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HELICOPTER DISPLAY IMPROVEMENT STUDY

William E. Clark, Jr.

Instrument Flight Center
Randolph Air Force Base, Texas

May 1975

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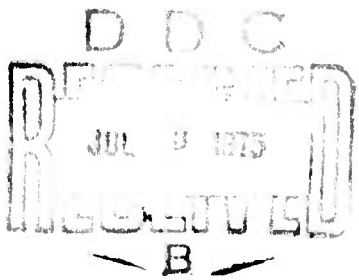
Final Report

May 1975



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This Technical Note, IFC-TN-75-1, presents the results of the USAF Instrument Flight Center Helicopter Display Improvement Study (CDG-PFH-1).

A representative cross-section of active duty Air Force Helicopter Pilots were sampled by means of a questionnaire. The returned questionnaires provide a data base of approximately 20% of the active helicopter force.

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PRICES SUBJECT TO CHANGE

Pilots responded to questions directed at their current instrument panels, as well as future panel designs with instrument location, lighting, and operation being addressed. Specific displays were also treated in that pilots were asked to rate their Attitude Indicators, Altimeters, Heading Indicators and Airspeed Displays.

The desirability of stability augmentation systems, as well as the priority the pilots place on augmenting the various axes is also established. The remaining questions treated helicopter flight directors, tape displays, navigation systems and the control and performance concept of instrument flying.

In addition to conventional analysis, certain responses are also compared on the basis of pilot experience and type helicopter.

The entire data base has been placed on computer magnetic tape to aid in analysis and provide an "add on" capability for future pilot opinion sampling.

PREFACE

This report (IFC-TN-75-1) is an analysis of the responses to a Helicopter Control/Display Improvement Study (Pilot Factors-Helicopter) Questionnaire distributed to a representative cross section of active duty Air Force helicopter pilots.

The project is a part of the Pilot Factors - Helicopter (PIFAX-H) program currently underway at the United States Air Force Instrument Flight Center (USAFIFC). It is believed that the information obtained from the project reported herein will help provide a data base of pilot opinion which will be used to improve existing displays and aid in the development cycle of future helicopter cockpit presentations and stability systems.

Special acknowledgement is given to Mrs Mary Lou Baisden, Air Force Flight Dynamics Lab, Wright-Patterson AFB and Mr Thomas Snyder, Bunker-Ramo Corp., for the computer programming utilized in the project.

This technical note has been reviewed and is approved.

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INTRODUCTION

Helicopters, both military and civilian, are presently operating with instruments designed for fixed wing aircraft. Such instrumentation, combined with limited stability, has resulted in a reduced instrument flying capability and has limited almost all helicopter operations to visual meteorological conditions (VMC). When required to operate in instrument meteorological conditions (IMC), the helicopter does so with fixed wing airspeeds and approach procedures. In accordance with Instrument Capabilities Survey Helicopter PIFAX-H Program CDG-PF-8 (IPIS-TN-71-1, April 1971), it has been established that helicopter pilots fly 50% fewer instrument hours than fixed wing pilots and that new instrument displays and associated systems (e.g., stability, rotor anti-icing, navigation systems) might increase mission effectiveness by up to 75%. These findings were based on pilots who "were involved with plans/requirements, standardization, and operations in major air command - the Air Rescue and Recovery Service, numbered Air Force, Wing, Group and Squadron levels" - all highly experienced and knowledgeable in helicopter operations.

Helicopter instrument approach criteria has been developed to allow the approach designer the latitude associated with the helicopter's "special maneuvering characteristics" and "unique maneuvering capability of the helicopter at airspeeds not exceeding 90 knots on final approach."[1]

Pilot's utilization of these unique capabilities (for example, slower speeds, steeper approach angles, reduced turn radius, etc.), is dependent on both improved displays and increased stability. Displays would provide the required "helicopter" information while increased stability would reduce pilot workload and increase helicopter controllability so that the improved information displayed could be most effectively utilized.

A vital, but often neglected factor in the development of instrument displays and flight controls, is the crews' opinion of the utility of their display and stability systems. A comprehensive analysis of subjective pilot opinion regarding their current operational systems can provide valid data indicative of present display/stability problems and possible methods of improvement. With this as the major goal, the present project reported herein was undertaken.

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1. AFM 55-9, U.S. Standard For Terminal Instrument Procedures (TERPS), Chapter 11, Helicopter Procedures, p. 93.

METHOD

A representative cross section of currently qualified Air Force helicopter pilots were queried by means of a questionnaire (Appendix B). A total of 208 questionnaires were sent out with 127 responses being received. With exception of two Coast Guard subjects, all returned questionnaires were from Air Force pilots. The 127 returned questionnaires represent a 61% return rate. This relatively high rate might be indicative of the interest and concern for the subject addressed. The 125 returned questionnaires provide a substantial data base (approximately 20%) of the currently qualified Air Force helicopter pilots whose primary duty is in the cockpit.

Subjects were selected on a modified random basis with restrictions to ensure a spread of various types of helicopters and military rank. The latter restriction being used as a probable indication of experience. A detailed breakdown of returned subjects experience level is discussed later.

All returned questionnaires were edited by the Project Officer and the Human Factors Engineer assigned to the project. Editing consisted of insuring proper length responses for conversion to computer punch cards, deletion of unnecessary words, spelling, and some changes in nomenclature were made to ease analysis, (for example, changed ID 249 to course indicator). After editing, a subject control number was assigned and the entire questionnaire was sent to Wright-Patterson AFB for key punching and inclusion in the computer data base.

During the data compilation phase of the project, the computer was queried on the basis of certain "flagged" items or by total responses to a particular question cross referenced to another question. An example might be relating all subjects who said they wanted a flight director system to how they rated their current panel arrangement or whether they had ever flown a flight director before.

The entire data base has been placed on magnetic tape, thus permitting future additions and varied types of analysis.

ANALYSIS

For the purpose of this report, data has been divided into two general categories: Heavy Lift (H/L) pilot responses and Light Lift (L/L) pilot responses. All responses were analyzed by specific type category and helicopter; however, it was determined that differences between types were generally not as significant as differences between H/L and L/L responses.

For the purpose of this report, Heavy Lift responses are derived from H-53 and H-3 pilots' responses while Light Lift data consists of the H-1 series and H-43 pilots' responses.

Generally, Light Lift category helicopters have a maximum gross weight of 10,500 pounds or less, are normally flown by a single pilot, do not have stability augmented controls, and, with the exception of the H-1N (Bell 212), are single engine helicopters.

The Heavy Lift Category aircraft is a twin engine, crew served (pilot, copilot, and flight mechanic) helicopter equipped with stability augmentation systems. Maximum takeoff gross weight is in excess of 19,000 pounds for this category. More specific information on each type helicopter is in appendix C.

Appendix B contains a copy of the questions used to gather data for this report. The numbers beside each response indicates total number of subjects responding with that answer. The page number beside each question indicates page number in the analysis section discussing that question's responses. All percentages are rounded off and thus might produce totals of 99% or 101%.

SECTION I

ANALYSIS OF PERSONAL DATA RESPONSES

Branch of Service

As previously mentioned, 125 of the 127 responses were from Air Force helicopter pilots. The two Coast Guard pilots were both H-3 pilots and are included in the Heavy Lift data.

Years Rated	H/L	L/L
Less than 3 Years	32%	42%
3-6 Years	18%	9%
6-10 Years	30%	27%
10-15 Years	10%	16%
Over 15 Years	10%	6%

The years rated information is very similar for both groups with approximately 50% of the pilots responding having their wings for less than six years. This does not necessarily mean the individuals have been assigned to flying duties for the entire time but this would be the case for the vast majority of the pilots.

Flight Experience

Perhaps a more meaningful criteria is the total flying time an individual has amassed in both fixed wing and helicopters. It is assumed that the difference between total time and helicopter time is fixed wing flying time.

	Total Time		Helicopter Time	
	H/L	L/L	H/L	L/L
Less than 800 hours	20%	19%	24%	23%
800-1500 hours	22%	30%	50%	44%
1500-2000 hours	6%	1%	8%	13%
2000-2500 hours	18%	16%	6%	6%
Over 2500 hours	34%	34%	12%	13%

Once again, very little distinction appears between H/L and L/L pilots. While approximately 50% of both groups have less than 1500 hours total time; 74% of H/L and 67% of L/L pilots have less than 1500 hours helicopter time. This serves to establish the fact that some pilots have flown both helicopters and fixed wing.

The Air Force currently has two types of pilots flying helicopters. The first category is the "conversion" pilot. This individual was originally a fixed wing pilot who received transition training to helicopters. The second type is the "helicopter only" pilot who underwent all his training (basic flight training with the Army) in helicopters and has never flown military fixed wing aircraft. At the completion of approximately four years of helicopter flying, the "helicopter only" pilot then undergoes fixed wing training and serves a tour as an Air Force fixed wing pilot. Both category pilots can then be utilized in either fixed wing or helicopter assignments. "Helicopter only" pilots comprised 60% of those responding to the questionnaire.

Type Helicopter Flown and Time in Type

Heavy Lift opinion is represented by 50 pilots while 77 pilots responding flew Light Lift helicopters. Time in types ranged from a low of a 490 hours average for H-1H pilots (newest helicopter in AF inventory) to a high of 1536 hours averaged by the H-43 (oldest helicopter in inventory).

Heavy lift pilots averaged 697.6 hours in their aircraft while Light Lift pilots have an 870.6 hour average. These average time figures are relatively low due to the large number of young pilots flying helicopters.

Actual Weather Time in Last 12 Months

The obvious lack of actual weather experience is apparent through the responses to this question. Actual weather time ranged from 14.1 hours for the TH-1F to a low of 1.1 hours for the H-1P. At this point it must be noted that seven of the 10 TH-1F pilots responding were instructors in the Air Force Instrument Pilot Instructor School (IPIS) and would, therefore, be expected to fly more weather time than an operational pilot. Average weather time for Heavy Lift was 12.1 hours with 5.3 hours being the Light Lift average. These averages are perhaps misleading when looking at weather time in another way. While 20% of H/L pilots reported 2 hours or less weather time in last twelve months, 53% of the L/L pilots logged 2 hours or less for the same period of time thus indicating a significantly greater percentage of H/L pilots flying more weather time than L/L pilots.

Question #2 - "On what percentage of your flights do you operate in Instrument Meterological Conditions (IMC)?"

a. Less than 5%

b. 5-10%

c. 10-20%

d. Over 20%

Analysis of responses to this question provides a further indication of the lack of instrument operations. Seventy-nine percent of pilots responding stated that less than 5% of their missions involve actual weather operations. Eighteen percent reported a 5-10% rate while the remaining 3% stated they encounter weather on from 10-20% of their missions. Not a single pilot claimed weather operations on over 20% of his missions.

The difference between H/L and L/L pilots again appears. Of 55 single engine, L/L helicopter pilots responding, only seven stated they encountered actual weather on 5-10% of their missions - the remaining pilots all said less than 5% of their missions involved weather operation. These seven pilots were TH-1F instructors involved in a formal Air Force Flying Training Course - IPIS.

When looking at the types of primary missions being flown by the responding pilots (see appendix B for breakdown), the lack of weather experience is even harder to reconcile. Training flights, rescue missions, and cross country support flying are common to all helicopter pilots and are missions where actual weather could and should be encountered. It must be obvious that the low incidents of actual instrument flying is attributed to more than type of missions being flown, rather it is a concentrated effort on the helicopter pilots' part to avoid weather and stay in VMC, even at extremely low altitudes. The remainder of this report will, hopefully, help explain a portion of this problem; that is, a general lack of confidence in his machine as an all weather platform.

Question One (see appendix B) was used to help establish subject's experience level with various stability/display systems. For this reason it was not analyzed separately but is used to qualify responses to later questions.

While no absolute statements can be made about the entire body of Air Force helicopter pilots based on the 20% sampled, it is felt that the sample accurately reflects the opinion shared by the entire force.

SECTION II

ANALYSIS OF DISPLAY RESPONSES

OVERALL INSTRUMENT PANEL

Question #3 - "Rate the general quality (e.g., efficiency, arrangement, ease of viewing, etc.), of your helicopter instrument panel."

a. Unacceptable

b. Acceptable for instrument training in VMC only

c. Adequate for instrument flying in IMC

d. Excellent

The following resulted:

	Heavy Lift	Light Lift
Unacceptable	4%	3%
VMC Training	4%	33%
Adequate for IMC	80%	59%
Excellent	12%	5%

The assumption that the H/L pilots are generally more satisfied with their instrument panel than their L/L counterparts is apparent. It must be reiterated that the H/L helicopters are crew served and thus have instrument panels for both pilots while the L/L pilots are faced with marginal panels when flying in the left seat (copilot's station). The L/L aircraft flight manuals recommend two pilots for planned IFR flight and thus force IMC operations from the left seat. Several comments were made which pointed to this fact.

Responses to this question were also treated by "conversion" vs "helicopter only" type pilots (see page 7 for explanation of terms) with the following results:

	"Conversion" Pilots	"Helo Only" Pilots
Unacceptable	0%	5%
VMC Only	16%	25%
Adequate for IMC	73%	64%
Excellent	11%	5%

While 30% of "helicopter only" pilots felt that their panels were unsuited for actual IMC flight, only 16% of the "conversion" pilots rated their panels in a similar manner.

After allowing for the type panels (H/L vs L/L) and finding no real distinction among pilots, it can only be determined that experience (that is, confidence) is the best explanation. This trend is found throughout - "Helicopter only" pilots tend to be a little more conservative than those pilots with fixed wing experience.

Question #4 - "What improvements would you make to your instrument panel?"

Since panel size, instrumentation and arrangement vary considerably, the following comments will be listed by specific type helicopter. These comments reflect the items most frequently mentioned.

H-3 (Heavy Lift)

- Course indicator changes were the most frequently mentioned item. Suggestions ranged from improving the lighting to total removal and replacement by a flight director system. The flight director was mentioned by 35% of the responding pilots.

- Several requests to move the turn and slip indicator up on the panel.

- Complaints about the copilot's cyclic grip blocking his turn and slip indicator was a common problem cited by several H-3 copilots.

- Many pilots identified problems with the entire left (copilots) side of the panel. The comments were aimed at providing the copilot the same quality of displays that the aircraft commander presently utilized. Specific left side displays mentioned as needing improvement were: reposition attitude indicator directly in front of the copilot, improve the turn and slip indicator and reposition; add a clock to copilot's panel, and put more effort in standardizing left and right side instrument locations.

- The entire cockpit was consistently written up for the poor quality of the lighting. This area is discussed in detail on page 12 .

- The radar altimeter also received some negative comments. These comments delt with the maintenance and reliability of the instrument rather than the location or "cosmetics" of the display.

- Forty-three percent of the responding pilots made suggestions involving either swapping presently installed instrument locations or moving instruments to totally new positions.

