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	JOB:		
	AREA:		
SRGE	TÍTLE: AERODYNAMIC AND THERMAL EFFECTS ANALYSIS FOR THE SAFE LOCATION DESIGN OF OFFSHORE HELIDECKS		INTERNAL
			ESUP

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REVISIONS INDEX

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SUMMARY

1. INTRODUCTION

Landing and take-off operations on an offshore helideck are subject to a number of potential risks due to environmental effects, such as low visibility, unfavorable wind directions, turbulence promoted by obstacles and hot exhaust gases from equipment, in addition to helideck motions in floating units due to the action of waves.

The study for the safe location design of helidecks, as defined in this document, is a consequence analysis used to assess the effects of the spatial distribution of the flow field (in terms of vortical turbulent structures and temperature) for the maneuverability of helicopters in the vicinity of the offshore helideck. In the execution of the study, the requirements of DR-ENGP-II-P1-5.1 (General Criteria for Arrangement of Production Units) shall be met.

The homologation of helidecks in vessels and offshore platforms is standardized by the Brazilian Navy, carried out by means of the NORMAN-223/DPC standard, however, it does not establish quantitative acceptance criteria regarding turbulence or velocity variation, or even evaluation of thermal effects resulting from systems emitting hot gases in the offshore helideck.

With respect to the presence of hot gases on the helideck, the CAA (Civil Aviation Authority), in its recommendation CAP 437 (Standards for Offshore Helicopter Landing Areas), recommends that the maximum temperature rise over the helideck airspace shall be below 2°C above room temperature. NORSOK C-004 (Helicopter Deck on Offshore Installations) suggests the same threshold, but when this criterion is not met, NORSOK proposes the Temperature Gradient Matrix (TGM), a risk based approach that provides qualitative recommendations for helideck operations.

Regarding the velocity field and turbulence, according to CAP 437 and NORSOK C-004 establish, as a general rule, a maximum limit of standard deviation of vertical velocity. The region where this parameter shall be evaluated as well as how to obtain it from CFD (Computational Fluid Dynamics) simulations will be discussed in this document. Similarly as the approach proposed by NORSOK for temperature, a Turbulent Kinetic Energy Gradient Matrix (KGM) is introduced, once more a risk based approach to provide qualitative recommendations for helideck operations, but specially developed to allow the direct utilization of CFD results.

In summary, the design or evaluation of helidecks shall comply with the standards NORMAN-223/DPC, NORSOK-C004 and the recommendation CAP 437. This Technical Specification (TS) intend to guide the development of the turbulence study in the airspace of the helideck, in addition to guiding the preparation of its respective report and results presentation.

2. OBJECTIVES

This Technical Specification (TS) has the following objectives:

- Define scope, methodology and criteria for the safe location design of helidecks, from the point of view of the expected spatial distribution of turbulent eddies and temperature for the basic design phases, Front End Engineering Design (FEED), executive project and assisted operation of the Offshore Installation. This TS may be optionally used as a guide in the operation phase of the Installation at the time of review of the study;

- Guide the dynamics for the planning, development and monitoring of the study by the parties involved and their final approval;

- Define the standardization, content and minimum requirements for presentation of the study report

3. SCOPE

The study shall evaluate the turbulence caused by obstacles and the temperature distribution resulting from the scenarios of operational and emergency discharges of hot gases to provide consistent information for the proper positioning (coordinates - x, y, z) of the helideck and to determine environmental and operational limits for safe approach, landing and take-off operations.

These evaluations shall be analyzed by simulations performed using Computational Fluid Dynamics (CFD) tools complemented by experiments wind tunnel models, when necessary.

From the analysis of the simulations and/or experiments carried out, the following results shall be presented:

A. Helideck Operations Risk Levels

Estimate the risk levels associated to relevant scenarios (combinations of environmental conditions and operational modes) for approach, landing and takeoff operations of helicopters considering the above criteria (turbulence and hot gas plumes).

If the resulting envelope indicates restrictions on the operation of the helideck, alternatives configurations shall be considered and validated by new simulations and/or experiments.

B. Adjustment in installation arrangement with impact on the helideck operation

Define the best positioning of obstructions to the flow (modules, equipment, antennas, etc.) as well as chimneys and gas discharge ducts in relation to the helideck in the vessel by means of the evaluation of their influence of hot gas plume and turbulence on the helideck airspace.

C. Evaluation of the positioning alternatives of the helideck

Define the best positioning of the helideck on the vessel by assessing the influence of hot gas plume and turbulence on the airspace over the helideck.

Note: The effects of offshore unit motions is not part of the study scope.

4. ABREVIATIONS AND DEFINITIONS

For the purpose of this specification the following abbreviations and definitions shall be considered:

Abreviations:

CAA – Civil Aviation Authority

CFD – Computational Fluid Dynamics

TS – Technical Specification

FEED – Front End Engineering Design

SIGEM– Enterprise Document Repository -

TGM – Temperature Gradient Matrix

KGM – Kinect Gradient Matrix

WHRU - Waste Heat Recovery Unit

Definitions:

Contractor - Is responsible for the execution of the helideck safe location design study, and may be a contracted company, either by the Designer or Petrobras, the Designer himself or an internal Petrobras body.

Designer - company responsible for the elaboration of the engineering project is this: conceptual project, basic project, FEED or executive project, being Petrobras itself or contracted company to carry out the project.

Discharge - Expected release of gas from a closed system, directly into the atmosphere.

Helideck airspace - Region of the space in which helicopters are expected to operate and in which the design criteria cited in this TS will be applied. It consists of a cylinder whose base circumscribes the helideck and the height, above the helideck, corresponds to 10 meters added to the height between the landing gear and the rotor, and to the diameter of the rotor of the largest helicopter that will operate in the helideck.

Helideck Risk Assessment – Evaluation of the simulation results in terms of the recommended thresholds of turbulence and temperature, as well as the distance to the helideck center.

Involved Parties - The designer, the study executor and Petrobras involved in the preparation or follow-up of the helidecks safe location design study.

Operational Envelope – Result post-processing in the format of table or polar chart, indicating the risk levels associated with each scenario analyzed (Normal, Attention and Risk) for the approach, landing and takeoff operations of aircraft.

