MIL-A-18717B(AS)
10 September 1979
SUPERSEDING
MIL-A-18717A(WP)
6 April 1965

MILITARY SPECIFICATION

ARRESTING HOOK INSTALLATIONS, AIRCRAFT

This specification is approved for use by the Naval Air Systems Command, Department of the Navy and is available for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers the design, development, construction, analysis, test, and documentation requirements for arresting-hook installations in aircraft for which detail specifications or other pertinent contractual documents require that arresting hooks be fitted.

2. APPLICABLE DOCUMENTS

2.1 Government documents normally furnished. The following documents, of the issue in effect on date of invitation for bids or request for proposal, form a part of the specification to the extent specified herein.

SPECIFICATIONS

Military

MIL-S-5002	Surface Treatments and Inorganic Coatings for Metal Surfaces of Weapon Systems
MIL-L-006730	Lighting Equipment; Exterior, Aircraft (General Requirements For)

Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Engineering Specifications and Standards Department (Code 93), Naval Air Engineering Center, Lakehurst, NJ 08733, by using self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

FSC 1710

SPECIFICATIONS

Military (Continued)

MIL-D-8706	Data and Tests, Engineering: Contract Requirements for Aircraft Weapon Systems
MIL-D-8708	Demonstration Requirements for Airplanes
MIL-A-8860	Airplane Strength and Rigidity - General Specification for
MIL-B-8906	Bolt, Tensile, Steel, 220 KSI Ftu, 450°F, External Wrenching, Flanged Head
MIL-N-8922	Nut, Self-Locking, Steel, 220 KSI Ftu, 450°F
MIL-P-15024	Plates, Tags, and Bands for Identification of Equipment
MIL-H-21594	Hook Point; Aircraft Arresting
MIL-D-23003	Deck Covering Compound, Non-Slip, Lightweight

PUBLICATIONS

Naval Air Systems Command

AD-1350	Engineering Drawing and Associated Data

STANDARDS

Military

MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-143	Specifications and Standards, Order of Precedence for the Selection of
MIL-STD-203	Cockpit Controls, Location and Actuation of, for Fixed Wing Aircraft

(Copies of documents, other than specifications and standards, required by contractors in connection with specific procurement functions shall be obtained from the procuring activity or as directed by the contracting officer. Specifications and standards are available from the Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, Pennsylvania 19120.)

3. REQUIREMENTS

3.1 Materials. Materials shall conform to applicable specifications and shall be as specified herein and on applicable drawings. Materials which are not covered by specifications, or which are not specifically described herein, shall be of the best quality for the purpose intended and of the lightest practicable weight.

3.1.1 Protective treatment. When materials are used in the construction of the system that are subject to deterioration when exposed to environmental conditions likely to occur during service usage, they shall be protected against such deterioration in a manner that will in no way prevent compliance with the performance requirements of this specification. The protective system shall be in accordance with the aircraft detail specification.

3.2 Selection of specifications and standards. Specifications and standards for necessary commodities and services not specified herein shall be selected in accordance with MIL-STD-143.

3.2.1 Standard parts. MS and AN standard parts shall be used where they suit the purpose. They shall be identified on the drawings by their part numbers.

3.3 Design information. Design information and suggested methods of determining the characteristics of arresting hook installations are presented in the appendix to this specification for the information and guidance of the contractor.

3.4 Nomenclature. The nomenclature of arresting hook installations and parts is as indicated on the figures and in the appendix of this specification.

3.5 Arresting hook installation. The type, location, arrangement, and detail design of the arresting hook installation for each model of aircraft shall be selected so as to obtain as light and simple an installation as possible, consistent with satisfactory performance under all design conditions, and with all arresting gear in which the aircraft may be required to operate.

3.5.1 Location. The arresting hook shall be so located that the aircraft is maintained in an attitude which insures clearances of all non-contact parts of the aircraft and external stores over six inch obstructions when the aircraft is subjected to the forces applied during an arrested landing.

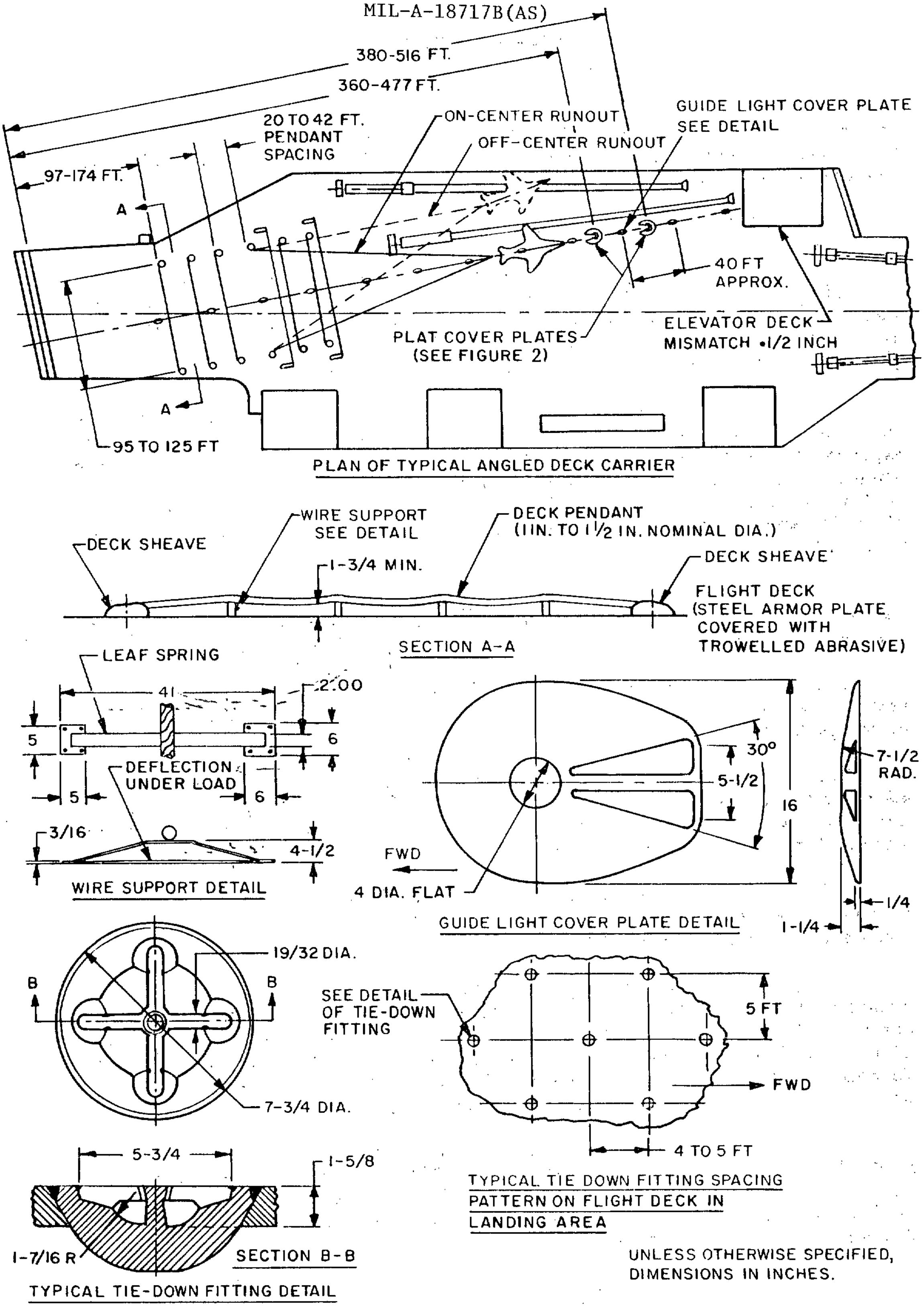

Figure 1. Typical Arrangement and Details of Arrested Landing Deck Area on CV Type Flight Deck

