CIVIL AVIATION AUTHORITY

CAA PAPER 95011

A FEASIBILITY STUDY INTO THE PROVISION OF AN OMNI-DIRECTIONAL VISUAL GLIDESLOPE INDICATOR FOR HELICOPTER OFF-SHORE APPROACHES

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A FEASIBILITY STUDY INTO THE PROVISION OF AN OMNI-DIRECTIONAL VISUAL GLIDESLOPE INDICATOR FOR HELICOPTER OFF-SHORE APPROACHES

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Foreword

The research reported in this paper was commissioned and funded by the Safety Regulation Group of the UK Civil Aviation Authority in response to Recommendation 4.4 in AAIB Aircraft Accident Report 5/88, Report on the incident to Sikorsky S-76A helicopter G-BHYB near Fulmar A Oil Platform in the North Sea on 09 December 1987.

The CAA concurs with the conclusions of this report. At the time of publication, the Authority is planning a proof of concept trial for Differential GPS-based approaches to off-shore platforms. It is considered that this instrument-based system has the potential to provide accurate and reliable 3-D guidance throughout the entire approach, regardless of the approach direction and the lighting environment. It is anticipated that visual aids will still be required to assist the final stages of approach and the landing, however, and a series of off-shore trials of improved helideck lighting schemes is planned for winter 1995/96. These trials are to include an evaluation of the use of the higher output intensity Helicopter Approach Path Indicator (HAPI) within the 210 degree obstacle-free sector.

Saftety Regulation Group

22 August 1995

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1 INTRODUCTION

In 1988, following an incident in the North Sea when an S-76 helicopter momentarily impacted the sea surface following the temporary incapacitation of the aircraft captain, the AAIB concluded that the first officer may have detected the excessive rate of descent earlier if a visual glideslope indicator had been available. The AAIB recommended that the CAA and the operating companies should review the production and provision of a visual approach aid for use on platforms and rig helidecks (Reference 1). In their conclusions the AAIB commented that "the provision of a visual flight path guidance system would have made the occurrence of the incident less likely, by providing a standardised approach". Since the publication of Reference 1 the CAA has actively pursued the course of action recommended in Reference 1 with the operating companies, a lighting manufacturer and the Defence Research Agency (DRA). This paper presents the results of this research and development work.

2 OPERATIONAL REQUIREMENTS

The International Civil Aviation Organisation in Reference 2 recommends that a visual glideslope indicator should be provided when:

- obstacle clearance, noise abatement or traffic control procedures require a particular slope to be flown
- the environment of the heliport provides few visual surface cues and
- the characteristics of the helicopter require a stabilised approach.

In Reference 2 a specification for the beam spread and intensity of a single light source aid to meet these operational requirements is published. The signal format and isocandela diagram are shown in Figures 1 and 2. These specifications were developed by the ICAO Visual Aids Panel and published in 1990. They were largely based on the results of flight trials conducted in the UK and France, but the specification has been endorsed by all ICAO member states. The ICAO specifications assume that the final approach will be flown on a standardised approach heading relative to the final approach and take-off area (FATO) or touchdown and lift-off area (TLOF) or helideck. It is also assumed that the aid should be seen by day at a range of 800 m when the visibility is 600 m; this requirement results in an intensity of 9000 cd being specified.

Off-shore approach operations in the North Sea are normally conducted into wind; as a result the approach direction to any platform is not fixed. In attempting to meet the AAIB recommendation, the difference in approach direction coverage between the ICAO standards and recommendations and the operational procedures in the off-shore industry presented significant problems to the lighting designers.

3 DESIGN CRITERIA

When developing a lighting aid for approach and landing the designer needs to know the beam characteristics of the light. The principle parameters are:

- beam dimensions
- light intensity
- signal coding, including colours.

The beam dimensions and light intensity requirements are defined in the isocandela diagram specified for the aid. The ICAO specification is shown in Figure 2. This requirement is based on the need for the aid to be seen by day and by night in visibilities as low as 600 m. Flight tests conducted by the DRA showed that the specified beam spread could provide the precise glideslope guidance required while having sufficient azimuth beam coverage to cope with approach track variations caused by cross-winds (Reference 3).

The signal coding and sector sizes chosen, demonstrably met the need for unambiguous colour recognition and a guidance signal that was easy to use while assisting the achievement of a stable approach path.

In the development of the lighting aid which is the subject of this paper, the designers tried to reconcile the requirements of the ICAO specification with the special needs of off-shore operations as currently conducted in the UK sector of the North Sea. In particular, this resulted in design criteria that retained the signal format characteristics of ICAO while providing guidance for all approach directions. It should be noted that this project started before ICAO published the specification now to be found in Reference 2. Hence, during the early trials, the signal colours were red and white, while the final colour combination chosen was red and green in conformity with the ICAO recommendations.

4 DESIGN ISSUES

The ability of a lighting designer to meet an operational requirement is influenced by several factors including:

- the total electrical power and therefore light flux available
- the size of the light source
- the beam dimensions
- the signal colours.

The total power available is significant since this determines the total light flux available to the designer. Different types of lamp have different light production efficiencies. For example, a tungsten filament lamp may typically produce 20 lumens/watt, whereas a discharge lamp may produce 80–100 lumens/watt.

While discharge sources offer higher efficiencies, they have significant disadvantages in that they require the provision of control gear which can be costly and bulky, and their brilliancy is not easily varied to cope with changes in lighting conditions. Furthermore, the light source dimensions of this type of lamp can make it more difficult for the designer to achieve the beam dimensions specified. A near point source, as typified by a tungsten halogen lamp, eases the problems associated with controlling the beam shape by the use of lenses or reflectors.

Large beam spreads require higher lumen outputs when compared with narrow beam spreads. For illustrative purposes it can be noted that the ICAO beam spread (30 degrees) is only approximately 8% of the omni-directional beam spread implied by the operational requirements envisaged for off-shore use described in Section 2 above. To a first approximation this means that, for a given light source, the light intensity of an omni-directional aid can only be 8% of that on an aid meeting the ICAO specification (e.g. 720 cd compared with 9000 cd). Alternatively, the total amount of light flux available to the designer must be increased by a ratio similar to that shown above (12:1). It can be noted that the ICAO specification can be met by the use of 2 x 200 W tungsten-halogen lamps. A 12-fold increase in light flux would probably require a 5 kW lamp. Such a source is not a practical proposition due to size, cost and heat dissipation considerations.

5 ENGINEERING SOLUTIONS

Prior to the incident to the S-76 reported in Reference 1, development of a visual glideslope indicator for off-shore use had been initiated by a consortia of UK companies; Total Oil Marine, British International Helicopters and Leech (Rochester) who had recognised the need for glideslope guidance at off-shore facilities.