- Items that were listed by relatively few pilots but have merit were: Use of tape instruments, addition of an approach plate holder, improve airspeed indications, tilt entire instrument panel to reduce paralax and add an "area navigation" system and Heads-Up Display.

H-53 (Heavy Lift)

A flight director also led the list (39%) of improvements requested by these pilots. Swapping instruments was not as common with this group as with the H-3 pilots. The only change mentioned by a significant number of subjects was swapping the radar altimeter with the vertical speed indicator. Poor lighting was consistently mentioned with one individual suggesting that the entire instrument panel be painted black with white faces on instruments. Tape instruments, a weather radar and a doppler with groundspeed readout were cited as possible improvements.

H-1 Series (Light Lift)

Light Lift comments were indicative of the relatively austere instrumentation provided in all types of helicopters making up this group.

Their desires were for such things as TACAN and ILS capability as compared to the weather radar and area navigation requested by their H/L counterparts.

Another trend was one which was found, to a lesser degree, in the H/L responses was the request for improvement of the copilot's displays. As previously mentioned, while the L/L helicopters are single pilot aircraft, flight manuals require planned instrument flight be conducted with two pilots at the controls and thus force instrument flight from the left seat (copilot's station).

Improvement of left panel was directed, primarily, at the replacement of the J-8 attitude indicator. Appendix D contains a brief description of this instrument with a more detailed discussion of its problems found on page 14 . Addition of a turn and slip indicator and course indicator type information was also listed as the minimum required for the upgrade of the copilot's station.

Another requested item was expanding the entire panel to the right in order to reduce paralax. Tilting the panel was also recommended.

Addition of radar altimeters, tape instruments, instantaneous vertical speed indicators and flight directors were commonly requested items.

The standby magnetic compass seemed to present a problem to several H-1 series pilots in that it was poorly located and should be moved. Possible locations included center post on wind screen or overhead (eyebrow) panel.

The only problems peculiar to any particular L/L type helicopter seems to be the UH-1N master caution light location. "N" model pilots stated that the two fire pull handles block the copilot's view of the master caution light (See appendix E).

The general trend established from the overall quality of the panel in question #3 continued in the comments question in that the H/L pilots requested refinements while the L/L pilots were more concerned with acquiring basic equipment installation. As one UH-1N pilot put it: "the ashtray is in a more prominent position than the clock."

In summary, the following general items were offered as improvements: The percentages indicate percent of total (H/L and L/L) responses

-28%* requested that the J-8 attitude indicator be replaced.

-28% wanted to add a flight director system.

-25% wanted to improve copilot's panel.

-22% wanted to improve course indicator.

-18% cited need for improved lighting.

-18% asked for changes in instrument arrangement.

-12% wanted radar altimeter installed or improvement made to currently installed system.

-11% cited need for improved turn and slip indicator.

-11% requested changes to attitude indicator.

-8% wanted entire panel either moved or tilted.

*Direct request for replacement of J-8 by pilots with J-8 equipped aircraft.

A much higher percentage would result if statements such as "redesign entire copilot's side," "Copilot's side unacceptable for IFR operation," etc., were added to the totals.

As has been previously mentioned, aircraft instrument lighting has been the single most critiqued item.

Instrument Panel Lighting (Q 25,26)

Question #25 - "Rate the Overall Quality of the Instrument Panel Lighting in your aircraft: A - Unsatisfactory, B - Fair, C - Good, D - Excellent."

Ratings were as follows:

	H/L	L/L
Unsatisfactory	29%	11%
Fair	37%	53%
Good	29%	30%
Excellent	5%	6%

Question #26 - "Describe any particular problems with the instrument lighting in your aircraft." In response to this question and #25, no real difference between the H/L and L/L pilots can be determined. The much larger percentage of H/L pilots finding their lighting unsatisfactory is unexplained by the analysis performed. When combined, the unsatisfactory and fair percentages (66% - H/L and 64% L/L), they tend to be allied in their general negative regard for their lighting.

Comments were generally applied to all the instruments with only the course indicator being singled out. Pilots were unanimous in their opinion that it is impossible to set a course in the indicator without either a flashlight or other aircraft lighting source; that is, map light, flood lights, etc.

The external type lighting (peanut or post lighting) received many negative comments. Flicker, short life, "hot spots" and resultant reflections as well as post blocking view of the instrument were all attributed to the external type lighting.

Internal type lighting was found to be more suitable but did draw some negative responses in that the pilots felt that it was very costly to replace an entire instrument when the bulbs burned out.

While the L/L panels used mostly red lights the H/L panels have mixes of red and white light displays. Both groups of pilots felt that white lighting was superior but that a mix was worse than an all red system.

Some problems with wiring (shorts that produce flickers), imbalanced rheostats resulting in bright spots, and, in one case (H-53), pilots rheostat that controls some of the copilots displays were mentioned.

A few pilots also identified instruments that were not lighted at all; for example, the UH-1Ns standby compass.

Both H/L and L/L pilots agreed that internal, white light was the best system currently in use.

INDIVIDUAL DISPLAYS

Attitude Indicators (Q 5, 6)

Question #5 - "Rate each of the following aspects of your attitude indicator: 1 = Unacceptable, 2 = Acceptable for instrument training in VMC only, 3 = Adequate for instrument flying in IMC, and 4 = Excellent."

	J-8	MM	Other
a. Precession.			
b. Color Scheme.			
c. Location of bank index.			
d. Graduation of pitch scale.			
e. Pitch/roll trim.			
f. "Thickness" of miniature aircraft.			
g. Ease of interpretation.			
h. Overall quality of display			

Question #6 - "Comment on any aspect of your attitude indicator you feel is important but which has not been adequately expressed above."

Attitude indicator data is based on type indicator rather than aircraft as ratings were found to be consistent from type helicopter to type helicopter. For description of specific attitude indicators, refer to appendix D.

The following chart represents the overall percentages of each rating award to the applicable attitude indicators.

	J-8	MM Series	4005
Unacceptable	37%	2%	0%
Acceptable for VMC Only	35%	10%	4%
Adequate for IMC	27%	70%	62%
Excellent	2%	18%	34%

When comparing both the overall ratings (above) and the individual parameter ratings for the J-8 vs the MM series attitude indicators, it is obvious what value the pilots place on the J-8.

While only 6% of the pilots found the precession qualities of MM indicator to be unsuited for actual weather flying, 89% of the J-8 raters placed that instrument in the unsuitable catagories. This trend continued throughout the ratings of aspects of the J-8 vs MM series attitude indicators. As a further indication of the display acceptability, the J-8 was rated in the lower two categories (unsuitable for actual

weather operations) by 70% or more in every rating parameter except location of bank index (54%), while 15% represents the biggest unsuitable rating received by the MM attitude indicator.

The rating distinctions between the 4005 attitude indicator and the MM type indicator are much less obvious than those between the J-8 and MM indicators. All parameter ratings of the 4005 indicators were rated as excellent by 25% or more of the subjects. This compares to only one parameter (precession) for the MM indicator receiving an excellent rating by the same 25% margin.

Location of the bank pointer was the only rating parameter that was found to be adequate for actual weather flying on all three indicators by any significant number of subjects (J-8 = 100%, MM = 93%, 4005 = 100%).

When given a chance to comment about their attitude indicators, the J-8 pilots stated that the instrument was "worthless," "needs pitch scale," "needs color," "precession is excessive", and "totally unacceptable for actual instrument flight." It must be remembered that the J-8 indicator is used on the copilot's side of the instrument panel and is his only attitude information source.

The MM and 4005 attitude indicators drew more constructive comments. In the case of the MM indicators, the need for a turn and slip indicator located at the bottom of the indicator was a common request. Expanded pitch scale, thinner miniature aircraft symbol and the need for a more accurate roll trim were commonly identified by both MM and 4005 display users.

One comment that was related to attitude instrument flying as it applies to helicopters was common to all type aircraft regardless of model attitude indicator being utilized. The pilots concern was with the extremely high pilot activity in the pitch axis necessary to maintain airspeed. This type of statement was usually followed by a request for a totally new attitude indicator designed specifically for helicopters. These attitude problems are unique to helicopters because all current attitude indicators reference fuselage attitude rather than the rotor plane attitude. As a result, a control input is applied through the cyclic stick producing a change in the rotor plane attitude. A lag is then induced while the fuselage (present aircraft attitude) indicator source, attempts to match actual attitude (rotor plane).

In summary, the pilots are commenting on the attitude displays as well as questioning the source of that attitude information displayed.

Altimeters (Q 7, 8)

Question #7 - "Do you feel that any aspects of your altimeter display lead to misreading altitude?"

3-Pointer		Counter-Drum-Pointer	
Yes ___	No ___	Yes___	No___

Question #8 - "What changes are desirable in your altimeter display (e.g., expanded scale, change low altitude warning symbol, tape)?"

Thirty percent of the pilots using the 3-pointer altimeter (see appendix D for description) reported misreading the altimeter as compared to 22% of the counter drum pointer users encountering interpretation problems.

The most common cause cited for misreading the 3-pointer altimeter was the 10,000-foot pointer. They indicated that the 10,000-foot information was not required and only served to "clutter" the display. Poor instrument lighting was also faulted by two subjects. The problems identified with the counter-drum-pointer system were mainly mechanical hangups in the drum display. Pauses of the pointer at 1,000-foot intervals were a common complaint. Most subjects stated that they preferred this system over the 3-pointer altimeter display.

Specific improvements expressed were basically common to both H/L and L/L pilots. Overall, 31% of the pilots felt that there was no change necessary in their altimeter display. The general improvements requested are as follows:

- 20% felt a tape display would improve their altimeter.

- 14% wanted a low altitude warning device.

- 12% requested an expanded altitude scale below 1,000 feet.

- 11% of the 3-pointer system users wanted to switch to the counter-drum-pointer system.

- 9% of Light Lift pilots requested a radar altimeter.

Other requested improvements included color coding of the pointers, improved lightings, a system which is not affected by rotor wash, moving indicators closer to attitude indicator, and work on eliminating the mechanical hang-ups in the counter-drum-pointer system.

Altimeters (Q 9, 10)

Question #9. "Rate the overall readability and effectiveness of your heading display: A = Unacceptable, B = Acceptable for instrument training in VMC only, C = Adequate for instrument flight in IMC, D = Excellent."

Question #10. "What improvements would increase the effectiveness of your heading display?"

There are two basic types of heading information indicators currently used in Air Force helicopters, the radio magnetic indicator (RMI) and the Bearing-Distance-Heading Indicator (BDHI). All helicopters also have a standby magnetic compass to be used as a backup source but were not addressed by the subject pilots since it is not a primary instrument. The BDHI is installed in the two heavy lift helicopters as well as the H-1N. All the remaining helicopters utilize the RMI type indicator. For more specific information about the RMI and BDHI, refer to appendix D.

The only apparent difference between the rating received by these two displays was that, while none of the RMI users found their heading display to be excellent, the BDHI systems were judged to be excellent by 14% of the pilots flying with BDHIs. Another interesting aspect of the heading display ratings is found in rating for the BDHI as they varied from type helicopter to helicopter. Only one heavy lift pilot (H-3) rated his heading display as unacceptable. The same instrument installed in the H-1N was unacceptable to 14% of the "N" pilots. At this point it is important to point out that both the H/L helicopters have stability augmentation systems with "heading hold" features, while the H-1N is unaugmented. The shift in ratings might be, in part, indicative of a stability problem. The problems of stability are discussed in Section III of this report. The following charts present the ratings for H/L and L/L heading displays.

	H/L	L/L
Unacceptable	2%	5%
VMC Instrument Training Only	6%	21%
Adequate for IMC flight	80%	67%
Excellent	12%	7%

A combination of display problems and lack of stability in Yaw Axis could possibly explain the lower L/L ratings.

Heading display improvements were suggested by 45 BDHI pilots and 54 RMI pilots. A Flight Director led the list (13 pilots) from the BDHI users followed by requests for increased size and scale of display (12 requests), improve lighting (8 requests), a moveable heading "Bug" (7 requests) and relocating the entire display (6 requests). Color coded bearing pointers, improved system accuracy (compass), moving heading information to the attitude indicator, and taking DME out of the instrument and relocating elsewhere were also mentioned by three or more pilots

using a BDHI display.

The RMI system received very similar comments in that the same items were mentioned with exception of the DME relocation as this indicator doesn't contain range information. The frequency in which items were requested varied slightly with increasing the size and scale leading the RMI list. A heading "bug" for the copilot's indicator (pilot already has one) was the second most frequently requested item with a flight director system, improved location and increased accuracy completing the RMI list.

Airspeed Indicators (Q 11)

Question #11 - "Please rate your airspeed display categories. Use the following scale: 1 - Unsatisfactory, 2 - Fair 3 - Good, 4 - Excellent."

	0-40 kts	40-70 kts	70-100 kts	Over 100 kts
Yaw Sensitivity				
Pitch Sensitivity				
Scale				
Overall Quality of Display				

All helicopters currently use conventional fixed wing pitot static airspeed sensors and displays. The effect of rotor wash on these systems necessitates comments in flight manuals warning pilots of limitations. An example of such a comment is the warning contained in the all weather procedures section of the H-1F flight manual under discussion of a restricted visibility takeoff. "Airspeed, vertical velocity, and altitude indications are unreliable below 25 knots indicated airspeed because of rotor downwash effect on the pitot static system. During takeoff, do not rely on these instruments until the airspeed indicator reads at least 25 knots indicated airspeed."[2] This limitation, coupled with an instrument originally designed to operate accurately at much higher airspeeds (fixed wing), combine to severely restrict low speed accuracy of the conventional pitot static system/display.

The ratings for the 0-40 knot operating range indicate that both H/L and L/L pilots found the yaw, pitch, and overall quality of the display to be unacceptable. The 'scale' parameter was rated "good" by the majority of the Light Lift pilots while it was dropped to "fair" by the majority of the Heavy Lift pilots. This difference between H/L and L/L raters is, in part, explained by comments directed at airspeed indicators during discussion

2. T.O. 1H-1H-1(U)F-1 Flight Manual, 1 April 1971, Change 5 - 15 Aug 75, p. 9-2.

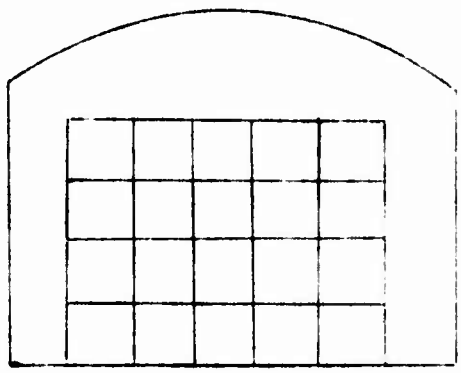
of the overall panel. Several H/L pilots expressed displeasure with the 0-250 knot range indicators installed in their cockpits. This display presents 50 knots at the 2 o'clock position while the L/L pilots have 50 knots positioned at the 5 o'clock position (0-150 knot range indicator). The resultant scale compression is reflected in the lower H/L ratings.

