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RNLAF BO - 105 C MISSION IMPROVEMENT PROGRAM

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ABSTRACT

By request of the Royal Netherlands Army Staff, a test and evaluation program was carried out by the Royal Netherlands Airforce. The overall aim of the program was to select and integrate a package of night vision and supporting equipment for the BO-105 C helicopter that will allow round the clock operations in support of the RNL Army, specifically at night at low altitudes. An ex civil BO-105 DB helicopter was used as a testbed in the program. In addition to the original dual pilot IFR equipment (VOR, VOR/ILS, Radar Altimeter and 2 axis Stability Augmentation System), a Doppler Navigation System with Mapreader, a TACAN and recording equipment were installed in the test helicopter . In a pre-evaluation program, two types of helmet mounted Night Vision Goggles (NVG') were selected for further evaluation. After the 2 axis SAS had been replaced by a 3 axis CSAS and NVG compatible cockpit lighting had been installed in the test helicopter, the night low level operational flight trials were carried out. This paper describes the selection of the NVG's, the NVG compatible lighting and presents the pilot experiences and opinions concerning the low level night flight trials. The trials indicated the feasibility of the concept. A selected equipment package will be retrofitted into the BO-105 fleet, development of a prototype will commence shortly.

INTRODUCTION

1. Up till today the BO-105 C is being used as an all purpose Light Observation Helicopter for day missions under Visual Metereological Conditions (VMC) only. Night flight is conducted under Special VFR, for training purposes only. Minimum metereological conditions for local nightflying are 3 kms visibility, 1000 ft cloudbase and 5 kms visibility and 1500 ft cloudbase for cross country flights outside controlled airspace, minimum height above ground is 600 ft.

In 1975 in connection with a night-landing-equipment evaluation program in an Alouette III, limited experience was gathered with a pair of 2nd generation AN/PVS-5 NVG's. Although the NVG's showed great potential as a pilots night-vision aid, it was immediately recognized and later confirmed by litterature, that, as a result of the limited field off view and resolution of the NVG's , workload and disorientation would be a limiting factor and could become a problem. For this reason it was our opinion that rather than starting with the basic aircraft and adding equipment as required, the test helicopter should be equipped with a low level navigation system with automatic map display and a radar altimeter. All flight and performance instrument dials must be easily readable while wearing NVG's. Also consideration was given to the fact that, if one wants to investigate the limits off the NVG's, inadvertent Instrument Metereological Conditions (IMC) are likely to be encountered. For this reason the test helicopter had to be certified according to Instrument Flight Rules (IFR).

In December of 1982 a civil, dual pilot IFR, BO-105 DB helicopter was purchased by the RNL Army, this helicopter was to function as a testbed for the equipment evaluation program. First the original civil avionics equipment was qualitatively evaluated for possible militairy application, later, at various stages in the program certain systems were either added or replaced. To satisfy procurement formalities all systems and equipment, used in the program, underwent comparitive testing. To limit the scope of the equipment selection program where possible, first consideration was given to avionics equipment that either was already available in the RNL Airforce inventory, or available as Optional Equipment for BO-105 (known technology). Most of the avionics equipment under test was installed on a pallet in the baggagecompartment of the test helicopter. Equipment installation was done by technicians of our overhaul facility (DVM) at Gilze Rijen Airbase, with assistance of the aiframe manufacturer. Concerning the mission supporting equipment, only those aspects that are relevant to the night low level mission will be discussed in this paper.

TRIAL OBJECTIVES

2. The main objective of the trials was, to select and integrate a cost effective package of Night Vision and mission supporting equipment, that will provide the BO-105 C with an around the clock operating capability , in its future role of rearward observation helicopter for the RNL Army.

RESULTS AND DISCUSSION

3. Night Vision Goggle selection. In May of 1984 a preliminary NVG evaluation program was carried out. To be complete and to satisfy procurement regulations, modified drivers goggles were also tested. 5 sets of NVG's were available for testing; Cyclops, (a bi-ocular monotube goggle), AN/PVS-5, MFP (Modified Face-Plate) , AN/AVS-6 Aviator Night Vision System .(ANVIS), BM 8043, (German Army development) and Cats Eyes, (UK prototype designed for fixed wing aircraft).

