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AIRCRAFT DESIGN REFERENCE DATA FOR EXPEDITIONARY AIRFIELDS

Sanders and Thomas, Incorporated

Prepared for:

Naval Air Engineering Center

27 September 1974

U. S. NAVAL AIR ENGINEERING CENTER

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NAEC-ENG-7856 27 September 1974

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PREPARED BY J. J. Creasy

CHECKED BY R. Q. McElwee

APPROVED BY H. L. Cupp

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A description of expeditionary airfields and associated components is presented to familiarize aircraft designers with the expeditionary aircraft concept. An expeditionary airfield is a complete airfield that can be transported and assembled easily and have the capability to launch, recover and support certain high performance tactical jet aircraft.
This report is intended to provide necessary design parameters to insure that future aircraft have expeditionary airfield operating capability.

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ABSTRACT

A description of expeditionary airfields and associated components is presented to familiarize aircraft designers with the expeditionary airfield concept. Reference to other documents are provided at the end of this report for use in obtaining more detailed information than that contained herein.

I. INTRODUCTION

Detail specifications for future Navy and Marine Corps carrier aircraft will probably require that they be compatible with expeditionary airfields.

An Expeditionary Airfield is a complete airfield that can be transported by ship, plane or truck. These airfields can be set up and ready for operation in a short period of time. The completed fields have the capabilities to launch, recover and support certain high-performance tactical jet aircraft.

Figure 1 illustrates a typical expeditionary airfield installation and includes major accessories. The field configuration shown is one of many configurations possible.

This report is intended to provide the necessary design parameters to insure that future aircraft have expeditionary airfield operating capability.

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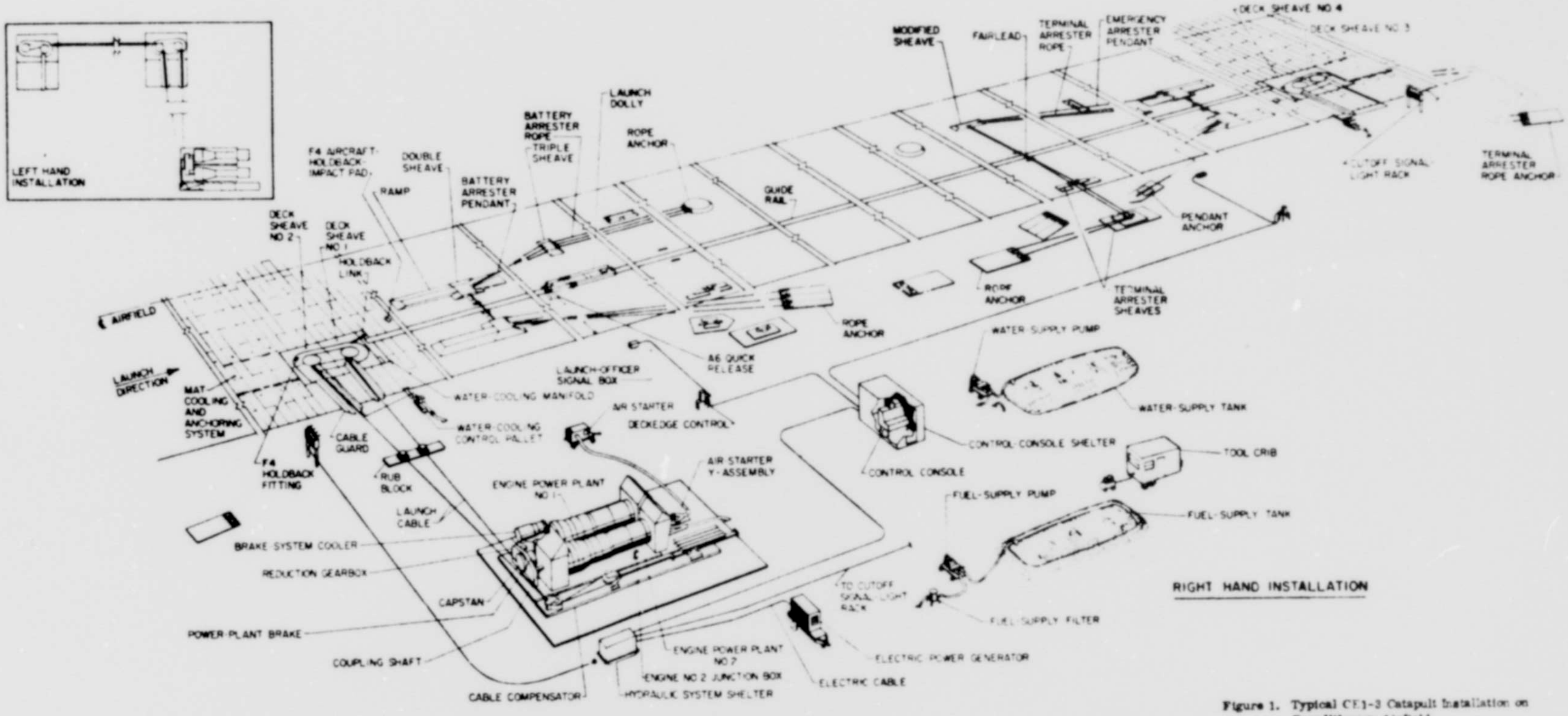


Figure 1. Typical CE1-3 Catapult Installation on Expeditionary Airfield

IV. TECHNICAL DISCUSSION

A. LAUNCH EQUIPMENT DESCRIPTION.

1. General.

Current configurations of the expeditionary airfields employ the CE1-3 Catapult. This catapult is bidirectional and is designed for airfields constructed from AM-2 landing mats. The catapult is capable of launching a 59,000 pound aircraft, at sea level, at an ambient temperature of 100° F. A listing of leading particulars for the CE1-3 catapult is provided in Table 1.

Launch power to drive the catapult is provided by a jet engine power plant anchored to the ground adjacent to the runway. Power is transmitted through a reduction gear and capstan to an endless (spliced) steel launch cable. From the capstan, the cable travels through a cable-tension-compensating device and then to the deck and back to the capstan. All launch controls and monitor devices are centered at a main control console which receives operational sequence signals from a deck-edge panel.