The 40-70 knot speed regime produced improved rating with all parameters being rated as "good" by the majority of the pilots both H/L and L/L, with the exception of the yaw sensitivity. While H/L pilots found this parameter to be "good", the L/L pilots judged their display to be only "fair" in this speed regime. Once again the possible lack of stability may be influencing the ratings.

The 70-100 knots and over 100-knot speed regimes produced "good" ratings in all parameters by the majority of pilots.

Improved Displays (Q 12)

Question #12 - "Please construct an ideal instrument panel display that you would like to fly. Use only the instruments you need for instrument flight and enter only one instrument letter per block."



a. Attitude Indicator
b. Attitude Director Indicator
c. Course Indicator
d. Airspeed Indicator.
e. Radio Magnetic Indicator
f. Altimeter
g. Vertical Velocity Indicator
h. (Round dial)
i. Turn and Slip Indicator
j. Bearing-Distance-Heading Indicator
k. Horizontal Situation Indicator
l. Radar Altimeter
m. Hover Indicator
n. Doppler
o. Power Instrument (i.e., fuel flow, torque, etc.)
p. Instantaneous Vertical Speed Indicator
q. (Other - specify) _____
r. (Other - specify) _____

This question provided an opportunity to not only change various displays but also rearrange current instruments. As would be expected, the variations were proportional to number of responses. Pilots tended to retain current locations for major components; for example, attitude indicators, heading information, airspeed, vertical rate, and altimeters while supporting displays such as radar altitudes, doppler, hover indicators power instruments were scattered around the perimeter of the basic

instruments. Those instruments placed in more than one block indicate more than one location identified by a significant number of pilots.

H/L

N	D	A	F	
N/P	E	B/C/E/H	F/G	
L		H/I/J	C/K/O	
M		L/M		

L/L

	D	A/B/E/L	O/G	
N/P	D/H	A/B/E/J	F/O/G	
P	M	A/C/H/J	I/K/M	
		M		M

Perhaps of more interest is the frequency at which instruments were selected. As would be expected, the possible combinations resulted in a relatively low percentage selection rate for most instruments. Those instruments most frequently selected were:

Airspeed Indicator - 94%

Altimeter - 93%

Radar Altimeter - 73%

Turn and Slip Indicator - 66%

Attitude Director Indicator - 60%

Horizontal Situation Indicator - 60%

Instanteous Vertical Speed Indicator - 60%

Bearing-Distance-Heading-Indicator - 58%

Hover Indicator - 48%

Vertical Velocity Indicator - 47%

Attitude Indicator - 45%

Doppler - 45%

Course Indicator - 44%

The remaining instruments were selected by less than 40% of the subjects answering the question. Power instruments and "other" ('P' and 'Q') were listed by all subjects but due to the variety of displays encompassed in these categories they are not addressed in this discussion.

of the overall panel. Several H/L pilots expressed displeasure with the 0-250 knot range indicators installed in their cockpits. This display presents 50 knots at the 2 o'clock position while the L/L pilots have 50 knots positioned at the 5 o'clock position (0-150 knot range indicator). The resultant scale compression is reflected in the lower H/L ratings.

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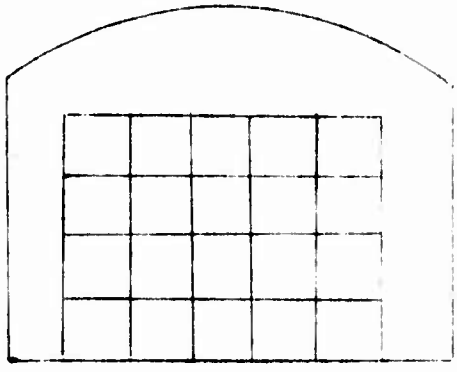
e. Radio Magnetic Indicator
f. Altimeter
g. Vertical Velocity Indicator
h. (Round dial)
i. Turn and Slip Indicator
j. Bearing-Distance-Heading Indicator
k. Horizontal Situation Indicator
l. Radar Altimeter
m. Hover Indicator
n. Doppler
o. Power Instrument (i.e., fuel flow, torque, etc.)
p. Instantaneous Vertical Speed Indicator
q. (Other - specify) _____
r. (Other - specify) _____



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instruments. Those instruments placed in more than one block indicate more than one location identified by a significant number of pilots.

H/L

N	D	A	F	
N/P	E	B/C/E/H	F/G	
L		H/I/J	C/K/O	
M		L/M		

L/L

	D	A/B/E/L	O/G	
N/P	D/H	A/B/E/J	F/O/G	
P	M	A/C/H/J	I/K/M	
		M		M

Perhaps of more interest is the frequency at which instruments were selected. As would be expected, the possible combinations resulted in a relatively low percentage selection rate for most instruments. Those instruments most frequently selected were:

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Vertical Velocity Indicator - 47%

Attitude Indicator - 45%

Doppler - 45%

Course Indicator - 44%

The remaining instruments were selected by less than 40% of the subjects answering the question. Power instruments and "other" ('P' and 'Q') were listed by all subjects but due to the variety of displays encompassed in these categories they are not addressed in this discussion.

In comparing H/L and L/L responses it was obvious that both groups were more concerned with arrangement of displays rather than including new (to their helicopters) displays. An example of this trend is the H/L pilot selecting radar altimeters (79%), hover indicators (70%), doppler (67%), and BDHI's (67%) - all equipment presently installed in most H/L helicopters. The same displays were selected by the following percentage of L/L pilots: Radar Altimeters (57%), Hover Indicators (26%), Doppler (22%), and BDHIs (52%) - all equipment not normally found in present L/L helicopters.

This trend is also indicative of the realization that aircraft limitations (for example, what good is a hover indicator if aircraft is not stable enough to hover on instruments?), very limited funds for retrofitting improvements, and the tendency to accept what you have and make do simply because you have "gotten by" with it for years. Once again, it must be stressed that 60% of the pilots responding have never flown fixed wing aircraft and, therefore, have little or no experience with some of the advanced displays mentioned.

Another difference between H/L and L/L panels was the selection rate for the turn and slip indicator. While only 49% of the H/L pilots included the turn and slip indicator in their panel, the same instrument was selected by 77% of the L/L pilots. A possible explanation might lie in the fact that H/L helicopters have stability in the yaw axes while L/L helicopters are unaugmented and, thus, require displays for yaw performance.

Flight Directors (Q 13, 14)

Question #13 -"Would you like to have a flight director system in your aircraft?

Yes ___, Why? No ___, Why Not?"

Question #14 - "What features would be most desirable in a flight director for helicopters (for example, power information, rising pad, hover information, etc.)?"

The flight director (F/D) has been mentioned as a possible improvement in response to questions #4, #6, and #10, and listed in ideal panel (#12).

Question #13 was the first direct reference as to the desirability of a helicopter F/D. Light Lift and Heavy Lift pilots were in agreement on this question in that 78% of the H/L pilots and 81% of the L/L pilots stated that they wanted a F/D for their helicopters. Ease and speed of cross-check, reducing panel "clutter" and ease of instrument training

and transition from one aircraft (fixed wing or helicopter) to another were the chief reasons for wanting a F/D system.

Those individuals that did not want the system cited age of aircraft, general pessimism about the availability of funds for future of advancing instrument flying in helicopters, and lack of application ("99% of mission is VMC") as reasons for not wanting a F/D system.

Lack of basic aircraft stability (primarily L/L) was presented as rationale by those both for and against a flight director system. Those for the system pointed out command information might help compensate for lack of stability while those opposed to the system felt that their helicopters were so unstable that the stability must be treated before the pilot could use any advanced displays.

While stability was the chief problem cited by L/L pilots, the H/L (already stabilized) helicopter pilots were skeptical about reliability and maintenance of such equipment.

Responses were also analyzed with respect to previous F/D experience. The information was obtained from responses to question #1 (appendix B).

Of the 13 "helicopter only" pilots who had flown a flight director before (presumably in civilian fixed wing aircraft), 92% wanted a F/D. Of the 39 "conversion" helicopter pilots with flight director experience, 82% wanted such a system installed in their helicopters. Those pilots who had no experience with flight directors were in favor of installation by 76% "helicopter only" and 71% "conversion." It appears that previous experience with a flight director system makes the addition of such a system even more desirable.

When asked to comment on desirable features for a helicopter flight director, no real difference between H/L vs L/L, or "conversion" vs "helicopter only" pilots appeared.

All the conventional flight director features were requested; navigation capability, approach information, and pitch and roll commands were among the most common. Features unique to a helicopter flight director were as follows (in order of most frequently selected):

Hover information.

Collective (power) command.

Rising Pad.

Radar Altitude.

Airspeed - including below 40-knot information.

Desirability of a F/D system was also related to the ratings subjects gave their current panel. Of those who rated their current panel:

"Excellent" - 70% wanted a F/D.

"Adequate for IMC" - 75% wanted a F/D.

"Acceptable for VMC Only" - 96% wanted a F/D.

"Unacceptable" - 75% wanted a F/D.

The combination of an already "excellent" panel and a 70% desirability rate for a F/D is a significant factor. At the other end of the scale - a currently "unacceptable" panel drew a 75% F/D rate. Comments similar to those previously discussed - lack of stability, not cost effective due to age of aircraft, and lack of mission application help explain the lower F/D selection rate with an unacceptable panel.

A similar comparison is made between the ratings given to the quality of his current heading display (question #9) and how the pilot felt about adding a Flight Director System.

Of the 93 pilots requesting a F/D, 75% found their current heading display adequate for IMC operations; 13% felt their heading display was suitable for VMC only; 7% felt they already had an excellent system but still wanted a F/D; and 5% rated their heading display as unsatisfactory. The obvious conclusion is that despite an already good heading system, the pilots felt a flight director system desirable.

These responses can leave little doubt as to the desire of the helicopter pilots - the flight director proved to be the most requested display improvement cited in this questionnaire.

Tape Displays (Q 18, 19)

Question #18 - "Would tape type displays improve your instrument flying? "

Yes ___ No ___ Please explain.

Question #19 - "If tape instruments were incorporated in your aircraft, which instruments would you like to see converted to tape type?"

	Yes	No
Engine Instruments		
Power Instruments (Collective)		
Altimeter		
Vertical Velocity		
Airspeed		
Other		

Only nine of the 116 subjects answering question #18 indicated that they had ever flown an aircraft with tape instruments (response to question #1 provides tape experience information). Despite the lack of experience an overall 71% answered question 18 with a "yes." H/L pilots were more in favor of tapes than L/L pilots with a 78% vs 64% selection rate being recorded. Comments dealt with explaining their lack of experience and, in the case of the Light Lift pilots, concern with the quality of the display for any information other than power instruments because of the unstable nature of the platform. Improved cross-check, reduced space, and increased accuracy and reliability were reasons cited for wanting such displays.

When asked to identify specific instruments for conversion to tapes, the subjects were even more hesitent in that only about 80 answered question #19. Once again, lack of experience is chief reason cited for not answering the question. The following information presents both subjects with no tape experience and the very small group (9 subjects) with previous experience. Percentages are of those answering "yes."

	No Experience	Previous Experience
Engine Instruments	58%	71%
Power Instruments	77%	71%
Altitude	54%	75%
Vertical Velocity	51%	75%
Airspeed	61%	83%

The differences between H/L and L/L pilots were not considered significant. Since so few pilots had any tape display experience, it might be concluded that their desires reflect a comment against conventional "round dial" displays as much as a desire for tapes. Those with previous experience gained all their tape experience in fixed wing aircraft but still felt that tapes could be applied to rotary wing aircraft instrumentation.

SECTION III

Analysis of Stability Responses

In order to understand how various axes of the aircraft relate to the pilot, we need to establish how the pilot relates his displays to these various axes. The follcwing question establishes this relationship.

Question #23 - "What instruments do you rely on most heavily for control/performance information related to (list only those instruments you use:)"

a. Pitch Axis _____ _____ _____

b. Roll Axis _____ _____ _____

c. Yaw Axis _____ _____ _____

The responses are broken down by pilots total flying time. Percentages represent percentage of total responses but only most frequently listed instruments are included.

1500 Hours or Less

	1st	2nd	3rd
Pitch Axis	Attitude Ind. 90%	Airspeed 42% Vertical Velocity 39%	Altimeter 50% Vertical Velocity 21% Airspeed 17%
Roll Axis	Attitude Ind. 90%	Turn/Slip 48% Compass 42%	Turn/Slip 53% Compass 41%
Yaw Axis	Turn/slip 63% Compass 33%	Turn/slip 52% Compass 30%	None significant

Over 1500 but Less Than 2500 Hours

	1st	2nd	3rd
Pitch Axis	Attitude Ind. 91% Airspeed 9%	Vertical Velocity 44% Airspeed 38%	Altimeter 62% Vertical Velocity - 23%
Roll Axis	Attitude Ind. 95%	Compass 61% Turn/Slip 39%	None Significant
Yaw Axis	Turn/Slip 71% Compass 29%	Compass 73% Turn/Slip 20%	None Significant

Over 2500 Hours

	1st	2nd	3rd
Pitch Axis	Attitude Ind. - 95%	Vertical Velocity 52% Airspeed - 32% Altimeter - 13%	Vertical Velocity 26% Altimeter - 23%
Roll Axis	Attitude Ind. - 100%	Compass - 59% Turn/Slip - 38%	Turn/Slip - 77% Compass - 23%
Yaw Axis	Turn/Slip - 87%	Compass 70% Turn/Slip 25%	None Significant

In all cases the attitude indicator is the primary instrument used to reference pitch axis performance with vertical velocity being the second performance source in this axis. The responses seem to indicate that the newer pilots use airspeed as a second source and, as experience is gained, the vertical velocity replaces airspeed as a secondary performance parameter. The altimeter is the most frequently used third order pitch performance instrument for all but the most experienced group of pilots. This group (over 2500 hours) favor the vertical velocity indicator over the altimeter as a third pitch performance source.

Roll information was most frequently obtained from the attitude indicator by all three groups of pilots. Pilots with less than 1500 hours used the turn and slip indicator as a secondary source of roll information while the higher time pilots listed the compass (heading indicator) as most frequently used to back up the altitude indicator for roll information. The turn and slip indicator was relegated to the third source by all but the 1500-2500 hour group which had no real preference for third order information.

Yaw axis performance was obtained from the turn and slip indicator with the compass providing a second source. The least experienced group (1500 hours or less) differed from the others in that they selected the turn and slip indicator more frequently as both first and second source information. No significant third order yaw axis performance source was identified.

The same question was also analyzed by comparing "helicopter only" vs "conversion" pilot responses. The first percentage listed applies to "helicopter only" pilot responses while the second number represents "conversion" pilot responses.

