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CF.105 BROCHURE FC.

FLYING CONTROLS SYSTEM

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[redacted]

COPY #24

MEMORANDUM

2130-2-6 (DRDA 8)

20 Nov 86

DSIS 3

DOWNGRADING OF AVRO ARROW REPORTS

Reference: 2130-2-6 (DSIS-3), dated 14 Nov 86

1. As requested in the reference, the following two AVRO reports have been reviewed:

a. Periodic Performance Report 1B - Performance of the Arrow 2

b. Brochure FC - Flying Control System

2. This review revealed that the reports do not contain sensitive information and they have been declassified.

C. L. Gardner

C.L. Gardner
DRDA 8
995-7714

Enclosures: (2)

QCX Avro C-105 Misc-15 | U

Brochure F.C. Description of Flying Control System
for CF 105 Supersonic All Weather Fighter.
Rose.
June 1, 1955.

NONE | copy-1

[redacted]

ILL. (Req.)
Give to Gerry P.
25¢. 9 MG 7953 | DEC 02 1986

QCX Avro CF105 Misc-15 | U

Brochure F.C. Description of Flying Control System
for CF 105 Supersonic All Weather Fighter.
Rose.
June 1, 1955.

NONE | copy-1

[redacted]

ILL. (Req.)
Give to Gerry P. ✓
25¢. 9 MG 7953 | DEC 02 1986

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AVRO AIRCRAFT LIMITED

MALTON ONTARIO

ANALYZED

BROCHURE F.C.

DESCRIPTION OF

FLYING CONTROL SYSTEM

FOR

CF 105

SUPERSONIC ALL WEATHER FIGHTER

CONSISTS OF 120 PAGES

UNLIMITED

COMPILED BY H. H. Rose. APPROVED BY

DATE June 1st / 1955 DATE 1/6/55

CHECKED BY RELEASED BY

DATE June 1st 1955 DATE 1st June 55

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4. DETAILED DESCRIPTION OF SYSTEM (Continued)

4.11 Rear Fuselage Quadrants

4.12 Feel and Trim Units

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4.15 Actuator Valves

4.16 Control Surface Actuators

4.17 Mechanical Connections Between Jacks and Control Surfaces

4.18 Control Surfaces

4.19 Speed Brake

5. MAINTENANCE REQUIREMENTS

6. APPENDIX I - quotes verbatim the applicable sections in the following documents and requirements manuals.

1. AIR 7-4
2. CAP 479
3. ARDCM 80-1
4. 1815 - B

7. APPENDIX II - Comments on the points in which detail design varies from the requirements of Appendix I and outlines the reasons for the variation.

8. APPENDIX III - provides an equipment list.

INDEX OF ILLUSTRATIONS

INDEX OF ILLUSTRATIONS (Continued)

1. INTRODUCTION

1.1 A fully powered flying control system has been selected for the CF105 because:

1.1.1 It appears to be the only practical solution to the operation of such large chord, highly loaded, control surfaces as are employed on the airplane.

1.1.2 Any other non irreversible type of system would require that the control surfaces be mass balanced, and in view of the large chord surfaces used this would involve a prohibitive weight penalty.

1.1.3 Any type of aerodynamically assisted control system employing geared tabs, etc., is ruled out because of the unpredictable and variable nature of supersonic airflow as far aft on the wing chord.

1.2 Having chosen a fully powered control system it is necessary that a standard of reliability comparable to a mechanical manual system be achieved. To this end, a system employing a minimum number of reliable actuators has been selected, and complete duplication of power systems has been provided for.

1.3 An hydraulic power system has been selected because of its reliability, actuator compactness, system response, and performance under extreme environmental pressure and temperature conditions. (Ref Brochure H-1, Description of Flying Control Hydraulic System).

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1. INTRODUCTION (Continued)

1.4 Because of the large power requirements for control of the aircraft the hydraulic power is derived from engine driven pumps, one half of each flying control hydraulic system being driven from each engine.

This arrangement provides for full control forces at half max. rate during single engine operation, and thereby permits complete control during the most extreme asymmetric thrust conditions.

1.5 There are three modes of control of the aircraft, namely:

1.5.1 The manual mode: This primary mode of operation uses signals from pilot input force tranducers to control, through magnetic amplifier circuits, elevator and aileron command servos. These electro-hydraulic servos then operate the actuator cylinder control valves through short mechanical linkage systems.

During the command servo operation turn co-ordination is provided by the aircraft damping system and the associated electronic coupling networks.

Pilot "feel" during this mode may be produced in any form found desirable, as it is comparatively simple to design a network which will produce as elaborate a feel system as may be desired, taking into account stick force/g, dynamic pressure on the control surfaces, stick position, stick rate, etc.

1. INTRODUCTION (Continued) CONFIDENTIAL

1.5 (Continued)

1.5.2 The automatic flight mode: In this mode signals are received from either ground control guidance stations or the aircraft fire control system, and are fed by the automatic flight control system as signals to the command servos, to be transformed as in 1.5.1 to control surface movements.

1.5.3 The emergency mode: This mode is provided for use in the event of failure of the primary stick force mode, and involves a conventional cable and mechanical linkage system to directly control the surface actuator valves. To provide the pilot with adequate control system "feel" during this mode, stick forces are produced by positional feel springs and an elevator stick force per "g" bob-weight. Rudder pedal forces are developed through a similar positional feel spring, the effective spring constant of which is variable with q_c. This latter feature is a requirement to prevent the pilot from inadvertently applying high side loads to the fin during supersonic flight.

1.6 Artificial damping system: Artificial damping is provided about all three axis by a rate gyro system, feeding through a scheduling network to differential servos which supply signals to the actuator control valves by differential

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1. INTRODUCTION (Continued)

1.6 (Continued)

movement of the pilots input linkage. This system is operative only during the two normal modes 1.5.1 and 1.5.2, and therefore there is no force feedback to the stick to make the pilot aware of the damping system operation. In the event of system failure both automatic and manual means of shutting the system off are provided.

1.7 Speed Brakes are supplied for subsonic use and are controlled manually by a selector switch and operated by two hydraulic jacks as shown in Fig. 17. In the interest of reliability of the Flying Control System, the brakes are powered by the Utility Hydraulic System (Ref Brochure H-2).

1.8 BROCHURE LAYOUT

The flying controls are subsequently described in greater detail under the following headings:-

2. Design Objectives
3. Modes of Control and Auto Stabilizer
4. Detailed Description of System
5. Appendix 1
6. Appendix 2
7. Appendix 3
8. Maintenance Requirements

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2. DESIGN OBJECTIVES

2.1 GENERAL

2.1.1 To provide a fully power operated flying control output system for the operation of the primary control surfaces, consisting of elevator, aileron and rudder.

2.1.2 To provide a fully power operated output control system, utilizing power from the Utilities Hydraulic System, for the operation of the speedbrakes.

2.1.3 To provide a primary system of controlling the surface actuators which will take full advantage of the features of the automatic flight control system to produce the most desirable pilot feel and response characteristics. Such a system is to sense input stick forces and transmit the signals via magnetic amplifier networks to the command servos, thereby ensuring high response and permitting the simulation of the most elaborate feel requirements.

2.1.4 To provide a standby system of controlling the surface actuators by utilizing a conventional mechanical input system and a simple artificial feel installation, which is to provide adequate stick force per unit stick displacement and stick force per "g" relationships.

2.1.5 To achieve a very high degree of reliability of the primary flying control system by utilizing a completely independent, duplicated hydraulic power system, and by duplicating the input system as outlined in 2.1.3 and 2.1.4.

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2. DESIGN OBJECTIVES (Continued)

2.1 GENERAL (Continued)

2.1.6 To provide a control system which will give full rate operation at a soaked temperature of 0°F and limited performance at -20°F. The system is to be capable of being rapidly warmed up from -65°F to operating temperature by pilot's input to the control system with the pumps running. See Fig. 33 for graph of time required to warm-up.

2.1.7 To restrict nominal operating temperature to a maximum of 250°F, and local hot-spots to 275°F, by the use of heat exchangers in the hydraulic circuits (Ref Brochure H-1) to permit the use of proven sealing methods and materials in the construction of the actuators.

2.1.8 To provide cable system tension regulation, by the use of mechanical tension regulators, to compensate for the effects of temperature changes and structural deflections.

2.1.9 To provide a primary flying control system capable of accepting command signals from an electronic fire control system or from other electronic navigation and flight control aids.

2.1.10 To provide a primary flying control system capable of accepting signals from an electronic damping system in order to operate the control surfaces differentially to the pilot's and command input system.

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2. DESIGN OBJECTIVES (Continued)

2.1 GENERAL (Continued)

2.1.11 To provide, in the case of the standby rudder input system, a feel system which will prevent the pilot from inadvertently applying large rudder deflections at high equivalent air speeds.

2.1.12 To provide a system which will produce adequate control during an asymmetric flying case, resulting from failure of an engine at any speed or altitude condition within the flight envelope.

2.1.13 To provide a mechanical system of adequate stiffness, free from structural feedback, and effectively mass balanced, to preclude the possibility of spurious signals being transmitted to the control valves.

2.1.14 To provide a system which will meet the requirements of:

(a) AIR 7-4 Specification for Prototype Supersonic All-weather Interceptor Aircraft, Type CF-105.

(b) CAP 479 Aircraft Design Requirements for the Royal Canadian Air Force.

(c) ARDCM 80-1 Handbook of Instructions for Aircraft Designers.

(d) Publications and specifications referred to by the above publications (Ref. Appendix 1).

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2. DESIGN OBJECTIVES (Continued)

2.2 ELEVATOR SYSTEM

2.2.1 To provide an elevator movement of 30° up and 20° down at a max. rate of 40°/sec at a max. hinge moment of 60,000 ft. lbs. per surface.

2.2.2 To provide the elevator pitch dampers movement authority of $\pm 6^\circ$ for any position of the elevator within the limits allowed by full travel.

2.3 AILERON SYSTEM

2.3.1 To provide an aileron movement of 19° up and 19° down at a max. rate of 35°/sec at a max. hinge moment of 25,000 ft. lbs. per surface.

2.3.2 To provide the aileron roll dampers movement authority of $\pm 7.5^\circ$ for any position of the aileron within the limits allowed by full travel.

2.4 RUDDER SYSTEM

2.4.1 To provide rudder movement of $\pm 30^\circ$ at a max. rate of 40°/sec at a max. hinge moment of 12,000 ft. lbs.

2.4.2 To provide the rudder movement yaw damper authority of $\pm 10^\circ$, for any position of the rudder, within the limits allowed by full travel.

2.4.3 To achieve the yaw damping requirement of para. 2.4.2 by the use of a duplicated signalling and power system, with automatic and instantaneous "switch over" from the normal to the emergency system in the event of a system failure.

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2. DESIGN OBJECTIVES (Continued)

2.5 SPEED BRAKES - SYSTEM

2.5.1 To extend, retract, or hold the speed brakes at any position by hydraulic actuation at airspeeds up to Mach. 1.0.

2.5.2 To provide a throttle mounted speed brake control switch which will:

2.5.2.1 Extend the speed brakes upon being moved against a spring load to the SPEED BRAKE EXTEND position, until airloads balance hydraulic input force, or until the selector switch lever is released.

2.5.2.2 Hold the speed brakes in any position on being released from SPEED BRAKES EXTEND to HOLD position, providing that the airloads on the speed brakes are not increased.

2.5.3 To provide overspeed relief within the speed brake selector valve, so that increasing airloads will cause extended speed brakes to "blow in" until a new pressure-airload equilibrium is reached.

2.5.4 To provide a control which prevents operation of the speed brakes at speeds in excess of Mach. 1.0.

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3. MODES OF CONTROL

3.1 MANUAL MODE (OR STICK FORCE MODE)

3.1.1 GENERAL

This mode of operating the flying control surfaces utilizes the same amplifiers as the automatic flight control system as a means of transmitting pilot input signals at the stick to the slide valves controlling the surface hydraulic servo actuators. Such a system readily allows for pilot "feel" and system response characteristics to be scheduled with altitude, acceleration, and Mach No. as may be desirable.

Because of the irreversibility of the command (parallel) servos, which transmit the stick electrical signals as motion to the main control valves, force feedback from the action of the differential servos of the artificial damping system is not transmitted to the stick, and the pilot is therefore completely unaware of their operation.

3.1.2 OPERATION (Ref Figs. 1 & 2)

To describe the principle of operation of this mode of signalling the surface actuator control valves, the elevator system will be first considered separately. The stick, on being moved by the pilot, will be loaded through the cable system by the parallel servo, see fig. 2, the hydraulic resistance of which the pilot is attempting to overcome. This force on the stick will induce deflections in the linkage, which are

3. MODES OF CONTROL (Continued)

3.1 MANUAL MODE (Continued)

3.1.2 OPERATION (Ref Figs. 1 & 2) (Continued)

used to signal a sensitive electrical transducer. The transducer signals are then transmitted to the appropriate command servo magnetic amplifiers, from which control signals are sent to the electro-hydraulic command (parallel) servos to energize them in a manner which will cause them to move in a direction which will unload the forces in the pilots stick, that is, reduce the error between the input signal and the output signal. In reducing this error to zero the parallel servos displace the main control actuator valves, through a linkage system, by the exact amount desired by the pilot, and in doing so cause the surface to move as required.

Within the damping system electronic circuits provision is made for generating signals which will result in pilot sensing constant force per "g" independent of flight condition, and the most desirable stick position force for special conditions (e.g. take-off).

During this mode of operation, to ensure that the mechanical standby input feel system is always in trim in the event of failure of the normal control

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3. MODES OF CONTROL (Continued)

3.1 MANUAL MODE (Continued)

3.1.2 OPERATION (Ref Figs. 1 & 2) (Continued)

system, the clutch of the trim brake of the spring feel system is energized to allow it to free wheel, and thereby ensure that the springs are always unloaded. On failure of the normal system, the trim brake clutch is released and the pilots feel system is automatically trimmed as of the instant of failure.

The operation of the aileron system is similar to the elevator system.

There is no similar system in the rudder circuit because the function of the rudder is turn co-ordination, and this is handled by the damper differential servos on signals from both the A.F.C.S. and the manual mode.

Intentional yawing of the aircraft is achieved by pushing the rudder with sufficient force to overcome a force switch, which will disengage the turn co-ordination circuit and allow the mechanical input system to displace the surface.

3.2 AUTOMATIC FLIGHT MODE

3.2.1 The automatic flight mode substitutes signals from ground and airborne navigation aids, or the fire

3. MODES OF CONTROL (Continued)

3.2 AUTOMATIC FLIGHT MODE (Continued)

3.2.1 control system for stick force signals. These are transmitted to the A.F.C.S., and the same circuits as outlined in 3.1.2 are then employed to cause the parallel servos to produce movement of the control surfaces. Pilot over-ride is achieved by imposing forces at the stick which will overpower the relief setting of the parallel servo. (Ref. para. 4.13).

3.3 EMERGENCY CONTROL MODE

3.3.1 The mechanical manual control mode is considered to be the standby one for use on failure of the electro-hydraulic normal mode described in 3.1 Reversion to it is automatic on failure of the normal mode and it is inferior to the normal mode to the extent of its less elaborate feel system and its emergency damping system which is restricted to the yaw axis only.

3.3.2 The mechanical manual control mode operates through cables and mechanical linkages to convey pilot movement of control column and rudder bar to the appropriate control surface actuator valves.

3.3.3 Identical tension regulator quadrants for each control run, situated under the cockpit floor, are driven by control column and rudder pedal movement and convey this movement by cable to an elevator quadrant and aileron quadrant situated in the rear fuselage, and to a rudder quadrant situated in the fin.