Plume - Three-dimensional representation, in views or contour plots, of simulation or experimental results of hot gas discharges represented in the form of isosurface or temperature-level curves.

Scenario - Is an offshore helideck operation condition that involves a specific environmental condition (wind direction and speed), physical configuration and operation of offshore unit that may affect the risk level of the helideck operation.

Turbulence - Flow characterized by the strong movement of fluid particles, in particular, by the randomness of the velocity field fluctuations.

Wake – is the region of disturbed flow downstream of a solid body caused by the fluid flow around the body.

5. REFERENCE DOCUMENTATION

– The following documents shall be considered, in its most up-to-date version and with RELEASED or RELEASED WITH COMMENTS status by Petrobras at SIGEM or another electronic document management system defined in the contract. The review of each document shall be clearly indicated in the analysis report.

– a) Arrangement drawings;

– b) 3D Model of the Offshore Unit;

– c) Data sheets of equipment that emit hot gases (FDs);

– d) Meteorological data;

– e) Equipment list;

– Additional documents shall be provided for the identification of other relevant aspects, such as:

– Location of the discharges of combustion related processes (e.g.: turbines, motors and furnaces);

– Type of floor that separates the decks to the helideck vicinity modules (plate or gridded floor);.

References for the study:

– Silva, D.F.C; Pagot, P.R, Nader, G.; Jabardo, P.J.S. – *CFD Simulation and wind tunnel investigation of a FPSO offshore helideck turbulent flow*, Proceedings of the ASME 2010 29th conference on Ocean, Offshore and Arctic Engineering OMAE2010;

– NORMAN-223_DPC_Rev.0– Normas da autoridade marítima para registro de helideques, 2023.

– ICAO Doc 9261 – NA/903 – *Heliport Manual*, third edition, 1995

– DNV-RP-C205 - *Environmental Conditions and Environmental Loads*

– ICAO ANNEX 14-3, *International standards and Recommended Pratices*, Annex 14,, Aerodromes, Volume II Heliports, 2009

– CAP 437 -, *Standards for Offshore Helicopter Landing Areas*, 9th Ed. *UK Civil Aviation Authority* 2023.

– NORSOK Standard C-004 - *Helicopter deck on offshore installations*, Edition 2019+AC:2022, Oct 2022.

– *Supporting document to NORSOK Standard C-004, Edition 2, May 2013, Section 5.4 Hot air flow*

– Pagot, P.R., Silva, D.F.C.; *Air Velocity and Temperature in the Offshore Helideck Design*, IBP2958_10, Rio Oil & Gas Expo and Conference 2010.

– Silva, D.F.C.; Oliveira, A.C.; Chads, C.E.H.; Ferreira, M.D.A.S; Liang, D.A.; Dolinsky, M.C.B. – Analysys of offshore helidecks turbulence and hot gas plumes – a systematic approach; Proceedings of the ASME 2023 42th conference on Ocean, Offshore and Arctic Engineering OMAE2023

6. RELEVANT ASPECTS OF ANALYSIS

The turbulence study on helidecks shall take into account at least the following aspects that influence the analysis:

– The geometry and physical arrangement around the helideck;

– The environmental conditions to be used in the simulations;

– Discharge conditions for the environment (discharge flow rates and gas temperature);

– The congestion of the areas around the helideck by equipment, structures and tubing, among other items.

7. SOFTWARE REQUIREMENTS

The study for the safe location design of helidecks shall be developed with the use of CFD tools to conduct the simulations.

General-purpose CFD programs can be adopted (Fluent, CFX or STAR-CCM+). Other software shall be previously authorized by Petrobras before being used in the simulations. Relevant published validation references may be required to the contractor to allow the utilization of alternative software.

8. ENVIRONMENTAL CONDITIONS

The meteorological conditions to be used in the study shall be those of the final location of the installation.

The evaluation shall be performed considering the 16 Secondary Intercardinal Directions. The first direction range shall be centered at North=0°, the second centered at NNE=22.5°, the third centered at NE=45° and so on.

The most frequent wind speed shall be obtained from the weighted average of the most frequent speed

values in each of the sixteen directions. The weighting is performed by the number of occurrences of each most frequent velocity considered in the calculation. When frequency values or number of occurrences are provided by speed ranges, use the average value of the speed range.

The study report shall present a table with wind directions, wind speeds of each wind direction, as well as calm condition, when applicable, and all the considerations and assumptions adopted for the simulations.

Taking into account the platform arrangement, symmetry and specific obstacles, reductions in the number of wind directions to be analyzed can proposed based on technical assumptions and submitted to Petrobras approval. In weather vanning mooring (turret) installations, the wind scenarios shall include at least the scenario of wind aligned with the longitudinal axis of the platform, as well as variations around this direction up to 60°, in increments of 30°, port and starboard.

9. STUDY METHODOLOGY

The methodology to be adopted in the helideck turbulence study shall meet the requirements of the current standards, complemented by the requirements contained in this TS.

The methodology for the preparation of the study shall follow the steps described in this technical specification. Any deviation from the methodology shall be presented for analysis and prior Petrobras validation. In the development of the study the following steps shall be followed:

9.1. Scenario Selection

The selection of the scenarios to be evaluated in the study shall be performed based on the following aspects:

Note: In case of CFD simulations, the same simulation file may be used to extract turbulence and hot gas plumes results.

9.1.1. Hot gas plume

Hot gas plume analyzes shall be conducted taking into account wind directions leading to the presence of exhaust gas scenarios into the helideck airspace. This scenario is generally related to the turbines exhaust of the power generation modules of the offshore unit, but the other modules and equipment (e.g.: emergency generators or auxiliaries and fire-fighting pumps, etc.) shall also be considered in the identification of potential hot gas sources. There may be multiple thermal plumes generated by different installation equipment.

In the evaluation of thermal plume, the displacement of the plume depends mainly on buoyancy effects (which tends to move the plume in the vertical direction) and advection (which tends to move the plume in the direction of the incident wind). For this reason, the wind velocity corresponding to the most critical condition shall be checked, meaning that the study will determine the most critical wind condition in terms of the presence of hot gases on the helideck airspace.

