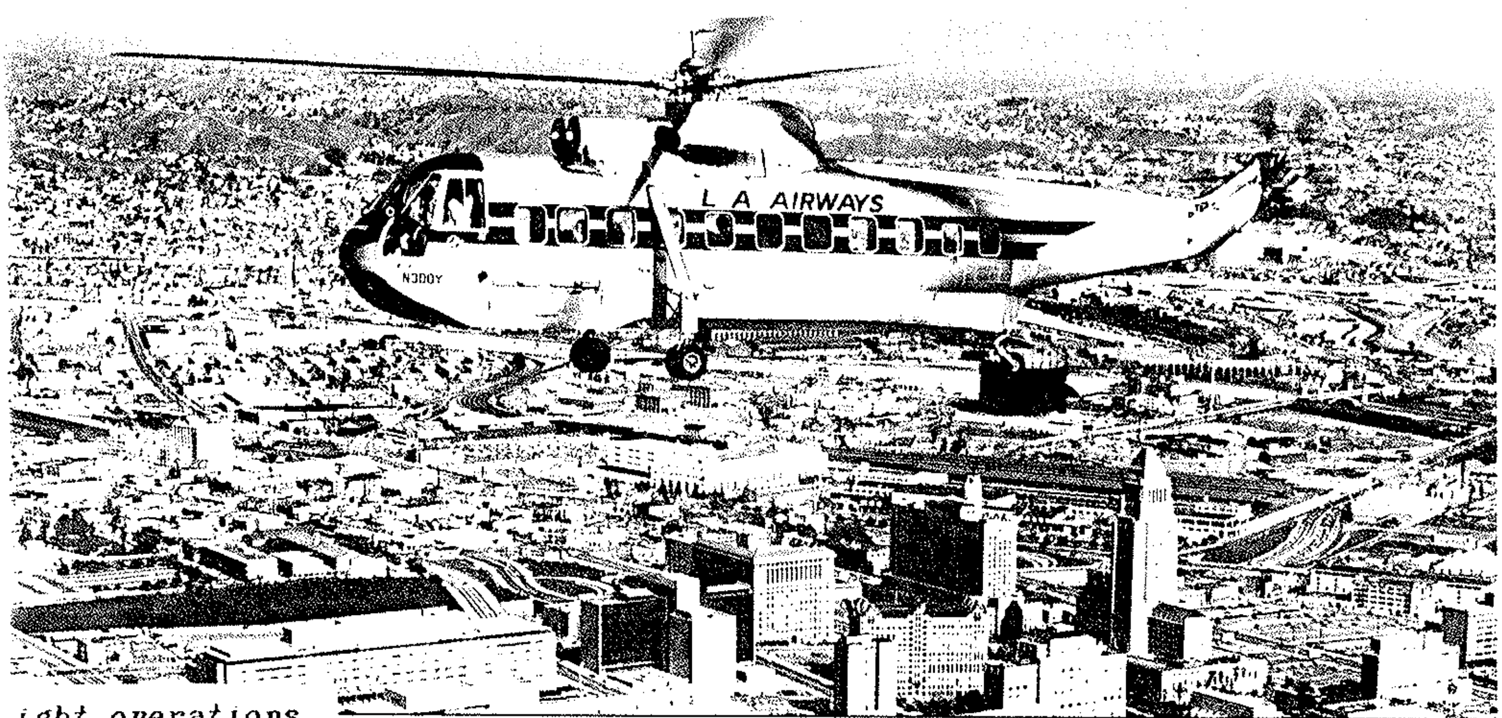

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Los Angeles Airways' S-61L. It and its predecessors have been providing unrestricted IFR service since 1964.

helicopter IFR

By Ronald G. Crawford

"Those who fail to learn from history are forced to repeat it." This famous quotation is especially meaningful when considering implementation of commercial helicopter IFR regulations. Operating civil helicopters IFR is neither novel nor unproven, except to those who ignore history—those who are unaware of the past are condemned to repeat the same laborious process that the earlier efforts required. In other words, instead of building on previous successes in the manner of most developments, helicopter IFR is proceeding today with limited knowledge of its actual accomplishments. To show how true this is, I would like to relate the highlights of one of the industry's successful attempts that has been largely ignored in the present efforts to establish current operations. I will leave it to the reader to decide whether there has been progress or regression since then:

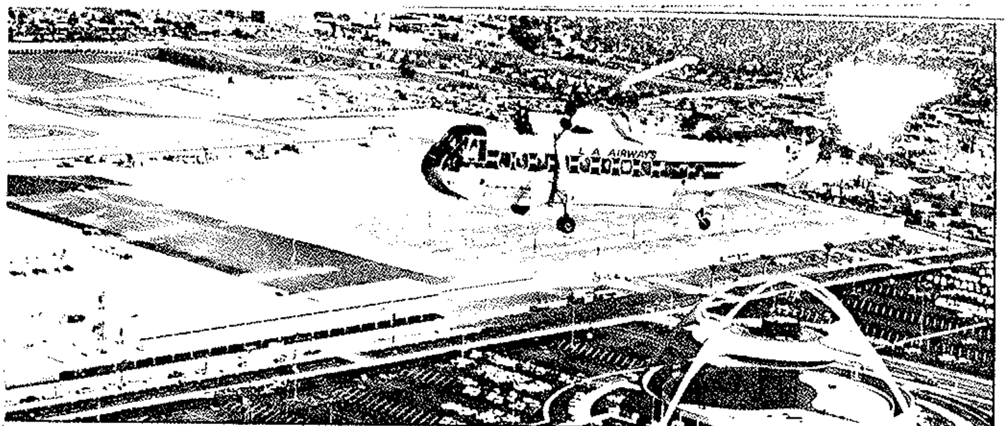
ED. NOTE: Ronald G. Crawford was chief pilot and operations manager for Los Angeles Airways. He joined Sikorsky Aircraft in 1974 and is now commercial marketing manager for the Eastern third of the U.S.