3. MODES OF CONTROL (Continued)

3.3 EMERGENCY CONTROL MODE (Continued)

3.3.4 The position for the introduction of the elevator and aileron command (parallel) servos into the mechanical system is at the rear fuselage quadrants as mentioned in para. 4.11., and from this point onwards all movement is mechanical and utilizes the appropriate automatic damping servo rod ends as fulcrum points for final movement of the servo control valves.

3.3.5 The rear fuselage elevator quadrant is connected, below the bottom surface of the wing, by push rods to the bell cranks at the elevator jack pivot points. The other arm of each bell crank, which is inside the wing, is connected to the centre of the main lever of the elevator jack follow-up mechanism and the valve is operated through this mechanism as described in section 3.3.8.

3.3.6 The rear fuselage aileron quadrant is connected, below the bottom surface of the wing, by push rods to the inner wing tension regulator quadrant levers. Movement is then conveyed from this quadrant by cables, along the rear face of the rear spar and close to the neutral axis, to the quadrant at the aileron jack pivot point. The quadrant at the aileron jack pivot point is also connected by push rod to the centre of the main lever of the aileron jack follow-up mechanism in the same manner as for the elevator.

3. MODES OF CONTROL (Continued)

3.3 EMERGENCY CONTROL MODE (Continued)

3.3.7 The rudder quadrant in the fin is connected by push rod to a bell crank at the rudder jack pivot point, and the other arm of the bell crank is connected by push rod to the centre of the main lever of the rudder jack follow-up mechanism in the same manner as for elevator and aileron.

3.3.8 The follow up mechanism is similar for elevator, aileron and rudder jacks and primary movement of the main lever is effected by movement of the push rods connected at its centre as described in previous paragraphs. The main lever pivots about an inboard extension of the jack piston rod so that actuation of the jack induces the follow-up motion. The other end of the main lever is connected by push rod to the valve operating lever which pivots about an end fitting on the differential servo piston rod and is connected at its other end to the end of the valve spool. Primary movement of the main lever therefore effects movement of the valve operating lever and so displaces the valve spool. The jack is displaced accordingly until the follow-up process induced by secondary movement of the main follow-up lever closes the valve again at the required control surface deflection. By pivoting the valve-operating lever on the end of the differential servo piston rod the

3. **MODES OF CONTROL** (Continued)

3.3 **EMERGENCY CONTROL MODE** (Continued)

3.3.8 (Continued)

valve position may be modified by differential movement from the damping servo during the electrical modes to achieve the required artificial damping.

3.3.9 Displacement of the jack is conveyed from the outboard end of the piston rod by a bell crank and push rod system described in section 4.17 to the control surfaces.

3.3.10 Artificial feel for the emergency mode is built into each system by the use of spring-loaded feel units. The aileron unit is situated at the quadrant under the cockpit floor, the elevator unit is at the rear fuselage quadrant, and the rudder unit is at the quadrant in the fin. The rudder quadrant feel unit also supplies hinge moment limitation.

The artificial feel units are described in section 4.12.

3.4 **AUTO STABILIZER** (See Figs. 2 & 3)

3.4.1 All modes of control are affected by the artificial damping system.

3.4.2 These signals are transmitted to the differential servos situated at each jack.

As the differential servo pistons act as the pivots for the levers connected to the actuator valves, as mentioned in 3.3.8, in response to these continuous damping signals the actuator valves, and consequently the actuators and control surfaces, are continuously adjusted to suit the aircraft stability requirements.

4. DETAILED DESCRIPTION

4.1 HYDRAULICS (See Brochure H-1 "Description of Flying Control Hydraulic System")

4.1.1 PRESSURES AND TEMPERATURES OF THE SYSTEM

Normal Operating Pressure	=	4,000 p.s.i.
Proof Pressure	=	6,000 p.s.i.
Bursting Pressure	=	10,000 p.s.i.
Normal System Return Pressure	=	100 p.s.i.
Max. Operating Temperature	=	275°F
Min. Operating Temperature	=	-65°F

4.1.2 The system consists of two pumps per engine with one pump from each providing fluid under pressure for the "A" system and the other pump supplying the "B" system.

4.1.3 The hydraulic control surface actuators are of the tandem dual piston and cylinder type, each piston being supplied by its completely independent system.

4.1.4 In the event of a single engine failure the pressure of each system is maintained at half flow capacity which is adequate for a limited capability not involving maximum rate of movement of control surfaces.

4.1.5 In the event of the loss of a single hydraulic system maximum rates of control surface movement are obtainable at one half the maximum hinge moment.

Under this condition the aircraft is limited by

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4. DETAILED DESCRIPTION (Continued)

4.1 HYDRAULICS (Continued)

4.1.5 (Continued)

available "g" throughout most of the flight envelope but otherwise the pilot would note no difference in performance.

4.1.6 The double differential servo unit which actuates the rudder jack valve consists of two integral units, one of which is supplied by the "A" hydraulic system for normal operation, and the other by the "B" system for emergency operation.

Similarly the complete electrical and electronic signalling network is duplicated because of the vital nature of the yaw axis damping.

4.1.7 The elevator and aileron differential servo units, which actuate the jack valves for damping purposes, are supplied by the "B" hydraulic system only.

4.1.8 The command (parallel) servos, which actuate the jack valves on receipt of signals from the stick force system or the A.F.C.S. are supplied by the "B" hydraulic system only.

4.1.9 The system is designed for full rate operation at a soaked temperature of 0^{o}F., and will give limited capability at -20^{o}F.

4. DETAILED DESCRIPTION (Continued)

4.1 HYDRAULICS (Continued)

4.1.9 (Continued)

The system may be warmed up to these operating conditions by manual movements of the cockpit flying controls during engine running within the times shown on figure 33.

4.2 CONTROL COLUMN (See Fig. 8)

4.2.1 The control column which is located at station 155.26, is of the conventional stick type, and operates the tension regulator quadrants under the cockpit floor through a lever system.

4.2.2 Max. Stick Travel at grip for Elevator movement = 11.0 ins.

Max. Stick Travel at grip for Aileron movement = 10.0 ins.

Pilot Limit Load at grip for Elevator movement = 200 lbs.

Pilot Limit Load at grip for Aileron movement = 100 lbs.

4.2.3 Trim control of the artificial stick force is by means of a thumb button control on the grip, which electrically releases the earthing point of the appropriate feel spring and allows it to unload. (see 4.12.)

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4. DETAILED DESCRIPTION (Continued)

4.3 RUDDER PEDALS (See Fig. 9)

4.3.1 The rudder pedals are suspended from an overhead hinge point at station 134.25 and are connected by push rods to the rudder bar which pivots about a torque tube passing through the cockpit floor. The torque tube is connected at its other end to the rudder tension regulator quadrant.

4.3.2 Total Rudder Pedal Travel = 6.65 ins.

Pilot Limit Load = 300 lbs.

4.4 TENSION REGULATORS UNDER COCKPIT FLOOR (See Fig. 22 & 10

4.4.1 The cable tension regulators used for each control axis cable system in their run aft to the rear fuselage quadrants and fin quadrant, are identical, and are located under the cockpit floor as shown in Fig. 1 & 10. For information on the cable run aft from the tension regulators see section 4.10.

4.4.2 Tension Regulator Diameter (to cable centres) = 12.0 ins.

Range of compensation = $2\frac{1}{2}$ ins per cable

Rig load variation for full range of compensation = 40 lbs. min. / 60 lbs. max.

4. DETAILED DESCRIPTION (Continued)

4.4 TENSION REGULATORS UNDER COCKPIT FLOOR (Continued)

4.4.3 THE ELEVATOR TENSION REGULATOR QUADRANT (See Fig. 10) is supported on a horizontal axis at station 168.25 and displaced 16 ins to the R.H. side of the A/C centre line.

The quadrant is supported by mounting brackets secured by eight bolts to two short fore and aft beams under the cockpit floor and is mounted on a torque tube 14 3/4" below the fuselage datum. The quadrant is driven by a 3.50 ins. lever mounted on the inboard end of the torque tube and connected by push rod to a crank on the control column.

A 3.7 lbs bob weight is also supported from this torque tube on a 7.0 ins lever arm as described in 4.6. The elevator stick force transducer is located on the torque tube between the bob weight and quadrant as described in 4.7.

4.4.3.1 Angular movement of elevator quadrant = 60° total

Total cable movement = 6.283 ins.

4.4.4 THE AILERON TENSION REGULATOR QUADRANT (See Fig. 10) is supported on a vertical axis, situated at station 158.77, 4.25 ins to the left of the A/C centre-line and 10 3/4 ins. below the aircraft datum, by a mounting built integrally with the control column

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4. DETAILED DESCRIPTION (Continued)

4.4 TENSION REGULATORS UNDER COCKPIT FLOOR (Continued)

4.4.4 (Continued)

mounting structure.

The quadrant is supported at the lower end of a torque shaft which passes through the cockpit floor. The upper end of the torque shaft carries a 3.60 ins. lever which is connected by a short push rod to the control column. (total push rod travel = 3.19 ins.)

A 3.74 ins radius lever attached to the same shaft carried the aileron spring feel unit and is located 8.83 ins below the A/C datum. The aileron spring feel unit is described in section 4.12.2.

4.4.4.1 Angular movement of aileron quadrant = $\pm 23^\circ - 39'$

Total cable movement = 4.953 ins.

4.4.5 THE RUDDER TENSION REGULATOR QUADRANT (See Fig. 10) is a horizontal quadrant situated at station 126.6 and supported on the rudder pedestal 9.75 ins below the fuselage datum.

This quadrant incorporates the pedal force switch of the turn coordinator over-ride circuit as described in 4.9.

4. DETAILED DESCRIPTION (Continued)

4.4 TENSION REGULATORS UNDER COCKPIT FLOOR (Continued)

4.4.6 Angular movement of quadrant = $\pm 20^\circ$

Total cable movement = 4.189 ins.

4.5 AILERON TENSION REGULATOR - INNER WING (See Figs. 23 & 13)

4.5.1 The tension regulator in the aileron wing cable run (see section 4.10.7) is situated at station 692.79 and 14.50 ins outboard of A/C centre line.

The quadrant transfers a total movement of 3.26 ins from the rear fuselage system to the wing cables by means of a shaft passing through the bottom surface of the wing. The lower end of the shaft is connected by a lever and push rod to the rear fuselage quadrant.

4.5.2 Tension regulator diameter = 5.65 ins.

Range of compensation = 1.28 ins.

Rig load variation for full range of compensation = 40 lbs. min. / 60 lbs. max.

4.6 BOB WEIGHT (See Fig. 10)

The purpose of the bob-weight mentioned in 4.4.3 is to supplement the feel springs to provide some natural feel proportional to "g" in the pitching plane. The effect, of aircraft normal acceleration on it, is to produce an opposing force at the stick grip of 3 lbs/"g" which, when added to the positional feel of the spring system, develops a total pilot feel of 10 lbs/"g" min.

4. DETAILED DESCRIPTION (Continued)

4.7 ELEVATOR STICK FORCE TRANSDUCER (See Fig. 4)

As explained in section 3.1, the purpose of the elevator stick force transducer is to translate pilot input load at the stick into electrical signals for transmission, via the magnetic amplifier circuit, to the elevator command servo.

The transducer is of the differential transformer type and is installed on the elevator quadrant torque tube so as to sense the resultant of pilot and bob-weight input force.

4.8 THE AILERON STICK FORCE TRANSDUCER

This is of the same type as that used in the elevator system and is located at the base of the control column. Its function is similar to that of the elevator system unit.

4.9 PEDAL FORCE SWITCH (See Fig. 5)

The purpose of this force switch is to cut out the electrical circuit providing turn coordination between rudder and aileron and thus allow the pilot to over-ride to produce intentional side slip.

This is achieved upon the application of a minimum asymmetric rudder pedal load of approx. 50 lbs. to cause the switch, which is mounted on the tension regulator quadrant, to be tripped.

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4. DETAILED DESCRIPTION (Continued)

4.10 CABLE SYSTEM (See figs. 1,4,9,5 & 6)

4.10.1 The main cable run connects the tension regulator quadrants under the cockpit floor (see section 4.4) with the elevator and aileron quadrants in the rear fuselage (see section 4.11) and with the rudder quadrant and "feel" system in the fin. (see section 4.12.4) There is also a cable run in the wing, transferring movement from the rear fuselage aileron quadrant by way of a tension regulator in the wing (see section 4.5) out to the aileron jack quadrant.

4.10.2 All cables are 1/8 in. dia. to spec. MIL-C-1511. They are aluminum clad to .201" dia. over as great a length as possible in order to reduce elastic stretch, and to increase their overall co-efficient of expansion to a value more near that of the airframe structure.

4.10.3 The following table gives the percentage of bare and clad cables to total length together with cable movements:

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4. DETAILED DESCRIPTION (Continued)

4.10 CABLE SYSTEM (Continued)

4.10.3 (Continued)

CABLE	TOTAL LENGTH INS	% TOTAL LENGTH		TOTAL CABLE MOVEMENT INS.	TOTAL TENSION REGULATOR COMPENSATION INS.
		BARE	ALUMINUM CLAD		
Elevator	1047.6	24.0	76.0	6.283	2.5
Aileron (Fuselage)	1081.9	19.0	81.0	4.95	2.5
Aileron (Wing)	828.24 (2)	23.0	77.0	3.26	1.28
Rudder	1301.2	16.5	83.5	4.189	2.5
Overall	4258.94	20%	80%		

4.10.4 All cable end fittings are swaged ball ends which fit into sockets at the end of the cable groove on the quadrants. The ball ends are locked in the sockets by means of cotter pins fitted to the sockets.

4.10.5 Adjustment of all cables is provided for by the use of turnbuckles which, in the case of the main cable runs, are located in the armament bay area between station 285 and station 485. A minimum of 1/4 inch longitudinal clearance is provided between turnbuckle ends.

4.10.6 The main cable run is carried between quadrants by a total of 32 pulleys and these are distributed as follows:

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4. DETAILED DESCRIPTION (Continued)

4.10 CABLE SYSTEM (Continued)

4.10.6 (Continued)

STATION NO.	NO. OF PULLEYS & LOCATION FROM ℄					
	ELEVATOR		AILERON		RUDDER	
	PORT	STAR	PORT	STAR	PORT	STAR
187	-	-	-	-	-	1
187.3	-	-	-	-	1	-
188.45	-	-	1	-	-	-
188.8	-	-	1	-	-	-
194.2	-	1	-	-	-	-
228	-	1	2	-	1	1
281	-	2	2	-	1	1
485	-	2	2	-	1	1
520	-	2	2	-	1	1
588	-	-	-	-	1	1
619.93	-	1	-	-	-	-
642	-	-	1	-	-	-

The main cable run aft from the front fuselage tension regulator quadrants is as follows:-

From the tension regulator quadrants to stations 228 the cables run close under the cockpit floor. Rising between station 228 and 281 they then run close under the armament bay roof to station 485. Rising again between station 485 and 520 they run aft close under the lower wing surface. The rudder cables change direction at station 588 and run up into the fin through ½ ins. dia tubes to the rudder feel unit and hinge moment limitation quadrant. The elevator and aileron cables continue on under the lower wing surface to attach to the rear fuselage quadrants.