In discussions within the consortia it was agreed that Leech would design and build a light unit based on the ICAO requirements, but projecting omni-directional signals at a light output sufficient to support the final stages of the approach.

The cardinal points of the specification were:

- all signals to be omni-directional
- signal colour and format to be in accordance with ICAO recommendations
- signal range to be not less than 800 m
- the size of the unit to be compatible with off-shore specifications.

The design proposed by Leech is fully described in Reference 4. A unit is shown in Figure 3.

The equipment housing contained the following basic components:

- a mounting plate
- 8 optical systems consisting of lenses, filter glasses, adjustable mirror and light source
- 4 masks
- a motor drive unit.

Figures 4 and 5 show internal views of the unit. The layout of the major components can be clearly seen. The unit was named 'Omni-Directional Approach Path Indicator' (ODAPI).

6 INITIAL DEVELOPMENT TESTING

6.1 In January 1988 the first evaluation flights using the prototype ODAPI were conducted at Beccles Heliport. During this trial the functionality of the aid was checked by the developers.

6.2 In March 1988 the ODAPI was temporarily installed off-shore on MCP01. The aid was positioned at the origin of the 210 degree obstacle free sector. Light output was limited to correspond to the 210 sector by the application of suitable blanking to the unit.

The on-slope signal provided by the aid was a 45 min arc sector of white light. The slightly low sector was a 42 min arc red signal. The complete signal format is shown in Figure 6. The aid was set up to provide a 5 degree glideslope.

Six approaches were flown to the aid, with 3 of them being at night. Throughout the test the visibility was reported as good, with light winds. At night it was noted that there was no natural horizon visible and that the general area was dark, there being no other platforms in the immediate vicinity.

The AS332L used for the test was flown by a BIH pilot and a CAA test pilot. The results and conclusions of this initial trial were summarised by the CAA pilot in his post-flight report as follows:

(a) The aid was useful in providing final approach guidance to an off-shore platform although it could be improved in several significant ways.

(b) There was a false flashing signal between the Steady White and Red sectors which must be eliminated.

(c) The frequency of rotation should be modified to prevent flickering of the 'steady' signals seen during the flight.

(d) An increase in light intensity would improve both acquisition and guidance, particularly in conditions of poor visibility. This may have the disadvantage that the intensity would be too high for close in operations, but this would be less of a problem in a bright off-shore lighting environment with the aid remotely positioned from the helideck.

(e) There was perceived to be a potential problem in that the correct angle of approach indication provided by the aid was a Steady White, which is a commonly occurring light on off-shore platforms. It was concluded that consideration should be given to changing the white colour, or providing a suitable device to aid identification (e.g. a suitable strobe).

(f) Significant efforts should be made to optimise the off-shore lighting environment to improve the value gained from visual approach aids.

(g) The aid could be better positioned to give a more appropriate final approach path.

(h) Guidance should be available over the full 360 degree capability of the aid, except perhaps in special circumstances.

(i) Although the aid showed considerable promise in an off-shore environment, it was recommended that further trials be carried out in view of the results and conclusions contained in this report.

6.3 Following the initial CAA trial the ODAPI was sent to DRA Bedford for a more detailed evaluation through flight and ground tests.

The ground testing of the aid consisted of an inspection of the signal sectors:

- to establish their angular size
- to identify any spurious signals.

A measurement of the visual range of the aid was also carried out.

The results of these ground tests on 2 March 1988 were as follows:

(a) Angular size

Sector	*ODAPI*	*Draft ICAO Specification*
White (on slope)	45 mins	45 mins
Red (slightly low)	40 mins	15 mins

(b) No spurious signals were observed. The transition from one sector to the adjacent sector was unambiguous, provided that a repetition rate of at least 2·7 Hz (160 rpm) was used. At lower speeds the signal in the steady sector appeared to scintillate.

(c) The visual range of a usable signal in overcast day conditions was approximately 800 m. The threshold-of-detection range was 1200 m. On the basis of these observations, the effective intensity of the unit was assessed as being of the order of 1000 cd. The ICAO specification, however, requires an intensity nearly 10 times this value.

It should be noted that the accuracy of this intensity assessment, which relies on the estimation of relevant parameters such as background luminance and eye illuminance threshold for detection, is such that the actual intensity value may have been as little as 25% of the estimated value.

A brief flight evaluation of the aid was conducted at Bedford on 30 March 1988 by the CAA using a Dauphin helicopter. The ODAPI was set up to define a $7\frac{1}{2}$ degree glideslope. Each approach was recorded by an accurate DRA tracking system. Copies of the glideslope traces obtained are given in Figure 7.

6.3.1 On the basis of the trials at Bedford, the following points were made to the CAA:

(a) The aid deviated from the ICAO specification in size of the 'slightly low' sector, in intensity and in beam coverage (omni-directional).

(b) The aid gave usable guidance and could provide safe glideslope information.

(c) The aid could be used for an approach from any direction.

(d) The aid only had an intensity sufficient for guidance during the deceleration phase of the approach.

(e) In a visually cluttered environment, such as an off-shore rig, an aid having this low intensity may be difficult to locate, particularly if the pilot is in the glideslope (white) sector. A change of signal colour from white to green would be advantageous to prevent mis-identification.

(f) While the signal was usable, the steady sectors exhibited a flicker characteristic that had the potential for mis-identification. It was strongly preferred that the signal should appear to be of constant intensity in the appropriate sectors. However, this characteristic should not be achieved by increasing the rotation rate, since this would increase the repetition rate of the flashing sectors significantly beyond the 2 Hz value determined by ICAO trials.

6.3.2 The DRA recommended to the CAA and the manufacturer that:

(a) Further evaluations be conducted at an oil rig.

(b) The manufacturer be asked to remove the flicker element from the steady sectors.

(c) That a change of colour from white to green be considered and the slightly low sector be reduced to 15 mins.

(d) That the siting criteria for the aid be carefully reviewed, bearing in mind the need for the aid to be located in a locally dark area. (This could be achieved by shielding of adjacent light sources.)

6.4 Overall the aid showed considerable promise as a short range, deceleration-phase aid but further development was desirable before it was cleared for general use.

Following the trials described above the manufacturer initiated optical development work to overcome the scintillation problems in the steady light sectors. A flight test in September 1988, flown by a CAA pilot at Beccles produced data that showed that the scintillation had been removed from the steady signals. At night, with a reported visibility of 15 km under a cloud base at 1000 ft the ODAPI was sighted at a range of 8·5 km and gave unambiguous guidance at ranges out to 3·7 km. The signal colours were red and white.