The preliminary evaluation was carried out in a fleet

BO-105 C, only the cockpit lighting had been adapted in a provisional manner, i.e. some light sources had blue filters taped on, other, less essential, were taped over. The instrument-panel was illuminated by an Electro luminescent wrist-lamp taped under the glareshield. Selection criteria were, weight, balance, stability, eye-relief, comfort, adjustment, alignment and ease of installation and removal.

3.1 The Cyclops mono-goggle. The Cyclops mono-goggle was originally designed as a driver's goggle, helmet mounting and counterbalance weight were improvised. The bi-ocular goggle consisted of a metal housing, which incorporated a single 2nd gen. Image Intensifying Tube (ITT), a battery case and glass optics. The single image was divided by prisms and presented to the user through two small diameter eyepieces. The Field of View was 40°. Advantages and disadvantages are listed below:

a. Advantages. Low cost, lightweight, easy to attach and remove.

b. Disadvantages. No alternate power source, difficult battery switching,insufficient eye-relief, no vertical adjustment, no stereopsis, eye discomfort, goggle misalignment, counterbalance weight required.

The disadvantages outweighed the advantages considerably, the Mono-goggle was therefore considered not acceptable for further use in the evaluation program.

3.2 AN/PVS-5 MFP. These goggles, as shown in Fig. 1, were basically a modified version of the well known and widely used driver's goggles. 2nd gen + ITT's were fitted. To aid peripheral vision and allow direct instrument monitoring, the faceplate had been altered (cut out). The helmet mounting attachment was improvised i.e. straps attached onto Velcro pads on top of the helmet. A dual battery pack, originally developed for AN/AVS-6 could be attached to a Velcro pad on the back of the helmet and functioned as a counterbalance weight. The only advantage, low cost, does not outweigh the shortcomings, i.e.:

a. Instable helmet attachment, causing misalignment of the small diameter eyepieces and subsequent eye discomfort and fatigue.

b. Insufficient eye relief to allow easy instrument monitoring.

c. Excessive weight, an extra balance weight was required to prevent helmet rotation.

The improvements as compared to the original AN/PVS-5 used in our earlier program in 1975, were considerable, but only are acceptable as an interim solution.

3.2 Cats Eyes. Cats Eyes, as shown in Fig.2, was a prototype helmet mounted design, under development for fixed wing aircraft, for use in combination with a Forward Looking Infrared (FLIR) image, displayed in a Head Up Display (HUD).

The goggle was attached to an SPH-4 helmet by a quick lock and release unit. The binocular goggle consisted of an all metal housing, which incorporated 2nd gen ITT's, a battery case, and glass optics. The forward end of the goggle was similar to other goggles, the rear end however, was quite different. The image is deflected 90" through a pair of prisms into a pair of small clear glass combiner blocks. The user sees the projected image at infinity, superimposed onto the outside world. The rationale behind this solution is that, through proper use of filtering and electronic switching, the pilot can observe the HUD scene directly through the eyepiece, instead of having to look underneath. The field of view per tube was 30°, to increase the lateral FOV to 40°, the tubes were installed with a 10° divergence. Red (minus blue) filters were available for installation over the objective lenses for use in combination with blue/green cockpit lighting.

The most important advantages and disadvantages of these prototype goggles are listed below:

a. Advantages. Good eye relief, excellent peripheral vision, clear stable image and corrective spectacles can be worn.

b. Disadvantages. Mounting was difficult, a considerable amount of counterbalance weight was required, double image of bright light sources at close range (projected image did not excactly overlay the real world scene), eye discomfort because of the 10° divergence of the tubes (after a certain period of time, at increasingly short intervals, the pilots had problems to make left and right images overlap).