4. DETAILED DESCRIPTION (Continued) CONFIDENTIAL UNCLASSIFIED

4.10 CABLE SYSTEM (Continued)

4.10.7 THE WING CABLE RUN

The wing cable run between the wing tension regulator and aileron jack quadrant is carried by 4 pulleys positioned along the aft face of the rear spar of each wing. They are distributed spanwise as follows:

1 pulley centred 1.35" inboard of T.E. Rib. #1 intersection with R/S datum

1 pulley centred 1.50" inboard of T.E. Rib #5 intersection with R/S datum

1 pulley centred 1.40" inboard of T.E. Rib. #5A intersection with R/S datum

1 pulley centred 2.20" inboard of T.E. Rib #6 intersection with R/S datum

4. DETAILED DESCRIPTION (Continued)

4.11 REAR FUSELAGE QUADRANTS (See Figs. 4 & 5)

The rear fuselage quadrants transfer elevator and aileron cable movement from the main run in the fuselage (see section 4.10) out to the control surface actuator systems in the wing.

4.11.1 THE ELEVATOR REAR FUSELAGE QUADRANT (See Fig. 11) is supported on a horizontal torque tube at station 675.75, 19.58 ins. above aircraft datum.

A push rod connects the quadrant with the R.H. elevator jack pivot point bell-crank.

A similar push rod connects the L.H. elevator jack pivot point bell-crank with a lever on the opposite end of the torque shaft.

This quadrant is the position at which both the elevator command (parallel) servo see 4.13.2 and and the elevator feel unit see 4.12.2 are introduced to the elevator system.

The total angular movement of the quandrant is 60° and with a diameter of 10.70 ins. (cable centre) this caters for a total cable movement of 6.283 ins.

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4. DETAILED DESCRIPTION (Continued)

4.11 REAR FUSELAGE QUADRANTS (See Figs. 4 & 5)

4.11.2 THE AILERON REAR FUSELAGE QUADRANT (See Fig. 11)

This is situated on the centre line at station 682.85 close under the bottom surface of the wing and on an axis normal to it.

Push rods between levers connect the quadrant with the aileron tension regulators in the wing.

This quadrant is the position at which the aileron command (parallel servo) is attached see 4.13.3.

The total angular movement of the quadrant is 60° and with a diameter of 9.129 ins. (cable centres) this caters for a total cable movement of 4.95 ins.

4.12 FEEL AND TRIM UNITS (See Figs. 4 & 5)

The feel units of the elevator, aileron and rudder systems are essentially positional springs of a suitable spring constant earthed to the fixed structure through an electrical trimming device. In addition, the rudder system employs a mechanical system to vary the bungee effective spring constant with q_c in order to restrict the pilot's input as a function of the compressible dynamic pressure.

4. DETAILED DESCRIPTION (Continued)

4.12 FEEL AND TRIM UNITS (Continued)

The trimming units consist of a small gear box driving a centrifugal friction damper capable of being locked in any position by a spring loaded and solenoid released disc type brake.

On energising the trim system the spring loaded brake is overpowered by the solenoid permitting the gear chain to free-wheel under the low forces from a practically unloaded feel bungee. The rate at which the unit may free-wheel is controlled by the centrifugal friction damper thereby preventing a compressed spring from unloading too rapidly.

4.12.1 THE ELEVATOR FEEL UNIT (See Fig. 24)

This is connected to the rear fuselage elevator quadrant and is earthed to the fuselage support yoke at station 697.38 by the electrical trim unit, (see fig. 11). The unit has been positioned as near to the elevator actuator control valves as is practical in order to minimise the effect of cable elasticity and backlash on system response when operated on the mechanical mode. Experience on fully powered elevator systems has indicated that this type of arrangement is desirable.

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4. DETAILED DESCRIPTION (Continued)

4.12 FEEL AND TRIM UNITS (Continued)

4.12.1 THE ELEVATOR FEEL UNIT (Continued)

The trim range forward is 33% of full forward stick movement and the trim range aft is 60% of full aft stick movement.

For trim forces under non accelerated flight see the graph in the system loads column on Fig. 4A.

4.12.2 THE AILERON FEEL UNIT (See Fig. 25)

This is connected to the aileron tension regulator quadrant under the cockpit floor and is earthed to the bulkhead at station 176 by the electrical trim unit (see fig. 10).

This location is a practical compromise between system performance and system weight. It would have been possible to have installed the unit adjacent to the rear fuselage aileron quadrant similar to the elevator system installation but such an arrangement would have still left a substantial length of cable between the feel unit and the control actuator valves and would have increased the serviceability problems in an already congested area. Experience on fully powered aileron system installations indicates that this type of installation will be acceptable for the mechanical mode of operation.

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4. DETAILED DESCRIPTION (Continued)

4.12 FEEL AND TRIM UNITS (Continued)

4.12.2 THE AILERON FEEL UNIT (Continued)

The aileron feel spring unit is of the positive break-out type, with a break-out stick force of 1.5 lbs. approx. The trim range is 40% of stick movement, symmetrical about the centre.

For trim forces see the graph in the system loads column on Fig. 5A.

4.12.3 RUDDER FEEL UNIT & HINGE MOMENT LIMITATION SYSTEM (See Figs. 26 & 15)

4.12.3.1 The rudder feel unit and hinge moment limitation system is installed in the rudder control system close to the rudder jack between fin ribs #4 and #5 and spars #7 and #9. At this position, the main rudder cable run (see section 4.10) transfers movement to the rudder jack valve linkage by means of a push rod connection between a cable quadrant and the bell crank lever at the jack pivot point. The rudder system feel and pilot hinge moment limitation is achieved by means of the mechanism shown in Fig.15,

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4. DETAILED DESCRIPTION (Continued)

4.12 FEEL AND TRIM UNITS (Continued)

4.12.3 RUDDER FEEL UNIT & HINGE MOMENT LIMITATION SYSTEM (Continued)

4.12.3.1 (Continued)

the power for driving the mechanism being supplied by the electric actuator acting on signals proportional to 'q_c'.

4.12.3.2 The diameter of the quadrant to cable centres = 6.0 ins., and this caters for a total cable movement of 4.189 ins. at an angular movement = $\pm 30^\circ$. The feel unit lever arm varies from 1.0 ins. radius to 8.35 ins. radius.

4.12.3.3 The reason for placing the feel and hinge moment limitation system as close to the rudder jack valve as is practicable is to ensure full movement of the rudder over the very small range available when the system is subjected to max. hinge moment limitation conditions.

Under these conditions displacement of the controls system is limited but deflection may be a maximum. Deflection in the part of the system between the feel

4. DETAILED DESCRIPTION (Continued)

4.12 FEEL AND TRIM UNITS (Continued)

4.12.3 RUDDER FEEL UNITS & HINGE MOMENT LIMITATION SYSTEM (Continued)

4.12.3.3 (Continued)

unit and rudder jack valve is reduced to a minimum by positioning these items close together, while the high deflection between the feel unit and rudder pedals is catered for by unrestricted rudder pedal movement.

4.12.3.4 Curves of rudder deflection v.s. pedal force with relation to 'q_c' are shown in Figs. 31 and 32.

4.13 PARALLEL SERVOS (See Figs. 4 & 5)

4.13.1 GENERAL

The parallel servo is an electro-hydraulic actuator which performs the function of moving the aircraft controls upon command from the stick force system or the A.F.C.S.

It consists of an hydraulic ram, a control valve, an engage and disengage valve and solenoid, trim switches, force-limiting valves and overpower valves.

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4. DETAILED DESCRIPTION (Continued)

4.13 PARALLEL SERVOS (Continued)

4.13.1 GENERAL (Continued)

The parallel servos are powered by the "B" hydraulic system and control the main elevators and aileron control valves through the mechanical control linkage in parallel with the pilot's mechanical system. They may be overpowered by the application of a predetermined force on the control stick. They can also be disengaged automatically or manually by electrically de-energizing the solenoids and upon disengagement the spring feel system is automatically left in trim.

4.13.2 THE ELEVATOR PARALLEL SERVO (See Fig. 11)

This is attached by its piston rod to the bottom part of the rear fuselage elevator quadrant. The pivot point is mounted forward of the quadrant on a bracket supported from the lower wing surface.

The servo is force limited to 150 lbs. and at an arm of 3 ins. exerts a max. moment of 450 lbs. ins. on the quadrant which may be overpowered by 60 lbs. at the stick grip.

4.13.3 THE AILERON PARALLEL SERVO (See Fig. 10)

This is attached by its piston rod to a lever on the rear fuselage aileron quadrant. The pivot

4. DETAILED DESCRIPTION (Continued)

4.13 PARALLEL SERVOS (Continued)

4.13.3 THE AILERON PARALLEL SERVO (Continued)

point is mounted aft of the quadrant on the fuselage support yoke at station 697.38.

The servo is force limited to 75 lbs. and at an arm of 3 ins. exerts a max. hinge moment of 225 lbs. ins. on the quadrant, which may be overpowered by 30 lbs. applied at the stick grip.

4.14 DIFFERENTIAL SERVOS (See Figs. 4 & 5)

The differential servo is a high response electro-hydraulic actuator which performs the function of differentially actuating the main control valve to apply artifical damping control. It consists of an hydraulic ram and an electric torque motor type control valve, a solenoid disengage valve, and a shaft lock and self centering spring, as required.

In the case of the elevator and aileron installations the units receive hydraulic power from the "B" hydraulic system through internal connections to the main control valve on which they are mounted directly.

Because of the critical nature of the rudder system its servo valve is a duplicated unit receiving hydraulic power from both the "A" and "B" hydraulic systems by similar internal connections to its main control valve. In the

4. DETAILED DESCRIPTION (Continued)

4.14 DIFFERENTIAL SERVOS (Continued)

non duplicated elevator and aileron units provision is made for spring self centering and shaft locking on shut-down of the servo electrical or hydraulic supply.

These units (for elevator and aileron) are identical, having an output force of 300 lbs. and a stroke of ±0.6 ins. The rudder unit, having a duplicated electrical and hydraulic system is not provided with the shaft-lock provision.

The standby electrical system is continuously in operation, and on failure of either the normal electrical or hydraulic power source the solenoid by-pass valve admits fluid to the standby side and by-passes the normal side.

This servo has a 300 lb. output force and a stroke of ±0.5 ins.

4.15 ACTUATOR VALVES (See Figs. 12, 14 & 16)

The actuator valves are of the double tandem type employing a common spool and two separate sets of pressure and return ports, one set each for the "A" and "B" hydraulic systems. They are mounted directly on the actuators with internally connected hydraulic systems between valve and actuator and provision is made for internal hydraulic connection between them and the differential servos which are mounted directly to them as outlined in 4.14.

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4. DETAILED DESCRIPTION (Continued)

4.15 ACTUATOR VALVES (Continued)

Interchangeability is provided between valves and actuators and valves and differential servos.

Control of the actuator valves is effected through the follow up mechanisms as described in 3.3.8.

Valve travels are as follows:

Elevator spool travel = ±.11 ins.
Aileron spool travel = ±.07 ins.
Rudder spool travel = ±.05 ins.

4.16 CONTROL SURFACE ACTUATORS (See Fig. 4 & 5)

4.16.1 GENERAL

The hydraulic control surface actuators are of the tandem dual piston and cylinder type with each piston supplied by a separate hydraulic system.

The use of high temperature flexible hose is avoided by the use of semi-coiled stainless steel line, which is adequate for the small amount of jack movement involved.

Flexible hose is used on the return lines of the elevator and aileron units only.

4.16.2 ELEVATOR JACK (See Fig. 18 & 12)

The root end of the jack pivots about a pre-loaded self-aligning bearing which is located 12.323 ins.

4.16 CONTROL SURFACE ACTUATORS (Continued)

4.16.2 ELEVATOR JACK (Continued)

outboard of the A/C centre-line at station 698.66. In order to facilitate removal of the jack through the access panel in the wing top skin this pivot point bearing is an interchangeable assembly bolted to the jack body. It is mounted on a support projecting from the fin box structure at the centre of the wing.

DATA

For curve of available max. static hinge moment see Fig. 27.

Static jack load at 4,000 p.s.i.	=	71,000 lbs.
Cylinder bore (max.)	=	4.19 ins.
Piston rod O/D (max.)	=	2.50 ins.
Working area (2 x 8.88)	=	17.76 $ins.^2$
Normal operating stroke	=	10.0 ins.
Total stroke	=	10.20 ins.

4.16.3 AILERON JACK (See Fig. 19 & 14)

The root end of the jack pivots about a universal joint which is located 5.5 ins. outboard of Rib 18 and 4.60 ins. aft of the centre spar. This universal joint utilizes four needle bearings and is mounted on a support which is attached to the wing skin and centre spar.

4. DETAILED DESCRIPTION (Continued)

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4.16 CONTROL SURFACE ACTUATORS (Continued)

4.16.3 AILERON JACK (Continued)

In order to facilitate removal of the jack through the access panel in the bottom skin the universal joint is an interchangeable sub-assembly bolted to the jack body.

DATA

For curve of max. static hinge moment see Fig. 28.

Static jack load	=	42,100 lbs.
Cylinder bore (max.)	=	3.125 ins.
Piston rod O/D (max.)	=	1.75 ins.
Working area (2 x 5.26)	=	10.5 $ins.^2$
Normal operating stroke	=	5.56 ins.
Total stroke	=	5.76 ins.

4.16.4 RUDDER JACK (See fig. 20 & 16)

The root end of the jack pivots about a pre-loaded self-aligning bearing which is located 10 ins. outboard of rudder station 42 and 2.75 ins. aft of spar #3. The jack is mounted on a support projecting from Spar #3 and Rib #4 and is removable through an access panel on the port side of the fin.

DATA

For curve of max. static hinge moment see fig. 29.

Static jack load	=	30,900 lbs.
Cylinder bore (max.)	=	2.75 ins.
Piston rod O/D (max.)	=	1.625 ins.
Working area (2 x 3.865)	=	7.73 $ins.^2$
Normal operating stroke	=	5.9 ins.
Total Stroke	=	6.10 ins.

4. DETAILED DESCRIPTION (Continued)

4.17 MECHANICAL CONNECTIONS BETWEEN JACKS & CONTROL SURFACES

4.17.1 GENERAL

The linkage from the end of the jack piston to the actual control surface is similar for all three systems. It consists of a long push rod, joined by a master bell crank to the fork end of the jack piston, and connecting a row of bell cranks which convey motion to the control surfaces by way of a link attachment.

The bell crank system is housed in the fin and wing trailing edge structure which extends from the rear spars to the hinge spars in the vicinity of the jacks.

4.17.2 ELEVATOR BELL-CRANK SYSTEM (See Figs. 1 & 4)

The elevator output system consists of the lateral push rod and six bell-cranks per side which are located aft of the wing rear spar between ribs #4 and #17. The bell cranks are aluminum alloy forgings, each housing a needle bearing at the pivot point and a pre-loaded self-aligning bearing at the push rod attachment. The master bell-crank contains an additional pre-loaded self aligning bearing at the jack piston fork-end pick up.

4. DETAILED DESCRIPTION (Continued)

4.17.2 ELEVATOR BELL-CRANK SYSTEM (Continued)

The assembly is supported at the pivot points by stiff forged aluminum alloy ribs which are attached to the rear spar and to the thick wing skins.

The lateral push rod is a one piece machining with a fork end at the master bell-crank pick-up and slots for the other bell-crank attachments.

The connecting links between the bell-cranks and elevator fittings are machined steel forgings and house a pre-loaded, self-aligning bearing at each end.

4.17.3 AILERON BELL-CRANK SYSTEM (See Figs. 1 & 5)

The aileron output system consists of seven bell-cranks and a push rod per side, all located aft of the wing rear spar between ribs #17 and #25 and supported at the pivot points by aluminum alloy ribs.

The bell-cranks are aluminum alloy forgings each housing a roller bearing at the pivot point and pre-loaded self-aligning bearings at the pick-up points.