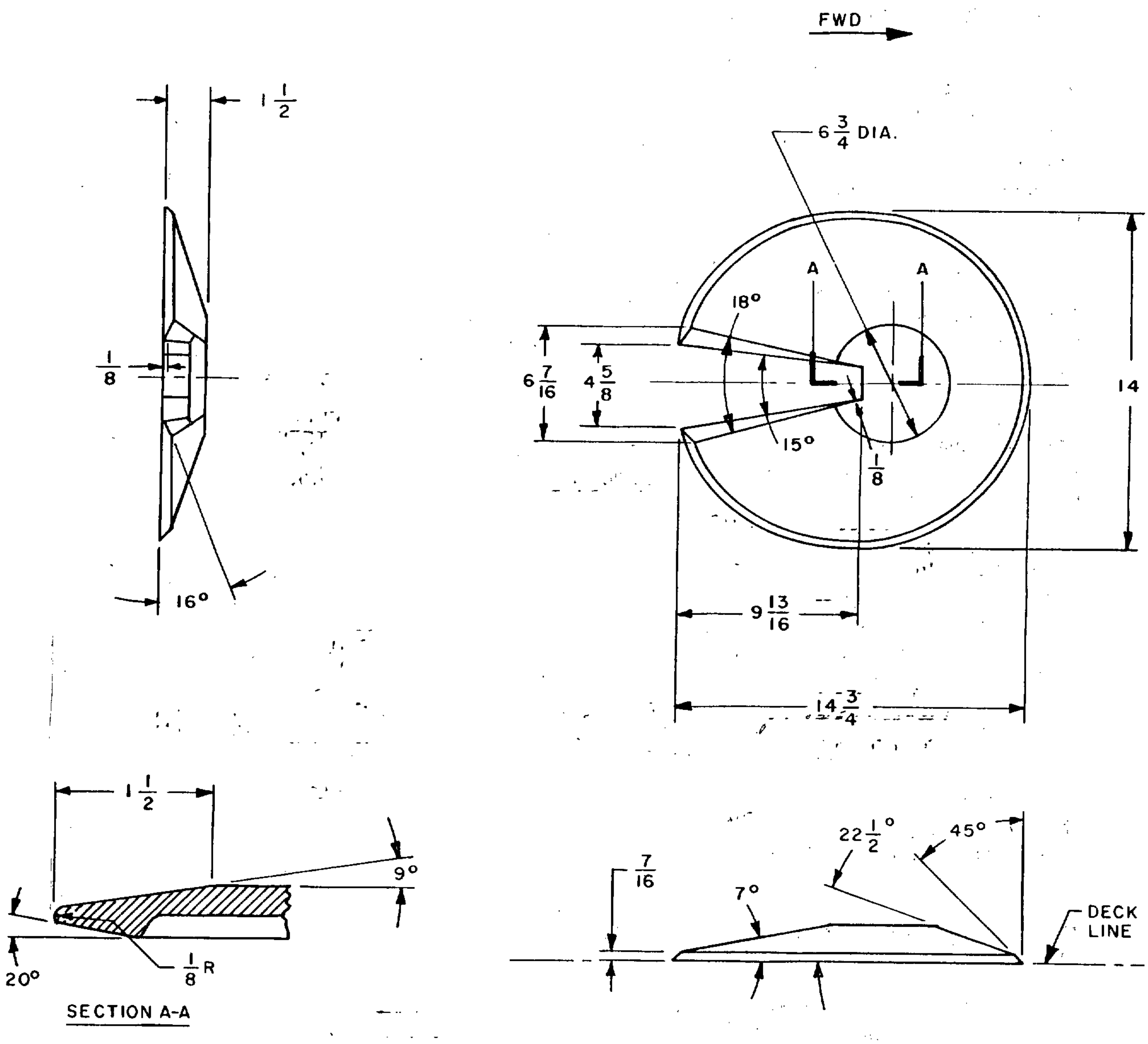

Figure 2. Pilot Landing Aid Television (PLAT) Cover Plate

3.5.1.1 Typical carrier flight deck. General arrangement and details of a typical carrier flight deck and its obstructions are shown in Figures 1 and 2.

3.5.1.2 Deck clearance. Recommendations for determining deck clearance are presented in Appendix A.

3.5.2 Damage from deck pendant. The arresting hook shall be so located, or suitable guards or structural strength shall be provided on the aircraft where necessary, to prevent the deck pendant from damaging the aircraft or from engaging parts of the aircraft other than those designed for such engagement during an arrested landing. The dynamics of the deck pendant shall be investigated to insure that this requirement is met.

3.5.3 Deck pendant displacement. The arresting hook shall be suitably designed and located with respect to the landing gear to insure engagement of a deck pendant by the hook after the pendant has been displaced by the nose wheel, main wheels, tail wheel, or tail bumper of the aircraft passing over it.

3.5.4 Tail wheel. On aircraft equipped with a tail wheel, the influence of the arresting hook location on the tail wheel loads which may occur during and at the end of the arrested landing run shall be investigated.

3.5.4.1 Tail wheel loads. If the selected hook location causes the tail wheel loads which result from the arrested landing conditions described herein to become more critical than those specified by MIL-A-8860, the more critical loads resulting from the selected hook location shall replace those of MIL-A-8860, when designing the tail wheel installation.

3.5.4.2 Determination of tail wheel loads. Recommendations for determining tail wheel loads are specified in Appendix A.

3.5.5 Nose wheel. On aircraft equipped with a nose wheel, the influence of the arresting hook location on the magnitude of the nose wheel loads shall be investigated.

3.5.5.1 Nose wheel loads. The design loads for the nose gear shall include those resulting from the envelope of arrested landings defined in MIL-A-8860, as modified by the detail specification.

3.5.5.2 Determination of nose wheel loads. Recommendations for determining nose wheel loads are presented in Appendix A.

3.5.6 Lateral movement. The arresting hook shall be free to move laterally not less than 20 degrees to each side of the center position, to permit it to align with the applied arresting forces in a "off-center" or "skid" landing, unless the hook is designed as a laterally rigid structure to carry the specified design side load.

3.5.6.1 Centering device. If the arresting hook assembly is designed to permit lateral movement, a centering device shall be provided to keep the hook laterally centered against aerodynamic loads and against those lateral inertial loads which may occur during the approach and just prior to the hook contacting the deck or a crossdeck pendant. In addition, when the hook is laterally displaced upon contact with the deck or a deck protrusion, the centering device shall return the arresting hook to an "arrestment-ready" position.

3.5.7 Upward swing. Suitable means shall be provided when necessary to protect the aircraft structure from the upward swing of the arresting hook shank assembly during arrestment and retraction.

3.5.8 Shock absorber. A shock absorber shall be provided for each arresting hook installation to control hook bounce.

3.5.9 Installation strength. Strength of the installation shall be as specified by MIL-A-8860.

3.6 Arresting hook design.

3.6.1 Hook trail angle. The arresting hook installation shall be designed to allow the arresting hook to trail aft at an angle such that, when the aircraft is at the angle of attack corresponding to the maximum lift coefficient with zero sink speed, the arresting hook will not contact the deck in a direction that will cause damaging compression loads to be developed in the hook shank and in the aircraft structure. (See Appendix A, paragraph 40.3).

3.6.2 Hook length. The arresting hook assembly shall have sufficient length to engage a deck pendant in all attitudes of the aircraft which may be reasonably expected during carrier or field landing operations and aborted take-offs including the most critical attitude defined by Figures 3 and 4, except that the arresting hook length may be determined by rational analysis subject to approval by NAVAIR.

3.6.3 Wear areas. The arresting hook shall be smoothly faced and made of wear-resistant material to minimize arresting hook and deck pendant wear. That area of the shank and hook point which the pendant can contact shall contain no surface irregularities or sharp corners. A hook point drawing shall be provided by the contractor which defines the maximum allowable wear and the inspection and rejection criteria. This drawing shall be submitted with drawings required by 3.10.2.

3.6.4 Second pendant pick up. The arresting hook shall be designed to minimize the possibility of picking up a second pendant after one has been engaged unless analysis of the arresting geometry shows no need.

NOTES:
1. REFERENCE SOURCE OF AERODYNAMIC DATA.
2. DIMENSIONS MARKED ▨ TO BE INDICATED ON DRAWING.
3. DRAWING TO BE MADE ACCURATELY TO A SCALE OF 1/20.
4. SHOW COORDINATES RELATIVE TO F.R.L.& STA.O OF AIRCRAFT OF MAIN WHEEL AXLES IN THE FULLY COMPRESSED, STATIC, AND FULLY EXTENDED STRUT CONDITIONS.
5. IF HOOK IS DISPLACED LATERALLY FROM ℄ OF AIRCRAFT, DIMENSION THIS DISPLACEMENT AT THE HOOK HEAD AND AT THE HOOK PIVOT.
6. USE FLIGHT DECK LINE OF FIG. A-1 DEFINED BY $V=V_{PAmin}$ FOR CARRIER DESIGN ARRESTED LANDING WEIGHT, V_W=35 KNOTS, AND $\gamma_{A/C}=4°$.
7. SHOW HOOK UPSWING LIMITS VERSUS LATERAL DISPLACEMENT.

