Safety for a Helicopter Load/Unload Operation on an Offshore Platform: Optimization From Several Viewpoints and the Psychological Aspects of the Marshaller

Hideharu Yonebayashi and **Tim Collins,** INPEX Corporation

Summary

When a slickline and/or an electrical wireline job is required on offshore oil/gas platforms that have no crane equipment, a helicopter load/unload operation is a common method used for transporting materials such as winch units, power-pack units, blowout-preventer (BOP) units, and lubricators from the platform or from the offshore complex to the platform. A series of materials is transported separately by helicopter so that one lifted material can be within the maximum loading capacity of the helicopter. A materials-transportation package typically consists of four or five load/unload operations for an entire set of materials. These frequent load/unload operations are performed with a hovering action, which has the highest risk among helicopter actions (i.e., taking off, cruising, and approaching/landing). To achieve safety, all risk-mitigating factors are adequately incorporated into a plan that should be shared with all crew (pilot, company supervisor, slickline/wireline operators) in advance of the operation.

This paper discusses mitigations from various points of view, in addition to summarizing general safety tips. As a result of considering the psychological response of the ground crew on the basis of actual field experience, this paper recommends how to remove mental factors that silently act on the actions of a helicopter marshaller. Moreover, fundamental measures are recommended to update marshalling methods and to use new-generation helicopters that are designed for improved safety requirements.

Introduction

Helicopter operations are important in the offshore oil and gas industry (Brittan and Douglas 2009). Helicopters perform a variety of roles, including crew change, logistics supply, and medical-emergency and evacuation duties. Because helicopter accidents can have fatal consequences, many helicopter safety reviews and arguments have been conducted (Ulleberg et al. 1991; De Rocca Serra 1998; Ayres and Oliveira 1998; Williams 2000; Hokstad et al. 2000; Rowe et al. 2002; Clark et al. 2006; Burton 2011). The pursuit of operational safety is continuous work. More industry experience contributes to more safety. This paper focuses on the specific helicopter operation that comprises the loading/unloading task of a slickline/wireline job on an offshore platform. The discussion was carried out as a case study that was based on actual operational experience.

Conditions

This case study assumes the following conditions.

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Field and Logistics. The field is located offshore, approximately 200 km (108 nm) away from the nearest airport. Flight time is 1 hour and 5 minutes in still air by a twin-engine medium-sized helicopter with two blades that has a cruise speed of 100 knots. In the case of a four-blade twin-engine helicopter with a cruise speed of 125 knots, flight time is 52 minutes in still air.

In the case of vessel transportation, it takes 1 day from the nearest port. The field has been developed with facilities consisting of a central complex with living quarters and surrounding unmanned platforms. All wells are tied-in platforms. Produced fluids are sent to the central complex through subsea flowlines. The central complex has both a helideck and large crane equipment, while the platforms have a helideck and simple human-powered hoist equipment only, without any crane equipment. Regular or ad hoc but prescheduled material transportation is performed by an offshore support vessel between the nearest port and the central complex, except urgent/emergency transportation. Once materials arrive at the complex, the method of transportation from the complex to the platform depends on the situation. If there are small materials that can be managed by human carrying or lifting with simple hoist equipment, then those materials are transported by supply boat. Heavier materials that cannot be lifted by human power are transported by helicopter. There are three types of platforms—one-leg, three-leg, and four-leg. The number of well slots and the size of the helideck increase with the number of legs on the platform.

Climate. The climate of the field area is characterized by a mild winter and a hot summer (Bower et al. 1992). Rainfall is slight, averaging less than 20 mm/a. The mean maximum/minimum temperature and sea-level pressure are varied at 103/86°F (39/30°C) and 996 to 998 mbar in summer and 73/59°F (23/15°C) and 1018 to 1020 mbar in winter. Wind direction is stable at northwest or north-northwest, with stable prevailing wind speed ranging from 9 to 12 knots throughout the year. It is reported that humidity ranged between 67 and 81% all year around.

Slickline/Wireline Operation. Through-tubing operations are carried out for purposes of bottomhole shut-in pressure survey, bottomhole fluid sampling, production logging, maintenance or replacement of subsurface safety valve, and gauge cutting to remove asphaltene deposits or scale. Typical operation teams consist of a company representative (supervisor), and four to five contractors from the service company (a slickline/wireline engineer and three or four workers). The operation tools consist of a winch unit, power-pack unit, BOP unit, lubricator, tool strings, stuffing box, joints, sockets, and other equipment. The winch and power pack are skid units that can be easily packed and lifted by industrial crane. Other equipment is packed in tool boxes or baskets for transportation. The tool boxes and baskets are types of portable freight containers that have a rectangular prism shape. At its four corners,

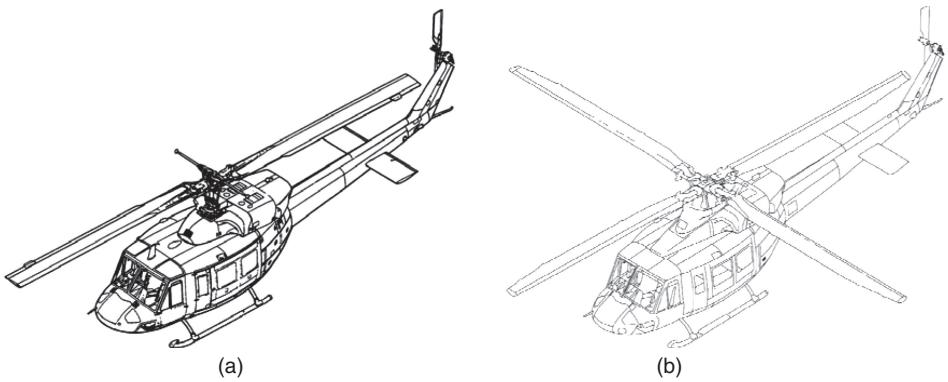


Fig. 1—Schematic of a twin-engine helicopter with two or four blades: (a) Bell 212 and (b) Bell 412 (Bell Helicopter 1998, 2007).

the container is equipped with corner castings. These castings can be connected to shackles that allow quick release and connection of metal loop wire for crane rigging or helicopter lifting. The number of tool boxes and baskets depends on operational requirements, but typically comes to three or four.

Helicopter. In this case study, a medium-sized, twin-turbine-engine helicopter with two (or four) blades is assumed for material transportation. A schematic of the external appearance is shown in **Fig. 1.** General helicopter specifications for each type are summarized in literature by Bell Helicopter (1998, 2013) as 57-ft (56-ft) length, 48-ft (46-ft) rotor diameter, 12-ft (15-ft) height, and 6,500-lbm (6,800-lbm) empty weight, respectively. The weight specification, however, supposes onshore usage, which means minimum equipment. The reality of offshore-equipped helicopters adds 200 to 300 lbm for equipment and life rafts to make the weight 6,700 to 6800 lbm (7,000 lbm). The helicopter maximum take-off weight (MTOW) is 11,200 and 11,900 lbm in types with two and four blades, respectively. The maximum external loading capacity is 5,000 and 4,500 lbm for types with two and four blades, respectively. However, the actual maximum loading capacity applied at the site is limited to less than those specifications because environmental conditions (i.e., temperature and altitude) may affect allowable payload. Generally, temperature and atmospheric pressure decrease with increasing altitude. Both have an effect on air density that is important for loading capacity. Because all operational places in this study are at sea level, temperature alone will increase the density altitude. Air density reduces with increasing air temperature and reducing air pressure. The resultant increased-density altitude results in an overall reduction in the aerodynamic performance of the helicopter. Increased humidity also reduces air density and, therefore, helicopter performance. Reduced performance results in decreased loading capacity. Because maximum temperature is reported to be more than 100°F (38°C) in summer and there is a high humidity condition at the workplace, the loading capacity should never be overestimated.