Because the goggles in question were a first prototype, much can be and has been corrected. Recently, the RNL Airforce had the opportunity to evaluate a more advanced prototype of reduced size and weight, in combination with a FLIR, in a fixed wing aircraft. In this program the feasibility of the concept was demonstrated . This model, however, was not available for helicopter evaluation in the required timeframe. Further investigation would be required to determine whether having a "See Thru" capability in a helicopter without a HUD, weighs up to the extra weight penalty and output reduction of the prism construction.

3.3 AN/AVS-6 and BM 8043. Both designs were quite similar, as is shown in Figs 3 and 4, both have twin intensifier units attached to the visor cover of the helmet and both use the battery case as a counterbalance weight.

Some particulars of AN/AVS-6 were, 2nd gen + ITT's were installed. A special visor constrution was required. In flight mounting and removal of the goggle was possible. The visor could be used in flight with the goggles in the stowed position. Red ("minus blue") filters were provided. The housing was made of plastic material. The objective lenses could be focussed from infinity down to 25 cm. The eye piece lenses could be ajusted individually over a range from -6 to +2 diopters. The demonstator goggles showed some signs of wear in the adjustment gears and threads, connections and adjustments were either to tight or to loose, on several occasions a diopter adjustment got stuck.

The BM 8043 system could be clamped onto a standard SPH-4 helmet. The goggles clamped onto the standard visor cover, a battery pack, connected by an armored cord, hooked up to the back of the helmet. The goggles were connected with a ball-and-socket joint onto the clamp on the visor cover. Vertical, longitudinal and tilt adjustments could be accomplished simultaneously in a single joint with clamping screw. The interpupillary distance could be adjusted by pushing or pulling the ocular ends of the goggles with both hands. A small, lipswitch operated, spotlight, mounted in between the tubes, could be used for instrument panel illumination. The focus of the objective lenses was fixed at infinity. The eyepiece lenses could be adjusted individually, over a range of ±5 diopters. FOV was 42° and 2nd gen plus tubes were installed.

The results of the pre-evaluation were not conclusive. Both types had acceptable weight and balance and adaquate eye relief. Alignment was not critical because of wide (25 mm in diameter) eye pieces. Corrective spectacles could be worn. Both types were recommended for further testing. The results of this evaluation are presented elsewhere in this paper.

4. Equipment Assessment. The assessment of the complete equipment package was conducted in a BO-105 DB ex civil helicopter, by testpilots, assisted by experienced helicopter pilots. The program was conducted according the following pattern. First experience and confidence were built up at safe heights in the local area of Deelen Airbase, then, in the well known local low flying area, height clearances were slowly reduced. Next selected low level routes were flown several times, to gain confidence and experience with the use of the Map Reader. Prior to each flight the route was reconnoitered by day for possible newly erected obstacles. Lastly, fairly difficult routes were selected in a relatively unfamiliar low flying area. To insure the safety of flight, prior to each flight, the general area and the boundaries were surveyed in daytime . The metereological conditions varied from clear sky, full moon, down to overcast 200ft, 1500 m visibility in rain and snow showers. 4 sets of NVG's were available for further evaluation, 1 set AN/AVS-6 with 3rd gen. ITT's and 3 sets of BM 8043, 2 sets with 2nd gen + and a set with 3rd gen ITT's. "Minus Blue" filters were available for the latter, the objective lenses of the former were treated with a "Minus Blue" coating. The cockpit of the test helicopter was equipped with several types of NVG compatible lighting. An AN/ASN-128 Light Doppler Navigation System (LDNS) with automatic Map Reader, K10-0, a 3 axis Control and Stability Augmentation System (CSAS), IFR instrumentation and a Tactical Air Navigation System (TACAN)
were also installed.

4.1 Dark Cockpit. The lipswitch operated spotlight mounted in between the tubes of the BM 8043 goggles was a German Army Aviation requirement, their mission requires a "Dark Cockpit".

During the initial phase, we attempted to operate in a completely blacked out cockpit, none of the pilots felt comfortable, mainly because all flight- and performance information a pilot unconsciouly uses for the execution of the flight was not readily available. A crosscheck of the instrument panel always required his full attention. With the experience level of the pilots in mind and because the BO-105 task does not require covert missions, further investigation into the "Dark Cockpit" concept was abandoned.