2. CE1-3 Operation.

With the catapult engines running at idle speed and the brake engaged, the aircraft to be catapulted is positioned so that its nosewheel rests on the dolly at the battery position. The aircraft is secured to a holdback link on the appropriate battery-end sheave by means of a holdback device then attached to the dolly by a bridle or nose-gear launch bar. (NOTE: A multi-position holdback deck cleat similar to that used aboard ship is being developed. While not yet operational, compatibility with the system should also be insured.) The dolly is fastenod to the launch cable by a wedge-shaped clamp which tightens under tension. The power plant brake is then slowly released until the launch cable, aircraft, and holdback are properly tensioned. The aircraft engine is then advanced to maximum power. The signal is given for the console operator to actuate the launch switch. Actuating the launch switch releases the power-plant brake again and advances the catapult-engine throttles to launch power. The combined force of the aircraft and catapult engines causes the holdback assembly to release. The holdback unit separates and the dolly, and aircraft are accelerated forward. When the catapult cutoff signal light changes from green to amber at the end of the power stroke, the automatic-launch-cutoff system is activated and catapult-engine power is decreased. The change of cutoff light color from green to amber is the pilot's cue to initiate any required control movements. The launch-cable velocity is decreased, the aircraft overruns the dolly, and the bridle slips off the hooks on the aircraft or the launch bar disengages from the spreader. The dolly continues to travel along the launch path until it hits the dolly-arrester ropes

Table 1. CE1-3 Catapult Leading Particulars

Item	Description	Data	Units
System Performance (Sea level, 100°F)	Design aircraft weight (maximum)	59,000	pounds
	Design aircraft launching speed (maximum)	175	knots
	Launching interval	90	seconds
	Launching capacity		
	Consecutive launchings (maximum)	20	launchings
	Rest period between 20 consecutive launchings	30	minutes
	Launch stroke	variable (1,460 cutoff)	feet
	Guide rail length	1,976	feet
Launch Cable Specifications	Type - 6 x 19 form set, extra improved glow steel, left lang lay IWRC wire rope spliced into endless loop		
	Diameter	1-1/4	inches
	Length	4,296	feet
	Breaking strength	151,810	pounds
Dolly-Arrester-Rope Specifications	Type - Nylon		
	Diameter	1-3/8	inches
	Length, battery end	265	feet
	Length, terminal end	1200	feet
	Breaking strength (average)	48,000	pounds
Pendant	Type - 18 x 7 non rotating wire rope, spec RR-W-410, Type IV, Class 2		
	Diameter	1-1/8	inches
	Length	75	feet
	Breaking strength	96,400	pounds
Cable	Type - 7 x 19 annealed, corrosion resistant, energy absorption		
	Diameter	1-1/4	inches
	Length	232	feet
	Breaking strength	75,000	pounds
Electrical Data	Control system voltage 60 cycle single phase	120	volts
	Motor voltage 60 cycle three phase	208	volts
	Emergency circuit and edge lights d.c. battery	24	volts
	Engine ignition system, throttle control system, and some instrumentation 400 cycle single phase	115	volts
Environmental Range	Ambient temperature range	-40 to + 125	°F
	Altitude range	0 to 5,000	feet
Estimated Weights	Power plants (2)		
	Net	20,880	pounds
	Gross	38,540	pounds
	Catapult, less power plants		
	Net	137,200	pounds
	Gross	162,300	pounds

which unlock the dolly from the launch cable, stop its forward motion, and sling it back along the cable to battery position where it is stopped by engagement with the dolly arrester cable. The power plant brake is applied and cable movement is stopped. Figure 2 illustrates the basic catapult configuration with appropriate dimensions. A complete description of the CE1-3 catapult and its operation can be found in publication NAVAIR 51-15ACA-1.

B. LAUNCH EQUIPMENT INTERFACE PARAMETERS.

1. General.

To be compatible with CE1-3 catapults, the following interface areas must be considered.

a. Holdback Cleat/Aircraft Holdback Device.

b. Release Element.

c. Dolly Arrester Rope Nose Wheel Ramp/Aircraft Nose Wheel.

d. Launch Dolly Wheel Ramp/Aircraft Nose Wheel.

e. Launch Dolly Guide Track and Tow Hook/Aircraft Launch Bar.

f. Catapult Tow Loads.

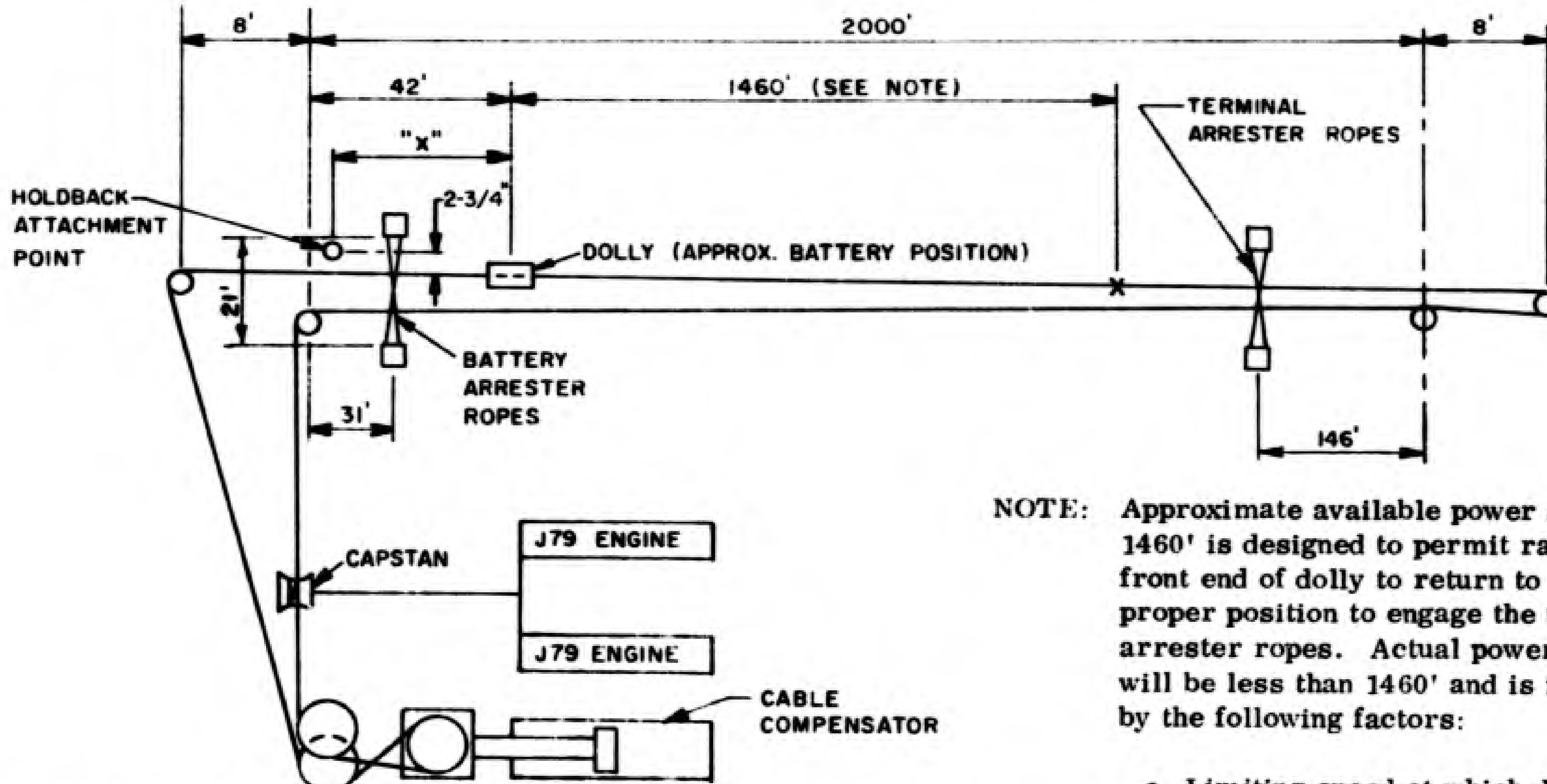
g. Aircraft/Dolly Endspeed.