4. DETAILED DESCRIPTION (Continued)

4.17.3 AILERON BELL-CRANK SYSTEM (Continued)

Each push rod consists of short lengths of steel tube flash welded to slotted steel fittings at the bell-crank pick-up points, and to a steel bearing housing at the master bell-crank pick-up point.

The connecting links between the bell-cranks and the aileron are machined steel forgings consisting of a fork end at the bell-crank pick-up point and a preloaded self-aligning bearing at the aileron attachment.

4.17.4 RUDDER BELL-CRANK SYSTEM (See Figs. 1 & 6)

The rudder linkage system is of similar detail design to that of the aileron except that it consists of a single push rod and only five bell-cranks all located aft of the fin spar #3 and outboard of rib #4.

The bell-cranks are supported at the pivot points by the integrally machined skin of the fin trailing edge structure.

4.18 CONTROL SURFACES

4.18.1 THE ELEVATOR

This surface is constructed of thin light alloy skin attached to formed light alloy ribs and an

4. DETAILED DESCRIPTION (Continued)

4.18 CONTROL SURFACE (Continued)

4.18.1 THE ELEVATOR (Continued)

extruded light alloy front spar.

Extruded integrally with the spar is one half of the elevator piano hinge, which runs along the leading edge on the upper surface.

The ribs at the control points are stiffened by the extrusions which attach to the connecting links from the bell-cranks.

DATA

Elevator area (2)	=	106.75 ft.^{2}
Elevator span (each)	=	10 ft. - 2 ins.
Elevator chord (constant)	=	5 ft. - 3 ins.
Elevator movement	=	30° up 20° down

4.18.2 THE AILERON

This is constructed similarly to the elevator but at each control point the complete rib is formed by the machined extrusion which picks up with connecting links from the bell-cranks.

DATA

Aileron area (2)	=	66.5 ft.^{2}
Aileron span (each)	=	10 ft.
Aileron chord	=	5 ft. - 3 ins. at root 1 ft. - 4.8 ins at tip
Aileron movement	=	19° up 19° down

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4. DETAILED DESCRIPTION (Continued)

4.18 CONTROL SURFACE (Continued)

4.18.3 THE RUDDER

This consists of light alloy skins attached to a formed light alloy spar and rib. It contains seven hinge points, all offset to the starboard side; the middle five, which form part of the ribs, support the bearings which pick-up with the connecting links from the bell-cranks. The bottom hinge point, which takes the vertical loads, and the top hinge point, are separate fittings which pick-up with oilite bearings in the fin.

DATA

Rudder area	= 38.85 ft.^{2}
Rudder height	≐ 10 ft. - 0.5 ins.
Rudder chord	= 5 ft. - 5.14 ins. at root 2 ft. - 3.7 ins. at tip
Rudder movement	= $\pm 30^\circ$

4.19 SPEEDBRAKES

4.19.1 GENERAL

The two speed-brakes are located in the bottom of the fuselage between frames at station 485 and 538.77, just aft of the armament bay.

Power for their operation is supplied by the Utilities hydraulic system (see brochure H-2).

4. DETAILED DESCRIPTION (Continued)

4.19 SPEEDBRAKES (Continued)

4.19.1 GENERAL (Continued)

The speedbrakes are controlled by a throttle lever mounted thumb button which opens or closes the electrical circuit to a solenoid operated hydraulic control valve.

A mach. over-ride is incorporated in the electrical circuit to prevent the brakes from being open during supersonic flight because of the adverse pitching moments they produce.

4.19.2 SELECTOR SWITCH AND VALVE (See Fig. 7 & 17)

The spring loaded three position switch on the pilot's inner throttle control lever which controls the operation of the speedbrakes at speeds below Mach. 1, is spring loaded from the "open" position to its mid or "hold" position. It may be moved through the hold position to select "close".

In the "hold" position the brakes are hydraulically locked in the position existing at the time of selection. In the "close" position the control valve solenoid is continuously energized and hydraulic pressure is applied in the corresponding direction.

4. DETAILED DESCRIPTION (Continued)

4.19 SPEEDBRAKES (Continued)

4.19.3 SPEEDBRAKE JACK (See Fig. 21)

There are two identical jacks situated 23.32 ins. outboard of, and each side of, the aircraft at station 517.

Each jack consists of a single cylinder and piston pivoted about a combined root end bearing and swivel hydraulic supply couplings.

DATA

Normal operating pressure	=	4,000 p.s.i.
proof pressure	=	6,000 p.s.i.
bursting pressure	=	10,000 p.s.i.
Static jack load	=	22,500 lbs.
Cylinder bore (max.)	=	2.875 ins.
Piston rod O/D (max.)	=	1.00 ins.
Working area (tension load)	=	5.70 ins.^{2}
Stroke	=	12.50 ins.

For curve of static hinge moment see Fig. 30.

4.19.4 SPEEDBRAKE SURFACES (See Fig. 1)

Construction of the speedbrake surface consists of two fore and aft beams, one at each edge, joined by transverse stiffeners supporting a .08 ins. thick magnesium alloy outer skin and a .064 ins. thick aluminum alloy inner skin.

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4. DETAILED DESCRIPTION (Continued)

4.19 SPEEDBRAKES (Continued)

4.19.4 SPEEDBRAKE SURFACES (Continued)

The hinge line is at the forward end and consists of oilite bearings supported in the fore and aft beams.

The inboard fore and aft beam is an aluminum alloy forging, with the operating lever at its forward end. The jack piston rod end attaches to this lever at a radius of 12½ ins. from the hinge line.

DATA

Width (each)	=	2 ft. - 2 ins.
Length	=	3 ft. - 3½ ins.
Area (total)	=	14.3 $ft.^2$

5. MAINTENANCE REQUIREMENTS

In the installation of the flying control system advantage has been taken of accessible areas, such as the nose wheel well, the armament bay and the fuselage equipment zones, for the mounting of all flying control units likely to require frequent inspection and maintenance. For equipment installed in the wing and fin structure adequate structural type access holes and quick release plugs are provided for the inspection and maintenance of the actuators and valves, tension regulators, filters, bell-crank bearings, cables and hydraulic fittings.

The output circuit linkages of the elevator, aileron and rudder systems are built-in to their respective trailing edge structures, and the complete units are removeable from the aircraft by undoing bolted joints. This is considered to be an adequate maintenance feature inasmuch as the complete units are designed to have a life of the same order as that of the basic aircraft structure. This life rating is being established by means of an extensive series of bearing tests and by operational and endurance tests of the complete installations.

APPENDIX 1

The flying control system is designed to meet the relevant sections of the following requirements as noted hereunder:

1. IN DOCUMENT AIR 7-4

2.4 DESIGN

2.4.1 The aircraft shall be designed in accordance with the Canadian Air Publication 479, "Manual of Aircraft Design Requirement for the Royal Canadian Air Force", the technical requirements of the United States Air Research and Development Command Manual No. 80-1, "Handbook of Instructions to Aircraft Designers", publications and specifications referred to therein and such additional requirements as may be specified by the Department and such deviations from these specifications and requirements as may be agreed between the Department and the Contractor. Where there is any conflict between the requirements of CAP 479 and those of USAF ARDCM 80-1, the former shall govern.

3.4 SCRAMBLE TIME

3.4.1 With the aircraft at normal gross weight and positioned at the end of the runway, the elapsed time from the pushing of the first button to start the first engine until the aircraft becomes airborne shall not be more than one minute.

APPENDIX 1

1. AIR 7-4 (Continued)

4.1 DESIGN REQUIREMENTS - GENERAL

4.1.4 The aircraft shall be designed such that the pilot can perform all the normal and emergency functions required to fly the aircraft without the assistance or presence of the second crew member.

4.4 SPEED BRAKES

4.4.1 Speed brakes shall be fitted to produce additional drag when opened. The controls shall be arranged such that the pilot can set the brakes at the fully opened, intermediate, or fully closed position. Actuation of the speed brakes shall have a minimum effect on the trim or attitude of the aircraft throughout the speed range of the aircraft.

4.6 PROTECTION FROM ENEMY FIRE

4.6.1 During the design of the aircraft special consideration shall be given to the building-in of invulnerability to enemy fire by the maximum use of such inherent types of protection as positioning of components, fuel and hydraulic lines and like items, providing such positioning does not result in unreasonable complication or weight penalty.

1. AIR 7-4 (Continued)

4.7 SERVICING AND STAND-BY

4.7.1 SERVICING

4.7.1.1 TURN-AROUND

The time required for "turn-around" shall not be more than 5 minutes. The turn-around operation shall include replenishment of all consumable stores and liquids and the required spot checking of equipment to bring the aircraft to a state of readiness such that it shall be capable of fulfilling its primary role as detailed in this specification.

4.7.1.2 Special servicing tools and ground handling equipment, subject to the prior approval of the Department shall be delivered concurrently with each aircraft.

4.7.2 STAND-BY

4.7.2.1 The aircraft shall be designed such that, once having been certified serviceable, it shall be capable of maintaining a state of immediate readiness for a period of at least 24 hours in the open.

4.7.2.2 Complete stand-by equipment required to meet the provisions of paragraph 4.7.2.1, subject to the approval of the Department shall be delivered concurrently with each aircraft.

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APPENDIX 1

1. AIR 7-4 (Continued)

7.4 AUTOMATIC CONTROL SYSTEM

7.4.1 Components of the type E10 autopilot suitably coupled to accept signals from the fire control system and navigation system shall be installed. The system shall provide three axis stabilization and shall automatically control the aircraft during normal flight, attack and breakaway.

7.4.2 Manual control shall be possible at the option of the pilot during any phase of the flight.

10.2 FIRE CONTROL SYSTEM

The aircraft shall be equipped with a two man position Fire Control System.

APPENDIX 1

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2. IN CAP 479

CHAPTER 21 CONTROLS

SECTION 1 - GENERAL

21.02 CLEARANCE AND EASE OF OPERATION

Controls shall be designed and located so that the operator can readily move each control throughout its entire range of travel, without moving any other control, while wearing heavy gloves and flying equipment, and with shoulder harness in place, but not necessarily locked.

21.03 DIRECTION OF MOTION

(1) Except for three-position switches, where the centre position shall be "OFF", all controls shall be so designed that their movement in a predominantly forward, upward, or clockwise direction shall result in increased performance of the component or the aircraft, and, conversely, their movement in a backward, downward, or counter - clockwise direction shall result in decreased performance of the component or the aircraft.

(2) All variable controls operated by a rotary motion shall move clockwise from the "OFF" position through "LOW" or "DIM" to "HIGH" or "BRIGHT".

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APPENDIX 1

2. IN CAP 479 (Continued)

21.04 SHAPE AND LOCATION OF CONTROL KNOBS

To assist identification without visual reference, control knobs shall be of distinctive shape. All controls of a like function should be grouped together, with normal operating and emergency controls having a preferred position.

SECTION 2 - FLIGHT CONTROLS

21.20 GENERAL

The control column and the rudder pedals shall be symmetrical about the plane of symmetry of the pilot's seat. All parts of the aircraft structure, auxiliary controls, furnishings, instruments etc., shall clear by at least one inch the control wheel or column and rudder pedals in all positions as well as the limbs of the pilot while he is wearing heavy gloves and flying equipment.

21.22 RUDDER CONTROLS

Rudder pedals shall be at least six inches wide to accommodate heavy flying boots. The rudder pedals shall be adjustable horizontally through a range of six inches. The rudder pedal adjustment mechanism shall be conveniently located and may be arranged for operation either by hand or foot. Depending upon the type of mechanism

APPENDIX 1

2. IN CAP 479 (Continued)

21.22 RUDDER CONTROLS (Continued)

used, the motion of the control to move the rudder pedals forward shall be clockwise, forward, or upward. If the pedals are locked in position by a catch, the motion to release the catch should be arranged in the most convenient manner.

21.25 SPEED BRAKE CONTROL

The speed brake control shall be located on the power control or adjacent to the power quadrant in stick - controlled aircraft. The control motion shall be aft for the speed brake operative, and the control shall be marked "OUT" and "IN" respectively.

21.26 AUTOMATIC PILOT

In single or tandem pilot aircraft all automatic pilot controls, except the emergency electrical release switch, shall be located on the right hand side of the cockpit adjacent to the radio controls. The emergency electrical automatic pilot release switch shall be on the control column grip.

24.01 TEMPERATURE RANGE

(1) All aircraft shall be designed so as to ensure satisfactory operation up to their service ceiling under the ICAO Standard Atmosphere Conditions and

2. IN CAP 479 (Continued)

24.01 TEMPERATURE RANGE (Continued)

at ground level under atmospheric conditions associated with temperatures ranging from -65°F to +100°F. All accessories and items of equipment however shall be designed for satisfactory operation over a temperature range of -65°F to +160°F, and when not in operation to withstand without damage temperatures up to +180°F.

(2) The aircraft, its accessories and equipment shall not be adversley affected by other climatic conditions incident to the temperature ranges specified in paragraph (1) and shall be capable of being transferred from one climate to another without the necessity of extensive modification or adjustment.

24.30 ALLOWANCE FOR WINTER CLOTHING

Aircraft operating in the Arctic normally have to be maintained in the open by personnel clad in heavy and bulky Arctic clothing. Provision shall be made in the design for ease of maintenance under such conditions..... All controls and switches shall be large enough and so placed that they can be operated by personnel wearing heavy mitts and flying boots.

2. IN CAP 479 (Continued)

24.31 CONTROL SYSTEMS

Suitable precautions shall be taken to prevent slackening of control cables caused by differential contraction of cables and airframe in low temperatures. Control cables shall be fitted with automatic tensioning devices where necessary, to prevent excessive slackening.

24.33 SNOW GUARDS

The use of snow guards is recommended to exclude blowing snow from airframe components such as wings, stabilizers, control surfaces, etc. It is particularly important that openings near control surface hinges be effectively sealed against the entry of blowing snow and rain, since the formation of ice on control surface hinges might lead to loss of control in flight.

24.34 SEALS

Particular attention should be given to the selection of materials and design of seals for shock absorbers, hydraulic jacks and valves which must be able to withstand operation and to remain leakproof after prolonged exposure to extremes of temperature.

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APPENDIX 1

2. IN CAP 479 (Continued)

24.35 PIPE JOINTS

Joints in pipe lines must remain leakproof throughout the temperature range specified in article 24.01.

CHAPTER 50 GENERAL REQTS

STANDARDS AND SPECIFICATIONS

SEE CAP 479

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APPENDIX 1

3. IN ARDCM 80-1

4.11 CONTROL SURFACE LIFT REVERSAL

4.111 MEASURES GENERALLY USED FOR PREVENTION

The parameter most important for avoiding control surface lift reversal is a high torsional rigidity of the fixed surface supporting the control surface ---.

4.112 DETAIL REQUIREMENTS FOR PREVENTION

The requirements for the prevention of control surface lift reversal are contained in Specification 1817.

5.40 PRIMARY CONTROLS

The size, proportions, location and motions of the primary control surfaces shall be such as to give performance in accordance with AF Specification R.1815 ------.

6.A.11 FLIGHT CONTROLS

6.A.110 GENERAL

The primary flight controls shall be located and have the motions as indicated in drawings AD.1 and AD.2 The primary flight controls shall clear all aircraft structures, auxiliary controls, furnishings, instruments, instrument panel, pilot's actuating members, etc., by at least 1½ inches in all control positions -----.

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APPENDIX 1

3. IN ARDCM 80-1 (Continued)

6.A.11 FLIGHT CONTROLS (Continued)

6.A.116 SPEED BRAKE CONTROL

The speed brake control shall be located on the throttle in stick controlled aircraft. The control motion shall be forward for "in" (speed brake inoperative) and aft for "out" (speed brake operative).