4.2 Floodlighting. Several types of floodlights were available for evaluation, (1) Micro-louvered E.L. lamps, mounted under the glare shield, (2) a blue Kopp #0005 filter over the Utility light in the overhead console and (3) an Ultra Violet (U.V.) lamp, mounted onto the overhead console.

Options 1 and 2, required relatively high light levels, this caused high lights on the instrument panel and reflections in the canopy. Large shadows were cast over the face of the instrument panel leaving important sections barely readable. Option 3 appeared to be the best solution of the 3. The only problem was that only those symbols, that had been treated with fluorescent paint, were visible. The effect looked good, even colours showed up.

Because U.V. light is invisible to the human eye, U.V. floodlighting is an ideal solution, if covert missions are required. Another advantage of U.V. light is that the frequency lies far outside the sensitive range of NVG's, "Cut Off" filters are not required. A disadvantage is that all instruments have to be treated with special paint, this may become cost prohibitive.

4.3 Blue Cockpit lighting. A combination of blue Electro Luminescent (E.L.) lamps and blue Kopp #0005 glass filters was used to make the cockpit NVG compatible. To avoid goggle "Shut Down", red ("Minus Blue") filtering of the NVG's was required. Glass filters (RG 645 and RG 665) were available for the BM 8043 goggles, the objective lenses of the 3rd gen. AN/AVS-6 goggles had been treated with a "Minus Blue" coating. Both options funtioned well, reflections in the cockpit windows were suppressed. We were however surprised to find out that 3rd gen goggles also required a "Cut Off" filter.

Most 3" and 4" dials in the instrument panel were fitted with E.L. Bezel lamps (Fig. 5), for the rest of the 3" and most of the 2" dials, blue filtered Post lights (Fig.6) were used. The readability of the 3" and 4", E.L. Bezel equipped, instruments was excellent, the dials stood out clearly against a dark background. The light was spread evenly over the whole face of the dial, coloured limit markings were highlighted. E.L. Bezels were not suited for instruments with a diameter $\leq$ 2" and 3" instruments with deep lying dials, because symbols close to the rim of the dial were obscured. Post lights gave satisfactory results with most 2" instruments, the position and the direction of the light beam however, have to be selected carefully.

A special problem was formed by the Steering Hover Indicator Unit (SHIU) of the LDNS, (Fig. 7), after several unsuccesful attempts with many yards of tape, a filter cap of blue Kopp #0005 filter material was made up, that could be fitted over the whole instrument. As an interim solution it functioned well.

A combination of E.L. Bezels and filtered Post lights has been recommended, cockpit layout and illumination will be optimized for the mission during prototyping.

All panel lights in the overhead- and center console were disconnected. The display windows of the Doppler - Control and Display Unit (CDU) and the Radio control panels were replaced by blue Kopp #0005 glass windows. The readability of the filament displays at night was excellent, in bright sunlight it was acceptable. The modification will be applied to the fleet. Further testing is required to determine whether blue filters can be applied to existing incandescent panels, or that new E.L. panels have to be ordered.

The Automatic Map Display (AMD K10-0) (Fig. 8) had no integral lighting, a hand held lamp had to be used. A provisional modification proved to be quite succesful. A large sheet of E.L. material, the size of the display window, was taped onto the top of the Map Display. A map placed over the E.L. lamp becomes a NVG compatible transparency with excellent readability, only a minute colour shift is evident. With the lid closed in the normal fashion, the cross hairs showed up clearly. A reostat was installed for dimcontrol.

Modified in this fashion, the Map Display became a very useful tool. With the Map Display integrally illuminated, the co-pilot/navigator had an extra hand free for writing and map changing.