Between 1965 and 1972 there were over six years of scheduled helicopter IFR passenger-carrying operations in a major terminal area, the Los Angeles Basin. Many hundreds of hours of actual IFR were flown carrying tens of thousands of fare-paying passengers while meeting airline standards of performance and safety. The operator was Los Angeles Airways, which had initiated scheduled day VFR operations in October 1947 and expanded this to night VFR operations in October 1948.

First IFR certification in 1950: Los Angeles Airways' initial helicopter IFR efforts started in June 1949 with the Sikorsky S-51. In June 1950 LAA received approval to operate its four S-51s in s[illegible]ed service under IFR for periods not exceeding 15 minutes. This permitted departures and approaches in localized IFR conditions. The aircraft were so certified and the pilots were instrument rated by the Civil Aeronautics Administration, the predecessor of the FAA. The aircraft were unstabilized with only a force trim system on the cyclic stick, utilizing bungee cords. An interesting sidelight is that the first two presidential pilots were sent from Washington, D.C. to LAA in 1952 for an instrument training course in these aircraft.

Unrestricted IFR in 1964: In 1961, LAA began working on an instrument program for the Sikorsky S-61. Primary responsibility for this program rested with Boyd Kesselring, the man who had developed the S-51 instrument operation 12 years earlier. Only now, it was to be unrestricted and provide scheduled passenger service to and from heliports in a network stretching from Los Angeles International Airport (LAX) on the west to Newport Beach on the south, San Bernadino on the east and Van Nuys on the north.

There were many delays and problems too numerous to cover in this article, but they were overcome. The IFR certification of the S-61 was completed by LAA in November 1964, and in April 1965 LAA flew their first IFR scheduled



Five IFR S-61's were serving Los Angeles Airways by 1967.

passenger flight. Pilots, dispatchers and heliport weather observers had been trained and licensed to airline standards.

A helicopter enroute IFR evaluation was flown, which substantiated helicopter-only IFR airways providing 500 feet of obstruction clearance two miles each side of centerline, reducing to 0 obstruction clearance at three miles each side. This utilized only VOR/DME without any RNAV system. Of course, fixed-wing routes in the same area are 10 miles wide with 1,000 to 2,000 feet of obstruction clearance required. The flight-test work is covered in FAA Project Report No. 65-920-6. This permitted the development of a segregated route structure between the LAA heliports.

Approaches: Helicopter-only instrument approaches and departures were developed for LAX and the heliports providing a complete IFR system. Helicopter SIDs at LAX permitted IFR departures from the passenger terminal area with minimal interference between rotary and fixed-wing traffic. Jeppesen published our approach plates and provided a subscription service tailored to Southern California.

It was determined that as long as we were headed towards the heliport on final approach, it could be considered a straight-in approach regardless of the maneuvering necessary for landing. On the other hand, the San Bernadino approach required a turn of 160 degrees at the missed approach point to proceed to the heliport 1.1 nautical miles away and still had minimums of 300 feet and one-half mile. This had to be the forerunner of the "point-in-space" approach now in use.

When utilizing the ILS at LAX, we would often be paralleled with the localizer at low altitude until inside the outer marker for a turn-on at approximately three miles out. An opening would have been created by speeding up one fixed-wing and slowing down the succeeding one slightly so we would have access to the ILS for a minimal time. That was all that was needed to complete the approach, make a quick break-off and proceed to the terminal.

We were also permitted simultaneous, nonprecision radar approaches with only one-mile lateral separation from fixed-wing aircraft on the ILS at LAX. It is covered in a Letter of Agreement, dated Sept. 20, 1965.

Reserves: Fuel reserves were 20 minutes for flight plans of one hour or less and 30 minutes if they were over an hour. Alternate minimums were 400/1 for flight plans of an hour or less, and 600/1 or 500/2 for flight plans over an hour. No alternate was required if destination weather was forecast to be 1,000/2 for one hour prior to and one hour after ETA. All of our trips had IFR flight plans stored in the ATC computer so the pilot only had to call clearance delivery with trip number and destination to turn on the system.

Equipment: By 1967, LAA had five IFR S-61s and they were equipped as follows: dual transceivers, dual VORs with glideslope receivers, dual remote gyro compass systems, single ADF, DME and marker beacon receivers. It was top-of-the-line airline equipment. Both panels were identical and had a reverse T layout in order to place the airspeed, triple tachometer and torquemeter in the captain's peripheral vision when contact. There was an HSI and flight director, but the flight director was not required equipment. We did *not* have a standby VGI, radar altimeter, weather radar or coupler.

