FINAL REPORT

VFR LIGHTED FLYWAYS IN THE TCA ENVIRONMENT

Project VC-A1, FY 92

Prepared by
J.R. Spiekermann, B.J. Dempsey
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Department of Civil Engineering
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October 1994

Illinois Transportation Research Center
Illinois Department of Transportation

ILLINOIS TRANSPORTATION RESEARCH CENTER

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Acknowledgments

This Final Report on the design, fabrication, and evaluation of a VFR lighted flyway marker for use in the TCA environment was prepared by the Department of Civil Engineering, University of illinois at Urbana-Champaign. The report is prepared from research sponsored by the Illinois Transportation Research Center. Dr. Steven J. Hanna is the Administrator for the Center.

The advice and the contribution of a flashing beacon by Mr. Larry J. Montuori from Flash Technology Corporation of America is greatly appreciated. Special thanks is extended to Mr. James Bildilli of the Illinois Department of Aeronautics for his helpful comments throughout the conduct of this project. Also the flyover evaluation of the marker system by Mr. James Bildilli and Mr. Roger Finnell of the Illinois Department of Aeronautics was very helpful for finalizing the project.

Disclaimer

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INTRODUCTION

Airspace Structure

As aviation continues to grow, it has become increasingly important to maintain operational safety in the airway system. The airspace system in the United States is divided into six designations. Each designation is identified by the letters A through E and G, and is illustrated in Figure 1. The six classes of airspace are described as follows:

A - Positive Control Areas (PCA), including jet routes and airspace from 18,000 MSL up to including FL 600,

B - Terminal Control Areas (TCA),

C - Airport Radar Service Areas (ARSA),

D - Control Zone/Airport Traffic Areas (ATA),

E - Control Zone/Nontower Airports and Controlled Airspace, including Victor airways, transition areas, and control areas, and

G - Uncontrolled Airspace.

Certain aircraft equipment requirements and pilot ratings are necessary to operate in some of these airspace classes.

At the larger airports with high traffic volumes it has been necessary to develop Class B Terminal Control Areas or TCA's which provide a positive radar environment for aircraft arriving and departing the airport. Figure 2 shows the size and shape of the TCA for Chicago-O'Hare International Airport. The TCA provides for safe transition between flight altitudes for landing or takeoff at O'Hare International Airport.

A TCA is essentially shaped like a "layered wedding cake" which has been turned upside down. There is a series of circular rings which extend from a lower altitude up to a designated ceiling altitude. As an aircraft gets closer to the airport, the lower altitude decreases or stepsdown until it is the same as the ground elevation within about a five mile radius of the airport. Generally the circular rings extend out to about twenty to twenty-five nautical miles (NM) from the airport center. For example, at Chicago-O'Hare International Airport, the TCA airspace ranges from the ground to 10,000 ft at the airport and changes from 1900 ft to 10,000 ft at 6- to 10-NM, 3000 ft to 10,000 ft at 10-to 15-NM, and 3600 ft to 10,000 ft at 15- to 25-NM, Figure 2. All altitudes for the TCA are referenced to mean sea level (MSL). Any aircraft flying into the TCA must have radio contact with approach control as well as certain navigational equipment as specified in FAR 91.215 and FAR 91.131. An encoding transponder which provides radar with location (distance, azimuth, and altitude) is required in the TCA.

In order to facilitate the movement of a Visual Flight Rules (VFR) aircraft around the TCA or under the TCA airspace, it is proposed to construct a lighted flyway marker which can be easily seen from altitudes up to 4000 feet above ground level (AGL). It will be important for the flyway marker to be located so that it can be easily identified and viewed from the aircraft cockpit in both daylight and at night.

Study Objectives

The general objectives of this study were to develop, fabricate, and evaluate a marker system which would function successfully for a VFR flyway. The specific study objectives include the following:

1. Evaluate the marker and light systems presently available which could function successfully for a VFR flyway.
2. Develop and fabricate a prototype flyway marker which will function in the field environment.

3. Conduct primary field evaluations of the flyway marker.

4. Prepare a final report for the study.

MARKERS AND LIGHT SYSTEMS PRESENTLY AVAILABLE

There are numerous markers and light systems presently used in the aviation system (1,2,3,4,5,6). A summary of aeronautical lighting is presented in Appendix A. In this summary it is noted that most light systems use white, red, green, blue, or yellow colors which are coded with either constant or sequenced flashing light sources.

In developing a VFR lighted flyway marker for the TCA environment it is believed that the marker should provide both a color and shape which are easily identified from the aircraft. It is also felt that the light color and sequence should be easily distinguished from the surrounding background lights that exist in a metropolitan environment.

Based on examination of signs and markings used in both highway and air transportation it was found that bright shades of orange and green provided excellent visibility in a broad range of background colors. It was found during flights to determine the visibility range for various colors that white was highly visible at considerable distances during the summer months. However, white colored objects were very difficult to identify in the winter when there was snow cover. Figure 3 shows an aerial photograph taken after the ground was covered with snow. It illustrates that the white buildings blend into the white snow background. The green signs used on interstate highways were quite visible from an aircraft when flying between 1500 ft AGL and 4000 ft AGL. Orange objects also showed up quite well at these altitudes.

During the evaluation of light systems for the flyway marker it became obvious that a steady burning or flashing white light was the easiest to identify in both daytime and at night. One major problem with white lighting is that it is widely used for obstruction lighting and for anticollision lighting on aircraft. However, this problem can be overcome by using a unique flash sequence. Red lighting is also commonly used in obstruction lighting but it is not as prominent as white lighting.

Based on existing aviation and highway markers and lighting systems it was determined that a bright orange or green marker with a white flashing beacon light would have a high probability of success for a VFR lighted flyway marker. The white flashing beacon selected would have a unique flashing sequence which would be different from that used in obstruction or aircraft anticollision lighting.

PROTOTYPE VFR LIGHTED FLYWAY MARKER

Design

Besides color, the size and shape of the VFR lighted flyway marker were important design considerations. The different shapes considered included cylindrical, spherical, cubic, and pyramid. Based on ease of construction a four sided pyramid was selected for the prototype marker.

The selection of the size of the marker was made from visual inspection of landmarks from an aircraft and by use of a computer aided design program in which the marker could be scaled to represent its size as seen from various distances. From this study a four sided pyramid with a 10 ft square base and 12.72 ft height was selected, Figure 4.

A major design consideration for this research study was portability of the marker system. The marker needed to be assembled and disassembled quickly for movement to various field locations. A frame and shell assembly was developed to provide the needed portability. Aluminum tubing with a 1 in. outside diameter was used to construct a sturdy, light weight frame. A local awning company was employed to piece together a canvas shell featuring the bright orange and green colors selected for the marker. In order to evaluate both colors two consecutive sides of the marker made orange with the other two sides green.

A flashing beacon for the flyway marker was obtained on loan from the Flash Technology Corporation of America, Appendix B. The beacon system was designated as a Flash Technology Electro Flash FTB 736 beacon which provided omnidirectional flashes of white light emitting the Morse Code "H" (four short flashes). The beacon is used to identify heliport pads and provided a light intensity of 3000 candelas and 8000 candelas. The components of the beacon consisted of a model FH301 flashhead and a model PC 736 power converter. The flashhead used a Fresnel lens assembly. Additional red and amber flashtubes were obtained with the beacon for evaluation in the study. The beacon power supply was provided by a portable generator.

A fluorescent orange and white checkerboard vinyl mesh 30 ft by 30 ft ground mat was placed at the base of the pyramid marker to improve visibility. Figures 5 and 6 show the entire VFR lighted flyway marker as it is set up for field evaluation.

Marker Assembly

Detailed instructions for field assembly of the VFR lighted flyway marker are provided in Appendix C. The marker was assembled in three components. One consisted of the bottom section of the pyramid, another was the top section of the pyramid, and the third was the beacon which capped the marker. Assembly of the marker required services of two people and approximately 1 hr of set up time. The marker could be totally disassembled in about 0.5 hrs.

FIELD EVALUATION OF
VFR LIGHTED FLYWAY MARKER

Testing Procedures

The prototype VFR lighted flyway marker was evaluated in the field through a series of flight studies. Field observations were made on the marker set up in several locations including the Monticello Airport and the roof of Newmark Civil Engineering Laboratory on the campus of the University of Illinois at Urbana-Champaign. Observations were made from a Grumman American AA5B aircraft, Figure 7, and recorded on flight record forms, Figure 8. All distances from the marker were obtained through the use of an onboard global positioning system which was accurate to within ± 50 ft. All altimeter settings were referenced to the elevation of the marker. The in-flight observations were conducted in varying weather conditions and in both daylight and night conditions.

In-Flight Observations

Flight One, Monticello Airport, July 14, 1993 - The first flight was conducted to determine the optimal color of lighting to use in the marker's flash beacon. Clear skies and good weather conditions were present for the first flight. Observations were made in the late afternoon followed by observations after dark to determine if a white, amber, or red flashtube would work best for sighting the marker. Upon evaluation, the red flashtube was determine to be the hardest to see in both daylight and night conditions. Both the white and amber flashtubes were acceptable choices for the final marker light. A light intensity of 3000 candelas proved bright enough and at the legal limit for nighttime sighting, but was not bright enough to provide much daylight visibility. The capacitance of the beacon was increased to allow for 8000 candelas during the day and 3000 candelas at night for the rest of the flights.

Flight Two, Monticello Airport, September 29, 1993 - The purpose of this observation was to determine the maximum acceptable sighting and spacing distances for the marker system in a flyway. The sky was clear with good visibility at the time of observation. The flights were made a few hours before sunset. The marker was set with the two orange sides facing to the South and West into the sun. The white flashtube was used in the beacon.

Distance Sighting: An approach was made from the North at a distance of 10 NM to determine the maximum visibility range of the light. This direction of approach gave the best visibility of the light. The light was first detected at 4.5 NM and 1500 ft AGL and became brighter as the aircraft progressed from 3.0 NM and 1500 ft AGL towards the marker.

Altitude Sighting: Aircraft altitudes of 500-, 1500-, 2000-, 2500-, and 3000-ft AGL were maintained on respective passes over the marker. Observations were made from 3.0 NM at all compass readings. From the North, the beacon light was most visible but the green marker color was not distinguishable. As the aircraft circled to the East, the light intensity seems to fade within 15 degrees on either side of directly into the sun. The marker's color was still not distinguishable as the marker itself fades into its own dark shadow in the direct sunlight. From the South, the light was again visible and the orange side of the marker became highly visible as it caught the sun, which was now getting lower in the West. The orange side of the marker remained highly visible for the rest of the pattern until the aircraft passed East of the marker where the green color again became shaded. The influence of the sun's reflection off the marker is shown in Figures 9 and 10. The effects of shading on the side of the marker away from the sun is also seen in Figure 10 and more dramatically at dusk in Figure 11. Essentially the color of the marker had little influence on the shaded side away from the sun. It appeared as a dark colored pyramid. The beacon light was visible throughout the pattern on the orange side of the marker, but momentarily faded within ± 15 degrees directly into the sun. The beacon light quickly became visible again once pass the point of looking into the sun.