4.4 <u>Goggle Design</u>. The BM 8043 and the AN/AVS-6 functioned well in the blue cockpit, a day VMC type cockpit cross-check could be adopted. Until late in the program the pilots had no particular preference for either type. Some found the BM 8043 easier to focus. All pilots liked the break away coupling of the AN/AVS-6. First of all, from the flight safety point of view and second, because it allows the user to stowe or remove the goggles in flight if so desired. Another useful feature was that the Visor was operable, with the goggles in the stowed position. This feature is particularly useful when flights are performed around sunrise or sunset, with the sun just over the horizon.

Towards the end of the flight trials another model of the BM 8043 with "Break Away" coupling became availabe for testing. A few minor modifications to the goggle- and visor assembly made the use of the Visor possible. This version was recommended.

4.5 <u>Goggle performance</u>. The performance of the 2nd and 3rd generation Image Intensifying Tubes (ITT) was qualitatively evaluated. At the start of the trials existing light levels were measured on the ground. We soon abandoned the procedure because the measured values at ground level were not representative for those that were encountered in flight.

All pilots preferred the 3rd generation ITT's, they had better resolution, lower noise and better performance under marginal condition. One set of 3rd gen. ITT's was of particularly poor quality, looking through these goggles was like looking through a dirty window. In spite of this, under marginal conditions they performed better than the best of the 2nd gen. + ITT's. 3rd generation tubes were recommended.

5.3 Stability Augmentation. The 2 axis SAS, the test bed originally was equipped with, only provided short term rate damping and could only be used in level cruise flight. We required a "Fly Thru" system that was optimized for low speed, low altitude manoeuvering. The only other BO-105 certified system that was available at that time was a 3 axis, attitude referenced Control and Stability Augmentation System (CSAS). The system was duplex in the roll and pitch channels. It could be operated in 2 modes, the Attitude Hold (ATT) mode, it provides longterm attitude retention and the Stability Augmentation (SAS) mode, it is a "Fly Thru" mode that provides short term attitude damping during manual flight. A rate damper and a "Force Gradient" with Mag Brake were used in the yaw axes. The Yaw SAS was designed for feet-the-floor operations in cruise flight, the system had to be switched off before landing. To allow the use of the Yaw SAS during low speed manoeuvering flight, the gradient of the pedal forces was altered.

The system eliminated the dynamic instability in pitch and reduced most of the control cross coupling effects that are inherent to "Hingeless" rotors. Specifically the low airspeed flying qualities were greatly improved, the reduction in pilot workload, when flying with NVG's at low altitude and in turbulence was considerable. The ATT mode was not intended to be used as a "Fly Thru" mode. During the low level navigation flights, we tried it anyway and found that the increased positive centering of the cyclic stick and the automatic return to wings level attitude reduced workload on long stretches even further. The improved stability and qualities are also satisfactory for IFR flight.

4.7 Low Level Navigation. For low level navigation an AN/ANS-128 LDNS was selected for evaluation. Up to 10 Waypoints could be entered into the Control an Display Unit (CDU). The CDU displays navigation data in a digital form. The CDU drives the Steering Hover Indicator (SHIU), in the NAV mode, it displays distance, left-right steering information and ground speed. This information is particularly useful for point to point navigation, it enables the crew to roughly estimate the position in relation to the destination. For contour flight navigation at night, accurate position information is essential. Without any additional equipment the co-pilot/navigator still had to keep track of his position on a hand held map. Only flight over memorized routes were considered safe.

The key to routine low level operations was the E.L. Illuminated Automatic Map Display. It allowed the co-pilot/navigator, to monitor his position instead of having to plot it continuously. Fast position updates on the map on any outstanding terrain feature were possible. We only had 1:50.000 and 1:250.000 scale maps of the area available. The latter did not have enough detail and the former had to be changed quite frequently. We hope that 1:100.000 scale maps with just enough detail to avoid clutter, will soon be available. Another improvement that would increase the value of the Map Display would be an interface that allows automatic update of the LDNS by means of a position update on the Map Display. Another welcome improvement would be a drastic reduction in weight and volume.

5. Resumè. With the recommended equipment package it was demonstrated that a BO-105 helicopter could be operated by experienced helicopter pilots low level at night over fairly unfamiliar terrain under adverse weather conditions.