We were working in one of the busiest air traffic areas in the world, and a crew could make as many as three departures and three approaches within an hour's time. Minimums were ultimately brought to 100 feet DH and one-fourth mile or 1,200 RVR visibility with no additional equipment. In order to establish these minimums, an evaluation program with the FAA was conducted in weather down to and including 0/0 conditions. All of this was done utilizing Category I ILS equipment.

Training standards were high, with heavy emphasis on flight without stabilization and gyros since the AFCS was nonredundant. Most of the initial training flights and check rides were conducted between midnight and 6:00 A.M. in order not to interfere with scheduled operations. At the peak, there were 45 instrument-rated pilots, 27 of whom had ATRs. A check ride would take two hours and covered basic airwork, navigation, emergencies, departures, approaches and VFR maneuvers.

Recency of experience was met during extended periods of VFR weather by enroute training on scheduled passenger flights. The captain occupied the right seat, a hooded pilot flew from the left seat and a copilot was on the jump seat as a safety observer. To our knowledge, this is the only instance where this has been permitted on an aircraft certified for two pilot operations.

The pilots' attitude toward instrument flying was excellent. They recognized that it was safer, more productive and increased their professional value. Our special VFR minimums were one-half mile visibility during daylight hours and one mile in darkness. Enroute minimum altitudes were from 300 feet to 500 feet, depending on location and time of day. The LAX control zone was 300 feet day and night. We also had a special VFR route structure with excellent control, but this still did not permit reliable, safe completion of all scheduled flights. Many trips had been stymied by only a short segment of below minimums weather. Instrument operations definitely increased completion factors while *decreasing* the pilot's work load. Enroute times did not increase significantly and, in fact, they declined in many instances. It often took longer to fly a trip Special VFR than it did IFR. The ATC people were excellent and imaginative. I can't relate in this short space the many examples of their assistance.

In May 1970, when the first helicopter TERPS conference was held, the Los Angeles Airways experience was practically the total civil IFR background available. It had a major impact on Chapter 11 as it is now written. Perhaps this experience should be reexamined to see if it can contribute to the industry's present efforts.

Possibly more could have been done, and I'm certain more will be accomplished in the future, with the equipment improvements being made. The important thing is: We should be moving forward, insisting we will not accept less than was proven more than 10 years ago. □

Some Aspects of Instrument Flight

By R. J. van der Harten*
KLM Noordzee Helikopters N.V.

KLM Noordzee Helikopters N.V. has been operating a successful, 24-hour service supplying oil rigs in the North Sea and transporting harbor pilots to ships since '68—a success based largely on flight in conditions of poor visibility

When my company became operational on March 15, 1968, the Dutch Civil Airworthiness Authority (RLD) already had decided that helicopter operations at night must be conducted under IFR as defined for fixed-wing aircraft. This was contrary to the practice in England where night operations with helicopters are still permitted under VFR in Visual Meteorological Conditions (VMC). However, in the opinion of RLD, the practice does not meet the safety level required for Airline Transport Category Operations, under which Dutch helicopter companies are certified. The RLD thus followed the example of the Norwegian Civil Airworthiness Authority that was the first in Europe to insist on flights under IFR with helicopters, at night over the North Sea for the oil rig operations of Helikopter Services A.s., a Norwegian firm.

Despite the fact that only 4 months were available between ordering the aircraft and commencing actual operations, Noordzee was able to provide from the start a 24-hr. full IFR service to the oil rigs for the Nederlandse Aardolie Maatschappij (NAM) with its first S-61N.

The company started operations with one S-61N and one S-62A. In 1969 this fleet was expanded with the acquisition of a second S-61N equipped with radar and a hoist (Fig. 1). A third S-61N equipped with radar and Decca Doppler 71 was delivered later.

The concept

The main purpose of this paper is to review the typical difficulties which were encountered, but also the possibilities that became clear when the RLD made its decision regarding IFR flight with helicopters.

As a fully owned subsidiary of KLM Royal Dutch Airlines, our company could use the immense background and the technical facilities of the mother company for the training of pilots, to equip the helicopters with the most reliable instruments and electronics, and to use airline methods and knowhow. Regarding the general directives for the calculation of weather minima, as required by the RLD, for obtaining approval of limits and procedures, we were on our own.

The main difficulty proved to be the lack of ICAO recommendations for instrumentation, approach aids and limits for helicopters. However, because the RLD compelled our company to instrument flight, they also took the consequences that, because of this lack of knowledge and recommendations of the ICAO, they should have an open mind for all proposals we made and could prove to be safe, without unnecessary reference to accepted fixed-wing standards.

They accepted in fact a different attitude toward instrument flying with helicopters because of the different characteristics of this aircraft, the main consideration being that a helicopter, using the right procedures, does not have to accelerate to best climbing speed after an aborted approach and thus has no appreciable sink rate.