The main rotor rotates in an anticlockwise direction, as viewed from above—this is an American design. When the option of selecting a helicopter with two or four blades is available, one should take into consideration that the Bell 412 helicopter, while faster and having a greater take-off weight, is not optimized for load-lifting operations and would probably not even achieve equivalent performance compared with the Bell 212 helicopter.

Load/Unload Operation

As ground crews, the operation team is separated into two groups for loading and unloading operations at two locations. In this study, Group A and Group B are defined as responsible for loading and unloading operations, respectively. Furthermore, in each group, ground crews take charge of the responsibility for marshalling (common in both groups) and hooking-up (Group A) or unloading support (Group B).

General Safety. The operational safety guidelines in general are summarized as follows.

- Keep eye contact: This operation requires nonverbal communication—visual check and marshalling signs. Therefore, the positional relationship between the marshaller and the helicopter is quite important. The helicopter assumed in this study has two seats—one for the captain and one for the copilot. The captain's seat is commonly located on the starboard side. Accordingly, the marshaller should stand at the right-hand side of the helicopter to remain within the captain's view. Otherwise, the marshaller would be in a blind spot off the port side. The marshaller is required to provide signals to the captain to ensure that there are no misunderstandings. Communication fulfillment is achieved by large, no-rush marshalling motion because human action tends to be quicker under stressful conditions. In the event that the marshaller needs to position at the edge of the helideck, an assistant marshaller is recommended to support the main marshaller from behind by holding the main marshaller's body. This helps to ensure that the main marshaller will not get pushed out of the helideck by the main rotor downwash. The sense of security provided by the assistant marshaller allows the main marshaller to maintain a higher level of concentration. Both the marshaller and the pilot must take a helicopter-marshalling training course for offshore-platform operation. Even after receiving certifications once, the marshaller and the pilot would benefit from refresher training in hand signals.
- Maximum loading limit: The maximum load-weight capacity depends on many factors, as discussed in the preceding section, and must be estimated carefully. Maximum loads are usually less in summer and more in winter. Helicopter performance is a complex area. In the temperatures specified, performance will be limited. To safely conduct this type of operation, the helicopter must be able to hover outside ground effect (OGE). Ground effect is a condition improving the helicopter's performance when hovering near the ground. The condition requires a reduced drag, and, therefore, power requirements are decreased the nearer the helicopter approaches the ground. The requirement to hover OGE restricts the weight of the helicopter while performing its task. In the case of the Bell 212, while on task, the OGE hover weight should not exceed 10,400 lbm at approximately 35°C [International Standard Atmosphere (ISA) +20]. For a flight between land and an offshore complex, all helicopters should be carrying sufficient fuel at all times to return to land, plus reserves of 30 minutes from the point of offshore refuel. The Bell 212 burns 350 L/h (630 lbm/hr)

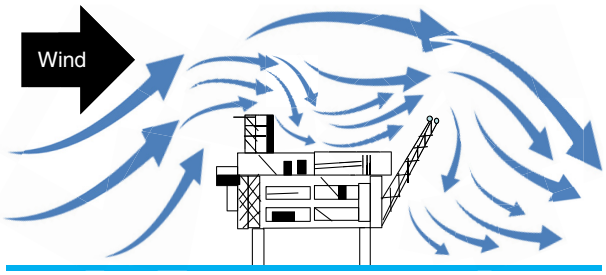


Fig. 2—Schematic of turbulent flow around an offshore platform.

of fuel. This means that in the event of a baulked landing on final approach to the refueling platform, the fuel state should never drop below return-to-base fuel, which would be 1,088 lbm (zero wind). In the field, payload is inversely proportional to the fuel load being carried—namely, more fuel means less load. When providing materials transportation that consists of five or six repetitive short-round trips between platforms and the complex, appropriate task fuel plus reserve spare is prepared so that sufficient lifting capacity can be secured. If extra operational time is needed, the helicopter suspends the operation and returns to the complex for refueling.

- Direction of approach: Pilots know there is turbulent air flow around the platform, depending on wind direction. In general, some turbulence is expected if any wind speed is present around high obstacles such as a platform located in an open, flat area. Updrafts are expected on the windward side of the platform, and downdrafts are expected on the lee side of the platform, as shown in **Fig. 2.** Pilots plan approaches with the wind direction and strength in mind. Details of wind are mentioned in the next section. The marshaller in Group B needs to consider the availability of an alternative approach direction while taking the post-unloading operation into account. This is a key issue because the pilot and the marshaller may have different drivers, resulting in different preferences for approach direction. The pilot has a simple driver, which is to approach the platform while taking head wind as much as possible because it is the most-favorable condition for helicopter performance. On the other hand, the marshaller in Group B has more-complicated drivers, which are to decide the approach direction on the basis of the well-slot position, to secure the marshaller position in limited helideck space while avoiding the blind spot of the pilot, and to move materials to the right location as part of the post-unloading work. There will be further discussion regarding this subject in the latter part of this paper.
- Balance of lifted objects: This subject is the responsibility of Group A. In the case of single-point loads (i.e., one load rigged and one helicopter hook used) that use one sling, the balance of the lifted load does not matter. In the case of sling legs used for lifting (see **Fig. 3**), sling-leg crews hold the sling legs clear of obstructions until the helicopter has lifted enough to apply tension to the sling, which removes all slack from each leg. If the helicopter dips down and the sling legs become entangled in the load, the sling-leg crews will correct the condition. The marshaller will not approve the helicopter to move until the sling-leg crews complete the operation. If necessary, the lifting operation will be reworked.
- Unloading objects: This subject is the responsibility of Group B. The marshaller carefully guides the helicopter to the right position for unloading the object. If the lifted object is stable (no rotation) and maintains the horizontal (for example, a cube-like material such as a winch skid unit), the marshaller can continue inducing the helicopter to unload the object to a certain position on the helideck without any support crews. If the lifted object is unstable (rotating action) or difficult to keep at horizontal (for example, a rectangular-like material with long side length such as a tool box), then the marshaller instructs the pilot to hold the object before touchdown, allowing one or two crews to surround the lifted object to help maintain stability of the object. Touchdown of the object to the helideck floor is carried out as softly as possible. A hard touchdown should be avoided to mitigate the risks of breaking the unloaded object or the wooden helideck floor. Once the object is unloaded, the marshaller checks to ensure that no ground crews are around the object, and then instructs the pilot to hook off the sling. If any member of the ground crew remains in close proximity to the unloaded object, the marshaller will not instruct the pilot to hook off to prevent the risk of the hooked-off sling possibly falling down to hit the crew. For temporary evacuation of those support crews before hook off, it is recommended that they go down to the intermediate-deck floor. During approach and/or temporary evacuation, crews are prohibited from moving by way of the back of the helicopter, even though it presents a detour. The unloading operation will be suspended if necessary, and started again after fixing problems.
- Post-unloading and preparatory work for subsequent unloading of objects: This subject depends on the available area of the helideck. If there is sufficient area to unload all objects, then it is not necessary to consider. However, in the case of a narrow-area helideck, it should be addressed. On such a narrow helideck, the center of the helideck might be the easiest position for a pilot to unload objects. Under a sequential-transport operation for a series of wireline/slickline equipment consisting of four or five objects, once the first object is un-