The helmet mounted NVG's gave us a night low level capability, the 3rd gen ITT's added an extra darkness and reduced visibility margin.

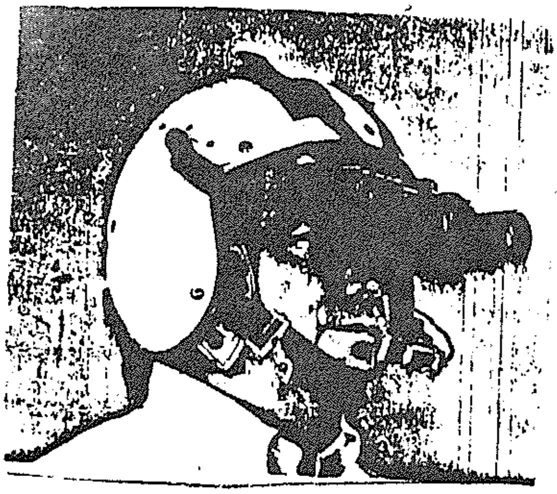
The blue NVG cockpit lighting made easy monitoring of flight and engine performance instruments possible and allowed the use of navigation equipment. Improved confidence and reduced workload.

The E.L. Illuminated Map Display improved navigation accuracy, reduced the workload of the navigator, and allowed him more "Eyes Out the Cockpit" time, with added flight safety.

The CSAS improved the overall flying qualities in cruise, in lowspeed manoeuvering flight and in turbulence. Pilot workload was greatly reduced.

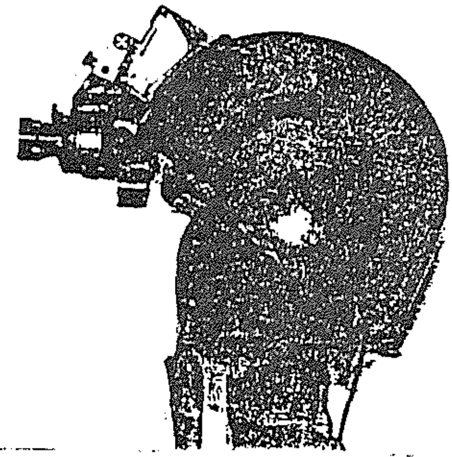
The IFR instruments in the test bed helicopter made IFR recovery possible in those events that the weather deteriorated below NVG capabilities. The addition of a TACAN has been recommended. It will give the BO-105 a militairy IFR capability, this will add to flight safety of NVG operations and greatly increase its "Round The Clock" operating capability.

6. Recognitions. We like to express our appreciation to all the manufacturers, that allowed us to evaluate their equipment, for their welcome advise and support, we must however apologize for the fact that due to procurement formalities their names have been withheld. We also like to thank the Royal Aircraft Establishment, Farnburough and the ATV, Bückeburg from whom we borrowed many ideas.