Exhaust temperature conditions shall be obtained on the basis of process data, once again searching for the most critical condition, considering aspects such as the number of turbogenerators in operation and the operating regime of the machines. In installations with waste heat recovery units (WHRU), this system shall be considered inoperative for the evaluation of thermal effects. When necessary, more than one operational condition may be analyzed and separated risk level assessments shall be presented (e.g.: with and without emergency generators in operation)

Taking into account the arrangement of the platform and symmetry of obstacles, reductions in the number of wind directions to be analyzed can be carried out through technical justifications and Petrobras approval.

9.1.2. Turbulence

Turbulence will be more critical for higher velocities. A reference wind speed for the turbulence analysis shall be typically not lower than 15 m/s (approximately 30 knots) at 10 m in relation to the mean sea level. The turbulence results and velocity profiles for other wind speeds may be calculated through extrapolations based on the obtained results, according to the references indicated in this document.

In case of turbulence study update or reassessment, special attention shall be dedicated to additional modules and equipment that may represent additional turbulent wakes over the helideck.

Taking into account the arrangement of the platform and symmetry of obstacles, reductions in the number of wind directions to be analyzed can be carried out through technical justifications and Petrobras approval.

9.2. Input Data

For the determination of the meteorological conditions, temperatures and exhaust gas flows and other data to be used in the study, only updated design data shall be used. All documents used as reference for obtaining the data shall be indicated in the item of reference documents of the report with the respective revisions.

All simulated cases shall have their respective fluid properties information presented in the report, and at least shall be indicated: density, viscosity, and any other properties that allow to track the origin and pertinence of the information used. These data shall be provided by the Designer and presented for analysis and validation by Petrobras before being used in the simulations. Validation of process data shall be performed by experienced professionals involved in the project.

It is the responsibility of the Designer to provide the reliable input data to be used in the simulations, so any detected errors that impact the results and that require new simulations is Designer ‘s responsibility. In case of changes in the project formally requested by Petrobras, as change in the composition of fluids produced or increase/reduction of capacity of the plant that impact the study, will be the responsibility of Petrobras.

For thermal plume analysis the composition of hot exhaust gases from turbogenerators, emergency generators, emergency pumps and other applicable equipment may be simplified considering pure hot air.

9.2.1. Wind Profile

Wind speed shall be represented by a typical boundary layer profile over the ocean. Depending on the location to be considered, a DNV-RP-C205 based power law profile may be employed. The considerations for adopting a certain wind profile shall be agreed with Petrobras.

9.2.2. Process Data

To evaluate the effects of a thermal plume on the helideck, it is necessary to establish which process conditions will lead to the operation with the criticality under analysis. From the establishment of the operational scenario, the data of temperature, flow and composition of hot gases in the exhaust of generation modules and other equipment shall be obtained. The process data shall be provided by the Designer and validated with participation of Petrobras prior to the execution of the simulations.

9.3. CFD Modeling

The Contractor shall present the detailed modeling options adopted in the CFD software. Definitions of mesh refinement, domain size, turbulence models, boundary conditions and convergence criteria shall be presented and justified.

A mesh refining study and its impacts on the evaluation of the helideck shall be presented, considering at least velocity profiles, temperature and turbulence variables (e.g.: kinetic energy of turbulence). Mesh refining analysis based on previous experience may be used, but the contractor shall include/present valid reference in the report.

The CFD modeling aims to characterize the environment to be faced by the aircraft during the approach, landing and takeoff operations in the offshore installation, so the presence of the aircraft itself is not considered directly in the simulations, but only the velocity fields (turbulence) and temperature (thermal plume) around the helideck.

The velocity profile and upstream turbulence around the offshore helideck resulting from the simulation model used shall be presented. Variations of the speed profile in relation to the profile imposed at the entrance of the domain shall be evaluated. The turbulence profile, represented by the kinetic energy of the turbulence, shall be coherent with data of scientific literature mentioned in item 5.

The CFD modeling shall be validated by the Petrobras project designer prior to the simulations.

9.3.1. Requirements for Geometry

The CFD geometric model shall be based on the most up-to-date 3D model available for the Installation or shall be constructed based on the actual geometry of the unit under review, if any.

It is fundamental that the degree of detail of the CFD model in the vicinity of the helideck region is close to the reality of the unit in the operational condition (as-built). In general, all details with main dimensions greater than one meter shall be represented in the vicinity of the helideck.

Special attention shall be given to the helideck airgap region, since over congested representation of that region may lead to over conservative turbulence results. Truss structures in the vicinity and under the helideck shall not be represented as solid blocks.

9.3.2. Analysis of CFD Simulation Results

There are a few international criteria for assessing the influence of environmental conditions on the availability of the helideck. As mentioned earlier, CAP 437 and NORSOK C-004 are widely used in this type of analysis.

This section describes the post-processing strategy to be adopted in order to evaluate the simulation or experimental results according to the available international criteria.

9.3.2.1. Thermal Plume Criteria (Temperature Profile)

The recommendation for the evaluation of a thermal plume quantitatively is made with the verification of a maximum temperature rise limit of 2° C in relation to the ambient temperature, according to CAP 437 and NORSOK C-004. The results post processing shall contain information that analyze the extension of the plumes with temperature above this limit as well as 10°C. The results post-processing shall include iso-surface and/or contour plots in order to provide a full characterization of the temperature field for these values in relevant conditions.

Since the threshold of 2°C is a quite restrictive condition, it is usual to have scenarios that violate this recommendation and therefore, for such cases the TGM (Temperature Gradient Matrix) approach shall be adopted, as proposed in NORSOK C-004 (Edition 2, May 2013, Section 5.4 Hot airflow). For each thermal plume, the temperature gradient matrices provided in the document shall be generated.