The following paragraphs provide design details or direct the designer to a source of information regarding the above interfaces.

2. Holdback Cleat/Aircraft Holdback Device.

The holdback attachment system currently in use with the CE1-3 catapult incorporates a quick release type of link which is manually released to permit abort of a launch. A secondary attachment point (further aft) is used for the F-4 aircraft only to avoid excessive heating of the launch cable and sheaves by the aircraft's jet blast. These holdback attachment points are shown in Figure 2.

With the addition of CE1-3 Service Change No. 122, a multi-position holdback cleat was introduced. Figure 3 is a simplified sketch of the cleat showing the pertinent dimensions. Depending upon aircraft configuration, hook-up with the cleat may vary from 26 feet to 2 feet aft of battery arrester ropes (see Figure 2).



NOTE: **Approximate available power stroke of 1460' is designed to permit raised front end of dolly to return to deck in proper position to engage the terminal arrester ropes. Actual power stroke will be less than 1460' and is influenced by the following factors:**

- **Limiting speed at which dolly may engage the dolly arrester ropes**
- **Need to have aircraft airborne early enough to avoid disturbing terminal arrester ropes from roll-over by aircraft landing gear**
- **Actual power stroke required to achieve aircraft takeoff speed**

TYPE HOLDBACK ATTACHMENT POINT	"X" DIMENSION
<u>Current System</u>	
All aircraft except F-4 **Special Position (F-4 only)**	38'-3" 44'
<u>Future Multi-position System</u>	
All aircraft except F-4	13' to 35'-8" range
Special Position (F-4 only)	44'