Radial Sighting: At all compass directions the beacon light visibility from altitudes between 500 ft AGL and 2500 ft AGL was relatively the same. However, as the aircraft rose to altitudes of 3000 ft AGL and above, the light intensity faded until it became almost nonexistent. This loss of light visibility is caused by the properties of the Fresnel lens on the beacon.

<u>Flight Three, Monticello Airport, October 22, 1993</u> - The purpose of this flight was to determine the maximum radial sighting capabilities, determine the best color responses, and to make night sighting observations. The sky at the time of evaluation was clear with good visibility. The observations were made later in the day and after sunset. The orange sides of the marker were faced

toward the South and West and a white flashtube was used in the beacon.

Radial Sighting: The aircraft altitude was maintained at 500 ft AGL. Observations were made from the radial distances of 2.0 NM to 3.5 NM from all compass headings. The marker was readily seen from 1.5 NM in all directions. From 2.0 NM to 2.5 NM the marker was readily observed except when the sun was a factor as discussed in the previous flight evaluation. At distances greater than 2.5 NM the marker was not always easily identified.

Color Response: The green side of the marker was faced into the sun to compare its sighting capabilities with that of the orange sides. The green side of the marker was brighter and more readily seen when approached from the sun side. It did not provide for any improvement when compared to the orange sides however. As found in previous observations, the color of the marker had little effect when flying towards the sun when it is low in the horizon. The marker appeared as a dark silhouette when flying towards the sun.

Night Sighting Capabilities: Observations were made well after sunset to determine the distance at which the marker could be seen at night. Various light intensities were observed and the shortest viewing distance was 10 NM at 500 ft AGL. This distance increased when passes were made at higher altitudes. This again indicated the importance of proper lighting direction. Nighttime sighting should not be a problem. The only important consideration would be the choice of a recognizable flash pattern. The Morse Code "H" flash pattern was easily recognized during this evaluation.

Flight Four, The University of Illinois Campus, November 22, 1993 - The purpose of this flight was to determine sighting capabilities in a congested city setting. The sky was clear and turning to overcast with good visibility. The marker was placed on the roof of Newmark Civil Engineering Laboratory on the campus of the University of Illinois. Distance sightings were made during this evaluation and the conclusions were similar to those from the Monticello Airport evaluations. There was some interference from ground objects of similar color and by the reflection of the sun that occurred in this location study.

Flight Five, Monticello Airport, December 10, 1993 - The purpose of this flight was to determine the appropriate angle of light emission necessary for the required level of sighting desired. The weather conditions were overcast for this observation. The sky was partly to mostly cloudy, but visibility was good below 3000 ft. It became apparent that the beacon light sighting would be necessary through almost the entire range of viewing angles. The lowest angle would be at a distance of 3.0 NM at an altitude of 1200 ft AGL or 3° to 5° above horizontal. Flying towards the marker to closer distances or to higher altitudes requires that the marker be seen from greater angles. Thus from 3.0 NM and 1000 ft AGL to until the aircraft is almost directly over the marker, the marker should be in view. This will provide pilots with the best opportunity to sight the marker should they not see it initially. The present lens for the flashtube, which has a Fresnel grating that emits light at approximately 3° to 30° above horizontal, has been found to be unacceptable. To correct this problem, direct lighting was evaluated during approach to the marker. It is possible that combination of a Fresnel lens emitting light radially and a directional light aimed vertically would eliminate the problem of light disappearance during overflight.

Flight Six, Monticello Airport, January 26, 1994 - The purpose of this flight was to determine the marker's sighting capability in snow conditions. The weather conditions were close to perfect for this observation. The sky was clear with few clouds and good visibility. A light snow cover of 1 in. to 2 in. had fallen a few days prior to making the evaluation. Initial concerns as to snow cover's adverse effect on sighting capability were confirmed by this flight. As in all the previous flights, a radial pattern with varying distances and altitudes was flown. At the best visual angle, sighting was limited to 1.5 NM for the marker and the beacon light was of little use regardless of distance from the marker. Sighting in these conditions will depend mostly on location of the marker and size, elevation, and color of the marker will become very important in snow conditions.

Flight Seven, Monticello Airport, May 3, 1994 - The purpose of this flight was to determine if increasing the marker's size increases the visibility of the marker. A 6 ft tall base was added to the pyramid to give added size to the marker. The ground mat was then draped over this base to complete the shell. The increased size of the marker made a dramatic impact on sightability. Illinois Department of Aeronautics officials joined the observations for this evaluation and were able to sight the marker from 5.0 NM to 6.0 NM when approaching from the direction of the setting sun. Not much increase was noted in sightability when flying towards the setting sun however.

Evening flight evaluation conducted by the Illinois Department of Aeronautics validated previous observations that the flashing beacon could easily be seen at 10.0 NM or greater at nighttime.

FIELD RESULTS AND DISCUSSION

Marker Evaluation

Marker Color and Reflectivity

Considerable effort went into choosing the combination of colors to specify for the prototype VFR flyway marker. The colors must be chosen to distinguish the marker from its surroundings and to make it highly visible from an aircraft. It became apparent that the direction of the sun and the marker reflective properties were key factors in visibility evaluation. The prototype marker shell was constructed of heavy duty awning canvas. The colors used in testing were bright orange and bright green. Each color covered two whole sides of the pyramid shaped marker.

Highway signs, water towers, grain bins, and buildings provided valuable examples of color that would be highly visible from an aircraft. It was determined that bright reflective colors such as orange, green, yellow, or white would be highly visible. However, the surrounding background colors are important when selecting a marker color. The lighter, reflective colors work well but some loose sharpness when contrasted to light surroundings such as fall corn fields or light colored buildings. White colored objects are highly visible from an aircraft in many instances but become almost impossible to identify when there is snow cover.

The large orange and white checkerboard ground mat was easily detected from 3000 ft AGL to 4000 ft AGL directly above the marker. However this mat provided for very little visibility improvement when the aircraft approached the marker from a distance at low altitude.

The use of retroflective materials from 3M in the marker were considered and could provide for some increase in visibility depending on the direction of the sun. However, no field evaluations were conducted to evaluate the influence of retroflective materials on visibility improvement.

Marker Shape

Numerous shapes were considered to optimize surface area and increase recognition of the marker system. The four sided pyramid was selected because of ease of construction. The pyramid shape was easily recognized from a distance of about 1.0 NM. Beyond this range the shape became more indistinguishable and had less impact on identification. This would probably be true of other shapes as well. However increasing the size of the marker would make the shape more distinguishable. The amount of surface area directly affects the amount of reflection that the marker would have. Choosing the right shape as well as increasing the size of the marker to maximize the surface area would be helpful. The pyramid surface area increases considerably when both the base size and height are increased.

Marker Size

Marker size is an important characteristic for which the best decisions can only be made through comparison and inspection. The prototype size was 10 ft by 10 ft on the base, 1.5 ft by 1.5 ft for the top platform, and 12.72 ft tall. Both the research team and Department of Aeronautics officials determined that the prototype marker is definitely too small for use in a VFR flyway. To provide improved sighting at 3 NM, or greater distance, the actual marker must be at least two to three times larger than the present marker. The main limitation to the larger size will be surrounding space constraints as well as aesthetic and community responses. Comparison and inspection of existing structures gives great insight as to the proper sizing. Water towers and grain bins were again used to aid in the recommendations. Test flight seven confirmed the fact that increasing the size of the marker caused major improvement in the sighting distance.

Beacon Evaluation

Color

A flashing beacon was obtained from Flash Technology Corporation of America. Different flashtube colors were tested in an attempt to determine the optimum color for visibility in both daytime and night conditions. White, amber, and red flashtubes were tested. The red flashtube lacked clarity even at close range and provided marginal help in sighting the marker during daytime. Both the white and amber flashtubes provided good visibility in daytime up to a distance of 2.0 NM to 3.0 NM and at nighttime at a distance of 10 NM or greater. Most of the flight evaluations were conducted with the white flashtube. However the amber flashtube would offer a distinctive color for the flyway marker beacon. It is believed that either white or amber colors could be used successfully in the flyway marker.

Flash Pattern

The beacon used in this study was set to identify a heliport and had a Morse Code "H" or four short flashes with a pause followed by a repeat sequence of flashes. A unique and distinctive flash pattern should be chosen to provide quick recognition of the flyway route. The four short flashes could be seen during daytime when 2.0 NM to 3.0 NM from the marker. At night the four short flashes were easily distinguishable at 10 NM or greater distance.

It is believed that a two flash sequence would be more ideal for the beacon system. These could be made up of some combination of long and short flashes which differentiate the flyway marker light from other lights used in aviation or in city and community lighting.

Light Intensity

The initial light intensity of the marker was set to 3000 candelas, but this was determined to be too low for daytime visual contact. The capacitance was increased to provide 8000 candelas. This proved to be an ample intensity during the daytime evaluation for visual contact at 2.0 NM to 3.0 NM depending on flight direction relative to the sun, Figure 12. As shown in Figure 12, the relative position of the aircraft in relation to the sun and marker influences the beacon light visibility. The beacon light cannot be seen when flying towards the marker with the sun directly behind the aircraft and when flying towards the marker and into the sun. Both of these conditions only occur when the sun is near the horizon. At night the FAA regulated limit is set to 3000 candelas. A simple timing device could be set to manipulate the brightness between day and night candela settings. In the final consideration of light intensity during various daytime atmospheric conditions, 16,000- to 20,000- candalas would optimize the lighting system.

Flight Approach Angle

The beacon uses a Fresnel lens which defines the angle of light emission. Based on field evaluation the Model FH 301 flashhead lens provided light visibility in the range of 3° to 30° above the horizon. Visual contact with the flashtube light in the daytime was very good at low approaches and at 2.0 NM to

3.0 NM from the marker, Figure 13. However, as the aircraft approached and overflew the marker, the light disappears because of the Fresnel lens. Methods were used during the field evaluation to tip the beacon at different angles in order to improve the full range of visibility. This did not work very well since it made the beacon more directional and not omnidirectional.

The Fresnel lens did not cause any problems during flight evaluation at night. The light could easily be seen during approach and overflight.

In the selection of a beacon for the VFR flyway marker the lens construction should be selected to give good light visibility throughout the approach to the marker. There is an advantage to using a Fresnel lens since it increases the size of the flashtube light source and the light intensity.

Marker Elevation

In this study it became obvious that the best way to sight the marker was to contrast and place the marker so as to emphasize its presence. In rural locations, typically fields, elevating the marker on a platform 50 ft to 100 ft AGL would increase visibility, Figure 14. Placement on natural geographic features such as hill tops and other well defined areas would be strategic in planning locations for the marker. In urban settings, elevation becomes even more important. Because many obstructions already exist, placement of the marker in an elevated position would be vital. Rooftops of most buildings would be acceptable as long as no obstructions are already present there. Again background colors will become almost as important as the marker color itself.

