Motion Severity Index
OIAC	Offshore Industry Advisory Committee
RANS	Reynolds-Averaged Navier-Stokes
RAO	Response Amplitude Operator
SD	Standard Deviation
SHR	Significant Heave Rate
TLP	Tension Leg Platform
WSI	Wind Severity Index

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