The TGM assessment assumes that temperature elevation tends to be more critical in the vicinity of the helideck and a matrix interpretation of the results allows aa appropriate risk assessment. The horizontal direction (columns) in the TGM represent the maximum temperature increase relative to the ambient temperature (in °C) over a given volume of helideck airspace. The vertical direction (lines) represents the height in the airspace over the helideck. The volume of the airspace is discretized in intervals of elevation of 5 meters (up to 30 m elevation) and intervals of 10 meters (between 30m and 50 m of elevation). Figure 1 presents an illustration of the TGM. The risk levels are then classified, with the associated recommendations, which shall be noted in the TGM. Figure **1** shows the TGM.

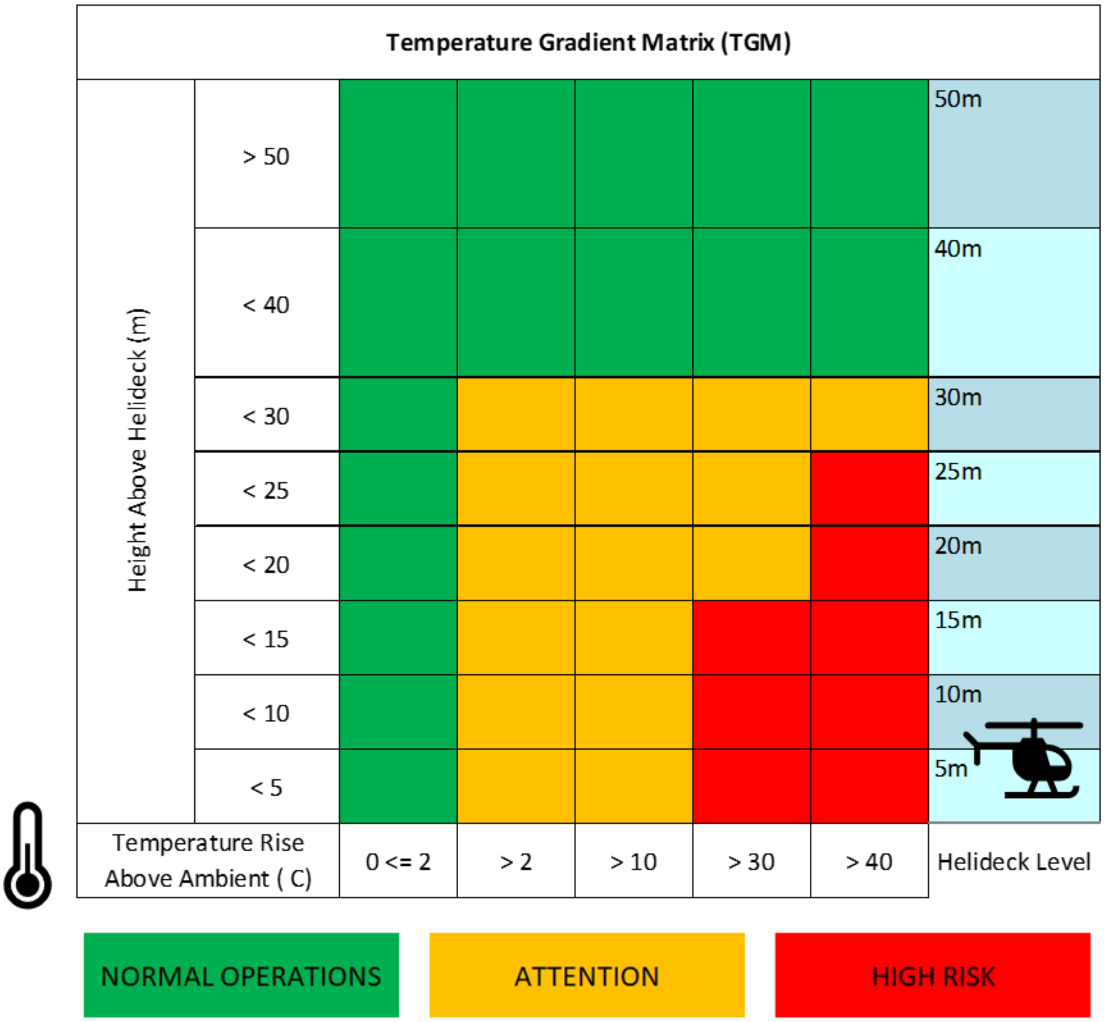


Figure 1 - Temperature Gradient Matrix (TGM)

Note: The criteria adopted is defined based on the maximum value of temperature on volumetric regions above the helideck. The results may indicate “HIGH RISK” conditions based on very spatially limited presence of high temperatures. Such cases must be highlighted and evaluated qualitatively. The study shall present additional risk assessment with the recommendation of “ATTENTION” level to the applicable cases. This recommendation has to be validated during operation in cooperation with helicopter operators.

9.3.2.2. Turbulence Criteria

There is great difficulty in characterizing the turbulence on a helideck in a simplified manner. Technical-scientific studies conducted by the CAA correlate the vertical velocity (sw) standard deviation with a measure of maneuverability of aircraft, indicating a boundary value of 1.75 m/s in the helideck airspace as a good metric to indicate warning levels of turbulence. According to CAA itself, this value considers some safety margin, since the upper limit indicated in the original studies was 2.4m/s, this value is considered as the upper limit by NORSOK C-004.

The results post processing shall contain information that analyze the extension of the plumes with standard deviation of vertical velocity above the limit of 1,75 and 2,4 m/s. In case of CFD simulations, these thresholds may be converted to Turbulent Kinetic Energy, being equivalent to 4,6 and 8,6 m²/s² (See ANNEX A). The results post-processing shall include iso-surface and/or contour plots in order to provide a full characterization of the flow field for these values in relevant conditions.

Since the threshold of 1,75 m/s is a quite restrictive condition, it is usual to have scenarios that violate this recommendation and therefore, for such cases the KGM (turbulent Kinetic energy Gradient Matrix) approach shall be adopted, as proposed by PETROBRAS, inspired in TGM approach.

The KGM assessment assumes that turbulence elevation tends to be more critical in the vicinity of the helideck and a matrix interpretation of the results allows an appropriate risk assessment. The horizontal direction (columns) in the KGM represents the maximum turbulent kinetic energy increase over a given volume of helideck airspace. The vertical direction (lines) represents the height in the airspace over the helideck. The volume of the airspace is discretized in intervals of elevation of 5 meters (up to 30 m elevation) and intervals of 10 meters (between 30m and 50 m of elevation). Figure 2 presents an illustration of the KGM. The risk levels are then classified, with the associated recommendations, which shall be noted in the KGM. Figure 2 shows the KGM.