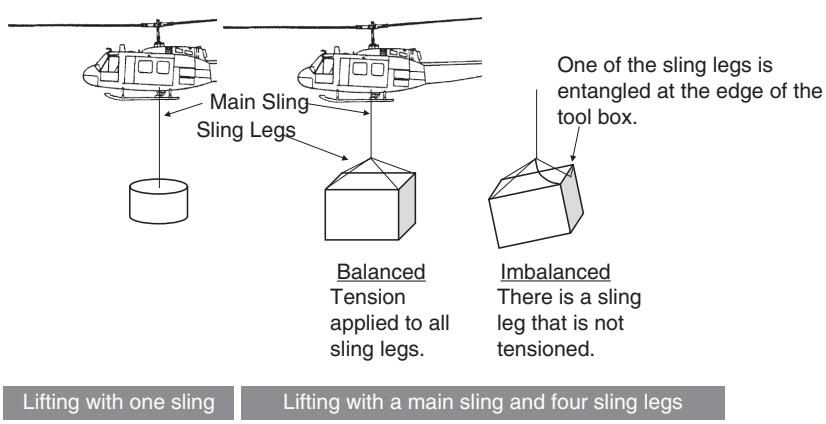


Fig. 3—Single-point loads.

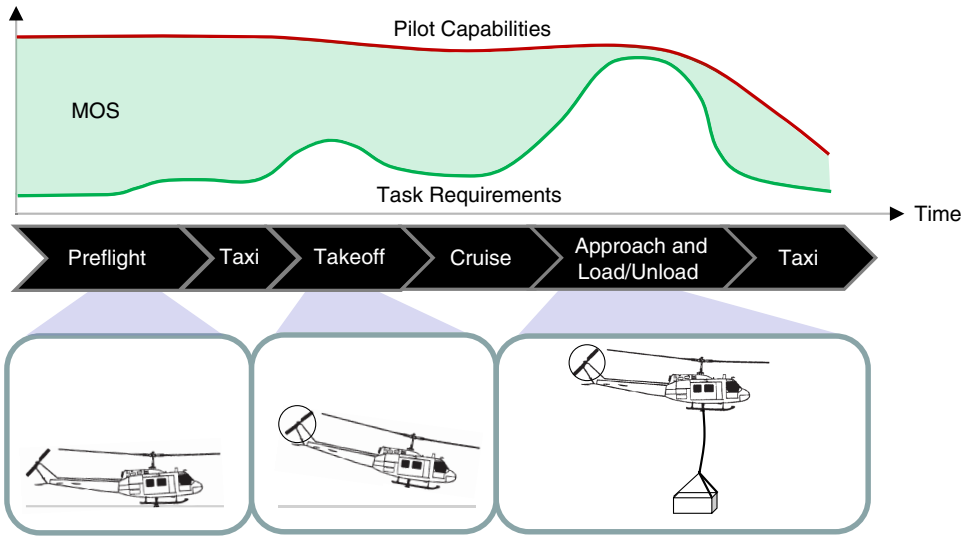


Fig. 4—Schematic of the relationship between helicopter task requirements and pilot capabilities.

loaded on the receiver platform, the helicopter returns to the sender platform to load the second object and transport it to the receiver platform. During this loading operation by Group A on the sender platform, Group B secures enough space on the receiver platform for the next unloading operation by moving the first unloaded object away from the center of the platform.

- Communication in advance: Each role should be confirmed and shared among all involved persons—marshaller, hooker, backup person, and pilot—before the operation. Prior planning is a key to the success of operational safety. In addition, an emergency plan should be shared with all members in advance.

Risk Assessment. Through risk assessment, the following were extracted as typical subjects, and their countermeasures were taken into account.

- Confirm weight of materials: In every operational campaign, before transporting materials to the central complex by vessel, the weight of all objects should be checked, even if they are within the maximum helicopter loading capacity. Routine paperwork should be avoided, even if usage of the identical wireline/slickline equipment of a usual operation is planned. Objects should be checked each time in advance because additional materials are sometimes added on tool boxes/baskets according to the specific wireline/slickline menu. Even the weight of a winch skid unit might vary according to consumption of slickline/wireline. A new drum reel of slickline/wireline is at its heaviest in its life cycle. After a certain number of actual slickline/wireline operations, a front-end side section of line actually used is cut and discarded as a preventive measure to avoid an unexpected cutting accident during the next slickline/wireline operation. Therefore, the weight of the drum reel decreases as it is used over a number of operations. Once judged as being at the end of its life cycle, all remaining line is replaced with a new reel, and the weight increases. In addition, the total length of line required depends on well depth. When planning the operational campaign for deeper wells after the previous job for shallower wells, the weight of the next drum reel might be heavier than that of the one used in the previous campaign.
- Monitor temperature: According to seasonal temperature monitoring in our operation area, any slickline/wireline operational campaign that requires material transportation by helicopter will not be scheduled in the summer season on the annual schedule. The spring or autumn seasons are preferable; however, the operation should be cancelled if an unseasonable heat wave occurs during these times.
- Allow daytime operation only: Any helicopter operation is prohibited during night time (from sunset until sunrise). Even though the helicopter operation can start during the day time, if a series of transportation operations is expected to be difficult to finish before sunset, a part of the operation should be postponed until the next day. Furthermore, the operation should be planned for a completion that allows the helicopter to return to the aviation airport on land by sunset.
- Check safety mesh of the helideck: According to target well-slot position, the marshaller needs to stand near the edge of the helideck, which is surrounded by safety wire mesh. Before taking such a position, the safety wire mesh should be visually checked. If any loose wire or rupture of mesh is found, the marshalling operation should be prohibited until it is repaired.
- Standby at intermediate deck: Ground crews not in charge of load/unload operations should stand by below at the intermediate-deck level during helicopter operations. Only the minimum number of ground crews should be allowed on the helideck, and all crews on the helideck should be those in charge of the load/unload operations.
- Walkie-talkie communication: Nonessential communication by walkie-talkie should be avoided during the helicopter operation to avoid distraction.

Helicopter Flight Characteristics

Correctly understanding helicopter flight characteristics is important not only for the pilot, but also for the ground crews and the marshaller in particular, because it can help in the decisions concerning helicopter-approach direction to the platform. However, the final approach direction shall always be the pilot's decision and must be made with safety as the first priority and payload as the second priority.

Sequential Risk in Flight. Fig. 4 illustrates the sequential relationship of helicopter task requirements and pilot capabilities (FAA 2000). Helicopter accidents occur when flying-task requirements exceed pilot capabilities. The margin of safety (MOS) is the difference between these two factors. As workload increases, the pilot's attention would be close to its limit for several tasks at one time. It becomes the minimum MOS at the tasks of approach and landing. The load/unload operation belongs to the task phase of approach, which is why this paper focuses on the load/unload operation in particular. The use of two pilots would assist in alleviating this workload and allow the "pilot flying" (PF) to fly the aircraft and the "pilot monitoring" (PM) to monitor instruments.