	1st	2nd	3rd
Pitch Axis	Attitude Ind. 87%/98%	Vertical Velocity 41%/55% Airspeed 34%/34%	Altimeter 32%/47% Vertical Velocity 20%/31%
Roll Axis	Attitude Ind. 90%/94%	Turn/Slip 52%/23% Compass 24%/73%	Turn/Slip 54%/63% Compass 38%/25%
Yaw Axis	Turn/Slip 68%/76%	Compass 61%/72% Turn/Slip 39%/28%	None Significant

The source of pitch information seems common to both groups with exception of the 3rd source. Data would indicate that the "conversion" pilots tend to use their vertical velocity indicator more than the "helicopter only" pilots. They also tend to agree more on their sources of information than the "helicopter only" pilots.

Roll information sources are comparable for both groups with the exception of the increased importance placed on the compass (heading indicator) as a secondary source by the "conversion" types.

Yaw axis information is common to both groups.

Generally, "conversion" pilots tended to use the turn and slip indicator as a second or third source of information more than the "helicopter only" pilots. The tendency to agree among themselves was also consistently exhibited by the "conversion" pilots and can be attributed to, in most cases, a higher experience level than the "helicopter only" pilots enjoy.

Trim Systems

Question #22 - "Please rate your helicopter trim system. Circle one. A = Unacceptable, B = Acceptable for VMC instrument training only, C = Adequate for instrument flying in IMC, D = Excellent."

While 60% of the L/L pilots felt their trim system not suited for actual IMC operation, only 8% of the H/L pilots placed their trim systems in the same category.

Comments from the H/L pilots indicated that the H-3 pilots wanted a turn coordination feature similar to the H-53 system included in their helicopters.

L/L pilot comments were very critical of their systems. "Constant attention," "retrimming constantly," "won't hold a set position," "lagging and sticking system," and several pilots saying they turn the system off were typical comments. Some pilots also stated that while it was a good VMC aid, it was worthless in IMC.

Automatized Flight Controls

Question #15 - "To operate in IMC for any extended period of time, would you consider automatized flight controls to be: A = Essential, B = Not essential but desirable, C = Not required."

As would be expected, H/L and L/L pilots had a considerable difference of opinion. Responses were as follows:

	H/L	L/L
"Essential"	68%	45%
"Not essential but desirable"	30%	51%
"Not required"	2%	4%

The most significant figure derived from this question is that 45% of the L/L pilots considered augmentation essential for extended IMC flight. When combining the first two ratings we can see the priority both types of helicopter pilots place on stability - 98% of H/L and 96% of Light Lift pilots want a stability augmentation system.

By relating responses to the trim question (#22) and to the stability question, the following results:

Those who considered automized flight controls	and who also rated their trim system			
	Unacceptable	VMC Only	IMC	Excellent
"Essential"	10%	32%	34%	24%
"Not essential but desirable"	19%	17%	46%	19%
"Not required"	0%	50%	50%	0%

Those that felt that stability was essential also felt trim was excellent by a larger percentage than any other group. Equally important was the large percentage of pilots that felt their trim was suitable for weather operations and still wanted a stability system. The very small group that felt stability was not required based their decision on age, airframe and lack of IMC mission.

The next few questions deal with identifying the axes which were most demanding in various approaches.

Question #21 - "If you were to fly a steep approach ILS (imagine your VFR steep approach, angle and airspeed), which axis would prove most difficult? Please rate degree of difficulty."

	Least Difficult 1	2	3	4	5 Most Difficult
Pitch Axis					
Roll Axis					
Yaw Axis					
Collective Control					

Results indicate that the roll axis proved to be the least difficult followed by yaw and collective control with pitch axis control being the most difficult to control.

Only slight differences were noted between H/L and L/L responses. While only 1% separated the yaw and roll axis ratings for least difficult axis by the L/L pilots; the H/L pilots were undecided as to the 2nd most difficult axis. H/L ratings resulted in an equal number of pilots finding collective control and pitch the second most difficult parameter.

Question #20 - "Have you ever flown an instrument approach steeper than 3°?"

Yes ___ No ___ If yes, please comment on difficulties encountered.

Only 30% of the responding pilots had ever flown an actual steep instrument approach (more than 3°). Most comments were directed at problems with vertical rate control. This tends to substantiate the ratings derived from question 21 in that collective control (altitude) and pitch (airspeed control) were the two most difficult parameters. Airspeed and its effect on vertical rates is a major problem encountered in any steep approach, whether a VFR type approach or on instrument approach.

Question #24 - "For a normal precision approach, rate the degree of difficulty in control:"

	Least Difficult 1	2	3	4	5 Most Difficult
Yaw Axis					
Roll Axis					
Pitch Axis					

Yaw was found to be the least difficult axis followed by roll axis with the pitch axis being rated the most difficult axis. Once again, ratings were much closer among the L/L pilots - only 3% difference between yaw being the least and the most difficult axis. The end result was that 41% of the L/L pilots rated yaw most difficult as compared to 20% yaw rating by H/L pilots - once again lack of stability (L/L) can be cited as a major factor.

The obvious difference between the steep approach ratings and the normal approach ratings was the least difficult rating swapped from yaw in the normal approach to roll in the steep approach. Pitch was judged most difficult in both cases. The conventional problems with pitch are due, in part, to the basic source of attitude information previously discussed (see page 15). The fact that yaw drops to least difficult in the normal approach can be explained by the reduced magnitude of power changes and thus reduced torque changes required on a normal approach. The subjects were then asked to establish a priority for installation of augmenting various axis.

Axes Augmentation Priority (Q 16, 17)

Question #16 - "If automatics were installed in your helicopter, what priority would you assess to their installation. Use 0 = Not required, 1 = First to be installed, 2 = Second to be installed, etc."

Instrument Flight

Under 50 Knots		Over 50 Knots	
Roll Axis		Yaw Axis	
Yaw Axis		Collective Assist	
Pitch Axis		Roll Axis	
Collective Assist		Pitch Axis	

Question #17 - "Make any further comments you feel would be appropriate in developing improved pitch, roll, yaw, and collective control."

Question 16 was intended to relate the under 50 knots responses to a steep approach with over 50 knots being typically employed on a normal approach. Order of installation was as follows:

Under 50 Knots	Over 50 Knots
Yaw Augmentation (first)	Pitch Augmentation (first)
Roll Augmentation	Roll Augmentation
Pitch Augmentation	Yaw Augmentation
Collective Assist (last)	Collective Assist (last)

When relating this information to the degree of difficulty awarded in questions 21 and 24, some apparent contradictions exist. This is especially true when it is noted that only 3% separated pitch and yaw for first to be installed in the over 50 knots category. Comments received in response to question 17 help to clarify the issue. While yaw was not identified as the most difficult axis in either type of approach, it was found to be active enough to dictate the pilots' selection as first to be installed in the under 50 knots category and within 3% of first to be installed in the over 50 knots approaches. Comments indicated that yaw, while not difficult to control, did occupy the pilot (that is, workload) to the extent that he felt that it should be the first axis augmented and thus unburden him the most. Turn coordination feature was a requested feature in a yaw augmentation system.

Pitch stability was also mentioned as an area of concern. Turbulence and its effect on airspeed/altitude was cited as an area needing improvement. Automatic hover coupler and ILS type approach capability was frequently requested.

The fact that none of the pilots rated any single axis as not required is significant.

Navigational Aids

Question #27 - "What type of navigation/approach system(s) would be best suited for helicopters?"

The most frequently requested systems are listed below along with number of subjects making the requests.

ILS (75)

TACAN (55)

VOR (29)

Area Navigation (RNAV), Inertial Navigation System (20)

ADF (10)

VOR/DME (9)

Precision approach capability - Remote (8)

Doppler (8)

Transponder (8)

On board radar (4)

Improved communication radios for radar approaches (3)

One can see that most pilots are striving to achieve even the most basic equipment for their aircraft. Refer to appendix 1 for description of current equipment.

Question #28 - "How would improvements listed in responses to questions 4 and 21 be utilized to improve your operational capability?"

When asked how improved stability and displays would be utilized, safety was the most frequently mentioned aspect. Night and weather rescues were also listed as being possible (safely) with improved systems. Reduced pilot workload, improved accuracy, and expanded mission capability were also frequently mentioned.

There were some that felt since "95% of their missions were conducted in VMC there would be no improved mission capability."

Question #29 - "Please comment on any aspect of helicopter instrument flying you would like to see investigated by the Instrument Flight Center".

Requests to improve current panels, stability, and instrument reliability (navigation) were most common.

Advanced navigation systems and helicopter approach procedures to include steep, remote area instrument approach equipment/procedures were also frequently requested.

SECTION IV

FINDINGS

This section presents what is considered to be the major findings of this survey as expressed by approximately 20% of the active duty Air Force helicopter pilots currently serving in cockpit duties.

Helicopter pilots reported an extremely low amount of actual weather time in the previous 12 months. A 7.7 hour average was recorded with 20% of the Heavy Lift pilots and 53% of the Light Lift pilots claiming two hours or less actual weather time in the last 12 months. This lack of experience is further evidenced in that 79% of the responding pilots stated that they encountered actual weather on less than 5% of their missions.

A significant number of responding helicopter pilots felt that their current instrument panels (for example, efficiency, arrangement, ease of viewing, etc.) were unsuited for actual weather flying. While 36% of the Light Lift pilots rated their panels in this category, only 8% of the Heavy Lift pilots rated their panels in a similar manner. The difference between the Heavy Lift and Light Lift pilot ratings appeared to be in the lack of adequate copilot displays in current Light Lift helicopters.

Instrument panel lighting was judged to be either "unsatisfactory" or "fair" by 65% of the responding pilots. Of the current instrument lighting systems in use, integral white lighting was considered to be the best available by the majority of responding pilots.

Several instrument displays were found to have severe deficiencies in both information displayed or lack of adequate information.

- Airspeed indicators were found to be totally unusable below 40 knots.

- The J-8 attitude indicator was judged to be unacceptable for actual weather flying.

- The MM and Lear 4005 attitude indicators were judged to be more superior to the J-8 type but still suffer from an improper attitude source: that is, helicopter fuselage. An attitude source based on rotor plane was thought to be a better source for helicopter attitude reference.

- Tendency to misread 3-pointer altimeters is more pronounced than with the Counter-Drum-Pointer system.

- Heading indicators were found unsuitable by 8% of the Heavy Lift pilots while 26% of the Light Lift pilots rated their displays in a similar manner. This disparity between types could reflect lack of yaw stability in the case of Light Lift.

The single most requested display improvement was the addition of a helicopter Flight Director System (78% of Heavy Lift pilots and 81% of the Light Lift pilots). Those pilots with previous flight director experience were more in favor of the system than those without previous experience. Increased pilot experience produces a shift in which instruments the pilot relys on for various axis performance information. The general trend indicates that with increased experience, pilots tend to rely more on vertical velocity and heading indicator than "low time" pilots. The Light Lift helicopter trim system was considered unsuitable for actual weather operations by 60% of the Light Lift pilots while only 8% of the Heavy Lift pilots felt the same about their helicopter's trim system. The lack of stability augmentation could explain the lower trim ratings received by pilots of the unaugmented Light Lift helicopters.

When asked to relate the degree of difficulty in controlling various axes during both steep and normal approaches, it was determined that the pitch axis was the most difficult in both cases. The roll axis was the least difficult to control in a steep approach while yaw was found to be least difficult for a normal (3°) approach.

When asked to assess the priority of stability augmentation for both approaches, the below 50 knots approach (steep) resulted in yaw axis stability identified as the first to be installed. The over 50 knots approach (normal) produced pitch axis stability requests as the first to be installed most frequently. These responses would indicate that, in the case of the steep approach, while yaw is not the most difficult to control, it does involve a great deal of pilot workload and should be augmented first.

When asked to identify navigational aids most suited for their helicopters, the Light Lift pilots requested basic navigation systems (TACAN, ILS, VOR) for their helicopters, further reflecting the austere configuration of current Light Lift helicopters. Both groups requested systems such as area navigation, Doppler, hover displays, and more communication radios as aids to their mission accomplishment.

SECTION V

RECOMMENDATIONS

1. Recommend that an all axes - stability augmentation system - be installed on all helicopters required to operate in actual weather conditions.

2. Recommend that an improved trim system be provided in order to further reduce the pilot workload encountered during instrument flight in Light Lift helicopters.

3. Recommend that the J-8 attitude indicator be replaced and further improvements be made in order to provide the copilots with adequate displays for actual weather operations.

4. Recommend that further studies be conducted in order to determine an improved source of helicopter attitude information.

5. Recommend that a three-cue helicopter flight director system be evaluated in order to determine its effect on the pilot workload encountered during instrument flight.

6. Recommend that studies be made to acquire an accurate low airspeed system with omnidirectional capability for installation in helicopters.

7. Recommend that studies be conducted to determine the suitability of tape displays for helicopters.

8. Recommend that studies be conducted to determine the suitability of "state-of-the-art" navigation systems (that is, area navigation, improved Doppler systems, inertial navigation systems) for helicopters.

9. Recommend that improved panel lighting, installation of equipment to ensure basic navigation capability (TACAN, VOR, ILS), and addition of radar altimeters be retrofitted in all helicopters.

10. Recommend that emphasis on IFR flight be continued in order to further identify potential problem areas and increase the instrument flying experience level of helicopter pilots.

LIST OF APPENDIXES

Date Sent_____

Date Received_____

USAFIFC

INSTRUMENT EVALUATION FORM

A vital factor in the development and improvement of instrument displays is the utility of the display from the crew member standpoint. Valid data regarding this aspect of various displays are available only through analysis of displays currently in operational aircraft. The purpose of this questionnaire is to aid in the collection of data which may then be used to improve existing displays and aid in the developmental cycle of future cockpit presentations. The extent to which this questionnaire can contribute to improved displays depends largely upon your personal analysis. It is critical that your comments be objective, and as specific as possible.

I Personal Data

Branch of Service:

1. Civil
2. USAF
3. Navy
4. Army
5. Marine Corps
6. Coast Guard

- 125
- 2

SEE PAGE #6.

Years Rated:

1. Less than 3
2. 3 6
3. 6 - 10
4. 10 - 15
5. Over 15

- 48
- 16
- 36
- 17
- 10

SEE PAGE #6.

Type Mission Normally Flown (Current Assignment):

1. Tactical
2. Rescue
3. Support
4. Training
5. Other (Please explain)

- 12
- 42
- 53
- 14
- 6

SEE PAGE #8.

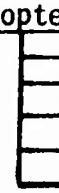
Flight Experience:

1. Less than 800 hours
2. 800 - 1500
3. 1500 - 2000
4. 2000 - 2500
5. Over 2500

Total Time

- 25
- 34
- 4
- 21
- 43

Helicopter Time



- 30
- 60
- 13
- 8
- 16

SEE PAGE #6.