8.3 BEARINGS, UNIVERSAL JOINTS, PULLEYS AND HINGES

MIL. JAN and AN Standard bearings, pulleys and universal joints shall be used wherever possible .... see Chapter 8. Detail Design ARDCM 80-1.

9.01 DESIGN FOR MAINTENANCE

Control surfaces shall be capable of replacement without disturbing rigging.

9.1 FLIGHT CONTROLS

Flight controls include primary flight controls - ailerons, rudder, elevators .... and flight path angle and speed controls .... These devices shall be operable from the cockpit either through direct or servo means.

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3. IN ARDCM 80-1

9.10 EXTREME TEMPERATURE OPERATION

Flight control systems shall be designed for operation at temperatures between +160°F (+70°C) and -65°F (-54°C). The systems shall be designed to permit take-off of the aircraft within 5 minutes from the starting of the engine after the aircraft has remained idle for 72 hours at either the highest or the lowest temperature indicated above. After the initial breakaway, the increase in force required to operate the control system at -65°F (-54°C) shall not exceed 150% of the force required at +70°F (+21°C).

9.11 CABLE CONTROL SYSTEMS

The reliability, strength and simplicity of the system shall be the paramount considerations. Routing shall be as straight as possible and the number of bends kept to a minimum. Cable control systems shall conform to para. 10.41 Cable Actuated System.

9.12 PUSH-PULL TUBE CONTROL SYSTEMS

Wherever push-pull tube systems are used in flight controls, they shall be so arranged that all the tubes are in tension for the greater load for which the system is designed. Push-pull tube control systems shall conform to para. 10.42., Tube Actuated System.

APPENDIX 1

3. IN ARDCM 80-1 (Continued)

9.13 SHIELDING

Wherever possible, advantage shall be taken of the shielding afforded by heavy structural members or existing plate installations for cable protection, such armour plate to be extended where necessary to protect vital places in the systems such as points of cable convergence, horns, bell-cranks, main sheaves and walking beams.

9.2 PRIMARY FLIGHT CONTROL SYSTEMS

9.20 GENERAL REQUIREMENTS

Control mechanisms and systems shall be as simple and direct as possible and shall be adequate for their loads and functions. Early and careful consideration shall be given in new designs to the arrangement of cables and other connecting elements that extend from the cockpit to the control surfaces so as to effect the most direct routing possible.

The number of bends or changes in direction shall be held to a minimum.

All practical compromises in the installation of equipment shall be made to favour the most direct control system possible......... A power control system shall be used.... ..... where the magnitudes of the hinge moments are too high for the pilot to handle through a mechanical control

3. IN ARDCM 80-1 (Continued)

9.20 GENERAL REQUIREMENTS (Continued)

system. In order to reduce pilot effort and fatigue, the degree of mechanical efficiency shall be such that requirements of Specification 1815 will be met for the frictional forces developed in the control system. For this purpose, antifriction bearings shall be used throughout the control system. Reference para. 8.31, Antifriction Bearings. The mechanism and controls shall be located so as to permit convenient, rapid and frequent inspection.

9.200 CONTROL SYSTEM DEVICES

Control system devices such as bob weights ---- spring bungees for trim ----- tension regulators etc., shall be submitted in drawing form with other data to the procuring agency for necessary approval. Consideration shall be given in the detail design of the control system and component parts so that their failure will not cause discontinuity of the control system, large changes in trim, or any other momentary flight hazard.

9.201 DIFFERENTIAL CONTROLS

Differential controls may be used either to secure better aerodynamic efficiency or to provide higher sensitivity in a portion of the range of movement

3. IN ARDCM 80-1 (Continued)

9.201 DIFFERENTIAL CONTROLS (Continued)

of a control.

Control systems in which differential motion is obtained by an arrangement of cranks shall incorporate stops to prevent the cranks from reaching the dead-centre position ----------.

Toggle motions, which may go by dead-centre when the system is sprung, forced, or maladjusted, shall not be used.

Stops shall be incorporated to prevent approach to critical positions.

9.202 FOOL-PROOFNESS

Control systems shall be so designed that incorrect assembly and reversed operation of controls will be impossible. This can be accomplished by so arranging turnbuckle ends, cable lengths, and joints that the assembly will not function in case of error.

9.203 FOULING PREVENTION

All control elements, mechanisms and cables shall be suitably protected or covered in cockpit ---- to prevent their being fouled by the dropping of articles, such as microphone, gloves etc. -------.

APPENDIX 1

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3. IN ARDCM 80-1 (Continued)

9.204 INREVERSIBLE & DAMPING FEATURES

Inreversible and damping features will greatly inhibit the development of control surface flutter, but such damping should never be attained by the increase of friction which would reduce the efficiency of control. These features should be such as to oppose rapid motions energetically, but not interefere with slow motions of the controls. Fluid damping is suitable for the purpose.

In the design of inreversible or damping control systems, particular attention should be paid to avoiding the use of any device in which play or backlash might develop and eliminate the irreversible or damping properties of the system, thus encouraging flutter of the control surfaces. In designs where play or backlash might develop, the irreversible or damping features of the system will not be accepted as valid reasons for waving the usual dynamic balance requirements for the control surfaces involved.

9.205 POWER CONTROL SYSTEMS

Where power control systems are employed, an emergency manual or power means shall be provided and the system shall be designed to meet the requirements of Spec. 1815.

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3. ARDCM 80-1 (Continued)

9.206 RIGIDITY OF CONTROLS

The design of the control system and its structural supports shall be based on rigidity and the elimination of deflection, as well as upon the ultimate strength requirement of Specification C-1803, superseded by MIL-S-5707.

Provisions shall be made to compensate for slack and lost motion due to the effect of temperature changes. Only approved types of mechanical tension regulators are permissible and if used, shall maintain rigging tensions over the full range of temperatures specified in para. 9.10, Extreme Temperature Operation, and shall compensate for any change in tension that may develop in the control system due to loads applied thereto. Consideration shall be given to the effect of heat from local areas such as engine nacelles, cabins, heat deicers, etc., which may cause temperature rises in an adjacent portion of a control system while the aircraft structure proper remains at the ambient air temperature. The designer shall determine proper rigging tensions in control cables and shall specify them in erection and maintenance instruction. It may be found desirable or

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3. IN ARDCM 80-1 (Continued)

9.206 RIGIDITY OF CONTROLS (Continued)

necessary to revise the originally specified tensions after flight and other tests have been completed. In the interest of reducing control system friction, initial tensions should be held to the lowest practical values that provide safe and satisfactory operation considering probable application of limit loads to the system and the effect of temperature changes. As a general rule, the minimum initial tension in a main or counter cable is either 2% of the breaking strength of the cable, or high enough to keep the system snug, prevent cables from jumping off pulleys and avoid slapping of adjacent portions of the aircraft by the cables, whichever is the greater. As a general rule, initial tension for main cables in normal fighter types should be not less than 35 lbs. to 50 lbs. When power control systems are used, the rigidity and balance of the control surfaces involved shall be such as to preclude flutter or undesirable oscillations if the actuator or any one of the actuatorsused is disconnected for any reason including battle damage.

3. IN ARDCM 80-1

9.207 SPACING

Cables to any one control surface shall be separated by at least 3 inches, preferably more. Adjacent controlhorns, or bellcranks, shall be separated by the maximum distance possible consistent with design.

9.21 DUPLICATE CONTROLS

9.210 AIRCRAFT OTHER THAN BOMBANDMENT

(a) ELEVATOR: Elevators shall be rigidly interconnected or consist of a continuous structure. -------- in aircraft of more than 7,500 lbs. gross weight the direct operation system shall be duplicated from the base of the stick or control column to the elevator spars ....

(b) RUDDER: Where cables are used for the rudder control on aircraft equipped with a single rudder, duplicate cables shall be provided from each pedal to the rudder mast ---------.

(c) AILERON: Aileron systems shall be so designed that, from the cockpit outboard, any or all elements leading to one aileron may be destroyed without interference with the operation of the other aileron.

APPENDIX 1

3. IN ARDCM 80-1 (Continued)

9.212 VULNERABILITY

Power Control Systems - Power Control systems shall be equal to, or better than mechanical systems from the standpoint of resistance to battle damage.

9.213 STOPS

Adjustable stops shall be provided to limit the cockpit control items to the desired motion ranges. The stops shall be located as near these items as possible. Stops shall maintain the clearances specified in para. 6.A.110, Flight Control, General.

10.4 MECHANICAL SYSTEM

10.40 GENERAL

Clearances in all the primary parts of mechanisms shall be kept to a minimum so that lost motion or play will be practically eliminated.

10.400 BEARINGS

All moving joints between push-pull rod, levers, and brackets shall have anti-friction bearings in accordance with para. 8.31.

10.401 HORNS AND BRACKETS

Horns and brackets used in air control systems shall be forgings, or high grade castings of

3. IN ARDCM 80-1 (Continued)

10.401 HORNS AND BRACKETS (Continued)

aluminum alloy, magnesium alloy, bronze or steel. Welding shall not be used ------. Horns may be fastened to torque tubes with rivets or taper pins. In the latter case, taper pins shall be safetied by a nut and cotter pin at the small end.

Attachment of control brackets shall be made with aircraft bolts and castellated or self locking nuts of approved type. Rivets may be used provided that none are in tension.

10.41 CABLE ACTUATED SYSTEM

The kinematic relation of the cables shall be such as to prevent an objectionable amount of change in cable tension throughout their flight and ground operational range.

10.410 CABLES

Control cables shall conform to Specification MIL-C-1511 or MIL-C-5424. ----- Continuous or intermittent loaded cables shall not be subjected to critical bends at the junction with cable terminals or other attaching points such as drums, horns, etc.

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3. IN ARDCM 80-1 (Continued)

10.411 PULLEYS

Pulleys shall be of adequate capacity and diameter for cables used. They shall conform to and meet the requirements of paragraph 8.315, Aircraft Control Pulleys.

10.412 FAIRLEADS

Fairleads shall be used wherever necessary to keep cables from chafing and slapping against parts of the aircraft in flight or in taxiing. Fairleads may be used to deflect cables through angles of not more than 2 degrees if the initial tension in the cable is less than 50 lbs, and through angles of not more than one degree, if the initial tension is between 51 lbs. and 150 lbs. ----- They shall be of non-hydroscopic, non-abrasive material, and split to permit easy removal.

10.413 TERMINALS

Terminals shall be of the swaged, wrapped, or spliced type. Swaged terminals shall be used wherever possible. ------- Swaged terminals shall conform to Specification JAN-T-781. Type II (i.e. AN 663 and AN 664) swaged terminals shall not be used in primary control systems except for

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3. ARDCM 80-1 (Continued)

10.413 TERMINALS (Continued)

attaching primary control cables to bellcranks and quadrants where standard fork and eye fittings AN 667 and AN 668 are not adaptable.

10.414 TURNBUCKLES

Turnbuckle terminals shall have not more than three threads exposed at either end. All turn-buckle assemblies shall be safetied as specified in para. 8.25, Safety Wiring.

10.415 MAINTENANCE

Adequate provisions shall be made for rapid inspection of all components of cable actuated systems, and for convenient use of a tensiometer adjacent to the point of cable tension adjustment.

10.42 TUBE ACTUATED SYSTEM

10.420 UNIVERSAL JOINT

Universal joints shall conform to and meet the requirements of paragraph 8.314 Universal joints.

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APPENDIX 1

4. IN 1815 - B

3. MECHANICAL CHARACTERISTICS OF CONTROL SYSTEMS

3.1 CONTROL SYSTEM FRICTION

For all airplanes, the control system friction for all three controls shall be as low as possible, and shall not exceed the values given below throughout the deflection range. The friction, measured on the ground at a temperature between 40° and 80°F, shall be that required to start the movement of the controls.

Elevator	Friction	Limit	=	4	lbs.
Aileron	Friction	Limit	=	3	lbs.
Rudder	Friction	Limit	=	10½	lbs.

5.6 DIRECTIONAL TRIMMING DEVICES

5.6.1 All prototype airplanes shall have provisions for maintaining directional trim in flight.

5.6.2 The rudder trimming device shall maintain a given setting indefinitely unless changed intentionally.

5.6.3 The directional trimming device shall be capable of reducing the pedal force to zero ---------

6.6 LATERAL TRIMMING DEVICES

6.6.3 The lateral trimming device shall be capable of reducing the aileron control force to zero ----

APPENDIX 1

8. IN 1815 - B

8.1 MECHANICAL DESIGN

8.1.1 The control system should be capable of moving the control surfaces at rates up to 50°/sec under any hinge moments encountered.

8.1.2 When the cockpit control is moved at its maximum rate to a given deflection, the control surface shall reach its corresponding deflection with a time by not greater than 0.05 secs.

8.1.3 The dead spots in the controls should not exceed plus or minus 0.1 inches motion of the pilots cockpit controls. The dead spots are defined as the motions of the pilot's cockpit controls which produce no motions of the control surfaces.

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APPENDIX II

The following is a list of the points in which detail design varies from the requirements laid down in the terms of reference in Appendix 1.

1. In AIR 7-4

All requirements satisfied.

2. In CAP 479

All requirements satisfied.

3. In ARDCM 80-1

3.1 Paragraph 9.10 states that the flight control system shall be designed for operation at temperatures between - 160°F and - 65°F.

This requirement is exceeded because it is necessary to cater for temperatures as high as + 250°F produced during supersonic flight.

3.2 Paragraph 9.206 states that rigidity and balance of the control surfaces shall be sufficient to prevent flutter if the actuator is disconnected.

This requirement is not compatible with the design aims of a fully powered, irreversible flying control system and, if met, would involve prohibitive weight penalties. There is no more chance of the actuators being disconnected than the pilot's input control system, and the consequences of the latter would be equally, if not more, catastrophic.

APPENDIX II

3. In ARDCM 80-1 (Continued)

3.3 Paragraph 9.207 states that cables to any one control surface shall be separated by at least 3 inches. This requirement has not been met because of space restrictions. The worst situation for each pair of cables is as follows:

$2\frac{1}{4}$ inch spacing for elevator cables
1 7/8 inch spacing for aileron cables
5/8 inch spacing for rudder cables

The elevator and aileron cable minimum spacing occurs at a point just forward of the rear fuselage quadrants and reasonable assurance of non-fouling of these cables is provided by properly spaced fairleads. The rudder cable minimum spacing occurs at the pulleys which change the direction of the cable run along the fuselage up into the fin. The clearance of the cables is assured by running them through $\frac{1}{2}$ inch dia. tubes.

3.4 Paragraph 9.210a. states that elevators shall be rigidly interconnected or consist of a continuous structure:

This requirement is not met because of the difficulty of achieving complete synchronization between two jacks on a single surface, and also because of the severe weight penalty which would be paid for such an installation on an aircraft of the C.105 plan form.

APPENDIX II

3. In ARDCM 80-1 (Continued)

3.4 (Continued)

There do not appear to be any real advantages to the interconnection of the surfaces on this design.

3.5 In paragraph 9.31.a,b & c, it is required that the control surface operating systems be duplicated:

This requirement is not met because of complexity and space reasons, and it is believed that this deviation is very common on many acceptable new designs, including the C.F.100.

3.6 Paragraph 10.411 refers to paragraph 8.315 in which it is stated that all pulleys and quadrants shall be provided with stationary guards fitting close to the point of tangency of the control cables.

In most cases this requirement has been met, but the front fuselage tension regulator quadrants and the rear fuselage elevator quadrant are equipped with cable guards attached to the quadrants themselves. These guards, which move with the quadrants, are much lighter and very simple compared to fixed guards, and provide ample protection against cables jumping the quadrant grooves.