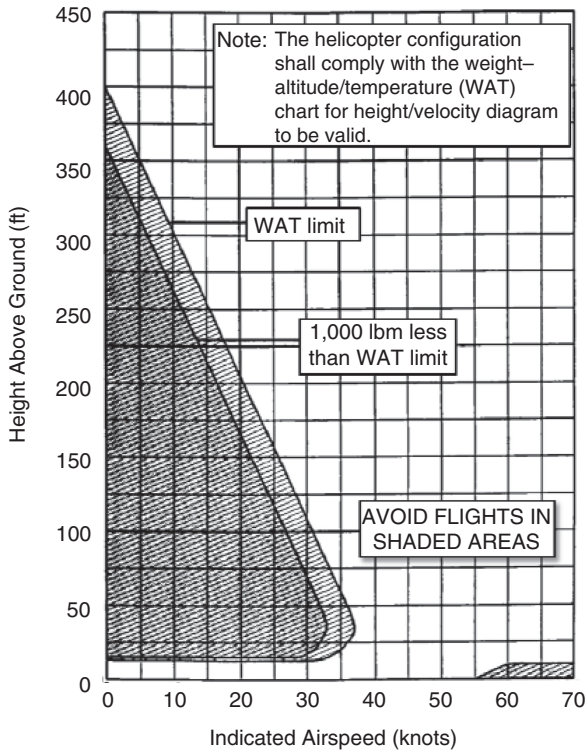


Fig. 5—Single-engine height-vs.-velocity chart for Bell 212 (Bell Helicopter 1998).

Loss of Tail-Rotor Effectiveness (LTE). LTE is a serious situation that can occur in single-rotor helicopters typically at low air speeds of less than 30 knots (FAA 1995, 2000). LTE significantly increases pilot workload and therefore reduces safety margins. LTE results when the tail rotor cannot provide adequate thrust to maintain directional control. Three relative wind directions are generally known to create an LTE environment. In the case of the counterclockwise-main-rotor helicopter types assumed in this study, the torque produced by the main rotor causes the helicopter body to rotate clockwise. The antitorque system provides thrust, which counteracts the torque produced by the main rotor. If the tail rotor generates excess thrust, the helicopter will yaw or turn to the left. If there is less thrust by the tail rotor, then the helicopter will execute right turns. Therefore, these three relative wind azimuths should be taken into account for the load/unload operation. The pilot must always face into the wind, which eliminates LTE because LTE in this type of operation would most likely result in a serious accident. More details are summarized in Appendix A. Additionally, this type of operation requires maximum use of any additional performance offered by wind, which should be factored to 50% for lifting planning purposes and to 100% for transit and return-to-base fuel planning. Therefore, it is preferred to take 100% head wind as much as possible.

Turbulence Around Platforms. Around tall construction such as platforms in open flat areas, there may be turbulent flow that decreases helicopter stability. In addition to common updrafts and downdrafts on the windward side and the lee side of obstacles, respectively, further attention should be considered when approaching an offshore complex that is exhausting gas from a flare or an exhaust system as part of a power-generation unit. In general, helicopters should not be flown adjacent to exhaust efflux of any description because flying through hot exhaust gases will lead to the helicopter losing performance and may be hazardous. The hot gases can cause a turbine engine to "surge," leading to engine failure/flame out. Moreover, a wind-tunnel study reported different wind-velocity distribution on helidecks depending on location (Chen et al. 1995).

Single-Engine Accountability. When conducting this operation, no accounting has been taken of an engine failure and its potential consequences. Helicopters use the most engine power in the hover condition and the least power at the most-efficient aerodynamic speed, known as the velocity take-off safety speed (VTOSS), which also approximates to the single-engine safety speed or the speed at which the aircraft can fly on a single engine. On most helicopters, this speed is between 50 and 70 knots. Within the flight envelope of a helicopter, excess height can be converted to speed or excess speed can be converted to height. However, there are some areas at which the helicopter is too slow to achieve VTOSS or not high enough to convert height to speed approaching VTOSS. Areas within the flight envelope from which VTOSS cannot be achieved are known as the "avoid curve" **(Fig. 5).** These operations are taking place inside the "avoid curve," sometimes known as dead man's curve**.** This means that, in the event of an engine failure, a safe single-engine landing is not guaranteed. Reducing the weight of the helicopter is one means of achieving VTOSS more quickly, so typically, in load lifting operations, engine failure is accounted for by jettisoning the external load, which should bring the aircraft back to within a single-engine accountable weight. When hovering over the platform, it is therefore likely that, in the event of an engine failure, the helicopter will crash land, risking occupants, surrounding personnel, the helicopter, and the platform, and increasing the likelihood of a fire.

- There is no safe place to jettison the load.
- There is no safe unobstructed landing area.
- The aircraft does not have sufficient altitude to achieve VTOSS and to fly away on a single engine.

Approach Direction

Considering the preceding helicopter flight characteristics, the helicopter-approach direction should be decided carefully to avoid LTE—namely, relative wind azimuth of 120 to 330°. There is no objection to making the approach-direction decision from the safety point of view at first, but it is necessary to consider the post-unloading operation at the same time (see **Fig. 6**). The final position of each material load depends on the slot position of the target well on the helideck. Winch and power-pack units are usually positioned away from the well. On the other hand, it is preferred that tool boxes and tool baskets containing BOP, lubricator, pipes, and gauge tools be located near the well to be as close as possible to final position so that the work of moving materials can be minimized. An example of an ideal case is shown in **Fig. 7,** which assumes 135° wind direction with 325° for the target well-slot position (i.e., upper-left corner). This satisfies both the allowable relative wind azimuths and the ideal unloaded position of heavier materials. Winch and power-pack units are higher priority because they are heavier loads as compared with other materials. Some tool boxes/baskets have wheels and others have no wheels. Materials with wheels can be moved easily by human force, but materials without wheels, even if lightweight, cannot be moved as easily. Therefore, the second priority is placed on materials that are not equipped with wheels, allowing the flexibility to unload tool boxes/baskets that have wheels farther from the final position.