Realizing that a helicopter thus, contrary to fixed wing aircraft, is *never committed to land*, it was possible to define a concept providing a 24-hr service, 7 days a week, to oil rigs and ships at a competitive flight-hour price. This concept can be defined as follows:

1. Use existing approach and navigation ground aids.
2. Prevent undue duplication of aircraft instrument and aoproach systems, saving unnecessary weight and cost, accepting higher weather limits for approaches when one system fails and has to be backed up by a different system. This includes nonduplicated multi-purpose navigation systems such as Decca navigation, radar, ADF, VOR/ILS and Doppler to provide airborne approach aids where practicable.
3. Define and certify procedures aiming for maximum reliability, passenger comfort and safety of the operation; proving that the helicopter can indeed safely achieve lower weather limits than possible with fixed-wing aircraft using the basic Cat I instrumentation, and exploiting the specific flight characteristics of the helicopter to its maximum safe potential.
4. As the crew always consists of 2 pilots, use their full potential to share tasks and divide the increased workload inherent with the simplified system concept.

Realization of the concept

Certification of the aircraft

Because of the KLM background of our company, choice of the Sikorsky S-61N helicopter was natural, because this aircraft was the only civil helicopter at that time which had been certified for instrument flight in the U.S. and also was at that moment operationally the best aircraft available. It had been in use with several operators in the North Sea area for a number of years and had shown itself to be very reliable.

The RLD requirements to certify helicopters for IFR flight state that:

a. A reliable automatic stabilization system with separate channels for roll, pitch and yaw must be provided.

*The author is deputy managing director. He will be remembered by *Vertiflite* readers as having been designated by his company to receive in its behalf the 1970 Capt. William J. Kossler Award of the Society at the 27th AHS Annual National Forum. The award was "for development of IFR and approach capabilities to serve North Sea oil rigs and provide harbor pilot service to ships on a 24-hour basis." He has been a member of AHS since 1960 and is an Associate Fellow, RAeS. This article was delivered as a lecture before the Nederlandse Vereniging voor Luchtvaarttechniek May 13, 1971.

b. The aircraft must be equipped with at least two engines.
c. The aircraft must be flown by 2 pilots and instrumentation must be duplicated.
d. The aircraft must be certified for IFR flight in its country of origin.
e. Navigation, instrumentation and communication systems as required by law for airline transport flights must be provided for.

The S-61N offered no problems as to the requirements under a, b, c and d. The requirements under e were discussed with the RLD, taking into account the concept as defined for instrument flight with helicopters.

Fig. 1. The Sikorsky S-61N.

Navigation systems

The first S-61N was equipped with dual ADF (Automatic Direction Finder), single VOR/ILS (Very High Frequency Omnidirectional Range/Instrument Landing System) and single Decca Mk 19 navigation system, providing 4 navigation systems, which is in excess of the requirement for duplicated systems for airline transport operations. All systems use different DC buses.

The second S-61N was equipped with the Bendix-Air Equipment RDR-1DM weather and approach radar, two ADFs, single Decca Mk 19 and single VOR/ILS. The third S-61N has been equipped with the same basic systems but the Decca Mk 19 has been replaced by a single Decca Doppler 71, providing hover and slow speed capability as well as a navigation aid. Only the hover indicator has presently been duplicated. All systems double as approach aids and are certified for different weather limits, thus backing up each other to a certain degree. Dual instrumentation is provided for navigation and approach information, except for Decca Mk 19 and radar where single presentation is provided at the center panel. In the case of the radar approach the captain directs the co-pilot in basically the same way as for groundbased GCA and PAR.

Instrumentation

Sikorsky provided dual instrumentation in the basic aircraft, with dual pitot and static sources as well as gyro horizon systems, except for the single, 3-channel Hamilton Standard Automatic Flight Control Stabilization System *(AFCS)* and the Sperry C-14 flux gate compass which has a master indicator on the pilot, and a slave indication on the co-pilot side, backed up by a magnetic standby compass.

The single C-14 compass was acceptable for the RLD after the standby compass was made to read accurate enough by reducing heater blower electric interference. For AFCS failures it was proven that an approach to modified Cat I limits (600 m visibility and 200 feet Break Off Altitude (BOA)) without AFCS, could safely be conducted. This modified Cat I limit will probably remain the limit for failure of any or all of the AFCS channels.

For accurate altitude information as required for radar approaches, a single Collins radio altimeter is installed with dual indicators.

The VOR/ILS signal is presented by a Radio Magnetic Indicator on the pilot's side with a slave on the co-pilot's side. Information from the ADF is presented on the course (Sperry/C6F) indicators which have a possibility to switch each needle also to VOR.

When developing instrument approach procedures with the original panel as installed by Sikorsky it was found that in unstabilized flight vertigo could easily occur. This phenomenon, caused by the inherent dynamic instability of the unstabilized helicopter, has mainly been responsible, for the long delay in the development of instrument flying.

Our solution to enable the pilot to cope with an AFCS failure before or during the approach was relatively simple. The instruments were regrouped as shown in Fig. 2 to provide for the possibility of a close scan for different flight conditions. With this panel a safe ILS procedure is possible to the existing limits without AFCS and, en route, the aircraft can safely be flown home on instruments with the pilots flying alternately.

On an ILS approach the pilot scans in one glance attitude, altitude, ILS, and course and uses a constant power setting to follow the ILS glide path. The glide path is followed by small attitude changes.

For ADF approaches basically the same scan is used. Radar approaches require basically only a scan of the upper row of instruments to fly as directed by the captain, who corrects course with the yaw trim of the AFCS.

This "close-scan panel" also deleted the need for a flight director system for the present weather limits, and has been found even to allow approaches below Cat II limits (400 meters visibility and 100 ft decision height). In particular when introducing Doppler Groundspeed and Hover indicators this panel may provide practically all-weather capability. Presently, all ILS approaches under training include complete blind landings.