H-3/36 TH-1F/10 H-1H/9
H-53/14 UH-1F/25 H-43/4 SEE PAGE #7.
H-1N/22 UH-1P/7

What helicopter are you presently flying? _____ Hours 796.6 Average

Approximately how many hours of helicopter weather time have you flown in the last 12 months? 7.7 Average

SEE PAGE #7.

II

1. Have you ever flown any aircraft equipped with any of the following:

	YES	NO	Type of Aircraft
a. Automatized Flight Controls.	___	___	INFORMATION
b. Hover Indicator.	___	___	IN
c. Radar Altimeter.	___	___	DATA BASE
d. Tape Instruments.	9	118	SEE PAGE #24.
e. Flight Director System.	44	67	SEE PAGE #22.

Please answer the following questions while considering only the helicopter you are currently flying. Reference all answers to Instrument Flying only.

2. On what percentage of your flights do you operate in Instrument Meterological Conditions (IMC)?

a. Less than 5% ☐ - 100
b. 5 - 10% ☐ - 23
c. 10 - 20% ☐ - 4 SEE PAGE #8.
d. Over 20% ☐ - 0

3. Rate the general quality (e.g., efficiency, arrangement, ease of viewing, etc.), of your helicopter instrument panel. Circle one:

4 - a. Unacceptable.
27 - b. Acceptable for Instrument Training in Visual Meterological Conditions (VMC) only.
86 - c. Adequate for Instrument Flying in IMC.
10 - d. Excellent.

SEE PAGE #9.

4. What improvements would you make to your Instrument Panel?

SEE PAGE #10.

SEE PAGE #14.

5. Rate each of the following aspects of your attitude indicator. Use the scale: 1 - Unacceptable, 2 - Acceptable for instrument training in VMC only, 3 - Adequate for instrument flying in IMC, 4 - Excellent.

Aspect	Rating		
	MM series	J-8	Other (list)
a. Precession.			
b. Color scheme.			
c. Location of bank index/pointer.			
d. Graduation of pitch scale.			
e. Pitch/roll trim.			
f. "Thickness" of miniature aircraft.			
g. Ease of interpretation.			
h. Overall quality of display.			

6. Comment on any aspect of your attitude indicator you feel is important but which has not been adequately expressed above.

SEE PAGE #15.

7. Do you feel that any aspects of your altimeter display lead to misreading altitude? Describe these, if any.

3-Pointer		Counter-Drum-Pointer	
Yes 24	No 56	Yes 11	No 40

SEE PAGE #16.

8. What changes are desirable in your altimeter display (e.g., expanded scale, change low altitude warning symbol, tape)?

SEE PAGE #16.

9. Rate the overall readability and effectiveness of your heading display. Circle one.

5 - a. Unacceptable.
18 - b. Acceptable for instrument training in VMC only.
90 - c. Adequate for instrument flight in IMC. SEE PAGE #17.
11 - d. Excellent.

10. What improvements would increase the effectiveness of your heading display?

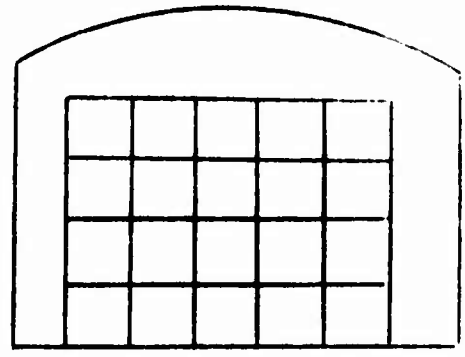
SEE PAGE #17.

11. Please rate your airspeed display in the following airspeed categories. Use the following scale: 1 - Unsatisfactory, 2 - Fair, 3 - Good, 4 - Excellent.

SEE PAGE #18.

	0-40 Kts.	40-70 Kts.	70-100 Kts.	Over 100 Kts.
Yaw Sensitivity				
Pitch Sensitivity				
Scale				
Overall Quality of Display				

12. Please construct an ideal instrument panel display that you would like to fly. Use only the instruments you need for Instrument Flight and enter only one instrument letter per block.



a. Attitude Indicator
b. Attitude Director Indicator.
c. Course Indicator.
d. Airspeed Indicator.
e. Radio Magnetic Indicator.
f. Altimeter.
g. Vertical Velocity Indicator, (round dial).
h. Turn and Slip Indicator.
i. Bearing-Distance-Heading Indicator.
j. Horizontal Situation Indicator.
k. Radar Altimeter.
l. Hover Indicator.
m. Doppler.
n. Power Instrument (i.e., fuel flow, torque, etc.).
o. Instantaneous Vertical Speed Indicator.
p. (Other - specify) _____ .
q. (Other - specify) _____ .

SEE PAGE #19.

13. Would you like to have a flight director system in your aircraft?

Yes 93, Why? No 24, Why not?

SEE PAGE #21.

14. What features would be most desirable in a flight director for helicopters (e.g., power information, rising pad, hover information, etc.)?

SEE PAGE #22.

15. To operate in IMC for any extended period of time, would you consider automatized flight controls to be:

68 - a. Essential.
48 - b. Not essential but desirable.
4 - c. Not required.

SEE PAGE #29.

16. If automatics were installed in your helicopter, what priority would you assess to their installation. Use: 0 - Not required, 1 - first installed, 2 - second to be installed, etc.

SEE PAGE #32.

Instrument Flight

Under 50 Kts.		Over 50 Kts.	
Roll Axis		Yaw Axis	
Yaw Axis		Collective Assist	
Pitch Axis		Roll Axis	
Collective Assist		Pitch Axis	

17. Make further comments you feel would be appropriate in developing improved pitch, roll, yaw and collective control.

SEE PAGE #32.

18. Would tape type displays improve your instrument flying?

Yes 48 No 23 Please explain.

SEE PAGE #24.

19. If Tape instruments were incorporated in your aircraft, which instruments would you like to see converted to Tape type?

SEE PAGE #24.

	YES	NO
Engine Instrument.	- 57	- 30
Power Instrument (Collective)	- 70	- 20
Altimeter.	- 52	- 35
Vertical Velocity.	- 47	- 39
Airspeed.	- 59	- 31
Other_____.	- 9	- 4

20. Have you ever flown an instrument approach steeper than 3°? Yes 35 No 83. If yes, please comment on difficulties encountered.

SEE PAGE #24.

21. If you were to fly a steep approach ILS (imagine your VFR Steep Approach, angle and airspeed), which axis would prove most difficult? Please rate degree of difficulty.

SEE PAGE #30.

	Least Difficult 1	2	3	4	5 Most Difficult
Pitch axis					
Roll axis					
Yaw axis					
Collective control					

22. Please rate your helicopter Trim system. Circle one.

15 - a. Unacceptable.
33 - b. Acceptable for VMC instrument training only.
51 - c. Adequate for instrument flying in IMC.
24 - d. Excellent.

Comments:

SEE PAGE #28.

23. What instruments do you rely on most heavily for control/performance information related to (list only those instruments you use):

	1	2	3
a. Pitch axis	_____	_____	_____
b. Roll axis	_____	_____	_____
c. Yaw axis	_____	_____	_____

SEE PAGE #26.

24. For a normal precision approach, rate the degree of difficulty in controlling:

	Least Difficult 1	2	3	4	5 Most Difficu
Yaw Axis					
Roll Axis					
Pitch Axis					

Comments:

SEE PAGE #31.

25. Rate the overall quality of the instrument panel lighting in your aircraft. Circle one.

SEE PAGE #13.

a. Unsatisfactory b. Fair c. Good d. Excellent

22 59 36 8

26. Describe any particular problems with the instrument lighting in your aircraft.

SEE PAGE #13.

27. What type of navigation/approach system(s) would be best suited for helicopters?

SEE PAGE #32.

28. How would improvements listed in response to questions 4 and 21 be utilized to improve your operational capability?

SEE PAGE #33.

29. Please comment on any aspect of helicopter instrument flying you would like to see investigated by the Instrument Flight Center.

SEE PAGE #33.

THANK YOU

LIGHT LIFT HELICOPTERS

H-1 Series Helicopters

The H-1 series helicopters were designed as a utility type aircraft capable of operating from either prepared or unprepared surfaces. Four of the five versions are equipped with a single engine and a 48-foot (diameter) two bladed main rotor with a tail rotor providing directional control. The maximum takeoff gross weight is 9000 pounds (9500 for H-1H) and maximum indicated airspeed is limited to 120 knots.

The aircraft is capable of operating under instrument conditions (with a copilot) to include trace icing, day or night. Instrument airspeeds below 70 knots are not recommended. Instrument cruise is usually flown at 90 knots with higher airspeeds being utilized at the pilot's discretion.

The flight controls (cyclic, collective, anti-torque pedals) employ a hydraulic boost system in order to reduce in-flight operational loads to the pilot. All flight controls are manually positioned by the pilot with a force trim system adding "artificial feel" to the cyclic and anti-torque pedals.

The following information highlights the equipment unique to each particular model of the basic H-1 series helicopters.

UH-1F

The "UH" version is most frequently used for support of the Strategic Air Command's Minuteman and Titian missile sites, A single UHF radio, ILS localizer receiver, and VOR receiver constitutes the communication/ navigation equipment on a typical UH-1F helicopter.

The "TH" model is the trainer version of the UH-1F and is used primarily by the Military Airlift Command and Air Training Command in the conduct of formal flying training courses. The addition of TACAN, ILS glide slope receiver capability and a course indicator and turn and slip indicator for the copilot's panel are the main differences between the "UH" and "TH" models.

The UH-1P is a tactical version of the UH-1F helicopter and is used primarily by the Tactical Air Command. Provisions for machine guns, rockets, tactical communication equipment and protective armor are the main distinctions between UH-1F and UH-1P models. For further information, refer to T.O. 1H-1(U)F-1, Flight Manual-USAF Series UH-1F, UH-1P, and TH-1F.

H-1H Helicopter

The H-1H is very similar to the UH-1F with the exception of an enlarged fuselage. The H-1H cargo compartment has been "stretched" to include an additional two troop seats. With exception of a slightly increased maximum takeoff gross weight (9,500 pounds), all other H-1H flight characteristics and airspeeds are typical of the basic H-1 series previously discussed.

Both active duty and reserve forces use the H-1H helicopters. Search and Rescue is the primary mission of H-1H units.

UH-1N Helicopter

The UH-1N represents a significant departure from the other H-1 series helicopters. While the fuselage is similar to the H-1H fuselage, the UH-1N has two engines, a takeoff gross weight of 10,500 pounds and a maximum indicated airspeed of 130 knots. Rotor system, flight controls, and instrument airspeeds are typical of the H-1 series. The UH-1N is used in support, tactical, and rescue missions. They are usually employed in areas where the two engine feature adds to mission safety; that is, over water and mountainous terrain.

H-43 Helicopter

The H-43 is a single engine helicopter which utilizes twin two-bladed rotors in a counter rotation-intermeshing fashion. As in the H-1 series helicopters, flight controls require full time "hands-on" operation from the pilot with hydraulic boost assistance provided only on the collective. The H-43 pilot controls the angle of attack on the rotor blades by means of conventional helicopter flight controls, which, in turn, control a flap located near the end of each blade. The aerodynamic action of the flap twists the main rotor blades to the desired angle of attack. Due to the counter rotating main rotors, no tail rotor is utilized. The H-43 flight manual calls for 60-70 knots instrument cruise airspeeds with 105 knots being the maximum indicated airspeed. A single ADF radio provides the only navigation system for the aircraft.

The 9,150 pound maximum gross weight limit enables the H-43 to carry up to 11 passengers. The primary mission of the H-43 is local base rescue.

HEAVY LIFT HELICOPTERS

H-3 Helicopter

The H-3 series helicopters use a five-bladed rotor system with a tail rotor providing directional control. Twin engines combine to enable a maximum takeoff gross weight of 22,050 pounds and a maximum airspeed of 142 knots. This crew served helicopter (pilot, copilot, and flight engineer) is capable of carrying 25 fully loaded combat troops. In-flight refueling, water landing capability and machine guns and armor are added depending on the mission.

Included in all H-3's is an automatic flight control system (AFCS). "The system maintains the stability of the helicopter on its reference pitch and roll attitude, about the reference directional heading, and at the engaged attitude to permit automatic hands-off flight and controlled hovering operations. The AFCS used in the helicopter differs from the autopilot used in fixed wing aircraft in that it may be engaged at all times, has less control authority than the primary flight control systems, and may be easily over-ridden through normal use of the flight controls'"[4]

The H-3 flight manual suggests instrument climb airspeeds of 70-80 knots with a minimum instrument airspeed (other than emergency) of 70 knots. Instrument cruise airspeed is normally 100 knots.

The H-3 helicopter is used for all types of missions but is perhaps best known for its rescue role in Southeast Asia as the "Jolly Green".

H-53 Helicopter

The H-53 is very similar to the H-3 in appearance. A six-bladed rotor system, improved engines (2) and further refinements have combined to increase the maximum gross weight to 42,000 pounds and increased the maximum speed to 162 knots.

The AFCS used in the H-53 is very similar to the H-3 system with a turn coordination feature being added in the H-53 system.

Recommended instrument climb speed is 100 knots with 100-120 knots being the cruise and approach speeds. Add on equipment, missions, and general operations are similar to those discussed in the H-3 description.

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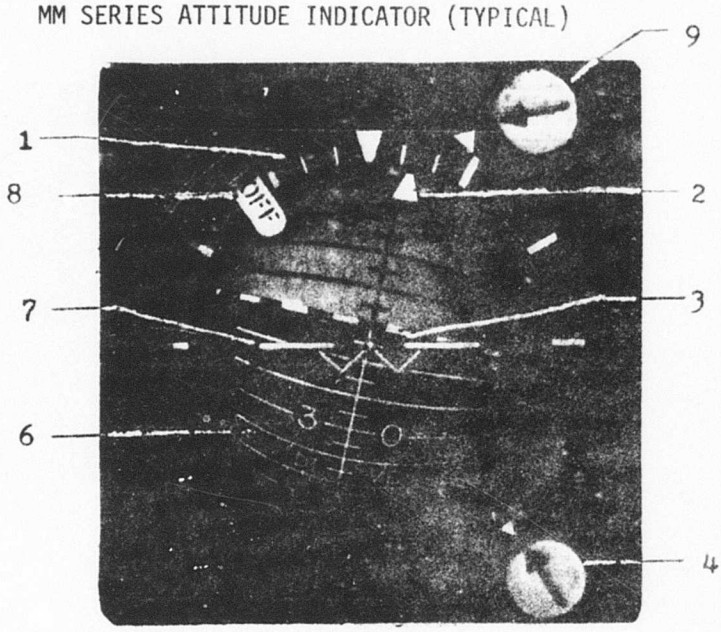
4. T.O. 1H-3(C)C-1, Flight Manual, 1 September 73, Change 2 10 February 1975, p 1-58.