3.7 Paragraph 10.413 states that Type 11 (ball end) swaged terminals shall not be used in primary control systems except for attachment to bell cranks and quadrants where standard fork and eye fittings are not adaptable.

APPENDIX II

3. In ARDCM 80-1

3.7 (Continued)

In the CF 105 control system, although it is possible to adapt fork and eye fittings for attachment to the quadrants, the use of tension regulator quadrants will take up any slack produced by the untwisting of loaded cable strands allowed by ball end type terminals.

The use of ball end type terminals results in a weight saving and a neat installation when compared with the result produced by the use of standard fork and eye fittings.

3.8 Paragraph 10.415 states that provision must be made for the use of a tensiometer adjacent to the point of cable tension adjustment.

This requirement is not met because it is made unnecessary by the employment of calibrated tension regulator quadrants.

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APPENDIX II

4. In 1815-B

4.2 Paragraph 8.1.1. states that the control system should be capable of moving the control surfaces at rates up to 50^{o}/sec.

This requirement is not met. Dynamic analysis of the aircraft indicates that such high rates are not required, and the system has therefore not been penalized by an oversized hydraulic system.

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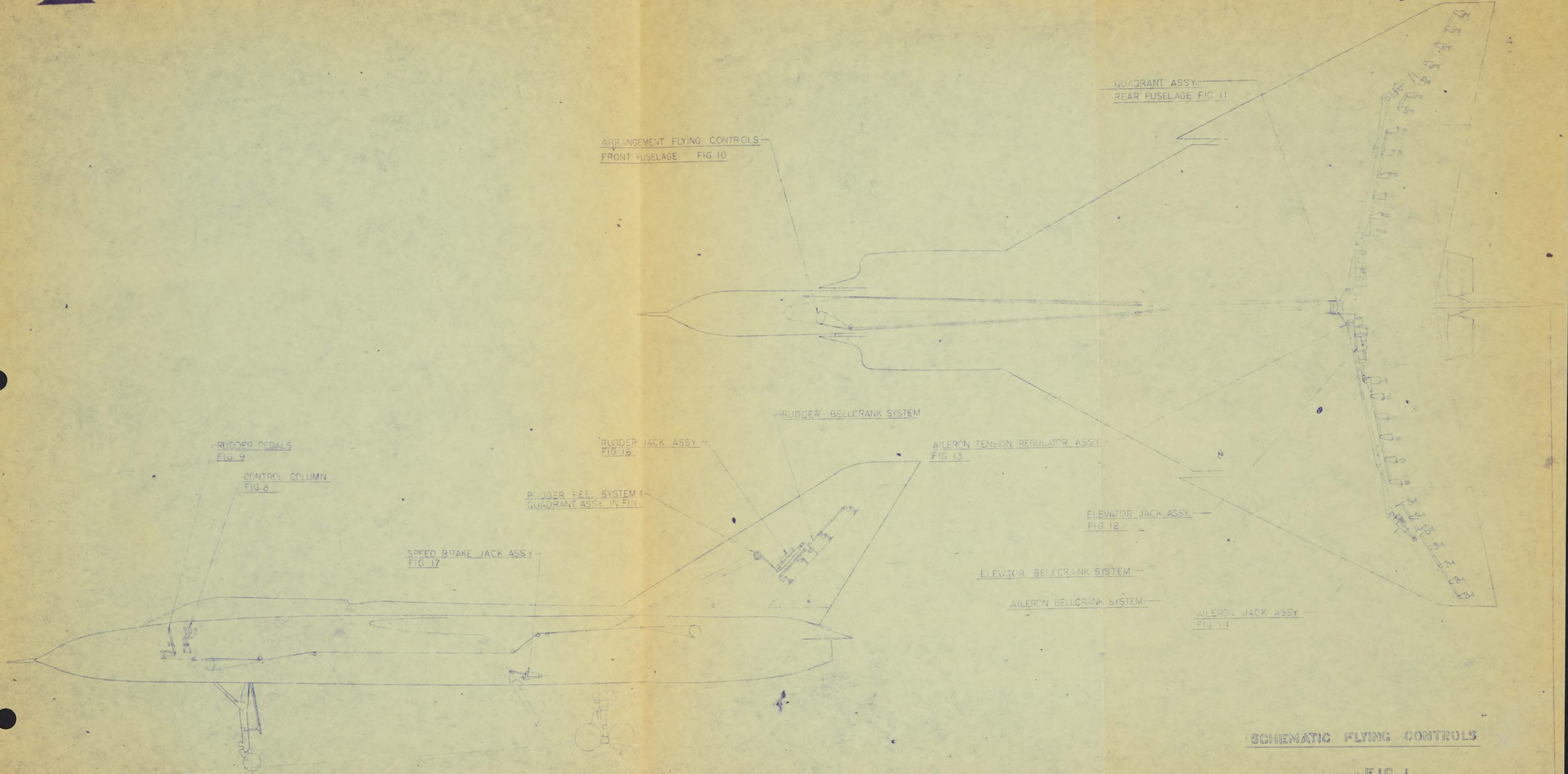
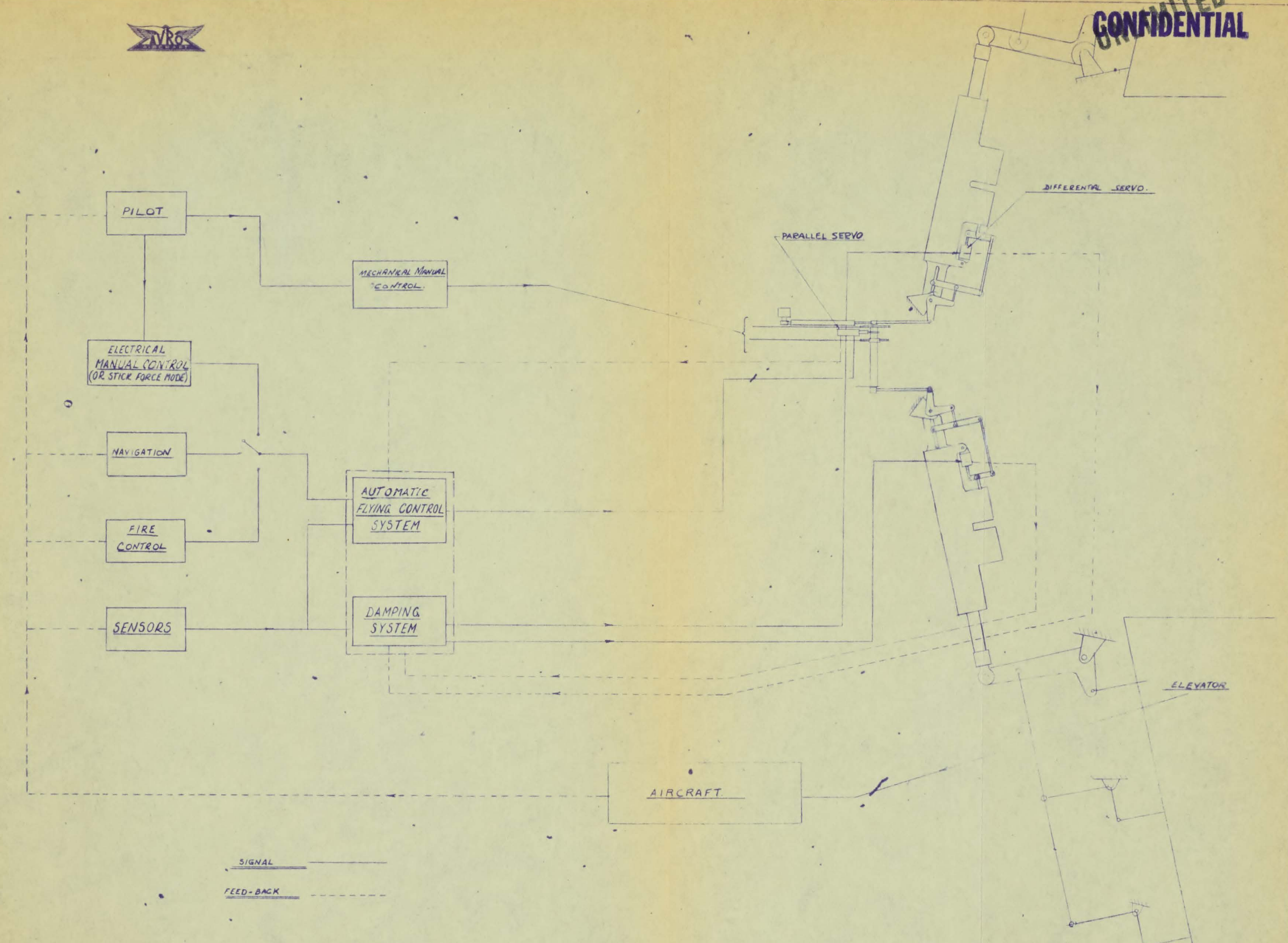
APPENDIX III

AVRO PART NO.	QUANTITY	DESCRIPTION	MANUFACTURER & PART NO. (WHERE APPLICABLE)
7-0115-15	2	Elevator Jack	Jarry Hydraulics #1013
	2	Elevator Jack Valve	
7-0115-84	2	Aileron Jack	Jarry Hydraulics #P.128
7-0115-83	2	Aileron Jack Valve	
7-3283-6	1	Rudder Jack	
7-3283-8	1	Rudder Jack Valve	
7-1956-15/16	2	Speed Brake Jack	
7-1956-13	1	Speed Brake Selector Valve	
7-3262-11	2	Parallel Servo - (Elev. & Aileron)	
7-0115-85	2	Differential Servo (Elev. & Aileron)	
7-3283-7	1	Double Differential Servo - Rudder	
7-0115-95	3	Tension Regulator Quadrant - Front Fuselage	Pacific Scientific XR.86-5001-50-00
7-0115-1	2	Aileron Tension Regulator Quadrant - Inner Wing	Pacific Scientific XR.75-9006-50-00
	2	Magnetic Brake Trim Unit	Airborne Accessories Corp. #OR.460.M4
7-1552-0017	1	Spring Feel Unit - Elevator	
7-1552-006	1	Spring Feel Unit - Aileron	
	1	Spring Feel Unit - Rudder	
7-1552-0117	1	Control Column	
7-0115-124	1	Rudder Pedals	



SCHEMATIC FLYING CONTROLS

FIG. 1



ELEVATOR BLOCK DIAGRAM

FIG. 2.

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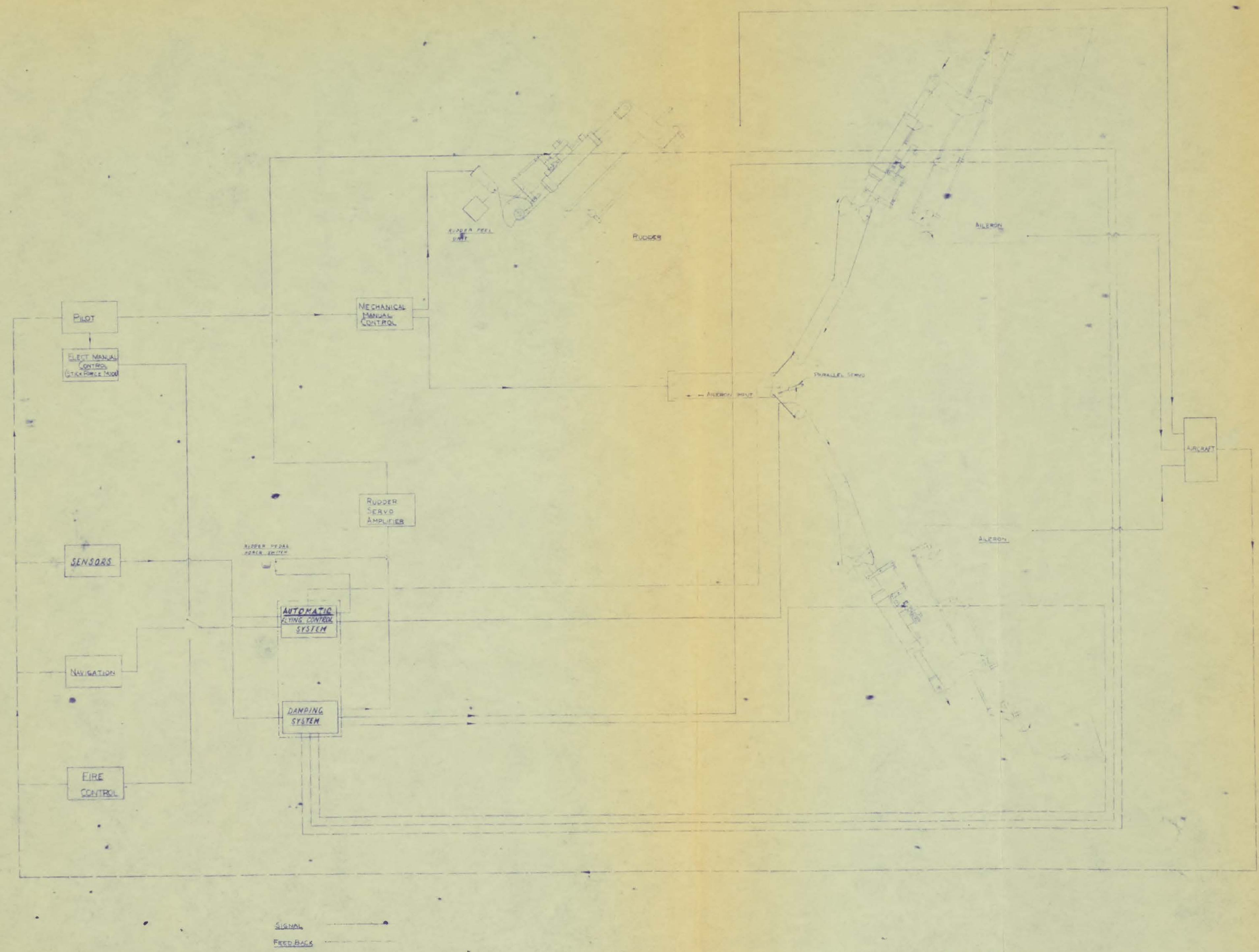

AILERON BLOCK DIAGRAM

FIG. 3.