Figure 2. CE1-3 Catapult Field Configuration

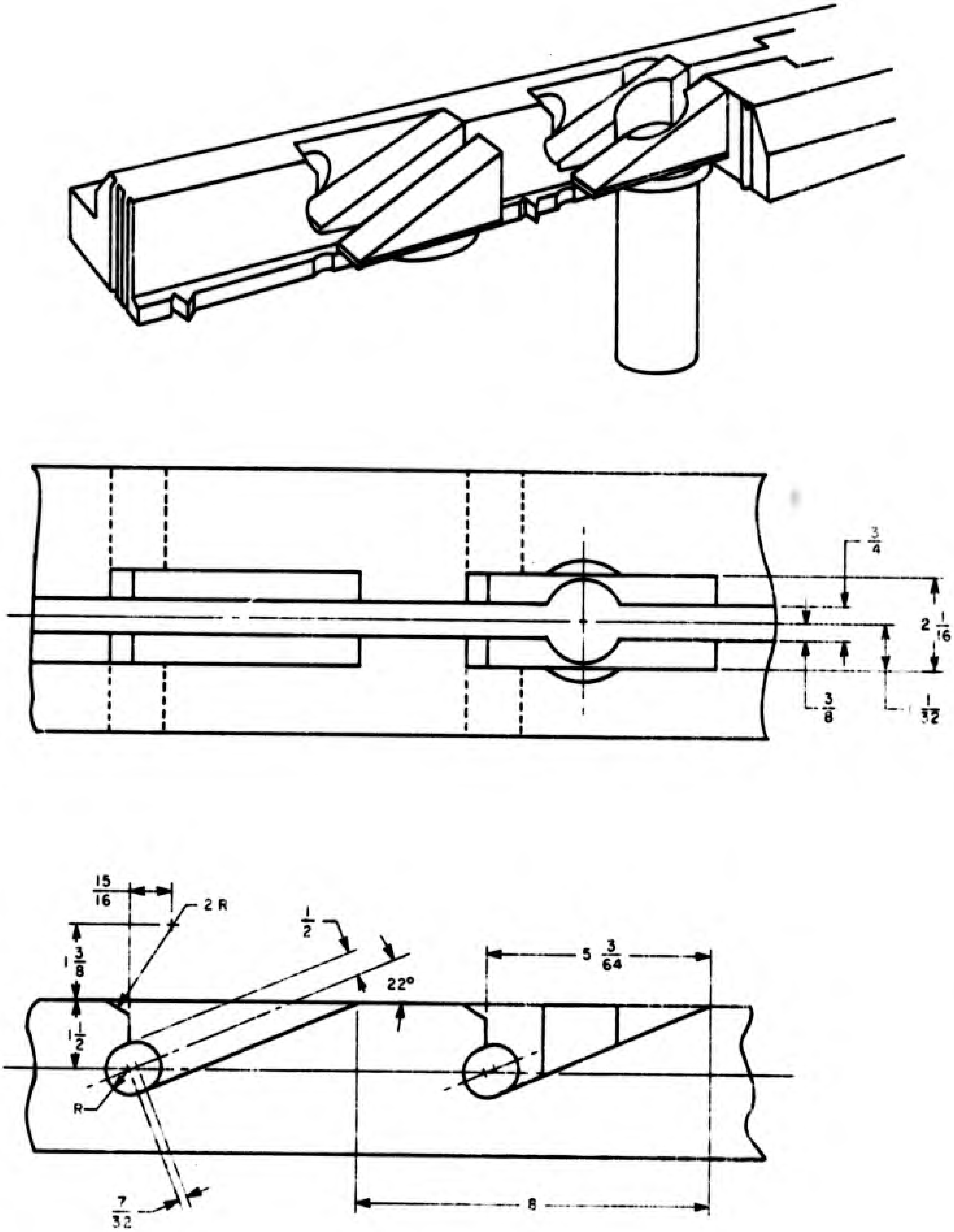


Figure 3. Multi-position Holdback Cleat

A significant feature of the holdback cleat is that it incorporates adapters which are angled toward the rear of the cleat. The release of stored energy in the holdback resulting from the separation of the release element upon launch, combined with the backwash effects of the aircraft jet blast, may be of sufficient magnitude to propel the aircraft holdback backward, out of the cleat, and past the dolly arrester ropes so that the device will not interfere with the rebounding dolly. Should this not be the case (e.g., low reaction force, jet blast angled up too high), a bungee system is usually used to pull the holdback from the cleat. SATS Catapult Accessories Service Bulletin No. 100 Rev C provides hook-up configurations of current expeditionary-airfield aircraft and illustrates several arrangements of bungees and lanyards. NAEC Drawing 614676 provides multi-position holdback cleat details. Installation of the cleat assembly is shown in NAEC Drawing 614682. The aircraft holdback device seats in the multi-position cleat through the use of a deck cleat link. NAEC Drawing Nos 512185 and 512633 are examples of deck cleat links designed by NAEC (Naval Air Engineering Center).

Aircraft designed for operation from the CE1-3 catapult should be compatible with current and the multi-position holdback cleat.

3. Release Element.

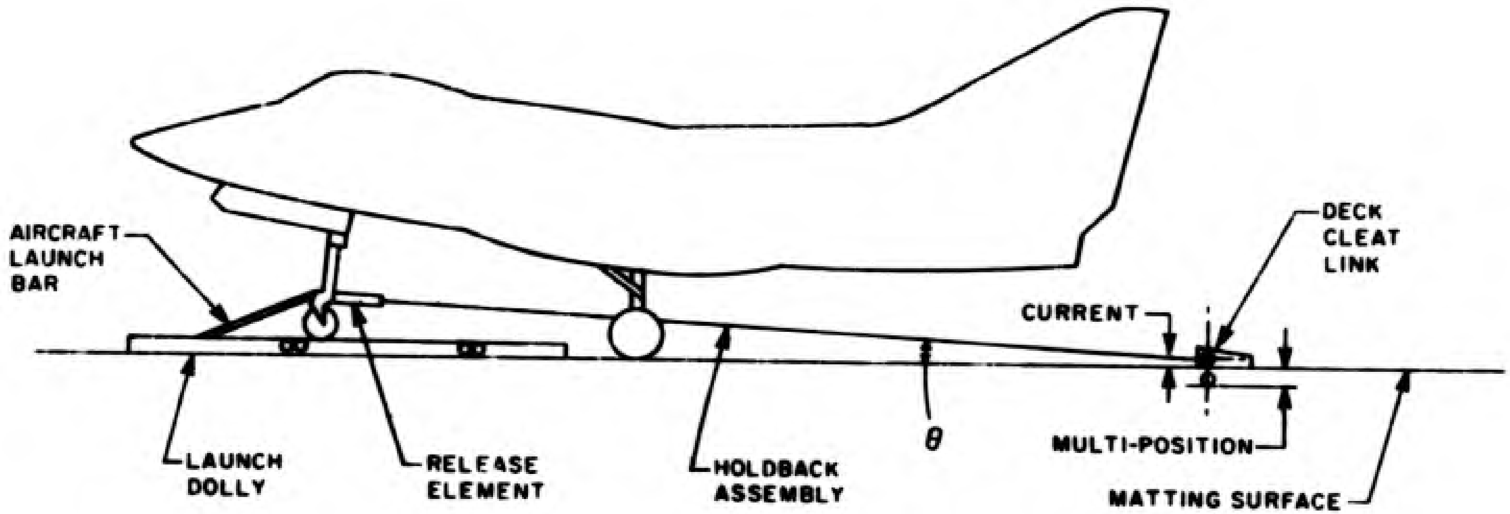
The release element connects the holdback device to the aircraft and reacts full engine thrust and catapult tensioning force.

All current aircraft which are capable of operating from expeditionary airfields use a tension bar as the release element. This bar is designed to structurally fail at a predetermined value, with one of the ruptured pieces remaining in the holdback device and the other staying in the aircraft holdback fitting.

Newer aircraft will incorporate a reusable release mechanism, similar to that specified in MIL-L-22589 . Detailed design criteria are given in report NAEC-ENG-7854.

It is difficult to determine the optimum value for the release load due to the presence of many variables inherent in the system. Engine thrust, aircraft dynamics and aerodynamics, catapult tow force, dolly uploads, and runway matting uplift, all affect launch performance. The formula shown on Figure 4 may be used to obtain an approximation of the optimum release load value. To obtain an actual value it may be necessary to conduct a complete test program to investigate various aircraft weights, center of gravity locations, drag indices, and endspeed requirements.

One consideration regarding the actual design of the release element is one of non-interchangeability with release elements of other aircraft. Prior to actual submission of drawings of this item to NAVAIR for approval it is requested that NAEC Code NE-4 be contacted to insure there are no problems in the area.



$$T = \frac{(T_E + 4000)\ 1.4}{\cos\theta}$$

however "T" need not exceed the release value "R" required for launch operations from shipboard catapults as specified in MIL-A-8863

where: T = Release value - lbs.