Marker Location

There is a definite advantage to placing the marker in a rural area.

Increased numbers of existing obstructions and light markers in an urban setting detract from sighting capabilities. Unfortunately, most TCA's necessitating a VFR flyway marker system will be located in a highly congested urban setting. The sighting factors of size, shape, and color become important for this reason. Finding suitable locations for large numbers of markers could pose some problems. It is important that the marker system be effective and easily distinguishable so that pilots will remain clear of the TCA.

A considerable number of the field evaluation flights focused on the marker spacing requirements. All flights were concentrated at altitudes between 500 ft AGL and 3000 ft AGL for this would be an appropriate range for a VFR pilot to be flying. The farthest distance that the marker was spotted was 4.5 NM at 1500 ft AGL. The average visibility distance from all directions, however, was 2.0 NM to 3.0 NM. Based on sighting distance, the spacing between consecutive markers placed around the airport TCA becomes about 3.0 NM to possibly 4.0 NM for a marker of the size used in this study. A larger marker system could extend the spacing to about 6.0 NM. These distances are based on the fact that once pilots cross a marker they must immediately identify the next marker in the flight path.

The object of this project was to develop a lighted flyway marker to keep VFR pilots out of large airport TCA's and to free up controllers to focus on the larger commercial aircraft. Setting the markers at a designated perimeter of about 15 NM for example at a spacing of 3.0 NM to 6.0 NM would warn VFR pilots that they were entering unauthorized airspace at approximately 15 NM away from the airport. The number of markers needed for a 15 NM perimeter to encircle the airport would be in the range of 15 to 30 depending upon the spacing chosen.

Sighting Deterrents

Several natural conditions present sighting problems which are uncontrollable by the markers design or placement. While flying radially about the marker it became clear that the sun was a major factor in sighting the marker, a variable that is constantly changing in location and magnitude. When looking at the marker directly into or directly away from the sun, the beacon light becomes undetectable. These problems will arise from different directions as the sun's position goes through its daily cycle. Other problems would be the changing surroundings as the seasons come and go. Snow in the winter causes extreme glare and possible coverage of the marker. Measures will be needed to prevent snow coverage. Fading is another problem that will need to be addressed. Simple structures that can be easily repainted or resurfaced will be needed.

SUMMARY AND CONCLUSIONS

The prototype VFR lighted flyway marker was observed through various methods of field evaluation. The initial design performed well throughout the project, exhibiting both good characteristics, and those that need improvement. Light systems already in existence can be utilized in a final marker design. The Fresnel lens in the flash beacon has several limitations regarding the angles of illumination that needs to be reengineered to allow the light to be seen throughout the approach and overflight of the marker. A white or amber flashtube set to a distinctive flash pattern is recommended to provide the best sightability. A light source of 3000 candelas is acceptable for night sighting, however, this must be increased to 8000 candelas or greater for good daytime sighting.

The physical structure of the marker must be durable under various climatic conditions. The pyramid shape is easily recognized at close distances but has little bearing on sightability at greater distances than 1.0 NM to 1.5 NM. Bright orange is the most recognizable color when utilizing the sun for good reflectivity. The sun does play a significant part in how well the marker is sighted and blind spots do occur. The final VFR marker will have to be increased 2 to 3 times in size when compared to the prototype used in this study. Sighting will be possible from 3.0 NM or greater distance. Therefore, the markers can be spaced at 3.0 NM to 6.0 NM. Elevating the marker will provide for major improvement in its sightability.

It is concluded that a lighted VFR flyway marker can be effectively implemented to minimize VFR traffic within TCA airspace. It is recommended that an implementation program be initiated to place flyway markers which will benefit VFR aviation traffic around the TCA for Chicago-O'Hare International Airport.

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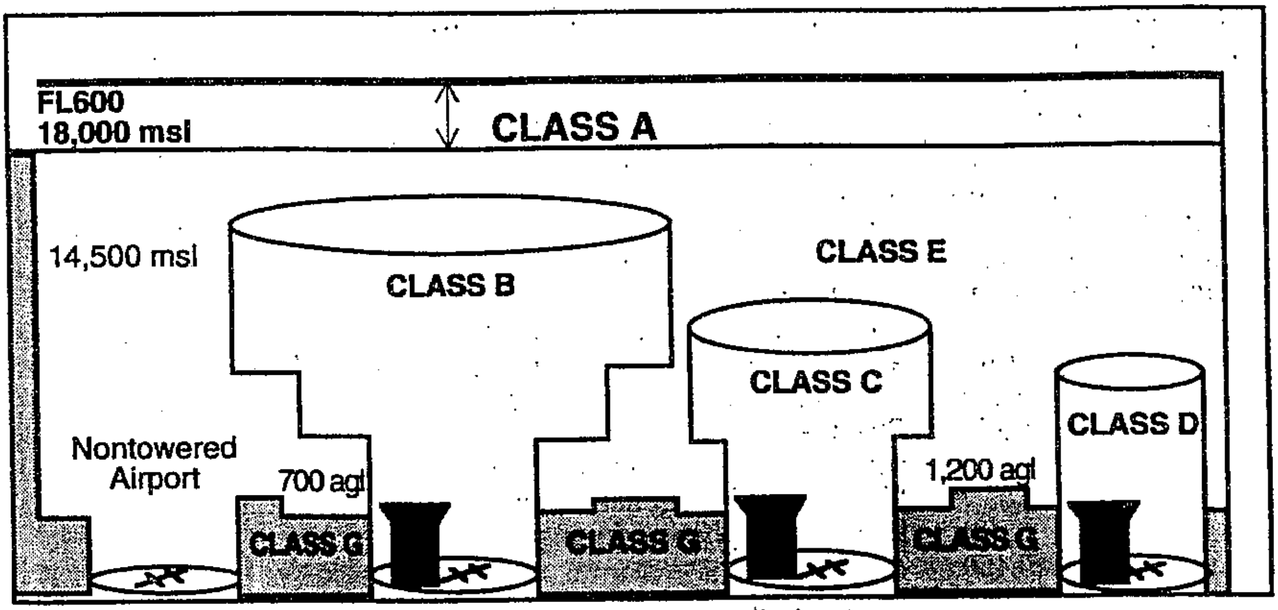


Figure 1. FAA Airspace Designations.

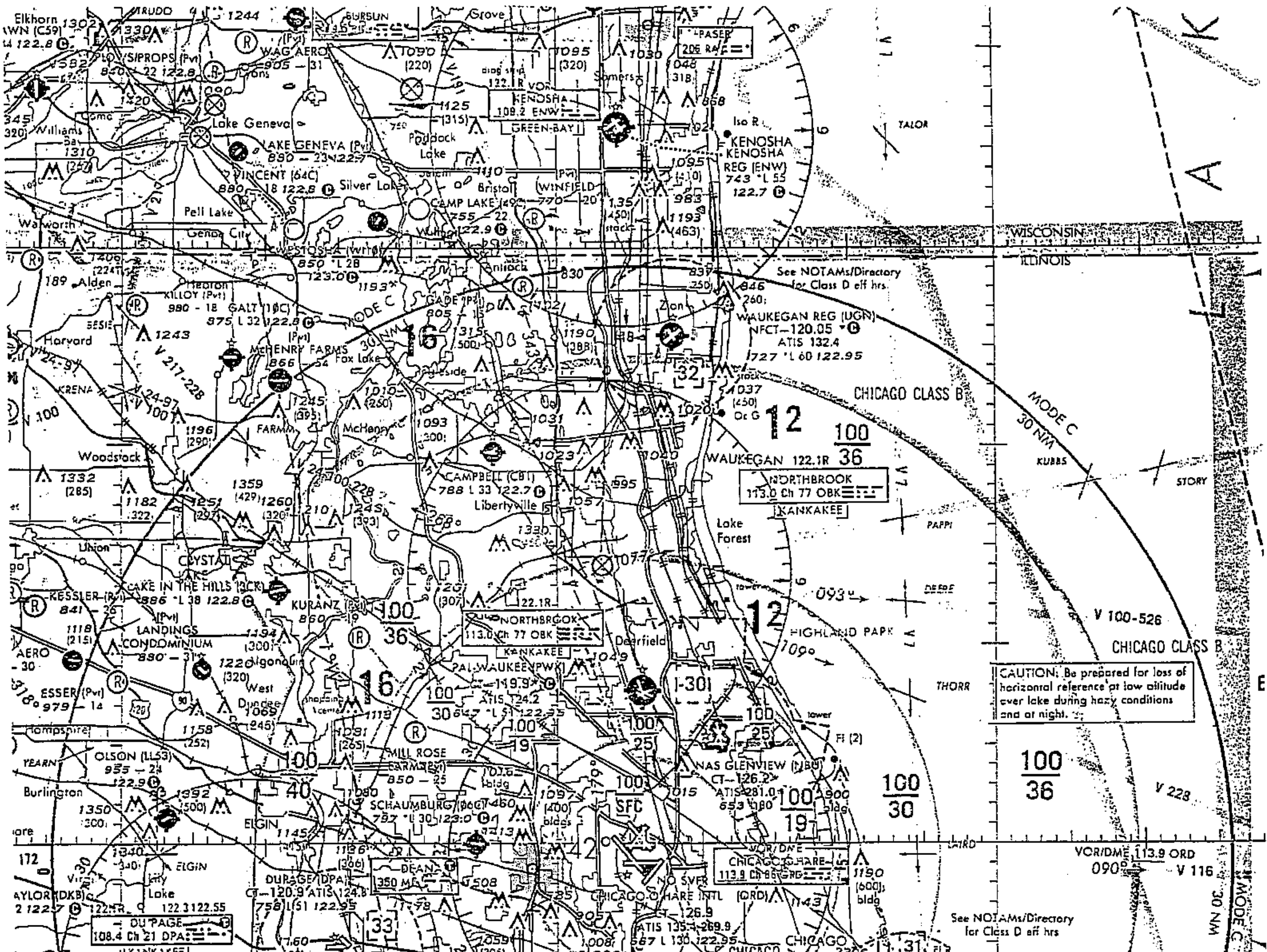
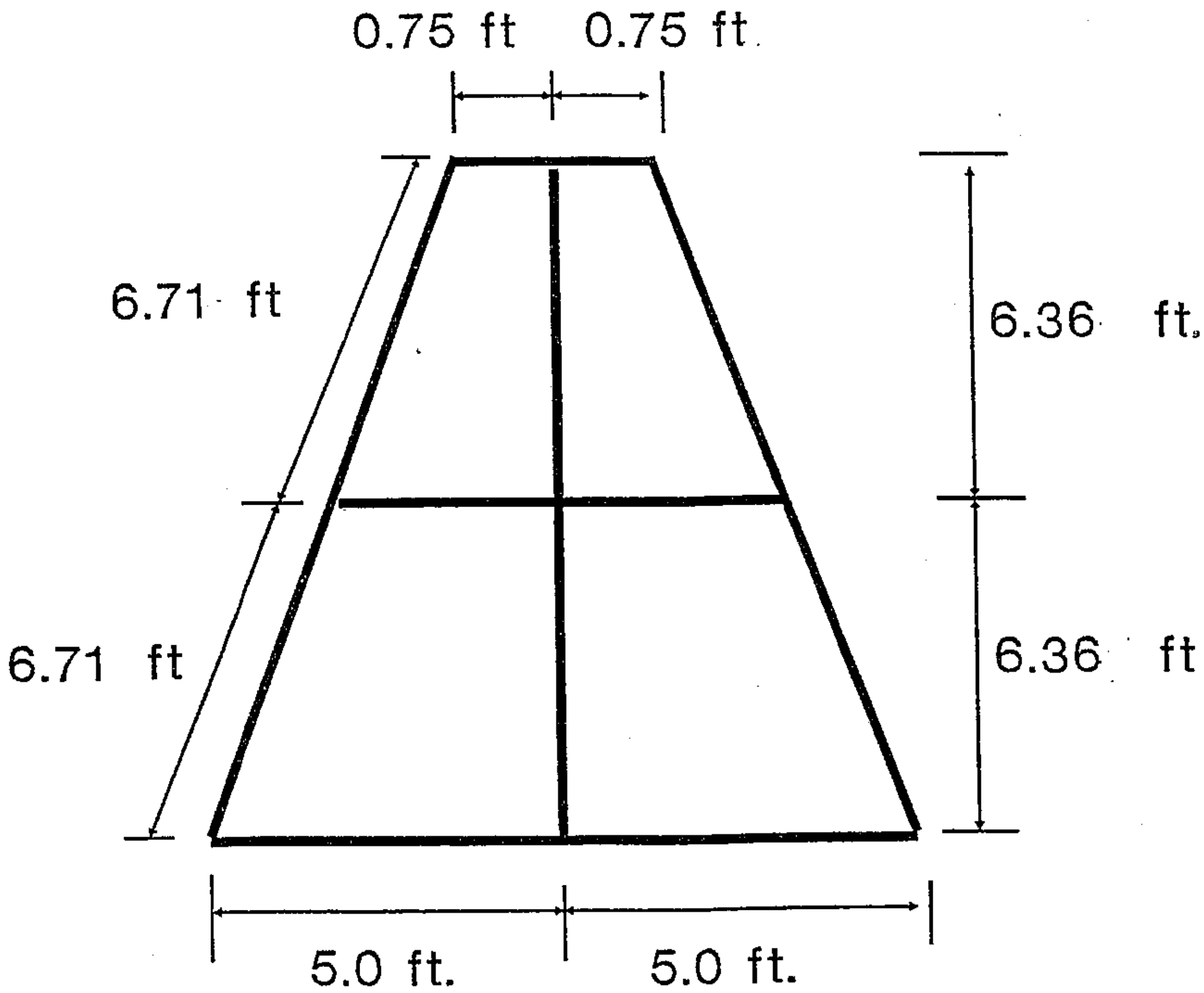