MM SERIES ATTITUDE INDICATOR (TYPICAL)



1. Bank Scale
2. Bank Pointer
3. Horizon Bar
4. Pitch Trim Knob
5. Pitch Reference Scale
6. Attitude Sphere
7. Miniature Aircraft
8. Attitude Warning Flag
9. Roll Trim Knob

The MM Series Attitude Indicator is very similar to those used in most fixed wing aircraft. This remote gyro attitude system utilizes an improved gyro erection mechanism and a rate switching gyro to reduce the precession problems common to the older self-contained attitude indicators such as the J-8.

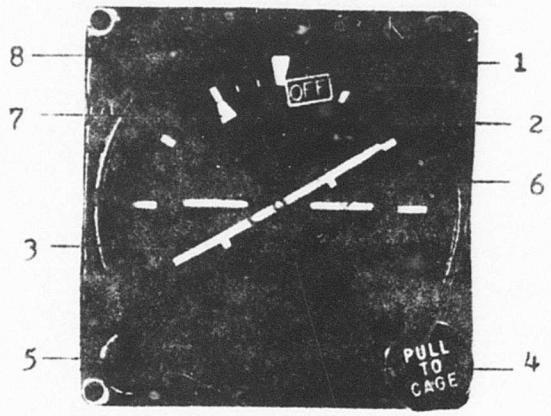
APPLICATION (Typical)
UH-1F, TH-1F, UH-1P, H-1H, H-1N, H-3 (older models), -Pilots Panel

4005 ATTITUDE INDICATOR (no picture)

The 4005 Attitude indicator is very similar to the MM series shown above. The roll trim knob has been moved to the lower left corner of the case and a turn and slip indicator included just below the attitude sphere.

APPLICATION (Typical):
H-53, H-3 (late models),- Pilot and Copilot's Panel

J-8 ATTITUDE INDICATOR (TYPICAL)

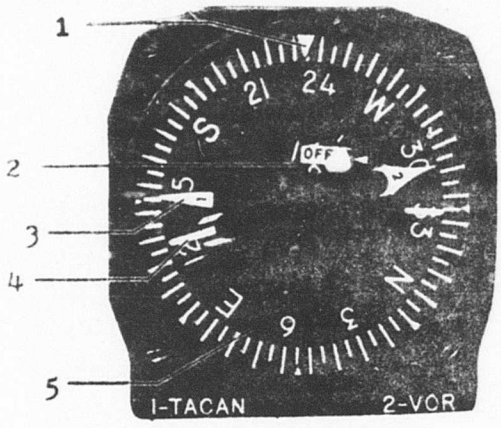


1. Attitude Warning Flag
2. Attitude Sphere
3. Miniature Aircraft
4. Caging Knob
5. Pitch Trim Knob
6. Horizon Bar
7. Bank Pointer
8. Bank Scale

The J-8 Attitude indicator is a self-contained (gyro) system. The model used in helicopters is identical to those used in several fixed wing aircraft. No pitch scale markings or roll trim capability is included in the J-8 attitude indicator.

APPLICATION (Typical):
UH-1F, TH-1F, UH-1P, H-1H, H-1N, H-43, - Copilots Panel

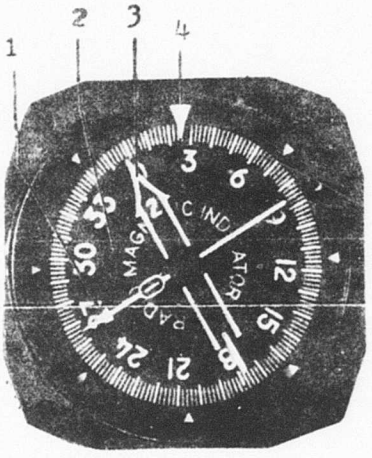
BEARING-DISTANCE-HEADING-INDICATOR (BDHI)



1. Top Index
2. Range Indicator Warning Flag
3. Bearing Pointer
4. Bearing Pointer
5. Rotating Compass Card

APPLICATION (Typical):
H-3, H-53, H-1N, - Pilot and Copilots Panel

RADIO MAGNETIC INDICATOR (RMI)

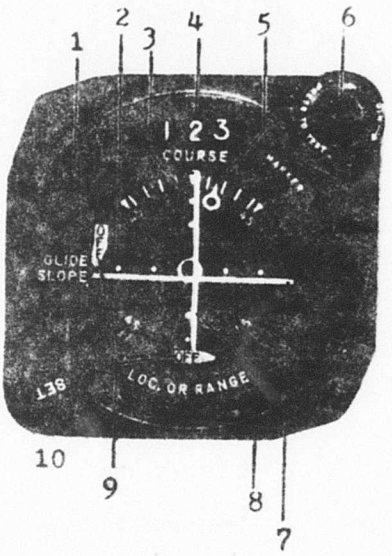


1. Bearing Pointer
2. Rotating Compass Card
3. Bearing Pointer
4. Top Index

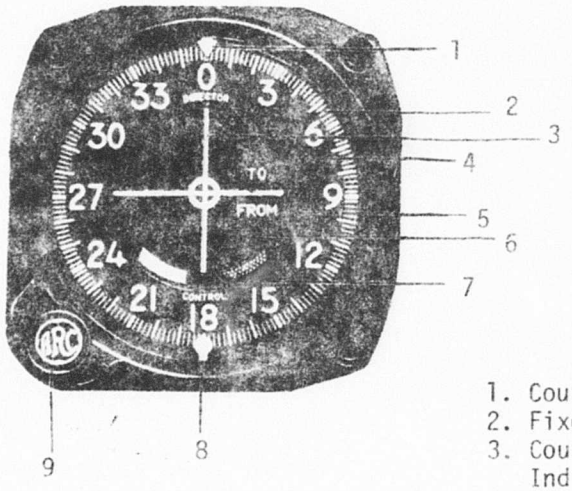
APPLICATION (Typical):
UH-1F, TH-1F, UH-1P, H-1H, - Pilots and Copilots Panel
H-43, - Pilots Panel

COURSE INDICATORS (TYPICAL)

1. To From Indicator
2. Course Deviation Scale
3. Glide Slope Deviation Scale
4. Course Selector Window
5. Heading Pointer
6. Marker Beacon Light
7. Glide Slope Indicator
8. Course Deviation Indicator
9. Course and Glide Slope Warning Flags
10. Course Set Knob



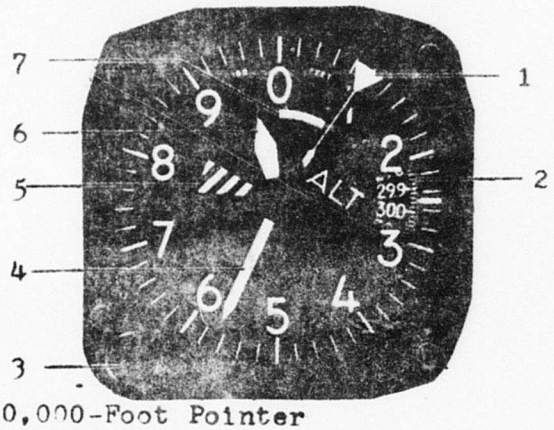
APPLICATION (Typical):
TH-1F, H-1N, H-1H, H-3, H-53, - Pilot and Copilots Panel
H-1P, - Pilots Panel



1. Course Arrow (Head)
2. Fixed Compass Card
3. Course Deviation Indicator
4. Glide Slope Indicator
5. Glide Slope Warning Flag
6. To-From Indicator
7. Course Warning Flag
8. Course Arrow (Tail)
9. Course Set Knob

APPLICATION (Typical):
UH-1F, - Pilots Panel

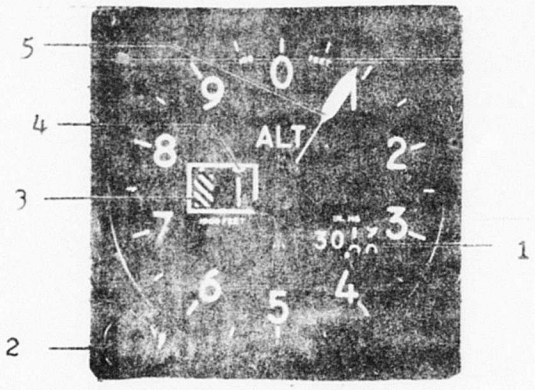
THREE POINTER ALTIMETER (TYPICAL)



1. 10,000-Foot Pointer
2. Barometric Scale
3. Barometric Pressure Set Knob
4. 100-Foot Pointer
5. Low Altitude Warning Symbol
6. 1,000-Foot Pointer
7. White Stripe follows 10,000-Foot pointer around inner perimeter of the altitude scale

APPLICATION (Typical): Found in all helicopters.

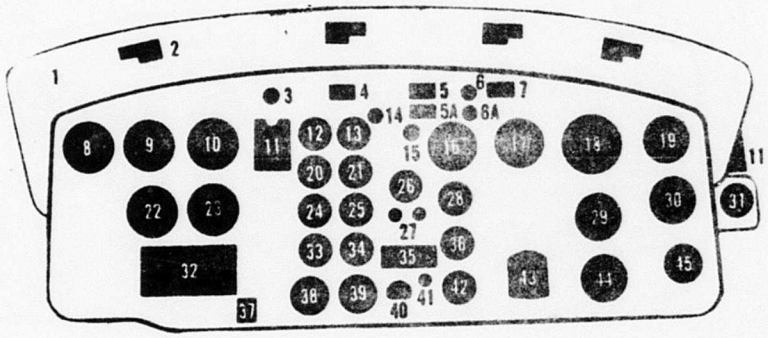
COUNTER-DRUM-POINTER ALTIMETER (TYPICAL)



1. Barometric Scale
2. Barometric Pressure Set Knob
3. 10,000 Foot-Counter
4. 1,000-Foot Counter
5. 100-Foot Pointer

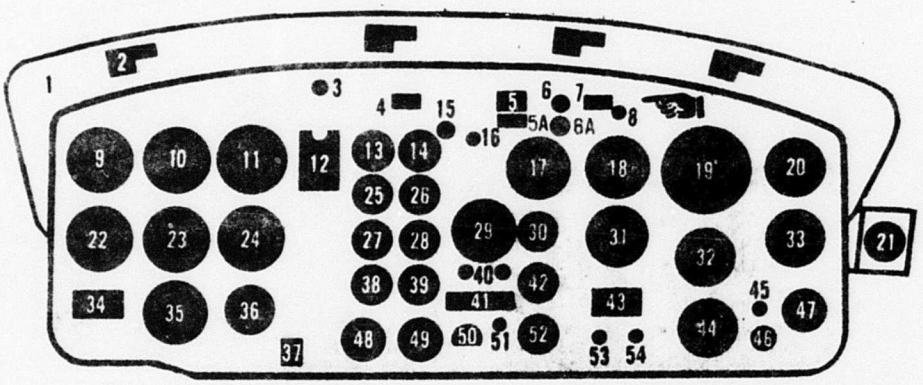
APPLICATION (Typical): System is being installed in all helicopters as a three pointer replacement.

UH-1F and UH-1P (TYPICAL)



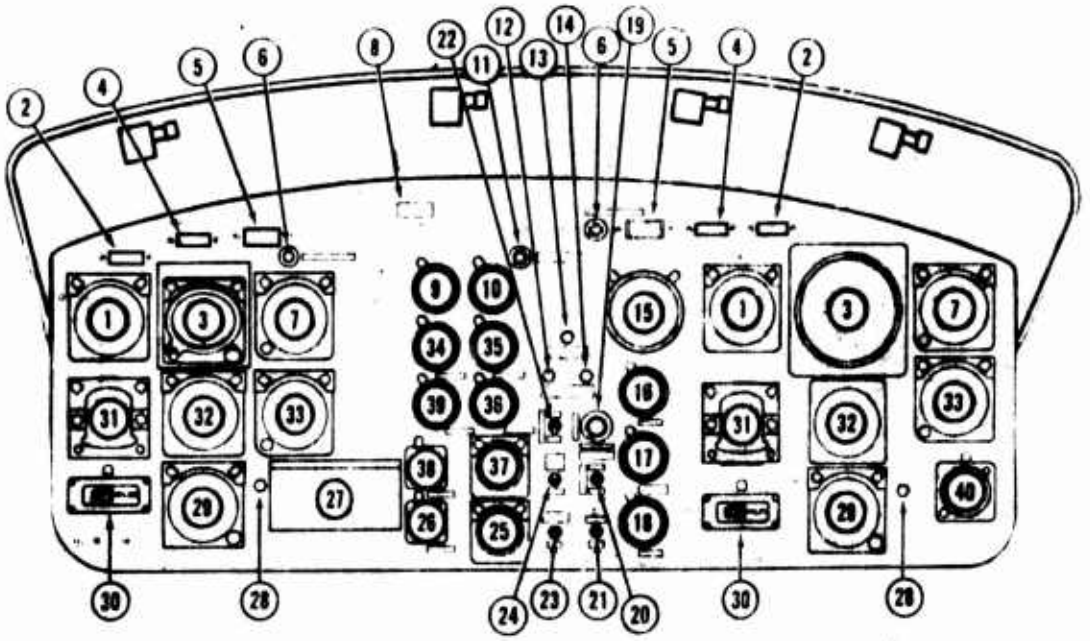
1. GLARE SHIELD
2. SECONDARY LIGHTS (4)
3. CARGO RELEASE ARMED LIGHT
4. MASTER CAUTION LIGHT
5. RPM WARNING
5A. ROTOR BRAKE WARNING LIGHT
6. FIRE DETECTOR TEST SWITCH
6A. ROTOR BRAKE PUSH-TO-TEST BUTTON
7. FIRE WARNING INDICATOR LIGHT
8. AIRSPEED INDICATOR
9. ATTITUDE INDICATOR
10. ALTIMETER
11. COMPASS CORRECTION CARD HOLDER (2)
12. FUEL PRESSURE INDICATOR
13. FUEL QUANTITY INDICATOR
14. FUEL GAGE TEST SWITCH
15. MANUAL FUEL CONTROL OPEN LIGHT
16. DUAL TACHOMETER
17. AIRSPEED INDICATOR
18. ATTITUDE INDICATOR
19. ALTIMETER
20. ENGINE OIL PRESSURE INDICATOR
21. ENGINE AND SDG OIL IN TEMPERATURE INDICATOR
22. RADIO MAGNETIC COMPASS INDICATOR
23. VERTICAL SPEED INDICATOR
24. SDG OIL PRESSURE INDICATOR
25. SDG OIL OUT TEMPERATURE INDICATOR
26. NEGATIVE PRESSURE INDICATOR
27. AIR FILTER WARNING LIGHTS
28. TORQUEMETER
29. RADIO MEGNETIC COMPASS INDICATOR
30. VERTICAL VELOCITY INDICATOR
31. MAGNETIC COMPASS
32. OPERATING LIMITS DECAL
33. TRANSMISSION OIL PRESSURE INDICATOR
34. TRANSMISSION OIL TEMPERATURE INDICATOR
35. CAUTION DECAL - WARM ENGINE UP SLOWLY AT −35°C OAT OR BELOW
36. N_g TACHOMETER
37. SELECTOR DECAL - ICS AND XMTR
38. DC VOLTMETER
39. AC VOLTMETER
40. GENERATOR LOADMETER
41. COMPASS SLAVING SWITCH
42. T_5 INDICATOR
43. TURN AND SLIP INDICATOR
44. COURSE INDICATOR
45. CLOCK