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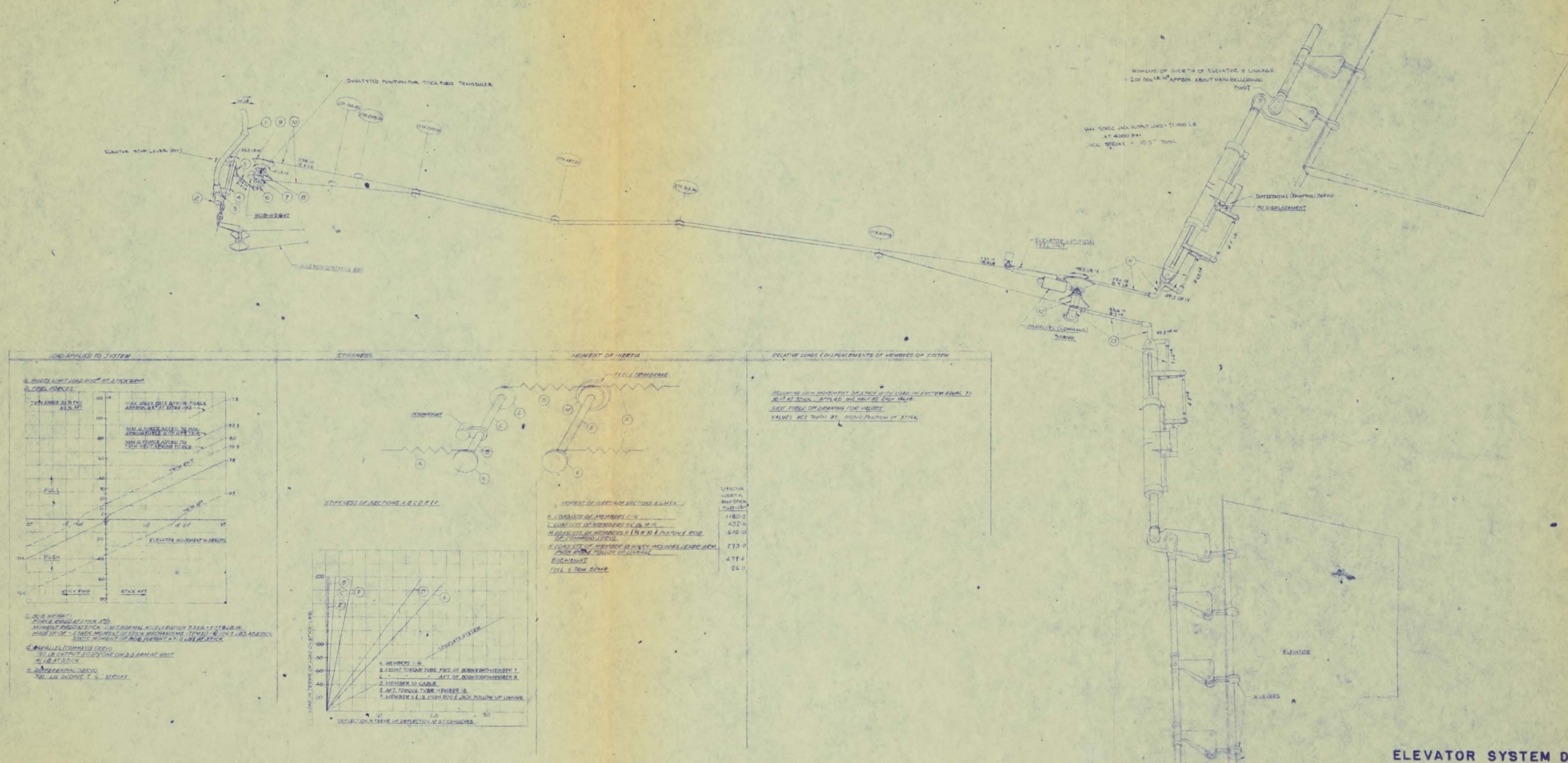


ELEVATOR SYSTEM DATA

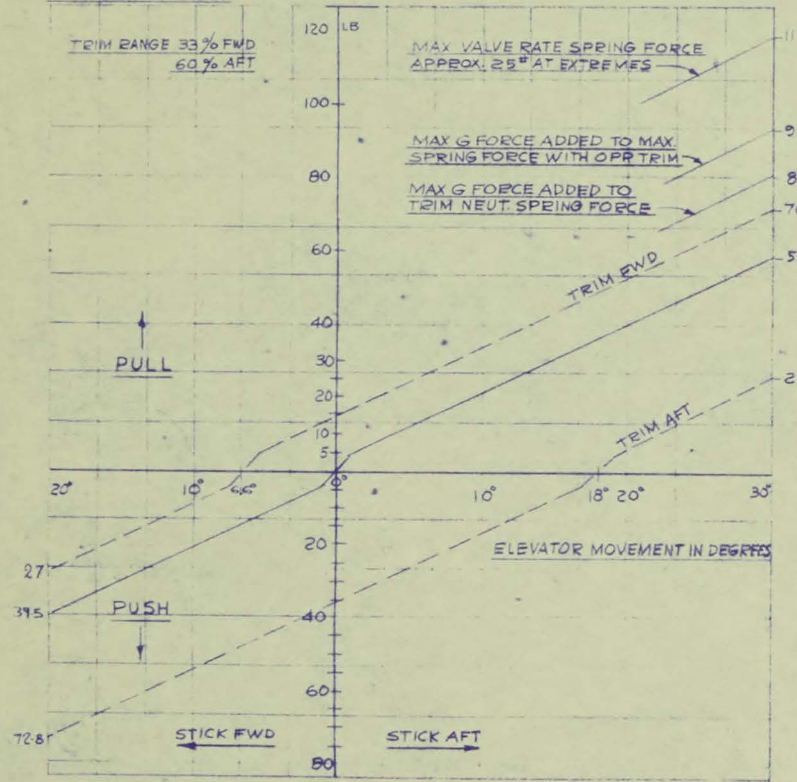
FIG. 4

AVRO AIRCRAFT

LOAD APPLIED TO SYSTEM

a. PILOTS LIMIT LOAD 200# AT STICK GRIP

b. FEEL FORCES:



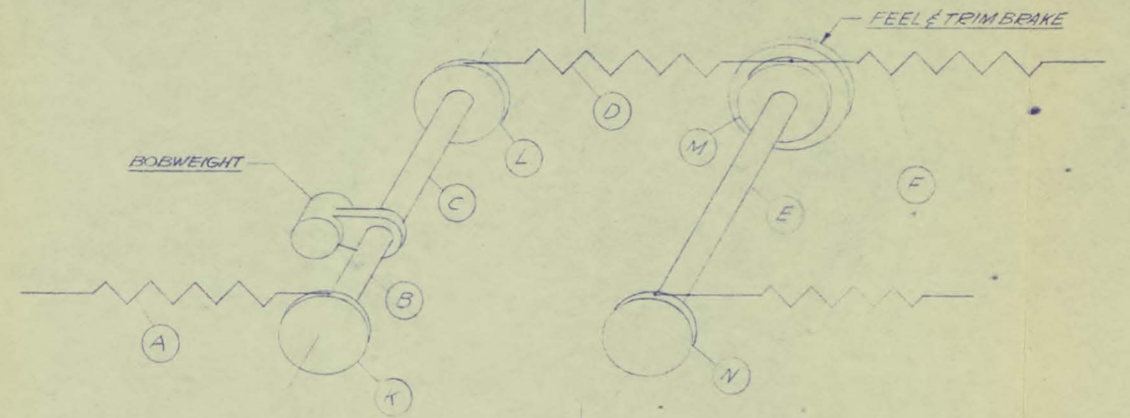
c. BOB WEIGHT:
FORCE REQD AT STICK 3#/G
MOMENT REQD AT STICK - LIMIT NORMAL ACCELERATION 7.33G = 577.5 LB.IN.
MADE UP OF - STATIC MOMENT OF STICK MECHANISMS ITEMS (1-6) 106.5 LBS AT STICK
STATIC MOMENT OF BOB WEIGHT 471.0 LBS AT STICK

d. PARALLEL (COMMAND) SERVO
150 LB OUTPUT 3.0 STROKE ON 3.0 ARM AT UNIT
4 LB AT STICK

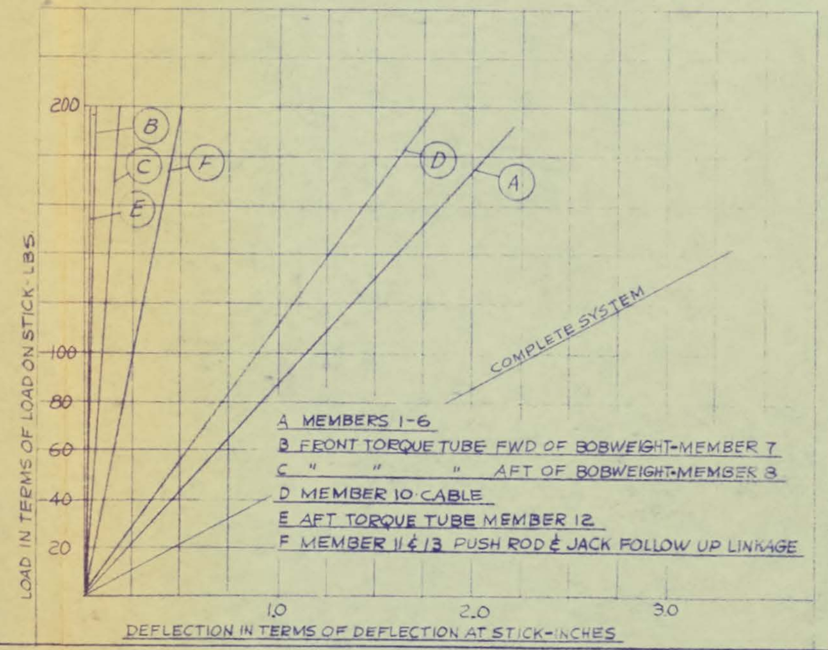
e. DIFFERENTIAL SERVO
300 LB OUTPUT ±.6" STROKE

STIFFNESS

MOMENT OF INERTIA



STIFFNESS OF SECTIONS A B C D E & F



MOMENT OF INERTIA OF SECTIONS K L M & N	EFFECTIVE INERTIA ABOUT STICK PIVOT - LB. IN²
K CONSISTS OF MEMBERS 1-6	1180.0
L CONSISTS OF MEMBERS 9 & 1/2 OF 10	452.0
M CONSISTS OF MEMBERS 11 & 1/2 OF 10 & PISTON & ROD OF COMMAND SERVO	610.0
N CONSISTS OF MEMBER 13 WHICH INCLUDES LEVER ARM PUSH ROD & FOLLOW UP LINKAGE	273.0
BOBWEIGHT	479.0
FEEL & TRIM BRAKE	[illegible]

RELATIVE LOADS & DISPLACEMENTS OF MEMBERS [illegible]

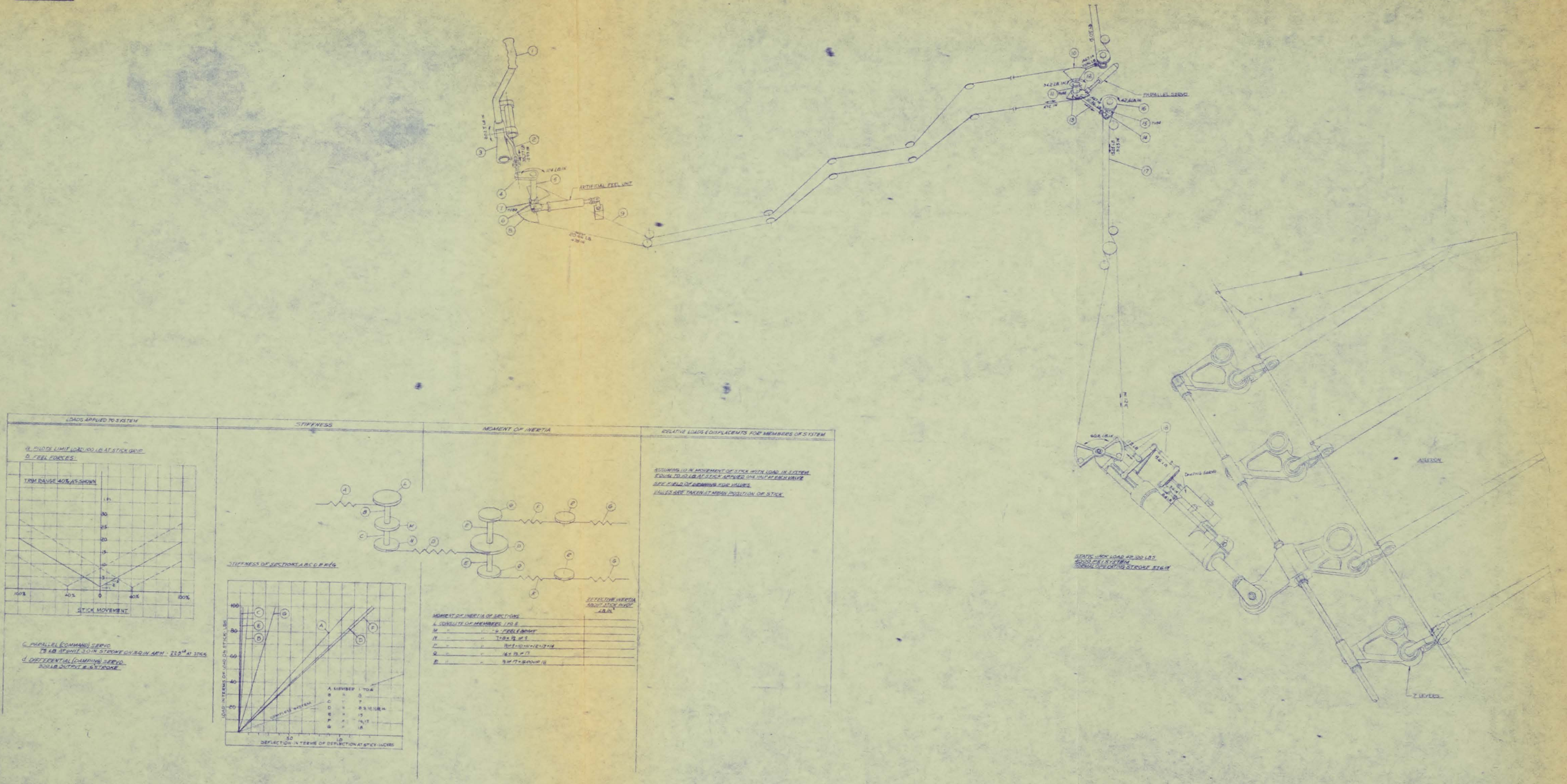
ASSUMING 1.0 IN MOVEMENT OF STICK WITH LOAD [illegible]
10 LB AT STICK. APPLIED ONE HALF AT EACH VALVE

SEE FIELD OF DRAWING FOR VALUES

VALUES ARE [illegible] AT [illegible] POSITION OF [illegible]

ELEVATOR SYSTEM DATA

FIG. 4-A



AILERON SYSTEM DATA

FIG. 5

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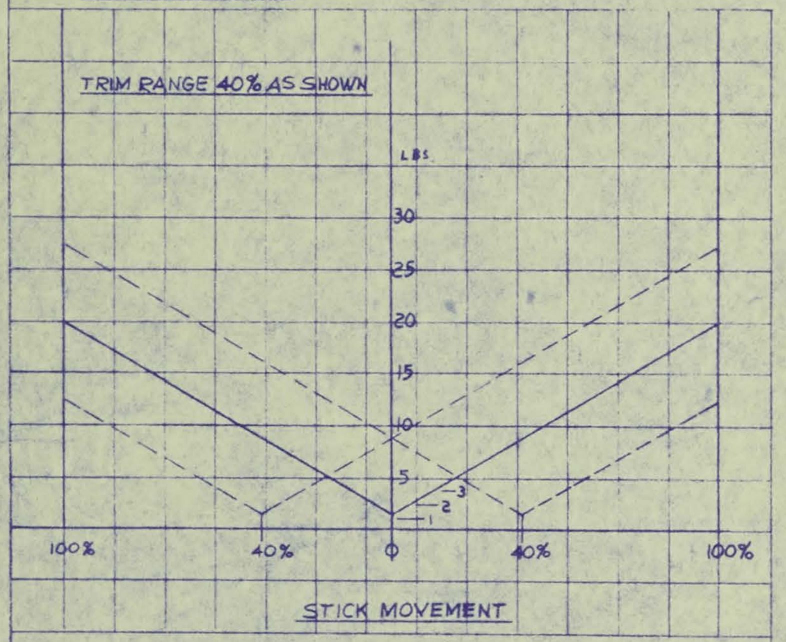
LOADS APPLIED TO SYSTEM	STIFFNESS	MOMENT OF INERTIA	RELATIVE LOADS & DISPLACEMTS FOR MEMBERS OF SYSTEM