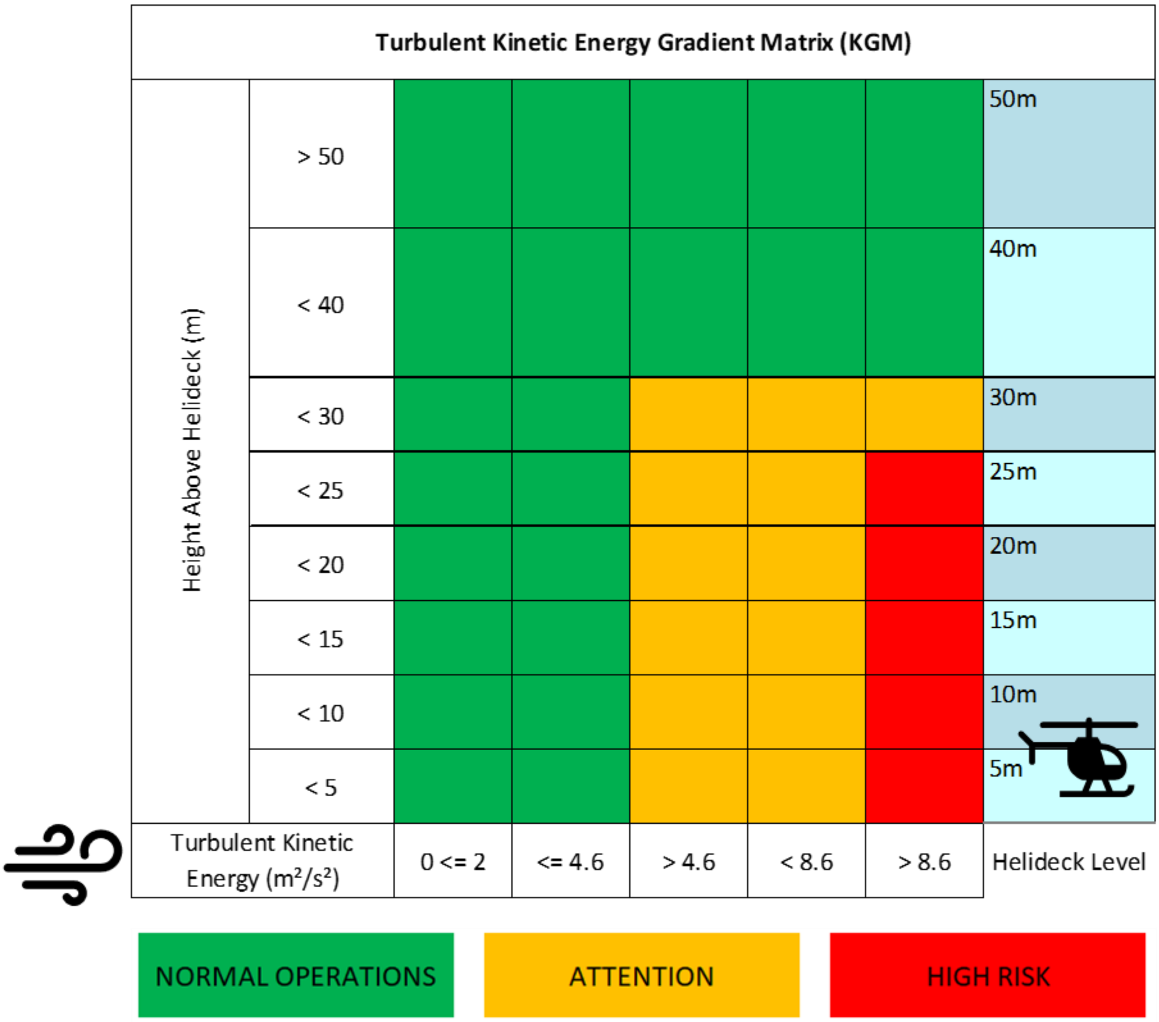


Figure 2 – Kinect Gradient Matrix (KGM)

Note: The criteria adopted is defined based on the maximum value of each variable on volumetric regions above the helideck. The results may indicate “HIGH RISK” conditions based on very spatially limited presence of turbulent eddies. Such cases must be highlighted and evaluated qualitatively. The study shall present additional risk assessment with the recommendation of “ATTENTION” level to the cases where limited influence on helicopter path is expected. This recommendation has to be validated during operation in cooperation with helicopter operators.

In addition to temporal fluctuations of the velocity field, some tests suggest the influence of the spatial variation of the mean velocity field, proposing that the horizontal velocity (U) shall respect the variation of up to 20% in relation to the velocity incident in a region not disturbed by obstacles (Uo). This variation can be calculated by the absolute difference between the maximum or minimum velocity in the helideck and the velocity of the flow (ΔU). This information is not to be considered as flight limitations in the report risk assessment, but shall be presented as additional information for flight operation.

9.4. Results Summary

The results of the turbulence and temperature field evaluations shall be consolidated into a Table representing the Facility's envelope of helideck operations with mapping of critical wind directions where special attention is required. Examples of operation envelopes are given in ANNEX C.

Additional simulations are required to detail the velocity and temperature fields of other scenarios with potential hazards identified after obtaining the results of previously simulated scenarios.

Any recommendations generated in the study shall be highlighted in a specific chapter of the report.

9.5. Experimental Trials

In installations with helidecks whose results of the simulations demonstrate restrictions of operation of the helideck, and which have technical limitations for changes in the arrangement or operating conditions, as well as impediments for the repositioning of the helideck, the simulation results shall be accompanied by recommendation of tests with scale model, using laboratories with an atmospheric boundary wind tunnel (for turbulence) in order to subsidize the decision-making regarding the modification of the project

10. REQUIREMENTS FOR MONITORING MEETINGS

The study follow-up meetings shall follow the guidelines below.

