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TECHNICAL REPORT NO.4–67

DEVELOPMENT STUDY FOR A HELIPAD STANDARD MARKING PATTERN

by

T.H. MORROW JR.

SEPTEMBER 1967

DEPARTMENT OF THE ARMY

OHIO RIVER DIVISION LABORATORIES, CORPS OF ENGINEERS

CINCINNATI, OHIO 45227

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T. H. Morrow Jr.

September 1967

Conducted by
U. S. Army Engineer Division, Ohio River
Corps of Engineers
Ohio River Division Laboratories
Cincinnati, Ohio 45227

in coordination with

Office, Chief of Engineers and Federal Aviation Administration

SUMMARY

This report presents the results in the development of a recommended marking pattern for helipads. The objective of the study was to determine the marking pattern which would best fulfill requirements which were established on the basis of current practices, discussions with helicopter pilots, and helicopter operational observations. Field tests were conducted following laboratory observations and scale-model studies. Those requirements which most influenced final selection of the marking pattern were (1) Visual Flight Rules conditions (daytime), (2) recognition of the pattern from one mile, and (3) a five-degree minimum approach angle. Elements of pattern size and contrast gained significance as a result of field test evaluation.

Aided by laboratory photographic techniques, model studies facilitated rapid evaluation of a large number of marking patterns. Results of laboratory tests provided seven patterns for field evaluation through pilot preference at Hanchey Army Heliport, Fort Rucker, Alabama. Based on those tests, two of the seven patterns were further evaluated by student pilots and instructors at U. S. Army Primary Helicopter School, Fort Wolters, Texas where tests indicated pilot preference, influence on pilot performance, and qualities of size and contrast.

Both laboratory and field tests determined one of the two final test patterns (designated as pattern Z in text) as best for providing identification from a distance of one mile, and for approach angles of 5^{o} to 20^{o} inclusive. Each of the final two patterns had some advantages, but considering all requirements pattern Z was judged to be best. In order that the selected pattern most effectively meet the requirements, minimum overall pattern size and line width were recommended. Also, to emphasize the importance of good contrast, it was recommended that the marking pattern be white, edged with a black border unless the surface is sufficiently dark that the border is not needed for good contrast. Finally, the selected pattern was recommended as an Army standard for helipad marking and, in addition, is being considered as a national and international standard.

PREFACE

This report describes the first phase of a two-phase study employing laboratory models and field tests to determine the optimum marking and lighting configuration for Army Heliport Landing Facilities. This study was made by the Research and Analysis Branch, Construction Engineering Laboratory, Ohio River Division Laboratories in accordance with the authorization contained in "Instructions and Outline Marking and Lighting of Army Heliport Landing Facilities, Army, Fiscal Year 1965." Financial support for the study has been provided by both the Army and Federal Aviation Administration.

Several government agencies are interested in this project and the utilization of the results. In order to keep abreast of the work and to contribute to progress in the work, these agencies provided technical assistance through participation by their personnel in consulting capacity at the periodic review and planning sessions held on the project: Office, Chief of Engineers, U. S. Army Assistant Chief of Staff for Force Development, U. S. Navy, U. S. Air Force, Federal Aviation Administration, and the National Bureau of Standards.

Personnel of the Ohio River Division Laboratories actively engaged in the planning and testing phases of this study were Messrs. E. A. Lotz, R. L. Hutchinson, T. H. Morrow, Jr., E. S. Gall, H. R. Barrett, and Miss S. E. Cluxton. This report was prepared by Mr. T. H. Morrow, Jr. under the supervision of Mr. E. A. Lotz, Chief, Construction Engineering Laboratory.

This report has been reviewed and revised based upon the comments received from the Office, Chief of Engineers, U. S. Army Assistant Chief of Staff for Force Development, and the Federal Aviation Administration.

The Director and Assistant Director of the Ohio River Division Laboratories during this study were Messrs. F. M. Mellinger and R. L. Hutchinson, respectively.

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PART I: INTRODUCTION

Background

1. During recent years there has been a marked increase in the number of Army helicopters and helicopter operations which has brought about a need for an increased number of facilities. Takeoff and landing operations with helicopters are sufficiently different from fixed-wing aircraft to warrant specially designed marking and lighting systems for heliport facilities. During fiscal year 1965 the Office of the Chief of Engineers (OCE) commenced planning for an investigational program to develop recommended Army heliport marking and lighting systems. The planned program was coordinated with the Federal Aviation Administration (FAA) which is responsible for the development of marking and lighting national standards. It was concluded that a cooperative investigational program would provide information needed by both agencies. The FAA supplemented the Army funding and a cooperative investigational program was initiated at the Ohio River Division Laboratories (ORDL) in the latter part of fiscal year 1965. The Navy, Air Force, and National Bureau of Standards furnished technical assistance throughout the conduct of the program.

Purpose and Scope

2. This report presents the first phase of the investigational program, the purpose of which was to develop a recommended marking pattern for helipads. The program included studies of marking pattern, pattern size, and contrast between the marking pattern and the helipad pavement. No studies were conducted for marking of helicopter taxiways or heliport parking areas.

Approach

3. Laboratory and field tests, in conjunction with questionnaires and opinionnaires, were used to develop the recommended marking pattern. Laboratory model studies and photographic techniques facilitated rapid evaluation of a large number of marking patterns and the study of marking pattern size and contrast. Opinionnaires were used frequently among the laboratory staff and representatives from other agencies, including operational personnel, to obtain a qualitative evaluation of various patterns. The marking patterns selected from the laboratory studies were installed on existing helipads at two active Army airfields. Questionnaires and pilot interviews provided information by which to evaluate the patterns.

Requirements

4. Fundamental requirements for the marking patterns were developed from a review of current practices, discussions with helicopter pilots, and observations of helicopter operations. The marking pattern requirements included approach angles, visibility and geometrics, and were designed to provide

a. identification at a minimum distance of 1.6 km (1.0 mi), measured on the ground for approach angles ranging from 5^{o} to 20^{o} inclusively under Visual Flight Rules (VFR) conditions.

b. directional control to the pilot during his approach to the helipad.

c. a field of reference to assist the pilot in maintaining the correct attitude of the helicopter during his approach to the helipad.

d. assistance to the pilot in controlling his rate of closure to the helipad.

e. a point of convergence to the desired touchdown or hover area.

f. assistance to the pilot in determining the location of the helicopter with respect to the touchdown or hover point when the helicopter is directly over the helipad.

PART II: LABORATORY TESTS

General

5. Following the preliminary evaluation of marking patterns, which was accomplished by visual observation and opinionnaires, laboratory photographic techniques were used to evaluate pattern identification, size, and contrast. However, the model studies of marking pattern size and contrast were conducted as a result of the field test evaluation of marking patterns. Photographs of the scaled models permitted a fairly accurate analysis of the effects of approach angle on pattern identification and permitted a reasonable comparison of the effectiveness of the various patterns. To insure reasonable marking pattern evaluation by photographic techniques, care was exercised in the scaling and construction of the models and selection of photographic equipment. Efforts were made to simulate daytime field conditions for the model tests.

Equipment

6. The natural terrain was simulated by a 3.7-m (12-ft) square platform. To establish realism, the platform was covered with burlap which was painted green and edged with artificial foliage. The model helipad, on which the marking patterns were painted, was placed in the geometric center of the platform. The platform was fixed to the floor in one position and the camera was located at a scaled one-ground-mile distance from the platform. The approach angles were simulated by elevating the camera to produce the desired angle with the model helipad surface. The model study setup is shown by Figure 1.

7. Based upon laboratory space available, a linear scaling of 1:60 was selected for all model testing. The model helipads were constructed 76 cm (30 in.) square simulating an actual helipad 45.7 m (150 ft) square. (A discussion of the scaling relationships used is contained in Appendix A.) Initially, the model helipads were constructed of portland cement-sand mortar and were 0.6 cm (1/4 in.) thick. Construction of the models was time consuming, and constant surface texture and color were difficult to maintain. (Paragraph 17 further discusses this problem.) Therefore, later model helipads were constructed from hardboard and the surface was painted medium gray to simulate a weathered portland cement concrete surface. All marking patterns were painted on the model helipads.

8. Xenon Arc lamps, which provide a constant color temperature during the life of the lamps, were used to light the platform and model helipad. Sufficient lighting was used to simulate daytime conditions providing maximum, uniform film plane coverage on the model for both color and black and white photography. In all tests, the lights were in the same position relative to the platform to simulate maximum lighting occurring from directly overhead, or noontime.

Photographic Techniques

9. From photographic scaling relationships, it was determined that the camera must be located 8.949 m (29.36 ft) from the model to produce an image on the photograph that would be the same size as a 45.7-m (150-ft) square pad seen by the eye from a distance of 1.6 km (1.0 mi). Likewise it was determined that the model, when viewed from a distance of 26.8 m (88.0 ft) would be the same size as a 45.7-m (150-ft) square pad viewed from a distance of 1.6 km (1.0 mi). (Appendix A contains a description of the method used to establish the scaled distances.) The approach angle is represented by the angle between a projection of the camera lens axis and a projection of the model pad surface (see Figure 1). Both color and black and white photography were used throughout. However, color photography was utilized for all pattern evaluation contrast studies.

Marking Pattern Evaluation Tests

Preliminary Tests

10. Following establishment of the marking pattern requirements, a large number of marking patterns was considered. The number was gradually reduced to the 25 patterns shown by Figure 2, which, from an initial review, were believed to satisfy the requirements. Each of these 25 patterns was painted on a simulated scaled helipad and given a critical review by visual observations. The scaled helipad and markings were observed by several personnel from a distance of 26.8 m (88.0 ft) which simulates the size of an actual helipad 45.7 m (150 ft) square when viewed from a distance of 1.6 km (1.0 mi). The marked helipads were viewed at several angles within the range covered by the approach angle requirements. The viewing personnel then completed opinionnaires rating the various patterns. From the opinionnaires, 15 patterns were rejected for one or more of the following reasons:

a. The pattern was not identifiable from a distance of one mile when viewed at the shallow approach angles.

b. The more complex patterns relayed a congested effect, and tended to be more confusing than helpful.

c. Some of the patterns could be mistaken for other geometric forms or designs used for the marking of parking areas, compass rose, closed facilities, highways, and crossings.

Initial Model Tests

11. From the results of the preliminary tests, ten patterns were selected for further evaluation utilizing photographic techniques. The patterns and dimensions which were scaled at a 1:60 ratio for the model tests, are shown by Figures 3 through 7. Each pattern was photographed at five-degree increments through the range of approach

angles of 5°, 10°, and 15° as shown by Plate 1. A 4 x 5 in. view camera equipped with a lens having a 150 mm focal length was used to photograph the scaled models. Ektacolor negative type "S" and Royal Pan black and white films were used.

12. Photographs of the ten marking patterns studied at each approach angle were analyzed by members of the laboratory staff, and representatives from other agencies. Also, preferential studies were conducted with a group of helicopter pilots. The results of these studies provided the following specific comments regarding the adequacy of the pattern studied and general comments applicable to any pattern:

a. Patterns 3 and 4 maintained identification at all approach angles; however, horizontal or near-horizontal lines began to disappear at angles of 10° or less.

b. Patterns 5 and 6 were identifiable at approach angles of 15° but became confusing and difficult to identify at 10° or less.

c. Patterns 1, 7, 8, 9, and 10 were identifiable at approach angles of 15° but lost identification at 10° due either to congestion or loss of a part of the pattern.

d. Pattern 2 lost its identity at an approach angle of 20° due to congestion and compactness of the pattern.

e. Circular patterns tended to lose identity more rapidly and did not provide guidance as well as straight-line patterns.

f. Small discontinuities, such as arrow heads, short bars, or short sections of circles became indistinguishable more rapidly than long solid lines.

g. Lines parallel or near-parallel to the direction of approach remained identifiable at all approach angles.

h. Lines normal or near-normal to the direction of approach disappeared as the approach angle became smaller, however, this was overcome somewhat by wider or thicker lines.

Final Model Tests

13. From the results of the initial model tests, nine patterns were selected for further evaluation utilizing photographic techniques as previously described. Patterns E, F, G, and H (Figure 8) are modifications of patterns 6, 4, 5, and 3 (Figure 2) respectively, which were selected from the ten patterns studied in the

initial model studies. Patterns J and K were recommended for study by the pilots in an attempt to retain some simulation to the already familiar triangle "H" marking pattern. Patterns A, B, and C are new patterns developed to make more use of wide straight lines, or line segments which from the initial model studies were considered to be more meaningful than curved or tapered lines. The dimensions of the patterns which were scaled at the 1:60 ratio for the model tests are shown by Figures 9 through 13.

14. Each of the nine patterns was observed from the scaled distance of one mile by laboratory staff members and each pattern was photographed at five-degree increments through the range of approach angles specified by the requirements as stated in paragraph 4a. The photographs were analyzed by members of the laboratory staff and representatives from the other participating agencies. The results of these tests indicated that patterns J and K became congested and were not identifiable at the shallow approach angles. The remaining seven patterns were recognizable at all angles of approach. Thus, further evaluation by field testing, as described in Part III, was conducted.

15. Throughout the laboratory model tests of pattern evaluation, pattern size was not a variable. With one exception, the scaled models studied were of a 45.7-m (150-ft) square pad with an overall outside pattern dimension of 30.5 m (100 ft). The only exception was the study of the existing triangle "H" pattern which was dimensioned as shown by Figure 3B. The field tests (Part III) indicated the need for a study to develop recommended dimensions for the marking pattern. A laboratory model study was performed which was designed to establish the minimum pattern size necessary to meet the requirement stated by paragraph 4a. Models of the marking pattern shown by Figure 11A (or Figure 14B) were used for the study. Scaled models were prepared representing pattern sizes of 7.6, 15, 23, 30.5, 38.1 and 45.7 m (25, 50, 75, 100, 125 and 150 ft) on a 45.7-m (150-ft) square helipad providing overall pattern to pad size ratios ranging from 0.17 to 1.00. In addition, three models were prepared for each overall pattern dimension in which the width of the lines making up the pattern was varied. Each model was then viewed from a scaled distance of 1.6 km (1.0 mi) at an approach angle of 5^o by several members of the laboratory staff. (Photographic enlargements on Plate 2 illustrate these scale models viewed at a 5^o approach angle.) The procedure used was to observe each model starting with the smallest pattern and progressing through the range of models to the largest pattern. After viewing each pattern, the observers were asked whether the pattern was identifiable and, if so, to rate the identification as to good, fair or poor with reasons for the ratings.

16. The consensus of the observers regarding pattern size was:

a. A minimum pattern size of 23 m (75 ft) is needed to be identifiable from a distance of 1.6 km (1.0 mi) at an approach angle of 5^o.

b. There was no appreciable difference concerning pattern identification for those models having overall pattern to pad size ratios from 0.50 to 0.83.

c. Identification of the pattern having a pattern to pad size ratio approaching 1.00 was confusing because the pattern blended with the perimeter marking.

d. A ratio of line width to pattern size of 0.07 provided the best pattern definition (see Plate 3).

e. Horizontal or near-horizontal lines disappeared, or were judged to be too thin to provide adequate definition, when the line width to pattern size was less than 0.05.

f. When the line width to pattern size ratio was 0.1 the pattern began to give the impression that the entire pad was painted.

Contrast Studies

17. As mentioned in paragraph 7, problems of maintaining uniform surface texture and constant color of the portland cement concrete model helipads were experienced early in the model studies. In these tests the problem did not so much concern the variation in color of the concrete; however, due to differences in the surface texture, or pad finish, the reflectivity of the light to the camera or observer varied considerably across the surface of the model helipad. This factor was complexed by the use of white paint to mark the relatively white-colored concrete pad. Thus, the marking on a photograph on one pad was difficult to distinguish while on another pad, under identical conditions, the marking was easily identified. While these problems in the model could not be totally associated with contrast, the importance of having adequate contrast to obtain the qualitative evaluation was indicated. The problem of contrast occurred again in the field tests at Fort Wolters where the surface of portland cement concrete helipads seemed unusually white. Subsequent field observations revealed considerable variance in tone in both bituminous and portland cement concrete surfaces. Some of this difference results from the selection of materials used for construction; the remaining difference results from the aging process and usage.

18. No attempt was made to study the effects of varying contrast between the marking pattern and helipad surface during the laboratory pattern evaluation tests. Instead, care was exercised to equalize contrast for all models so the results could be compared. Some studies of the effects of contrast were carried out in the field

as described in Part III. Laboratory model studies were used to determine the minimum width of black border around the white marking pattern required to provide sufficient contrast between the pattern and a light-toned helipad surface so that the pattern would meet the requirement in paragraph 4a. Pattern F (Figure 11A) was used for the study. Scaled models representing a 23-m (75-ft) pattern on a 45.7-m (150-ft) square pad were prepared. The width of the white lines making up the pattern were held constant at 1.5 m (5.0 ft). The white lines were bordered with black, using widths of 0.31, 0.46, 0.61, and 0.76 m (1.0, 1.5, 2.0 and 2.5 ft). (See photographically enlarged examples of line width and edging size studies on Plate 3.) The models were viewed from a scaled distance of 1.6 km (1.0 mi) at an approach angle of 5^{o} by several members of the laboratory staff. The consensus of the observers was that the black border width of 0.46m (1.5 ft) was adequate, or perhaps a little more than needed to provide sufficient contrast for the marking pattern to meet the requirement of paragraph 4a. The black border width of 0.31m (1.0 ft) was judged insufficient because the horizontal or near-horizontal lines tended to disappear. Black border widths of 0.61 and 0.76 m (2.0 and 2.5 ft) were too wide, giving the illusion that the marking pattern was in black rather than white. Photographic enlargements on Plate 3 illustrate comparative contrast between marking patterns with and without a black border as well as maximum contrast produced by a white pattern on a black pad.

PART III: FIELD TESTS

Fort Rucker Experiment

19. Following the conclusion of the final laboratory model tests (paragraphs 13 and 14) the seven selected patterns were subjected to pilot evaluation at Hanchey Army Heliport, Fort Rucker, Alabama. The seven patterns (A, B, C, E, F, G, and H of Figure 8) were painted on the east and west overrun areas of the airfield (see Plates 4 and 5). Asphaltic concrete overrun areas were 38.1 m (125 ft) square and the overall size of the patterns, which were marked with white paint, was 30.5 m (100 ft). Detailed dimensions of each marking pattern used are shown by Figures 9 through 12A.

20. The program was explained to the pilots so that they were aware of being involved in a marking pattern evaluation program. However, they were also told that this program was not to interfere with their basic mission which was pilot training. The pilots were instructed to approach the marked overrun areas but to land on the helipads (see Plates 4 and 5). A questionnaire was prepared by the FAA which asked pertinent questions as to pattern preference, pattern size, and desirable or undesirable features of the patterns. After about one month, the pilots were interviewed and asked to complete the questionnaires, which were then analyzed by the FAA. (Detailed results are included in Appendix B.) Generally, pilot evaluations revealed that

a. pattern F (Figure 8) was the first choice by a great majority.

b. pattern B (Figure 8) was the second choice with the remaining five patterns about equally rated.

c. practically all pilots indicated that pattern sizes were suitable.

d. the patterns selected provided good guidance control and did not lose their identification at the shallow approach angles.

21. In addition to pilot evaluation, the patterns were observed by laboratory personnel flying as passengers in a few helicopter operations. Observations by the laboratory staff members revealed that

a. the patterns were readily visible at all approach angles at a distance of one mile, and furthermore, could be distinguished from a distance of one and a half miles.

b. from a distance of one mile the patterns appeared to be very similar to those produced by the laboratory scaled model tests, i. e. both visual observations from the scaled one mile distance and the photographs of the scaled models from the scaled mile distance.

Fort Wolters Experiment

22. The two marking patterns (F and B, Figure 8) which were favored by the pilots during the Fort Rucker experiment were subjected to further evaluation at the U.S. Army Primary Helicopter School at Fort Wolters, Texas. However, because of the helipad size 9.1m (30 ft) at Fort Wolters, the dimensions of the marking pattern had to be changed and the patterns were redesignated as Y and Z as shown by Figures 14A and 14B. The patterns installed at three tactical staging areas and at one airfield area were similar, each area having two rows of four helipads as shown by Figure 15. All of the helipads were constructed of portland cement concrete and each had an unusually white color. The helipads in the staging areas were bordered with turf while those in the airfield area were bordered with asphaltic concrete, having been constructed within old asphaltic concrete runways.

23. Since the Fort Rucker tests had consisted of white patterns on a black (asphaltic concrete) surface, it was decided that some pads at Fort Wolters would be similarly marked so the results would be comparable. This also offered the opportunity to study the effects of both white markings on black surfaces and black markings on white surfaces. There were sufficient helipads to observe the effects on operations of marked and unmarked helipads. Therefore, the helipads were painted and marked as shown by Figure 15. Portland cement concrete constituted the white pad surfaces while the black pads were produced by painting the portland cement concrete surfaces with a black-pigmented concrete curing compound material.