Figure 2. Chicago-O'Hare International Airport TCA.

Figure 3. Influence of Snow Cover on Ground Object Identity.



Note: Fabric for Pyramid Face Should Have Channels To Accept Frame

Figure 4. Side Dimensions for VFR Flyway Marker.

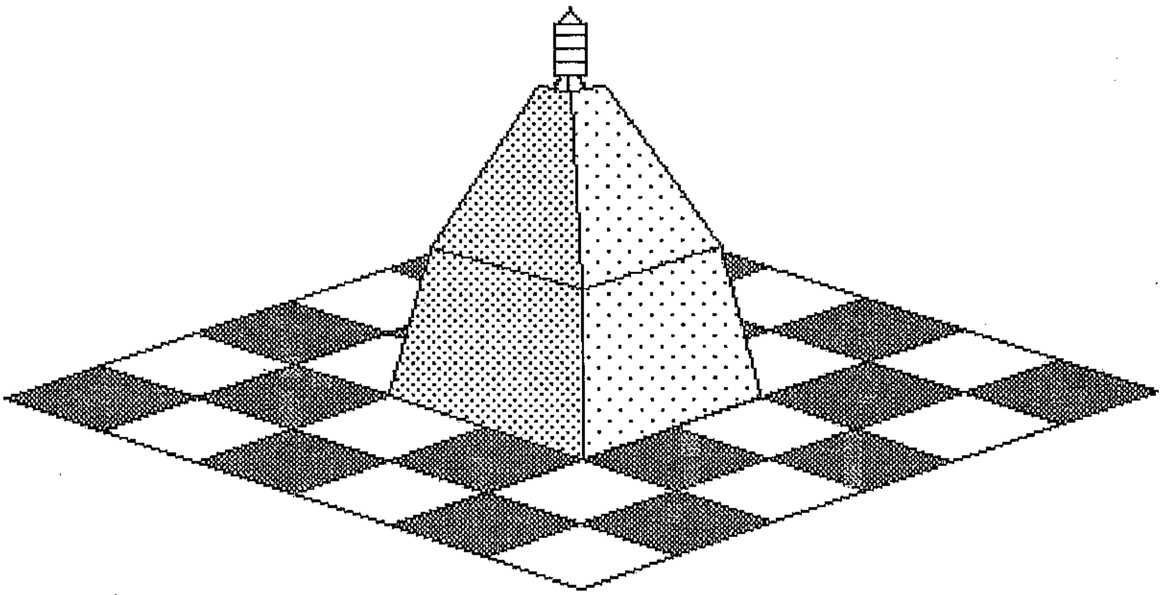


Figure 5. VFR Lighted Flyway Marker Concept.

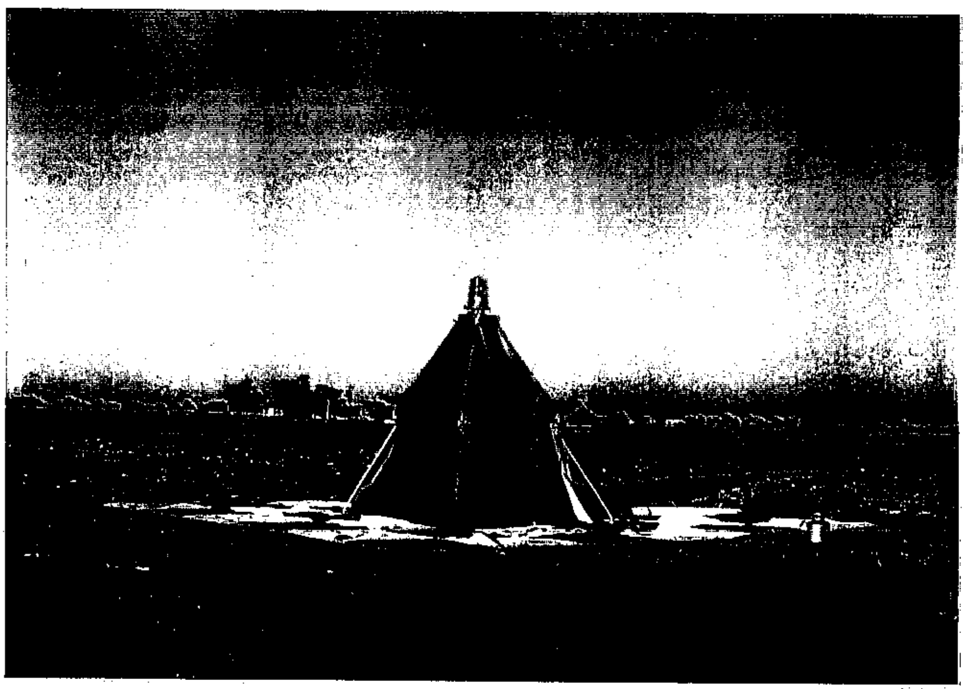


Figure 6. VFR Lighted Flyway Marker Setup in the Field.

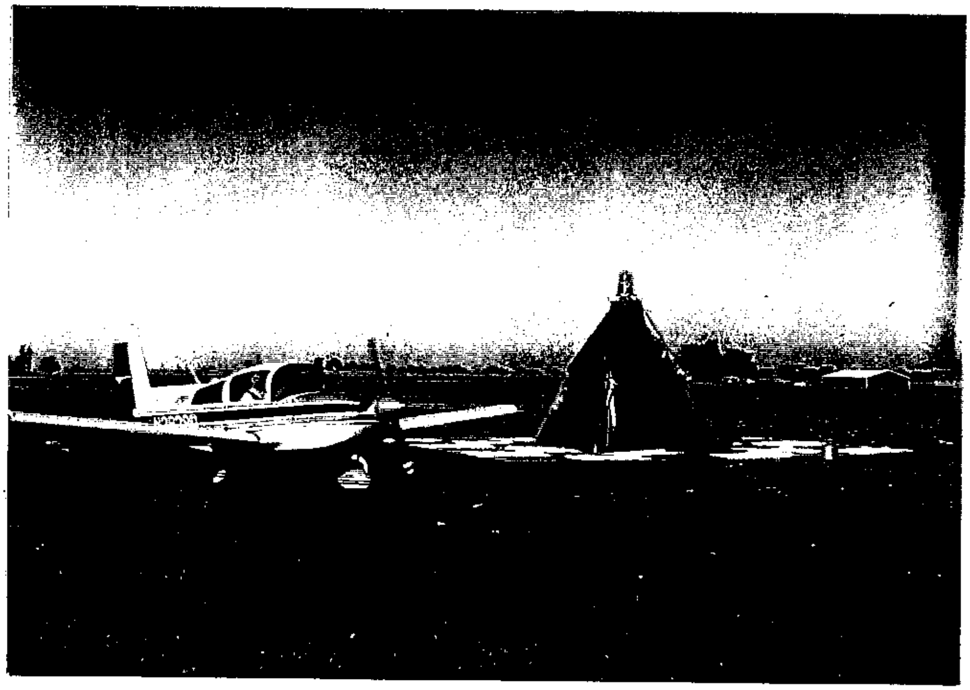


Figure 7. VFR Lighted Flyway Marker and Observation Aircraft.

VFR LIGHTED FLYWAY
OBSERVATION SHEET

DATE OF FLIGHT: ____________

TIME OF DAY OF FLIGHT: ____________ Day or Night (circle)

AIRCRAFT TYPE: ____________

WEATHER IDENTIFIER: ____________

SKY/CEILING HEIGHT: ____________ Clear - Scattered - Broken - Overcast (circle)

VISIBILITY: ____________

OBSTRUCTION TO VISION: Hail - Dust - Fog - Ground Fog - Haze - Smoke - Drizzle

Rain - Snow - Showers - Thunderstorm - None (circle)

WEATHER COMMENTS: ____________________________________ (if applicable)

DISTANCE AT WHICH PYRAMID IS VISIBLE: ____________ COLOR OF PYRAMID: ____________

PYRAMID DISTINCTIVE: Yes - No - Maybe (Please comment below)

DISTANCE AT WHICH LIGHT IS VISIBLE: ____________ COLOR OF LIGHT: ____________

LIGHT FLASHES DISTINCTIVE: Yes - No - Maybe (Please comment below)

ALTITUDE - AGL 500 FT. 1,000 FT. 1,500 FT. 2,000 FT.