10.1. General Considerations

The follow up of the development of the study shall be carried out by the team of the Designer with Petrobras participation in the cases mentioned in this specification.

The follow-up meetings shall be held in the premises of the Study, with the exception of the planning and analysis meeting of the project documentation, which shall be carried out at the Designer's premises. The meeting local may be changed by agreement between the parties involved. Petrobras, at its discretion, may attend meetings by videoconference.

The minutes of the meeting shall be drawn up by the Designer and made available as a project document or included as an annex to the report in its final review.

All validation decisions (of premises, of data, of geometry among others) shall be included in the final study report as an annex. The validations shall be signed by those responsible for each party involved.

10.2. Planning meeting

Meeting for the summary presentation of the project, clarification of aspects related to the objectives and scope of the study, delivery of project documentation, evaluation and necessary adjustments in the work schedule and resources required for the study, where the minimum agenda shall be:

- Safety briefing - (Designer);

- Presentation of the Project for the Contractor- (Designer);

- Clarifications on objectives, scope of analysis and requirements of the study (Designer and Petrobras);

- Delivery of the project documentation as foreseen in item 5 of this TS (Designer), including the 3D model of the Facility;

- Sizing the teams of the designer and executor of the study that will participate in the preparation and follow-up of the study, with the definition of the matrix of responsibilities;

- Presentation of the focal points of each involved party and identification of the responsible of each discipline of each involved party that will participate in the follow-up meetings and the validations required in this TS;

- Presentation of the planned schedule for the execution of the study in accordance with the project schedule (Contractor and Designer);

- Definition of locations, resources needed and duration of follow-up meetings (Designer and Study Performer).

Participants of the planning meeting: the focal points of the parties involved, the professionals of the Study Performer involved and the leaders of the Designer's disciplines responsible for monitoring the study shall participate.

Note: The schedule shall include a deadline of ten working days for comments (partial and final) by Petrobras.

10.3. Documentation Review Meeting

Meeting for the analysis and validation of the project documentation required for the development of the Study and preparation of the pending list, if any. The objective is to avoid errors and rework in studies due to possible failures or omissions of information in the documentation, which will serve as the input database for the study.

The meeting shall also cover the evaluation and validation of the installation's 3D model as to its suitability for exporting or drawing up the CFD model.

From the analysis of the document list of project and documents provided, the Contractor may request clarification and clear questions about the information contained in the documents. In case of identification of pending documents or the need to provide other documents, the Designer shall inform the deadline necessary to solve the pending issues and/or to send the documents, in a way that does not affect the schedule for the study.

At the end of the meeting, the Contractor shall sign an accepted document containing the pending list, if any. This document shall be annexed to the final report.

Note: The designer, as responsible for project change management, shall inform the other parties involved of any change in the project that affects the study. Documents changed as a result of the project changes affecting the study shall be sent to the Study Performer.

The Contractor shall evaluate the changes and report the impacts of the changes in the analysis and schedule. This information shall be sent formally to the designer and communicated to Petrobras.

Participants in the documentation analysis: Participant's study professionals involved and the discipline's design leaders shall be involved in the follow-up of the study. This meeting is optional for Petrobras.

10.4. Premisses and Methodology Meeting

Meeting aimed at the presentation and definition of premises to be used in the study, clarification of the methodology and confirmation of data from the Installation.

The Contractor shall present the proposed premises for the development of the study and its doubts about the methodology proposed in this TS. The Designer with the participation of Petrobras shall clarify the doubts.

- Wind directions: one shall evaluate the variability and applicability of the dispersions to be simulated. Some very similar cases can be extrapolated, while others may simply disperse out of the Facility and be disregarded;

- Deleted scenarios: agree and document deleted scenarios;

Assumptions shall be defined by agreement between the parties involved and shall be included in the study report.

In addition to the assumptions and methodology, the designer shall confirm the basic information prior the simulations and/or analysis. Special attention shall be given to meteorological conditions and wind relative directions that will be evaluated. The planned scenarios for evaluation shall be ratified or rectified by Petrobras.

Participants of the meeting of premises and methodology: Participant professionals involved in the study and the discipline leaders of the Designer and Petrobras responsible for the follow-up of the study shall participate.

10.5. Follow-up and Validation Meeting

These are meetings aimed at monitoring the study by the Designer with the participation of Petrobras where the items provided for in the methodology shall be addressed.

The Designer in agreement with the Contractor, and considering the schedule for the study, shall present the agenda of meetings to follow up the development of the study. The meetings shall comprise the study steps foreseen in item 9 (Methodology) of this TS. Follow-up and validation meetings shall be provided in Table 2 below:

Table 1 - Monitoring and Validation Meetings

Item	Pauta Mínima	Ref.
R1	**Geometry validation:** Presentation of the CFD model - evaluation of geometry, congestion and obstructions to be added in the model.	9.3.1
R2	**Validation of results and compliance with recommendations:** Presentation, discussion and validation of the simulation results. Verification of the need to execute additional simulations	9.4
R3	**Presentation of the Partial Report:** Presentation, discussion and validation of the results of the additional simulations.	9.6

Table 2 is based on Petrobras' experience, and the number of meetings may be altered by agreement between the parties involved, provided that all the items that compose the methodology and that require validation are addressed, as well as the analysis of results and recommendations are discussed and evaluated for their applicability to the project.

Participants in monitoring and validation meetings: Participants in the meetings of the Contractor involved in the study and the discipline leaders of the Designer and Petrobras responsible for the study follow-up shall attend the meetings.

10.6. Final Report Presentation Meeting - Preliminary Version

Meeting to present the final report (preliminary version) before its issuance to Petrobras. The final report is the responsibility of the Designer. The final report shall include the report of the Contractor plus the treatment of the study recommendations to be implemented in the project by the Designer. The codification of the report and its stamp shall identify the designer as originating from the document. The coding shall be in accordance with Petrobras N-1710 and the format in accordance with N-381.

The presentation shall focus on the most critical scenarios, the main results, conclusions and recommendations of the study. The treatment given to each of the study recommendations shall be addressed.