Fig. 8 supposes 0° wind direction and 325° for the target well-slot position. When achieving 0° relative wind azimuth, a tool basket that does not have wheels can be unloaded at the final position; however, winch and power-pack units cannot (see Fig. 8a). Therefore, an alternative approach direction is applied, as shown in Fig. 8b. This allows unloading of the winch and power-pack units at the final position while satisfying the allowable relative wind azimuth of 120 to 330°. However, one should keep in mind that this approach direction cannot access the maximum use of additional performance offered by the wind. This means that robust safety might be deterio-

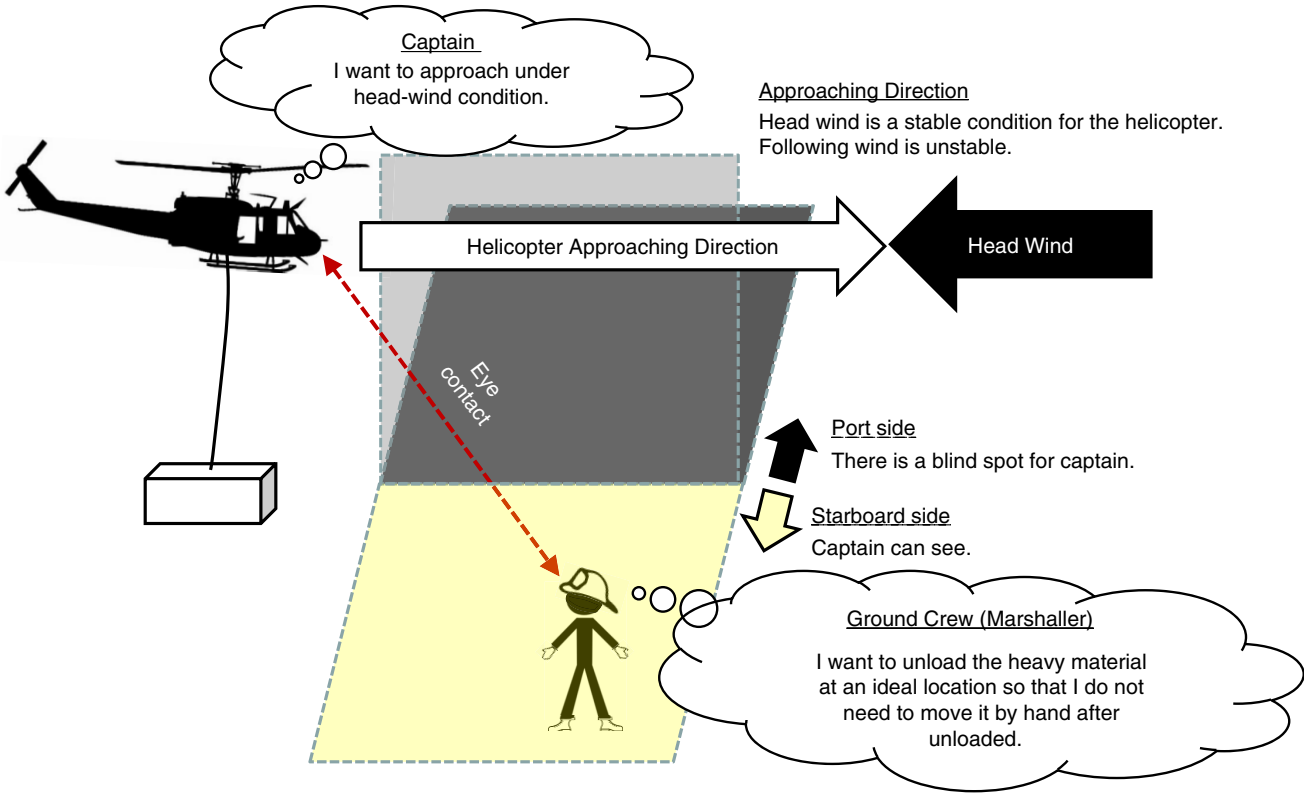


Fig. 6—Conflicts between pilot and marshaller.

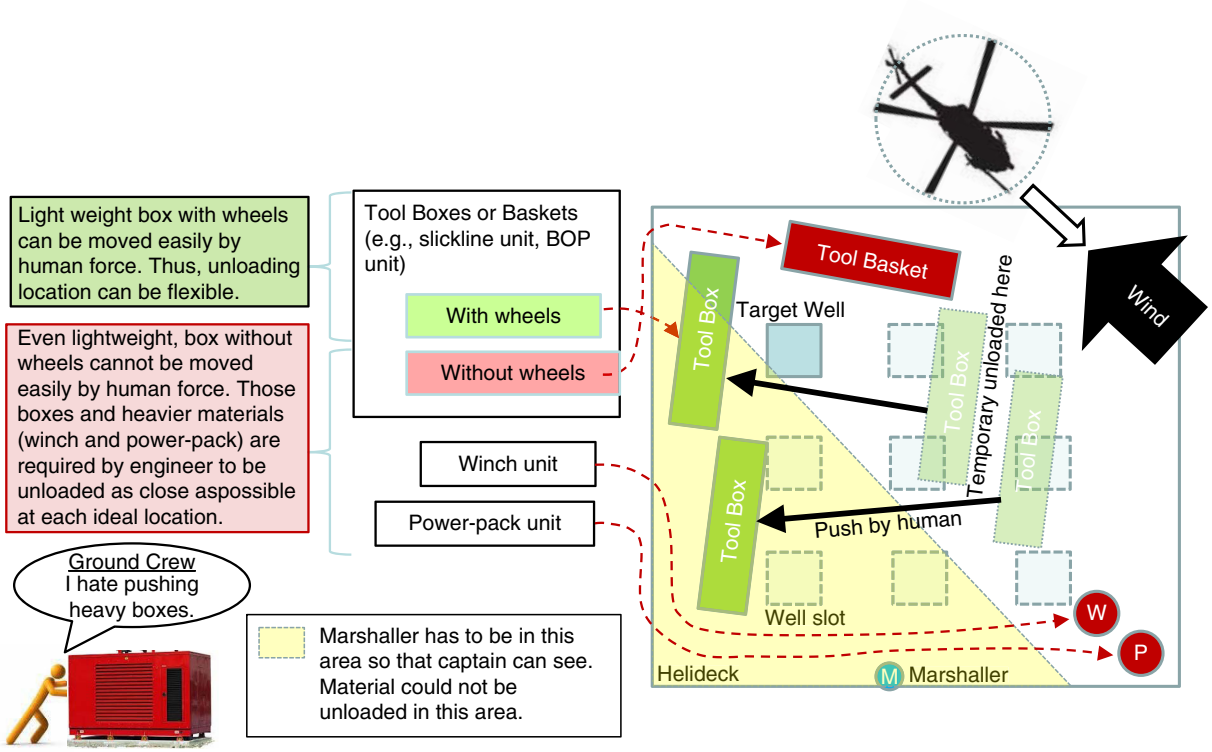
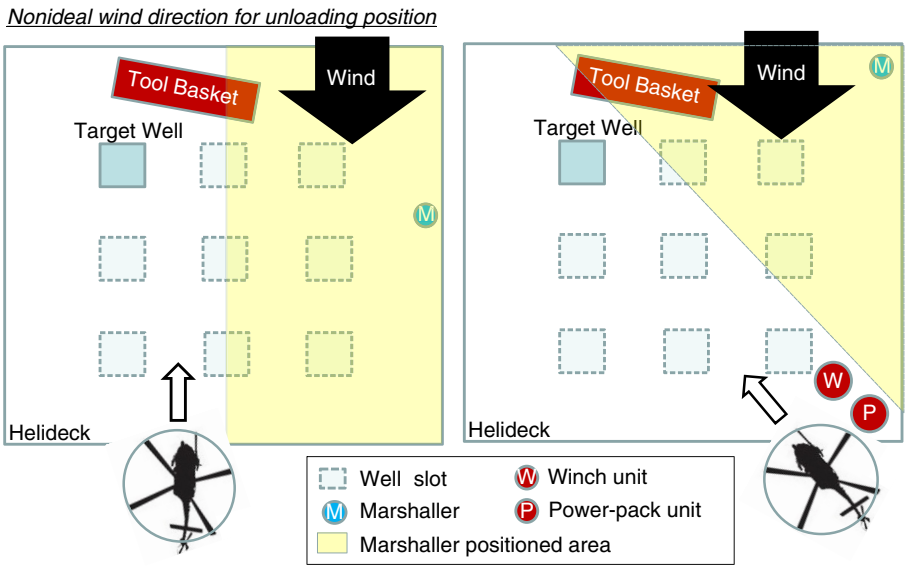


Fig. 7—Typical ideal position of unloaded materials for slickline operation.