24. Unlike the Fort Rucker tests, the experiment at Fort Wolters was designed to obtain evaluations of the marking by both students and instructors and to obtain the instructors' evaluations of the marking patterns based on student performance. The instructor and student pilots were each briefed prior to the beginning of the evaluation using the briefing material included as Exhibits 8 and 9, Appendix B. After a period of about one month, the student pilots were asked to complete a comparative questionnaire and a preference questionnaire (Exhibits 4 and 6, Appendix B) and the instructors completed a preference rating and a student performance evaluation (Exhibits 5 and 7, Appendix B). These questionnaires were designed by the FAA for analysis. The results and analysis of data collected is shown by Appendix B. Basically, the results were:

<u>a</u>. Pattern Z (Figure 14B) was preferred slightly to Pattern Y (Figure 14A) but the difference was practically insignificant.

b. The majority of students and instructors preferred a white on black rather than the black on white marking, however, the plain pad preference was for white.

c. Pattern Z was considered superior in approach angle and closure rate while pattern Y was considered superior for ground track.

25. The maximum pattern size practical, 8.5 m (28 ft), was used on the 9.1-m (30-ft) square pads. This gave a pattern to pad size ratio of 0.93. Student pilots and instructors alike reported that the patterns were not identifiable from one mile, especially at the more shallow approach angles. Therefore, the evaluation tests at Fort Wolters were performed by making approaches from a distance of one-half mile, about the maximum distance from which the patterns were identifiable. The requirement of identification of the marking pattern at a minimum of 1.6 km (1.0 mi) was not attained at Fort Wolters, emphasizing the need for a minimum pattern size necessary to meet the requirement. As a result, the pattern size studies (paragraphs 15 and 16) were performed.

PART IV: DISCUSSION

26. This study has been primarily concerned with the development of a marking pattern shape which would readily identify the existence of a helipad to the pilot. In general, laboratory tests facilitated qualitative comparison of numerous patterns to eliminate those with obvious deficiencies. Field tests determined final selection of the marking pattern. In selecting the pattern shape, pattern dimensions were not of prime concern as evidenced by the fact that different overall pattern sizes were used both in the laboratory and field. Rather, the selection was based upon the ability of the pattern to be easily and rapidly identifiable and to provide orientation information to the pilot.

27. Since one of the basic requirements for the study was to be able to identify a helipad by means of the marking pattern from one mile at approach angles of 5^o to 20^o inclusively, laboratory tests were conducted to determine overall pattern dimensions. It was found that the selected pattern had to be at least 23m (75 ft) in overall dimensions to meet the above requirement. For the 45.7-m (150-ft) helipad used in the study, as the ratio of overall pattern to pad size varied between 0.50 and 0.83 the pattern retained identity while fulfilling all basic requirements. However, it is obvious that this relationship is not true regardless of pad size. For example, a ratio less than 0.50 could be used for extremely large pads, and the pattern may still be identified from the one mile required distance. Similarly, for pads less than 45.7m (150 ft) a ratio of 0.50 would not yield a pattern size sufficiently large to meet the requirements. Thus, a larger ratio would be necessary.

28. Patterns larger than the selected 23m (75 ft) were of course more easily identifiable but only until the pattern became so large on a specific pad size that it conflicted with the perimeter marking. In order to eliminate possible confusion by the pattern's blending with perimeter marking the maximum overall pattern to pad size ratio was determined to be 0.83. Under such conditions the minimum pad size must necessarily be 27m (90 ft). When it is necessary to construct pads smaller than the minimum 27m (90 ft) it will be impossible to install a marking pattern large enough to meet the stated requirements and yet maintain adequate definition between the pattern and perimeter marking. For these smaller pads the marking pattern should be as large as possible to provide identification from the greatest possible distance. Model studies indicated that this may be accomplished by using the ratio of overall pattern to pad size of 0.83 (see Figure 17).

29. As the pattern study progressed the importance of contrast between the marking pattern and helipad in pattern identification became evident. Some contrast studies were conducted at Fort Wolters while others were performed by laboratory

model tests. At Fort Wolters the white marking pattern on a black pad appeared to be more easily identified than the black pattern on a white pad. Observers agreed that the width of lines making up the black pattern on a white pad seemed narrower than for the reverse condition. This was an optical illusion since the line widths used for each were equal.

30. While the Fort Wolters tests provided valuable information, the results were inconclusive since, in most instances, bituminous concrete pads will not be as black nor will portland cement concrete pads be as white as those studied. The laboratory tests performed are considered to be more indicative of normal pad colors which will be a light grey-tone for portland cement and a deeper grey-tone for bituminous concrete. These studies indicated that adequate contrast can be obtained by the white pattern on dark surfaces. Increased contrast is gained by using a black border around the white pattern for installations on light-toned surfaces. The contrast studies conducted were not comprehensive enough to define the exact color tone necessary to use the black border. Thus it can only be pointed out that the black border does improve contrast and should be used unless the existing surface is sufficiently dark.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

31. The following conclusions have been drawn based upon the results of tests conducted during the first phase of the program:

a. The model and photographic techniques provided a valuable tool for the qualitative evaluation of the ability of the various patterns to meet the requirement stated in paragraph 4 a.

b. The field test provided the only evaluations of the ability of the patterns to meet the requirements stated in sub-paragraphs 4 b through 4 f.

c. Both the laboratory and field tests indicated that the marking pattern F (Figure 11 A) or Z (Figure 14 B) was best for providing identification from a distance of one mile and for approach angles 5° to 20° inclusively.

d. Field tests indicated marking patterns Y (Figure 14 A) and Z (Figure 14 B) to be about equally effective for providing guidance and assistance to the pilot during approach and hover or touchdown. Pattern Y provided better ground track and stop/hover help while pattern Z provided more assistance in the approach angle, closure rate and roll attitude.

e. Considering all requirements (paragraph 4), pattern F (Figure 11 A) or Z (Figure 14 B) was considered to be the best.

f. Based upon the laboratory tests of pattern size, and supplemented by the field tests, a minimum overall size of marking pattern of 23 m (75 ft) and a minimum width of lines within the pattern of 1. 5 m (5. 0 ft) are needed to meet the requirement stated in paragraph 4 a.

g. The laboratory and field tests alike indicated the importance of contrast between the marking pattern and helipad surface. It was found that a white marking pattern on black pad surface provided maximum contrast and definition (Plate 3).

h. Based upon the field tests, it was concluded that a helipad with a marking pattern provided aids to pilotage and was preferred to a non-marked helipad.

Recommendations

32. The following recommendations are based upon the results of this study:

a. The marking pattern and pattern dimensions shown by Figure 16 should be adopted as a standard marking pattern for Army helipads.

b. When the helipad dimensions are not sufficiently large (less than 90 ft) to accomodate the pattern dimensions shown by Figure 16, the pattern size should be reduced but maintain a ratio of overall pattern size to pad size of 0.83 and a ratio between width of line and overall pattern size of 0.07.

c. The marking pattern should be white when the helipad surface is sufficiently dark. Otherwise the pattern should be edged with a black border, keeping the ratio of the black border and the width of white line at not less than 0.25 to increase contrast.

d. Civil pilot evaluation of marking pattern should be obtained by marking selected helipads at civil airports and obtaining a sampling of pilot opinion using methods similar to those used for this study.

e. The pattern shown by Figure 16 should be recommended as a national and international standard for marking helipads.

f. The pattern shown by Figure 16 should be included in the proposed field lighting tests to obtain pilot evaluation of the marking pattern during night-time operations.

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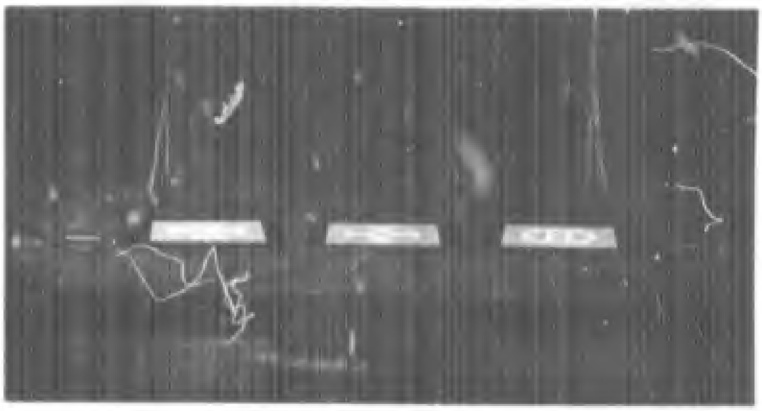
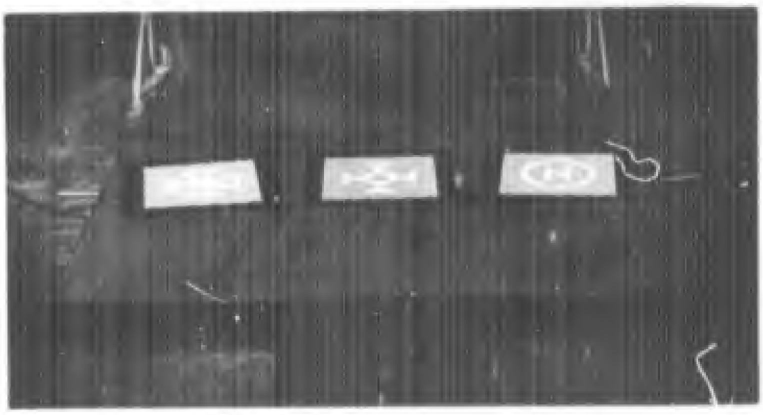
PAD F PAD B PAD J



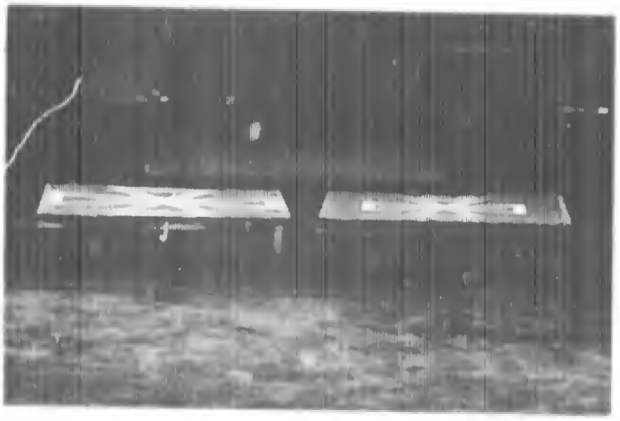
5°

10°

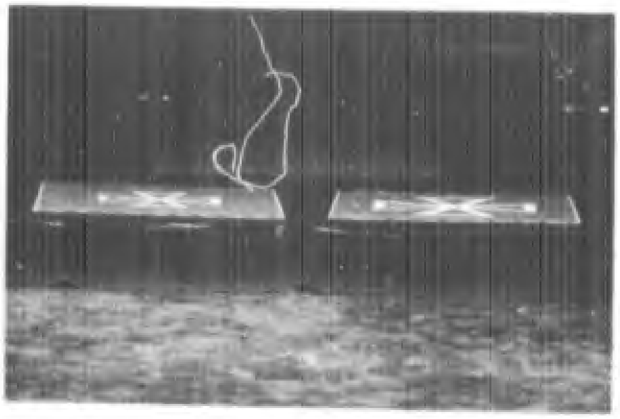


15°

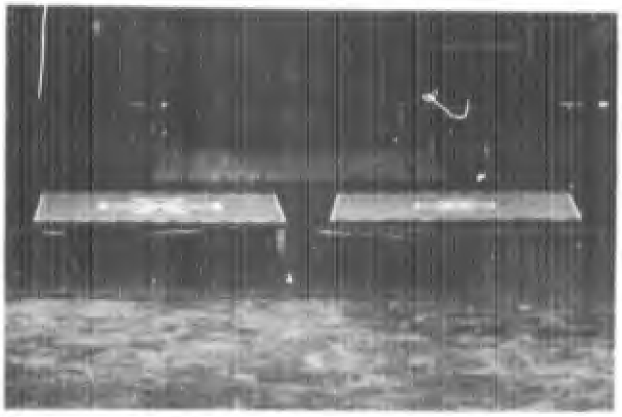
INITIAL MODEL TESTS ILLUSTRATING VARYING APPROACH ANGLES



150'　　100'



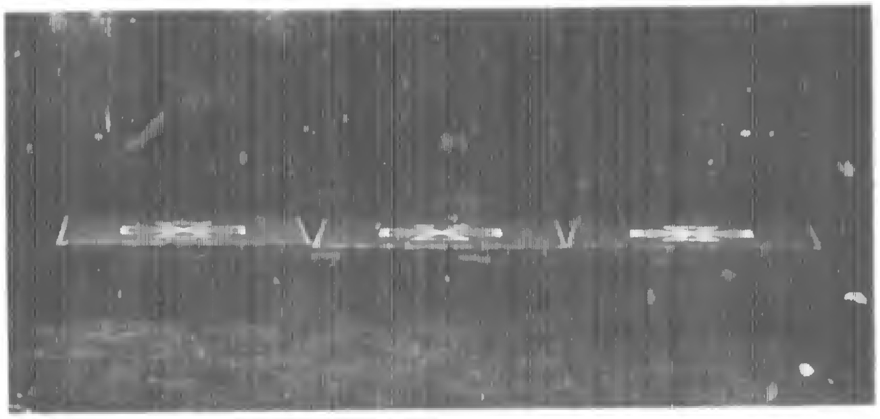
75'　　100'



75'　　50'

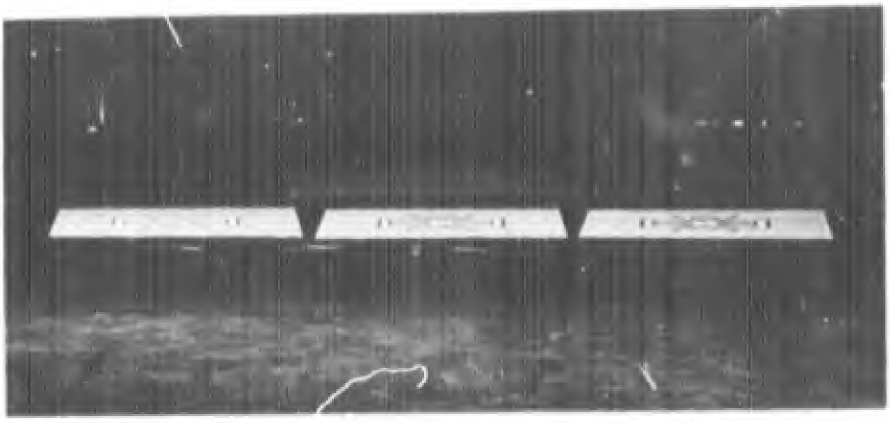
PATTERN SIZE STUDY AT 5° APPROACH ANGLE

PLATE 2



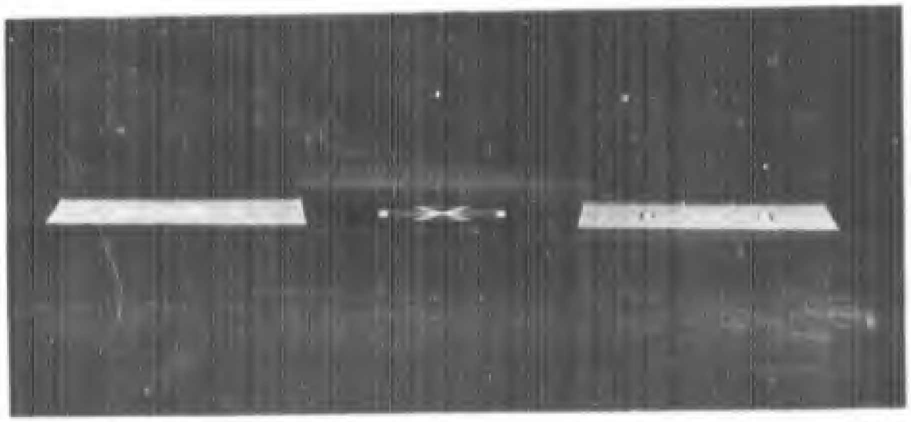
3.5' 5.0' 7.5'

Width Size



1.0' 1.5' 2.5'

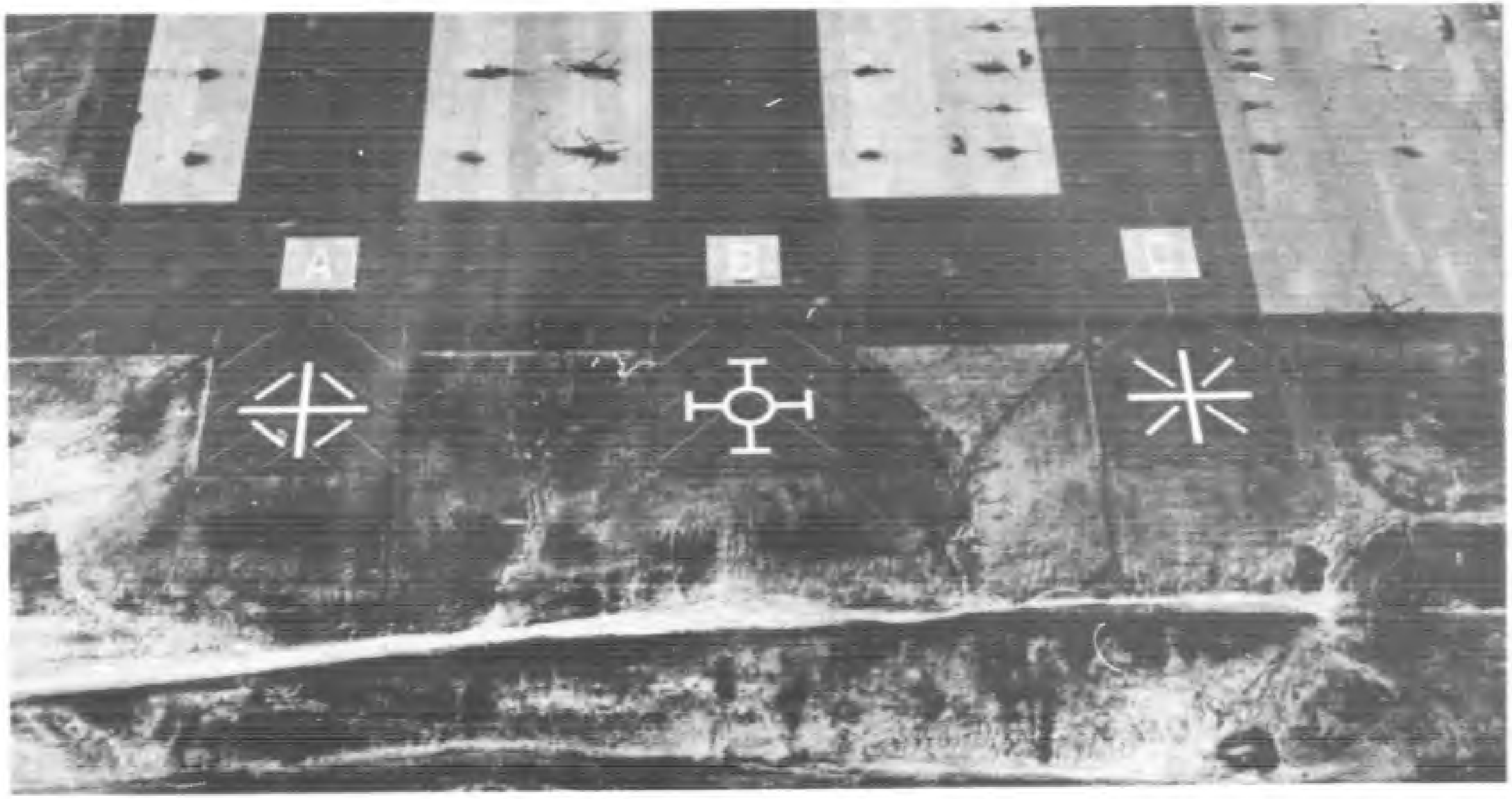
Edging Size



Selected Edging Comparison with Maximum Contrast and Plain Pattern

PATTERN WIDTH AND CONTRAST STUDIES USING PATTERN SIZE 75'