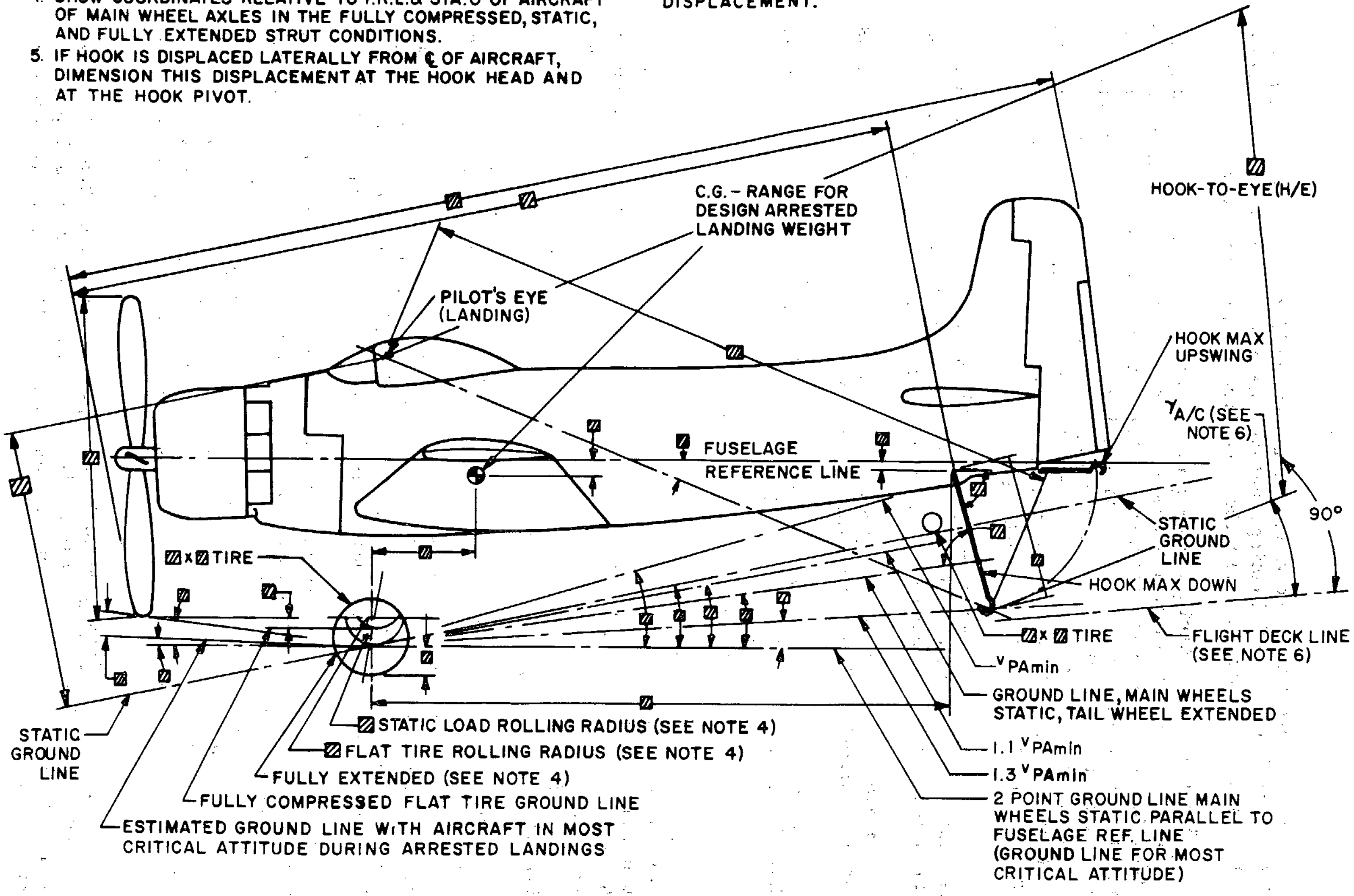

Figure 3. Arrested Landing Arrangement Drawing - Tail Wheel Type Aircraft

NOTES:

1. REFERENCE SOURCE OF AERODYNAMIC DATA.
2. DIMENSIONS MARKED ▨ TO BE INDICATED ON DRAWING.
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6. SHOW HOOK UPSWING LIMITS VERSUS LATERAL DISPLACEMENT.
7. SHOW COORDINATES RELATIVE TO F.R.L. AND STA. 0 OF AIRCRAFT FOR NOSE AND MAIN WHEEL AXLES IN THE FULLY COMPRESSED, STATIC, AND FULLY EXTENDED STRUT CONDITIONS.

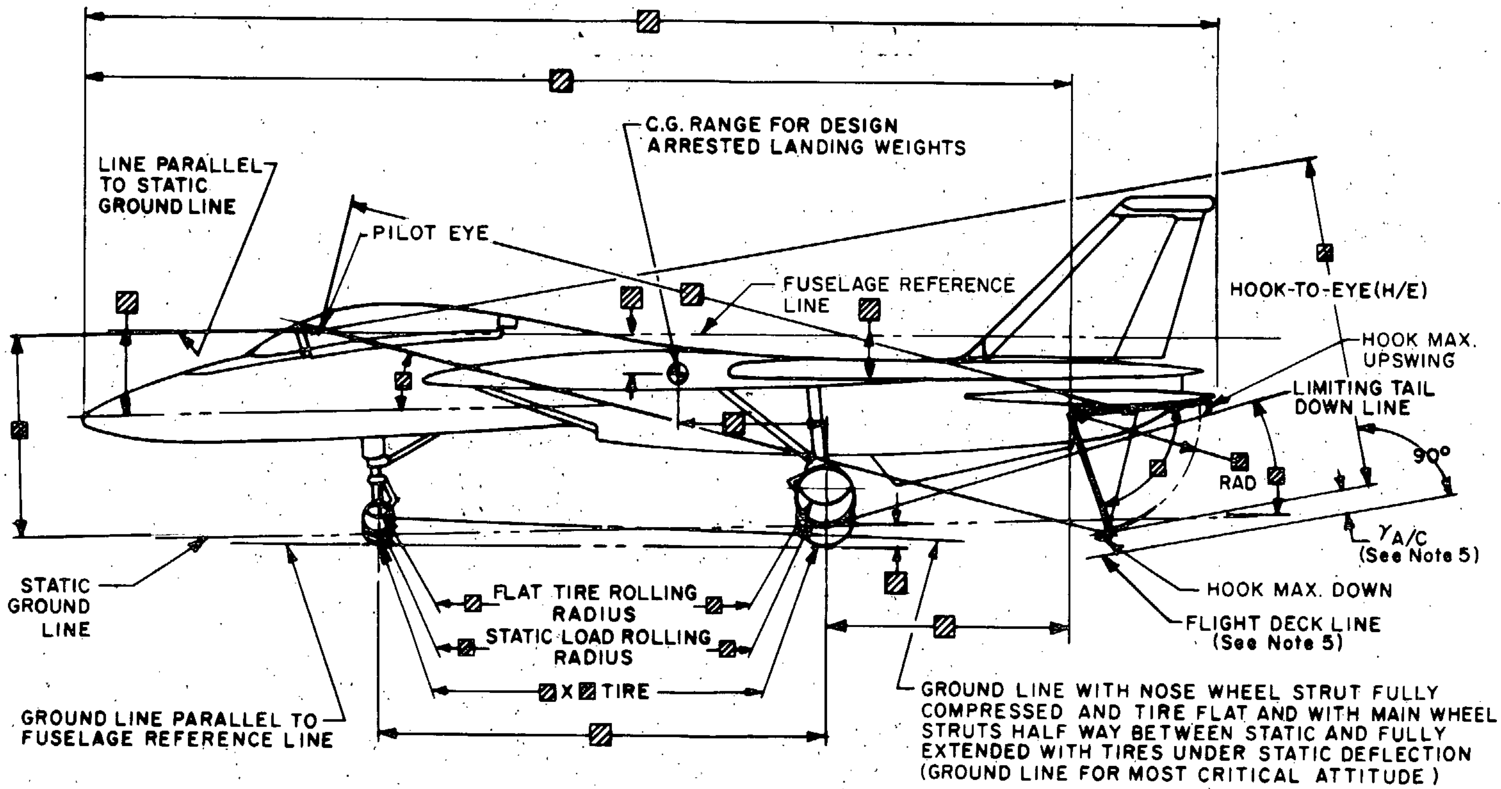

Figure 4. Arrested Landing Arrangement Drawing - Nose Wheel Type Aircraft

3.6.5 Detachable hook point. The arresting hook installation shall have a detachable hook point.

3.6.6 Hook point to shank attachment. Configurations which employ bolts or pins to attach the hook point to the shank shall have the axis of such attachment in a plane perpendicular to the shank and parallel to the landing surface. Methods of attaching the hook point to the shank that differ from the preceding must be approved by NAVAIR.

3.6.7 Hook point to shank attachment hardware. Hook point to shank attachment hardware shall conform to the following:

a. Bolt(s) used to attach the aircraft arresting hook point to the hook shank shall be in accordance with MIL-B-8906.

b. Nut(s) used in conjunction with the above bolt(s) shall be in accordance with MIL-N-8922.

c. If a washer or other metallic material is required between the nut and shank or between the bolt head and shank, then this washer or metallic material shall have a minimum heat treat of 180,000 psi.

d. Surface treatments for the bolts, nuts, washers or other metallic material shall be in accordance with MIL-S-5002.

e. Hook point attachment hardware shall be solely for attaching the hook point to the hook shank. Its use for collateral purposes, such as attaching bumpers or up-locks, or as shank assembly hardware, is not acceptable.

3.7 Arresting hook control. Provision shall be made for lowering or raising the arresting hook by a control mechanism. The control shall be either manually or power operated.

3.7.1 Arresting hook control location. The arresting hook control shall be located in the cockpit as specified in MIL-STD-203. It shall be easily operable by the pilot regardless of the position of adjustment of the pilot's seat or pilot's shoulder harness.

3.7.2 Arresting hook control design. The control shall have a unique design to be readily distinguishable from adjacent cockpit controls, both by day and night in order that the pilot need not divert his attention to locate and check the control.

3.7.3 Actuator. An actuator shall be provided to raise and lower the arresting hook.

3.7.3.1 Times for hook positioning. The arresting hook system shall be designed to raise the hook to the stowed position within 4 seconds and to be fully extended to the arrestment-ready position within 2 seconds after the cockpit control has been actuated.

3.7.4 System failure. The arresting hook control shall be designed to allow the pilot to lower the hook and the arresting hook shall remain down in the event of a failure of the power system or control system.

3.7.5 Connection to angle of attack approach lights. The arresting hook control shall be interconnected with the angle of attack approach lights as specified in MIL-L-006730.

3.8 Shock absorber design.

3.8.1 Shock from round down. The arresting hook installation or structure shall be designed to absorb the shock loads caused by sudden extension of the arresting hook when the aircraft passes over the forward round down of the carrier angled deck after missing a deck pendant engagement. The hook shall be assumed to extend from the "full-up" position.

3.8.2 Hold down. The shock absorber shall include a hold down feature to minimize the bounce of the arresting hook when it strikes the deck protrusion during a carrier landing. Typical flight deck protrusions are shown on Figures 1 and 2.

