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# DETERMINATION OF LIMITATIONS FOR HELICOPTER SHIP-BORNE OPERATIONS

by

C.F.G.M. Hofman and R. Fang

National Aerospace Laboratory NLR

Amsterdam, The Netherlands

SUMMARY

Nowadays, due to the increasing demand for helicopter operations from ships, the helicopter manufacturer sometimes provides general operational performance data (flight envelope) for such operations. By necessity the envelopes are conservative in nature, since they cover a wide variety of helicopter/ship combinations. An operator may wish to extend the operational envelope for a specific class of ships to maximize the operational availability of helicopter services. In such cases a dedicated qualification programme has to be carried out.
In this paper a brief outline is given of such helicopter-ship qualification programmes as carried out by NLR. It is described in what way detailed information about the helicopter capabilities, ship's motion characteristics and the wind-climate above the ship's flight deck, is used to set up and to execute a safe and efficient helicopter flight test programme.
The programme leads to a safe and maximum operational availability of the helicopter on board the ship in terms of take-off and landing capabilities as function of relative wind and sea-state.

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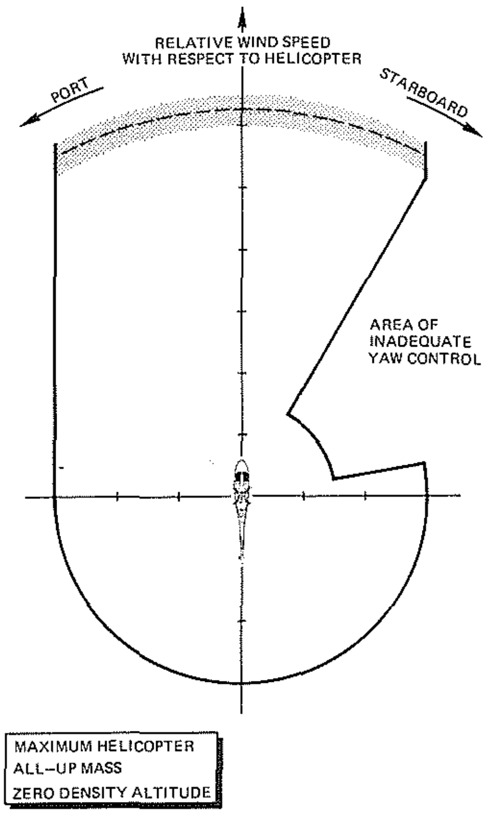
Fig. 1 Helicopter operations on board ships; a rough environment



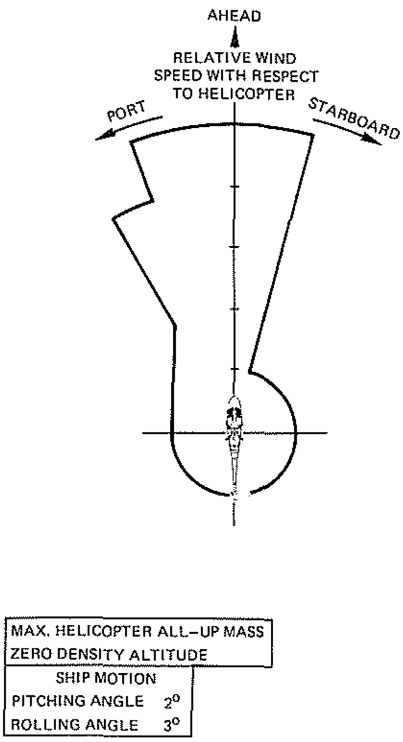




Fig. 2 Relative wind- and mass limitations for helicopter take-off and landing for shore-based operations, as provided by the manufacturer

Fig. 3 Relative wind-, helicopter mass- and ship motion limitations for helicopter take-off and landing on board ships as given by the helicopter manufacturer

# 1 INTRODUCTION

In recent years operations of a large variety of helicopter types from various classes of navy ships have steadily increased worldwide. The improved capabilities of present-generation helicopters offer a wide range of possibilities for attractive ship-helicopter combinations to cope with the growing demand being put on modern navies. Therefore, many even relatively small vessels are being equipped with a helicopter flight deck. Sometimes an almost marginal facility is provided for take-off, landing and deck handling. Yet, helicopter operations are required in a rough environment (Fig. 1) by day and at night.

Of course one wants to operate the helicopter in as many operational conditions (day, night, sea-state, wind, visibility etc) with as high a payload as possible.
Nowadays, in line with the increasing importance of helicopter/ship operations the helicopter manufacturer sometimes provides, in addition to limitations for shore-based take-off and landing (Fig. 2), limitations of a general nature for helicopter-ship operations of which an example is given in figure 3.

The difference between the two sets of limitations is explained by the fact that for shore-based operations the limitations (determined after extensive factory testing) are based a.o. on a rigid and unobstructed landing site whereas the limitations for ship-borne operations are to be based on an obstructed landing site (flight deck) which shows oscillatory movement and where a.o. extremely turbulent conditions can prevail.

Because of the unique characteristics of each helicopter type/class of ship combination and the innumerable combinations possible it is understandable that usually no (extensive) testing has been carried out by the manufacturer for the combination that is of interest. It follows that the limitations given, if any must be considered as general guidelines, with large safety margins with respect to the helicopter capabilities and pilot ability to control the helicopter, and thus do not provide a maximum availability of the helicopter on board the ship. It is expected that the actual limitations, i.e. those that allow maximum availability of the helicopter within the constraints of safety, are lying somewhere between the limitations for shore-based and those for ship-borne operations as given by the manufacturer. To determine these limitations a dedicated helicopter-ship qualification programme is needed. The effort required is justified because of the rather positive effect of a small increase of the relative-wind envelope (Fig. 3) on the operational availability of the helicopter on board the ship.

During about 20 years NLR has carried out successfully 12 test programmes (for Dutch as well as foreign contractors) in which 9 classes of ships and 6 types of helicopters were involved.

In this paper an overview is given about the factors influencing the helicopter-ship operations, the way they are determined in various qualification programme elements and how they are used to set up a flight test programme on board the ship.