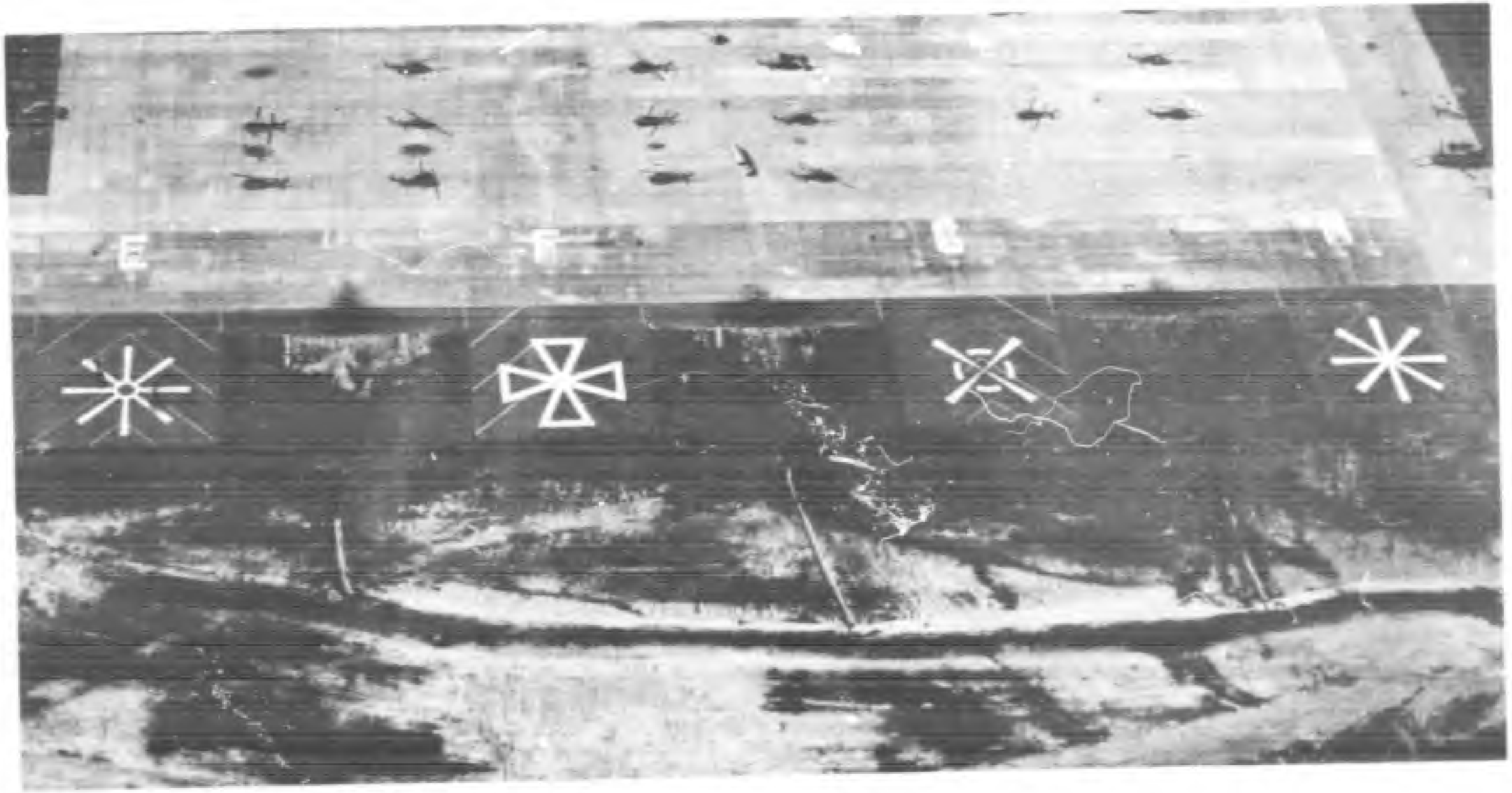
PLATE 3



HANCHEY ARMY HELIPORT

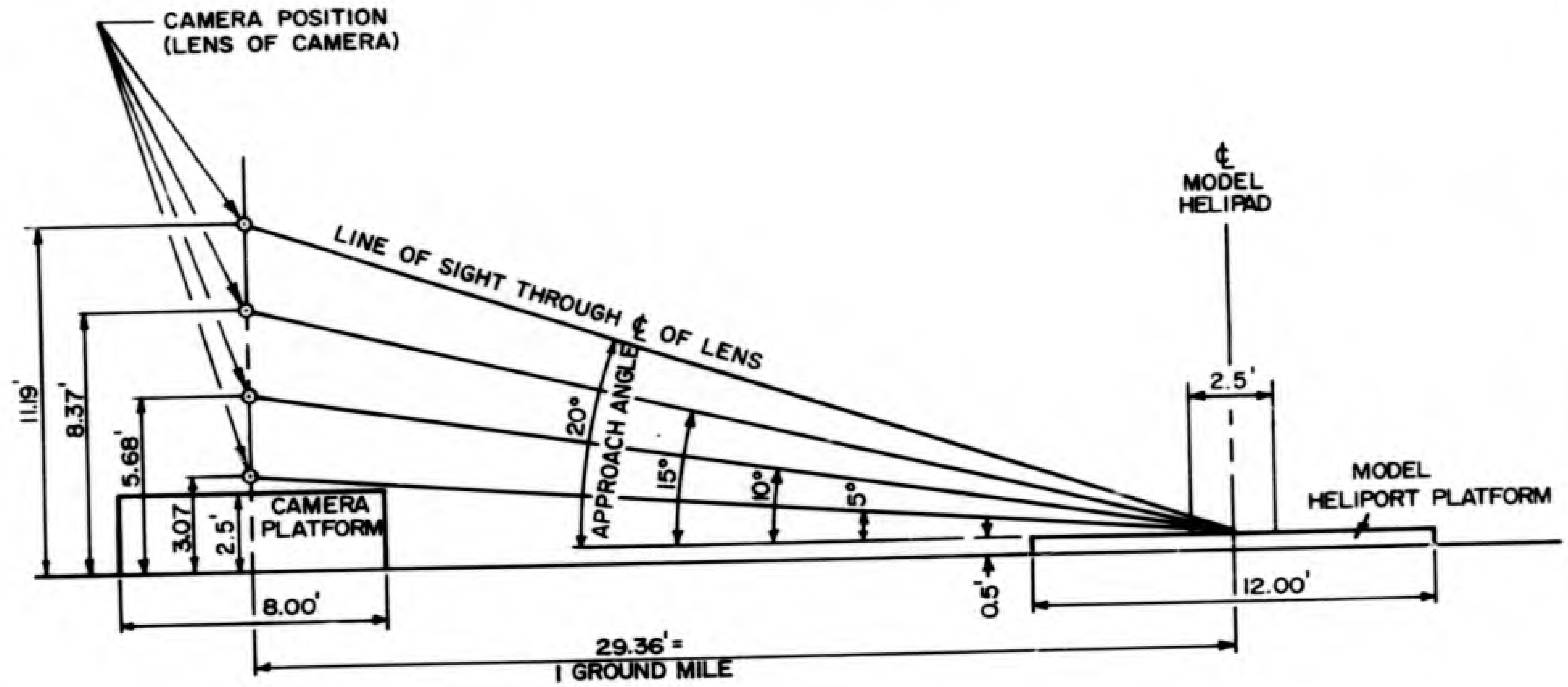
West Side
(Looking North)
Patterns A, B, and C

PLATE 4



HANCHEY ARMY HELIPORT

East Side
(Looking North)
Patterns E, F, G, and H

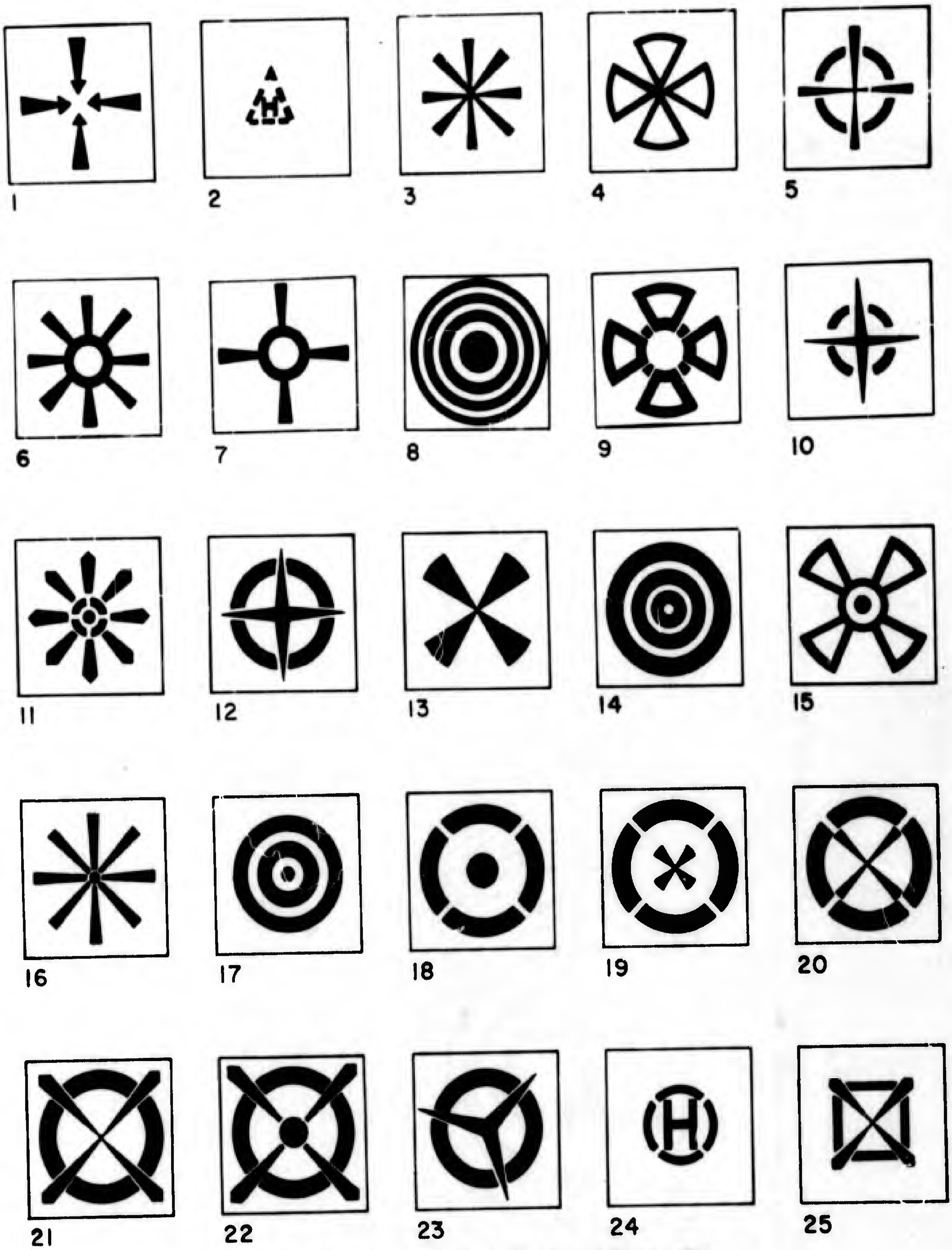


SKETCH OF HELIPORT MODEL STUDY CHAMBER
SHOWING PHOTOGRAPHIC SCALING TECHNIQUE
FOR APPROACH ANGLES TO HELIPAD

1.0 mi = 1.6 km
1.0' = 0.3048 m

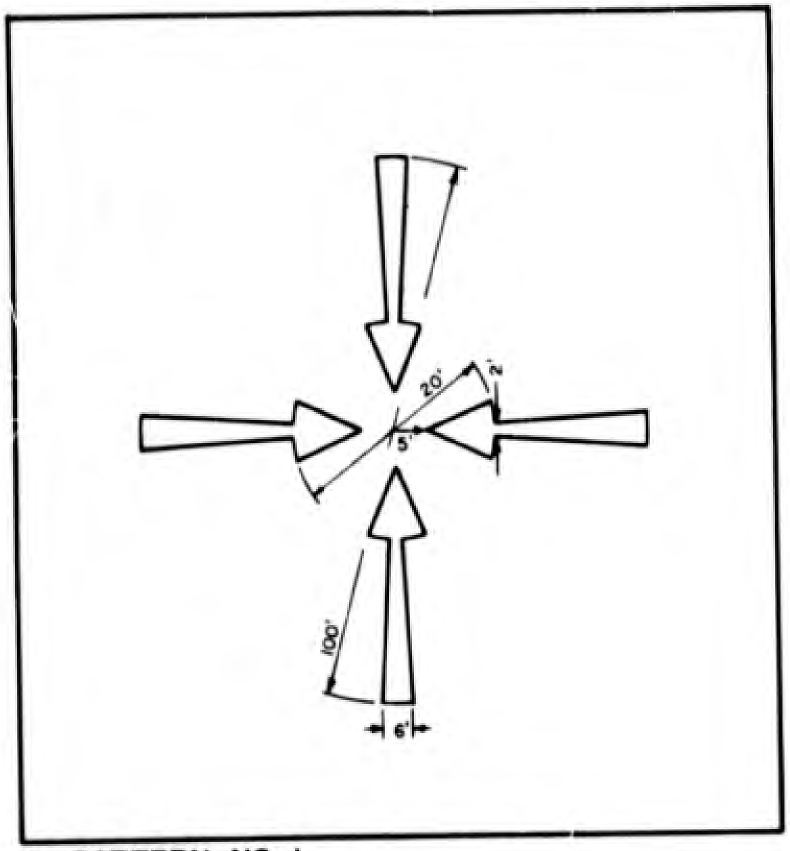
SCALE: 1" = 5'

FIGURE 1

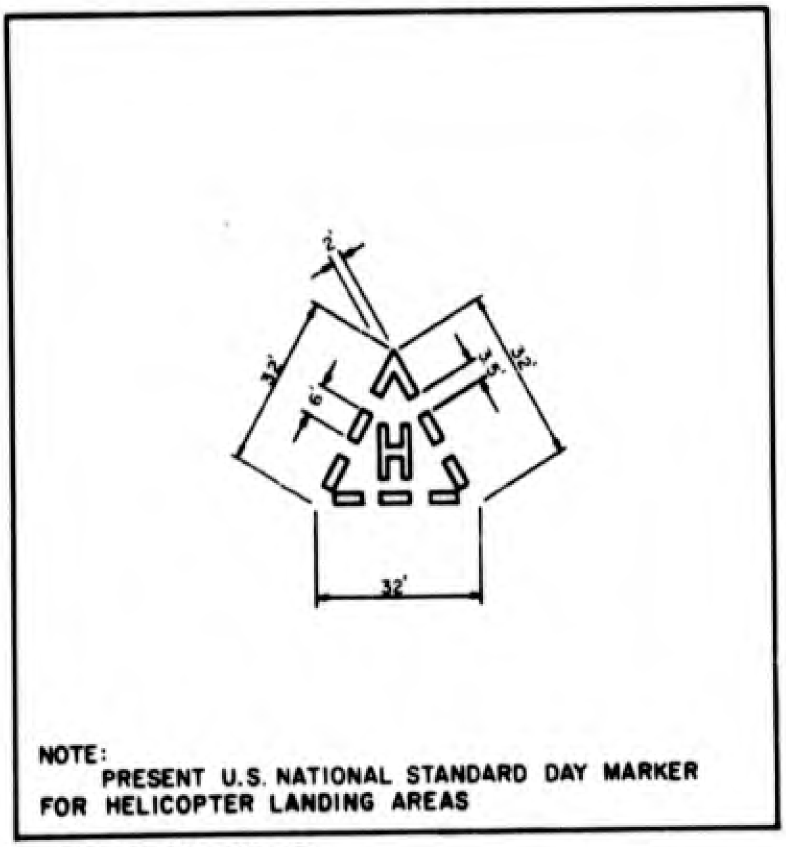


MARKING PATTERNS EVALUATED BY PRELIMINARY TESTS

FIGURE 2



A. PATTERN NO. I

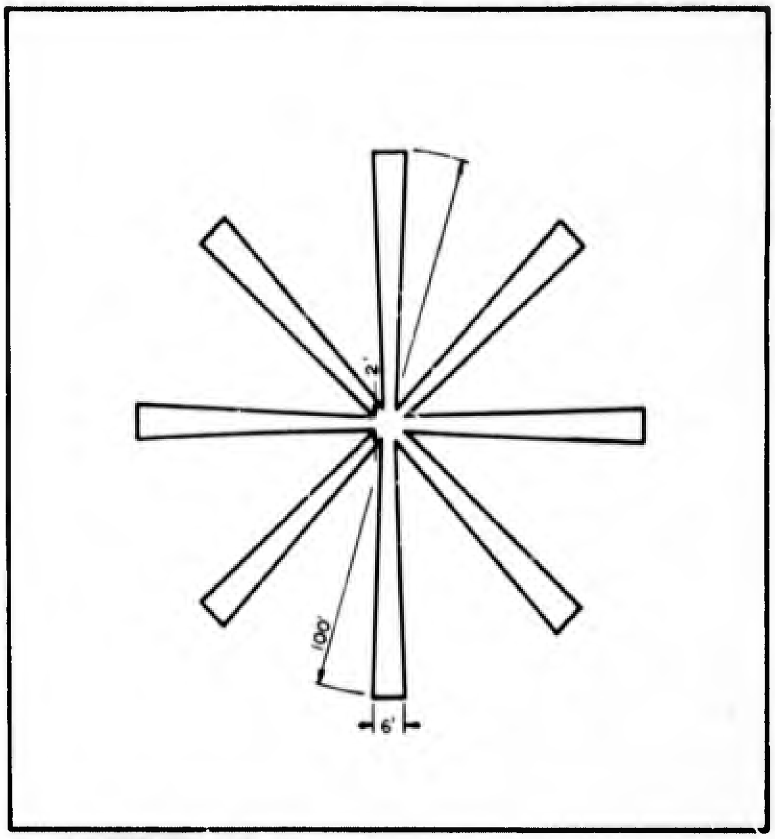


B. PATTERN NO. 2

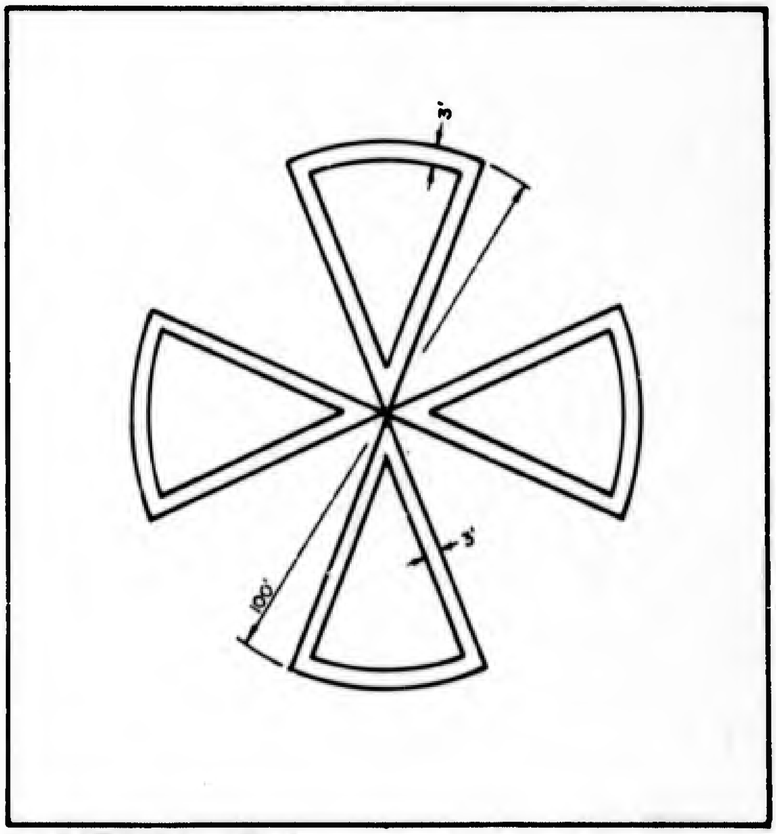
MARKING PATTERNS EVALUATED BY INITIAL MODEL TESTS

1.0' = 0.3048 m

FIGURE 3



A. PATTERN NO. 3

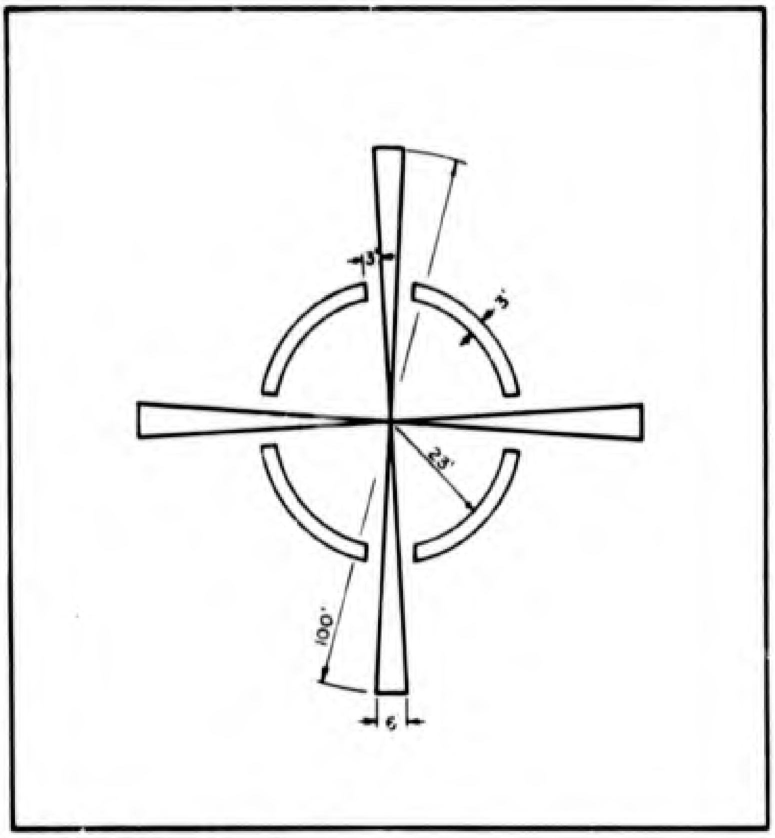


B. PATTERN NO. 4

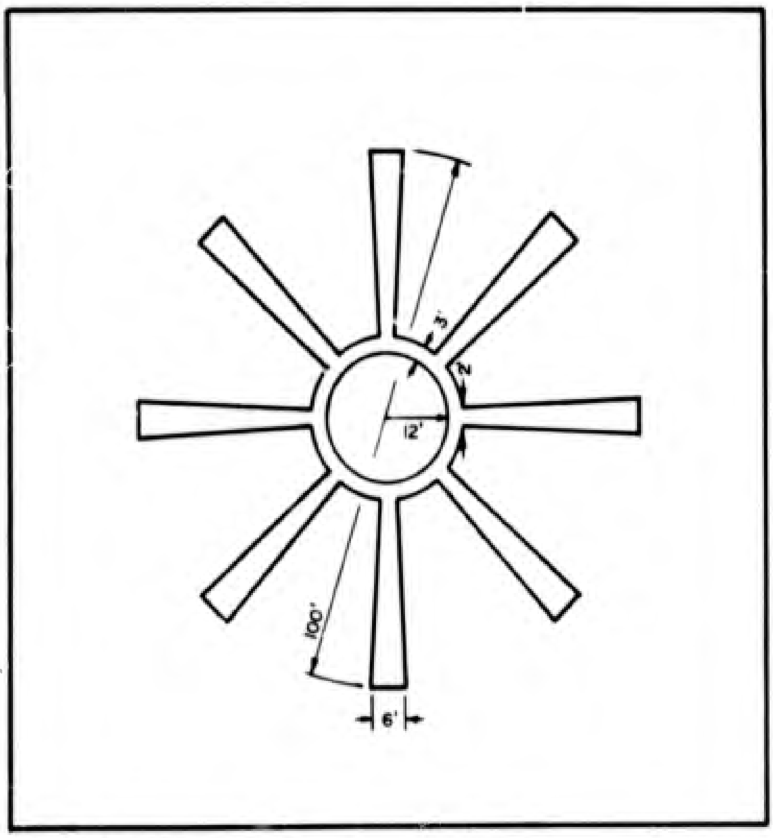
MARKING PATTERNS EVALUATED BY INITIAL MODEL TESTS