PVS-5 MFP

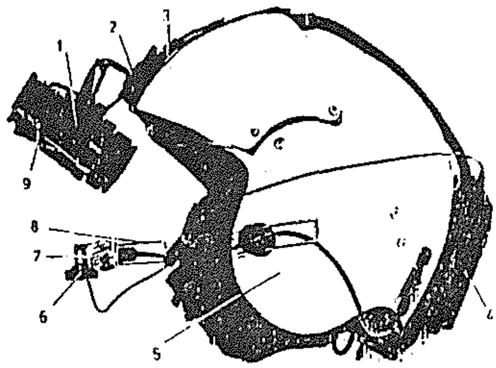
Fig. 1



Cats Eyes

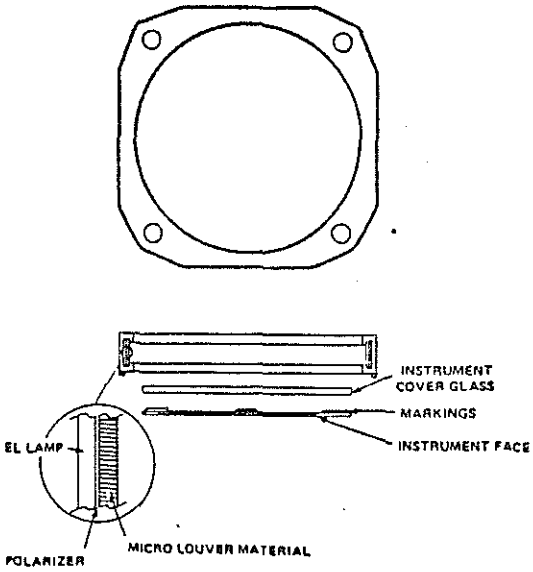
Fig. 2

AN/AVS-6
Fig. 3



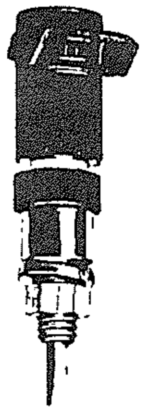
BM 8043

Fig. 4



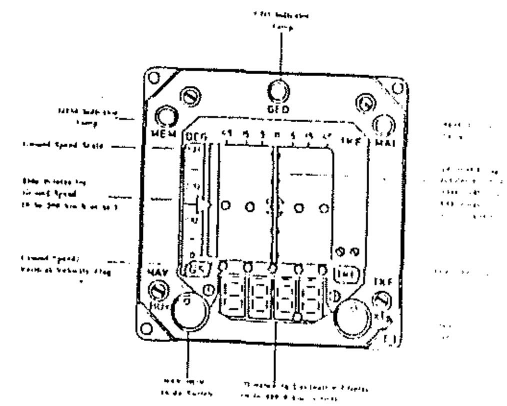