3.8.2.1 Hook bounce. The holddown feature shall return the arresting hook rapidly to the deck following initial hook bounce. The first bounce shall not be more than 20 feet long and 4 inches high. Any succeeding bounces shall be low enough to allow the hook to engage a deck pendant.

3.8.3 Flight speeds. The shock absorber shall be designed so that the arresting hook can be released and lowered at all flight speeds up to 2.5 times the power approach speed at maximum arrested landing weight. The arresting hook shall also be capable of remaining in the full-down position at all flight speeds up to 2 times the power approach speed at maximum arrested landing weight.

3.8.4 Limit load design. The shock absorber and its supporting structure shall be designed for limit loads equal to the loads imposed on it when the design ultimate vertical bending moment is applied to the arresting hook. This requirement will insure the structural integrity of the shock absorber during acceptance tests when the shock absorber loads are varied to determine optimum orifice size.

3.9 Ground lock. Provisions for attachment of an arresting hook ground lock shall be provided unless otherwise specified in the detail specification. The ground lock shall prevent release of the arresting hook in the event that cockpit control is actuated. Design of the ground lock shall prohibit removal if the control is actuated.

3.10 Drawings and reports. Three drawings (3.10.1 through 3.10.4) are required to establish the complete operational characteristics and interface requirements of the arresting hook installation. The data to be furnished shall be listed on DD Form 1423 (Contractor Data Requirements List), which shall be attached to and made a part of the contract or order. NAVAIR Form 4200/25 (Drawings, Lists, and Specifications Required) shall be attached where applicable.

3.10.1 Preliminary. A preliminary study or layout of the hook arrangement and location shall be made during the early stages of design and forwarded to the Naval Air Systems Command (NAVAIR) for advance comment with information copies to Naval Air Engineering Center (NAEC) and the Naval Air Test Center (NATC). Addresses of these activities are given in 6.3.

3.10.2 Installation. Arresting hook installation drawings showing the arrangement and details of hook installation, controls, shock absorber, holddown device, etc., and indicating or accompanied by pertinent data relating to the operating characteristics of the arresting hook installation, shall be submitted to NAVAIR for release with copies to NAEC and NATC in accordance with MIL-D-8706.

3.10.3 Scale arrested landing arrangement drawing. An accurate drawing, to a scale of 1/20 and similar to Figure 3 or Figure 4 herein, as applicable, shall be included with the drawings required by 3.10.2. Necessary additional drawings to show fulfillment of clearances, and other critical areas during landing run out and roll back, and indicating pertinent measurable data shall also be submitted with this drawing.

3.10.4 Drawing update. It is essential that all drawings be kept up to date during the design and construction of the aircraft. The contractor shall submit drawings of all new design and construction revisions, as they occur, to NAVAIR for approval with copies to NAEC and NATC.

3.11 Identification plates. Each arresting hook shank shall bear a metal plate in accordance with MIL-P-15024, Type A, G or H on which a serial number (6.2.3) and a part number are stamped. The plate shall provide sufficient blank surface to permit the stamping of symbols by inspection/overhaul activities to record the number of inspection and overhaul cycles as required and space to record accessory changes incorporated. In addition, serial numbers must be permanently affixed to, or marked on, the above components in noncritical areas.

3.12 Interchangeability. All parts having the same manufacturer's part number shall be functionally and dimensionally interchangeable. The item identification and part number requirements of AD-1350 shall govern the manufacturer's part numbers and changes thereto.

3.13 Identification of parts. All parts used in the arresting hook installation shall be marked with the manufacturer's code number in accordance with MIL-STD-130.

3.14 Workmanship. The arresting hook installation shall be uniform in quality and shall be free from irregularities or defects which could affect performance, reliability, durability, or maintainability.

4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for inspection. Unless otherwise specified in the contract or purchase order, the supplier is responsible for the performance of all inspection requirements as specified herein. Except as otherwise specified in the contract or order, the supplier may use his own or other facilities suitable for the performance of the inspection requirements specified herein, unless disapproved by the Government. The Government reserves the right to perform any of the inspections set forth in the specification where such inspections are deemed necessary to assure supplies and services conform to prescribed requirements.

4.2 Classification of inspections. The inspections of the arresting hook installation shall be classified as follows:

(a) Prototype inspection

(b) Quality conformance inspection

4.2.1 Prototype inspection. Prototype inspections shall consist of the following inspections:

a. Examination (4.3.1)

b. Development tests (4.3.4)

c. Structural tests (4.3.5)

d. Dynamic tests (4.3.6)

4.2.2 Quality conformance inspection. The quality conformance inspection shall consist of the Naval Acceptance Tests (4.3.7).

4.3 Inspection methods

4.3.1 Examination. The arresting hook installation shall be thoroughly examined by the contractor to determine conformance with this specification and applicable drawings with respect to all the requirements not covered by tests.

4.3.2 Arresting hook installation descriptive narrative. An arresting hook installation descriptive narrative shall be prepared by the contractor and submitted to AIR-551 for approval no later than 30 days after completion of design. The arresting hook installation narrative shall be a written description, illustrated as necessary, containing, but not limited to the following components and functions:

a. Mechanical, electrical and hydraulic/pneumatic systems and components.

b. Normal extend

c. Retract

d. Damping

e. Centering

f. Cockpit controls

g. Redundancy/fail safe features

4.3.3 Failure mode and effects analysis (FMEA) report. A failure mode and effects analysis report shall be submitted on the complete aircraft arresting hook installation system described herein. The analysis shall cover the entire cycle of operation from release of the hook to retraction. Operation of the hook system both airborne and on the ground (deck) shall be included where different. Both normal and emergency modes of operation shall be covered. The FMEA report shall be prepared by the contractor and submitted to AIR-551 for approval no later than 30 days after completion of design.

4.3.4 Development tests. The contractor shall conduct such tests as are necessary to develop suitable aircraft arresting features and aircraft arresting hook installation. This requirement shall be construed to encompass the design and construction of deadloads and modification of an aircraft to produce a suitable test vehicle if necessary. A report shall be prepared by the contractor and submitted to AIR-551 for approval no later than 30 days after completion of development tests.

4.3.4.1 Navy facilities. Development tests may be conducted at Navy facilities, made available upon request. The arresting hook installations may be tested during arresting tests conducted with a full scale dynamic deadload.

4.3.5 Structural tests. The contractor shall conduct structural tests on the aircraft arresting hook installation and associated arresting hook components in accordance with the requirements of MIL-A-8860.

4.3.6 Dynamic tests. The dynamic characteristics and the structural integrity of the aircraft and its arresting hook installation will be tested in various arresting gear and in various landing attitudes and configurations during acceptance trials. These trials will include the requirements of MIL-D-8708.

4.3.6.1 Spares. One spare arresting hook and shock absorber assembly shall be provided with the prototype aircraft.

4.3.7 Naval acceptance tests. The aircraft arresting hook installation will be tested during acceptance trials in accordance with current Board of Inspection and Survey directives.

5. PREPARATION FOR DELIVERY

5.1 Applicability. This section is not applicable to this specification.

6. NOTES AND CONCLUDING MATERIAL

6.1 Intended use. The requirements of this specification are intended for use by aircraft contractors in the design of aircraft for the U.S. Navy, to assure an arresting hook installation that is suitable for use with carrier, field, and Expeditionary Airfield (EAF) type arresting gear.

6.2 Ordering data.

6.2.1 Procurement requirements. Procurement documents should specify the following:

a. Title, number and date of this specification.

b. Applicable aircraft detail specification.

6.2.2 Contract data requirements. When this specification is used in a procurement which incorporates a DD Form 1423 and invokes the provisions of 7-104.9(n) of the Armed Services Procurement Regulations, the data requirements identified below will be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved Contract Data Requirements List (DD Form 1423) incorporated into the contract. When the provisions of ASPR-7-104.9(n) are not invoked, the data specified below will be delivered by the contractor in accordance with the contract requirements. Deliverable data required by this specification is cited in the following paragraphs:

Paragraph	Data requirement	Applicable DID
3.6.3	Wear limits	DI-E-7031
3.10.1	Preliminary	DI-E-7031
3.10.2	Installation	DI-E-7031
3.10.3	Arrested landing arrangement	DI-E-7031
3.10.4	Drawing update	DI-E-7031
4.3.2	Arresting hook narrative	UDI-S-20444
4.3.3	FMEA report	UDI-R-21140
4.3.4	Development tests	DI-T-2072

(Copies of data item descriptions required by the contractors in connection with specific procurement functions should be obtained from the procuring activity or as directed by the contracting officer).

6.2.3 Serial numbers. Serial numbers required by 3.11 shall be obtained from NAEC.

6.3 NAVAIR, NAEC, and NATC. Where reference is made in this specification to NAVAIR correspondence, where required, it shall be addressed to:

Commander
Naval Air Systems Command
Code AIR-551
Washington, D.C. 20361

Where NAEC is to be contacted the address shall be:

Commanding Officer
Naval Air Engineering Center
Codes 911 and 943
Lakehurst, NJ 08733

Where NATC is to be contacted the address shall be:

Strike Aircraft Test Directorate
Code SA 70
Naval Air Test Center
Patuxent River, MD 20670

6.4 Definitions.

6.4.1 Deck pendant. A wire rope cable stretched across the landing area and connected to an energy absorber which applied a retarding force through the arresting hook to an aircraft during an arrested landing.

6.4.2 Arresting hook. A metal device, attached to an aircraft, used to transmit a retarding force during an arrested landing.