1.0' = 0.3048 m

FIGURE 4



A. PATTERN NO. 5

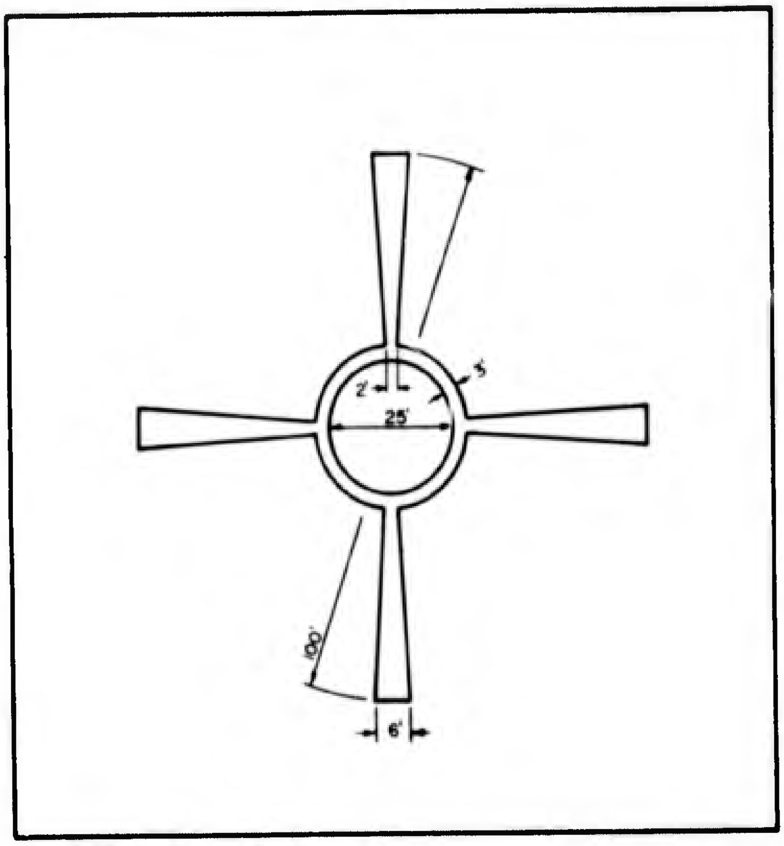


B. PATTERN NO. 6

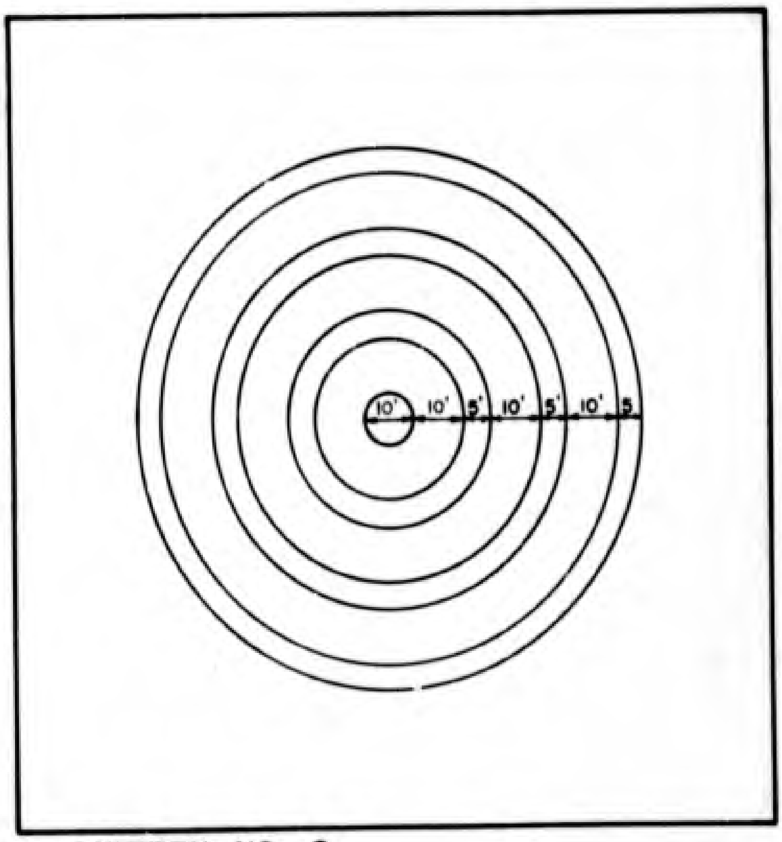
MARKING PATTERNS EVALUATED BY INITIAL MODEL TESTS

1.0' = 0.3048 m

FIGURE 5



A. PATTERN NO. 7

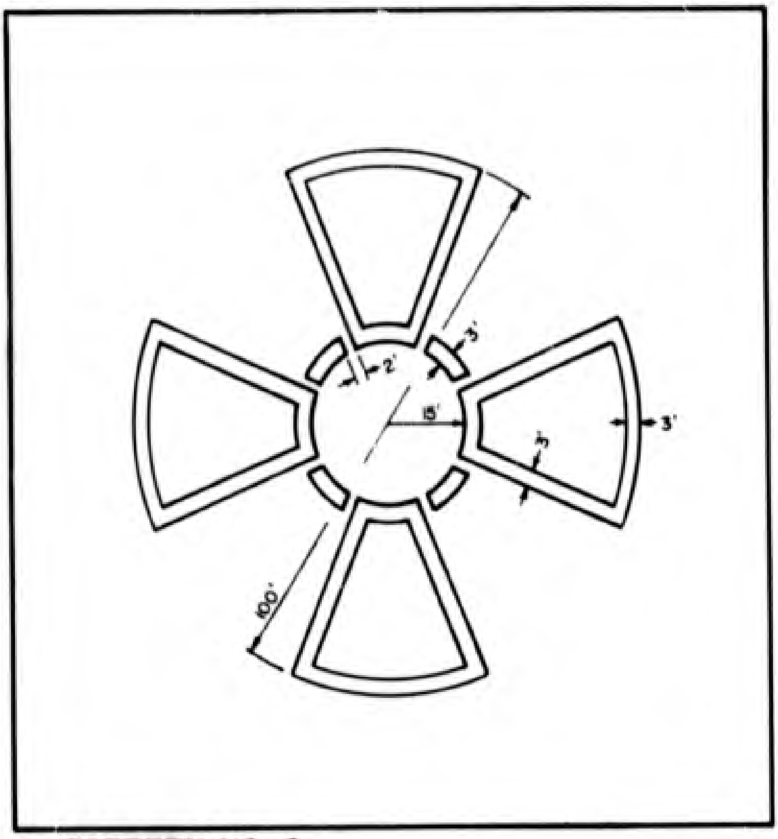


B. PATTERN NO. 8

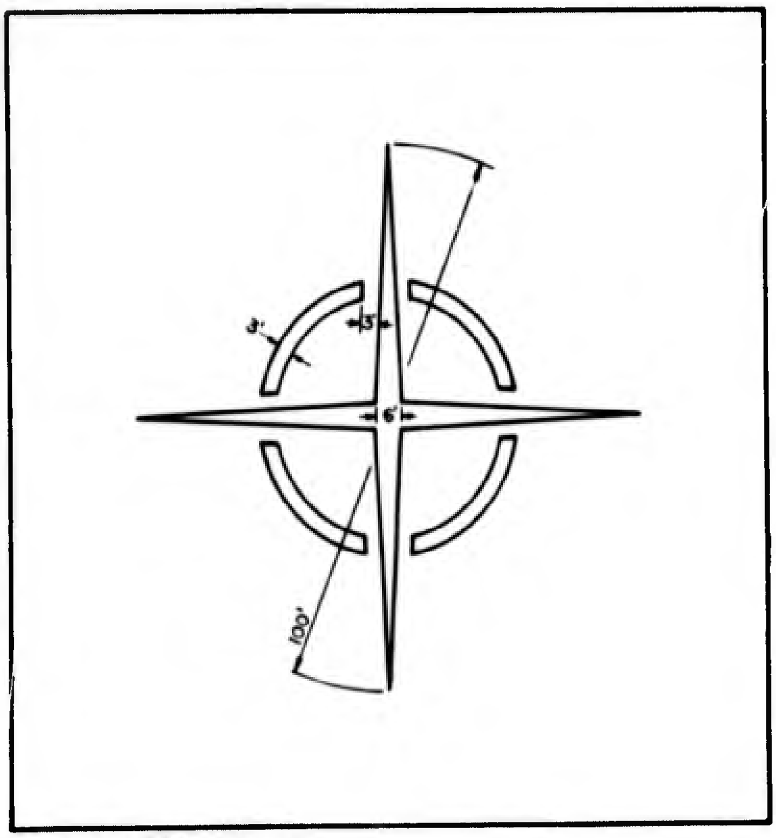
MARKING PATTERNS EVALUATED
BY INITIAL MODEL TESTS