The range data obtained in this trial indicated that the ODAPI, as tested, had an intensity of approximately 500 cd in the red sector. If this data was taken to be representative of the performance of production units, then the maximum acquisition range of the aid in low visibility conditions (800 m reported visibility) would be:

day	–	620 m
night	–	1400 m (dark background environment)

Following this and other brief trials, the manufacturer agreed that the signal colour should be changed by replacing the white sectors with green.

7 PRELIMINARY TRIALS OF THE FULLY DEVELOPED ODAPI

7.1 In November 1991, a fully developed ODAPI unit incorporating all the improvements identified in the earlier phases of the project was offered to the CAA for testing. Following industry shake-down flying at Beccles, the aid was set for a glideslope angle of 5 degrees and temporarily installed on the Leman A platform. It was located at deck level and at the origin of the 210 degree arc. A night evaluation took place on 10 December 1991. The evaluation was flown in a BIH S61N and was observed by a number of industry personnel from the P3 seat position, and by a CAA flight operations inspector in the left hand seat. The weather conditions reported were:

- wind direction and speed - 180/25 – 30 kt
- visibility - >20 km
- little ambient illumination.

The Leman A was an extended structure with the helideck at the western end. The deck was linked to the gas process facility by a long, well lit pipeway and walkway. The whole structure was floodlit and provided many visual cues but, because of the surrounding lighting, gave a testing environment for the ODAPI in respect of initial acquisition and interpretation of its signals.

7.1.1 A total of three approaches were flown:

(a) The first approach commenced from below the glidepath at 7 km, flying through the entire signal format and then settling in the steady green sector from 1·8 km. A positively identified and usable signal was available from 7 km to touchdown.

(b) The second approach commenced at 5·5 km in the flashing red sector. The helicopter was then flown into the steady green sector before descending to the red cut off (at 300 ft Rad Alt). Flashing green was then acquired and retained for the remainder of the approach.

(c) The third approach commenced at 4 km in the flashing red sector. Steady green was acquired and followed to landing. This approach was flown at normal speed and using normal techniques the first and second approaches were flown at 2060 kt ground speed to increase the time available for examination of the signal.

The acquisition range of the ODAPI was reported as approximately 8 km. Based on this observation the intensity was assessed as being approximately 400 cd.

7.1.2 The post-flight report by the CAA concluded that:

(a) All signals radiated were unambiguous and could be interpreted and flown at night by pilots using normal skills.

(b) Although the test approaches were only flown at night in good visibility, the ODAPI may also be suitable for daytime use and in conditions of reduced visibility.

(c) The effects of precipitation had not been assessed.

(d) The unit was suitable for final approach guidance but cannot be used for rig identification.

(e) The optical properties of the device should be further assessed by DRA.

(f) Those sectors of the signal which can radiate onto adjacent installation structure should be blanked off.

(g) Pilots should be made aware of the position of the ODAPI relative to deck level because of the implication this had on wheel clearance when crossing the deck edge.

(h) The device was suitable for installation for an extended user trial and post flight report evaluation.

(i) The device had the potential to fulfil a long recognised need for visual approach path guidance at off-shore installations.

7.2 During 1992 the CAA tasked the DRA with conducting a further evaluation to make an independent assessment of some of the features reported during the Leman A trial.

Consequently a night sortie using an S61 helicopter was carried out at Bedford airfield. The airfield test site provided an environment where there was little ambient light. The reported visibility below cloud was greater than 10 km.

The ODAPI set at 5 degrees was sighted from below the glideslope at ranges in excess of 5 km, which would suggest a light output of approximately 300 cd for the below-slope signal.

The approaches were recorded and the results are shown in Figure 8. Once acquired the ODAPI aided stable approaches. Deviations from the glideslope were readily identified and corrected.

The pilots rated the workload whilst using the aid as being low enough to provide enough spare capacity for all normal additional tasks.

At ranges of 5 km the signal colours were not always easy to recognise, but at a range of 3 km the signal colours were always correctly identified even though the pilots commented that they appeared at times to be desaturated colours.

No false signals, such as can result from gaps between filters or from secondary sources caused by reflection or refraction, were observed. It was noted that, at short ranges, the flashing red signal could be seen illuminating the ground around the ODAPI.

On completion of this trial the DRA reported that:

(a) The ODAPI provided a signal format that conformed to the ICAO specifications.

(b) The omni-directional beam projected no false signals.

(c) Colour recognition was unambiguous in operational ranges out to 3 km, even though the colours are not saturated colours.

(d) The ODAPI was easy to use. It produced a low pilot workload.

(e) It was recommended that consideration should be given to restricting the flashing red sector to an angle just below the horizontal, such that the beam does not impinge on the landing deck.

(f) The estimated intensity of the aid was such that the signal will be visible, and usable, from a range of at least 800 m in a visibility as low as 800 m provided that the background luminance is <1000 cd/m² (i.e. overcast day). The aid can support the deceleration phase of approaches in all but the brightest of fog conditions. To meet the requirements of a bright day fog a HAPI, as specified by ICAO, would be required.

(g) In dark environments a brilliancy control that would allow an intensity reduction of at least one order should be provided. This requirement would not apply, at least to the same extent, on well lit decks.

8 IN SERVICE EVALUATION OF THE FULLY DEVELOPED ODAPI

The final phase of trials was conducted during February and March 1993 by industry personnel at the Kittiwake platform. The trial was funded by the CAA, who awarded a contract to co-ordinate the trial to British International Helicopters (BIH). The platform helideck for the trial was provided by Shell who also undertook the off-shore installation work. Both BIH and Bristow pilots took part in the evaluation. The trial data was analysed by the DRA.

The trial addressed 2 aspects; the operational usefulness of the aid and the maintainability of the aid in the hostile environment of an off-shore platform where contamination may be significant.

8.1 Pilot evaluation

By using written questionnaires the following data was collected:

8.1.1 *Operational Data*

The trial period extended from 25 February – 31 March 1993.

22 pilots responded to the questionnaire.

Rain was present on two occasions. No other precipitation was recorded.

The minimum meteorological visibility during the trials was 5 km and the maximum was 30 km. The average visibility was 11 km.

Mist was reported on 5% of occasions and haze on 35%. No fog was encountered. The wind direction centred around three cases – 040–090, 200–260, 320–260 degrees.

Wind speeds were in the range 10–50 kts with an average of 24 kts.

The approach direction was into the prevailing wind on over 90% of approaches, the remainder were made with a crosswind.

77% of approaches were carried out in daylight, 10% were carried out at twilight, 13% were carried out at night.

Of the daylight approaches, 12% were conducted in heavy overcast, 60% in overcast and 28% in clear conditions.