Communication

The communication system consists of a dual VHF radio as required by law, a single HF system for communication at low altitudes and in areas without VHF coverage such as Flight Information Regions (FIR's), and a VHF/FM radio as required for communication with ships.

Using quite a number of single systems with only partial backup possibilities of a different nature required reliable equipment to prevent diversions or cancellations of

Fig. 2. Close-scan instrument panel.

flights, which would be against the policy of providing a reliable service at all times.

Thus the Instruments and Electronics Department of KLM (IERA) recommended to use KLM or related equipment where possible. The weight and cost penalty involved in this recommendation was largely offset by lower investments for spares and the improvements in reliability, as well as the possibility to exchange and repair this equipment rapidly, using KLM facilities. The RDR-1DM radar for example is basically the same as the RDR-1D used by KLM.

Certification and training of pilots

As to the certification of the pilots, the main problem was that never before in the Netherlands had an instrument or airline transport license for helicopters been issued by the RLD. Certification was accomplished as follows:

1. One of our first pilots was in the possession of a fixed-wing commercial and instrument license, and had obtained considerable instrument and instructors experience on U.S. Army helicopters when employed as a production acceptance pilot by this organization. He received the first Netherlands helicopter airline transport pilot's license and was appointed as an instructor and general advisor as well as an RLD examiner for the instrument training and certification program.

2. The RLD consented to issue a restricted helicopter airline transport pilot license excluding the normal instrument rating on the basis of a commercial helicopter pilot's license and a type rating on the S-61N.

After passing the instrument theory and flight examinations, the complete helicopter airline transport pilot's license was issued.

When the first pilots were under training, the few night flights at that time were carried out by the instructor and a hired Norwegian pilot from Helicopter Services A.s. Norway had issued the first instrument license for helicopters in 1966 and this license was validated by the RLD for the time that our company had a shortage of instrument-rated pilots.

The second pilot received his instrument license June 18, 1968, [illegible]s after commencing operations. This pilot was al[illegible]pointed as an instructor and examiner. These pilots trained all other pilots and are doing this as of today.

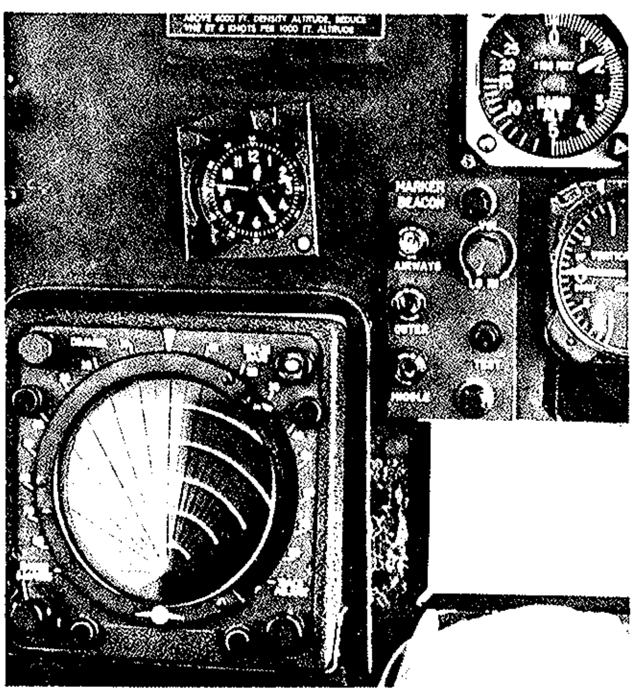


Fig. 3. RDR-1DM radar scope in instrument panel.

In the meantime training programs including instruction handbooks, proficiency and captain decks were produced and, where applicable, certified by the RLD, before the middle of 1968. All pilots are trained from the start to obtain their captaincy within 2 years. They rotate regularly as captain and co-pilot without seniority restrictions.

RLD approval of the directives

To obtain certified take off and approach weather limits for airfields, oil rigs and ships, directives to calculate these limits have to be approved by the RLD. These general directives were developed in close cooperation with the KLM Navigation Department and approved Oct. 7, 1969. Thereafter it was possible to have lower limits certified than the provisional Cat I limits (800 m visibility and 200 feet cloudbase) for ILS approaches and the 800 m visibility and 400 feet cloudbase for ADF approaches to oil rigs allowed in the preliminary period. In a later stage radar approaches to rigs and ships were included.

Certification of weather limits

The certification of the weather limits required calculation of limits for the different airfields in use, as well as for heliports, oil rigs and ships, according to the approved directives, that in a later stage also included radar aporoaches. Procedures were standardized and approved for each approach system and separately flight tested with the RLD for concurrence with the predictions of the concept and the method.

Approaches are presently being carried out at near cruise speeds. This means that an approach can be aborted without a sink rate at any altitude, up to the landing stage. Furthermore, as the helicopter also has the possibility to abort a landing at any point, accepting a small sink rate at lower airspeeds, when full power is available, it is possible to decrease the present weather limits further, by decreasing the airspeed in the approach. Attitude changes according to the attitude indicator readings are tolerable to around 60k IAS, which presently is used after passing the middle marker beacon.