TH-1F (TYPICAL)



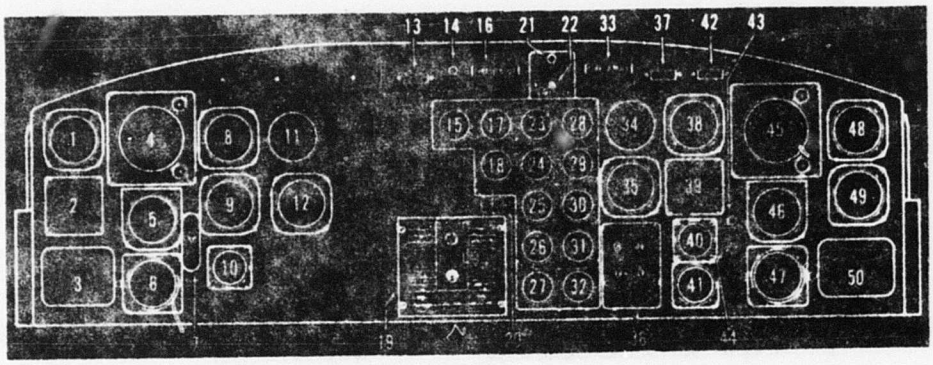
1. GLARE SHIELD
2. SECONDARY LIGHTS (4)
3. CARGO RELEASE ARMED LIGHT
4. MASTER CAUTION LIGHT
5. RPM WARNING
5A. ROTOR BRAKE WARNING LIGHT
6. FIRE DETECTOR TEST SWITCH
6A. ROTOR BRAKE PUSH-TO-TEST BUTTON
7. FIRE WARNING INDICATOR LIGHT
8. RESCUE HOIST 20 FT. WARNING LIGHT
9. AIRSPEED INDICATOR
10. ATTITUDE INDICATOR
11. VERTICAL SPEED INDICATOR
12. COMPASS CORRECTION CARD HOLDER
13. FUEL PRESSURE INDICATOR
14. FUEL QUANTITY INDICATOR
15. FUEL GAGE TEST SWITCH
16. MANUAL FUEL CONTROL OPEN LIGHT
17. DUAL TACHOMETER
18. AIRSPEED INDICATOR
19. ATTITUDE INDICATOR
20. VERTICAL SPEED INDICATOR
21. MAGNETIC COMPASS
22. TURN AND SLIP INDICATOR
23. RADIO MAGNETIC COMPASS INDICATOR
24. ALTIMETER
25. ENGINE OIL PRESSURE INDICATOR
26. ENGINE AND SDG OIL IN TEMPERATURE INDICATOR
27. SDG OIL PRESSURE INDICATOR
28. SDG OIL OUT TEMPERATURE INDICATOR
29. NEGATIVE PRESSURE INDICATOR
30. TORQUEMETER
31. TURN AND SLIP INDICATOR
32. RADIO MAGNETIC COMPASS INDICATOR
33. ALTIMETER
34. DME INDICATOR
35. COURSE INDICATOR
36. CLOCK
37. SELECTOR DECAL - ICS AND SMTR
38. TRANSMISSION OIL PRESSURE INDICATOR
39. TRANSMISSION OIL TEMPERATURE INDICATOR
40. AIR FILTER WARNING LIGHTS
41. CAUTION DECAL - WARM ENGINE UP SLOWLY AT −35°C OAT OR BELOW
42. N_g TACHOMETER
43. DME INDICATOR
44. COURSE INDICATOR
45. MARKER BEACON HIGH-LOW SENSING SWITCH
46. MARKER BEACON OFF-VOLUME CONTROL
47. CLOCK
48. DC VOLTMETER
49. AC VOLTMETER
50. GENERATOR LOADMETER
51. COMPASS SLAVING SWITCH
52. T_5 INDICATOR
53. TACAN - VOR - ILS SELECTOR SWITCH
54. ADF RANGE SELECT SWITCH

H-1H (TYPICAL)



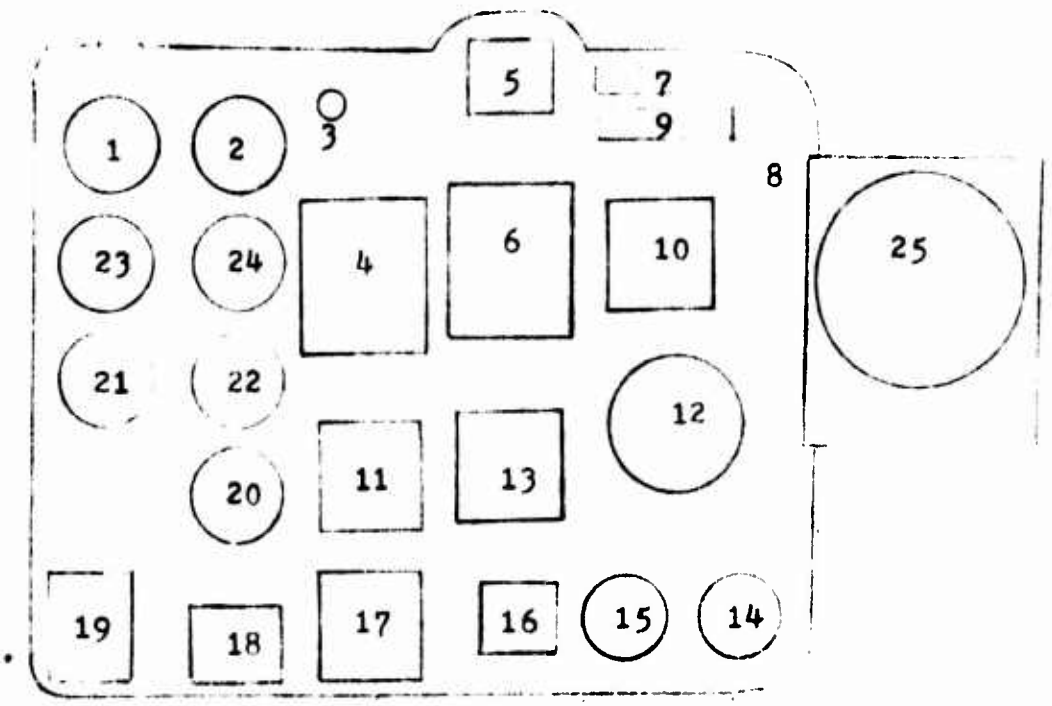
1. Airspeed Indicator
2. Master Caution Light
3. Attitude Indicator
4. RPM Warning Light
5. Fire Warning Light
6. Fire Detector Test Switch
7. Altimeter
8. Rfdio Call Designator
9. Fuel Pressure Indicator
10. Fuel Quantity Indicator
11. Fuel Gage Test Switch
12. Cargo Release Armed Light
13. Rescue Hoist 20 Foot Caution Light
14. Cargo Release Open Light
15. Dual Tachometer Indicator
16. Torquemeter Indicator
17. Gas Producer Tachometer Indicator
18. Exhaust Gas Temperature Indicator
19. Marker Beacon Volume Control
20. Marker Beacon Sensing Switch
21. TACAN/VOR Switch
22. Compass DG/MAG Switch
23. IFF Code Hold Switch
24. UHF-DF Range Switch
25. AC Voltmeter
26. Standby Generator Load Ammeter
27. Operating Limits Decal
28. Marker Beacon Light
29. Course Indicator
30. DME Indicator
31. Turn and Slip Indicator
32. Radio Magnetic Indicator
33. Vertical Velocity Indicator
34. Engine Oil Pressure Indicator
35. Engine Oil Temperature Indicator
36. Transmission Oil Temperature Indicator
37. DC Voltmeter
38. Main Generator Load/ Ammeter
39. Transmission Oil Pressure Indicator
40. Clock

UH-1N (TYPICAL)



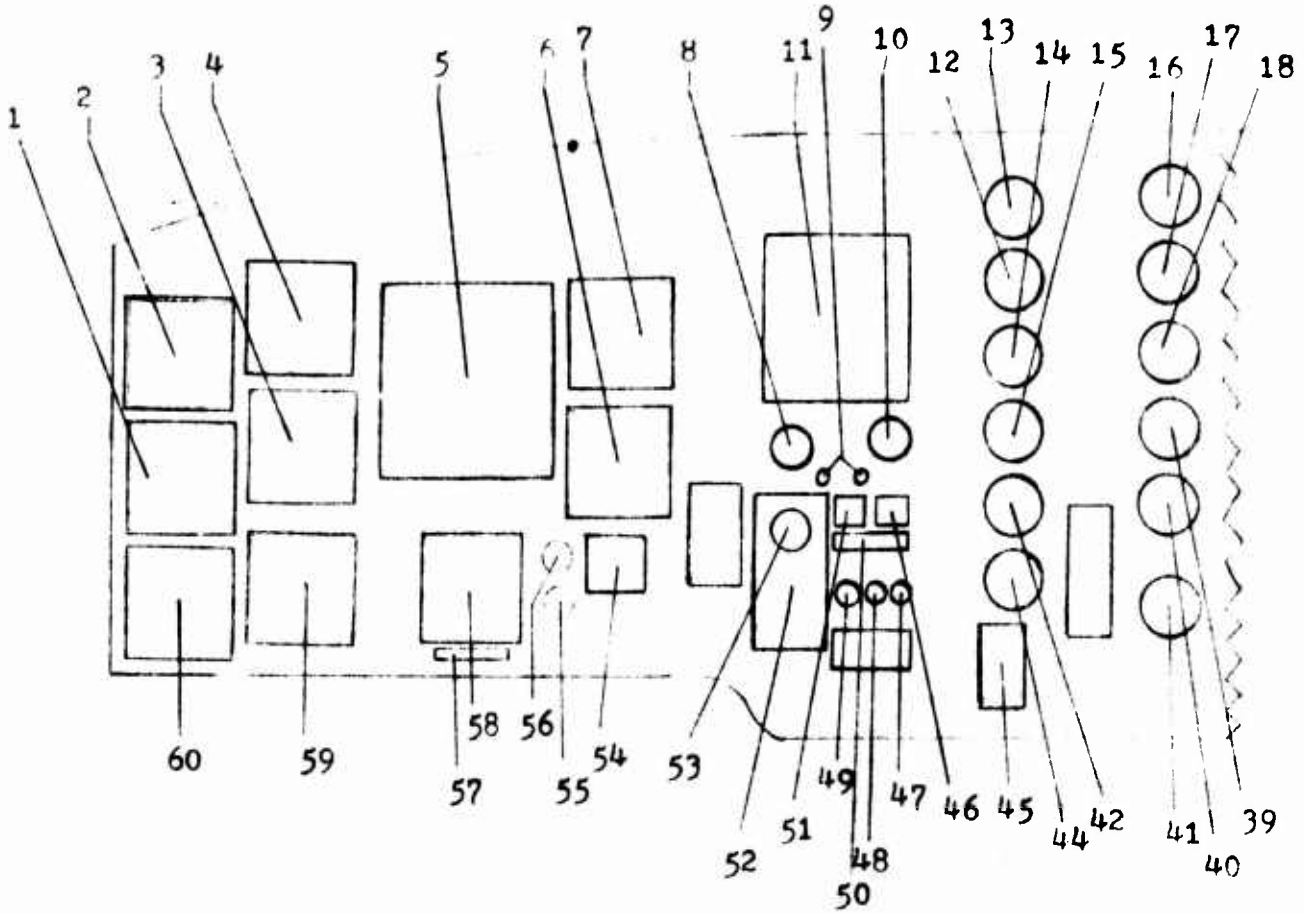
1. Airspeed Indicator (Copilot)
2. Radar Altimeter (When Installed)
3. Ash Tray
4. Attitude Indicator
5. Bearing Distance Heading Indicator (BDHI)
6. ID-387 Course Indicator
7. TACAN-VOR Selector Switch
8. Altimeter
9. Vertical Velocity Indicator
10. Turn and Slip
11. Dual Torque Indicator
12. Tripple Tachometer
13. Ice Detector Warning Light
14. Fuel Gauge Test Switch
15. Fuel Quantity Indicator
16. Fire Pull Handle (Eng. 1)
17. Transmission Temperature and Pressure Indicator
18. Combining Gearbox Temperature and Pressure Indicator
19. Caution Panel
20. Chip Detector Panel
21. Press To Test Switch (Fire Handle Lights)
22. Fire Extinguisher Selector Switch
23. Gas Producer Tachometer (Eng. 1)
24. Inlet Temp. Indicator (ITT, Eng. 1)
25. Engine Oil Temperature and Pressure (Eng. 1)
26. Fuel Flow Indicator (Eng. 1)
27. Voltmeter
28. Gas Producer Tachometer (Eng. 2)
29. Inlet Temp. Indicator (ITT, Eng. 2)
30. Engine Oil Temperature and Pressure (Eng. 2)
31. Fuel Flow Indicator (Eng. 2)
32. Ammeter
33. Fire Pull Handle (Eng. 2)
34. Dual Torque Indicator
35. Triple Tachometer
36. NAV Equipment Selector Panel
37. Master Caution Light
38. Airspeed Indicator (Pilot)
39. Radar Altimeter (When Installed)
40. Turn and Slip
41. Clock
42. RPM Warning Light
43. Cargo Release Armed Light
44. Rescue Hoist (20 foot) Caution Light
45. Attitude Indicator
46. Bearing Distance Heading Indicator (BDHI)
47. ID-387 Course Indicator
48. Altimeter
49. Vertical Velocity Indicator
50. Ash Tray

H-43 (TYPICAL)