Furthermore it is described how the ship-borne flight tests, within the constraints of safety and efficiency, are carried out and in what way, during the tests, again use is made of the data obtained in the previous programme elements, as well as the experience of the test team, resulting in an as small as possible number of flying hours without affecting the quality of the results. The attention is focussed on helicopter take-off and landing which in fact constitutes the main part of the tests. Finally some results are given.

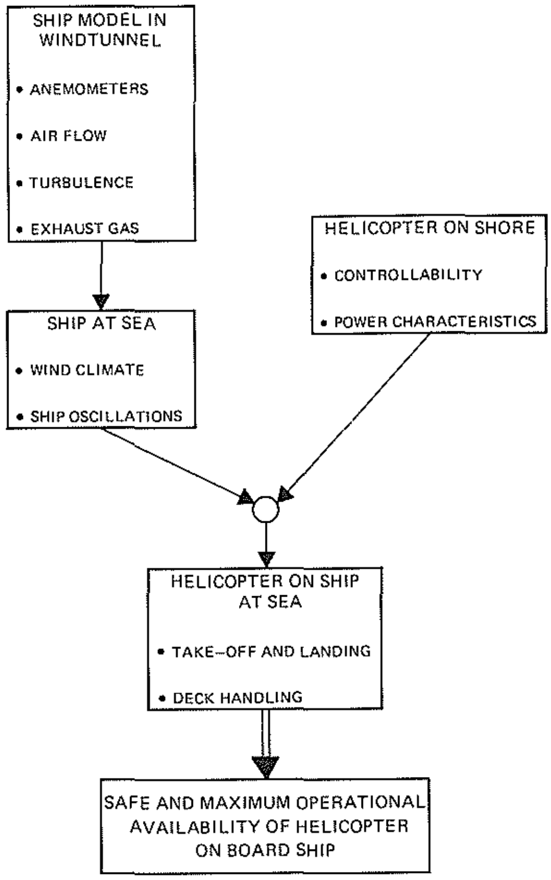



Fig. 4 Set-up of helicopter-ship qualification programme as carried out by NLR

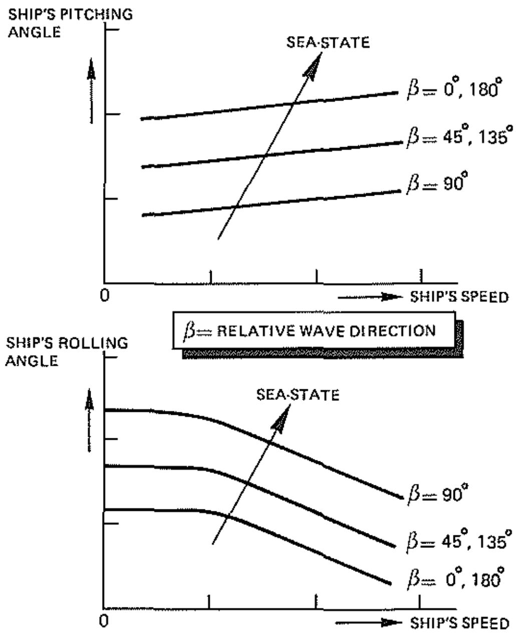



Fig. 5 Ship's pitching- and rolling angle as function of ship's speed, relative wave direction and sea-state

## 2 ESTIMATION OF THE OPERATIONAL ENVELOPE FOR HELICOPTER-SHIP OPERATIONS

### 2.1 General

An important aspect of helicopter-ship qualification testing is safety. The problem is to define this in quantitative terms, taking into account the limitations imposed by the environment, the capabilities of the helicopter and the abilities of the pilot.

In order to obtain the required data in a safe and efficient way a mix of preparatory measurements, analyses and flight testing is executed. The scheme, presently in use, is depicted in figure 4.

The nature of the problems that may be encountered, and the preparatory measurements and analyses that can be carried out to estimate the operational envelope for helicopter-ship operations are discussed in this chapter.

The additional flight tests, that are required because some aspects cannot be evaluated analytically, are discussed in the next chapter.

### 2.2 The effect of the ship on the environment for helicopter operations.

The basic factor, limiting the helicopter operations from ships, in comparison to shore-based operations is the small flight deck for take-off and landing, which is:

- oscillating (pitch, roll)
- surrounded by obstacles (mainly the hangar in front of the flight deck) which, apart from collision risk, generate
  - . distorted air flow
  - . a complicated turbulence field (in addition to natural turbulence)

and where are present

- exhaust gas, which may cause
  - . additional turbulence
  - . an increase of the outside air temperature above the flight deck (increase of density altitude)
  - . a reduced view over the flight deck
- spray also causing a reduced view over the flight deck.

Although the ship's speed and course as such do not constitute limiting factors for helicopter-ship operations, yet they may create, in combination with sea-state, wave/swell direction and natural wind a limiting condition.

To determine the environment of the flight deck quantitatively, the following measurements are carried out:

Wind-tunnel tests on a scale model of the ship

These tests are carried out to determine the air flow characteristics (air flow deviations, turbulence) above the flight deck and at the possible approach paths of the helicopter to the ship as function of true wind and ship's course and speed (relative wind condition). Furthermore determination of the ship's exhaust plume paths and prediction of plume temperatures (by plume dispersion measurement) as a function of ship's power settings and relative wind conditions. Finally the position error of the ship's anemometer is determined which is, apart from the instrumentation error of the anemometer, needed to establish the relation between the undisturbed relative wind conditions and those prevailing above the flight deck and at the helicopter approach paths.

Note: If these tests are carried out in the design stage of the ship and if it is determined e.g. that with a small change to the super structure the wind climate above the flight deck can be improved and the exhaust gas nuisance can be decreased, costly modifications of the existing ship may be prevented. The same holds for the position of the ships's anemometer.