6.4.3 MIL-A-8860. This refers to a series of specifications which will include MIL-A-8860 through MIL-A-8870.

6.5 Changes from previous issue. Asterisks are not used in this revision to identify changes with respect to the previous issue, due to the extensiveness of the changes.

Preparing Activity:

Navy - AS

(Project No. 1710-N023)

APPENDIX A

10. SCOPE

10.1 Scope. This appendix covers recommended design considerations and criteria concerning the following:

a. Arresting hook location and installation geometry

b. Arrested landing analysis conditions

c. Recommended analytical procedures

d. Conventional arresting hook installations

e. Arresting hook and arresting hook component design

f. Shock absorber and hold down criteria

20. ARRESTING HOOK LOCATION

20.1 Hook location. In determining the location of the arresting hook the effect of such location on nose wheel loads, tail wheel drop at the end of the runout, propeller or store clearances, and main wheel/deck contact, as applicable to the type of aircraft involved, must be considered. The following paragraphs present general information about various types of arresting gear and general recommendations for determining the adequacy of the hook location.

20.2 Carrier type arresting gear. U.S. Navy aircraft carriers incorporate a constant runout type of arresting gear. Thus a fixed runout distance, regardless of the weight or engaging speed of the aircraft (within the arresting gear design limit) is characteristic of this type of arresting gear.

20.3 Field type arresting gear. Carrier based aircraft are required to operate in field arresting gear of various types. These operations include emergency arrestments resulting from runway overrun or aborted takeoff and Expeditionary Airfield (EAF). Deck spans for these gear range from 70 to 330 feet and most of these gear do not provide a constant runout. In general, arresting hook locations suitable for use with carrier type arresting gear have proved suitable for use with field types.

20.4 Arresting gear time histories. Runout, peak deceleration, and representative deceleration and cable tension time histories for the various models of arresting gear can be obtained from NAVAIR or will be supplied in the airplane detail specification. The forces and accelerations shown in such time histories do not necessarily represent the magnitudes applicable to structural design specified in MIL-A-8860.

20.5 Preliminary arresting hook location. The following paragraphs present criteria for checking the effect of the proposed arresting hook location on the factors of 20.1 in the preliminary design stages of the hook. The acceptability of the final hook location must be verified by a full dynamic analysis of all forces (including aerodynamic forces) acting on the aircraft during runout and by test as required by the basic specification.

20.5.1 Aircraft attitudes. The aircraft may engage the deck pendant in free flight, three point, or two point attitude. For purposes of the preliminary analysis included herein the following aircraft attitudes should be considered.

20.5.1.1 Static deflection. In general, at the instant that the arresting hook engages the deck pendant, the aircraft may be assumed in contact with the deck with its main landing gear struts and tires under static deflection. For purposes of analysis, the main landing gear struts and tires may be assumed to remain under static deflection during the entire arrested run.

20.5.1.1.1 Engagement attitudes for tail wheel aircraft. For tail wheel equipped aircraft, the following attitudes at engagement should be considered:

a. Assume the tail wheel is fully extended and in contact with the deck with no load.

b. Assume the aircraft in tail high position with the hook in the full down position and the hook throat center 5 inches above the flight deck.

c. The tail wheel load may be assumed to remain zero during the entire arrested run.

20.5.1.1.2 Engagement attitudes for nose wheel aircraft. For nose wheel equipped aircraft, assume that aircraft at engagement in the following conditions with the weight and engaging speed as specified in 20.5.3.

a. Tail down position as defined in 3.6.1 with nose clear of deck and with $V_{V_{max}}$ at touchdown.

b. Pitch attitude corresponding to $V_{V_{max}}$ as determined from MIL-A-8860.

c. Pitch attitude corresponding to 3-1/2° glide path relative to the carrier deck.

20.5.2 Other conditions. If necessary, the investigation should be extended to include conditions other than those specified.

20.5.3 Preliminary analysis conditions. A preliminary analysis of the proposed hook location with the aircraft in the attitudes specified in 20.5.1 should be made for the following conditions:

a. Aircraft at carrier landing design weight and an engaging speed of 1.1 $V_{PA_{min}}$.

b. Aircraft at carrier landing design weight and an engaging speed of 1.1 $(V_{PA_{min}} - V_w)$.

Where: $V_{PA_{min}}$ = Power approach speed for carrier landing

V_w = Minimum Wind-Over-Deck (WOD) for carrier landing and specified in aircraft detail specification.

For field type arrestments, the weight should be the maximum field arrested landing weight and the engaging speed equal to V_{PA} + 10 knots.

20.5.3.1 Preliminary analysis procedure. The following analysis is applicable to both nose wheel and tail wheel type aircraft.

a. Estimate a suitable hook location. Observed tail rise during arrested landings of conventional tail wheel equipped aircraft indicate that the hook location is satisfactory if the hook line of action passes not less than 12 inches above the C.G. when the aircraft attitude is defined by a deck line determined at 90 feet of runout by a six inch propeller clearance and the main wheel gear in the static position.

b. Assume that the only forces acting on the aircraft during the arrestment are the aircraft weight, main gear reactions, hook load, engine thrust, and the resulting inertia forces. For jet and turbo-prop type aircraft, engine thrust should be equal to the maximum thrust. For propeller aircraft with reciprocating engine(s) the thrust value should be the thrust developed at $V_{PA_{min}}$.

c. Equate the applied moments and the inertia moments of these forces about the main gear axle at the instant of deck pendant engagement. Assure that angular velocity at this instant is zero.

d. Assume an incremental angular change in the reference line of the aircraft ($\Delta\phi$) from the initial engagement attitude.

e. Compute the angular acceleration (α_t) at the end of the interval. Applied forces and moments about main wheel axle should be based on attitude at midpoint of interval.

f. Compute the average angular acceleration (α avg) over the interval assuming the change in angular velocity (ω) to take place uniformly over the interval.

g. Compute the angular velocity at the end of the interval using α avg.

h. Compute the average angular velocity (ω avg) during the interval.

i. Compute the angular travel of the reference line during the interval and determine the angle between the reference line and the ground line at the end of the interval.

j. Compare the computed ground angle with that originally assumed in step (d).

k. If the discrepancy between the assumed and computed angle is greater than 0.05 degrees, assume a new ground angle and recompute until the assumed angle and the computed angle agree. To facilitate accurate prediction of a new ground angle it is suggested that a curve of ϕ versus time be drawn and extrapolated with each computation.

l. Continue this analysis through successive increments of time throughout the arrested run. The increments of time should be sufficiently small so that the changes taking place during the increment may be assumed to occur uniformly.

20.5.3.2 Tail down engagement. For tail down engagement of nose wheel equipped aircraft the analysis need not be carried beyond the point of impact of the nose wheel.

20.5.3.3 Nose wheel load. For aircraft equipped with a nose wheel, the nose wheel load during the impact can be estimated in the following manner:

a. Assume that the angular velocity at impact is reduced to zero during the angular travel about the main gear axle resulting from compression of the nose wheel strut from the fully extended to the fully compressed position plus 75 percent of the available deflection of the nose wheel tire. Available deflection shall be the change in rolling radius of the nose wheel tire from the unloaded condition to a flat tire condition.

b. Calculate the average angular acceleration during the nose gear stroke and determine the average force (F avg) acting on the nose wheel.

c. Limit load acting on the nose wheel shall be assumed to be 1.43 F avg (assuming a strut-tire efficiency of 70%) unless improved efficiency is to be verified by test.

20.5.3.4 Tail drop loads. Calculations similar to those of 20.5.3.3 can be made to estimate the tail drop loads on tail wheels at the end of the arrested run.

20.5.3.5 Selection of new hook location. If the preliminary calculations of 20.5.3 show excessive nose gear or tail wheel loads, or insufficient propeller or store clearance, a new hook location should be selected and the preliminary analysis repeated.

30. ARRESTING HOOK INSTALLATION ARRANGEMENTS

30.1 Design stage. It is urged that the location and arrangement of the hook be considered at an early stage of the design, before the final configuration of the aircraft is set, to insure that the simplest and most reliable installation can be incorporated.

30.2 Proven hook installations. It is desirable to incorporate a proven hook installation where practicable. In this connection it is stressed that preliminary layouts be discussed with NAVAIR at an early design stage to determine what proven and standard hook installation components can be incorporated.

40. ARRESTING HOOK DETAIL DESIGN

40.1 Design parameters. The arresting hook is required to have sufficient length and the hook point to be suitably shaped to permit ready engagement with the deck pendants of any of the arresting gear in which the aircraft is designed to operate and with the aircraft in any attitude which can reasonably be expected during such arrestment. A discussion of the requirements upon which arresting hook design should be based, and pertinent recommended design criteria and considerations, are presented in the following paragraphs.

40.2 Arresting hook length.

40.2.1 Prediction. The prediction of the correct length of the arresting hook which will insure a reasonable degree of engagement with the arresting gear is influenced by the following factors:

a. The number, spacing, and height of the deck pendants on the deck.

b. The desirability of maintaining short hook length to reduce weight and minimize hook rotational velocities.

c. Control characteristics of the aircraft near the stall attitude.

d. The usual attitude in which the aircraft makes initial contact with the deck.

e. The location of the hook with respect to the wheels of the aircraft.

f. The type of landing gear of the aircraft and its effectiveness in preventing nose-up rebound from the deck and resultant "aerodynamic bounce".

g. The effectiveness of the arresting hook shock absorber and holddown device.