The focal points of the parties involved, the Study Executives involved and the discipline leaders of the Designer and Petrobras responsible for the study follow-up shall attend the meeting. At this meeting, it is recommended the participation of professionals acting in flight safety.

11. STUDY REPORTS

The final report shall be issued in Portuguese and English. The report shall comply with the content required in Annex VI of the Safety Guideline DR-ENGP-M-1-1.3 in the current revision of the respective contract with the Designer and specified in this document.

All assumptions of simplification and premises adopted shall be presented and explained in the corresponding part of the report. In addition, the minutes of the meetings shall be presented in annex, especially those that have validation of stages of the methodology. The charts and figures of the reports shall be presented with the respective scales, captions, the rose of the winds, and predominant direction of the wind. For the elaboration of the tables, graphs and figures, the units of the International System - SI shall be applied.

All charts and figures that support the conclusions and recommendations of the study shall be presented in the final report..

11.1. Partial Report

At least one partial report shall be submitted by the Contractor to Petrobras for acceptance prior to the issuance of the final report.

The Partial Report contains at least the requirements:

– - Scenarios analyzed and scenarios discarded (item 9.1);

– - 3D model and geometry (item 1);

– - Mesh and simulation domain (item 9.3);

– - Process data (item 9.2);

– - Partial results of the simulations (item 9.4););

11.2. Final Report

The Final Report corresponds to the issuance of the report under review 0. It shall contain all the requirements of item 11.1, take into account the comments made to the Partial Report, and additionally contain:

- Attached meeting minutes (item 10.1);

- Checklist attached (item 14);

- Velocity and turbulence profiles on the helideck (ANNEX A);

- TGM Table, when applicable (ANNEX B);

- Estimating envelope of helideck operation (ANNEX C);

Additional revisions shall be provided for cases where there are project changes that impact the study or if failures in the final emission are identified.

12. DEADLINESOS

According to the complexity of the project, the scope of the study and the deadlines established in the contract shall be defined by the Designer, in agreement with the Contractor, the deadlines required for the study and the issuance of the partial and final reports. These deadlines shall be included in the study planning, mentioned in item 10.2 of this TS.

13. QUALIFICATION TO CARRY OUT THE STUDY

Due to the complexity involved in the methodology and the use of the CFD software applicable to the study, and also due to the importance of this study for the safety of the Installation, the elaboration of the same shall be done by a qualified company, belonging to the registry of suppliers of goods and services.

14. CHECK LIST APPLICATION (LV)

The Designer shall provide a checklist (LV), which shall be included as an annex to the report, as a follow-up to the activities of the contractor. The LV shall be developed by the Designer and shall contain the requirements contained in the standards cited in the document and those in this TS. The verification of each requirement shall have the identification and signature of the person in charge of the verification.

15. INFORMATION SECURITY

The Project Designer and contractor shall have a data security system that guarantees the integrity, reliability, traceability, confidentiality and inviolability of the data contained in the analysis and the data provided by Petrobras. All information shall be preserved against accidental or information security events for at least five years.

ANNEX A – STANDARD DEVIATION OF THE VERTICAL VELOCITY AND TURBULENT KINECT ENERGY RELATIONSHIP

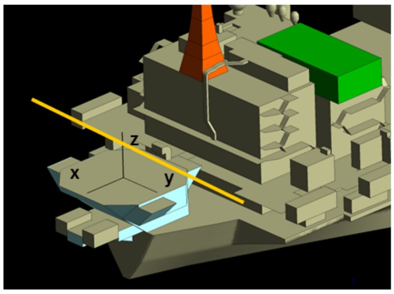
The CAP437 guideline for helideck design recommends a maximum turbulence level based on the standard deviation of the vertical velocity sw. The simulation, however, calculates only the turbulence kinetic energy k, which is defined by equation bellow:

$$k = \frac{1}{2}\left(u'u' + v'v' + w'w'\right)$$

Recalling that the turbulence is assumed as fully developed and isotropic in the RANS models, the velocity fluctuations can be assumed to be all equal. For the steady state regime, the term w´w′ may be interpreted as the variance of the vertical velocity w. Using these assumptions in equation (3), the standard deviation of the vertical velocity sw may be expressed in terms of the turbulence kinetic energy:

$$sw = \sqrt{\overline{w'w'}} = \sqrt{\frac{2}{3}k}$$ (Silva, OMAE 2010)

ANNEX B – EXAMPLE OF KINECT ENERGY RESULTS



Reference line,
5m above helideck

Reference velocity: 15m/s
CFD Resutls

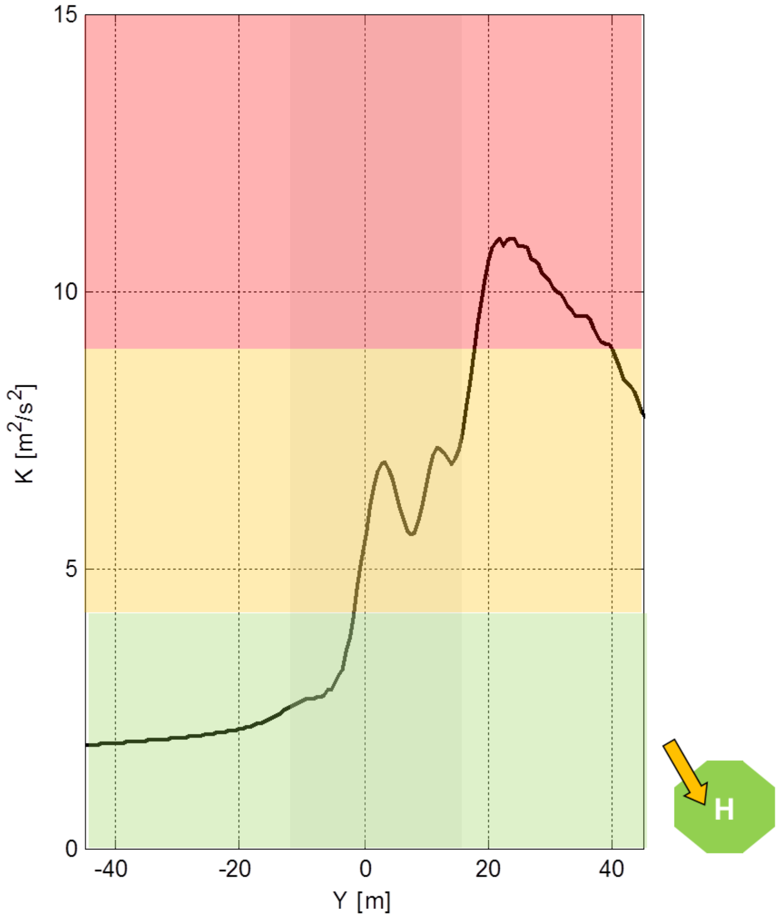


Figure B.1 – Transverse profile of turbulent kinetic energy.