(a) Unloading of tool basket by approaching while taking 100% head wind.

(b) Unloading of winch and power-pack units by approaching at intermediate angle toward wind direction.

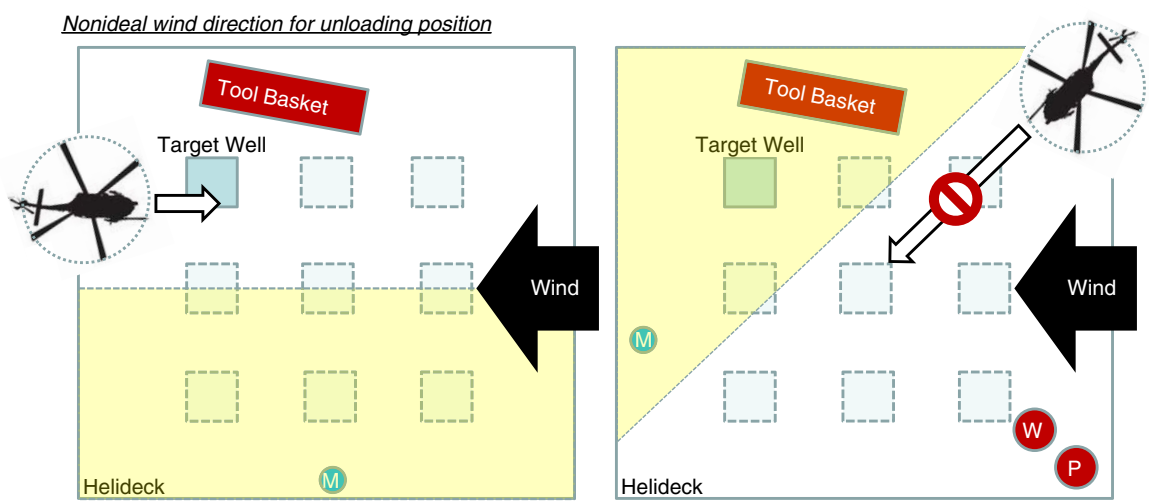
Fig. 8—Alternative approaching direction in the event of a nonideal wind direction.

rating as the approach direction moves away from head-wind direction. Once the helicopter starts to approach at a certain direction, the pilot should keep on course and never turn out of the wind during the approach or during load lifting. Otherwise, recovery from LTE would not be possible, and could result in an accident.

Another wind-direction case is illustrated in **Fig. 9.** It supposes 90° wind direction and 325° for the target well-slot position. A tool basket can be unloaded by taking head wind, but winch and power-pack units cannot, as shown in Fig. 9a. For unloading those two units at the final position, the helicopter is required to approach with 225° relative wind azimuth, as shown in Fig. 9b. However, this should be avoided for safety reasons.

Discussions for Safety

Psychological Factors. If it is possible to take approximately 0° allowable relative wind azimuth, then it is easy for the marshaller to make a decision about the helicopter-approach direction. However, some cases are in a gray area—namely, around the edges of the allowable relative wind azimuth range. In such cases, the marshaller may subconsciously give in to the pressure to enforce a risky decision. Here, we discuss the factors that can affect the marshaller's psychology. Each factor represents a minor hazard that can be visible, but is often discounted. However, they become obvious hazardous factors if accumulated. Conversely, it might be said that removal of those minor factors can contribute to the mitigation of



(a) Unloading of tool basket by approaching at 100% head wind

(b) Prohibited approach direction. For unloading of winch and power-pack units, 225°relative wind azimuth is needed, but should be avoided.

Fig. 9—Example of a prohibited approaching direction.

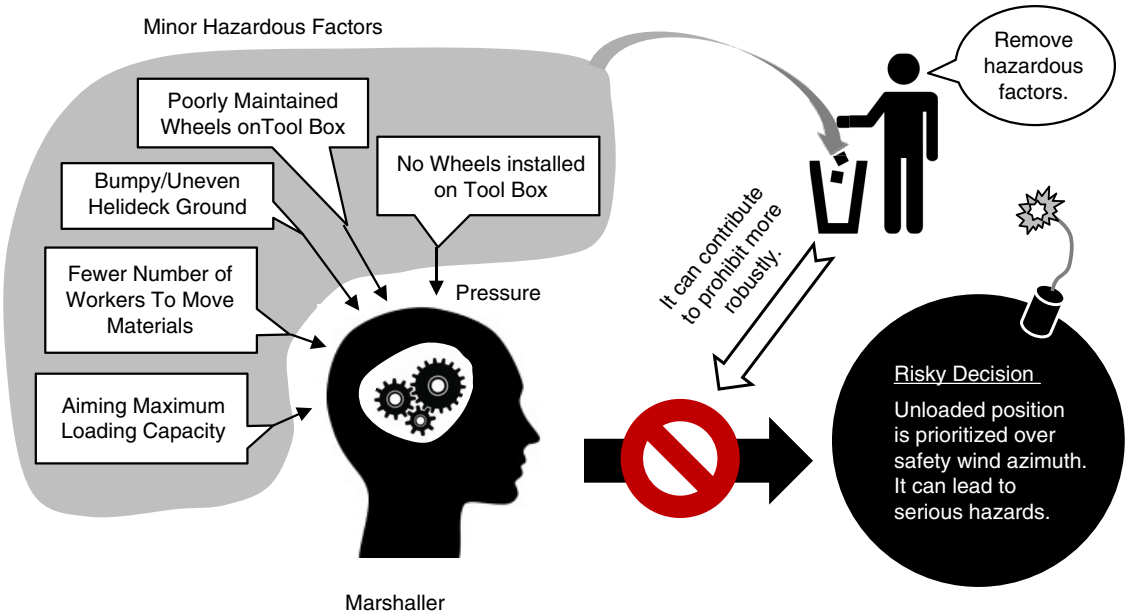


Fig. 10—Schematic of minor hazardous factors that result in pressure to enforce risky decisions.

serious hazards, as shown in **Fig. 10.** Typical possible minor factors are summarized as follows.

- No wheels are installed on the tool box or basket: Moving heavy materials that are not equipped with wheels requires the use of a primitive roller. Material transfer by roller might have a higher risk of injury compared with transfer by wheels.
- Poorly maintained wheels: Metal parts used in offshore operations are easily rusted. It is hard to move heavy materials with rusted wheels; therefore, frequent maintenance is required. However, maintenance often cannot catch up with requirements because of a tight schedule.
- Bumpy/uneven helideck ground: In the case of a wooden deck after long-term use, there are cracks, damage, and chipped edges on the helideck. These present obstructions to moving heavy materials, even when wheels are available.
- Fewer workers to move materials: The number of workers is minimized as a result of cost-saving measures. Ground crews, consisting of company supervisor and slickline/wireline team, are separated into two groups (sender and receiver), and there are usually two to three personnel in Group B (receiver) available to push materials.
- Aiming for maximum loading capacity: For cost-saving reasons, the number of transportation runs (loading/unloading) must be minimized. Therefore, more tools are put into a tool box or basket—as much as possible to reduce the number of boxes or baskets. This means that the weight of a box or basket becomes greater.