40.2.1.1 Arresting gear characteristics. For the purposes of this appendix the characteristics of the arresting gear pendant spacing, height, etc., may be considered to be fixed as a result of experiment, statistical analysis, and structural considerations in the aircraft carrier. For a typical carrier flight deck arrangement refer to Figure 1 of the basic specification. Field arresting gear layouts generally have only one deck pendant. Deck pendant height is similar to that for carrier type gear, although deck pendant diameters generally are smaller.

40.2.1.2 Shortest hook. The considerations of weight, hook rate of rotation, and ease of locating and housing the hook, dictate the use of the shortest hook which will satisfactorily engage the deck pendant.

40.2.1.3 Airplane control characteristics. In making a carrier approach and landing, a certain margin of speed greater than the stalling speed is required. This is dependent on the control characteristics of the aircraft (when near stall speed), engine acceleration characteristics of the aircraft in the event of a wave-off or a missed wire, and by the aircraft attitude required to insure pilot's visibility of the landing area. If these characteristics are poor, higher landing speeds will be required which increases the probability of the aircraft bouncing or otherwise being in an attitude in which it is difficult to engage the deck pendant, thus necessitating a longer hook to insure satisfactory engagement.

40.2.1.4 Tail high attitude. If the aircraft will normally contact the deck in a tail high attitude due to its aerodynamic or control characteristics, it is necessary to provide a longer hook on tail wheel equipped aircraft.

40.2.2 Tail wheel aircraft hook length criteria. Since many of the factors in 40.2.1 influencing hook design cannot be determined during the design stage, it is recommended that the following hook length criteria for tail wheel equipped aircraft, based on statistical analysis of hook length of past and present carrier aircraft, be used where necessary in lieu of definite data.

40.2.2.1 Hook length. With the hook trailing aft, the length of the hook on tail wheel equipped aircraft should reach a line parallel to the fuselage reference line and tangent to the main wheels, compressed under normal static load. For an example of this attitude, refer to Figure 3 of the basic specification.

40.2.3 Nose wheel aircraft hook length. Arresting hook lengths based on the following formula have proven adequate for nose wheel type aircraft in service.

40.2.3.1 Hook point-ground line relationship. With the hook trailing aft, the nose wheel strut fully compressed, the nose wheel tire flat, the main-wheel tires under normal static load, and the main gear struts extended to a point 50 percent between the normal static and the fully extended positions, the hook point should touch or extend below the resulting ground line. For an example of this attitude, refer to Figure 4 of the basic specification.

40.2.3.2 Shorter hook. A shorter hook length than that specified in 40.2.3.1 may be used if the contractor can provide a rational analysis proving the adequacy of the shorter length to engage a deck pendant, which is acceptable to NAVAIR.

40.3 Arresting hook trail angle. The determination of the optimum arresting hook trail angle is influenced by the following factors:

a. The arresting hook must trail aft sufficiently to prevent the aircraft sitting on the hook in a normal "full stall" carrier landing.

b. In general, hook bounce is reduced when the hook trail angle is increased since the initial rotational acceleration resulting from kinematic bounce is less when the hook is subjected to initial impact at a decreased angle with the deck.

c. An increase in hook trail angle together with the corresponding increase in hook length required, will improve the engaging attitude of the hook head for normal engaging positions of the aircraft. Figure A-2 demonstrates this condition.

d. An increase in hook trail angle is objectionable only from the standpoint that it necessitates the provision of a longer hook to meet the length requirements of 40.2.3. This results in an increase in weight and makes the locating and housing of the hook more difficult.

40.3.1 Hook deck angle. Recommended criteria for the hook deck angle and its relationship to the hook trail angle, applicable to conventional designs, are shown on Figure A-1 as a general design guide. Generally, the required hook holddown force increases rapidly as the hook deck angle increases above 65°.

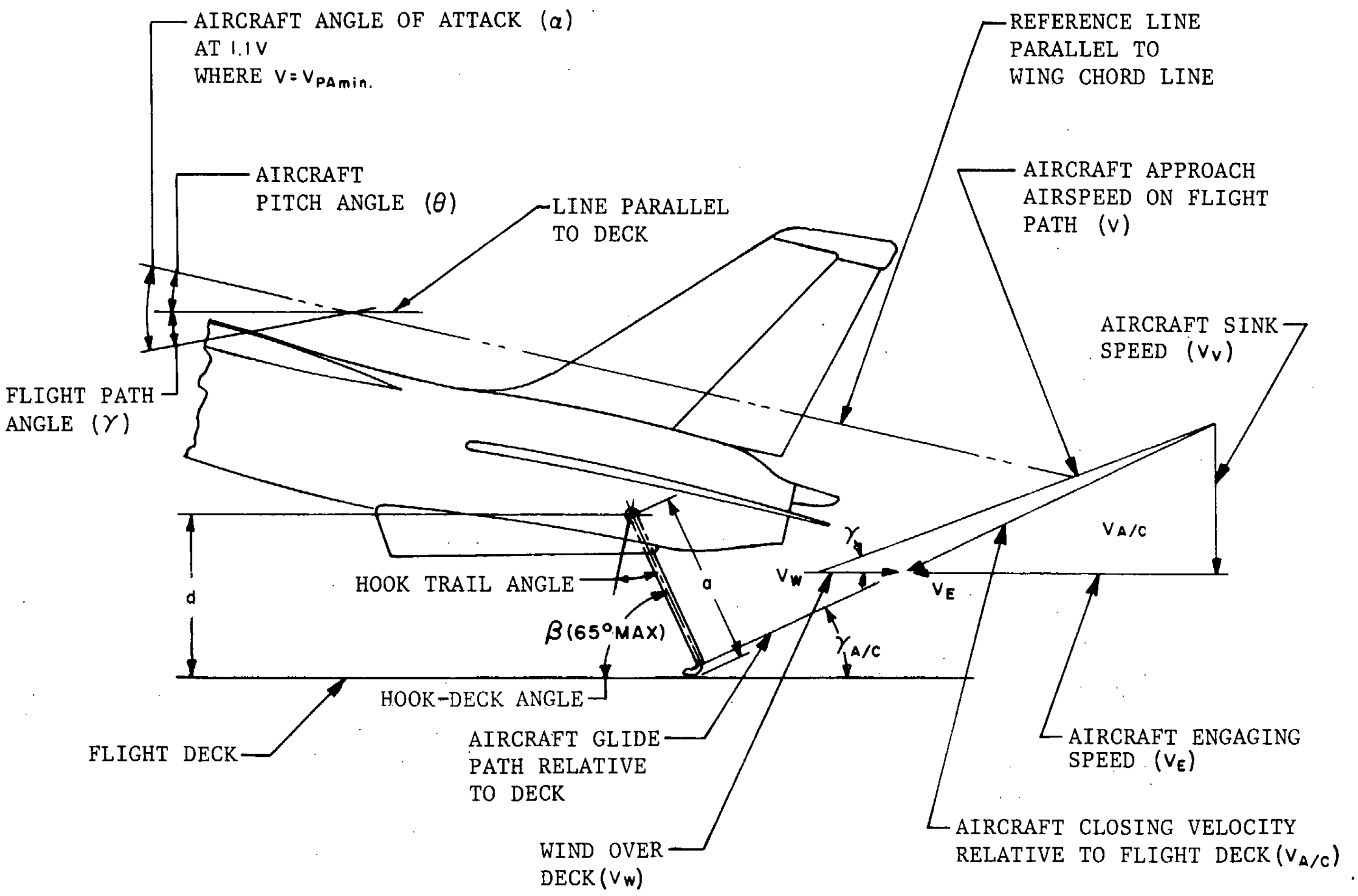

Figure A-1. Typical Hook Deck Angle and Hook Trail Angle

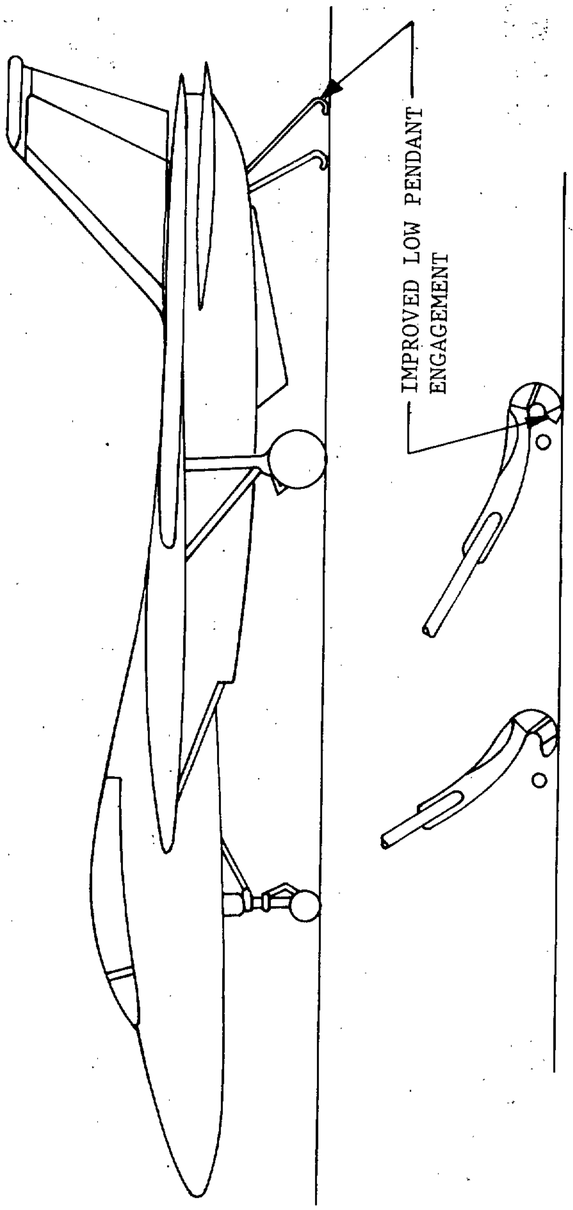

Figure A-2. Effect of Increased Tail Angle on Low Pendant Pickup Characteristics

40.4 Arresting hook point and hook shank. A typical hook point and hook shank design, free from obstructions in the deck pendant contact region, and the angle of trail relationship to the critical deck line is illustrated in Figure A-3.