The twilight approaches were equally divided between overcast and clear conditions.

At night, 66% of the approaches were in overcast conditions and the remainder were in clear, no moon conditions.

Overall the test conditions provided good meteorological visibility, without precipitation, in moderate winds. Most of the approaches took place into-wind during the daytime.

8.1.2 *Initial Visual Contact Data*

The average initial contact range of the ODAPI was 2 km. The maximum range achieved was 5·5 km at night and in twilight. On one occasion by day the ODAPI was not sighted at all. In addition, on 15% of occasions the ODAPI could not be seen on the approach because it was obscured by the rig superstructure. Daytime ranges were generally below 800 m.

When visual contact was made with the ODAPI the first sector to be sighted was the flashing green on 67% of occasions and the flashing red signal was seen on the other 33%.

Three quarters of observations rated the ODAPI as 'not easy to find', the remainder rating it easy.

The most frequently applied rating for colour recognition was adequate (53%). It was rated as poor on 30% of occasions, ambiguous on 11% of occasions (daytime), with 6% reporting good colour recognition at initial contact.

8.1.3 *Approach Data*

The range at which pilots were confident to use ODAPI guidance varied from 0·2 km – 5·5 km (average 2 km).

Pilots reported that the minimum range to which the aid could be used varied from 0·2 – 0·7 km.

Colour recognition during the approach was rated as good by 11%, adequate by 53%, poor by 25% and ambiguous by 11% of the pilots.

Recognition of the sectors was rated as good by 11%, adequate by 78% and poor by 11%.

There was total agreement (100%) that no ambiguous signals were seen during the approaches.

Overall, the results show that the aid as tested has no dangerous characteristics, such as false signals.

The fact that colour recognition was generally adequate can also be noted.

Operationally most of the reported shortcomings were related to the conspicuity of the aid and the range of initial contact. A review of the data shows that most of the approaches were made in daytime conditions where the intensity of the ODAPI would tend to cause such observations to be made.

Sighting problems, resulting in the aid not being visible for a significant proportion of approach directions, are also clearly highlighted by the data.

8.2 **Contamination Trials**

The issues to be addressed by the trial were:

(a) The nature and rate of build up of contamination on an ODAPI sited on an off-shore facility.

(b) The effect of contamination on the ODAPI signal with particular reference to the intensity, sharpness of transition between signal sectors and the signal colours.

8.2.1 The contamination trial was conducted as follows:

(a) Samples of ODAPI glass windows were exposed in a frame in the same location on Kittiwake as ODAPI for periods of 0·5, 1, 2 and 4 months.

(b) Using a set of ODAPI optics supplied by the manufacturer these glasses were tested for attenuation and inspected in the laboratory at DRA(B) for any degradation of the signal format.

(c) Other glass samples were deliberately contaminated in the laboratory, and tested as in (b) above to determine the levels of contamination that caused operationally significant deterioration of performance.

8.2.2 The results of these measurement trials were as shown in the Tables 1 and 2.

Table 1 Transmission losses through the ODAPI front glass

Glass	*Total Transmission Loss %*	*Contamination %*
clean	12	0
1 week	17	5
2 weeks	20	8
3 weeks	12·5	0·5
4 weeks	21·0	9
5 weeks	23·0	11
6 weeks	25·0	13

The data showed that:

(a) There was a 12% loss of light resulting from the use of a glass front window.

(b) It was not possible to ascertain the cause of the anomalous reading in 3 weeks. It may have been caused by inadvertent wiping of the glass.

(c) Overall the trend was for contamination to increase steadily with time, after an initial significant increment.

Table 2 Effects of contamination on the signal format

Glass	*Width of colour transition*
clean	2·0 mins
1 week	2·5 mins
2 weeks	2·5 mins
3 weeks	2·0 mins
4 weeks	3·0 mins
5 weeks	4·0 mins
6 weeks	4·5 mins
clean, cold, condensation	2·0 deg

In this second test, it was shown that after 3–4 weeks the glass contamination begins to significantly effect the colour transition, and that water condensation will prevent the aid being used.

As a result of these tests, it was concluded that ODAPI would require regular maintenance in the off-shore environment to ensure that contamination does not degrade both the signal format and the light output. On the basis of these tests, a 2 week cleaning cycle would be required to ensure performance and safety levels were maintained. The data from the condensation trial, shown in Table 2, would indicate that before acceptance into service ODAPI would need to be subjected to tests to investigate means of ensuring that the aid was not used with condensation or ice present on the front glasses.

9 DISCUSSION

9.1 This paper reviews a programme of development and testing whose object was to investigate the feasibility and, if possible, to produce a practical and operationally effective visual glideslope indicator to support helicopter approaches to off-shore facilities.

The need for some form of glideslope information for the final approach to off-shore facilities is now widely agreed within the industry. The requirement had been identified prior to the S-76 incident and action was being taken by the oil industry, a helicopter operator and a manufacturer. At the same time the CAA was strongly supporting the development of a visual aid within the work programme of the ICAO Visual Aids Panel prior to the S-76 incident.

The usefulness of visual glideslope indicators has been well established over many years. Appropriately designed and sited they provide pilots with guidance that ensures safe and repeatable glidepaths are flown.

During the development of the ODAPI unit most of the design problems that were encountered were satisfactorily resolved. The final design emitted a signal format that complied with the ICAO requirements for colours, sector sizes and occulting. However, it was not possible to provide a practical design that emitted the signal omni-directional at an intensity sufficient for all the specified operational activities.

9.2 The unit developed by the manufacturer produced an intensity of approximately 500–1000 cd in the peak of the beam. The intensity was less than half this value in the occulting red sector. Since on many occasions in service the ODAPI guidance would be joined from below the glideslope it is this lower value which in operations would define the contact range.

The range of a light source that appears to be effectively a point of light to the observer can be estimated by the use of Allard Law i.e.

$$E\tau = \frac{I}{R} e^{-\sigma R}$$

where $E\tau$ = eye illumination threshold (a level below which the light will not be seen). This threshold is related to the general luminance of the scene in the direction of view. For a night adapted eye in a dark environment E is typically 10^{-6} lux. On a very dull day E is typically $10^{-4.5}$ lux and on a very bright day E is typically $10^{-3.5}$ lux.

I = the intensity of the light (cd).

R = acquisition range of the light.

σ = extinction coefficient (a measure of atmospheric attenuation). For practical purposes the value of σ can be computed from the relationship $\sigma = 3$ / meteorological visibility.

Inspection of this equation indicates for a given visibility a direct relationship between the eye illumination threshold and the intensity required for a light to be seen at range R. If $E\tau$ is increased from 10^{-6} to 10^{-4} lux then the intensity of the light must also be increased by a factor of 100.