2,500 FT. 3,000 FT. 3,500 FT. 4,000 FT.

DIRECTION 360° 045° 090° 135° 180° 225° 270° 315°

Figure 8. Flight Record Form.

Figure 9. Sun Reflection Off Orange Side of Marker.

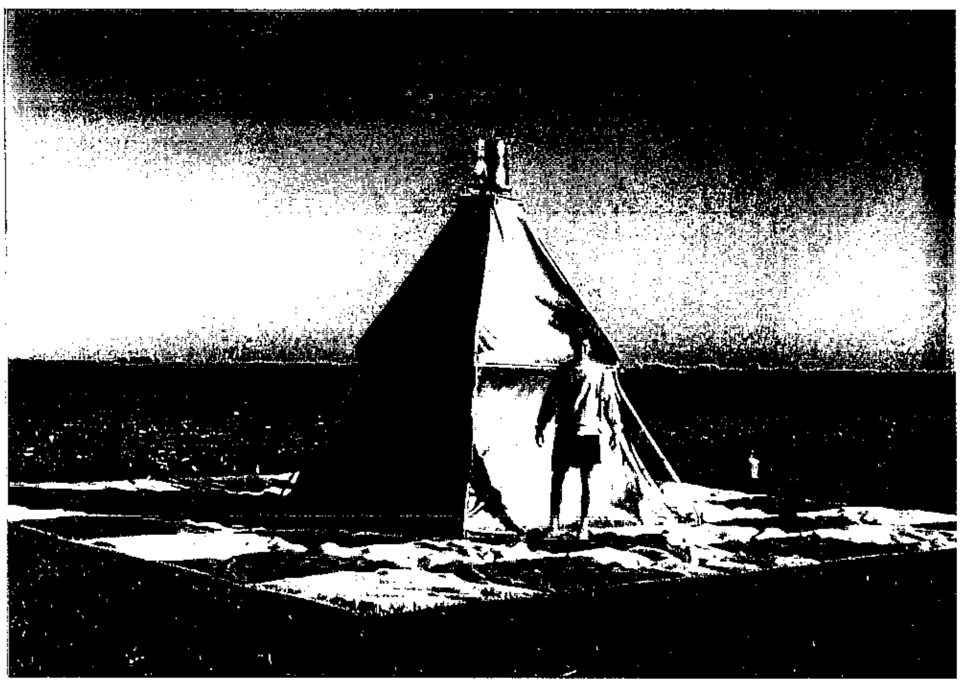


Figure 10. Sun Reflection and Shaded Side of Marker.

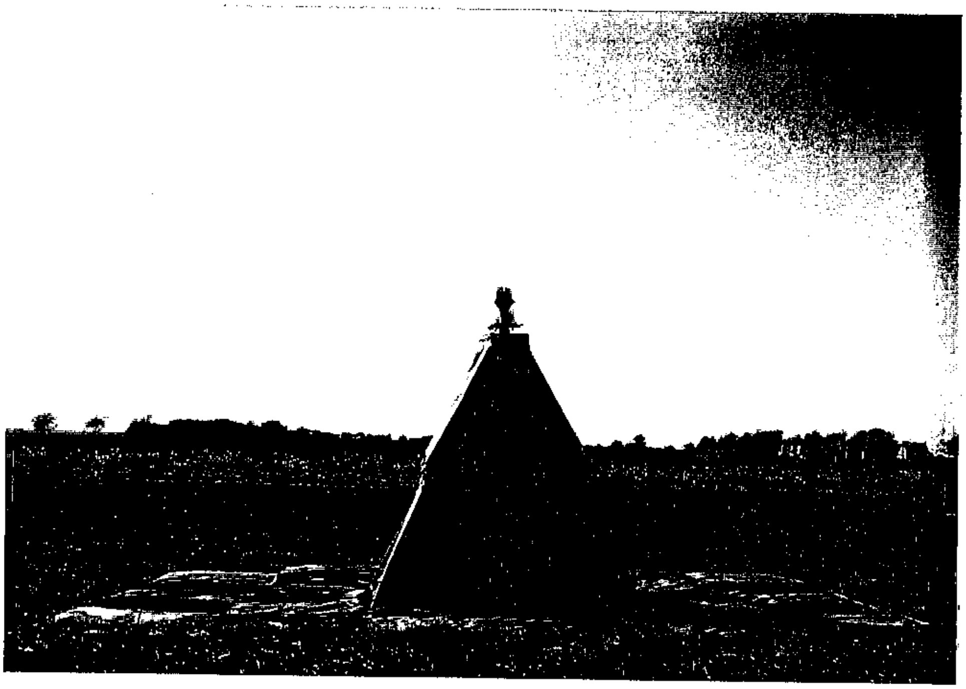


Figure 11. Shaded Side of the VFR Lighted Flyway Marker at Dusk.

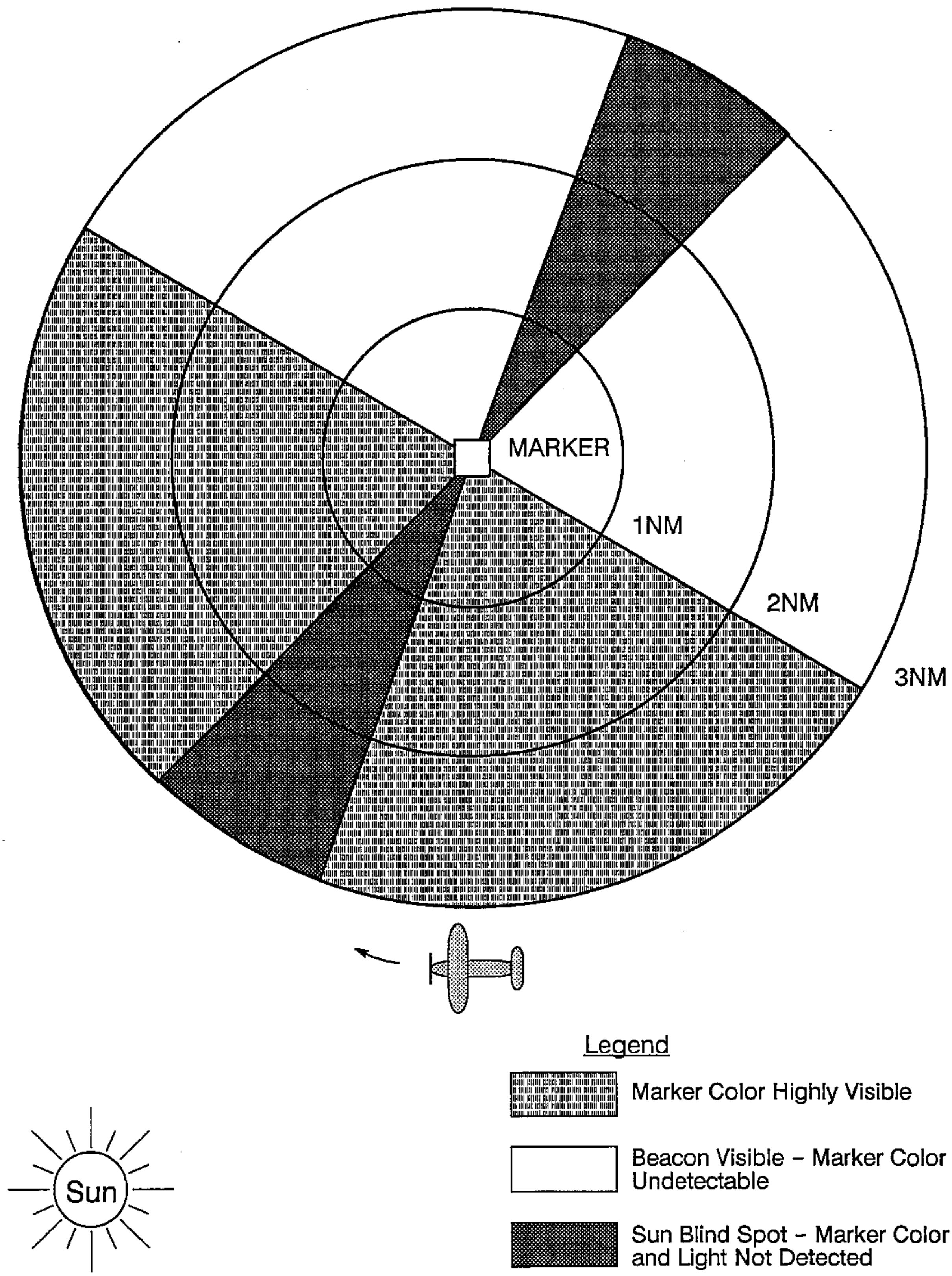


Figure 12. Influence of Marker Visibility Relative to Sun and Aircraft Position.

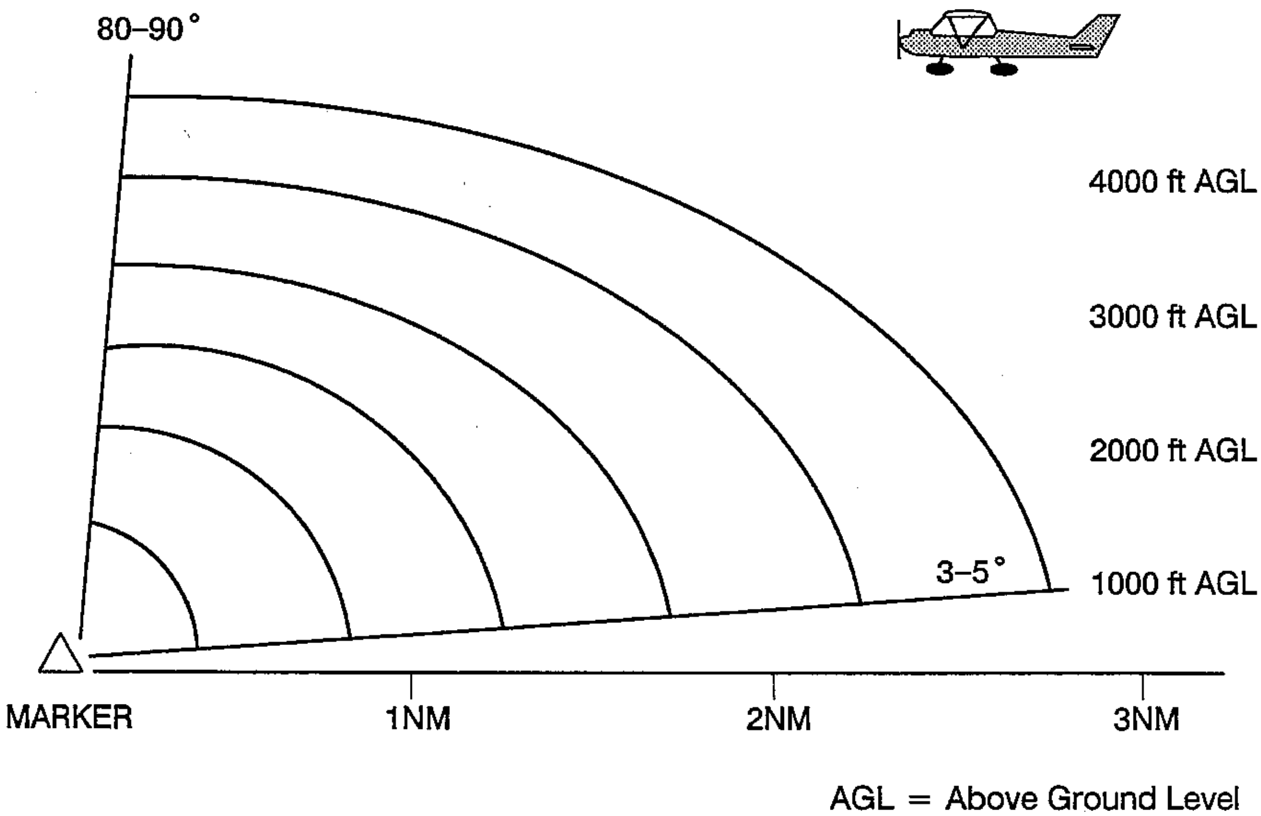


Figure 13. Influence of Aircraft Approach Altitude and Distance on Marker Visibility.