1.0' = 0.3048 m

FIGURE 6



A. PATTERN NO. 9

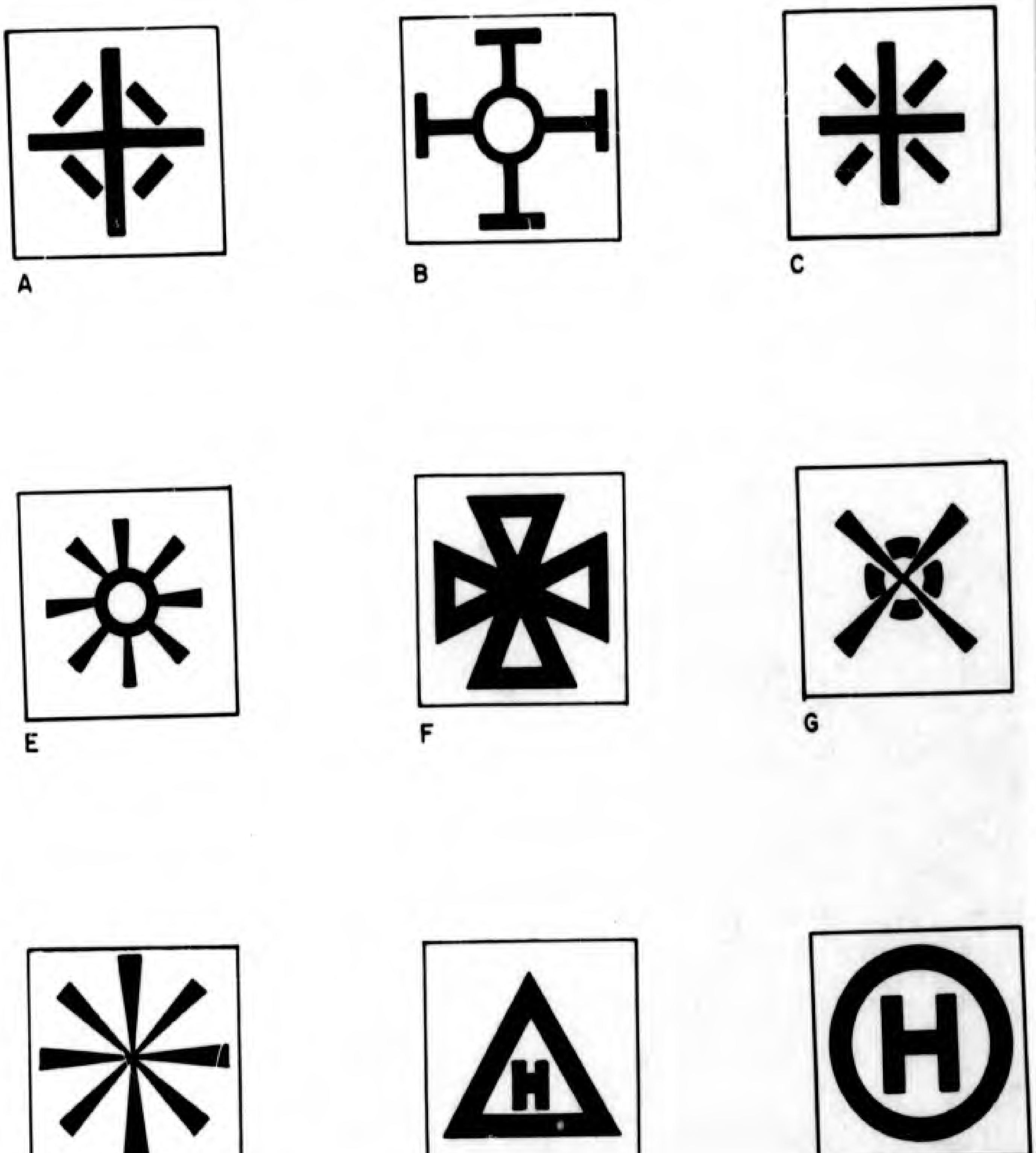


B. PATTERN NO. 10

MARKING PATTERNS EVALUATED BY INITIAL MODEL TESTS

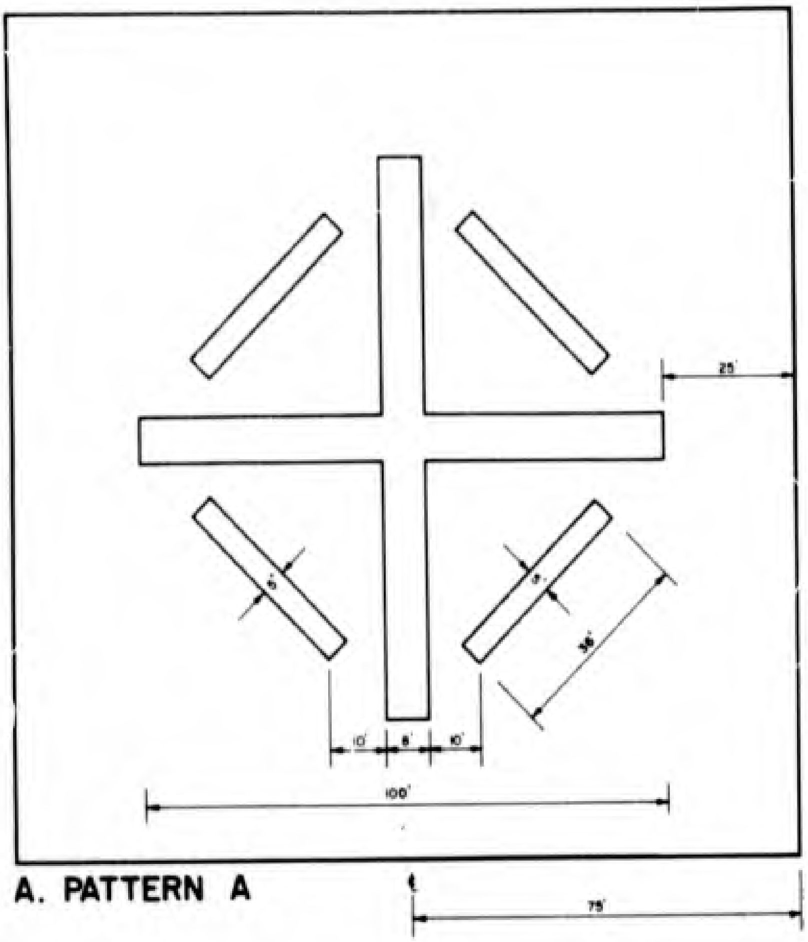
1.0' = 0.3048 m

FIGURE 7

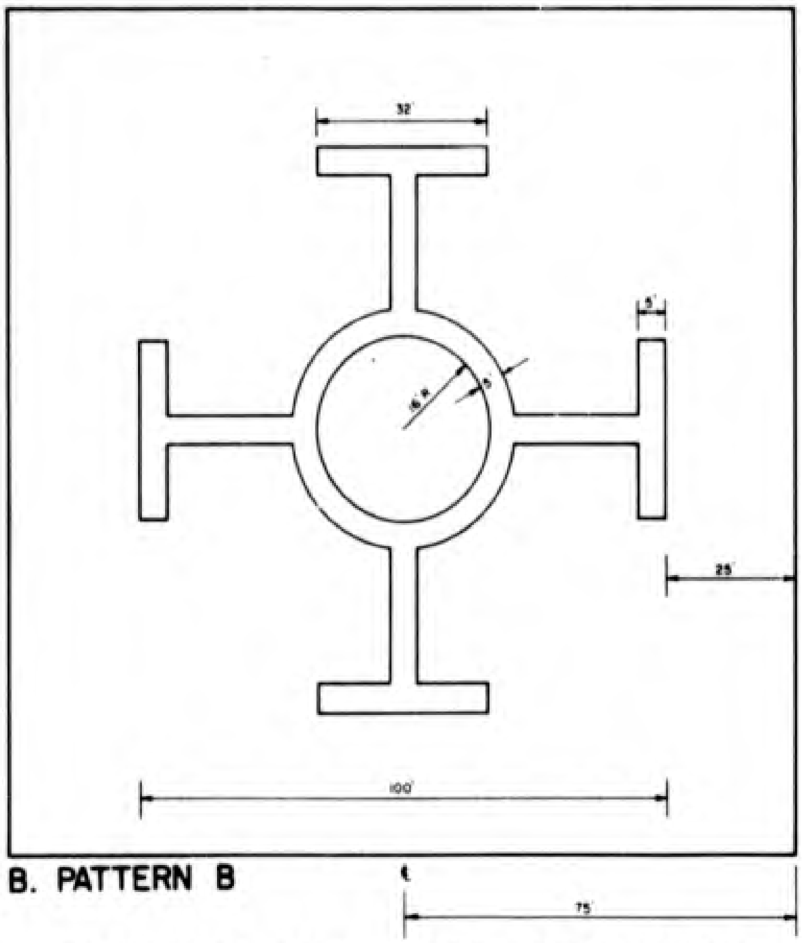


MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

FIGURE 8



A. PATTERN A

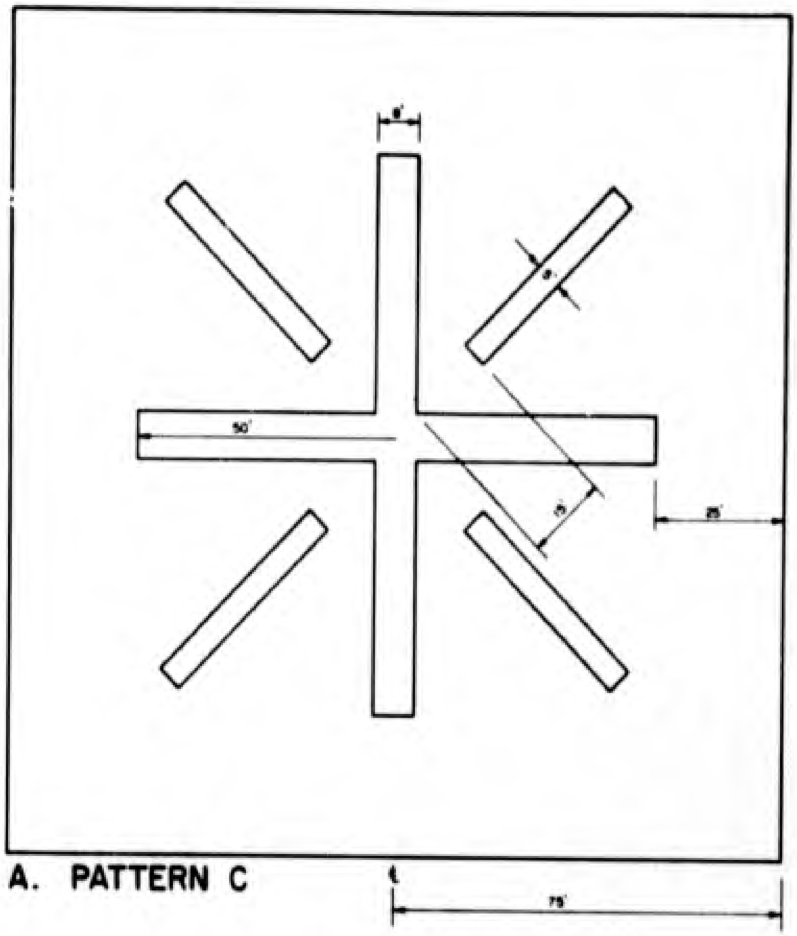


B. PATTERN B

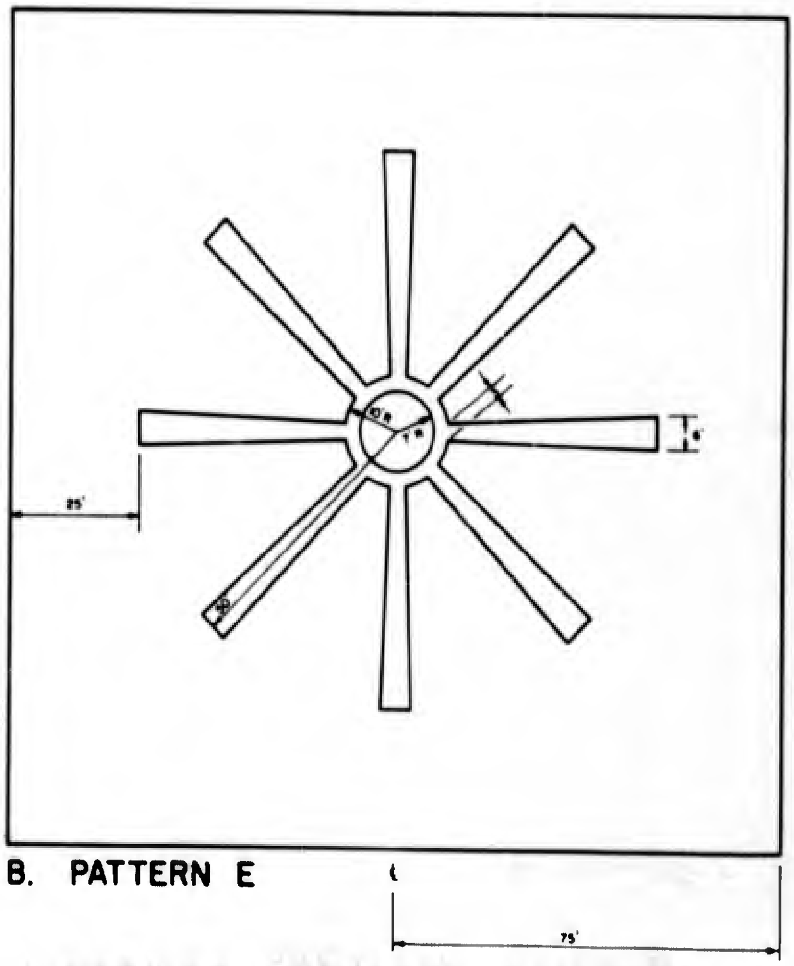
1.0' = 0.3048 m

MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

FIGURE 9



A. PATTERN C

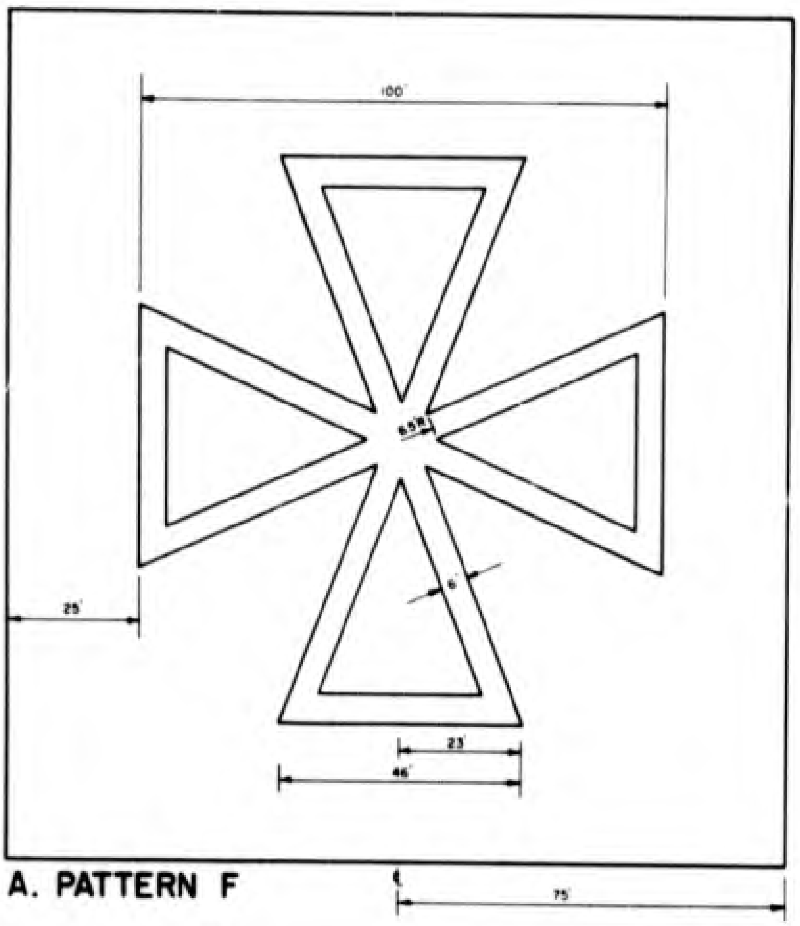


B. PATTERN E

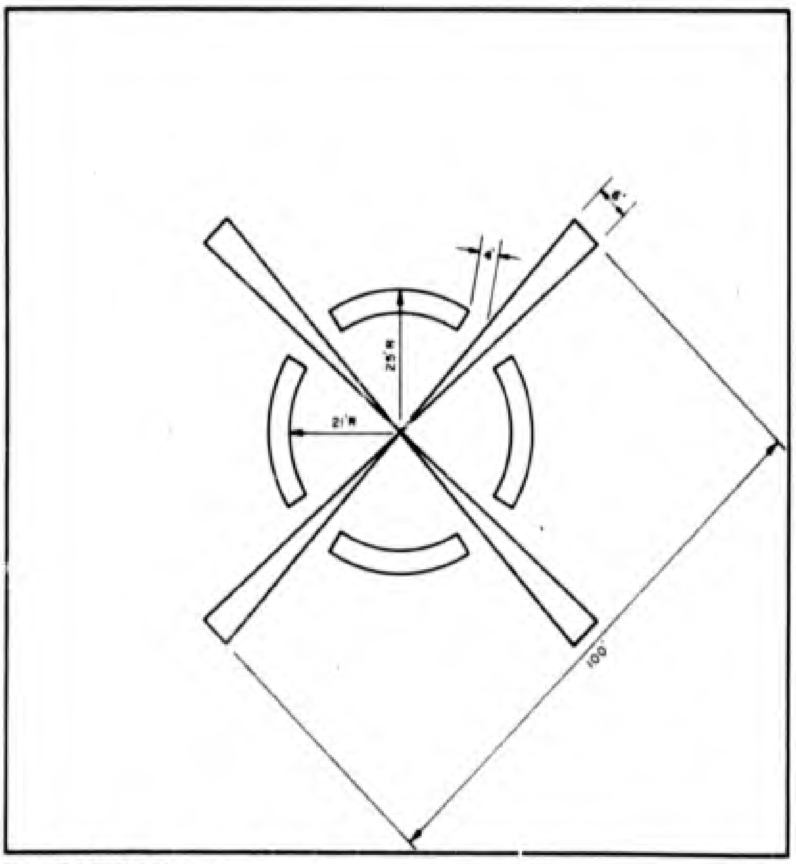
1.0' = 0.3048 m

MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

FIGURE 10



A. PATTERN F

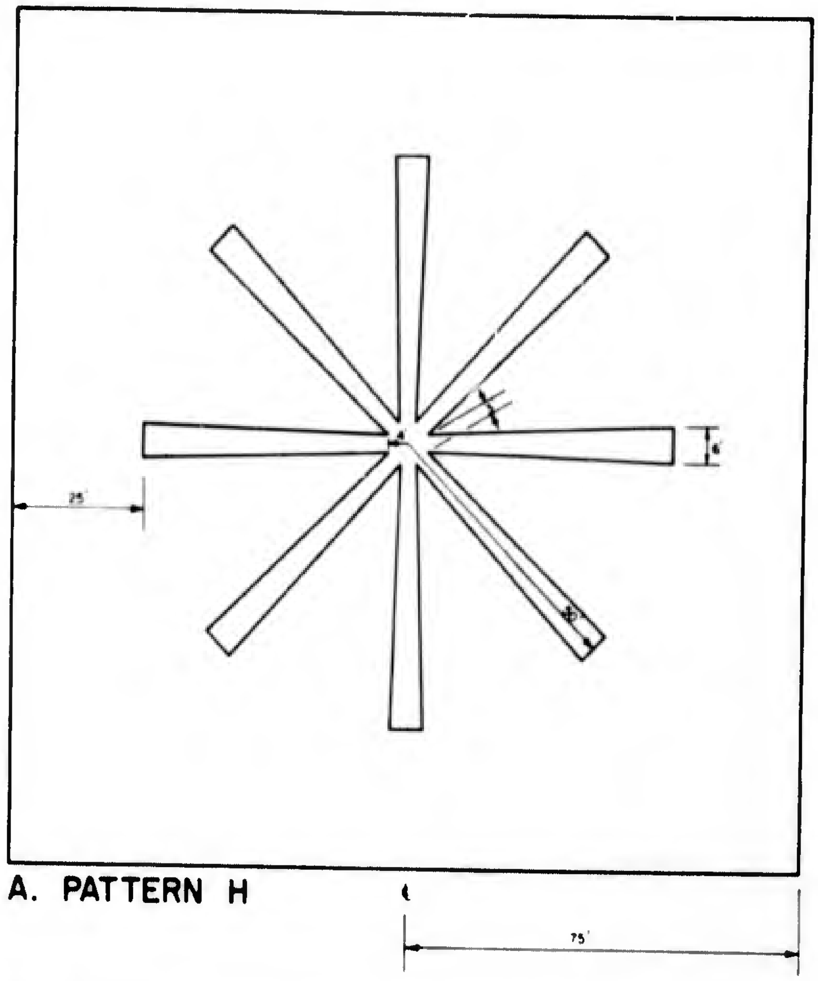


B. PATTERN G

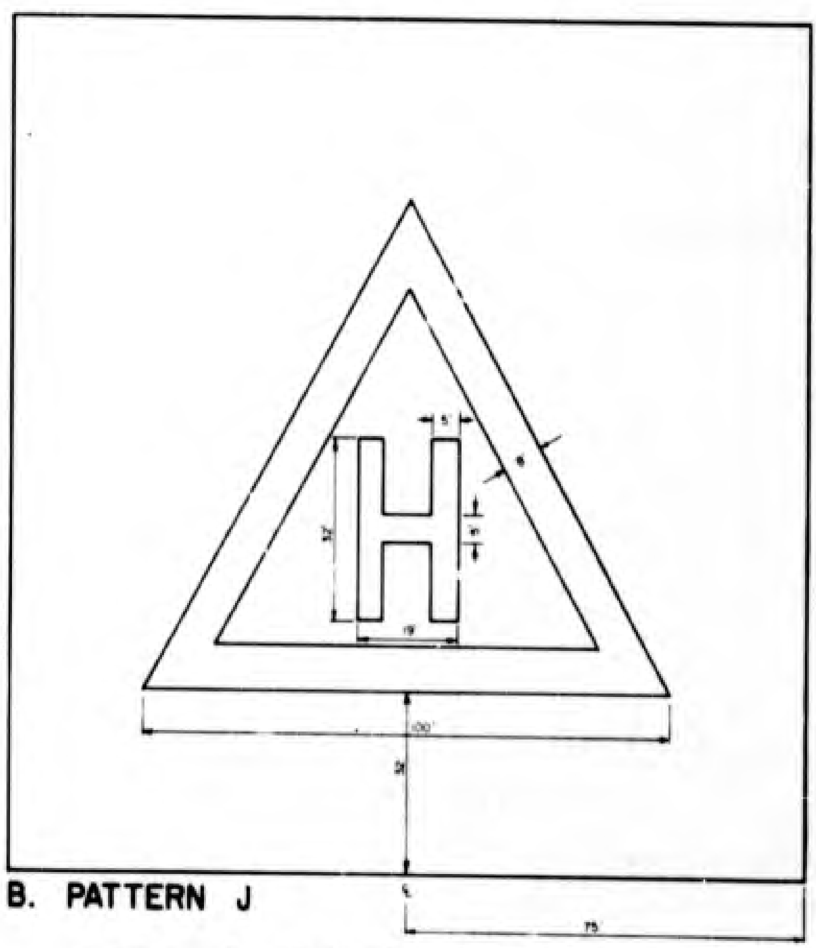
1.0' = 0.3048 m

MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

FIGURE 11



A. PATTERN H

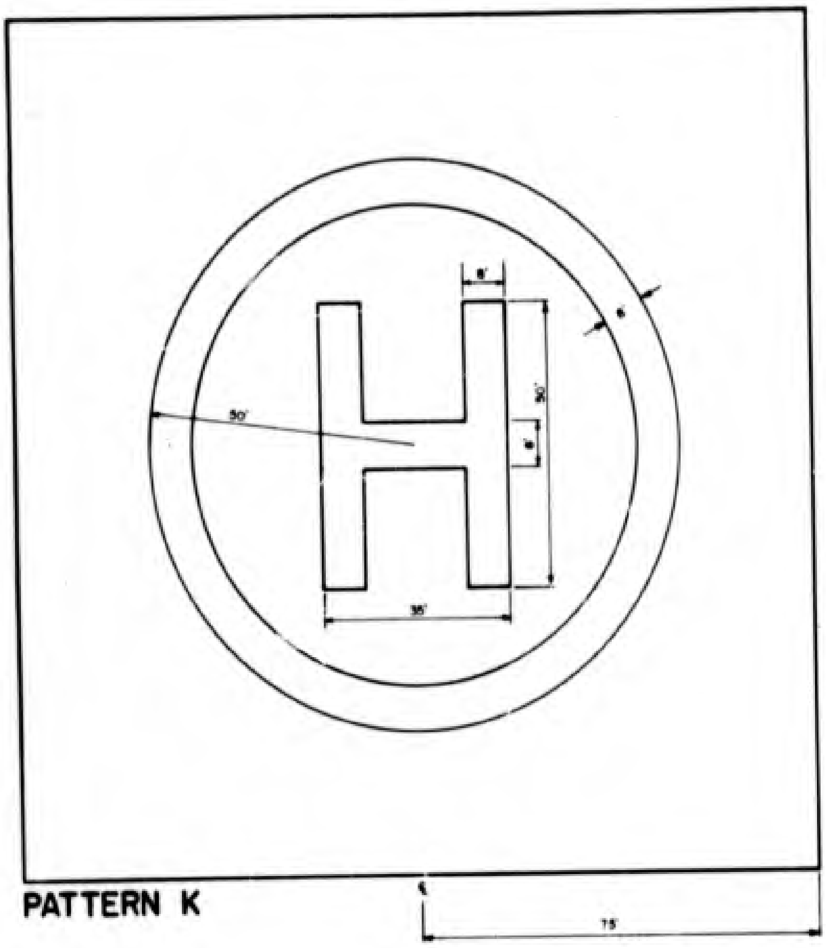


B. PATTERN J

1.0' = 0.3048 m

MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

FIGURE 12

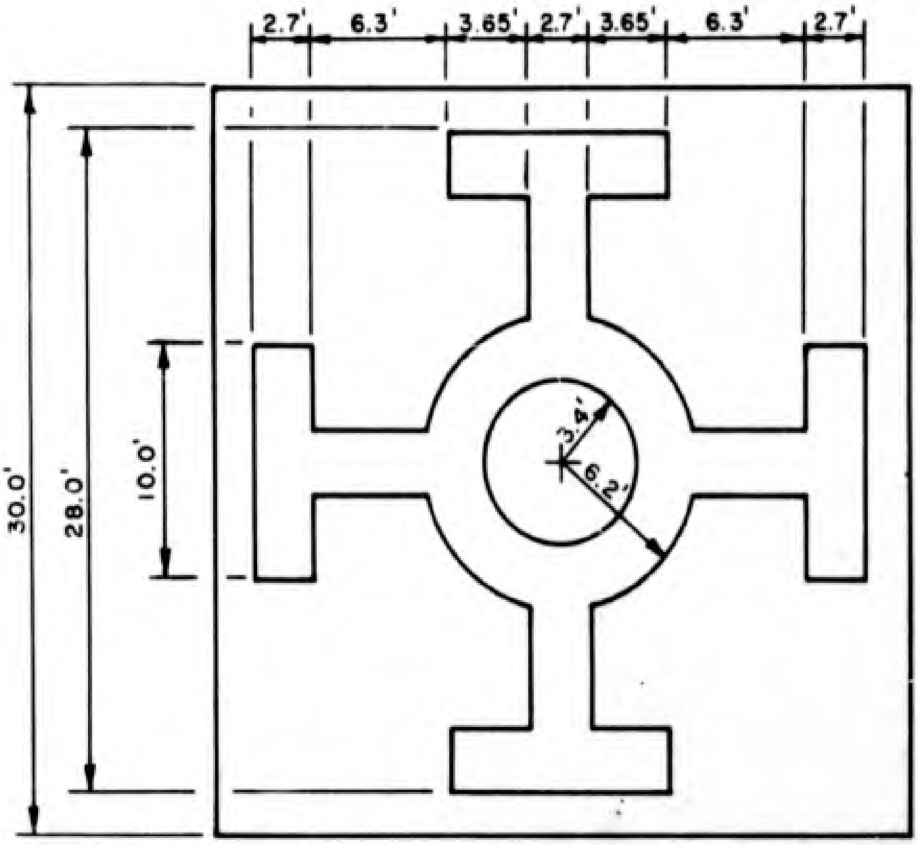


PATTERN K

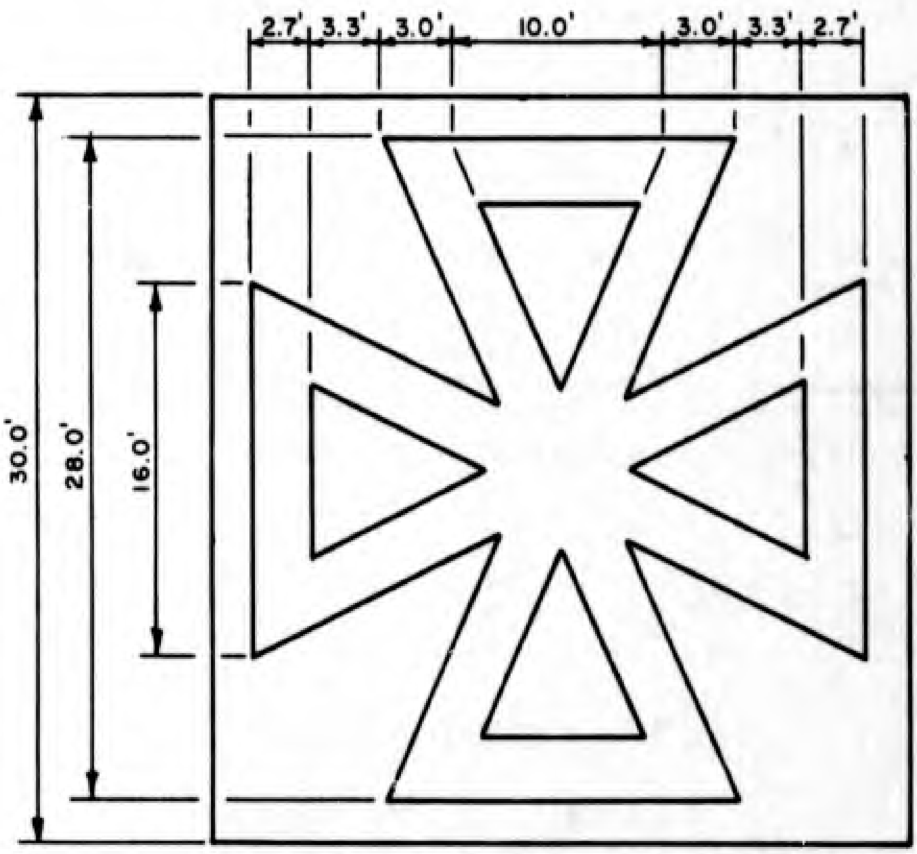
MARKING PATTERNS EVALUATED BY FINAL MODEL TESTS