BEZEL

Fig. 5



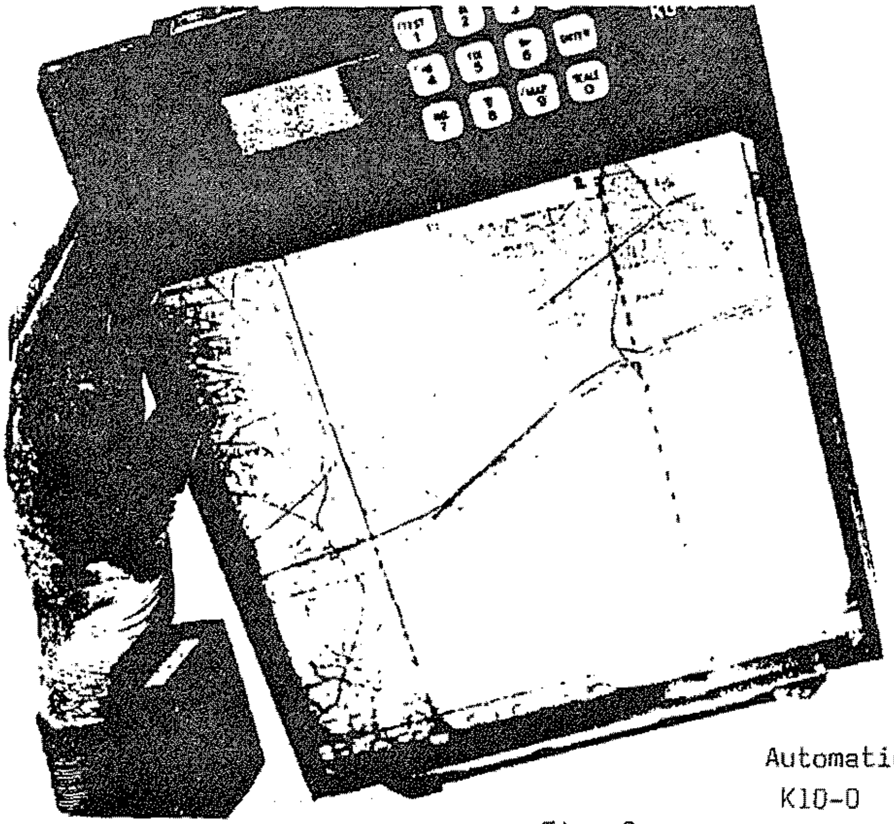
Post light

Fig. 6



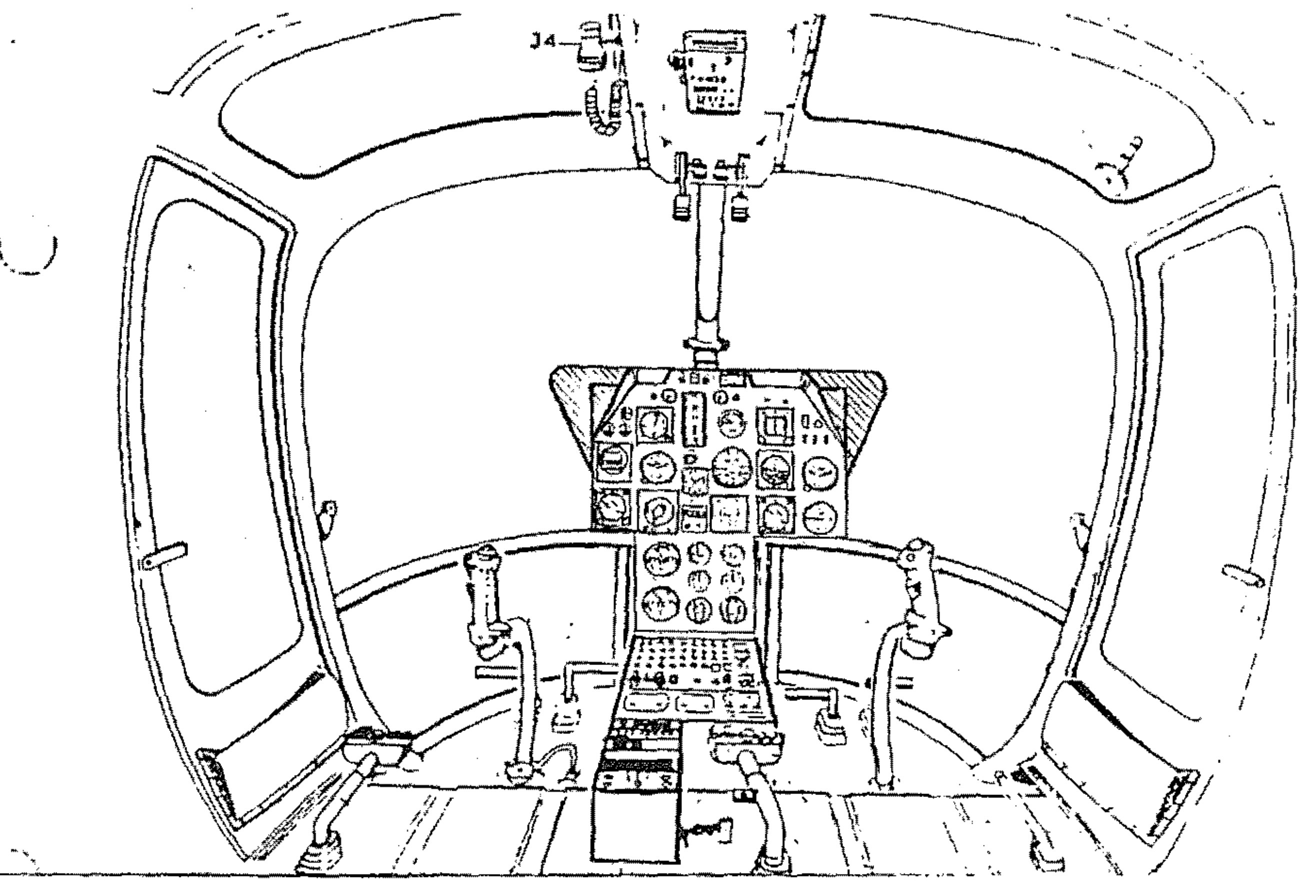
SHIU

Fig. 7



Automatic Map Display
K10-0

Fig. 8



Instrument Panel Improved BO -105

Fig. 9