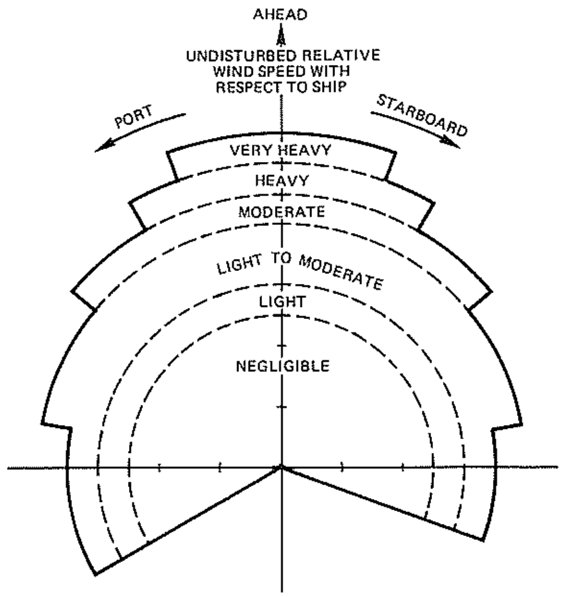



Fig. 6 Turbulence levels above the flight deck as function of relative wind

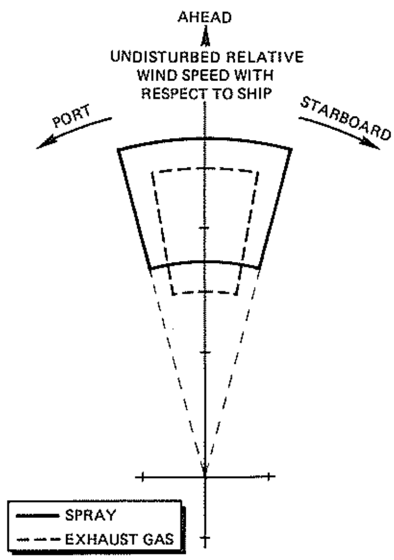



Fig. 7 Relative wind conditions during which spray- and exhaust gas nuisance above the flight deck are present

Full-scale ship's wind climate and motion tests

The wind climate tests on board the ship are carried out to verify the wind-tunnel test results concerning the air flow characteristics above the flight deck. With the established relation between both types of results the real wind climate at the various helicopter approach paths is predicted. Furthermore the instrumentation error of the ship anemometer is determined and the position error, established during the wind-tunnel tests, is verified. With the information obtained an unambiguous relation between the anemometer readings, the air flow conditions above the flight deck and at the helicopter approach paths and the undisturbed relative wind condition is determined.

Ship motion characteristics (pitching, rolling) are determined as a function of sea-state, wave/swell direction and ship's speed. Examples of results concerning ship motion, turbulence, exhaust gas and spray above the flight deck are shown in the figures 5, 6 and 7.

## 2.3 The effect of the ship environment on the helicopter performance

Since the operational environment on a ship is much more complex than for shore-based operations it should be determined in what way the take-off and landing envelope as provided in the flight manual for shore-based operations (Fig. 2) is affected.

To evaluate the effect of the ship environment on the helicopter performance, detailed data of the helicopter capabilities are needed. If not available in advance, these are obtained during shore-based hover tests. These tests are used to evaluate yaw control performance in cross wind conditions and also at high torque values needed in the low speed region. Furthermore helicopter pitch- and bank angles needed for hover at high wind speeds are determined. Finally tests are carried out in those wind conditions where main-/tail rotor interference might exist, causing helicopter yaw oscillations.

It is understood that these tests are executed within the limitations for shore-based operations as given by the helicopter manufacturer (Fig. 2).

The data obtained should indicate where, within the shore-based envelope, regions exist where the margin between available and required helicopter performance is small. An example of torque- and yaw control performance obtained from such tests is given in figure 8.

Knowing the operational environment created by the ship, and the relevant properties of the helicopter, the effects on helicopter performance can be estimated, if not quantitatively, then at least qualitatively.

Such effects can be grouped into two classes:

- effects that may result in hazardous flight conditions, which will have to be prohibited
- effects which will create a difficult and demanding situation for the pilot. These situations should be evaluated carefully and the operational applicability should be evaluated by means of flight testing.

In most cases the operational envelope for ship-borne operations will be reduced with respect to the shore-based envelope under the following conditions.

Hazardous conditions

Inadequate yaw control

Conditions where inadequate yaw control exists (areas B and E in Figure 8) must be avoided. Furthermore when performing a decelerating flight from approach speed to hover, while the relative wind above the flight deck is situated in one of the shaded areas (Fig. 8), the relative wind condition of the area B or E will be traversed. Such an approach to an obstructed flight deck with inadequate yaw control is