1.0' = 0.3048 m

FIGURE 13



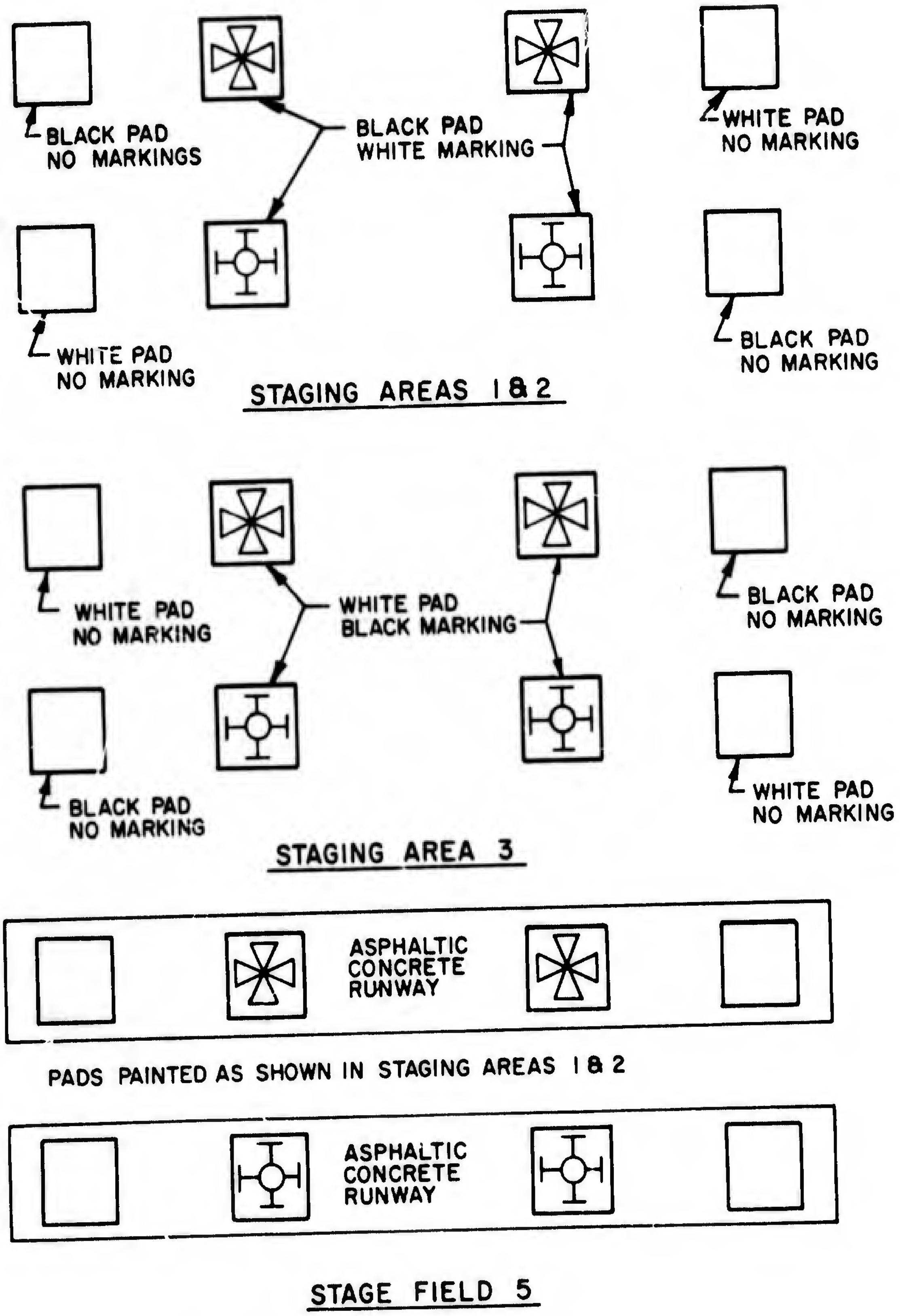
A. PATTERN Y FORT WOLTERS EXPERIMENT



B. PATTERN Z FORT WOLTERS EXPERIMENT

1.0' = 0.3048 m

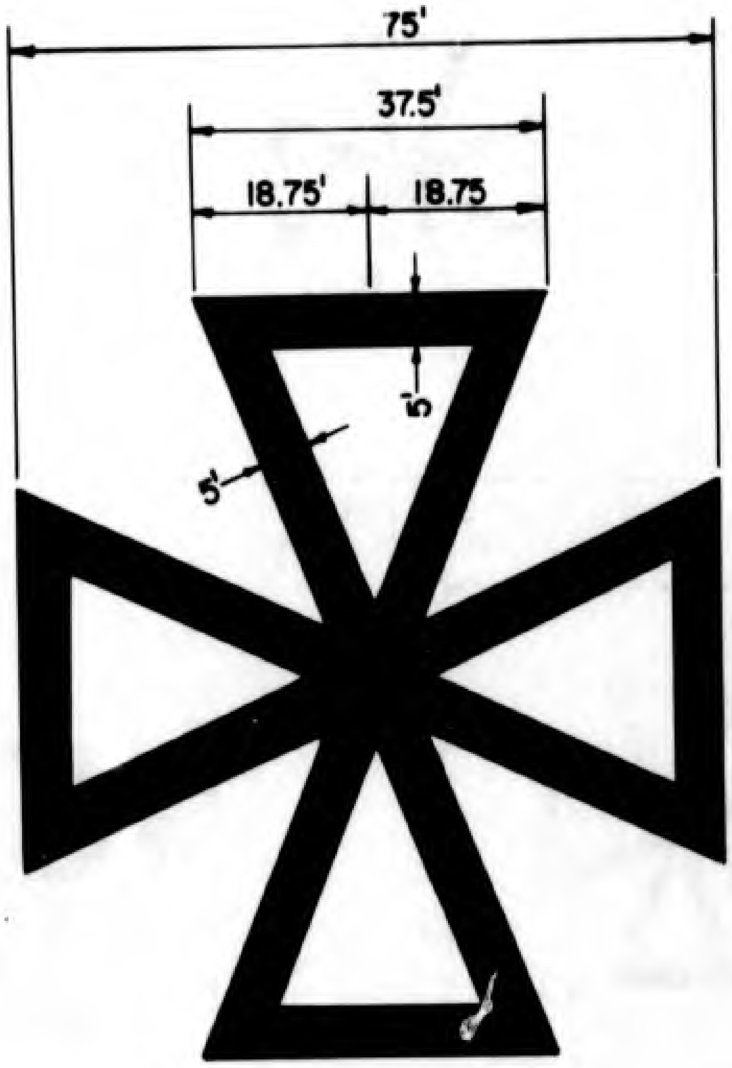
FIGURE 14



LAYOUT OF PATTERNS

FORT WOLTERS EXPERIMENT

FIGURE 15

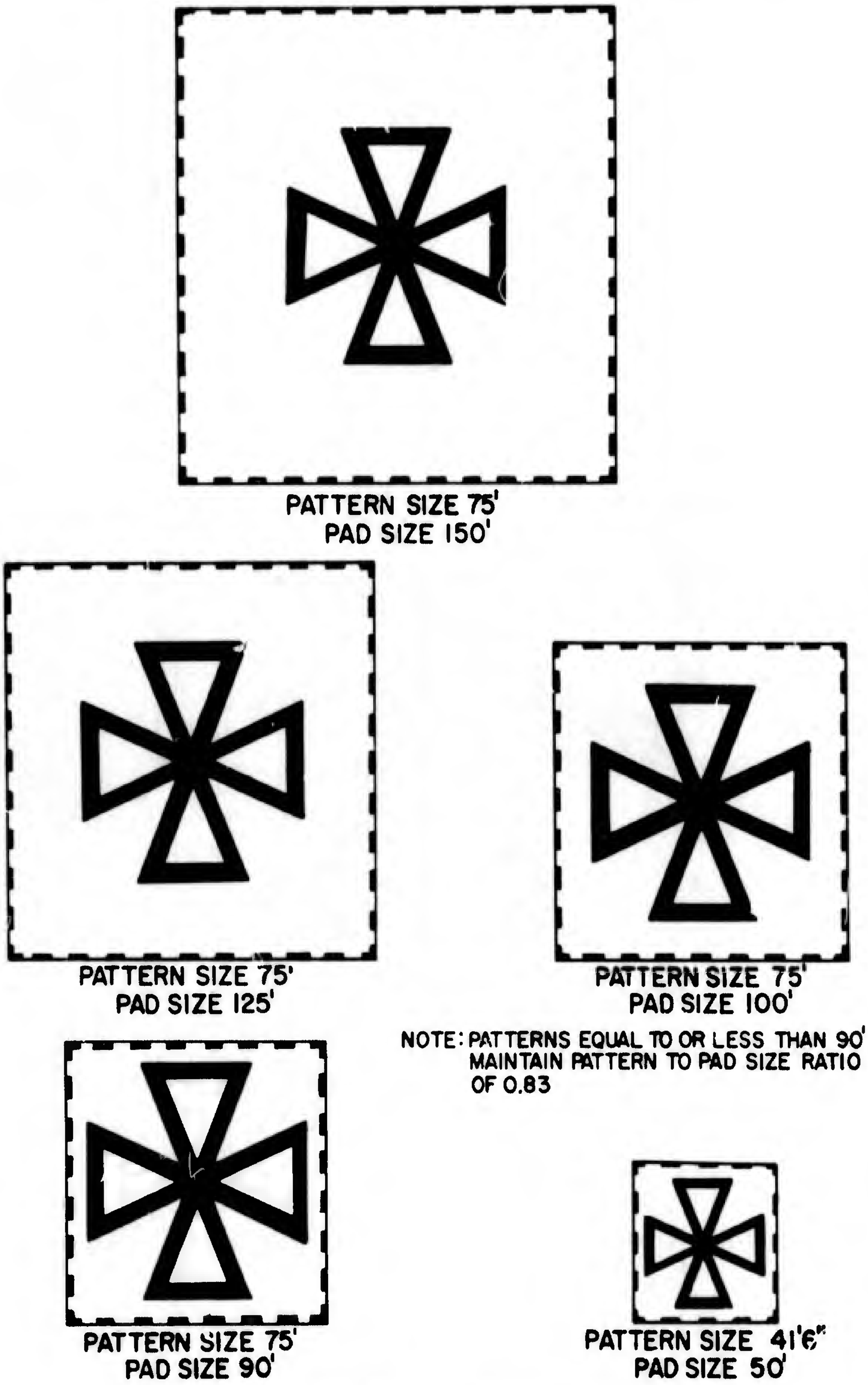


NOTE: FOR PATTERN SIZES OTHER THAN 75 FT SCALE DIMENSIONS PROPORTIONATELY

RECOMMENDED MARKING PATTERN STANDARD
FOR PADS EQUAL TO
OR GREATER THAN 90 FT

1.0' = 0.3048 m

FIGURE 16



MARKING PATTERN

PROPORTIONED TO VARIOUS HELIPAD SIZES

1.0' = 0.3048 m

SCALE: 1" = 50'

FIGURE 17

APPENDIX A

DESCRIPTION OF THE METHODS USED IN ESTABLISHING THE PHOTOGRAPHIC SCALE RELATIONSHIPS IN THE MODEL HELIPORT STUDY CHAMBER

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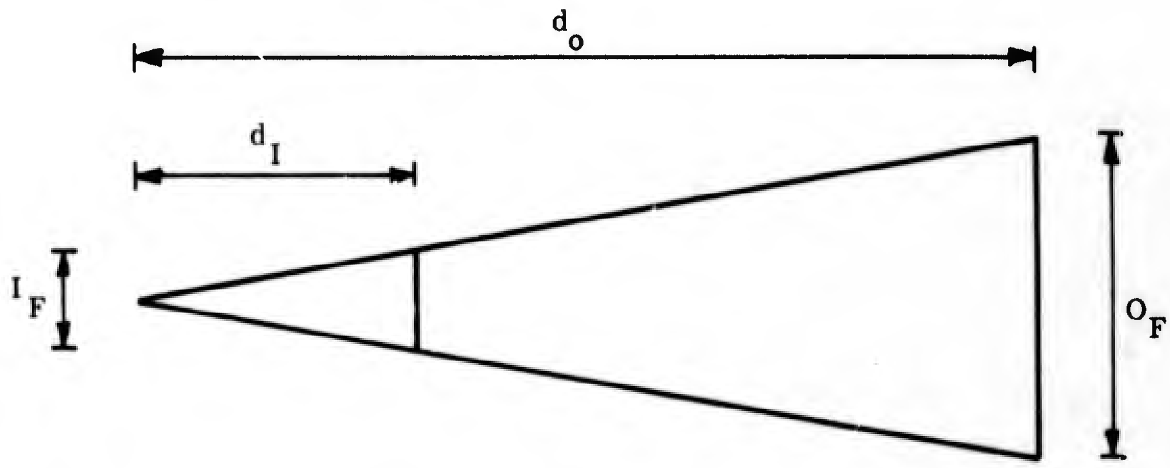
APPENDIX A

DESCRIPTION OF THE METHODS USED IN ESTABLISHING THE PHOTOGRAPHIC SCALE RELATIONSHIPS IN THE MODEL HELIPORT STUDY CHAMBER

1. Since this study was concerned with simulating prototype helipads by modeling techniques, a scale relationship was established in order to achieve comparative results. The first step was to establish what image the eye sees if the helipad is one mile away. To determine this, the image the eye would see of the pad was set 18 inches away from the eye. This was done in order to set a standard repeatable distance to compare the scaling of the model with its prototype.

2. From the image formula, by similar triangles



$$\boxed{\frac{I_F}{O_F} = \left(\frac{d_I}{d_o}\right)}$$

Solving for I_F:

$$I_F = O_F\left(\frac{d_I}{d_o}\right)$$

where

I_F = image eye sees of prototype 18 inches from the eye

O_F = size of prototype subject (150-ft helipad)

d_I = distance of 18 inches

d_o = distance of prototype from eye, or one mile

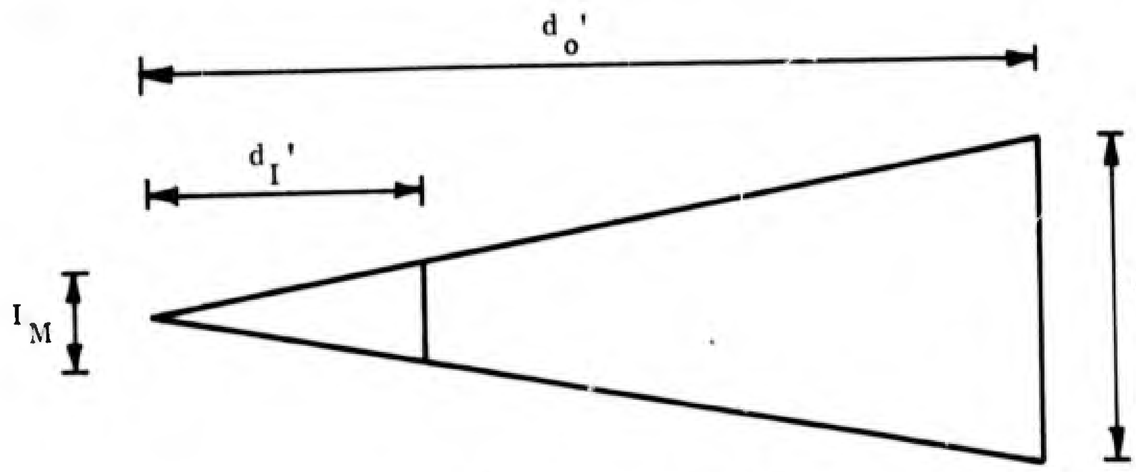
then

$$I_F = 150 \text{ feet} \left(\frac{1.5 \text{ feet}}{5280 \text{ feet}}\right)$$

$$I_F = 0.043 \text{ feet}$$

3. The linear scaling was set at 60:1, scaling the prototype 150-ft helipad down to 2.5 feet on the model, and one mile or 5,280 feet equal to 88 feet from the model.

4. Assuming that the eye sees the same image size $I_F = I_M$ in both cases, and again using the image formula, by similar triangles,



$$\boxed{\frac{I_M}{O_M} = \frac{d_I'}{d_o'}}$$

Solving for $d_o{}'$:

$$d_o{}' = d_I \left(\frac{O_M}{I_M} \right)$$

where

I_M = I_F = image eye sees of model 18 inches from eye

O_M = size of model helipad (2.5 feet)

$d_I{}'$ = distance of 18 inches

$d_o{}'$ = distance of model from eye in model study chamber

then

$$d_o{}' = 1.5 \text{ feet} \left(\frac{2.5 \text{ feet}}{0.043 \text{ feet}} \right)$$

$$\underline{d_o{}' = 88 \text{ feet}}$$

Therefore, assumption $I_F = I_M$ is correct, because 60:1 scale distance of eye from model is checked by,

$$\frac{1}{60} = \frac{x}{5280 \text{ feet}} \qquad \text{where } \underline{x = 88 \text{ feet}}$$

5. The camera distance from the model in the model study chamber had to be calculated in order to simulate the actual mile from the pad in the field. This was accomplished by using

(a) magnification equation:

$$m = - \frac{I_M}{O_M} = - \frac{S'}{S}$$

(b) the lens equation:

$$1/S = 1/s' = 1/f$$

(c) the image formula:

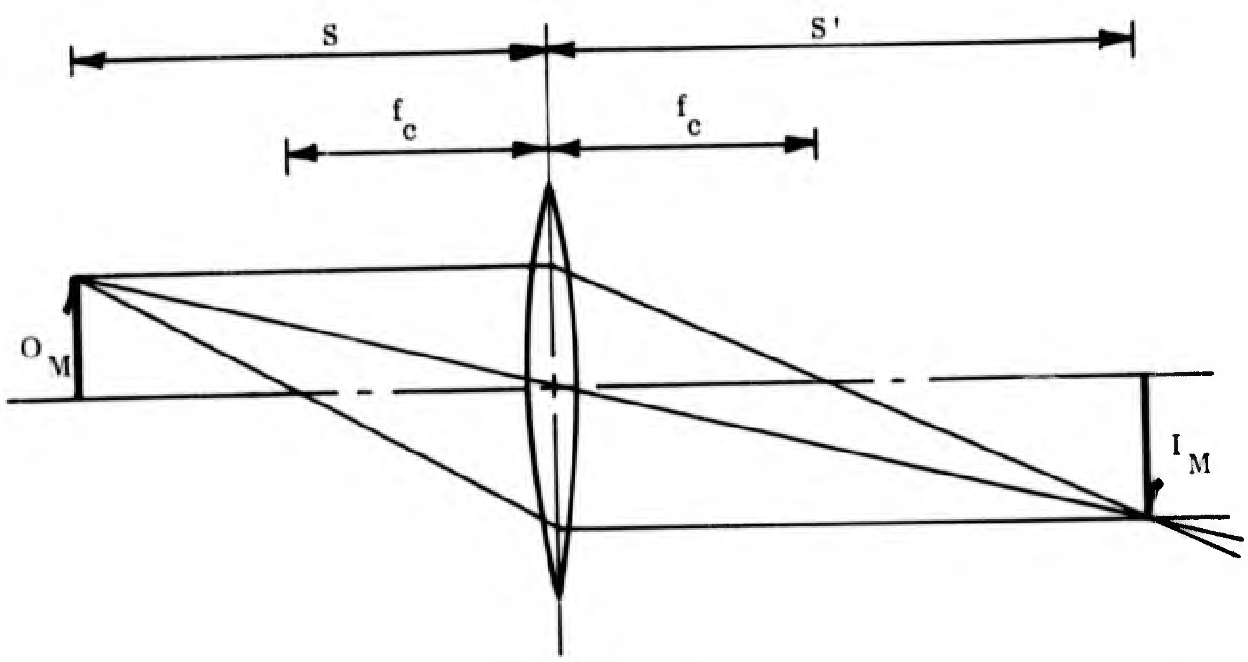
$$\frac{I_M}{O_M} = \frac{d_I{}'}{d_o{}'}$$

and calculating the required distance from the model by deriving the following equation:

$$\boxed{S = \left(1 = \frac{n d_o{}'}{d_I{}'}\right) f_c}$$

where

n	=	number of miles
$d_o{}'$	=	distance of the model scale mile
$d_I{}'$	=	distance of image from eye
f_c	=	focal length of camera



Graphical Representation of a Complex Lens System from the magnification equation,

$$S' = \left(\frac{I_M}{O_M}\right) S$$

substituting in the lens equation,

$$\frac{1}{S} + \frac{1}{\left(\frac{I_M}{O_M}\right)S} = \frac{1}{f_c}$$

$$\frac{1}{S} + \frac{O_M}{I_M S} = \frac{1}{f_c}$$

$$\frac{I_M + O_M}{I_M S} = \frac{1}{f_c}$$

therefore,

$$S = \left(\frac{I_M + O_M}{I_M}\right) f_c = \left(1 + \frac{O_M}{I_M}\right) f_c$$

but from image formula,

$$I_M = O_M \left(\frac{d_I'}{nd_o'}\right) \quad \text{(where n = number of miles)}$$

substituting for I_M

$$S = 1 + \left(\frac{O_M}{O_M \frac{d_I'}{(nd_o)}}\right) f_c$$

yields the final equation:

$$\boxed{S = \left(1 + \frac{nd_o'}{d_I'}\right) f_c}$$

Using a camera having a focal length

$$f_c = 150 \text{ mm or } 0.49 \text{ feet},$$

then the distance, S, from model in model study chamber is found to be

$$S = 0.49 \text{ feet} \left(1 + \frac{(1) \quad 88 \text{ feet}}{1.5 \text{ feet}}\right)$$

$$\underline{S = 29.36 \text{ feet}}$$

Thus, in order to obtain the image size that the eye sees at the simulated scale one mile in the model study chamber, the camera (focal length, 150 mm) must be placed 29.4 feet away from the center of the model helipad.

6. If the camera is used in the field to record the image the eye sees of the prototype pad one mile away, then the distance at which the camera should be placed from the pad can be calculated from the following equation:

$$\boxed{S_F = \left(1 + \frac{O_F}{I_F}\right) f_c}$$

where

S_F = distance of camera in field from prototype

O_F = size of object (prototype pad)

I_F = image eye sees at one mile 18 inches from eye

f_c = focal length of camera

then

with $f_c = 150$ mm or 0.49 feet,

$$S_F = 0.49 \text{ feet} \left(1 + \frac{150 \text{ feet}}{0.04 \text{ feet}} \right)$$

$$\underline{S_F = 1730 \text{ feet}}$$

Thus, when a camera (focal length, 150 mm) is placed 1730 feet from center of the prototype helipad, the image size would correspond to the image size that the eye would see one mile away from the pad.