With the introduction of the Doppler hover and groundspeed indicators much lower airspeeds up to an actual hover can be envisaged. The reason for this is that the attitude indicator does not show rotor disc but airframe attitude and thus does not present the true situation. It may even lag out of phase due to the delay of the airframe in following the rotor, which is the case at lower airspeeds in particular. The Doppler groundspeed and hover indicator, however, can present the pilot the true picture of his actual movements in space.

The present weather limits for take-off and approaches, as certified by the RLD, are basically for Schiphol Airport:

Take-off	—visibility—300 meters
	—cloudbase—non required
Approach	—visibility—600 meters
ILS and PAR	—cloudbase—200 ft (BOA)
ILS backbeam	—visibility—800 meters
and PPI	—cloudbase—250 ft (BOA)

Furthermore, approaches may be initiated under a "look see" policy, where a reduced visibility and cloudbase may be accepted of respectively two (200 meters) and

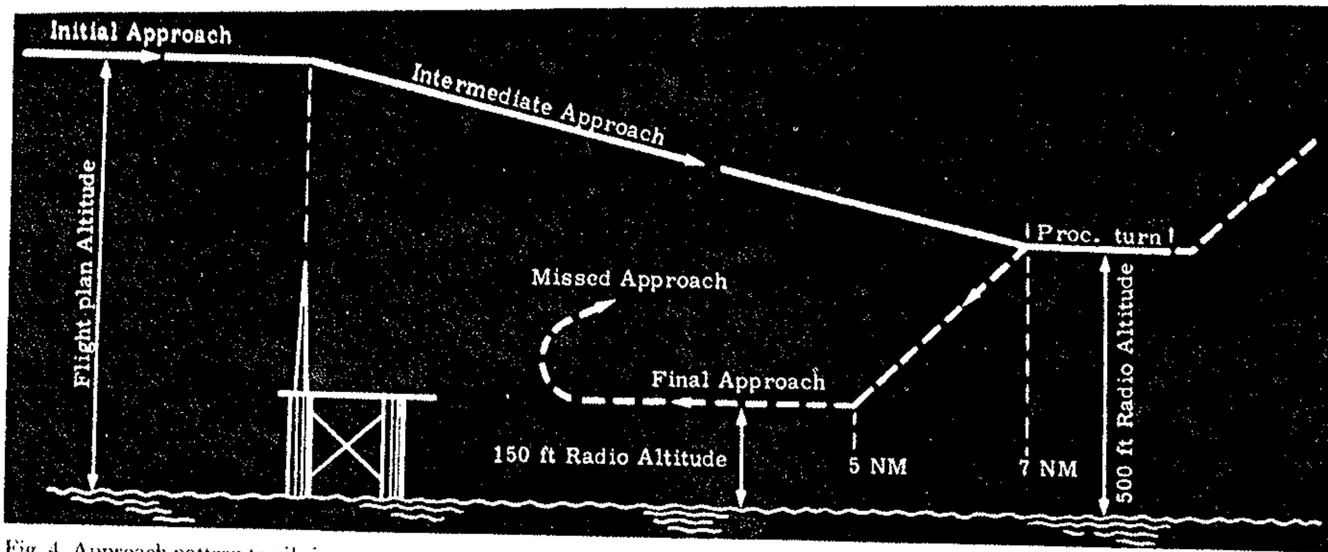


Fig. 4. Approach pattern to oil rig.

one (100 ft) increment allowing e.g. an approach on the ILS or PAR to be initiated when a visibility of 400 meters and a cloudbase of 100 feet are reported by ATC (CAT II conditions).

When RVR (Runway Visual Range) is reported, this always prevails regardless of a reported cloudbase, and an approach must be aborted if visibility is below minimum when arriving at the designated Break Off Altitude.

The weather minima for ADF approaches to oil rigs and ships were defined at 800 meters visibility and 400 ft cloudbase. Because the Decca Mk 1g navigation system and the ADF were found to be unreliable at night and in static, and the ADF limits (particularly with regard to the cloudbase) were insufficient to warrant regularity, the use of radar as an airborne approach aid was developed and certified Oct. 14, 1969 for oil rigs and Aug. 14, 1970 for ships—this last one providing the required regularity in the pilot service. The weather limits for approaches to oil rigs and ships, using the RDR-1DM radar, are presently 800 meters visibility and 150 ft cloudbase. The visibility limit will probably be reduced to 600 meters.

This is, we believe, the first time that an airborne approach system has been certified by a civil aviation authority.

The radar system has furthermore been approved for instrument approaches to heliports and small airports without ATC or approach aids, situated near the coast where this coast is used as a reference for the let-down within defined sectors. The present weather limitations are a cloudbase of 500 ft at a visibility of 1500 meters.

For these heliports and airfields an inexpensive lighting system has also now been developed and certified, in close co-operation with Philips N.V. and the RLD.

IFR flights furthermore, when conducted to and from oil rigs and ships, may be carried out to a minimum altitude of 250 ft en route when the visibility at that altitude is 1500 meters.

The RLD has recently granted a waiver of the alternate airports, for which fuel has to be carried, when filing IFR flight plans at night, if the airport weather reports indicate a visibility of at least 1500 meters lasting for at least 2 hr after the ETA.