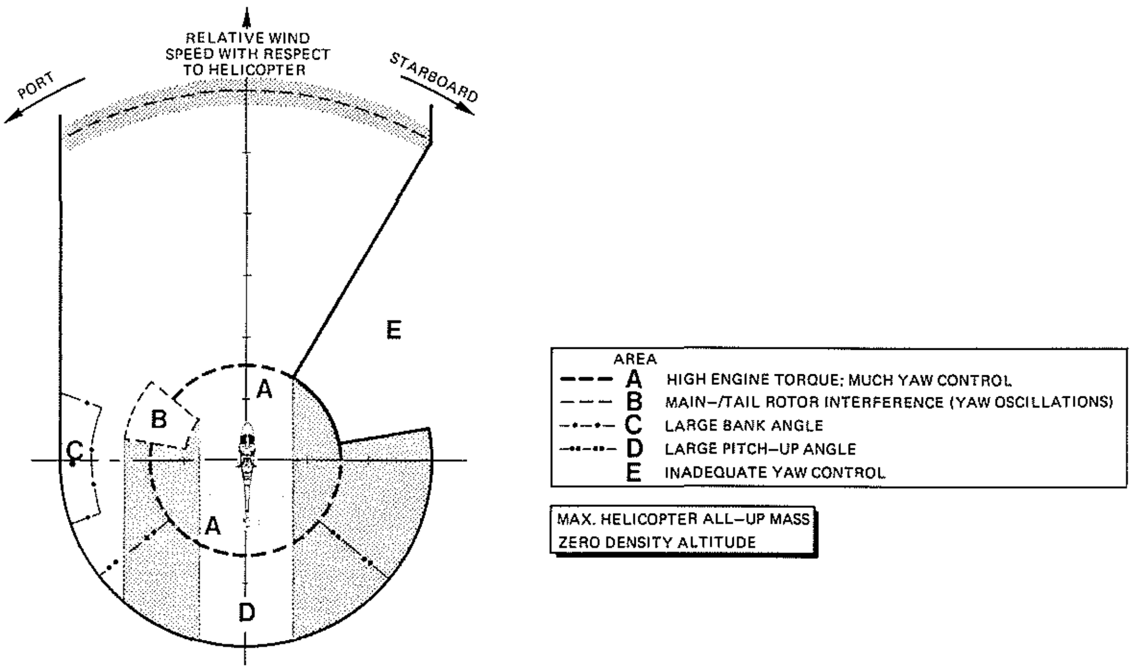



Fig. 8 Some detailed results of shore-based helicopter hover tests

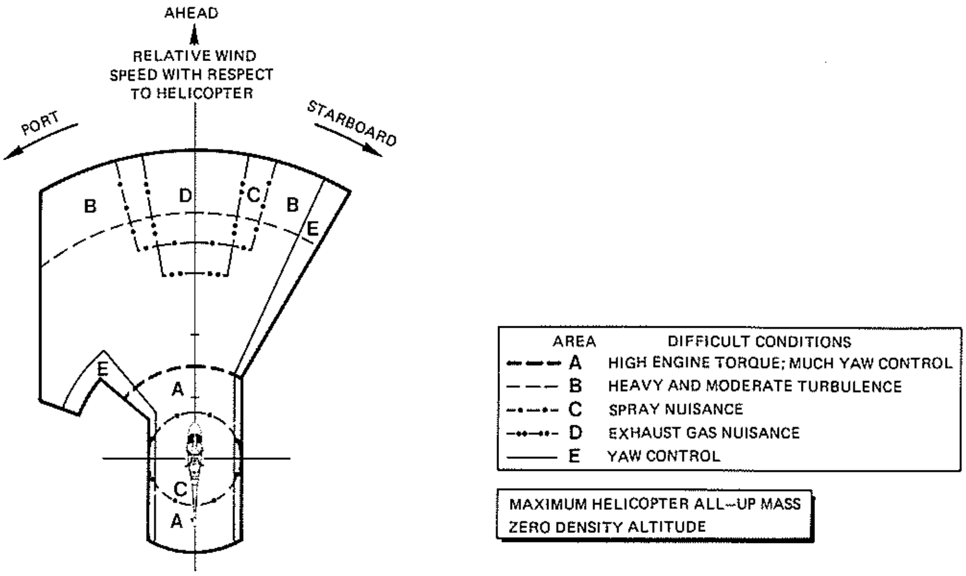



Fig. 9 Relative-wind envelope to be tested during helicopter flight tests on board the ship

hazardous and has to be avoided. Relative wind conditions with large cross wind components where large helicopter bank angles are needed (area C in Figure 8) to hover above the flight deck must also be avoided. This large bank angle reduces the pilot's view over the flight deck.

High wind speed from ahead

Relative wind conditions where very heavy turbulence exists (Fig. 6; high wind speed from ahead), in combination with rather large ship's oscillations especially in pitch (Fig. 5; inherent to the accompanying large sea-state), and spray nuisance (Fig. 7; reducing pilot's view over the flight deck), have to be avoided. In such cases the control inputs required to counteract the helicopter response to turbulence in combination with manoeuvring, necessary to avoid collision with the oscillating obstructions may be too large (overtorquing, pedal stop), and create a hazardous condition.

Strong tail-wind

Taking into consideration the presence of obstacles near the flight deck, strong tail-wind conditions (area D in Figure 8) can create a hazardous situation in case of an engine failure. Such wind conditions further result in large helicopter pitch-up angles reducing pilots view over the flight deck. For these reasons strong tail-winds have to be avoided.

When areas of the shore-based relative-wind diagram in which either of the hazardous conditions may occur are left out, a candidate ship-operation-relative-wind diagram results of which an example is shown in figure 9.

It should be noted that this diagram results from measurement of the ship's environment, helicopter performance measurements and analyses. Whether or not the diagram can be used operationally has to be determined by means of dedicated flight tests. To determine those areas, in which testing has to be carried out an evaluation (also based on the measurement and analysis mentioned before) of the following conditions, where difficult and demanding situations will occur for the pilot, has to be made.

"Difficult" conditions

Low relative wind speed

Because much engine torque is needed at low relative wind speed and at high helicopter mass (area A in Figure 9), the power- and yaw control margins might be too small in that condition to counteract adequately a certain amount of ship's oscillation to avoid collision with the obstacles. Therefore helicopter mass and density altitude should be watched very carefully. Furthermore at low relative wind speed spray is generated by the downwash of the rotor which is most bothersome when the helicopter hovers alongside the flight deck.

High relative wind speed from ahead

At high relative wind speed from ahead, the accompanying turbulence (heavy and moderate; area B, Fig. 9) and especially the large pitch oscillations of the ship (Fig. 5) need much control effort of the pilot which might result in such large torque variations that the maximum allowable torque is often exceeded. Besides, the presence of spray and