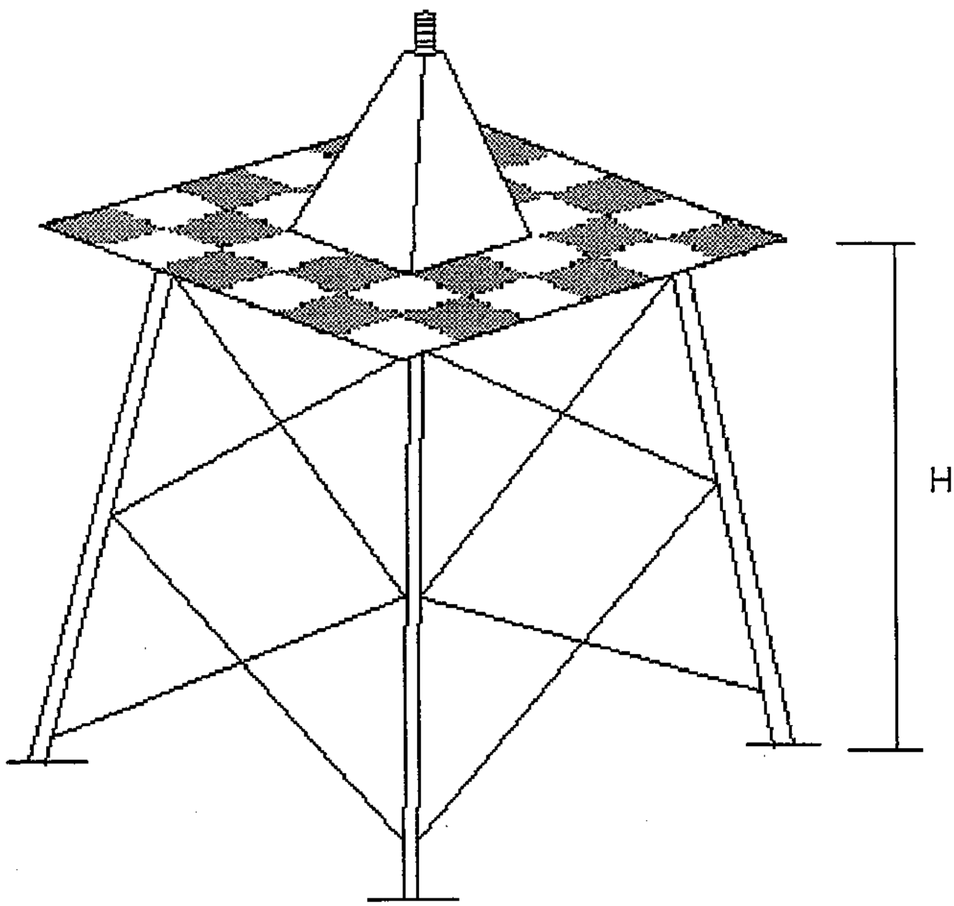


Figure 14. Elevated Marker Concept.

APPENDIX A

SUMMARY OF AERONAUTICAL

LIGHTING

AERONAUTICAL LIGHTING SURVEY

TYPE	COLOR	DESCRIPTION
Runway/Taxiway Lighting --		
Low Intensity Runway Lights (LIRL)	White	May be Amber last
Medium Intensity Runway Lights (MIRL)	White	2,000 ft. or 1/2 runway
High Intensity Runway Lights (HIRL)	White	
Runway End Lighting	Red/Green	Red toward runway ends. Green outward.
Runway End Identifier Lights (REIL)	White	Pair of synchronizing flashing lights.
Touchdown Zone Lights (TDZL)	White	2 rows of transverse light bars in runway.
Runway Centerline Lighting (RCLS)	White	In runway.
Runway Remaining Lighting	Red/White	In runway last 3,000 ft., alternating red/white, all red last 1,000 ft.
Taxiway Turnoff Lights	Green	In runway to taxiway.
Taxiway Edge Lights	Blue	
Taxiway Centerline Lights	Green	In taxiway.
Approach Lighting --		
Omnidirectional Approach Lighting (ODALS)	White	Operational requirements
Air Force Overrun 1000 Ft. Standard (AF OVRN)		dictate configuration patterns.
Lead-in Lighting System (LDIN)	White	Guide to approach zone.
Medium Intensity Approach Lighting System (MALS)	White/Green	
MALS with Sequenced Flashing Lights (MALSF)	White/Green	
MALS with Runway Alignment Indicator Lights (MALSR)	White/Green	
Short Approach Lighting System (SALS)	White/Green	
SALS with Sequenced Flashing Lights (SALSF)	White/Green	
Simplified Short Approach Lighting System (SSALS)	White/Green	
SSAL with Sequenced Flashing Lights (SSALF)	White/Green	
SSALS with Runway Alignment Indicator Lights (SSALR)	White/Green	
High Intensity Approach Lighting System with Sequenced Flashing Lights (ALSAF)	White/Green/Red	
ALSAF for Category 1 (ALSF1)	White/Green/Red	
ALSAF for Category 2 (ALSF2)	White/Green/Red	

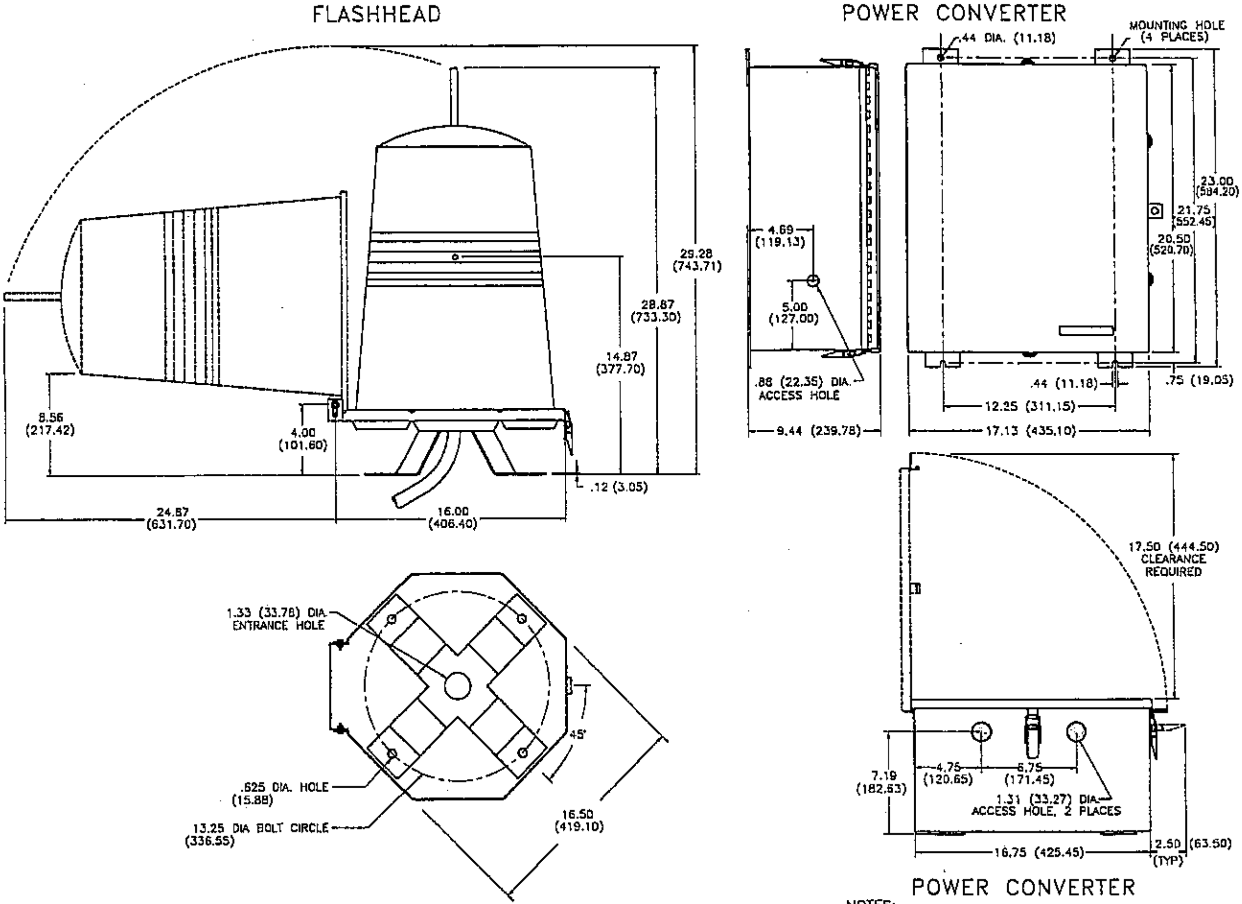
AERONAUTICAL LIGHTING SURVEY CONTINUED

TYPE	COLOR	DESCRIPTION
Beacon/Navigation/Obstruction Lighting --		
Airport Beacon		
Land Airport	White/Green	Approximately 12 flashes/min.
Heliport	Green/Yellow/ White	Approximately 30/40 flashes/ minute
Water Airport	White/Yellow	
Military	Two quick White flashes between Green flashes	
Code Beacons (omnidirectional)	Green or Yellow	not more than 40 flashes/min., or constant flashes of 12-15/min., for land & water airports respectively.
	or Red	12-40/minute constant flashes for hazards.
Course Lights (unidirectional) Remnant of lighted airways system.		used only with rotating beacons, 2 course lights back to back direct coded flashes along airway.
Obstruction Lights	Red or White or Red/White	High intensity flashing white lights either 40 or 60 flashes/ minute.
Visual Glideslope Indicators --		
Precision Approach Path Indicator (PAPI)	Red & White	Range to 5 m day to 20 m night.
Visual Approach Slope Indicator (VASI)	Red & White	Range to 5 m day to 20 m night.
Pulsating Visual Approach Slope Indicator (PVASI) [pulsating white = above glide path, steady white = on glide path, and pulsating red = below glide path.]	Red & White	Range to 4 m day to 10 m night.
Simplified Abbreviated Visual Approach Slope Indicator (SAVASI)	Red & White	Range to 5 m day to 20 m night.
Tricolor Visual Approach Slope Indicator (TRCV) [amber = above glide path, green = on glide path, & red = below glide path.]	Red, Amber, & Green	Range to 1 m day to 5 m night.