7. The greatest distance that can be simulated by photographic means in the model study chamber was found to be 9 miles, using a camera of focal length 65 mm, at a distance of 112. 81 feet from the center of the model pad.

APPENDIX B

INTERIM REPORT

DEVELOPMENT OF HELIPAD MARKING CONFIGURATION

by

R. E. McKenzie
Lt. Col. USAF BSC

Technical Report No. 4-55

DEVELOPMENT OF HELIPAD MARKING CONFIGURATION

INTERIM REPORT

by

R. E. McKenzie
Lt. Col. USAF BSC

October 1966

DEPARTMENT OF THE ARMY
Ohio River Division Laboratories, Corps of Engineers
Cincinnati, Ohio 45227

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SUMMARY

The results of experiments at Fort Rucker, Alabama and Fort Wolters, Texas relative to standard helipad marking patterns indicate that contrast may be the major contribution of a marking system. Two patterns selected were: the cross, and the broken wheel; both of which were highly acceptable to pilots. From a preference standpoint, a pattern acts to improve approach angle establishment, line of descent, and closure rate.

It was found that helipads constructed without markings should be white instead of black; and if a pattern is used, the pattern should be white on a black pad. Pattern size is apparently related only to the distance required for recognition, and not to suitability as an aid to pilot performance; since both 30-foot and 100-foot square patterns were judged equally suitable by pilots.

PREFACE

This study was part of an overall program to establish optimum criteria for visual aids, marking and lighting for Army heliport landing facilities. This study was initiated by the Construction Engineering Laboratory, Ohio River Division Laboratory, Corps of Engineers, U. S. Army, Cincinnati, Ohio. This program was a cooperative effort with the Federal Aviation Agency. A final report will be prepared by personnel of the Construction Engineering Laboratory, Ohio River Division Laboratory at the conclusion of this program.

The study presented in this interim report was conducted while Lt. Col. McKenzie was assigned, by the Air Force, to the Federal Aviation Agency's National Aviation Experimental Center, Atlantic City, New Jersey as a Research Psychologist, Human Engineering Branch, AS FAA Project 430-206-01R.

The author wishes to acknowledge the assistance of Mr. Thomas H. Morrow, Jr., Engineer, and Mr. Harvey R. Barrett, Engineering Technician, both of the staff of the Ohio River Division Laboratories who conducted extensive model studies prior to the field studies covered by this report.

CONTENTS

LIST OF TABLES

LIST OF EXHIBITS

DEVELOPMENT OF HELIPAD MARKING CONFIGURATION

Background

1. This report concerns two distinct studies designed to provide a suitable standard marking pattern for helicopter operations. However, it should be noted that the actual field studies which the report details were preceded by extensive model studies conducted at the Ohio River Division Laboratories (ORDL). These model studies resulted in seven marking patterns having desirable characteristics according to the developmental criteria. Representatives of ORDL arranged to have these patterns placed in position on the overrun areas of Hanchey Army Heliport, Fort Rucker, Alabama (an advanced helicopter training facility) for actual inflight pilot evaluation. The first selection of the report will describe what we will call "The Fort Rucker Experiment".

2. Following the Fort Rucker Survey, it was determined that a more definitive study was in order. The goals of the second field study would be: (1) to further study the patterns selected at Fort Rucker; (2) to determine the effect of a white pattern on a black pad compared to a black pattern on a white pad, (since some helipads are of black asphalt construction, while others are of white concrete); (3) to attempt to discover what factors are preferred, and further, to ascertain if preference is reflected in actual pilot performance. Accordingly, the second study was designed, and subsequently carried out, at the U.S. Army Primary Helicopter School at Fort Wolters, Texas. This study will be reported as "The Fort Wolters Experiment".

The Fort Rucker Experiment

3. The method selected for this initial survey was a pilot questionnaire supplemented by informal flight line and briefing room interviews. It should be noted that there were several constraints involved in the selection of method, most importantly, that any technique would not unduly interfere with the operational mission. In considering the operational factors and the type of subjects, together with the fact that our goal was to make an <u>initial</u> field survey to aid in the evaluation of the model studies approach, the questionnaire seemed to be the only feasible approach. Fortunately, the pilots at Hanchey were all highly-qualified, experienced helicopter pilots, many of whom were in training as instructor pilots in instrument techniques. Thus, they were actively interested in the problem and offered full cooperation.

4. With this type of population, we hoped to gather as much useful information as possible in a brief time without imposing a time-consuming, detailed questionnaire on the subjects by the use of preference selection and open-ended questions, including one which offered them the opportunity of suggesting their own marking pattern.

5. The patterns were placed at Hanchey approximately one month prior to the administration of the questionnaire to allow for adequate pilot viewing under various conditions of visibility, angles of approach, etc. Thus, while operational considerations precluded any actual control over these variables, including frequency of observation, supplemental interview information confirmed the fact that most of the pilots surveyed felt that they had adequate opportunity to view the patterns. However, it must be noted that the patterns were not actually used to land on, but were in the line of approach.

6. The pilots were not told previously that they would be directly involved in an evaluation of the markings in order to prevent a "halo" effect, or some form of consensus, from developing. The questionnaire itself was given out by the Flight Section Chiefs immediately prior to a morning or afternoon of flying. They were filled out immediately after the flying session and collected. We felt this would permit our subjects, having some knowledge of the type of information we were seeking, to intelligently cooperate with us. The questionnaire and the seven marking patterns are given in Exhibit 1.

Results and Comment

7. Questionnaires were collected from 124 subjects. For some reason, 5 subjects did not express a preference, and their questionnaires were not considered in the results. Out of 119 remaining questionnaires, 18 expressed only 1 preference. The patterns were evaluated by scoring the questionnaires on a rank order basis, where preference 1 received a score of 3, preference 2 a score of 2, and preference 3 a score of 1. In addition, undesirable scores were also tabulated. The results are presented in Tables 1 and 1a, showing the subject ratings and the preference scores respectively.

Table 1

Pattern Preference Rating - Fort Rucker Experiment

Pattern No.	Preference Ranks				Total
	First	Second	Third	Undesirable	
A	3	8	8	14	33
B	18	23	13	5	59
C	6	13	17	17	53
E	7	14	23	16	60
F	76	9	9	0	94
G	3	15	17	10	45
H	6	19	14	17	56
Totals	119	101	101	79	400/400

Table 1a

Pattern Preference Scores - Fort Rucker Experiment

Pattern No.	First	Second	Third	Rating Total	Undesirable Score	Adjusted Rating*
A	9	16	8	33	42	-9
B	54	46	13	113	15	98
C	18	26	17	61	51	10
E	21	28	23	72	48	24
F	228	18	9	255	0	255
G	9	30	17	56	30	26
H	18	38	14	70	51	19

* Initial rating minus undesirable score.

8. It will be noted that, in order to arrive at a final pattern preference score, the ratings were adjusted for any undesirable comments. These undesirable comments were tallied and then given an arbitrary weight equal to a preference rank of 1, since it was felt than undesirable characteristic was at least as important as the highest possible preference score.

9. Thus, the survey indicates an overwhelming preference for pattern F (subsequently called Z in the second experiment) and, what may be more important, an absence of undesirable comment. Pattern B (called Y in the second study) is the second most preferred and also has fewer undesirable "scores" than any pattern except F. The other patterns rate so far out on our scoring scale that for our purpose there are no other choices which the survey discriminates.

10. Perhaps the most significant aspects of these two patterns are derived from examination of the other survey questions. These subjective comments indicate that both of these patterns are distinctive and are not readily confused with any other ground markings. Many comments on patterns C, H, and E indicate that these might be mistaken for a compass rose, while pattern G might be taken to indicate a closed field or closed runway marking.

11. Two other significant aspects of the F and B patterns emerge: (1) they provide an aiming point, and (2) they do not lose their pattern at shallow approach angles. One can speculate why pilots commented upon the aiming point characteristics, when some of the other patterns also appear to provide a "point of convergence" -- in fact, some of them apparently better than pattern B. We feel that the factor of import here is the "bar" effect formed by the member of the "cross", which is perpendicular to the aiming point of F, and the corresponding effect due to the "T" which is perpendicular to the circle of B. This may very likely give the pilot some indication of approach attitude and an indication of an outer boundary or limit to his approach as he passes over the aiming point.

12. Initially, it was felt that the pattern designers at ORDL did an excellent job of arriving at a desirable size for their patterns because 97.5% of those in our survey indicated that the size was "suitable". While the designers did perform an excellent job, it was later found that size was not a significant factor in their success.

13. Perhaps the only other significant finding of this survey is revealed in response to question 6 where pilots were asked to indicate some other marking pattern they would like considered. Twenty-five percent of those surveyed gave a positive response to this question. Of these, 5% were "original", but could be disregarded because of some practical or known human factors principle. The remaining 20% indicated a choice of the "traditional" H enclosed in a circle or a

square. This, in spite of the fact that the "traditional" heliport marking is usually found to be a dashed triangle enclosing a letter H.

14. Psychologists and human factors engineers, know that there are many undesirable qualities to this "traditional" marking. In fact, this is one of the reasons for the present effort. Among the important reasons to discard the H in circle, square, or triangle, is the fact that most letters and numbers, including H lose their familiar distinctiveness when viewed at shallow angles of regard. Another important consideration, and one voiced by our survey subjects, is that the proposed patterns were preferred, in part, because they provide an "aiming point". Since no aiming point is provided by the "traditional" marking, one is left to conclude that perhaps one-fifth of our subjects are themselves somewhat "traditional" in that they prefer, or do not like to part with, a familiar pattern.

The Fort Wolters Experiment

15. As previously indicated, this study was designed to investigate a number of variables using the two patterns which survived the Fort Rucker survey. In preparation, the Corps of Engineers again provided the stimulus material by marking 30 x 30-foot helipads at three tactical stage fields according to Exhibit 2. Note that at these locations the pads were painted black and the patterns applied in white to replicate the Fort Rucker experiment on a smaller scale. In addition to the markings, one pad in each lane was painted black in order to provide a comparison with a plain white pad without markings and to serve as a control for one aspect of the experiment.

16. At a fourth location the stage field was prepared according to Exhibit 3. Here, the patterns were painted in black upon the existing white concrete pads. Again, two pads were painted black to provide a no-pattern control and comparison with a plain white pad.

17. The data desired were of two kinds: preference and performance. The device used to gather these data was again the paper and pencil questionnaire. Four such forms were designed: (1) a Student Comparative Questionnaire (Exhibit 4) to elicit preference for pattern and plain pad color and to check on the performance enhancement question; (2) an Instructor Preference Rating (Exhibit 5), to elicit instructor pattern and plain pad color preference and to check on the performance enhancement question, plus one question relative to the WOB/BOW question to be discussed shortly; (3) a Student Preference Questionnaire (Exhibit 6) called "preference" but actually designed to be a self-rated performance factor evaluation to be completed for each pattern, and (4) A Student Performance Evaluation (Exhibit 7) as an instructor performance rating for each student on each of the two patterns plus a plain (no-pattern) pad to serve as a control.

18. In order to implement this rather complex data-gathering process under field conditions, detailed briefing material for both instructors and supervisory personnel and the participating student pilot subjects was provided to the Safety Directorate at Fort Wolters who held the necessary briefings and were responsible for the distribution and collection of forms. This material is presented as Exhibits 8 and 9 in order to provide additional insight into the design and to show how we attempted to secure the motivation and cooperation of all concerned.

19. In summary, the two patterns, Y (dubbed "broken-wheel") and Z (dubbed "the cross") were painted in white on a black pad at three stage fields, while the same patterns were painted in black upon white pads at another. At all four locations, plain white and plain black pads were provided for comparison, preference evaluation, and control. Student pilots flew and rated each pattern as independently as possible, made self performance evaluations, and then made out a comparative evaluation. Instructors rated student performance as each pattern plus a no-pattern series of approaches was flown. Instructors then filled out their own preference rating forms at the conclusion of the experiment.

Results and Comment

20. As can be expected in an operational field study of this nature, some of the data had to be discarded because instructions had not been followed. Fortunately, most of the data loss was confined to one flight where about 80% of the forms were incomplete across students. In most flights, the data was at least 95% complete and reflected outstanding cooperation of students, instructors and supervisory personnel at Fort Wolters.

21. The first concern was to determine if there were significant differences* in the student group that flew the black pattern on white pad (BOW) location when compared with those who flew the white on black (WOB) locale. Table 2 shows the results obtained from the Student Preference Questionnaires for patterns Y and Z from both WOB and BOW groups. The mean responses for each item are presented in percent in order to adjust the scores to the same base.

22. An analysis of this data indicates that there are significant differences in the results of the two groups; and therefore, we cannot pool this data. The differences which are apparent will be discussed; but it should be noted that, unfortunately, the BOW group made approximately one-half fewer approaches

* Chi Square Test of response frequencies used to test for significance throughout

Table 2

Responses from Student Preference Questionnaire for WOB and BOW Groups - Fort Wolters Experiment

Factor	WOB Group (N = 106)		BOW Group (N = 31)	
	Pattern Y	Pattern Z	Pattern Y	Pattern Z
1. Number Approaches	278	282	53	51
Mean	2.63	2.67	1.71	1.65
2. Pattern Bother				
Yes	4.8	5.5	6.5	3.2
No	95.1	94.3	93.5	96.7
3. Pattern Help				
Yes	72.6	71.0	54.8	58.0
No	25.4	27.1	41.9	38.7
N/A*	1.8	1.8	3.2	3.2
4. Approach Angle Help				
Yes	51.3	57.2	58.0	45.1
No	44.8	38.6	35.4	48.3
N/A	3.8	4.1	6.5	6.5
5. Closure Rate Help				
Yes	49.0	49.8	35.4	48.3
No	46.5	41.5	58.0	45.1
N/A	8.8	9.5	6.5	6.5
6. Ground Track Help				
Yes	53.4	47.3	41.9	35.4
No	35.7	39.5	51.6	54.8
N/A	10.8	11.4	6.5	9.7
7. Roll Attitude Help				
Yes	30.3	31.3	19.4	22.5
No	50.1	49.6	67.7	61.5
N/A	19.7	19.0	12.9	16.1
8. Stop/Hover Help				
Yes	59.2	57.3	41.9	41.9
No	31.7	32.3	45.1	48.3
N/A	9.1	10.3	12.9	9.7
11. Pattern Size				
Suitable	93.5	80.7	96.7	90.3
Too Small	3.7	2.8	0.0	6.5
Too Big	2.8	6.5	3.2	3.2

* N/A - Not Observed

on the average than the WOB group; this factor might account for at least some of the differences. At any rate, we see that the pattern is less help, regardless of pattern, in the BOW group as revealed by an average of 15% fewer "yes" responses and a corresponding increase in "no" responses. This would suggest that the BOW stimulus did not provide the figure-ground contrast as compared with WOB. This is further suggested by the fact that BOW apparently decreases the effectiveness of both patterns relative to the factor of ground track help. BOW also apparently acts to markedly decrease the closure rate help factor for pattern Y and the pattern bother factor is also slightly higher for this same pattern. While roll attitude help is apparently not aided in either group, it is even less help in the case of BOW.

23. Instructors were asked to view both BOW and WOB stimuli and to indicate their preference on the Instructor Preference Rating form. The results (N = 137) indicate that WOB is preferred by 42.8 percent, compared with 35.8 percent for BOW; while 11.8 percent thought them equally preferable, and 9.5 percent reported they had not been able to observe both situations.

24. With the issue of BOW versus WOB out of the way, at least as far as this data is concerned, the remainder of the results and discussion will concern the WOB stimulus situation only. First we will discuss student and instructor preferences and then we will turn to performance.

25. Table 3 presents the data obtained from the two preference-type questionnaires, the Instructor Preference Rating and the Student Comparative Questionnaire. In analyzing this data it is noted that the approaches made to each pattern are approximately equal with means of 2.63 and 2.67 for pattern Y and Z respectively (Table 2). There is no essential difference in the low incidence of "bother" for each pattern. It is apparent that both patterns are felt to aid performance about equally. Since this is such a general factor, it cannot be readily used to select the best pattern and one must turn to the more specific factors. Nevertheless, preference in terms of the pattern as an aid to performance favors pattern Y, although the self-rated performance factors do not support this preference.

26. In order to better evaluate the data of Table 3, the scores were adjusted according to the following rationale.

Table 3

Student-Instructor Pattern (WOB) and Plain Pad Preferences Expressed in Percent Fort Wolters Experiment

	Students (N = 106)	Instructors (N = 137)	Both (N = 243)
Pattern:			
Y	40.8	30.9	35.9
Z	54.4	46.9	50.6
NP*	4.7	22.1	13.4
Helps to Improve Performance:			
Yes	87.8	55.6	71.7
No	12.1	44.3	28.2
Plain Pad Preference:			
Black	22.1	29.0	25.5
White	77.8	70.9	74.3

* NP - No Preference

We reasoned that we could not simply evaluate the positive or "yes" responses without considering that the negative or "no" responses were at least as important (we assumed that the N/A or not observed responses were exactly that, although one could speculate upon their negative aspects). The positive responses were weighted by adding the difference between the positive and negative scores to them. This has the effect of increasing the positive score in relation to the smaller value of the negative score. The fewer the negative responses, the more the positive response is weighted. These adjusted scores are presented in Table 4.

Table 4
Adjusted Scores from the Student Preference Questionnaires
For Patterns Y and Z (WOB)
Fort Wolters Experiment

Item	Factor	Pattern Y	Pattern Z
2	Pattern Bother	185.4	183.1
3	Pattern Help	170.6	114.9
4	Approach Angle	57.8	76.2
5	Closure Rate	51.5	58.1
6	Ground Track	71.1	55.1
7	Roll Attitude	-69.9	-67.9
8	Stop/Hover Help	86.7	82.3

27. These adjusted scores show that there are only two performance factors where patterns Y and Z differ significantly, that is on Approach Angle and Ground Track. Unfortunately, each of these two factors favors a different pattern. The student responses indicate that pattern Z aids in establishing an approach angle, while pattern Y aids in maintaining a better ground track. The Stop/Hover Help factor favors pattern Y, while Closure Rate is apparently aided by pattern Z. While it is purely a matter of opinion at this point, it seems fair to state that in the landing process both factors favored by pattern Z, approach angle and Closure Rate, are probably more important to the pilot than is ground track. Still, one would not care to select pattern Z over pattern Y on this evidence alone.

28. The instructors were quite divided over the issue of the value of the patterns as an instructional aid; but this may only reflect the fact that they were not accustomed to such a usage. Even so, a majority of them felt that the patterns were of help to the students and aided their performance.

29. Since both preference and self-performance evaluations are highly subjective measures, the experimental design included the instructor rating of student performance as a more objective evaluation of these same factors Instructors rated each of 93 students on six factors: approach angle, line of descent, ground track, touch down point, closure rate, and control handling. In addition, we provided a measure of variability with which to weight each factor.

30. Before presenting the results, a word about the rationale behind our use and scoring of the Student Performance Evaluation forms is in order. To begin with, we selected the first five factors from the "check ride" forms normally used to evaluate students during the course of training. Thus we had no problem with instructor familiarity. Our knowledge of performance measurement indicates that among reasonably skilled pilots, for example, the use of end-point performance measurements, like touch down point, or smoothness of landing, usually fails to discriminate. Most landings are reasonably good under most conditions, but under more adverse conditions, the control movements and adjustments the pilot makes to accomplish the end result are more discriminating measures. Thus, it was desirable to score for performance variance as much as possible.

31. In order to load the factors for variance, each student's form for each of three conditions (Pattern Y, Pattern Z, and No-pattern) was scored only when deviation (variance) from the average had been rated by the instructor. Those showing no deviation were merely counted as average. Thus, for each stimulus condition the total number of deviations from average for each factor was tabulated. The deviations were then weighted by the variability ratings, Average, Moderate, Excess, by a factor of 1, 2, or 3 respectively. The summation of all variability weights plus factor 6, Control Handling, was used as a total variability index. By this method, an index for each factor (1 thru 5) was obtained by multiplying (weighting) the deviations tabulated for each factor by the variability and dividing by N. These results are presented in Table 5. An analysis of this data shows first that total variability is much lower for both patterns than when no pattern is present. Pattern Z is superior to Pattern Y - 99 to 129 respectively - compared to a 164 for the no-pattern condition. The number of students scored "average" for each factor is higher with a pattern than without. Here, again, pattern Z is favored.

32. Turning to the individual factor indexes, we find that the previously noted subjective performance factors are supported. Pattern Z is superior to Y in all respects except ground track, especially in terms of approach angle and line of descent. Both patterns are obviously superior to the no-pattern situation.

33. It would have been interesting to include a statistical examination of the subjective, open-ended questions contained in the various questionnaires. Unfortunately, time did not permit a more extensive treatment of the data. We can state, that a reading of all such comments shows that they essentially support the more objective findings, and are much more like the survey in the Fort Rucker Experiment, with the exception that we noted very little plea or comment for the "traditional" marking pattern.