Considering an intensity of 500 cd as a representative intensity for the ODAPI then the following performance can be estimated when the meteorological visibility is 800 m.

$E\tau$ (lux)	Range (m)
Bright day $10^{-3.5}$	500
Dull day 10^{-4}	640
Bright night 10^{-5}	1000
Dark night 10^{-6}	1400

During the various field and flight trials reported in this paper the eye illumination was estimated to be within the range $10^{-3.5} - 10^{-6}$ lux. In particular, based on the reported visibilities, cloud cover, approach directions and times of day the eye illumination thresholds were approximately

10^{-4} lux for the day field trials
$10^{-3.5} - 10^{-4}$ lux for the day off-shore trials
10^{-5} lux for night off-shore trials
10^{-6} lux for the night on-shore trials.

During the early flight trials, one of the reported concerns was that the intensity of the light might be insufficient for it to be readily seen when surrounded by many other lights – a situation typical of many off-shore helideck environments. A similar comment was made by the DRA. Following their final on-shore evaluation the DRA suggested that the aid would only have sufficient daytime range performance on dull, overcast days. The results obtained by the in-service trial at the Kittiwake platform confirmed these reservations. In advantageous circumstances the ODAPI was acquired and used from ranges that were operationally fully satisfactory. On some day flights the range of ODAPI was well below the required value, probably in bright conditions. Overall, the average daytime range was just sufficient to support operations – but this meant that for many approaches the ODAPI did not give the required service. At night ranges were generally greater than by day, but the aid was not always easy to locate positively amongst the other lights on the platform.

As has been discussed above, the influence of the many other lights surrounding the ODAPI site at night would have adversely affected the range predicted from Allards Law. This is partly due to the higher eye illumination threshold that they will induce, and partly due to the increased search task imposed by the ODAPI being surrounded by many other light sources.

The ODAPI, in the final version, produced a light output just sufficient to support the specified operations on dull, overcast days and more than sufficient to support operations at night in a dark environment, such as was encountered in some of the on-shore trials. However, the ODAPI did not provide assured guidance in bright day conditions (when it may not be an important aid) or in the visually cluttered environment off-shore at night.

9.3 Apart from the intensity characteristic of the ODAPI the aid fully conformed to the stated signal requirements. No ambiguous or false signals were transmitted. Signal colours were adequately recognised.

9.4 The contamination data collected during the off-shore trial illustrated the need for a frequent inspection and maintenance programme to be applied if ODAPI, or any other projector-type aid were to be deployed off-shore at oil or gas production facilities. The combination of industrial pollutants and salt present at such locations will impose a significant and important maintenance requirement if safety and efficiency levels are to be maintained.

9.5 Apart from the main light performance issues discussed above, 3 siting considerations were identified:

(a) The first related to the position in space of the indicated glideslope. With the aid placed on or near the helideck the on-slope signal if flown to touchdown does not provide wheel clearance at the deck edge. Pilots would need to be trained to accept that ODAPI is an approach aid, not a touchdown aid. Minimum useable range would probably be not less than 150 – 200 m from the helideck edge.

(b) The second issue concerns the projection of light on to deck and super-structure areas close to the aid. Generally this effect will be no more than a slight annoyance to rig staff and pilots. However, in wet weather conditions, light falling on the deck may be reflected towards the pilot.

(c) The third issue arises from the observation that with the ODAPI sited at the apex of the 150/210 degree sector there are approach directions from which the aid cannot be seen due to interference from rig structures. True omni-direction coverage from any visual aid is similarly subject to physical restriction, particularly if sited on or near the helideck. It should be noted that rigs are normally oriented so that the helideck is upwind of the superstructure for the prevailing wind direction, which means that the majority of approaches will be from behind the obstacle free sector where ODAPI cannot reliably be used.

9.6 In summary, the ODAPI as tested produces the specified signal format as regards to colour, coding and sector sizes. The achievable light intensity is sufficient to support the deceleration phase in visibilities down to approximately 800 m by day, provided the background luminance is <1000 cd/m^2, and similarly by night in environments when other lighting is limited in extent and intensity.

ODAPI does not reliably provide the required guidance in the circumstances discussed above (bright day or visually cluttered night light environment). Furthermore omni-directional coverage will be prevented on some installations due to the relative locations of the aid and adjacent structures.

10 CONCLUSIONS

The development and trials work reported in this paper represents an extended programme of work aimed at investigating the feasibility and if possible demonstrating the viability of a visual glideslope indicator that can properly support helicopter deceleration manoeuvres to off-shore helidecks from all directions.

For the reasons reported and discussed above the objectives cannot be fully accomplished using a visual aid but, in some circumstances, ODAPI could be effective. The glideslope indicator developed by ICAO (Helicopter Approach Path Indicator) is designed to have sufficient intensity, but it only provides guidance over a relatively narrow sector of approach azimuth angles. If restrictions on the final approach track can be accepted then HAPI offers a suitable capability. On the other hand, if wide angle coverage is essential, then some form of non-visual guidance will provide the most likely means of meeting the requirements.

11 RECOMMENDATIONS

11.1 The deployment of ODAPI should be subject to an aeronautical study in each case. Use should be restricted to those operations where a service is not required in bright day conditions. The aid should also not be used in the presence of significant arrays of other lights.

11.2 The development of equipment and procedures to allow approaches using non-visual glideslope guidance up to the final stages of the approach should be investigated.

11.3 To ensure that lighting and marking, other than glideslope information can be seen during the latter stages of the approach it is recommended that approach tracks should be constrained to be within the 210 degree obstacle-free sector.

12 REFERENCES

1 Report on an incident to Sikorsky S-76 helicopter G-BHYB near Fulmar A Oil Platform in the North Sea on 9 December 1987.
– Aircraft Accident Report 5/88 HMSO