The radar system

When starting operations, weather radar was found to be essential to avoid flying into icing conditions. The S-61N is not certified for flights in weather conditions where icing can be expected. This still holds true for all helicopters manufactured in the Western hemisphere.

The Russians are using an electrical blade deicing system with a fair amount of success, and Sikorsky has been trying to certify such a system. But the FAA requirements in the USA are apparently much more severe than in Russia, and based on the icing conditions expected at the low altitude at which the helicopter is expected to fly. Airframe icing is in that case also probably more important than blade icing and comparable with the fixed-wing aircraft. However, icing can mostly be avoided since radar can detect icing conditions in clouds at a sufficient distance to avoid them.

The engines of the S-61 are, of course, equipped with the normal anti-icing devices and an ice-deflector. The blades are coated in the winter with an anti-icing fluid, which prevents ice accretions very successfully. BEAH is presently on the verge of obtaining permission from the ARB to accept light to moderate icing conditions using this system combined with an ice detection system.

The black dots on the sponsons shown in Fig. 1 are used to detect icing and will show icing growth fairly well if not as accurately as the electrical ice detectors used by BEAH.

During the study of available radar equipment, it became clear that radar could be used to detect obstacles in the approach path to oil rigs and ships, thus providing a safe means to descend on instruments to lower altitudes than were possible with ADF and Decca.

The RDR-1DM radar, a basic Bendix RDR-1D modified by Air Equipement in France, provided, next to

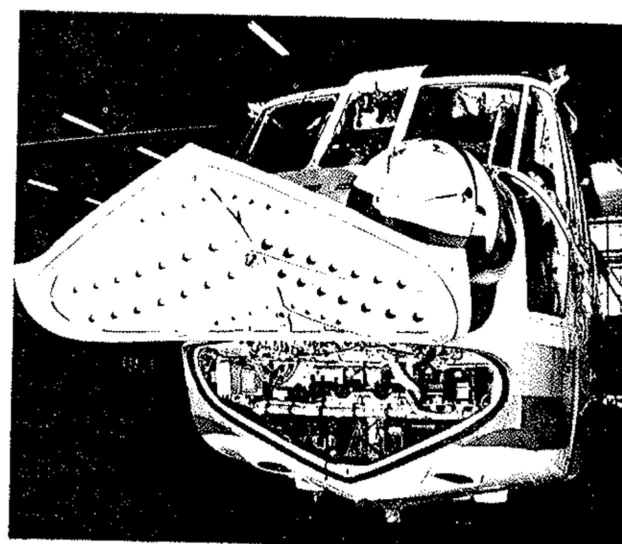


Fig. 5. Electronic equipment bay and radar antenna.

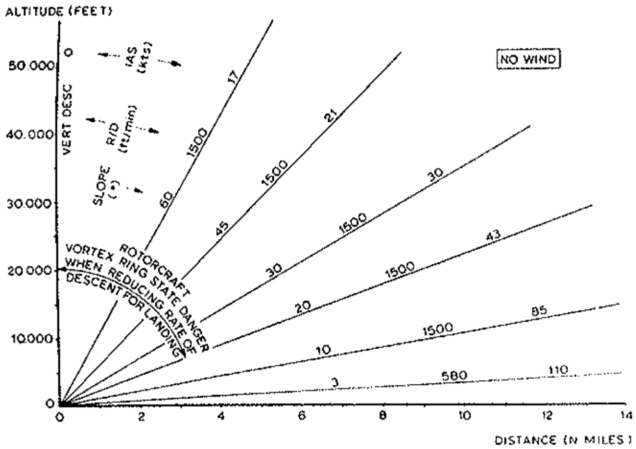


Fig. 6. Airspeed and glideslope angle vs altitude and distance.

weather detection, also the short ranges necessary for approaches. The range settings are 5, 10, 20, 50, and 150 n.mi. The minimal power is 17 KW. The pulserate for long range is 2.5 μsec and for short range 1 μsec.

The radar operates in the X band (3 cm) which combines excellent weather information with sufficient resolution, to clearly pick up oil rigs and ships at sea, without too much clutter because of waves. The resolution is even sufficient to pick up separately the oil rig and its rescue vessel, which is normally closer than 400 meters to the rig. This is clearly visible in Fig. 3. The approach procedure is shown in Fig. 4. The radar installation is shown in Fig. 5.

Thus also with the radar, the concept of combining several possibilities in one system was realized, as the radar can be used for navigation, weather detection and approaches.

Future developments

The RLD has been very responsive to our developments and has always shown a good understanding of our concept. The inspector in charge of helicopter operations should be particularly mentioned for his vision and critical

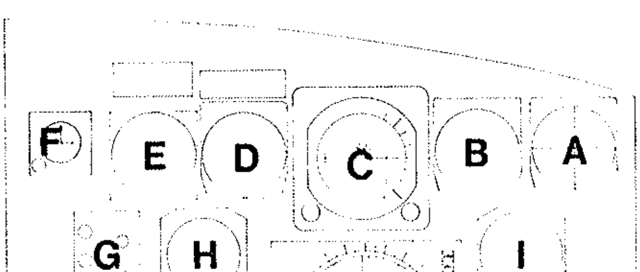


Fig. 7. Possible instrument panel arrangement for future VTOL aircraft. A. Doppler hover indicator. B. Airspeed indicator. C. Artificial horizon with flight director and radio altitude signal. D. Radio altimeter. E. Barometric altimeter. F. Clock. G. Marker beacon. H. Rate-of-climb indicator. I. Engine torque. J. Flight director monitor panel. K. Selector panel automatic approach to hover. L. ADF/VOR/ILS/compass indicator. M. Radar for weather and approach, and master compass indicator. N. Rotor/engine rpm.

thinking in ... ng this, for the RLD, completely new concept a... operational development. This also ensures their future cooperation to certify still lower limits and e.g. Doppler approaches.