40.4.1 Arresting hook shank.

40.4.1.1 Hook shank torsional stiffness. One of the major design problems of hook shank design is providing the required torsional stiffness values while minimizing the weight. Previous experience on all arresting hook shank designs have demonstrated that the tubular type members have the greatest torsional stiffness with a history of the fewest failures and the minimum number of operational problems and less maintenance.

40.4.2 Arresting hook point.

40.4.2.1 Multiple deck pendant engagement. Because the engagement of more than one deck pendant by an arresting hook will probably result in aircraft overload, every consideration should be given to designing a hook which will minimize this possibility. Generally, shortening the hook face and increasing the hook face angle will improve the ability of the hook to shed a second deck pendant. Some compromise in hook point design will often be required, however, since the factors which improve the ability of the hook to shed a second deck pendant, decrease somewhat the ability of the hook point to pick up a deck pendant after the aircraft's wheels have depressed the pendant.

40.4.2.2 Toe radius. The toe radius is important in determining the ability of the hook point to pick up a deck pendant: a small toe radius facilitating pick-up, especially from a depressed condition; an unduly small toe radius can damage the deck pendant.

40.4.2.3 Transverse curvature. The transverse curvature of the hook face and cable groove should be of large radius to minimize bending stresses in the deck pendant when it wraps around the hook point.

40.4.2.4 Tangent radius. The throat radius of the hook point should be large enough to accept deck pendants up to 1-1/2 inches nominal (1-5/8 inches maximum) in diameter. The smallest deck pendant in use is 1 inch in diameter.

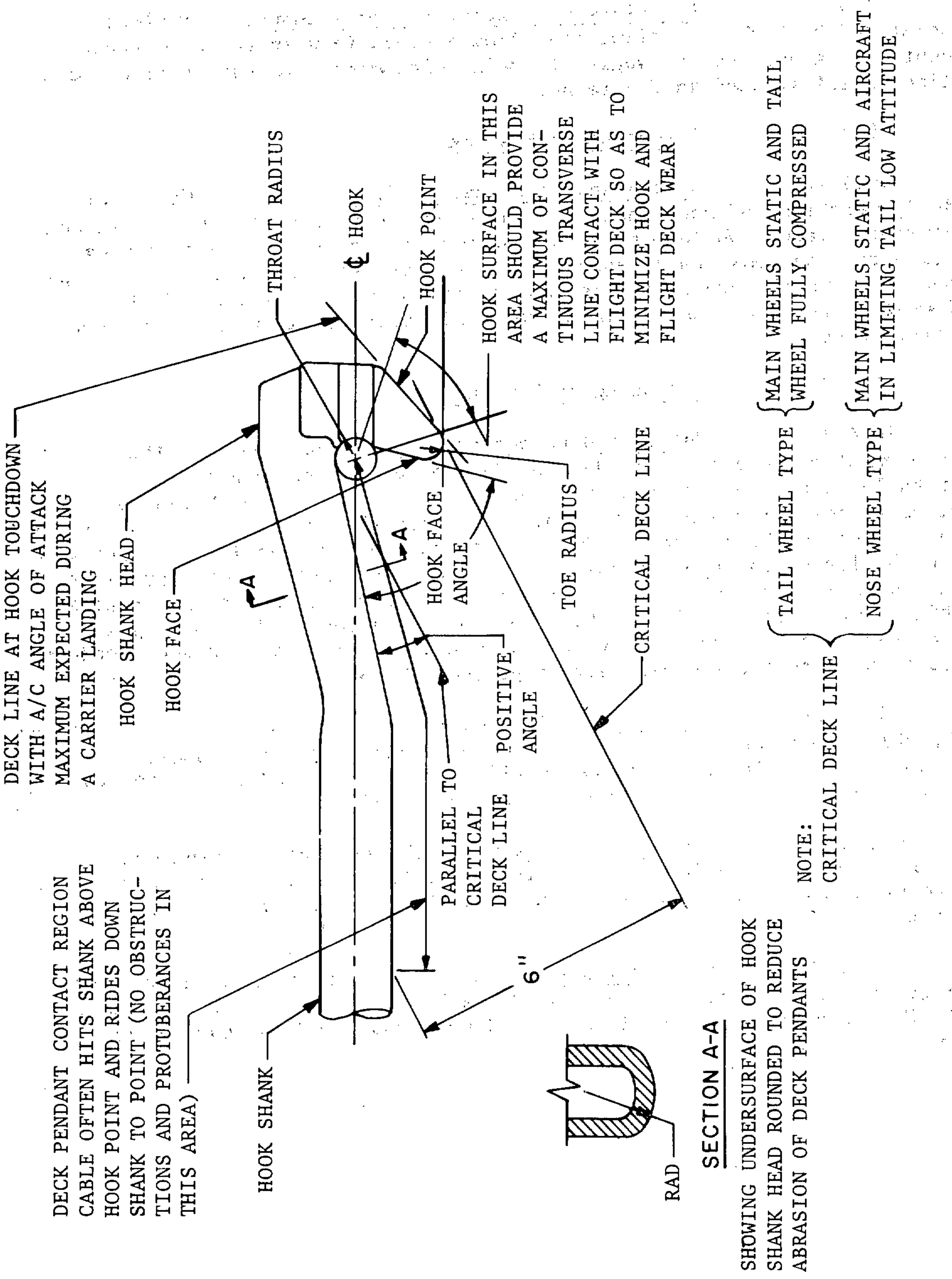

Figure A-3. Arresting Hook Design Features

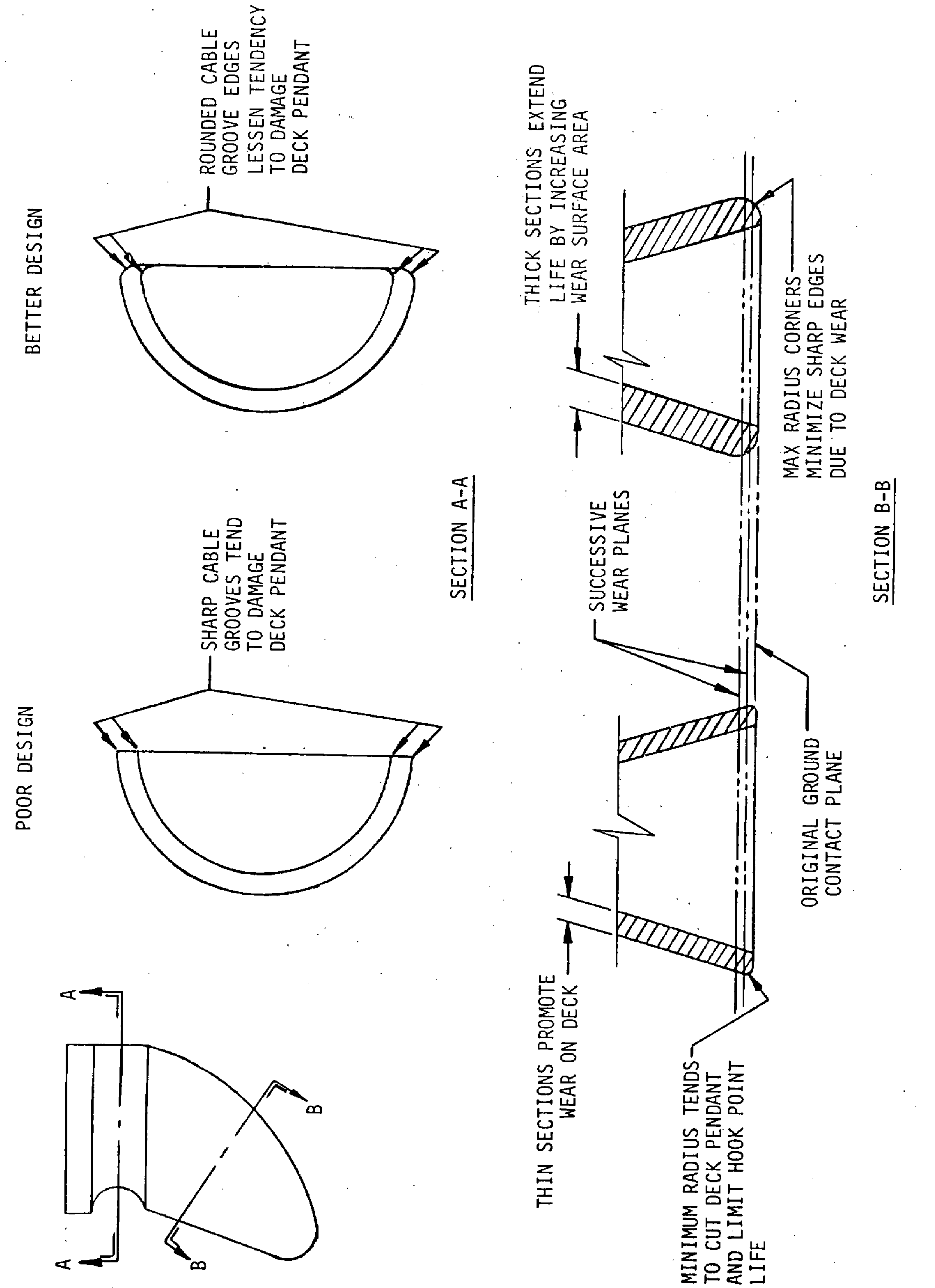

Figure A-4. Hook Point Design Features

40.4.2.5 Wear resistance. The wear requirements for arresting hooks are severe. During off-center arrestments the deck pendant tends to slide through the hook throat with rubbing velocities on the order of 40 feet/second. The hook point throat must be composed of material which will preclude welding of the deck pendant to the cable groove under the conditions of heat and pressures which exist during off-center engagements. The Colmonoy No. 6 or Metco No. 16C coated cable grooves of the hook points covered by MIL-H-21594 have proved suitable for use with both carrier type and field type arresting gear cables. Metco No. 12C has shown promise in extensive tests. Portions of the back of the hook point and the toe radius are subject to severe abrasion during arrestment on concrete runways and on carrier decks and EAF field landing mats both of which are covered with the anti-skid compound of MIL-D-23003. Field type arrested landings are especially severe since the hook point may drag the runway for considerable distances before engagement with the deck pendant.