APPENDIX B

BEACON SYSTEM

Physical Dimensions



FLASHHEAD

NOTES:

1. Weight: 18 lbs (8 kg)
2. Wind area: 1.99 sq ft (0.18 sq m)
3. All dimensions are in inches and (millimeters)

NOTES:

1. Weight: 67 lbs. (30.4 kg)
2. Wind area: 2.4 sq ft (0.22 sq m)
3. All dimensions are in inches and (millimeters)
4. Side hole may be used for PEC, if required.

FLASH TECHNOLOGY

System Performance Data:

Flashhead - FH 301

8,000 ± 25% effective candelas - **high**
2,500 ± 25% effective candelas - **high-ICAO**
2,000 ± 25% effective candelas - **medium**
250 ± 25% effective candelas - **medium-ICAO**
75 ± 25% effective candelas - **low**

A group of 4 flashes (Morse Code "H") in 0.8 second with a 1.2 second interval between groups.
360° Horizontal Coverage
11° Vertical Beam

Power Converter - PC 736

120, 208, 240, 480 Volt 60 HZ, or 230 Volt 50 HZ, single phase (specify on order)
150 watts maximum power consumption
50 watts maximum power consumption ICAO
250 VA peak
Status relay with form C contact, contacts change state on fail

OPTIONS:

Interconnect cable - P/N 6340 (PC 736 to FH 301)
(Conduit is not normally required)
Available with three switchable intensities up to 8,000 effective candelas
System installation

APPLICATIONS:

All heliport landing pads such as hospitals, off-shore rigs, military, municipal, police, private.

Flash Technology Corporation of America
P.O. Box 329 • Nashua, NH 03060 • Phone: (603) 883-6500 • FAX: (603) 883-0205

APPENDIX C

VFR LIGHTED FLYWAY MARKER

ASSEMBLY INSTRUCTIONS

VFR LIGHTED FLYWAY

MARKER ASSEMBLY INSTRUCTIONS

These instructions are provided in a step-wise fashion to acquaint the first-time user with complete fabrication procedures for the marker assembly. After becoming familiar with the assembly procedures, simplifications may become evident. Total assembly time for the marker is approximately one hour. For assistance refer to Figure A1 through Figure A4.

1. Unfold and stretch out the 30 ft X 30 ft checkerboard mat to lay flat on the ground, Figures A1 and A2.

2. Drive the oversized nails into the ground through the eyelets provided in the checkerboard. Use as many nails as needed to stabilize the checkerboard under prevailing wind conditions.

3. Place the eight straight tube sections which comprise the base for the bottom section of the marker in the central opening of the checkerboard, Figure A3. Tighten the tube fitting using a small allen wrench. Make sure that each side outlet elbow (Connection A-1 to A-4) is situated such that the remaining opening is perpendicular to the ground and that enough room is allowed for the complete insertion of the angled tubes. When connecting the Joining Tees (Connections B-1 to B-4), be sure that fitting B-2 and B-4 are situated such that the remaining opening is approximately 30 degrees from vertical towards the center of the base. Connection B-1 and B-3 may be situated in any convenient fashion.

4. Place the four angled sections into the corner fittings (Connections A-1 to A-4) and position such that each is pointed towards the center of the base along a corner bisector. Tighten the allen screws to secure angled sections.

5. Position the four straight tubes which comprise the top level of the base section into the side outlet elbows affixed to the top of each angled section and lightly tighten the allen screws. Each of these four straight tubes has two holes drilled through to allow for the top section to be secured to the bottom section. Therefore, the holes should be position at the top and bottom of each bar. This will be important after the canvas shell is placed over the frame. One can now drive the large tent stakes into the ground to secure the bottom section. Use either one or two per side, depending on the wind conditions.

6. Position the straight braces between the top and bottom levels (Connections B-2 and B-4). It may be necessary to reposition the Joining Tees along the

bottom levels to accommodate the braces. Leave the top joint unassembled, but make sure that the Male-Female Socket Swivels along the top line up properly.

7. Position the straight corner braces between the angled sections and the base level and connect the Male-Female Socket Swivels with the short bolts.

8. Take a section of the bottom canvas shell and position it over two sides of the bottom section. Remove <u>one</u> section of tube from the top level and slide this through the upper channel of the shell. (Note: when working on the sides between Connections C-2 - C-3 or C-4 - C-1, make sure to slide off the Female Socket Swivel before sliding the tube through the first half of the channel and then position the Female Socket Swivel in the opening and continue pushing the tube through the remainder of the shell channel). Reposition the top level tube into the side outlet elbows and firmly tighten the allen screws after making sure that the holes through either end of the tube are pointing straight up and down. Remove the second section of the top level and attach the shell as before. You can now connect the straight braces to the top level by placing a short bolt through the Male-Female Socket Swivel. Do not use the velcro connections at the bottom level yet. Just let the shell hang free until the top section is positioned properly.

9. Complete the assembly of the second portion of the bottom shell as detailed in Step 8, Figure A4. Place two long connecting screws through the holes in the top level tubes between Connections C-1, C-2, C-3, and C-4 and bolt them in place. These bolts should be pointing straight up and down and should have the maximum possible length extending upwards from the tubes.

10. Position the four straight tubes which comprise the base of the top section in a convenient location near the completed base section, Connections D-1, D-2, D-3, and D-4. Tighten the allen screws on the side outlet elbows, making sure the remaining opening is positioned straight up and that enough room is allowed for the complete insertion of angled tubes. Also make sure that the oversized holes on each end of the straight tubes are pointing straight up and down.

11. Insert the angled tubes and position them so they are pointing towards the center of the section along the corner bisectors. Tighten all allen screws.

12. Position the four straight tubes for the top of the upper level into the side outlet elbows and affix to the top of the angled tubes.

13. Take the canvas shell for the top section and drape it over the tubes. Make sure that the shell is oriented so that the proper colors will line up with the base section after they are stacked together. It is also convenient to roll up the bottom of the shell to facilitate movements. Remove one tube from the top level of the top section and slide it through the shell channel and then replace the tube in the side outlet elbows and tighten the allen screws. Complete this procedure for the remaining three top level tubes.

14. Place the aluminum plate onto the screws protruding from the side outlet elbows and affix them with wing nuts. Remove the wing nuts and washers from the bolts affixed to the central portion of the aluminum plate.

15. Take the beacon from the box and uncoil the extension of wire to be connected to the control panel. Place a washer on each bolt on the top plate. Slide as much of the wire as possible through the hole in the center of the plate. Place the beacon on the top plate and affix it with a washer and a wing nut on each bolt, making sure all the remaining wire is pushed through the hole in the top plate. Attach one 25-ft length of nylon rope to each side outlet elbow on the top level of the top section. This will provide stability in wind conditions. Prepare to place the top section upon the bottom section by coiling wire out of the way.

16. Lift the top section onto the bottom section and fasten it to the four connecting bolts on the top level of the base. Tighten the top section down with wing nuts. Place bolts through the remaining holes of the two sections so that each side is secured in place with two bolts.

17. Drive the four short tent stakes into the ground near the outer corners of the checkerboard and tether the marker with the nylon ropes.

18. Place the control panel on the center of the marker. Take the wire from the beacon, push it through the opening in the side of the control panel, and attach the wires into the paver convertor. Place a generator in a convenient location and start it up. Plug in the control panel and the beacon should begin to flash. The toggle switch on the side of the control panel is provided to switch between day and night settings. Some delay will occur when switching between the two settings. (Note: If the flashtube is changed and reconnected improperly the setup will not flash. Be sure to line up the three stud connections properly, red dot to red dot.

19. Stretch out all of the canvas shell surfaces and attach them at the bottom of each section with the velcro provided.

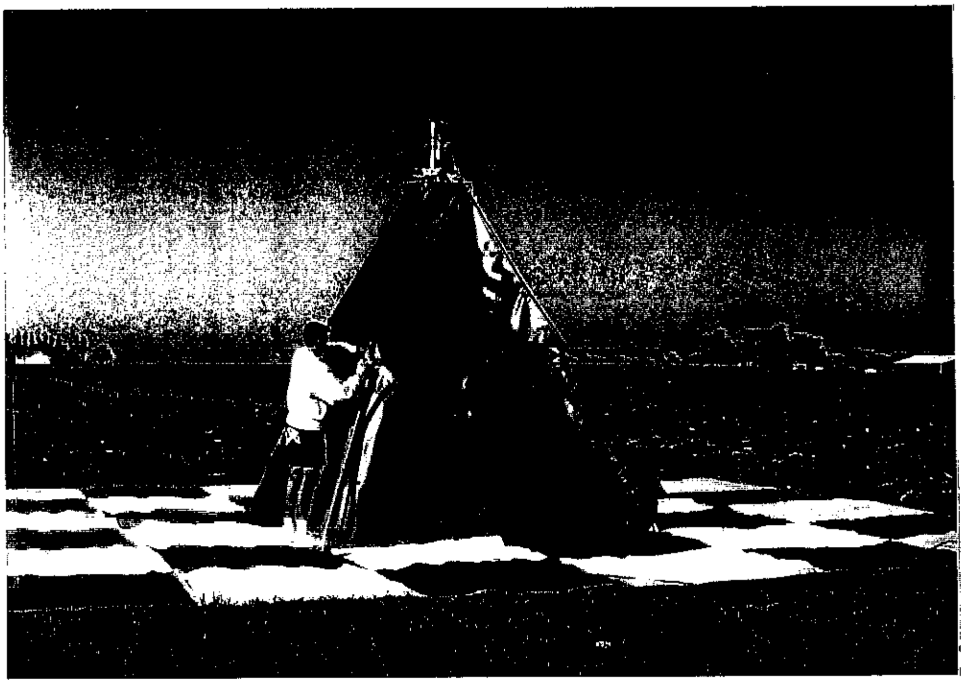


Figure 1A. Assembled VFR Lighted Flyway Marker.