T_E = Total maximum (after burner where applicable) engine thrust on -20° day - lbs.

θ = Angle between holdback assembly and matting surface when system is tensioned.

Figure 4 Calculating Optimum Value for Release Element

4. Dolly Arrester Rope Nose Wheel Ramp/Aircraft Nose Wheel.

As the aircraft approaches the dolly for hook-up prior to launch, it must pass over the Battery Dolly Arrester Ropes. To facilitate this operation, a nose wheel ramp which fits directly over the arrester ropes is used. The ramp has a 15° slope on both sides. The width of the ramp is 23 inches. At present, use of this ramp is optional and its implementation is determined by individual CE1-3 sites. For detailed information on the nose wheel ramp, refer to NAEC Drawing 614227.

5. Launch Dolly Wheel Ramp/Aircraft Nose Wheel.

In order for the aircraft nose wheel to easily ride up on top of the launch dolly, the rear section is composed of a ramp, inclined at a 14° angle. The maximum width of the ramp is 23-1/4 inches. NAEC Drawing 616811 is the assembly drawing of the Nose Gear and Bridle Launch Dolly, which is shown in Figure 5. NAEC Drawing 612570 gives full details of the wheel ramp.

6. Launch Dolly Guide Track and Tow Hook/Aircraft Launch Bar.

The launch bar hook-up system of the CE1-3 launch dolly is similar to the shipboard configuration as detailed in NAEC Drawing 607770. The dimensions given in Figure 6 are applicable to the present launch dolly assembly of NAEC Drawing 616811. Slight differences in dimensions of the guide track and spreader slots do exist between the shipboard and expeditionary airfield dolly configurations; however, for design purposes, NAEC Drawing 607770 is the governing drawing.

Consideration must also be given to the fact, that when the aircraft nose wheel is positioned on top of the dolly, the aircraft will be in a slightly higher nose-up attitude then when it is positioned for a shipboard catapult launch. This is due to the fact that the upper surface (nose wheel contact area) of the dolly is approximately 6 inches above the deck. Because of this, a slightly greater angle of downward travel of the launch bar is required for proper engagement with the dolly tow hook, than is necessary for shipboard hook-up.

7. Catapult Tow Loads.

Load-stroke values and catapult tow loads on the aircraft by the CE1-3 Catapult, are functions of three variables: aircraft launch weight, end speed requirements, and airplane thrust (thrust to weight ratio). Report AR58 "U.S. Navy Catapulting and Arresting Gear Forcing Functions for Aircraft Structural Design" is normally specified in the detail specification for the determination of catapult loads. Actual CE1-3 catapult performance should be discussed with the Naval Air Engineering Center.

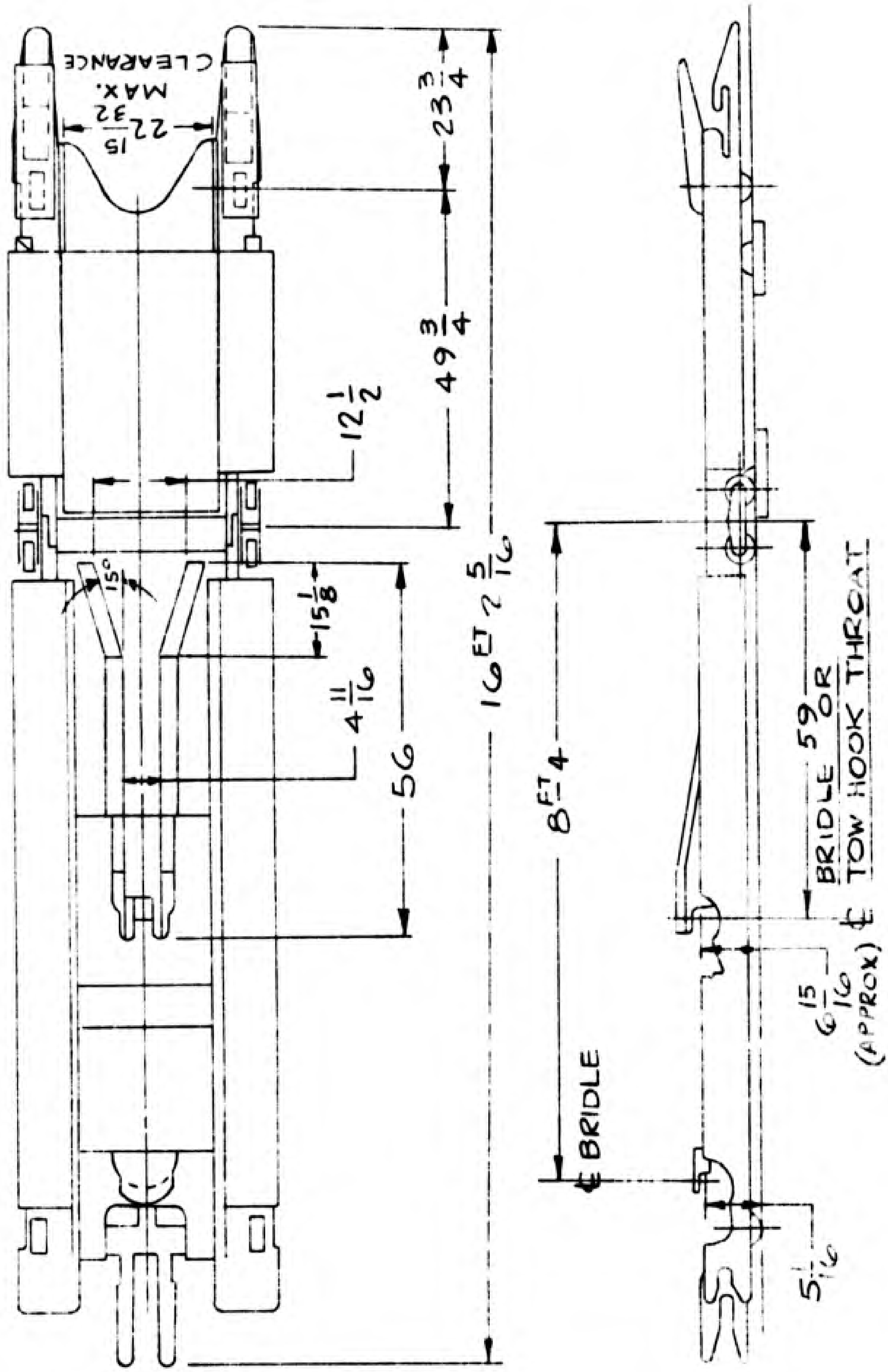


Figure 5. Nose Tow and Bridle Launch Dolly (NAEC 616811-3)