Remote Operation by Pilot Only. One mitigation to be discussed is the remote operation by a pilot because the position of the marshaller in this operation includes a risk. In the case of unloading just one object on a location that is clear of other loads, the operation might possibly be performed remotely by a sole pilot. However, typical wireline/slickline jobs have multiple objects (usually five or six packages) to be transported by helicopter; therefore, remote unloading by a single pilot is difficult on a helideck where items have been placed here and there. Therefore, in our case including multiple transportation items, a marshaller's instruction is definitely needed.

Alternative Marshalling Operation. A more fundamental countermeasure would be not to use a ground marshaller for this task, but instead to use a crewman positioned inside the helicopter, on a safety harness, leaning out of the door to give instructions to the pilot over intercom. Marshalling is generally too slow for an operation such as this, and an internal crewman can keep the aircraft clear of obstacles. Furthermore, these small, flat platforms lack any vertical features for a stable hover reference, and the pilot has to continuously look down. There should always be a pilot monitoring instruments at all times, especially in high-power-demand flying such as prolonged hovering, during which the aircraft is using 100% of its available power. Using too much power on a Bell 212 helicopter is known as "overtorque," and nearly always requires some remedial maintenance action or inspection before further flight. This monitoring requirement would increase the air crew to two pilots plus one crewman, which would further reduce the infield payload. Moreover, a no-ground-marshaller operation can improve the flexibility of an unloading position because an area that is inaccessible to the ground marshaller becomes an accessible area for unloading. When considering this case, the payload reduction caused by adding one additional pilot and one crewman (e.g., 180 lbm × 2 personnel = 360 lbm) should be checked carefully.

New-Generation Helicopters

The helicopter used in this study is an older-generation design (1960s/1970s). Older-generation helicopters are typically civilian adaptations of a military design and have been certified under older Federal Aviation Administration (*FAR 29* 1970) or European (*EASA CS-29* 2003) certification rules. The aircraft referred to in this study are typical of helicopters that have made the military-to-civilian transition. The Bell 212 helicopter is a derivative of the "Huey" used in Vietnam by the US, which was designed in the 1960s. The Huey was a single-engine helicopter. For safety and redundancy reasons, the Bell 212 has two engines; however, the main gearbox is from the Huey and therefore has the capability for only one main input shaft. To overcome this, the Bell 212 has a combining gearbox between the two engines and the main gearbox. The combining gearbox itself uses some power, so it is not as efficient as a helicopter that has a main gearbox with two separate inputs.

Because certification requirements have become more stringent as a result of safety requirements and a combining gearbox is a single

point of failure, later-designed and -certified helicopters have main gearboxes with two separate engine drive inputs, eliminating the need for a combining gearbox. Improved material and computerized engine-management-control technology have improved the available power from engines by more accurately managing fuel and air ratios, resulting in improved power, response, and engine control when the helicopter goes into one-engine-inoperative (OEI) mode. Newer-generation aircraft also offer improved overall performance; the development curve is chronologically similar to that of the automobile. In addition to more accountable weight in the emergency case of OEI conditions, digital flight and engine-management systems reduce pilot workload. Therefore, it is recommended to find an alternative helicopter designed to new-generation requirements. It would be beneficial to use a helicopter type that has sufficient single-engine hover capability, in particular, to perform the task safely.

Portable Manual Hoist. To mitigate the aforementioned minor hazards that can affect a marshaller's instruction on a platform not equipped with any fixed power hoists, portable manual hoists, such as Tirfor machines, are worth considering for moving items that have poorly maintained wheels. The portable manual hoists are lever-operated tools that use a separate wire rope, are lightweight, and are manageable to bring to site easily. They can pull loads to decrease the workforce needed for pushing materials by human power. To apply the hoist, an anchor point is needed on the helideck floor. If there is no anchor point available on the helideck, the legs of the platform might be an alternative. In this case, the anchor point is positioned below helideck level. Accordingly, a fulcrum point, to which a tensioned rope connects, is generated at a certain point on the edge of the helideck. Therefore, the strength of the anchor and fulcrum points needs to be checked.

Alternative Transport Methods Without Helicopter. As further fundamental solutions, many alternative transport methods were considered; however, all were judged to have no advantage compared with helicopter operation given our assumptions and situation. The first alternative was installation of crane equipment on each satellite platform. However, this would require a large investment with little chance to make a cost justification for our oil field. There were many other factors (number of platforms, maturity of the field, small size of the platform, low oil price) that made the investment environment more difficult in our case.

Another alternative was use of a vessel with a crane; however, no such vessel was available in the local area. The use of a jack-up barge was the last alternative considered; however, comparative cost analysis clearly revealed that its charter fee was higher than that of a helicopter. Furthermore, barge availability was always limited while a helicopter was easy to hire for ad hoc operation.

Conclusions

1. The marshaller should place higher priority on the safe relative wind azimuth for a helicopter approach. When the condition is available, the marshaller is allowed to set the unloading location to be the final position.
2. It was discussed that minor hazardous factors can affect the marshaller psychologically to enforce making risky decisions that might lead to more serious hazards. It is recommended that these factors be removed or mitigated.
3. As a more fundamental countermeasure, the possibility of applying an alternative marshalling method is investigated. The aircraft should be crewed with two pilots and one crewman at all times, removing the need for a ground marshaller.
4. It is recommended that an alternative helicopter that is designed to new-generation requirements be found.

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References

Ayres, C. A. C. and Oliveira, J. C. 1998. Flight Safety in Campos Basin Offshore Activity. Presented at the SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Caracas, Venezuela, 7–10 June. SPE-46736-MS. http://dx.doi.org/10.2118/46736-MS.

Bell Helicopter. 1998. Bell Model 212 Rotorcraft Flight Manual, BHT-212IFR-FM-1, Revision 3. Fort Worth, Texas: Bell Helicopter Textron Inc.

Bell Helicopter. 2007. Bell Model 412EP Rotorcraft Flight Manual, BHT-412-FM-4, Revision 27. Fort Wirth, Texas: Bell Helicopter Textron Inc.

Bell Helicopter. 2013. Bell 412EP Product Specifications (February 2013). Fort Worth, Texas: Bell Helicopter Textron Inc.

Bower, W. A. Jr., Baldwin, R. G., and Franks, P. L. 1992. US Navy Regional Climatic Study of the Persian Gulf and the Northern Arabian Sea. Final Report, AD-A260 363, NAVAIR 50-1C-561, Naval Oceanography Command Detachment, National Climatic Data Center Global Analysis Branch, Ashevill, North Carolina, USA (July 1992).

Brittan, D. and Douglas, S. 2009. Offshore Crew Supply—Modern Marine Options Challenge Helicopters. Presented at the SPE Offshore Europe Oil and Gas Conference and Exhibition, Aberdeen, UK, 8–11 September. SPE-123889-MS. http://dx.doi.org/10.2118/123889-MS.