40.4.2.6 Hook point weight. Arresting hook point weight influences the hold-down forces required to resist hook bounce. Hook point and shank weight should be kept to a minimum.

40.4.2.7 Transverse contours. Consideration should be given to the transverse contours of the toe and the back of the hook point to insure that the point can properly engage the deck pendant with the aircraft in a rolled or yawed handling attitude, or with the hook point displaced from its centered position. Figure A-4 illustrates poor and better hook point design features.

40.4.2.8 Face angle. The optimum face angle is a compromise between deck pendant engagement and retention, and shedding characteristics. A sharp face angle will promote pickup of low pendants and retention during the early part of runout, while a shallower face angle will facilitate pendant shedding at the end of runout.

40.5 Arresting hook shock absorber. The determination of the optimum shock absorber and holddown characteristics is dependent upon the following variables:

a. The elastic properties of the arresting hook.

b. The weight and weight distribution of the rotating hook parts.

c. The velocity with which the hook strikes the deck.

d. The angle at which the hook strikes the deck.

e. The elastic properties of the deck surface.

f. The hook-deck angle (See Figure A-1).

40.5.1 Kinematic bounce. When the aircraft is approaching the deck on a constant glide path, the arresting hook trails at a fixed angle until the hook point contacts the deck at which time the hook is forced to rotate about its pivot point (See Figure A-5). Theoretical analysis of the hook motion after it contacts the deck indicates that the angular velocity is $\frac{d\beta}{dt} \doteq \frac{-V_{A/C}}{d} \sin \gamma_{A/C} \tan \beta$.

Since the only variable is tan β, and β is decreasing with time, the angular velocity subsequent to hook/deck contact must also be reduced if deck contact is to be maintained (zero hook bounce). This requires that the hold-down device impart an angular acceleration to the hook. This angular acceleration is $\frac{d^2\beta}{dt^2} = \left|\frac{d\beta}{dt}\right|^2 \tan \beta$.

The angular velocity and angular acceleration will approach infinity as β approaches 90°. Obstructions in the way of the hook increase the hold-down force requirements to maintain deck contact of the hook point. It should be noted that the foregoing formulas do not take into account the flexibility of the shank and the resiliency of the hook point and deck.

50. DETERMINATION OF AIRCRAFT PITCH ATTITUDE

50.1 Methodology. The following is a method for determining the pitch attitude of the aircraft during landing at the instant of hook-deck contact.

50.1.1 Notations.

V_V Sinking speed . . . . ft/sec

V_E Engaging speed . . . . ft/sec

$V_{A/C}$ Velocity of aircraft with respect to the deck . . . . ft/sec

V_w Headwind velocity relative to deck . . . ft/sec

α Angle of attack . . . . RAD

θ Pitch attitude . . . . RAD

$\gamma_{A/C}$ Glide path angle of aircraft with respect to the deck . . . . RAD

V Approach air speed of aircraft . . . . ft/sec

W Aircraft weight . . . . lb

γ Aircraft glide path angle . . . . RAD

T	Engine thrust	lb
D	Aerodynamic drag	lb
L	Aerodynamic lift	lb
ρ	Air density	$lb\frac{sec^2}{ft^4}$
S	Wing area	ft^2
$C_{L/O}$	Vertical intercept of C_L VSα curve	DIM
$\frac{dC_L}{d\alpha}$	Slope of C_L VSα curve	1/RAD
$C_{D/O}$	Vertical intercept of C_D VSα curve	DIM
$\frac{dC_D}{d\alpha}$	Slope of C_D VSα curve	1/RAD

50.2 <u>Analytical procedure for determining aircraft pitch attitude</u>. The analytical schematic of the aircraft arresting hook is shown in Figure A-5. The sinking speed (V_V) and the engaging speed (V_E) are the velocities of the aircraft. The horizontal and vertical velocities can be derived from $V_{A/C}$ and $\gamma_{A/C}$.

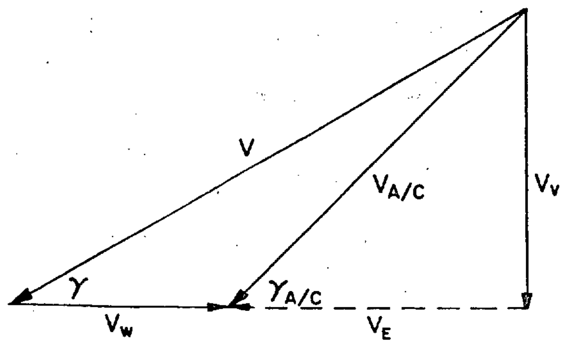

Figure A-5. Aircraft Velocity Diagram

Using the law of cosines and considering the velocity diagram of Figure A-4, the velocity of the aircraft with respect to the carrier deck is:

$$V_{A/C} = \frac{-2\ V_w \cos \gamma_{A/C} \pm \sqrt{(2V_w \cos \gamma_{A/C})^2 - 4(V_w^2 - V^2)}}{2}$$

Where:

$V = f(w)$ and V_w and $\gamma_{A/C}$ are specified for each landing.

The sinking speed is then determined from

$$V_V = V_{A/C} \sin \gamma_{A/C}$$

and the engaging velocity is given by:

$$V_E = V_{A/C} \cos \gamma_{A/C}$$

The glide path angle (γ) is then defined by

$$\gamma = \sin^{-1} \frac{V_V}{V}$$

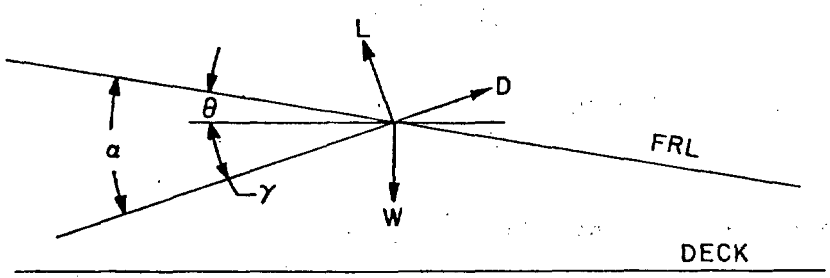

Figure A-6. Aircraft Forces Diagram

An aircraft making a steady state approach during an arrested landing possesses a definite angle of attack, thrust, etc., for each particular condition of approach speed (V) and glide path angle (γ). The forces on the aircraft shown in Figure A-6 are defined assuming:

a. The aircraft in the landing configuration out of the ground plane.

b. Constant approach speed.

c. Constant glide path angle.

Since the velocity along and perpendicular to the glide path is constant, the summation of forces along the glide path equals:

$$T(\cos \alpha) - W(\sin \gamma) - D = 0$$

and the summation of forces perpendicular to the glide path equals:

$$L - W(\cos \gamma) + T(\sin \alpha) = 0$$

assuming small angles $\cos \gamma = 1$, $\sin \gamma = \gamma$

This yields

$$L - W + T\alpha = 0$$

$$T + W\gamma - D = 0$$

Eliminating thrust gives

(1) $$L - W + \alpha(D - W\gamma) = 0$$

The untrimmed aerodynamic coefficients are

(2) $$L = (C_{LO} + \frac{dC_L}{d\alpha} \alpha)\tfrac{1}{2}\rho_V{}^2 S$$

(3) $$D = (C_{DO} + \frac{dC_D}{d\alpha} \alpha)\tfrac{1}{2}\rho_V{}^2 S$$

Substituting equations (2) and (3) into (1) gives:

$$(C_{LO} + \frac{dC_L}{d\alpha} \alpha)\tfrac{1}{2}\rho_V{}^2 S - W + \alpha\{(C_{DO} + \frac{dC_D}{d\alpha} \alpha)\tfrac{1}{2}\rho_V{}^2 S - W\gamma\} = 0$$

Where the angle of attack (α) is the only unknown

The pitch attitude (θ) of the aircraft is then defined by

$$\theta = \alpha - \gamma$$

NUMERICAL INDEX

NUMERICAL INDEX (Continued)

NUMERICAL INDEX (Continued)

NUMERICAL INDEX (Continued)

FIGURES

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