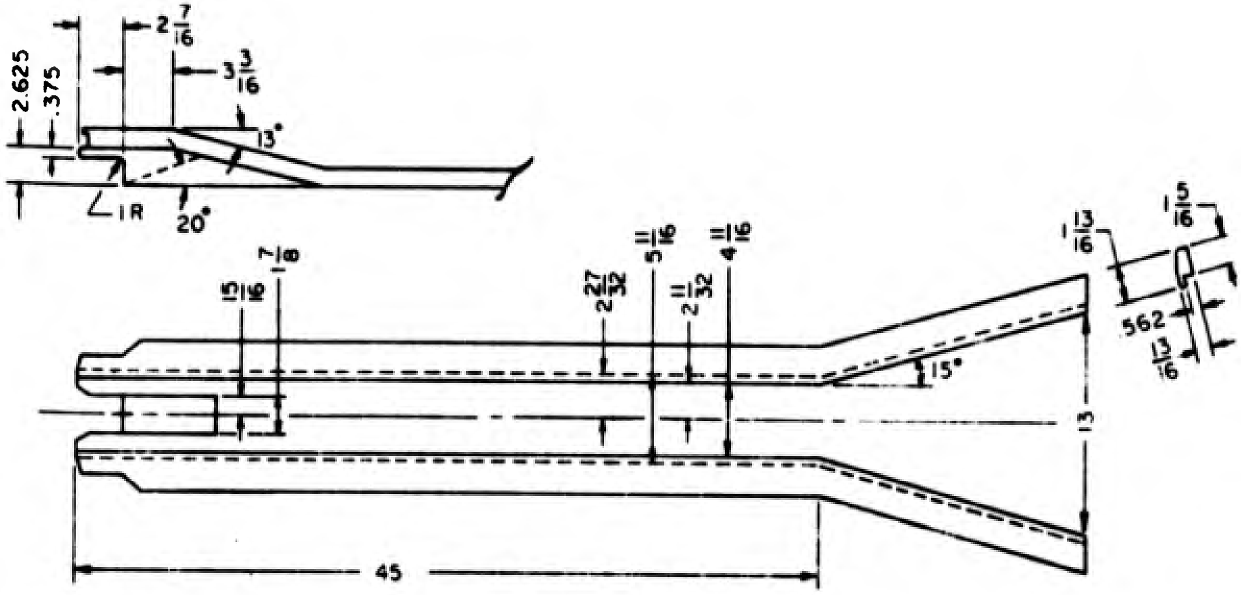


Figure 6. Launch Dolly Guide Track

8. Aircraft/Dolly Endspeed.

The aircraft's main gear must be clear of the runway surface by the time it reaches the terminal dolly arrester ropes, in order that the aircraft will not interfere with the arrestment and subsequent rebounding of the dolly. The launch bar separates from the dolly or the bridle falls off of the aircraft hooks and the aircraft overruns the dolly. With incorporation of CE1-3 Catapult Service Change No. 167, the maximum allowable dolly endspeed is 185 knots. Speeds in excess of this amount may cause failure of the terminal dolly arrester ropes. When determining the required airspeed for proper rotation and liftoff of the aircraft, the dolly ground speed limitation must be considered.

C. RECOVERY EQUIPMENT DESCRIPTION.

1. General.

Aircraft recovery at an expeditionary airfield site is accomplished by the M-21 Expeditionary Aircraft Recovery System. An M-21 system usually consists of two separate installations: (1) a Primary Recovery Installation for normal deck pendant/arresting hook type arrestments, and (2) an Emergency Recovery Installation for barricade-type arrestments. A listing of leading particulars for the M-21 arresting gear is provided in Table 2.

2. M-21 Operation.

The M-21 Primary Recovery Installation consists of two arresting units, one on each side of the runway, approximately 150 feet apart, connected by a deck

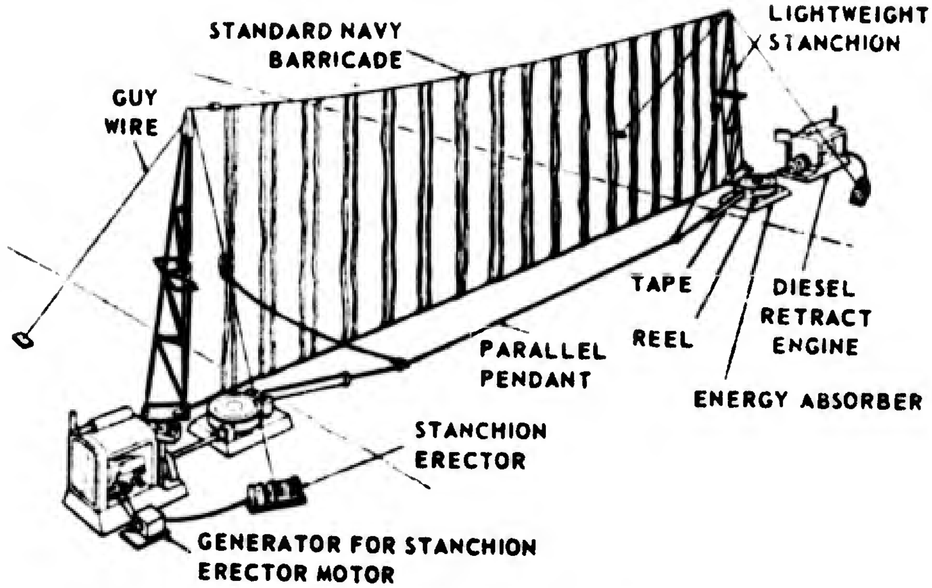
Table 2. Leading Particulars for M-21 Arresting Gear