2 International Stewards and Recommended Practices Annex 14, Aerodromes, Volume 2, Heliports.
– ICAO 1990

3 The Development of a Helicopter Glideslope Indicator Specification.
– Unpublished paper ICAO/VAP/WG

4 Path Guidance Indicator Apparatus for Vehicles or Craft.
– UK Patent Application No 8800759 – January 1988

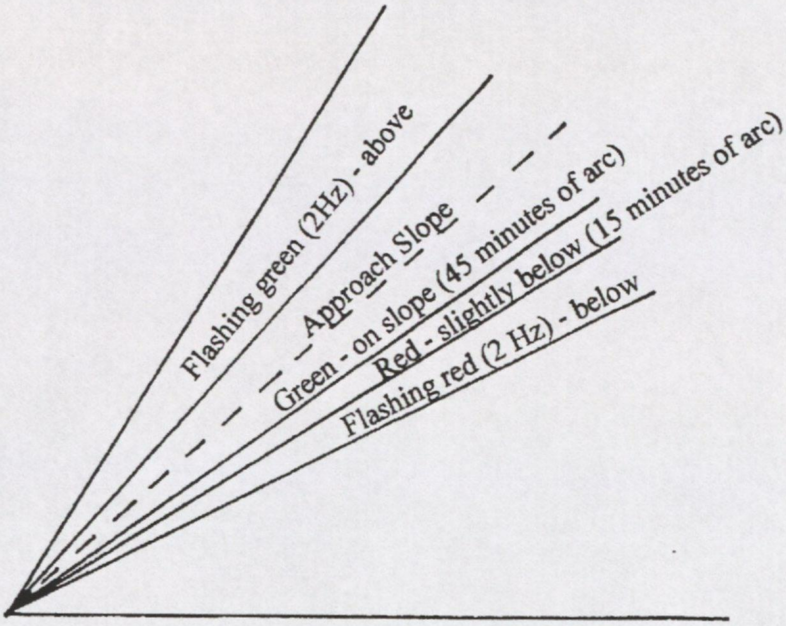

Figure 1 Signal Format (ICAO)

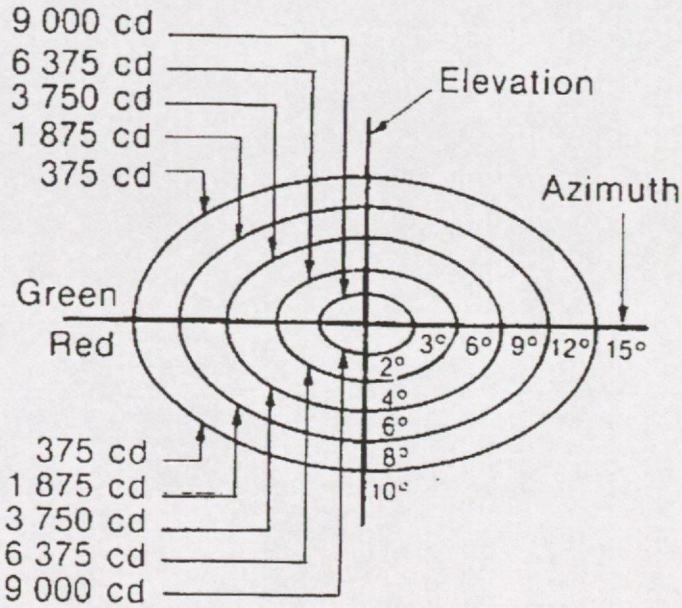

Figure 2 Isocandela Diagram (ICAO)