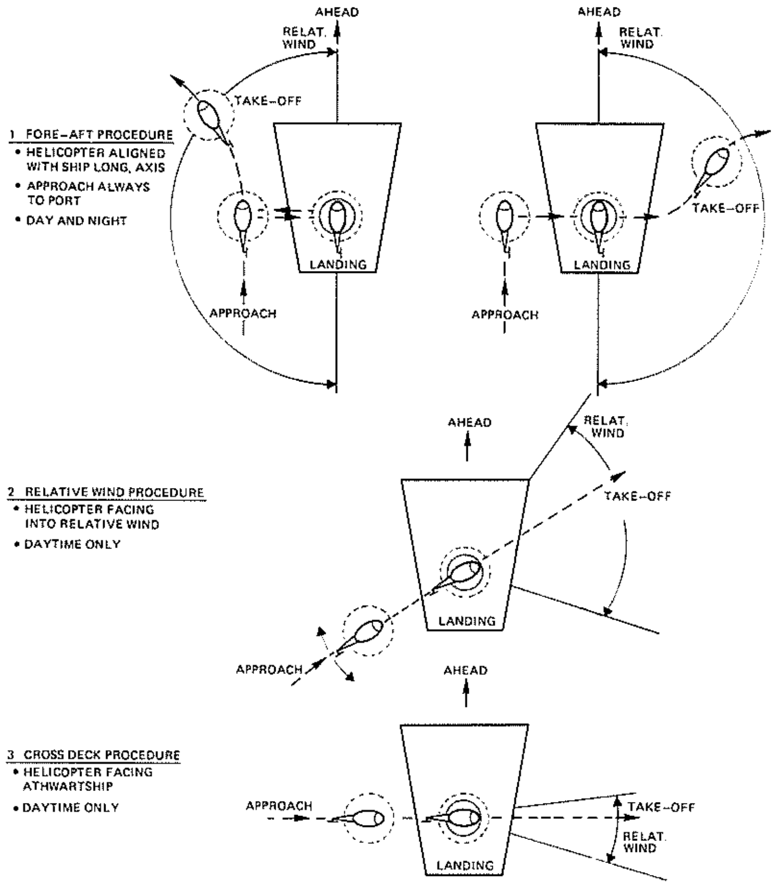



Fig. 10 Take-off and landing procedures on board the ship

exhaust gas (Fig. 7; Fig. 9, areas C, D), reducing the pilot's view over the flight deck, increases his workload even more. Furthermore the hot exhaust gas, increasing the density altitude above the flight deck and possibly at the helicopter approach path, affects rotor- and engine performance.

Helicopter yaw control

Wind conditions bordering on those areas where inadequate yaw control exists (hazardous conditions B and E in figure 8) must be approached very carefully because of yaw control variations needed to counteract turbulence and ship's oscillations adequately. These are shown in figure 9 area E.

The relative-wind envelope (Fig. 9) in which the "difficult" conditions are indicated, is the basis for the flight test programme to be carried out on board the ship.

## 2.4 Take-off and landing procedures

In general take-off and landing with a helicopter are easiest into the wind. However, on ships this procedure is not always applicable and furthermore does not always provide optimal results because of the presence of obstacles. Because of that other take-off and landing procedures are applied, thus increasing the operational availability of the helicopter on board the ship enormously, as will be seen in the following.
The procedures given hereafter are visualized in figure 10.

Fore-aft procedure (FA)

A fore-aft take-off is performed as follows:
- the helicopter is aligned with the ship's centerline, with its nose in the sailing direction;
- hover above the flight deck with initial heading;
- fly sidewards to hover position alongside the ship either to port or starboard (windward side);
- turn away $30^{\circ}$ from ship's heading;
- climb out.

A fore-aft landing is performed as follows:
- approach the ship to a hover position alongside the ship (preferably to port because of pilot's view over the flight deck). The helicopter's longitudinal axis is parallel to the ship's centerline;
- fly sidewards to the hover position over the landing spot;
- land.

Relative-wind procedure (RW)

The relative-wind take-off is performed as follows:
- swivel (if possible) the helicopter with its nose into the relative wind direction;
- hover with this heading above the flight deck;
- if necessary to avoid obstacles (e.g. the hangar), fly sidewards to a hover position alongside the ship;
- climb out.

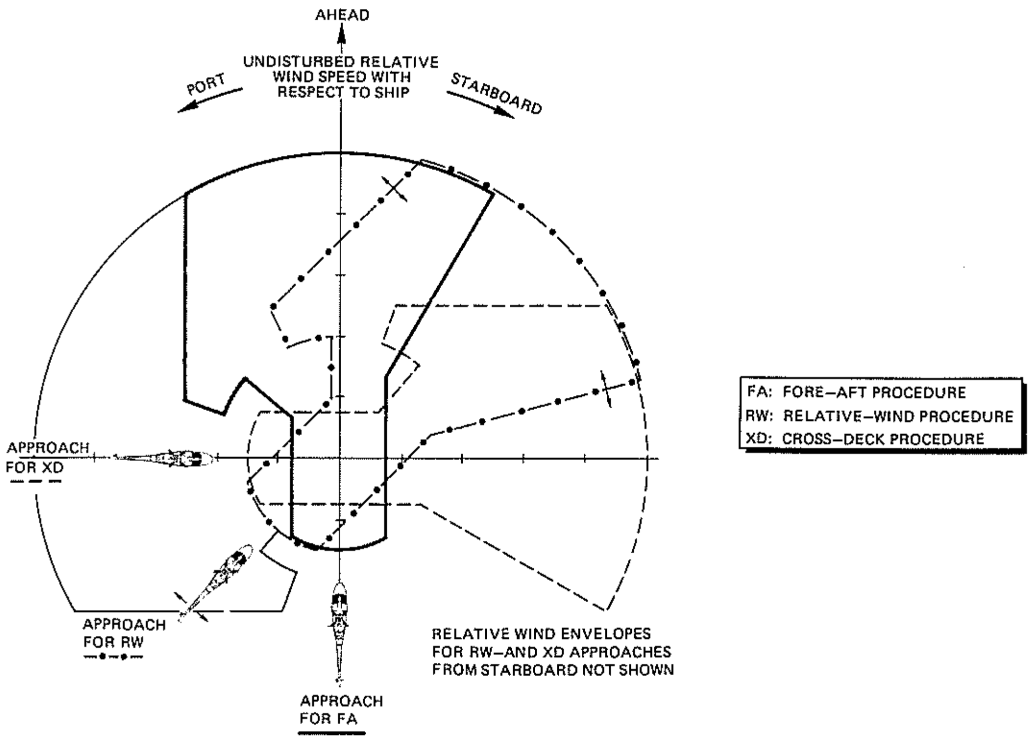



Fig. 11 Relative-wind envelopes for various helicopter approach headings with respect to the ship