Aircraft Weight Capacity	10,000 pounds (minimum)
	80,000 pounds (maximum)
Runout	775 feet (maximum)
Span	150 feet
Energy per Engagement (Primary Recovery Installation)	56,000,000 pound-feet (maximum)*
Pendant Diameter	1-1/4 inch (nom)
Barricade Webbing (Emergency Recovery Installation)	
Span	108 feet
Height	24 feet
Energy per Engagement	40,000,000 pound-feet (design)

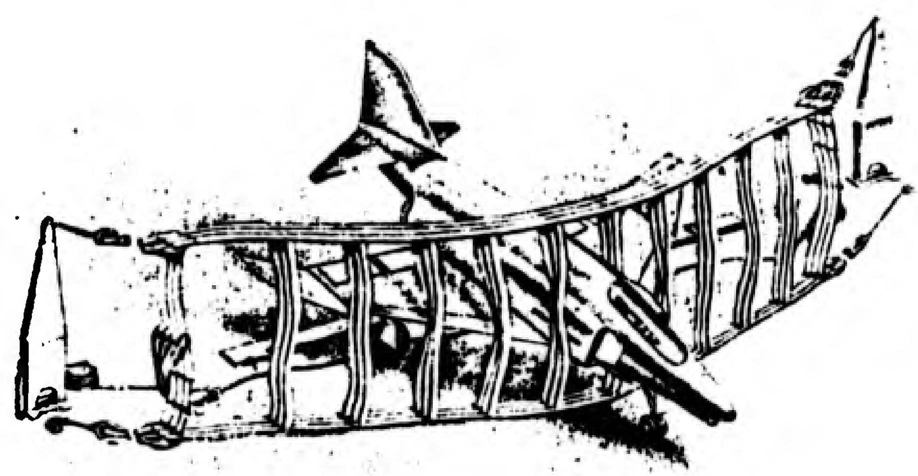
*Energy absorbing capability with arrestment made 20 feet off runway centerline, within 3 degrees of runway heading.

pendant. Each arresting unit consists of an arrester engine assembly (energy absorber) and a retrieve engine assembly. Each end of the deck pendant is connected to a purchase tape that is wrapped around a drum on the arrester engine. When the aircraft hook engages the pendant, the purchase tape unwinds from the drum, causing a rotor, with fixed pitch blades, to rotate within a container of pressurized fluid. The resistance of the fluid to the rotor's motion results in a programmed arrestment. The retrieve system is run by a diesel engine, and rewinds the tape until the pendant is returned to the battery position after each arrestment.

The M-21 Emergency Recovery Installation consists of a barricade system (which is similar to the Mk 7 triple webbing used aboard ships) and two M-21 arrester units. Normally the barricade webbing is maintained in a stowed condition and is rigged only when its use is required in an emergency situation. When needed, the barricade is stretched across the runway between two stanchions which are then raised to a vertical position by an electric winch. Each side of the barricade is attached to the tape of the nearer M-21 energy absorber. As the wings of the incoming aircraft engage the barricade webbing, a breakaway unit releases the barricade from the stanchions. As the plane becomes wrapped in the barricade the tape begins to unwind from the energy absorbers. The arresting action is then the same as with the standard M-21 system. Upon completion of the arrestment, the barricade, an expendable item, is discarded and the stanchions lowered to the stowed position. Figure 7 shows the arrangement of the M-21 barricade system. NAVAIR 51-5EAA-2-1 provides a complete detailed description of the M-21 Expeditionary Aircraft Recovery System.



M-21 BARRICADE SYSTEM



M-21 BARRICADE ENGAGEMENT

Figure 7. M-21 Emergency Recovery System

D. RECOVERY EQUIPMENT INTERFACE PARAMETERS

1. General.

Table 2 provides a listing of necessary particulars pertaining to both the Primary and Emergency Recovery Installations. Given the aircraft weight and engaging speed, the arresting loads can be calculated using the AR-58, "U.S. Navy Catapulting and Arresting Gear Forcing Functions for Aircraft Structural Designs." Actual M-21 arresting gear performance should be discussed with the Naval Air Engineering Center.

When designing for compatability with the M-21 Arresting Gear System, it is important to take into consideration the fact that bumper loads on the aircraft may be more severe than those encountered in shipboard arrestments. This is largely due to the fact that higher engaging speeds exist and there will be less up-swing damping due to a lighter cross-deck pendant.

E. OPTICAL LANDING SYSTEM DESCRIPTION.

1. General.

The short length of an expeditionary airfield runway necessitates the mechanical arrestment of all aircraft, making the touchdown point an important factor in the landing operation. An optical landing system provides the pilot with a visual indication of his position relative to a prescribed glide slope which is designed to bring the aircraft down to the runway at approximately 150 feet before the deck pendant. The system currently being used with expeditionary airfields is the Mark 8 Mod 0 trailer mounted Fresnel Lens Optical Landing System equipped with roll angle drive (Service Change Number 33). Basically similar to shipboard optical landing systems, the lens unit provides optical glide slope information within approximately 3/4 of a degree above and below the prescribed glide slope. The current recommended glide slope is three degrees although the basic angle of the system may be set at any angle between zero and six degrees. The meatball may be seen within approximately 20 degrees of azimuth to each side of the indicator assembly centerline.

NAVAIR 51-40ABA-3 and Recovery Bulletin 80-12C provide further description of and operating instructions for the Mark 8, Mod 0 Optical Landing System.

F. OPTICAL LANDING SYSTEM INTERFACE PARAMETERS

1. General.

Two parameters are used to determine the settings for the optical landing system: H/E (aircraft hook-to-eye dimension) and HTDP (hook touchdown point). Hook-to-eye distance is the vertical distance between the path of the pilot's eye and the path of the arresting hook point on glide slope. The

HTDP is normally 150 feet before the deck pendant; however, actual aircraft tests may show interference between aircraft structure (notably horizontal stabilizers) and the cable wave generated to the deck pendant. In such case a greater HTDP may be desirable to increase the time for tail use to occur. Aircraft Recovery Bulletin 80-12 provides MK 8 Mod 0 Fresnel Lens Optical Landing System operating instructions.

G. GENERALIZED EXPEDITIONARY AIRFIELD COMPONENTS

1. General.

The following paragraphs pertain to expeditionary airfield components which do not place design requirements on the aircraft. The purpose of this information is to further describe the make-up of expeditionary airfield and state its remaining capabilities.