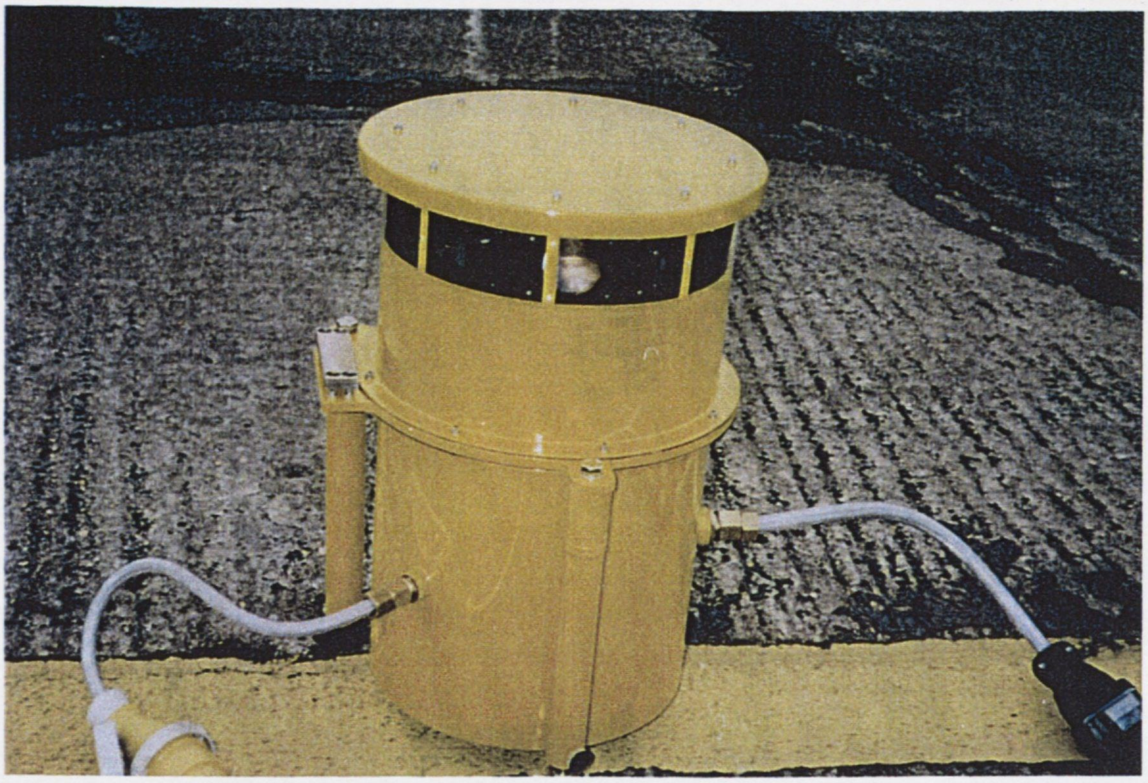

Figure 3 ODAPI

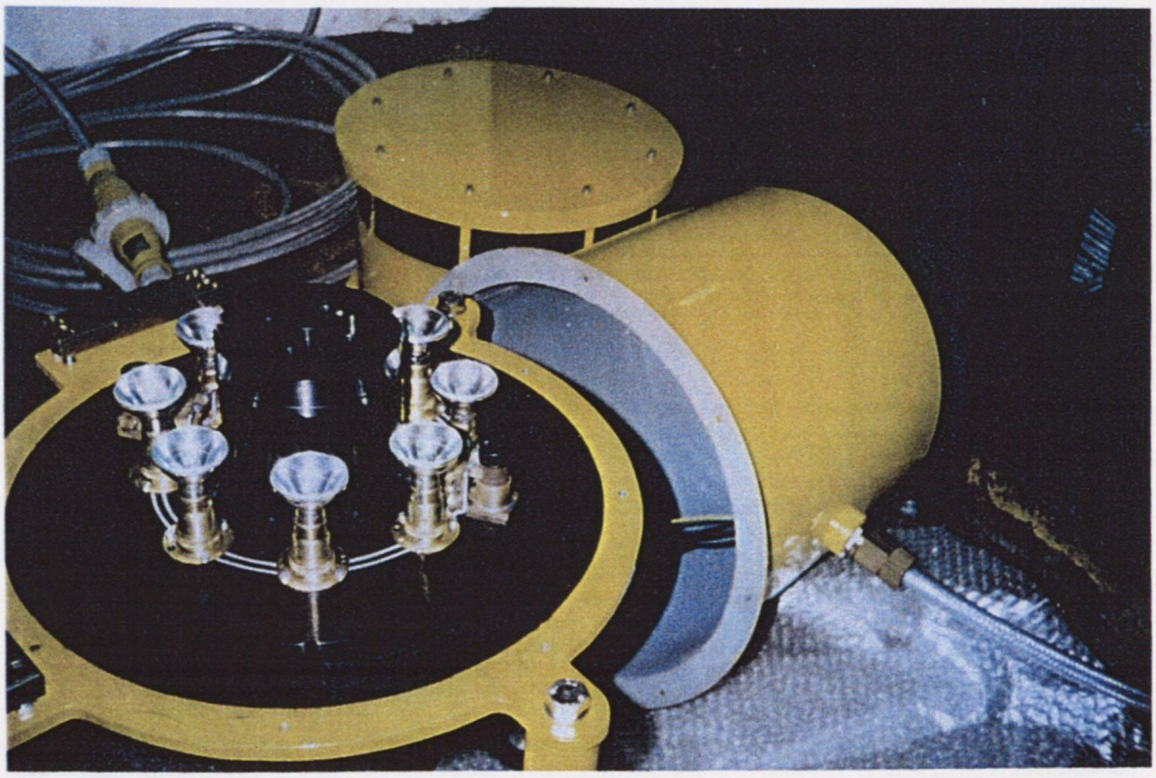

Figure 4 Internal View of ODAPI

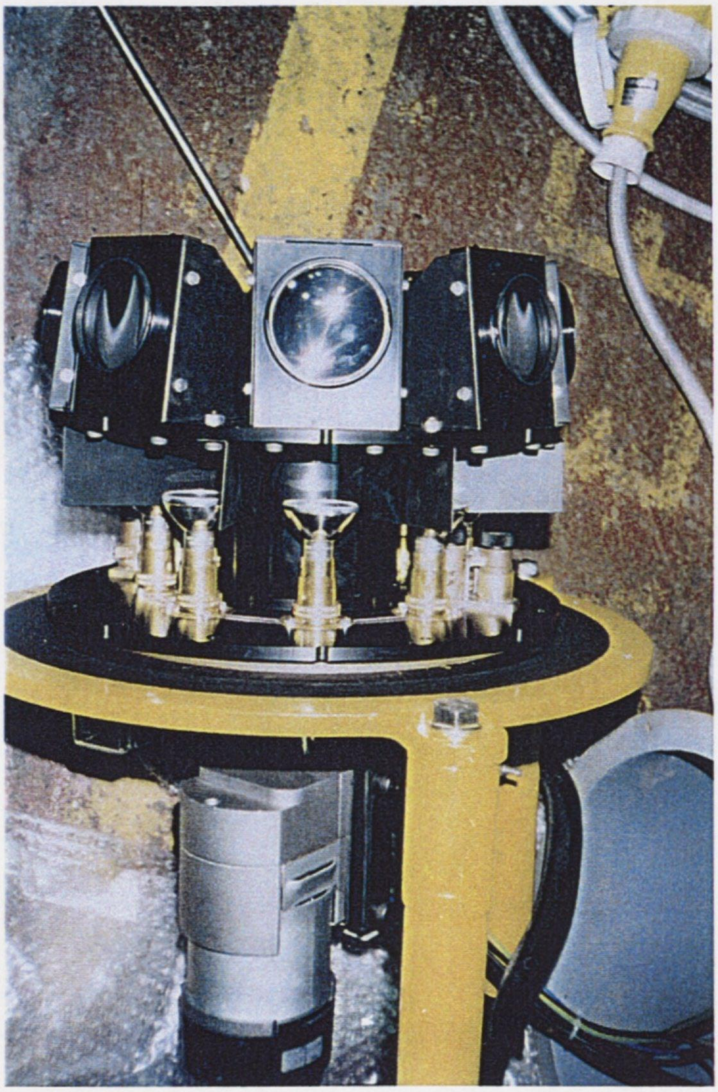

Figure 5 Internal view ODAPI