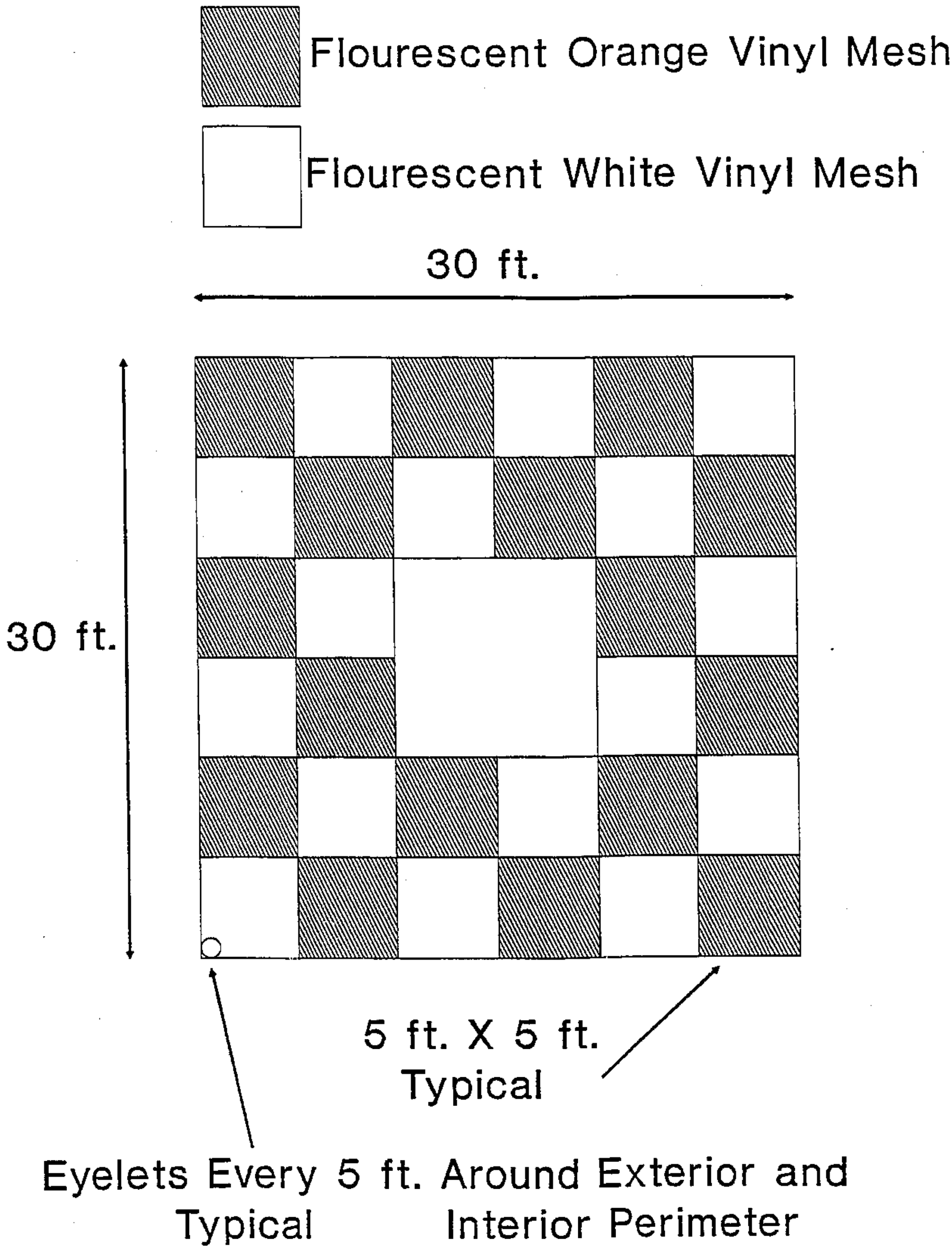


Figure 2A. Checkerboard Ground Mat.

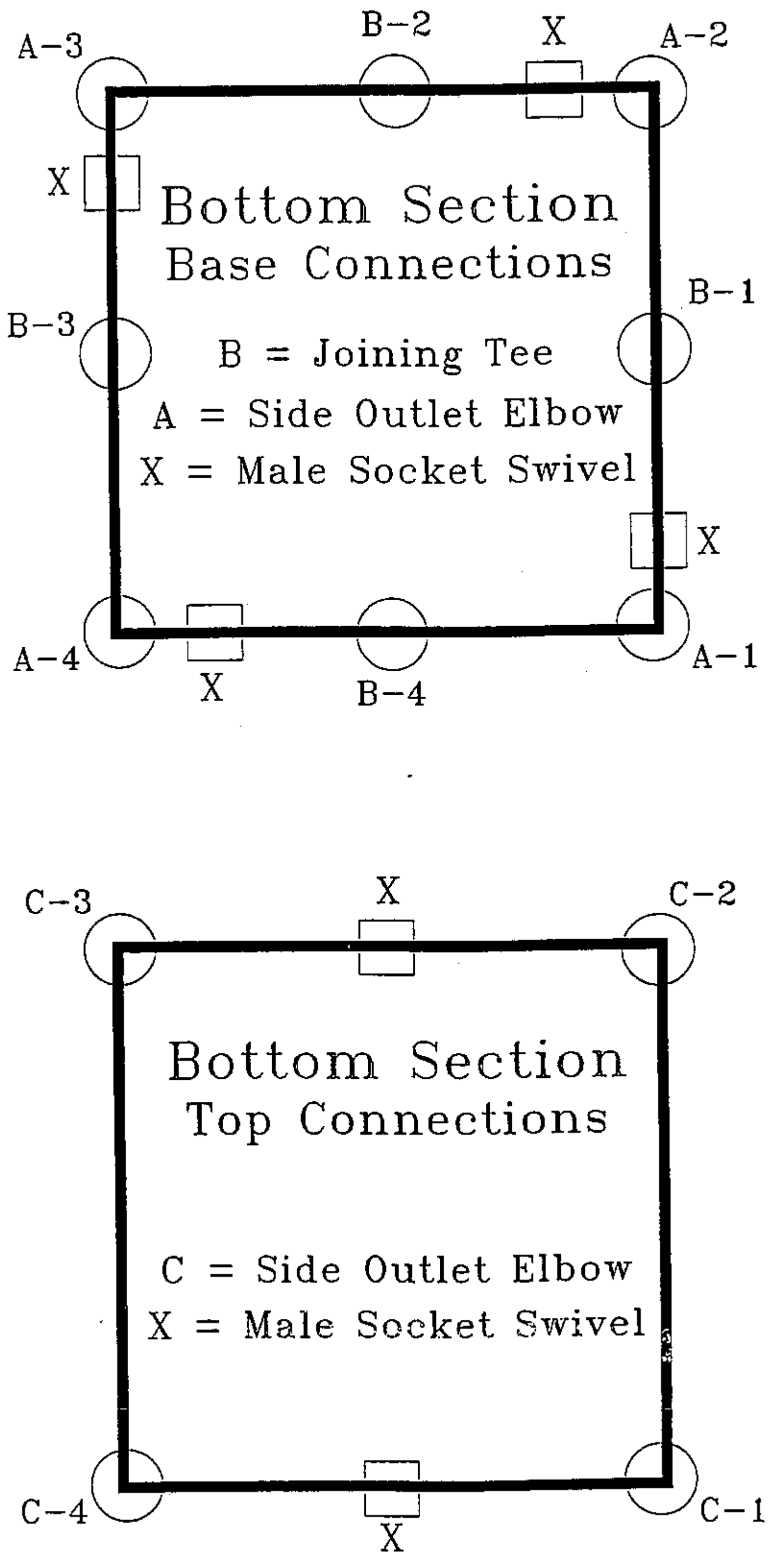
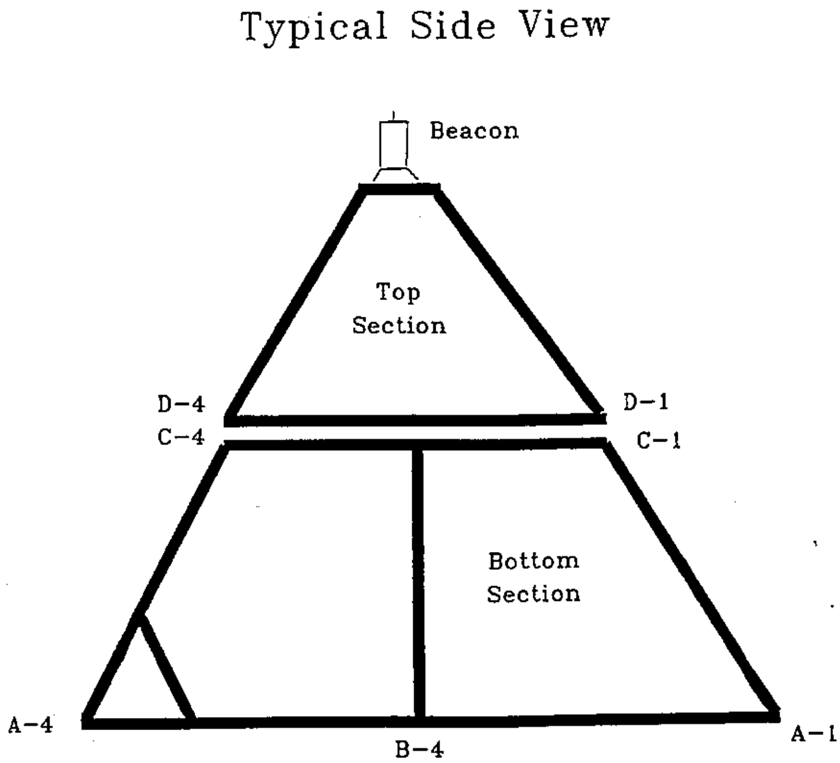


Figure 3A. Marker Assembly Diagram.



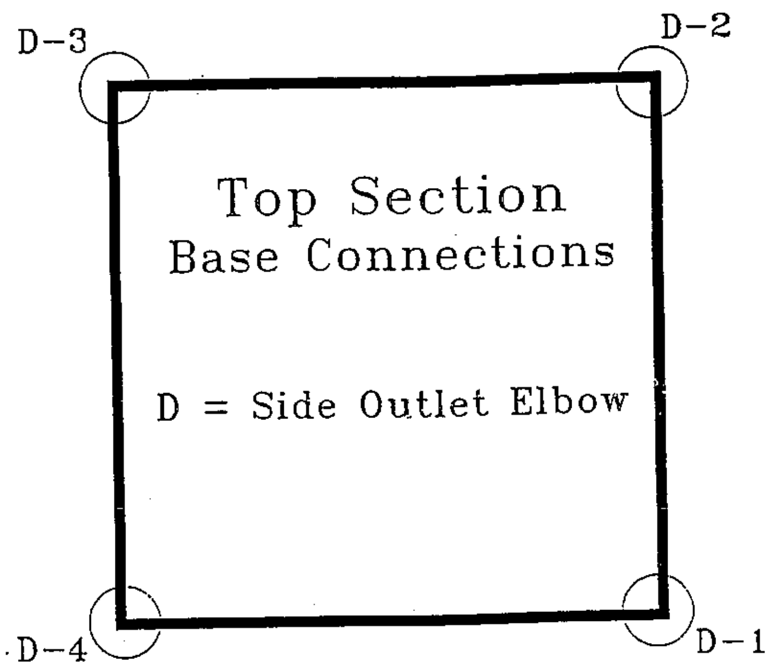


Figure 4A. Marker Assembly Diagram.