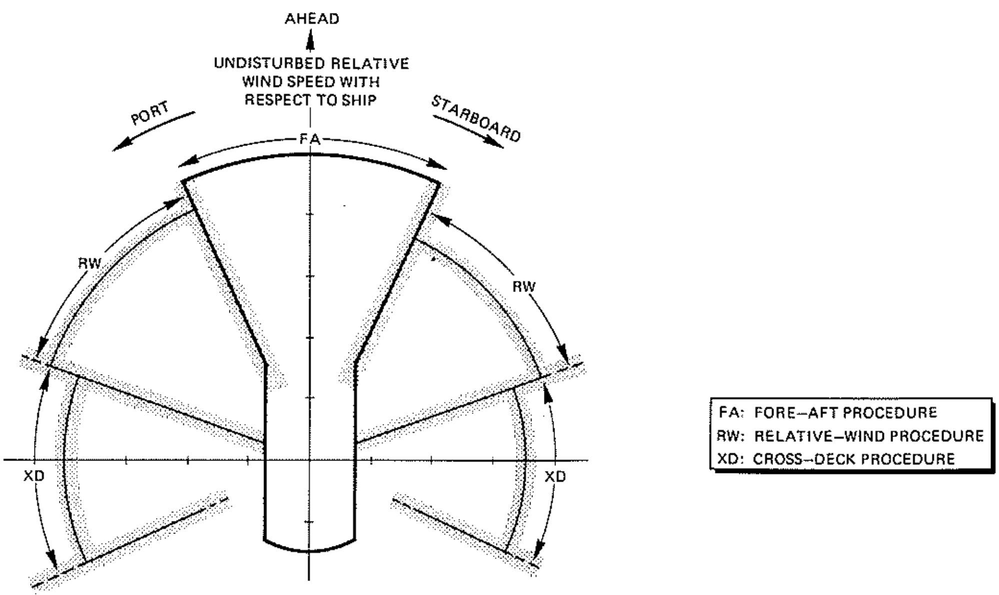



Fig. 12 Total relative-wind envelope for take-off and landing to be tes during helicopter flight tests on board the ship

The relative-wind <u>landing</u> is performed as follows:
- approach the ship from the leeward side;
- continue flight up to the hover position above the landing spot (helicopter nose into the relative wind);
- land.

<u>Cross-deck procedure (XD)</u>
The cross-deck <u>take-off</u> is performed as follows:
- swivel (if possible) the helicopter until its longitudinal axis is perpendicular to the ship's centerline;
- lift off and climb out at this heading.

The cross-deck <u>landing</u> is performed as follows:
- approach the ship from abeam either from port or starboard (leeward side);
- continue flight up to the hover position above the landing spot;
- land.

Comparing the take-off and landing procedures, the following remarks can be made:
- The FA procedure has the advantage that pilot's view over the flight deck is rather good, especially during the approach (to the port side of the ship) and sidewards flight before landing. For that reason this procedure can also be carried out at night. However, this procedure is only applicable if the cross-wind component with respect to the helicopter (and thus also to the ship) does not exceed the helicopter limitations (Fig. 9).
- During the RW procedure where no or only small cross-wind components are present, yaw control is not a factor. However, during this procedure pilot's view over the flight deck is rather poor especially during the approach from port. In spite of the fact that wind is from ahead it is expected that a lower wind speed limit will apply compared to the FA procedure. The same holds for ship's oscillations. The RW procedure is only carried out by day.
- During the XD procedure cross-wind components can be encountered. Therefore yaw control has to be watched very carefully. Besides, the pilot's view over the flight deck is, compared to that during the RW procedure, rather restricted, especially during the approach from port. Because of this, the wind speed- and ship's oscillation limits are expected to be even lower than those for the RW procedure. The XD procedure is only carried out by day.

## 2.5 <u>The pilot</u>

Controlling the helicopter in the conditions encountered during ship operations is a demanding job. The workload depends a.o. on the amount of ship (flight deck) motion, the turbulence level encountered, the view over the flight deck, visibility and lighting conditions (day or night). In this highly dynamic environment the workload of the pilot may become too high, and conflict with the safety of operation. Thus additional operational limitations may result due to excessive workload situations.

While at the present time no analytical or experimental means other than flight tests are available to evaluate the dynamic behaviour of the helicopter/pilot combination in the complex turbulent environment of the moving flight deck of a ship the use of skilled test pilots is crucial in the process of establishing operational limitations for operations from ships. Apart from flight-technical skills that are required a good

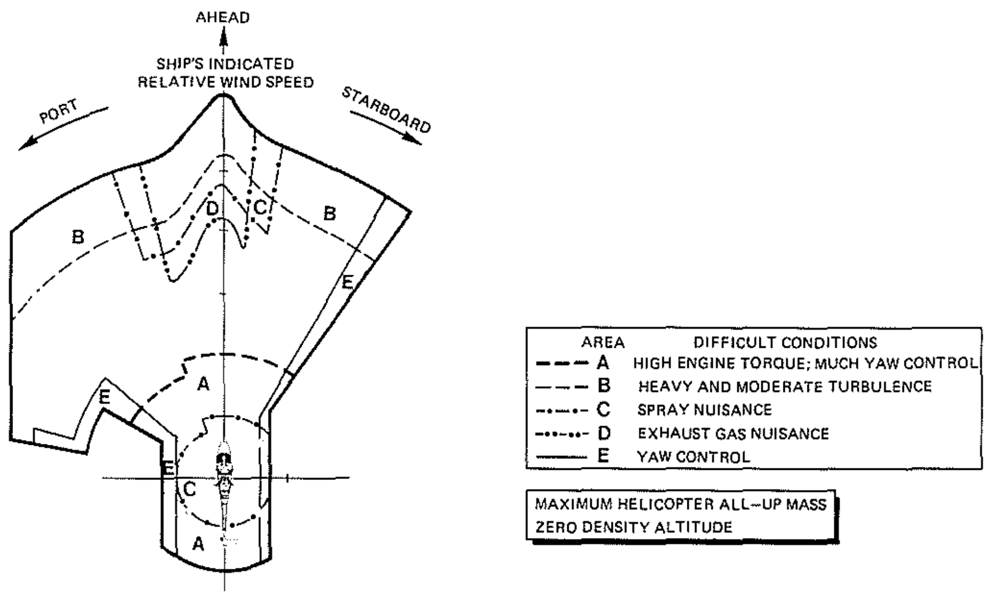



Fig. 13 Relative-wind envelope for fore-aft take-off and landing to be tested on board the ship

knowledge of the skill level that can be expected from normal operational pilots is mandatory. Although during the qualification flight tests the pilot is backed up by recordings of the helicopter performance and behaviour, his opinion remains one of the most important contributions to the process of determining operational limitations due to high workload and dynamic response effects. Furthermore the safety of the flight testing ultimately rests on his ability to properly judge the severity of the actual conditions in which the testing takes place.