Burton, J. 2011. The Work of the UK Helicopter Task Group. Presented at the SPE European Health, Safety, and Environmental Conference in Oil and Gas Exploration and Production, Vienna, Austria, 22–24 February. SPE-140760-MS. http://dx.doi.org/10.2118/140760-MS.

Chen, Q., Gu, Z., Sun, T. 1995. Wind Environment Over the Helideck of an Offshore Platform. *Journal of Wind Engineering and Industrial Aerodynamics* **54–55:** 621–631. http://dx.doi.org/10.1016/0167-6105(94)00077-Q.

Clark, E., Edwards, C., Perry, P. et al. 2006. Helicopter Safety in the Oil and Gas Business. Presented at the IADC/SPE Drilling Conference, Miami, Florida, USA, 21–23 February. SPE-98672-MS. http://dx.doi.org/10.2118/98672-MS.

De Rocca Serra, V. 1998. Safety in Helicopter Transport of Personnel in Elf Exploration Production (EEP). Presented at the SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Caracas, Venezuela, 7–10 June. SPE-46623-MS. http://dx.doi.org/10.2118/46623-MS.

EASA CS-29, Certification Specifications for Large Rotorcraft. 2003. Cologne, Germany: European Aviation Safety Agency.

FAR 29, Airworthiness Standards: Transport Category Rotorcraft. 1970. In Title 14, Chapter 1, Subschapter C, Part 29 of the Code of Federal Regulations, Federal Aviation Administration, Washington, DC.

Federal Aviation Administration (FAA). 2000. Rotorcraft Flying Handbook. FAA-H-8083-21, US Department of Transportation, Federal Aviation Administration, Oklahoma City, Oklahoma.

Federal Aviation Administration (FAA). 1995. Unanticipated Right Yaw in Helicopters. Advisory Circular 90-95, US Department of Transportation, Federal Aviation Administration, Washington, DC (February 1995).

Hokstad, P., Jersin, E., and Sten, T. 2000. Helicopter Safety Study 2 - A Report on North Sea Helicopter Operations. Presented at the SPE International Conference on Health, Safety, and Environment in Oil and Gas Exploration and Production, Stavanger, Norway, 26–28 June. SPE-61085-MS. http://dx.doi.org/10.2118/61085-MS.

Rowe, S. J., Howson, D. and Sparkes, P. 2002. Research Improving the Safety of Offshore Helicopter Operations. Presented at the Offshore Technology Conference, Houston, 6–9 May. OTC-14162-MS. http://dx.doi.org/10.4043/14162-MS.

Ulleberg, T., Ingstad, O., Rosness, R. et al. 1991. Helicopter Safety Study. Presented at the SPE Health, Safety and Environment in Oil and Gas Exploration and Production Conference, The Hague, The Netherlands, 11–14 November. SPE-23310-MS. http://dx.doi.org/10.2118/23310-MS.

Williams, R. G. 2000. Worldwide Oil Industry Helicopter Operations and Safety Review. Presented at the SPE International Conference on Health, Safety, and Environmental in Oil and Gas Exploration and Production, Stavanger, Norway, 26–28 June. SPE-61084-MS. http://dx.doi.org/10.2118/61084-MS.

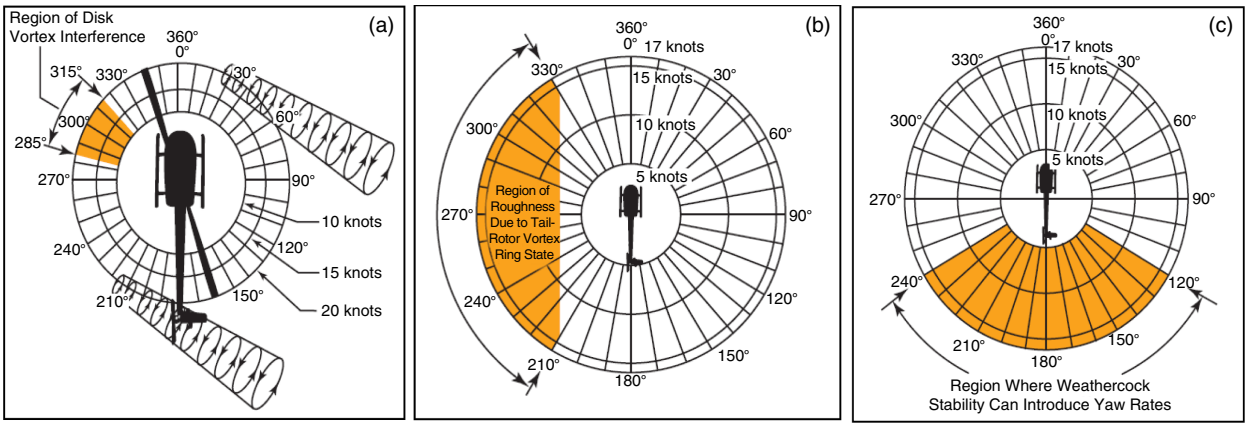

Fig. A–1—Three wind azimuths to be avoided to prevent LTE: (a) Main rotor disk vortex interference, (b) tail rotor vortex ring state, (c) weathercock stability. (FAA 1995).

Appendix A: Three Wind Azimuths To Be Avoided To Prevent LTE

Main Rotor Disk Vortex Interference (Fig. A-1a). A relative wind azimuth between 285 and 315° will cause the main rotor vortex to be blown into the tail rotor by the relative wind, resulting in tail-rotor operation in an extremely turbulent environment. If thrust reduction occurs suddenly and is not corrected, the mast will have an uncontrollable rapid rotation.

Tail-Rotor Vortex Ring State (Fig. A-1b). In wind azimuth of 210 to 330°, the vortex ring state of the tail rotor will be developed. As the inflow passes through the tail rotor, a thrust to the left is given to the tail rotor. A left crosswind will oppose this tail-rotor thrust, resulting in a vortex ring state that causes unsteady flow into the tail rotor.

Weathercock Stability (Fig. A-1c). Tail winds from 120 to 240° will cause yaw rate acceleration. Winds in this azimuth will work to weathervane the nose of the helicopter into the relative wind.

SI Metric Conversion Factors

°F	(°F−32)/1.8	= °C
mbar × 0.01		= Pa
ft × 3.048*		E–01 = m
knot × 5.144 444		E–01 = m/s

*Conversion factor is exact.

Hideharu Yonebayashi is currently working for INPEX Corporation and is assigned in research and development as the manager of the Reservoir Group. His main interests are enhanced oil recovery (carbon dioxide foam and low-salinity waterfloodings) and related technologies. Yonebayashi has more than 20 years of experience in the oil industry, and his expertise includes microbial enhanced oil recovery, gas injection, steam-assisted gravity drainage, asphaltene flow assurance, and supervising field operations such as asphaltene removal, acidizing, production logging, and well tests. He holds BS, MS, and PhD degrees from Tohoku University, Japan, all in petroleum engineering.

Tim Collins is the aviation manager and technical authority with INPEX Corporation. He has been with INPEX for 5 years and has set up all aviation support for the Ichthys Project in remote Western Australia. Collins has been in the aviation business for 35 years, starting his career as a North Sea helicopter pilot and achieving 9,000 safe-flying hours. His interests are aviation safety, air logistics, and helicopter performance. Collins is considered a helicopter industry leader.