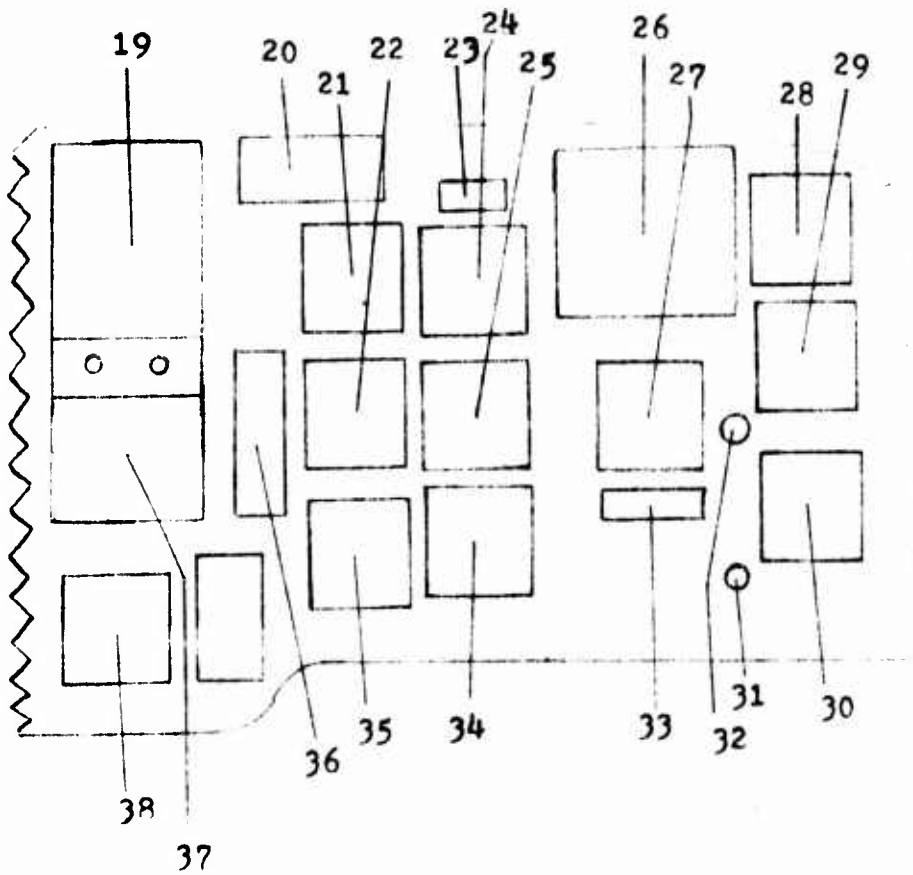
1. FUEL BOOST PRESSURE GAGE
2. FUEL QUANTITY GAGE
3. FUEL QUANTITY GAGE TEST BUTTON
4. RADIO MAGNETIC INDICATOR
5. MAGNETIC COMPASS
6. J-8 ATTITUDE INDICATOR
7. FIRE WARNING LIGHT
8. INSTRUMENT PANEL
9. MASTER CAUTION LIGHT
10. AIRSPEED INDICATOR
11. ALTIMETER
12. DUAL TACHOMETER (N_2)
13. VERTICAL VELOCITY INDICATOR
14. ENGINE TORQUEMETER
15. EXHAUST GAS TEMPERATURE GAGE
16. CLOCK
17. TURN AND SLIP INDICATOR
18. LOADMETER
19. VOLTMETER
20. GAS PRODUCER TACHOMETER (N_1)
21. TRANSMISSION OIL PRESSURE GAGE
22. TRANSMISSION OIL TEMPERATURE GAGE
23. ENGINE OIL PRESSURE GAGE
24. ENGINE OIL TEMPERATURE GAGE
25. ARU-14/A ATTITUDE INDICATOR

H-3 COPILOT PANEL (TYPICAL)



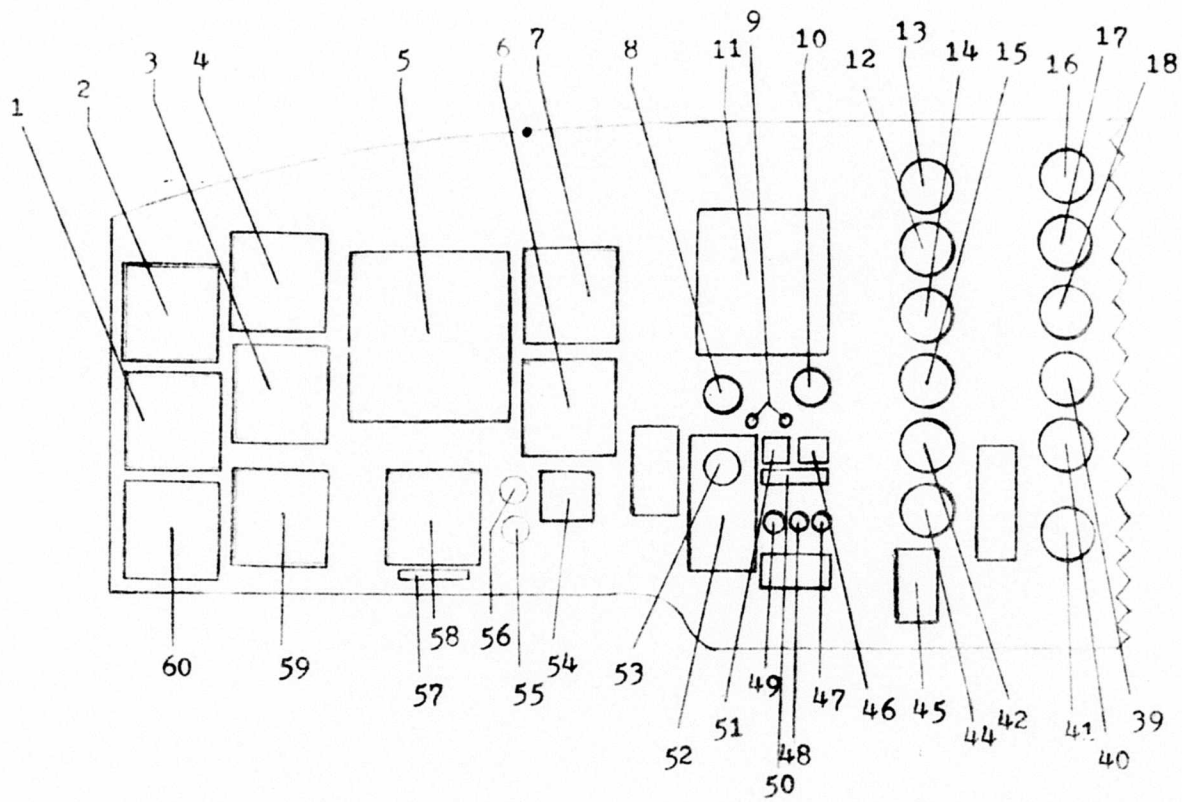
1. COPILOT'S TRIPLE TACHOMETER
2. COPILOT'S TORQUE METER
3. COPILOT'S RADAR ALTIMETER
4. COPILOT'S AIRSPEED INDICATOR
5. COPILOT'S ATTITUDE INDICATOR
6. COPILOT'S VERTICAL VELOCITY INDICATOR
7. COPILOT'S ALTIMETER
8. FORWARD TANK FUEL QUANTITY GAGE
9. FUEL QUANTITY GAGE TEST SWITCH PANEL
10. AFT TANK FUEL QUANTITY GAGE
11. FUEL MANAGEMENT PANEL
12. NO. 1 ENGINE POWER TURBINE INLET TEMPERATURE (T_5) INDICATOR
13. NO. 1 ENGINE GAS GENERATOR (N_g) TACHOMETER
14. NO. 1 ENGINE FUEL FLOW INDICATOR
15. NO. 1 ENGINE OIL PRESSURE INDICATOR
16. NO. 2 ENGINE GAS GENERATOR (N_g) TACHOMETER
17. NO. 2 ENGINE POWER TURBINE INLET TEMPERATURE (T_5) INDICATOR
18. NO. 2 ENGINE FUEL FLOW INDICATOR
19. CAUTION LIGHT PANEL
20. FIRE WARNING LIGHTS AND TEST SWITCH PANEL
21. PILOT'S TORQUE METER
22. PILOT'S TRIPLE TACHOMETER
23. MASTER CAUTION LIGHT
24. PILOT'S AIRSPEED INDICATOR
25. PILOT'S RADAR ALTIMETER
26. PILOT'S ATTITUDE INDICATOR
27. PILOT'S BEARING, DISTANCE, HEADING INDICATOR
28. PILOT'S ALTIMETER

H-3 PILOT PANEL (TYPICAL)



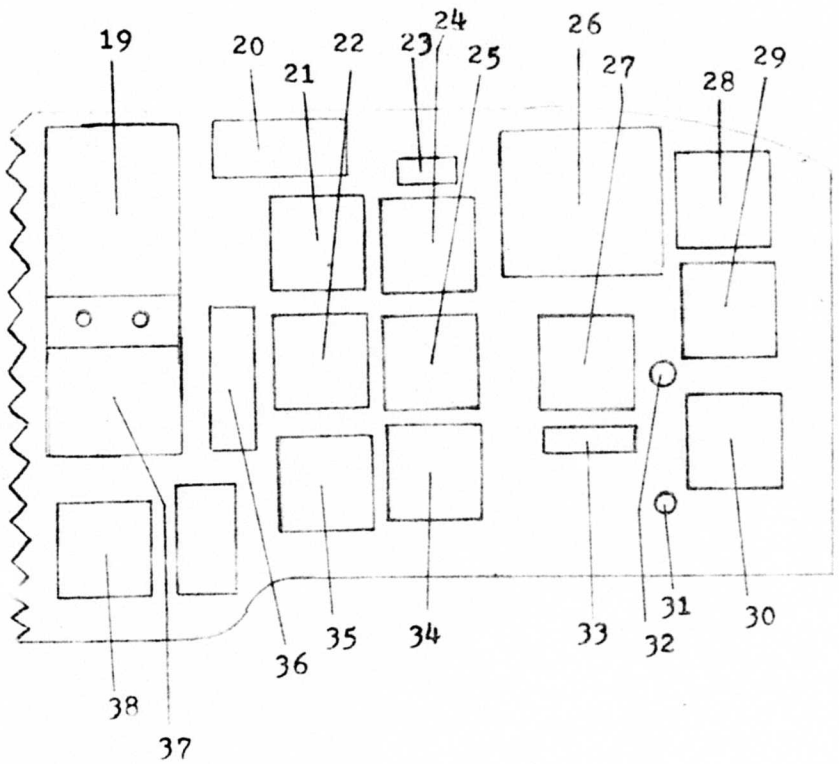
29. PILOT'S VERTICAL VELOCITY INDICATOR
30. PILOT'S CLOCK
31. PILOT'S VOR/TACAN SELECTOR SWITCH
32. PILOT'S TURN RATE SWITCH
33. PILOT'S BDHI POINTER IDENTIFICATION DECAL
34. PILOT'S AFCS INDICATOR
35. PILOT'S COURSE INDICATOR
36. CHECK OFF LIST
37. ADVISORY LIGHT PANEL
38. VELOCITY STEERING INDICATOR
39. NO. 2 ENGINE OIL PRESSURE INDICATOR
40. NO. 2 ENGINE OIL TEMPERATURE INDICATOR
41. TRANSMISSION OIL PRESSURE INDICATOR
42. NO. 1 ENGINE OIL TEMPERATURE INDICATOR
43. DELETED
44. TRANSMISSION OIL TEMPERATURE INDICATOR
45. DF RANGE SWITCH
46. NO. 2 LOAD METER
47. PRIMARY HYDRAULIC PRESSURE INDICATOR
48. AUXILIARY HYDRAULIC PRESSURE INDICATOR
49. UTILITY HYDRAULIC PRESSURE INDICATOR
50. LOAD METER IDENTIFICATION PANEL
51. NO. 1 LOAD METER
52. VOLTMETER SELECTOR PANEL
53. DC VOLTMETER
54. COPILOT'S CLOCK
55. COPILOT'S VOR/TACAN SELECTOR SWITCH
56. COPILOT'S TURN RATE SWITCH
57. COPILOT'S BDHI POINTER IDENTIFICATION PANEL
58. COPILOT'S BEARING, DISTANCE HEADING INDICATOR
59. COPILOT'S AFCS INDICATOR
60. COPILOT'S COURSE INDICATOR

H-3 COPILOT PANEL (TYPICAL)



1. COPILOT'S TRIPLE TACHOMETER
2. COPILOT'S TORQUE METER
3. COPILOT'S RADAR ALTIMETER
4. COPILOT'S AIRSPEED INDICATOR
5. COPILOT'S ATTITUDE INDICATOR
6. COPILOT'S VERTICAL VELOCITY INDICATOR
7. COPILOT'S ALTIMETER
8. FORWARD TANK FUEL QUANTITY GAGE
9. FUEL QUANTITY GAGE TEST SWITCH PANEL
10. AFT TANK FUEL QUANTITY GAGE
11. FUEL MANAGEMENT PANEL
12. NO. 1 ENGINE POWER TURBINE INLET TEMPERATURE (T_5) INDICATOR
13. NO. 1 ENGINE GAS GENERATOR (N_g) TACHOMETER
14. NO. 1 ENGINE FUEL FLOW INDICATOR
15. NO. 1 ENGINE OIL PRESSURE INDICATOR
16. NO. 2 ENGINE GAS GENERATOR (N_g) TACHOMETER
17. NO. 2 ENGINE POWER TURBINE INLET TEMPERATURE (T_5) INDICATOR
18. NO. 2 ENGINE FUEL FLOW INDICATOR
19. CAUTION LIGHT PANEL
20. FIRE WARNING LIGHTS AND TEST SWITCH PANEL
21. PILOT'S TORQUE METER
22. PILOT'S TRIPLE TACHOMETER
23. MASTER CAUTION LIGHT
24. PILOT'S AIRSPEED INDICATOR
25. PILOT'S RADAR ALTIMETER
26. PILOT'S ATTITUDE INDICATOR
27. PILOT'S BEARING, DISTANCE, HEADING INDICATOR
28. PILOT'S ALTIMETER

H-3 PILOT PANEL (TYPICAL)



29. PILOT'S VERTICAL VELOCITY INDICATOR
30. PILOT'S CLOCK
31. PILOT'S VOR/TACAN SELECTOR SWITCH
32. PILOT'S TURN RATE SWITCH
33. PILOT'S BDHI POINTER IDENTIFICATION DECAL
34. PILOT'S AFCS INDICATOR
35. PILOT'S COURSE INDICATOR
36. CHECK OFF LIST
37. ADVISORY LIGHT PANEL
38. VELOCITY STEERING INDICATOR
39. NO. 2 ENGINE OIL PRESSURE INDICATOR
40. NO. 2 ENGINE OIL TEMPERATURE INDICATOR
41. TRANSMISSION OIL PRESSURE INDICATOR
42. NO. 1 ENGINE OIL TEMPERATURE INDICATOR
43. DELETED
44. TRANSMISSION OIL TEMPERATURE INDICATOR
45. DF RANGE SWITCH
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53. DC VOLTMETER
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56. COPILOT'S TURN RATE SWITCH
57. COPILOT'S BDHI POINTER IDENTIFICATION PANEL
58. COPILOT'S BEARING, DISTANCE, HEADING INDICATOR
59. COPILOT'S AFCS INDICATOR
60. COPILOT'S COURSE INDICATOR