Our company has presently defined the criterion for the minimum approach speed at 60k, which is the best climb speed on one engine. With Doppler information this could theoretically become a very low speed, up to the critical decision point altitude for the hover at 50 ft, from which point a single engine climb away is still possible.

In practice however, approach speeds lower than 43k might introduce vortex ringstate conditions and might furthermore be uncomfortable for the passengers. Also the rate of descent should not increase above 1500 ft/min, when using steeper glide paths. In Fig. 6 it is shown that for future vertical take off and landing (VTOL) aircraft the limit for the glidepath slope, without using automatic approach couplers is probably in the region of 20°.

This is more than twice as steep as for short take off and landing (STOL) aircraft (8°) and results in a shorter noise footprint. By increasing the slope of the approach path from 3° to 8° the length of the footprint decreases to 37% of the original figure. Further increase to 20° decreases the footprint length to just over 14% of its original length. It should be borne in mind that for all-weather operations CTOL and STOL aircraft have to be equipped with the same expensive multiplicated automatic approach systems, while VTOL aircraft up to a 20° glide slope can keep the pilot in the control loop. At any time the pilot can take over control under much less critical conditions than faced by a fixed-wing pilot on a 3° approach for CTOL, or 8° approach for STOL aircraft at low altitude. At glide slopes over 20° VTOL aircraft will have to rely also on automatic approach systems. Our feeling is that steeper glide slopes than 20° are not worth the complication and extensive equipment.

In principle the all-weather characteristics of the helicopter, and thus of VTOL aircraft in general, will be defined in the next decade. Some aspects of the superior safety and reliability of VTOL aircraft will be proven by our company as a result of the certification of more sophisticated procedures and lower limits.

Our first aim will be to decrease the present radar approach visibility limit of 800 meters to 600 meters by reducing airspeed in the final approach to 60k instead of the present 70k. When using Doppler information this limit may be lowered further. ILS approaches have already experimentally been carried out at a visibility less than 250 meters and a cloudbase below 100 ft without the use of flight directors. This confirmed the NLR study, which reported a sufficient number of useful approach lights at the measured cockpit slant angles, for different visibility-altitude combinations, allowing visual continuation of the approach.

Probably the visibility limits for ILS and PAR will be certified to 400 meters at a cloudbase or decision height of 150 ft. The next step will be to reduce the cloudbase or BOA to 100 ft. The 2-pilot concept is then a necessity, one pilot going visual at the outer marker and carrying out the landing when he considers that sufficient guidance is available from the approach lights.

The "look see" policy should then allow initiation of an approach at very low limits. With Doppler information available it is expected to satisfy the RLD that an accurate azimuth and glide path can be maintained on the ILS at the lower airspeeds required for this accuracy, without flight directors.

When more experience has been gained this could ultimately lead to a waiver of all limits for certain airfields, which have approach systems certified for Cat II approaches. Flight directors may be useful to reduce the workload and therefore could be added when the cost of these systems, in the case of large VTOL aircraft, is a less dominant factor.

Concluding remarks

In our type of unscheduled operations it is not feasible to proceed to limits lower than Cat II. From what we already have obtained using a basically Cat I panel, we can be quite certain that future large VTOL aircraft will be truly safe, all-weather aircraft, and at the same time considerably decrease noise pollution in the built-up areas around VTOLports and particularly airports.

With the advance in radar approach systems, already in military use or development as airborne fire control systems, it may be possible to use cheap VTOLports in adverse weather conditions without ground aids.

VTOL aircraft, as we have proven in our IFR operations from Schiphol, rarely have to cope with delays due to traffic and runway congestion. Furthermore helicopters can accept any ILS approach up to 90° out of the prevailing wind. They do not have to cope with drift in the landing, as they can land from the hover in any wind direction.

The delays due to weather, in seconds per flight hour as recorded at Schiphol Airport were: 1969, 77; 1970, 71; 1971, 58.

The number of cancellations due to weather, mainly icing, as recorded per 1000 flights averaged in 1969 - nil; 1970, 14; 1971, 11.

Of course, these figures are debatable for scheduled services with VTOL aircraft, but it should also be borne in mind that this result was obtained with the minimum of equipment. Thus the same or better results may be expected for the large VTOL aircraft of the future, equipped as envisaged in Fig. 7. Preventing delays will then mainly be an area navigation problem and this is already being studied by several airlines in the U.S. for the Northeast Corridor, as well as by other companies in Europe. It will be certain, however, when economic VTOL aircraft become available, and this is envisaged by the manufacturers between 1975 and 1980, that these aircraft with their inherent all-weather capability can provide a service as reliable and safe as present ground transportation. They thus can become a definite competitor of fixed-wing aircraft on medium haul operations, in particular when VTOL ports can be more conveniently situated, because of relatively low cost, than present airfields.

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