# 3 HELICOPTER FLIGHT TESTS ON BOARD SHIPS

## 3.1 Preparations

From the analyses described in the previous chapter a number of take-off and landing procedures result, with for each of these a candidate wind diagram. (Example in Fig. 11.)
These diagrams then are combined to a candidate helicopter-ship operations envelope. Since overlaps of the relative-wind diagrams for the various procedures will occur a choice is made, taking into account the relative size of each of the overlapping sectors (maximizing the ship-based operations envelope) and the expected ease of operating the helicopter. The trade-off is made, using operator requirements, engineering- and pilot judgement. An example of a candidate helicopter-ship operations diagram is shown in figure 12. Using ship anemometer calibration data, obtained during the wind climate measurements that have been carried out, this operational envelope is related to relative-wind indication available on the ship in relation to actual wind condition above the flight deck. An example of such an envelope (valid for the fore-aft procedure) is shown in figure 13.

In this candidate operational envelope there will be a number of areas for which the analyses indicate a requirement for testing. The problems that may occur are identified and the test procedure and instrumentation, required to investigate these areas safely, are determined.

Since the flight testing is to be carried out on board a ship in a limited period of time, the exact conditions at which tests have to take place cannot be determined beforehand. Conditions that will be tested depend on the sea-state and wind conditions that will become available in the area in which the tests are going to take place. Of course, selection of the area and time of the year so as to maximize the probable occurrence of the desired test conditions is possible, but this still does not provide the experimenter with a free hand to vary his environment at will.

## 3.2 Flight testing

As evident from the previous paragraph, the flight-test programme has to be defined in an interactive way during the testing period.
The actual execution of the flight-test programme is governed by two main aspects:
- safety
- efficiency.

Safety is principally obtained by starting the flight tests at easy conditions for pilot and test team familiarization:
- . low helicopter mass
- . relative-wind conditions, far within the boundaries of the relative-wind envelope (no "difficult" conditions; e.g. Fig. 13)
- . fore-aft procedure (easiest)

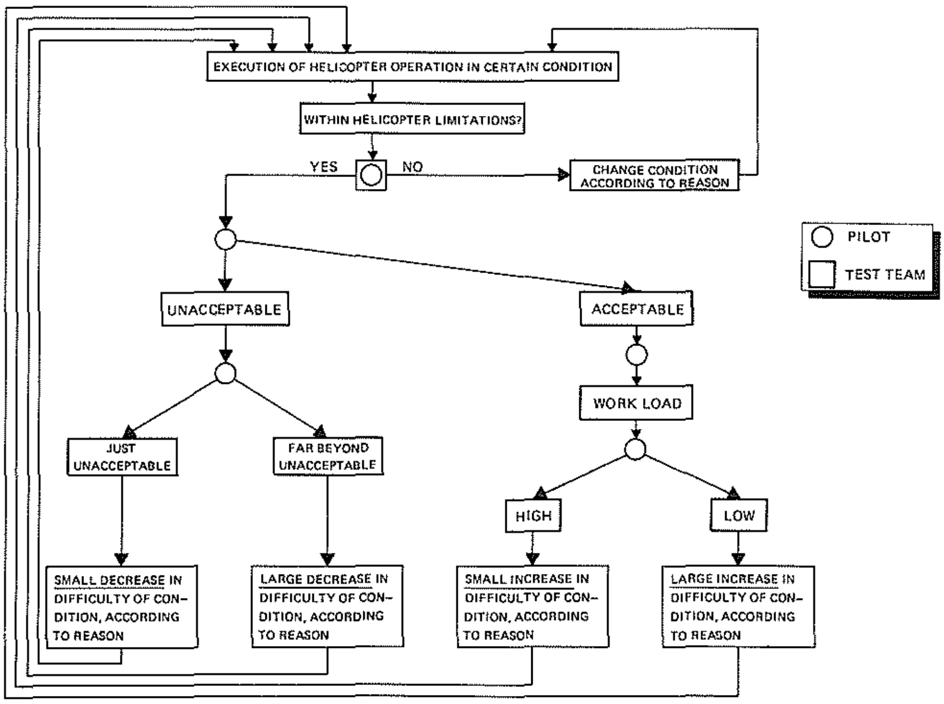



Fig. 14 Flight-test procedure on board the ship

. fair weather
. first by day, later on at night.

After a thorough familiarization, efficiency is obtained by making adequate use of the information that becomes available during the flight tests and by analyzing, on board the ship, that information in conjunction with the data base obtained prior to the tests. Thus maximum use is made of the information obtained from the tests, and the number of test flights required can be minimized.

During the test period the selection of test conditions is a major task. Based on the interpreted results of tests that have already been carried out, a number of alternatives for the next test point is defined. This exercise is carried out in parallel for test points related to each of the potential problem areas of the candidate operational envelope, thus yielding a large selection of usable test conditions. The choice of the next test point then depends on the available forecast wind/sea- state conditions in the area within reach of the ship. Problems like judging the reliability of weather forecast versus time of the ship to travel to the area of interest are to be solved.

Given certain environmental conditions (wind, sea state, temperature) a number of conditions can be created by changing ship speed and heading relative to the wind (relative wind conditions) and waves (flight deck motion), although these cannot be changed independently. The only parameter that can be changed independently appears to be helicopter mass.

Clever use of information obtained on board, in conjunction with thorough knowledge of the factors that limit operations will have to offset the problems created by the difficulty to establish the most desirable test conditions. Thus often it is not a question of demonstrating the capability to operate the helicopter at the point specified, but to obtain data at differing conditions and interpolating or extrapolating the results to the conditions required.