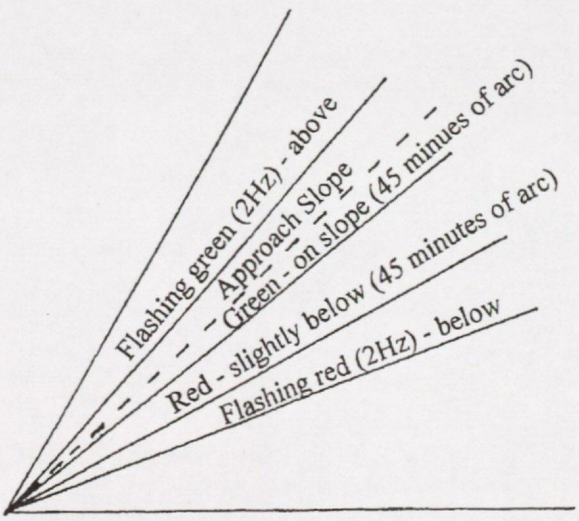

Figure 6 Initial ODAPI Format

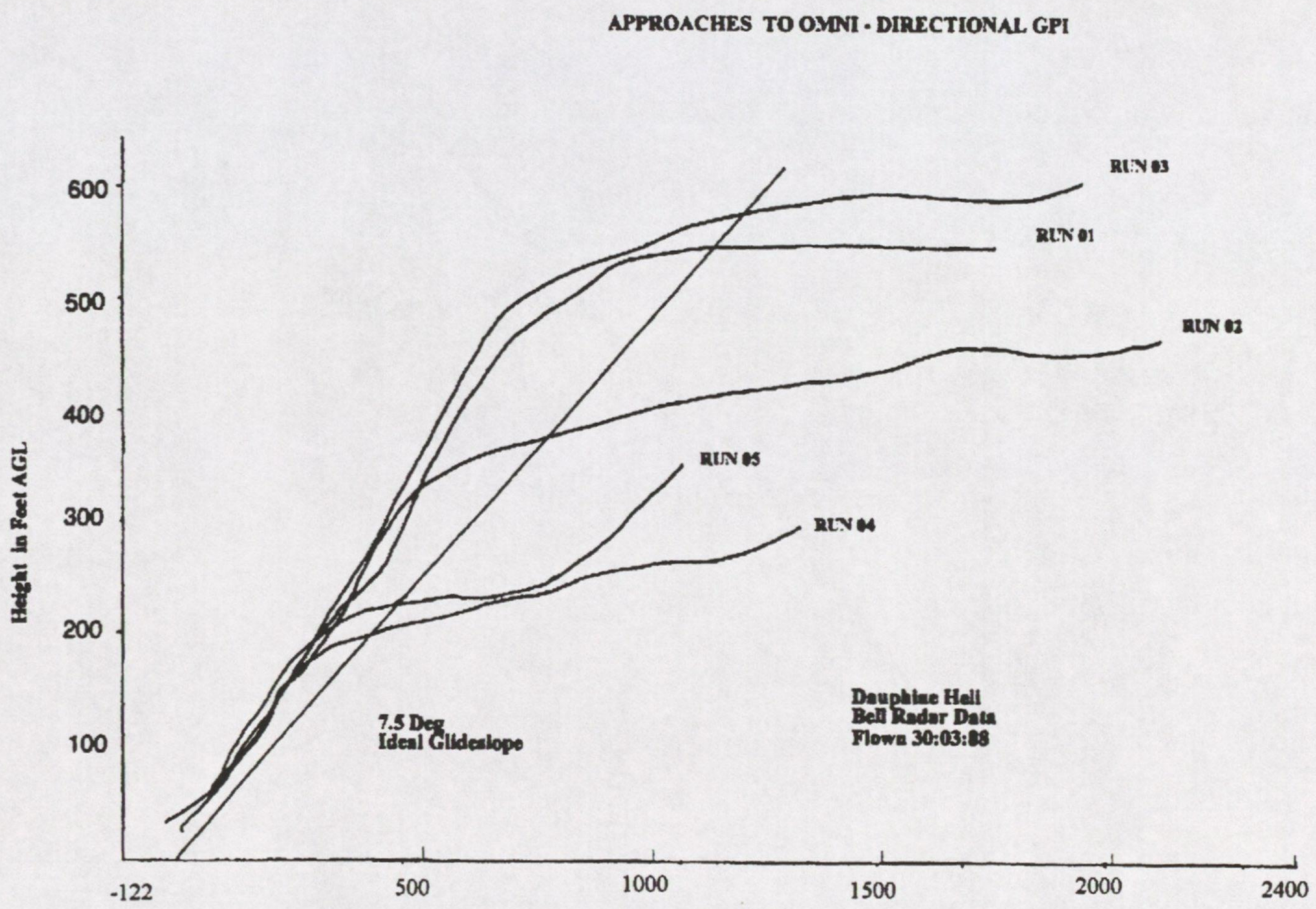

Figure 7 Flight Path Records 30/03/88

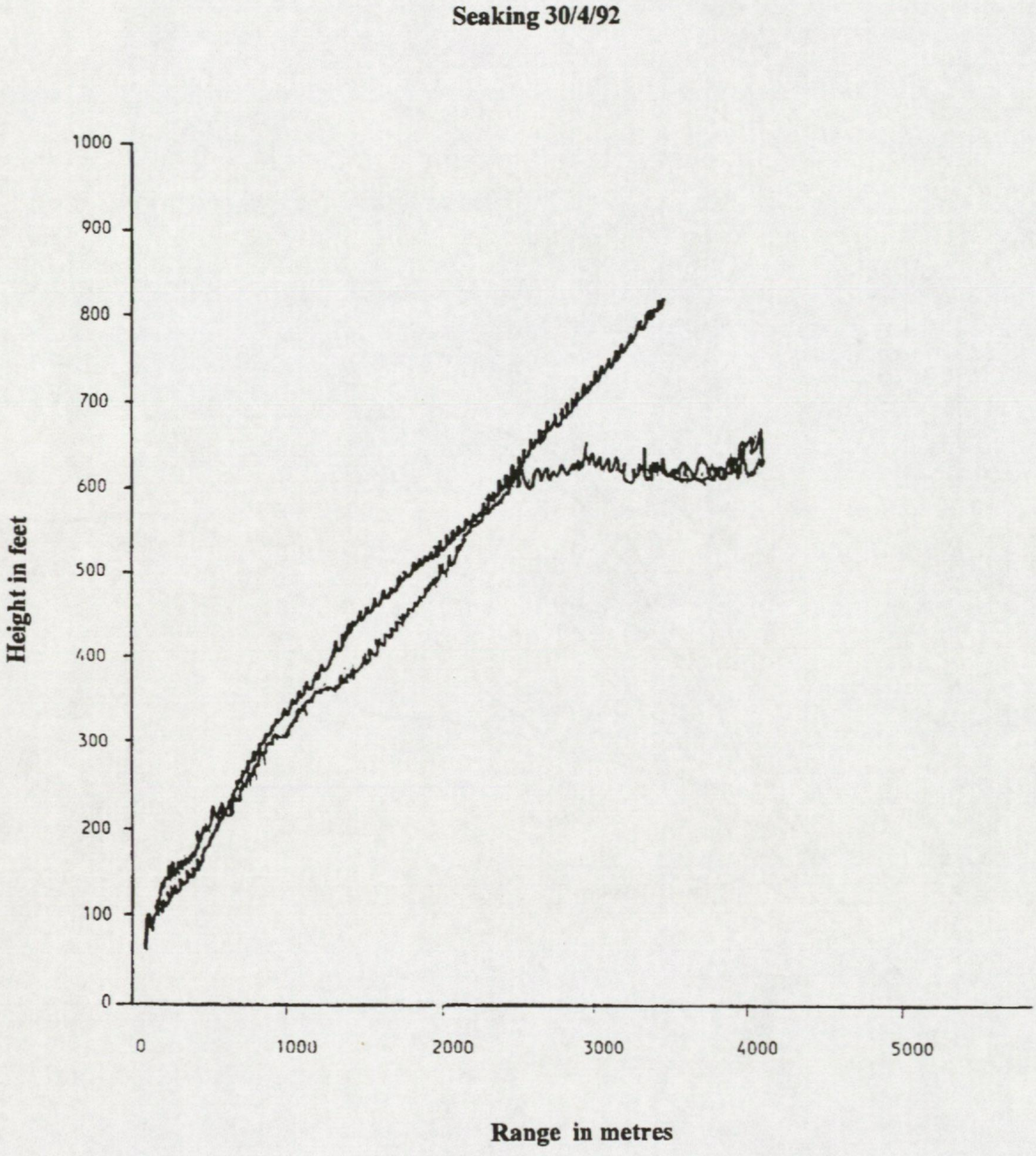

Figure 8 Flight Path Records 30/4/92