2. Airfield Matting.

Airfield matting is the surface material used to provide the level runway taxi, and parking areas required. The matting (NAEC Drawing 615526) has the designation AM-2. Each section is a fabricated aluminum panel, 1-1/2 inches thick, which consists of a hollow, extruded, one-piece main section with extruded end connectors welded to each end. The matting is covered with a non-skid coating. Tests have indicated that aircraft having single wheel loads of 27,000 pounds, 400 psi tire pressure, and 17 feet per second sink speed can operate on AM-2 matting. NAVAIR 51-60A-1 is the handbook for the AM-2 Matting.

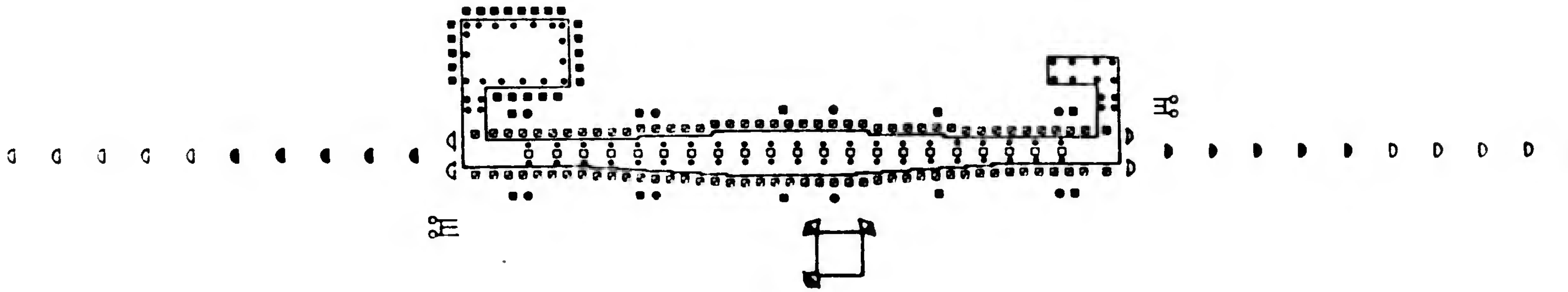
3. Field Lighting System.

The Field Lighting System consists of runway lights, centerline lights, runway status lights, threshold lights, circling guidance lights, taxiway lights, obstruction lights, approach lights (steady burning and sequencer flashing), bolter lights, floodlights, and an airfield beacon. This system provides all the necessary lighting fixtures to guide, warn, and signal the pilot through his approach, landing, and traffic patterns. The lighting is sufficient for day and night operations under visibility conditions down to two hundred feet and one-half mile under all weather conditions. It will accommodate a traffic pattern within a three-mile radius of the airfield to a height of 1500 feet. Figure 8 is a general arrangement of a typical field lighting system.

4. Support Equipment.

In general, airplanes that are compatible with aircraft carrier support equipment will be compatible with expeditionary support equipment, although the availability of some items may differ from field to field. These items include servicing facilities (liquid oxygen/nitrogen generator, suit dryers and maintenance vans) and yellow gear (external power units, missile testers, tow tractors and weapons loaders).

Included in support equipment is the Tactical Airfield Fuel Dispensing System (TAFDS). TAFDS is composed of six collapsible rubber tanks and self-priming pumps. The system can supply 350 gallons of jet fuel per minute to aircraft. Each tank has a fuel capacity of 10,000 gallons and can be refilled from tankers or fuel trucks through simple hose connectors.



LEGEND	DESCRIPTION	QTY
	RUNWAY LIGHTS	42
	CENTERLINE LIGHTS	21
	THRESHOLD LIGHTS	4
	BOLTER LIGHTS	2
	ROTATING BEACON LIGHT	1
	STATUS LIGHTS	4
	CIRCLING GUIDANCE LIGHTS	8
	TAXIWAY LIGHTS	66
	APPROACH LIGHTS	10
	APPROACH LIGHTS WITH STROBE LIGHTS	10
	OBSTRUCTION LIGHTS	10
	200W FLOODLIGHTS	170
	500W FLOODLIGHTS	56
	REMOTE CONTROL PANEL	1
	REGULATOR	12

Figure 8. Typical SATS Field Lighting Arrangement

REFERENCES

1. NAVAIR 51-15ACA-1 of 1 January 1972 - Handbook, Installation and Operation Instructions, Catapult Type CE Mark 1 Mod 3.

2. SATS Catapult Accessories Service Bulletin No. 100 Rev. C.

3. NAEC Drawing No. 614676 - Multi-position Holdback Cleat

4. NAEC Drawing No. 614682 - Flush Deck Multi-position Holdback Cleat Installation

5. NAEC Drawing No. 512185 - Link Assembly

6. NAEC Drawing No. 512633 - Components

7. MIL-L-22589 - Launching System, Nose Gear Type, Aircraft

8. NAEC Drawing No. 614227 - Nose Wheel Ramp

9. NAEC Drawing No. 616811 - Launch Dolly Assembly

10. NAEC Drawing No. 612570 - Wheel Ramp

11. NAEC Drawing No. 607770 - Design Requirements Catapulting Arrangement Nose Gear Type Launch

12. AR-58 - U.S. Navy Catapulting and Arresting Gear Forcing Functions for Aircraft Structural Design

13. NAVAIR 51-5EAA-2-1 of 1 May 1972 - M-21 Expeditionary Aircraft Recovery System

14. NAVAIR 51-40ABA-3 - Installation, Service, Operation, and Maintenance Instructions with Illustrated Parts Breakdown for Portable Shore-based Fresnel Lens Optical Landing System MK 8 Mods 0 and 1

15. Aircraft Recovery Bulletin No. 80-12C for Mark 8 Mod 0 Fresnel Lens Optical Landing System Equipped with Roll Angle Drive Assembly

16. Aircraft Recovery Bulletin No. 10-10A for all Arresting Gear and Optical Landing Systems

17. NAEC Drawing No. 615526 - AM-2 Mat

18. NAVAIR 51-60A-1 of 1 April 1974 - AM-2 Airfield Landing Mat and Accessories