Table 5

Student Performance (Instructor Ratings) Scored for Variability Index (N = 93), Fort Wolters Experiment

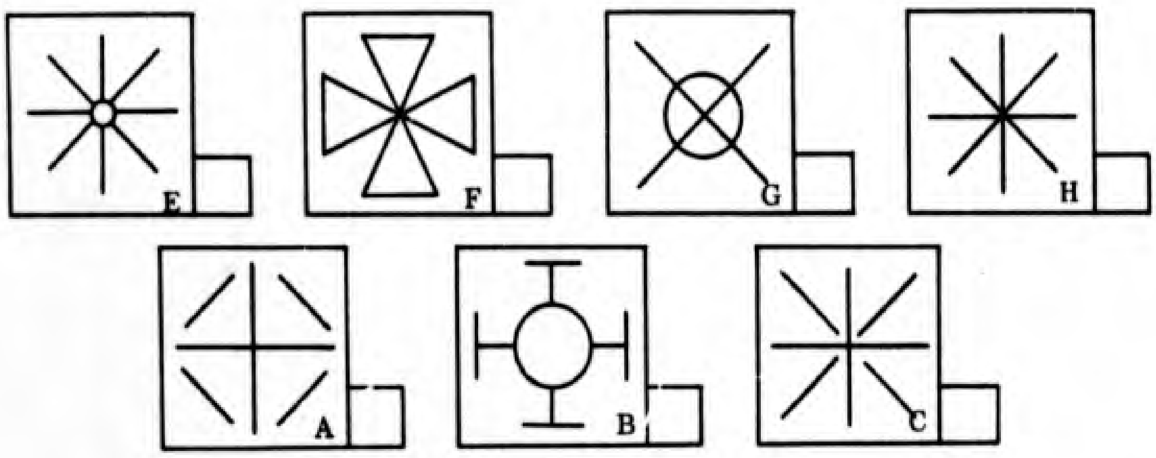
Factor	Tabulation (T)	Variability (V)	T x V	Index* (T x V/N)
No-Pattern (Control)				
1. Approach Angle	40	33	1320	14.1
2. Line of Descent	33	36	1188	12.7
3. Ground Track	18	16	288	3.1
4. T. D. Point	24	16	384	4.1
5. Closure Rate	28	37	1036	11.1
6. Control Handling	--	26	--	--
Total Variability		164		
No. of students scored "average" = 31				
Pattern Y				
1. Approach Angle	38	22	836	9.0
2. Line of Descent	37	24	888	9.5
3. Ground Track	10	12	120	1.3
4. T. D. Point	24	22	528	5.7
5. Closure Rate	30	23	690	7.4
6. Control Handling	--	26	--	--
Total Variability.		129		
No. of students scored "average" = 35				
Pattern Z				
1. Approach Angle	30	15	450	4.8
2. Line of Descent	23	19	437	4.7
3. Ground Track	15	10	150	1.6
4. T. D. Point	19	18	342	3.7
5. Closure Rate	22	23	506	5.4
6. Control Handling	--	14	--	--
Total Variability		99		
No. of students scored "average" = 40				

* Note: The higher the index, the poorer the performance.

HELIPORT MARKING & LIGHTING QUESTIONNAIRE

Patterns

1. Of these patterns installed on the overrun areas, which is your first choice? Please mark first three in order of preference.



2. Of these patterns what is the feature you like and why?

3. Do you believe these patterns are:

   Suitable size ____________

   Too small ____________

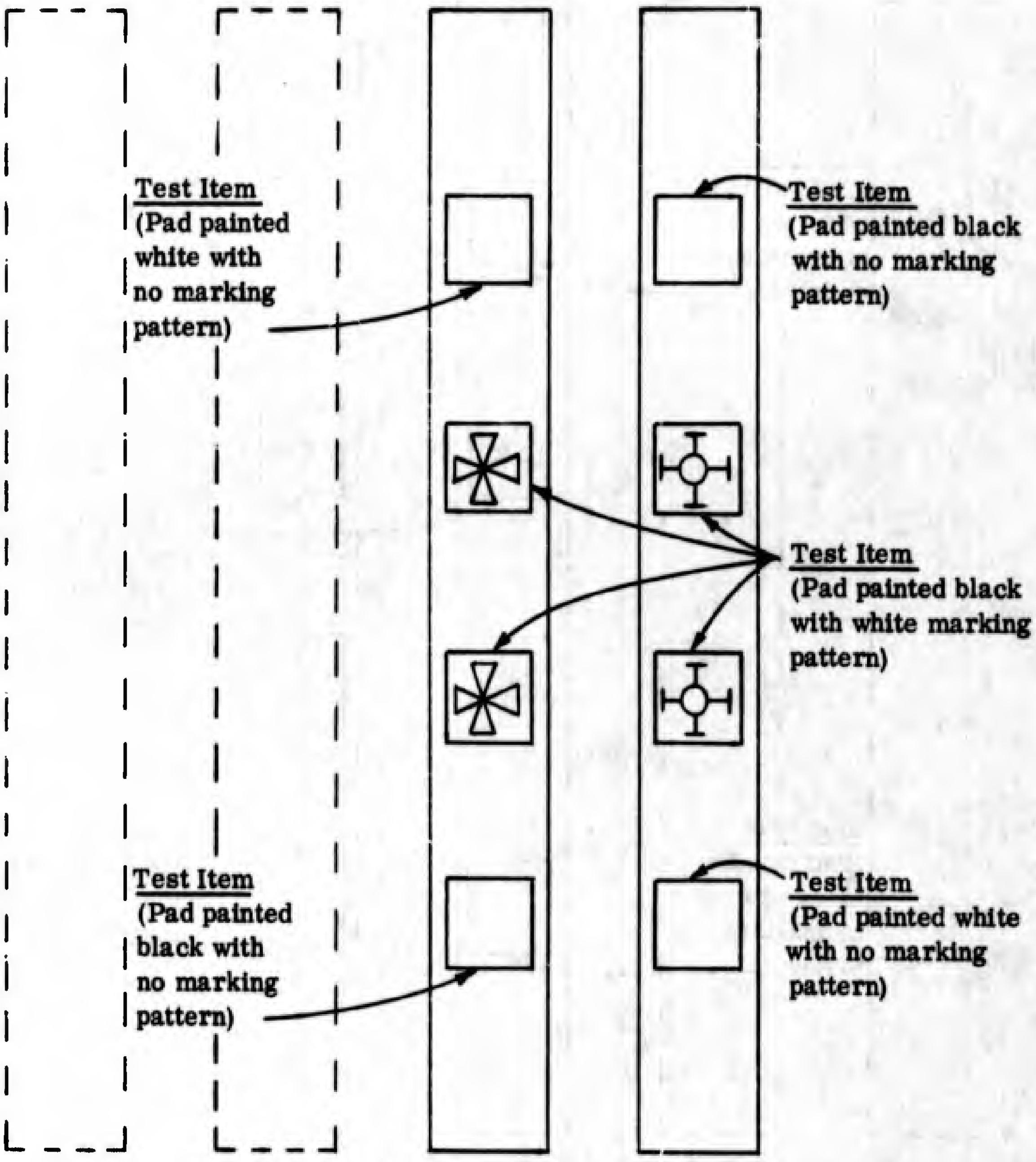
   Too big ____________

4. At any time during approach do any of these patterns give a false or unusual impression? If so, please describe.

5. Are any of these patterns undesirable?

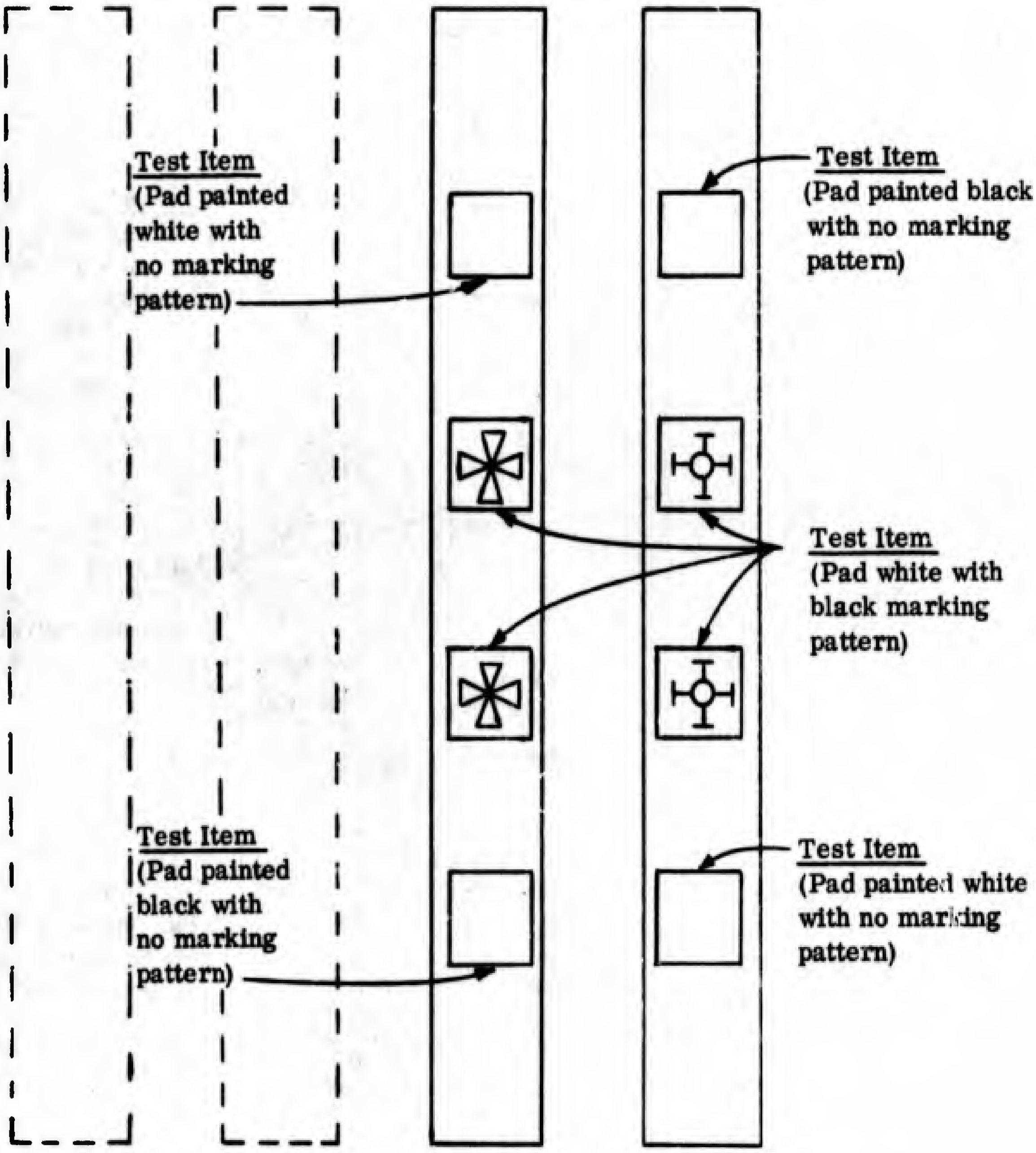
6. Do you have a marking pattern in mind that you would like considered? _____ If so, please sketch on reverse side of this questionnaire.

Exhibit 1



MARKING PATTERN SURVEY
BLACK PAD WITH WHITE MARKING PATTERN
FORT WOLTERS, TEXAS

Exhibit 2



MARKING PATTERN SURVEY
WHITE PAD WITH BLACK MARKING PATTERN
FORT WOLTERS, TEXAS

Exhibit 3

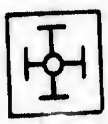
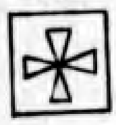
Heliport Marking Study

STUDENT COMPARATIVE QUESTIONNAIRE *

____
Date

_____________________ Initial _____________________
Student's Last Name Class and Flight

1. Indicate which pattern you preferred:

_____  _____  _____ No Pattern

2. Do you feel that a pattern is a pilotage aid, that is, helps to improve performance?

_________Yes _____________No

3. Any other comments? ______________________________

____

____

* Complete after you have flown both patterns and the no-pattern areas.

Exhibit 4

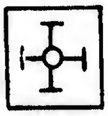
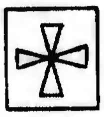
Heliport Marking Survey

INSTRUCTOR PREFERENCE RATING*

____ ____________________

Instructor's Name Initial Date

1. Which pattern did you prefer?

_____  _____  _____ No Pattern

2. Do you feel that the patterns are an aid to pilotage, that is, do they help to improve performance?

_________Yes_________No

3. Do you feel that the patterns were helpful to the students?

_________Yes_________No

a If yes, in what way?____

____

____

4. Were the patterns of any help in instructing?

_________Yes_________No

5. Other comments:____

____

____

____

* Complete at the end of the student performance rating phase.

Exhibit 5

Heliport Marking Study

STUDENT PREFERENCE QUESTIONNAIRE

(Complete for <u>each</u> pattern independently)

______________________________________ ______________________

Student's Last Name Initial Class and Flight

Flight Area: _____SF-5 _____Bien Hoa Aircraft Type:

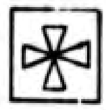
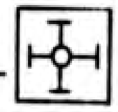
_____Da Nang _____Qui Nhon _____TH-55A

_____OH-23D

____

Date and Time of Flight

Which pattern are you reporting on? (Indicate one):

___  ___ 

1. Approximately how many approaches have you made to this pattern?

____

2. Did the pattern bother you in any way? _______Yes _______No

   a. If yes, how? ____

____

3. Do you feel the pattern helped you? _____Yes _____No _____N/A*
4. Did it help you establish approach angle? _____Yes _____No _____N/A
5. Did it help you with closure rate? _____Yes _____No _____N/A
6. Did it help you maintain a better ground track? _____Yes _____No _____N/A
7. Did it help you with roll attitude? _____Yes _____No _____N/A
8. Did it help you with stopping and hovering? _____Yes _____No _____N/A
9. State any other way you feel that this <u>particular</u> pattern may have helped you:

____

____

____

10. What specific feature (s) of <u>this</u> pattern did you like? _______________

____

____

11. What about the size of the pattern?

_______Suitable _______Too Small _____Too Big

*N/A Not Observed

Exhibit 6

Heliport Marking Study

STUDENT PERFORMANCE EVALUATION

________________________________ ____________________

Student's Last Name Initial Class and Flight

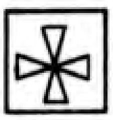
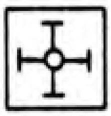
________________________________ ____________________

Instructor's Last Name Date and Time of Flight

Wind Conditions:	____Nominal	____Mod. X-Wind	____Exc. X-Wind
	____Calm	____Light Turb.	____Hvy. Turb.

Flight Area:	____SF-5	____Bien Hoa	Aircraft Type:	____TH-55A
	____Da Nang	____Qui Nhon		____OH-23D

Which Pattern? (Indicate One):

____  ____  ____ No Pattern

INSTRUCTOR'S EVALUATION: APPROACH AND LANDING/HOVER

Factor	Performance		Variability**		
			Average	Moderate	Excess
1. Approach Angle:	____ Shallow	____ Steep	A	M	E
2. Line of Descent:	____	____	A	M	E
3. Ground Track:	____ Left	____ Right	A	M	E
4. Touch Down Point:	____ Short	____ Over	A	M	E
5. Closure Rate:	____ Slow	____ Fast	A	M	E
6. Control Handling:	____ Average	____ Moderately Over Cntl	____ Excessive Over Cntl		

* Complete for each student, for each pattern, and for no-pattern (Control)
This means three (3) of these SPE forms per student

** Indication of rate changes in factor being evaluated. Example: Average changes in closure rate (Item 5) versus step changes from slow to fast to slow.

Exhibit 7

BRIEFING MATERIAL FOR INSTRUCTOR AND SUPERVISORY PERSONNEL

The U. S. Army Corps of Engineers and the Federal Aviation Administration are engaged in an extensive program aimed at establishing specifications and standards for daytime marking, night lighting, and identification beacons for heliports.

The first phase of this program concerns heliport or pad marking for daytime identification and pilotage. Earlier modeling studies at the Corps Ohio River Development Laboratories have been completed on a large number of geometric marking patterns, including the so-called "traditional" triangle-H pattern. The end result of these studies was the identification of seven markings which were felt to have some utility. These seven markings were placed on the overrun areas of Hanchey Army Heliport at Fort Rucker. Pilots there flew the markings and evaluated them by questionnaire and interview. Two patterns survived this initial survey.

The study is now in its final phase, and we here at Fort Wolters have been asked to participate. I would like to point out that this is an official study sponsored by the Department of the Army and one the FAA expects to use to establish standards for both national and international application.

In order to cooperate fully, it is important that you understand the nature of the research task. We are interested in two aspects of the markings: (1) Which of the patterns are preferred by pilots using them (and why), and (2) Do they provide any actual aids to pilotage, aside from designating a helicopter landing area.

To get the required information, the two patterns will be placed at four locations, Stage Field 5, Bien Hoa, Da Nang, and Qui Nhon, so that both students and instructors can make various approaches and landings or hoverings to them. Since we are interested in both preference and performance measures, both students and instructors will be asked to fill out two (2) forms each: one dealing with preference, the other with performance. Instructors flying with students will be asked to rate the student's approaches and landings to each pattern, as well as to non-marked areas to serve as a control. This rating form is a simple six (6) item check-sheet, similar to the more complete PPDR check-list, but with an additional scoring area for variability of performance. In summary, you are being asked to compare each pattern in terms of preference and performance against the no-pattern condition, and then to compare one pattern with the other.

The forms will be distributed through your flight commanders, who will also be responsible for their completion and return. We estimate that the study will be completed in a week or ten days of flying. I want to point out that these forms will in no way be used for any sort of evaluation at this level. All forms will be collected and sent to the Human Engineering Branch of the FAA for statistical treatment and analysis.

Exhibit 8

Let's give these people our wholehearted and intelligent cooperation. They are working on problems of interest and benefit to us. Remember, they want each man's independent judgment in the questionnaire. Don't load the dice in favor of either pattern or any question. Just report your honest evaluation and encourage your students to do likewise. We don't want a consensus. We want independent judgments. It is also important to remember that one pattern does not have to be ruled out. It is possible that both patterns are equally good or equally poor, or in fact, have different applicability. Further instructions will be available with each form. Students will be briefed on their role as well. In order to further familiarize you, I will read you the student's briefing.

BRIEFING MATERIAL FOR STUDENT PERSONNEL

You are being asked to participate in an evaluation of heliport marking as part of a study directed by the Army Corps of Engineers and the Federal Aviation Agency. This is a final phase of the study which has eliminated all but two of the many patterns originally considered. You will be asked to compare each pattern against an absence of markings and then with each other.

We are interested in two aspects of the markings under consideration, namely: (1) Your preference, and (2) any indication that the markings can, or do, provide an aid to pilotage - that is, do either (or both) of the patterns provide you with some form of approach and landing aid.

In order to get at this information you will be required to complete a simple 11 item questionnaire for each pattern, right after you have flown it during a session of approach and landings. Later, after you have flown both patterns, as well as the areas without patterns, you will complete a brief 3 item comparative questionnaire.

In summary, the two patterns under consideration will be placed at three stage fields which you normally use. After you have flown a pattern sufficiently to form a judgment, you will fill out a Student Preference Questionnaire for it. NOTE: Since there are two patterns, you will fill out one form for each pattern independently. After you have flown each pattern sufficiently, you will then fill out the comparative questionnaire.

Therefore, to comply with the requirements of this study, you will have completed three forms; one for each pattern, and one for comparison.

While you are flying these patterns, as well as the no-pattern areas for comparison, you will be evaluated by your instructor using a Student Performance check sheet made up for this purpose. He will fill out one performance evaluation sheet for each student for each of the two patterns, plus one evaluation for your performance on the no-pattern areas, to serve as a control.

Your instructors will also be asked to indicate their preference for the patterns by means of a separate questionnaire.

Remember, we need your <u>own</u> independent evaluation. Don't worry about what someone else thinks about the situation, and don't be concerned about ruling one pattern or the other "in" or "out". It's possible that both patterns could be equally good or equally poor. Just give us your honest evaluation and let your classmates and instructors give theirs.

Exhibit 9

I want to clearly point out that this study and the ratings given you will not be a part of your regular flight checks. Individual ratings will not be revealed and they will not form any part of your official records. They will be collected and sent directly to the Human Engineering Branch of the FAA for independent analysis.

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Final Report

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13 ABSTRACT

This report presents the results in the development of a recommended marking pattern for helipads. The objective of the study was to determine the marking pattern which would best fulfill requirements which were established on the basis of current practices, discussions with helicopter pilots, and helicopter operational observations. Field tests were conducted following laboratory observations and scale-model studies. Those requirements which most influenced final selection of the marking pattern were (1) Visual Flight Rules conditions (daytime), (2) recognition of the pattern from one mile, and (3) a five-degree minimum approach angle. Elements of pattern size and contrast gained significance as a result of field test evaluation.

In order that the selected pattern most effectively meet the requirements, minimum overall pattern size and line width were recommended. Also, to emphasize the importance of good contrast, it was recommended that the marking pattern be white, edged with a black border unless the surface is sufficiently dark that the border is not needed for good contrast. The selected pattern was recommended as an Army standard for helipad marking and, in addition, is being considered as a national and international standard.

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Helipad Marking Pattern						
Pattern Size						
Pattern Contrast						

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