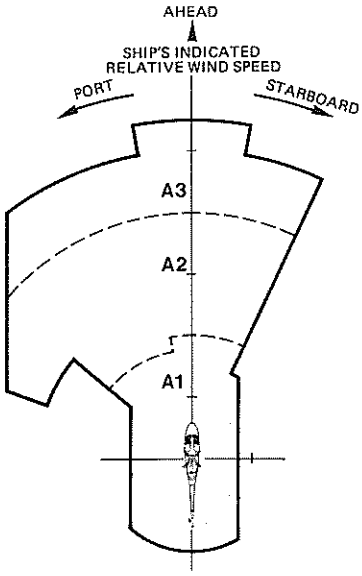
To aid this process, the following data are normally acquired during the tests:

Information becoming available during the flight tests is:

- actual data of helicopter parameters such as:
  . engine torque
  . pedal deflection
  . pitch- and bank angles;
- actual data of ship parameters such as:
  . speed
  . course with respect to wave/swell direction
  . pitching- and rolling angles
  . anemometer readings (relative wind condition);
- pilot's comment on workload, influenced by:
  . take-off and landing procedure
  . ship's oscillation
  . turbulence
  . view over the flight deck
  . spray and exhaust gas nuisance.

Pilot's workload is expressed with the following adjectival rating scale:
  . minimal
  . moderate
  . considerable
  . unacceptable.

Note that two types of data become available. Quantitative data on helicopter performance and ship state and qualitative data on pilot




| ALLOWABLE HELICOPTER MASS AND SHIP'S OSCILLATIONS | | | |
|---|---|---|---|
| AREA | PERCENTAGE OF MAX. HELICOPTER ALL-UP MASS | AMPLITUDES OF SHIP'S OSCILLATIONS | |
| | | PITCHING (deg) | ROLLING (deg) |
| A1 | 94<br>97 | 3.0<br>1.0 | 9.0<br>1.5 |
| A2 | 100 | 5.0 | 9.0 |
| A3 | 100 | 5.0 | 7.0 |

ZERO DENSITY ALTITUDE

Fig. 15 Take-off and landing limitations for fore-aft procedure; daytime

| ALLOWABLE HELICOPTER MASS AND SHIP'S OSCILLATIONS | | | |
|---|---|---|---|
| AREA | PERCENTAGE OF MAX. HELICOPTER ALL-UP MASS | AMPLITUDES OF SHIP'S OSCILLATIONS | |
| | | PITCHING (deg) | ROLLING (deg) |
| A1 | 94<br>97 | 3.0<br>1.0 | 9.0<br>1.5 |
| A2 | 100 | 5.0 | 9.0 |
| A3 | 100 | 5.0 | 7.0 |
| B1 | 94<br>97 | 2.0<br>1.0 | 8.0<br>1.5 |
| B2 | 100 | 5.0 | 9.0 |
| B3 | 100 | 4.0 | 9.0 |
| B4 | 94<br>97 | 1.5<br>1.0 | 6.0<br>1.5 |
| B5 | 100 | 3.5 | 8.0 |
| B6 | 100 | 3.0 | 6.0 |
| C1 | 94<br>97 | 2.0<br>1.0 | 7.0<br>1.5 |
| C2 | 100 | 5.0 | 8.0 |
| C3 | 94<br>97 | 1.5<br>1.0 | 5.0<br>1.5 |
| C4 | 100 | 3.0 | 6.0 |

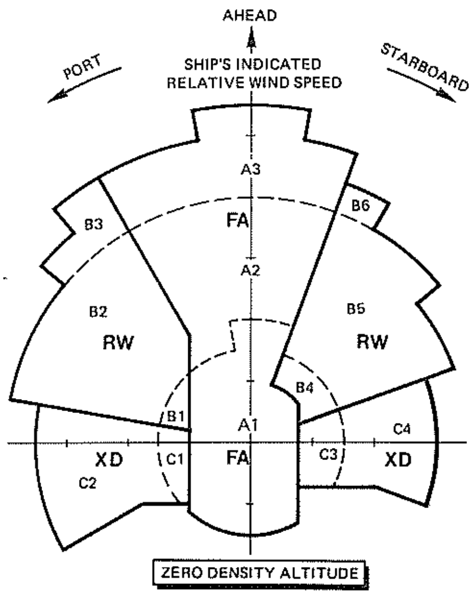



Fig. 16 Limitations for take-off and landing procedures (by day) optimized within the constraints of safety and helicopter availability

workload and helicopter controllability. The latter should be referenced to the normal operational pilot skill level.

Within the constraints imposed by the environment in which the tests have to be carried out, all effort is made to carry out the testing as efficient as possible. To this end the nominal procedure as depicted in figure 14 is used. For each condition tested the results are evaluated and subsequently the required increase in severity of the conditions of the next test point is determined. Of course in this process both engineering and flight technical skill (the pilot) is involved.

The influence of a certain increase in difficulty on the helicopter can, with the knowledge available in advance and the data obtained during the previous test flight, be predicted rather well.

A prediction of the increase in pilot workload, for a certain increase in the difficulty of a condition, is only possible to a certain extent. If for example the workload in a certain condition is "low", the permitted increase in difficulty of the condition will be more than in case the workload would have been "high". The same is applied (in reverse) in case a condition is considered "unacceptable". If it is "far beyond unacceptable" (occurring sporadically) a large decrease in difficulty is applied whereas if the condition is considered "just unacceptable" a small decrease in difficulty is applied.

With the application of these simple prediction methods, good engineering judgement and the experience of pilot and test team, the number of flying hours can be reduced to a minimum, and a maximum of results will be obtained in a as short as possible time period.

## 4 RESULTS

At the completion of the flight tests on board the ship, a fair idea about the operational limitations has usually been obtained. For final results, measured data (helicopter, ship) together with pilot's comment are analyzed in detail.

The operational limitations are presented in the form of graphs. Examples of these graphs are given in the figures 15 and 16.

In figure 15 limitations are given for the fore-aft take-off and landing procedure while in figure 16 the result is shown for the total relative-wind envelope optimized within the constraints of safety and maximum availability of the helicopter.

## 5 CONCLUDING REMARKS

In conclusion it may be stated that the qualification of helicopters for use on board ships can be carried out safely and efficiently when the procedures described in this report are followed. The effort to be invested in the helicopter flight programme on board the ship is minimized by a thorough preparation, which consists of obtaining detailed information about the helicopter capabilities, ship's motion characteristics and the wind-climate above the ship's flight deck, by means of experimental tests and analyses. Such a qualification programme leads to an optimum operational availability of the helicopter on board the ship.