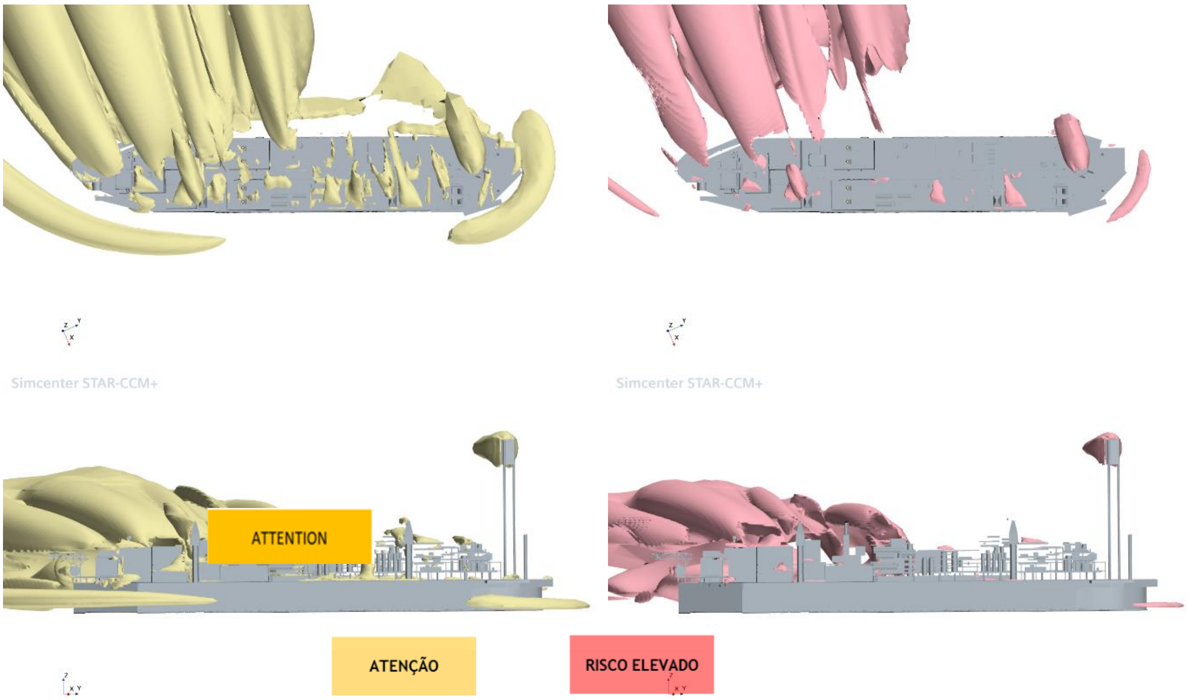
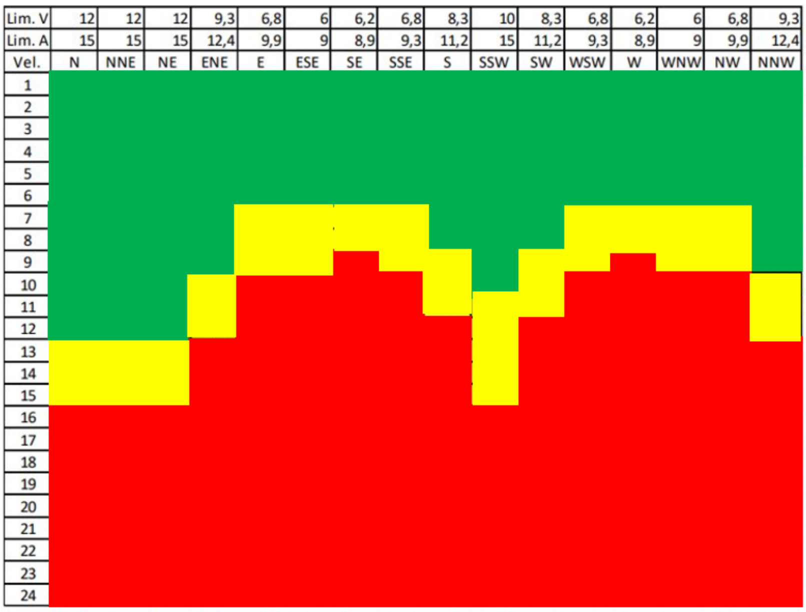


Figure B.2– turbulent kinetic energy Isosurface.

ANNEX C - EXAMPLE OPERATIONAL ENVELOPEWind Directions	Wind speed V (m/s)				% of restrictions / attention
N		V>7			1,35
NNE		V>7			9,77
NE		V>7			13,52
ENE		V>7			7,82
E		V>8			2,7
ESE		V>7			2,7
SE		V>7			2,1
SSE		7<V<9	V>9		1,81
S		8<V<11	V>11		1,21
SSW			11<V<19	V>19	4,07
SW		7<V<10	V>10		1,98
WSW		8<V<9	V>10		0,87
W			9<V<11	V>11	0,4
WNW		V>7			0,23
NW		V>7			0,18
NNW		V>7			0,23
				Total	51,1

D.1 – Operations envelope, based on the results of temperature or turbulence distribution.



D.2– Operations envelope, based on the results of temperature or turbulence distribution.

Note: There shall be a table for turbulence envelope and other for thermal plume envelope in normal operations and other for emergency operations*

*Operations considering emergency generators, auxiliary genertors, fire pumps and/or other relevant hot gas sources