LOADS APPLIED TO SYSTEM

a. PILOTS LIMIT LOAD 100 LB AT STICK GRIP

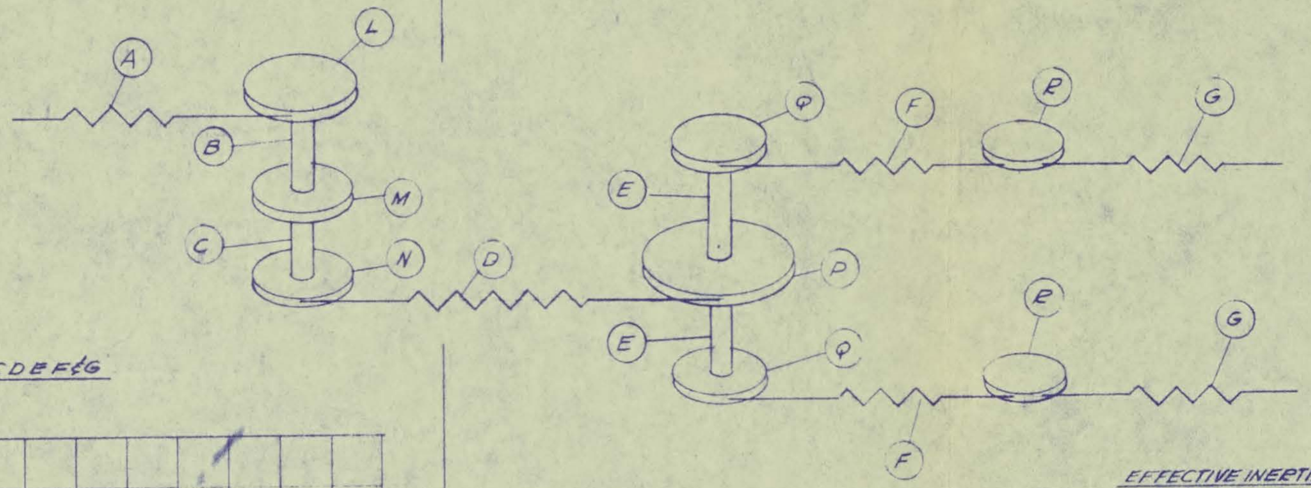
b. FEEL FORCES:



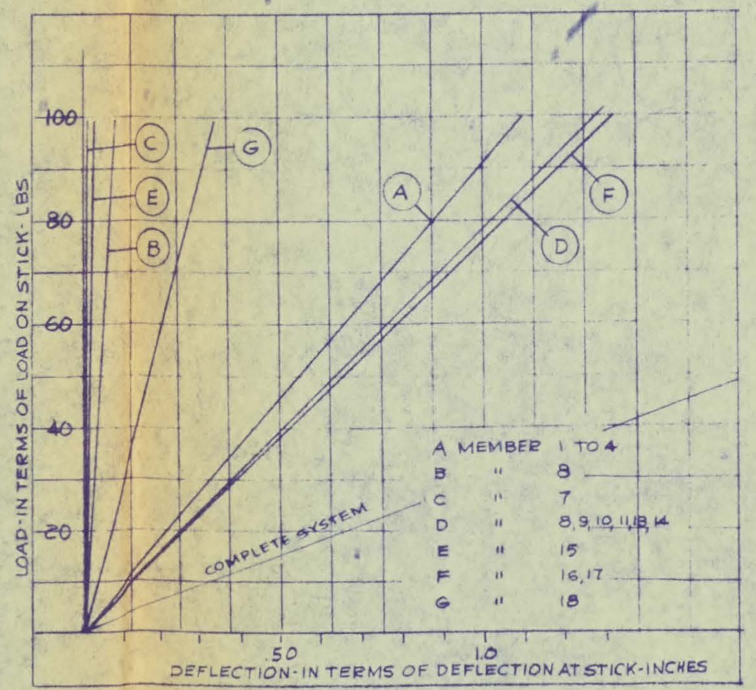
c. PARALLEL (COMMAND) SERVO
75 LB AT UNIT 3.0 IN STROKE ON 3.0 IN. ARM - 22.5 LB AT STICK

d. DIFFERENTIAL (DAMPING) SERVO
300 LB OUTPUT ± .6" STROKE

STIFFNESS



STIFFNESS OF SECTIONS A B C D E F & G



MOMENT OF INERTIA

MOMENT OF INERTIA OF SECTIONS	EFFECTIVE INERTIA ABOUT STICK PIVOT LB.IN.²
L CONSISTS OF MEMBERS 1 TO 5	619·25
M " " -6- FEEL & BRAKE	55 05
N " " 7+8+½ OF 9	301·65
P " " ½ OF 9+10+11+12+13+14	292 29
Q " " 16+½ OF 17	150·60
R " " ½ OF 17 + GROUP 18	157·96

NOTE - VALUES FOR INERTIA WILL BE ADDED AT NEXT ISSUE

RELATIVE LOADS & DISPLACEMTS FOR MEMBERS OF SYSTEM

ASSUMING 1.0 IN. MOVEMENT OF STICK WITH LOAD IN SYSTEM EQUAL TO 10 LB AT STICK APPLIED ONE HALF AT EACH VALVE

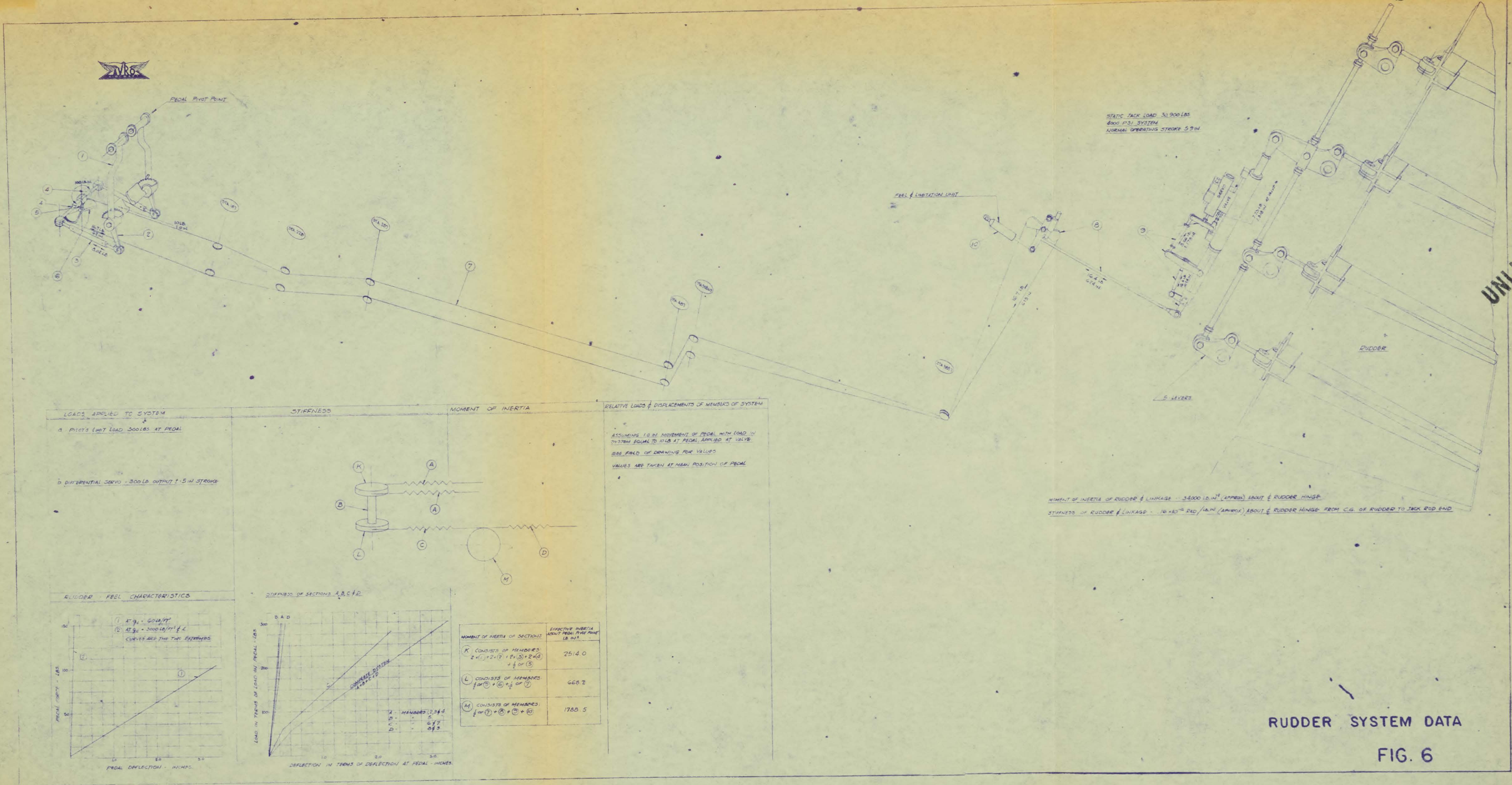
SEE FIELD OF DRAWING FOR VALUES.

VALUES ARE TAKEN AT MEAN POSITION OF STICK

AILERON SYSTEM DATA

FIG. 5-A

UNLIMITED



UNLIMITED

~~CONFIDENTIAL~~

RUDDER SYSTEM DATA

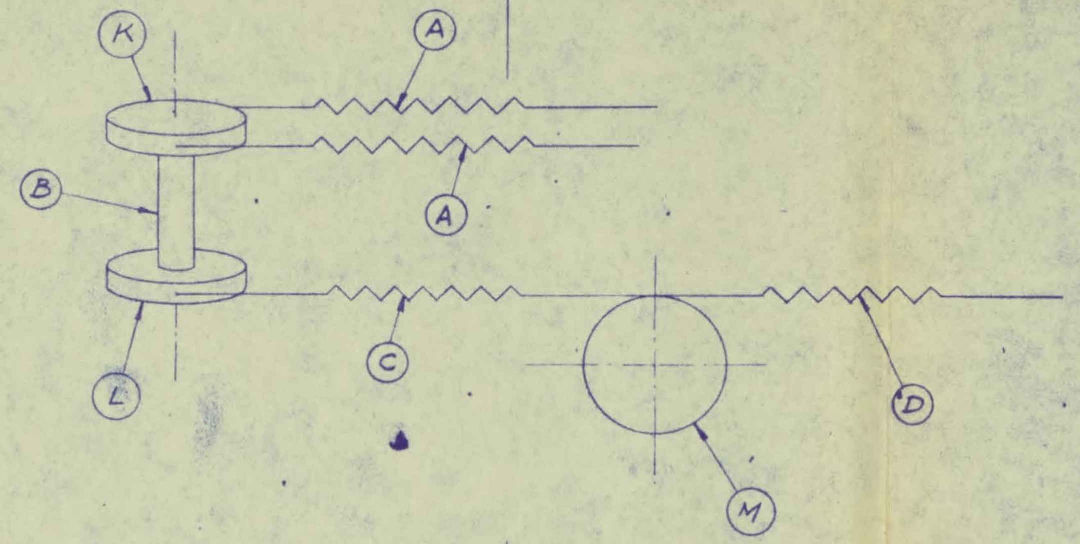
FIG. 6

LOADS APPLIED TO SYSTEM

a. PILOT'S LIMIT LOAD 300 LBS AT PEDAL.

b. DIFFERENTIAL SERVO - 300 LB. OUTPUT ± ·5 IN. STROKE.

STIFFNESS



MOMENT OF INERTIA

MOMENT OF INERTIA OF SECTIONS	EFFECTIVE INERTIA ABOUT PEDAL PIVOT POINT LB. IN.²
K CONSISTS OF MEMBERS: 2×1+2×2+2×3+2×4 + ½ OF 5	2514.0
L CONSISTS OF MEMBERS: ½ OF 5 + 6 + ½ OF 7	668.2
M CONSISTS OF MEMBERS: ½ OF 7 + 8 + 9 + 10	1788.5

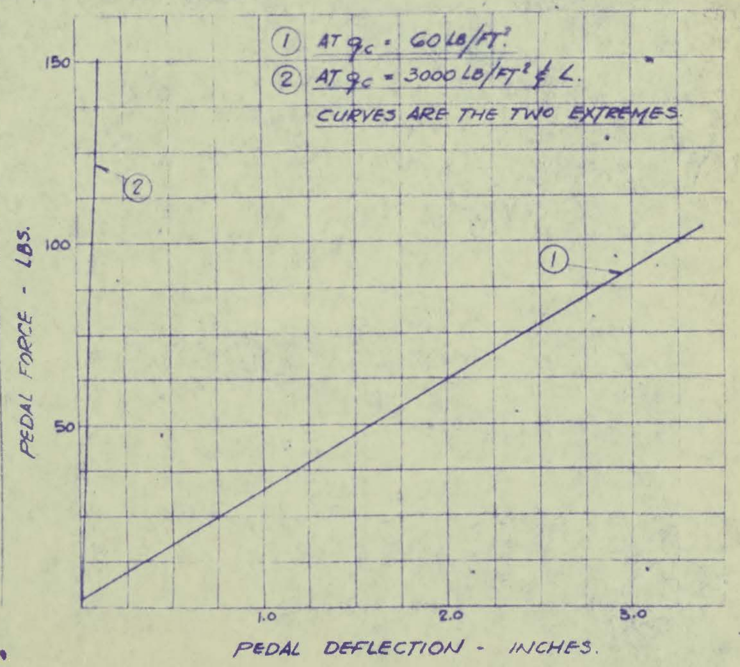
RELATIVE LOADS & DISPLACEMENTS OF MEMBERS OF SYSTEM

ASSUMING 1.0 IN. MOVEMENT OF PEDAL WITH LOAD IN SYSTEM EQUAL TO 10 LB AT PEDAL, APPLIED AT VALVE.

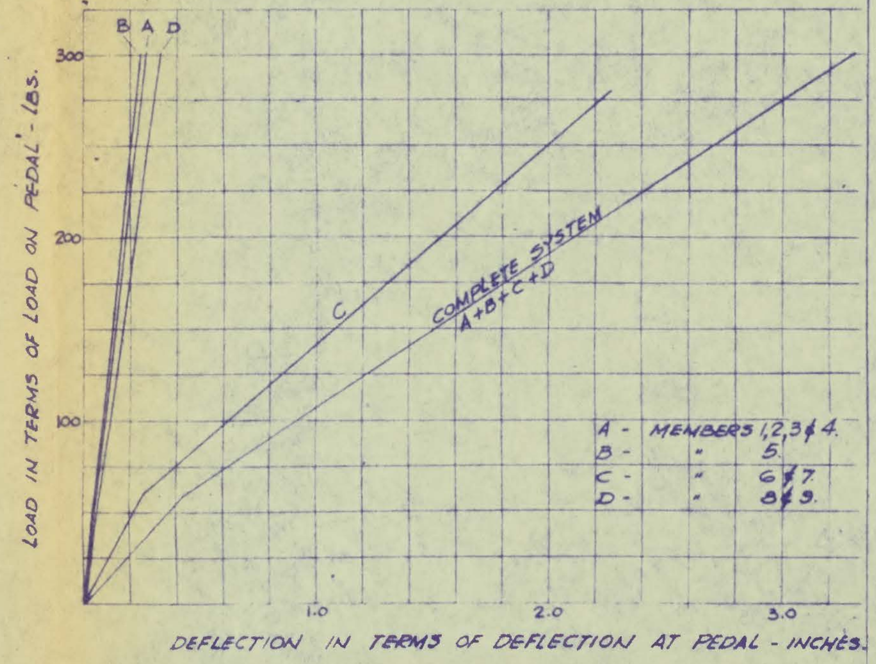
SEE FIELD OF DRAWING FOR VALUES.

VALUES ARE TAKEN AT MEAN POSITION OF PEDAL.

RUDDER - FEEL CHARACTERISTICS



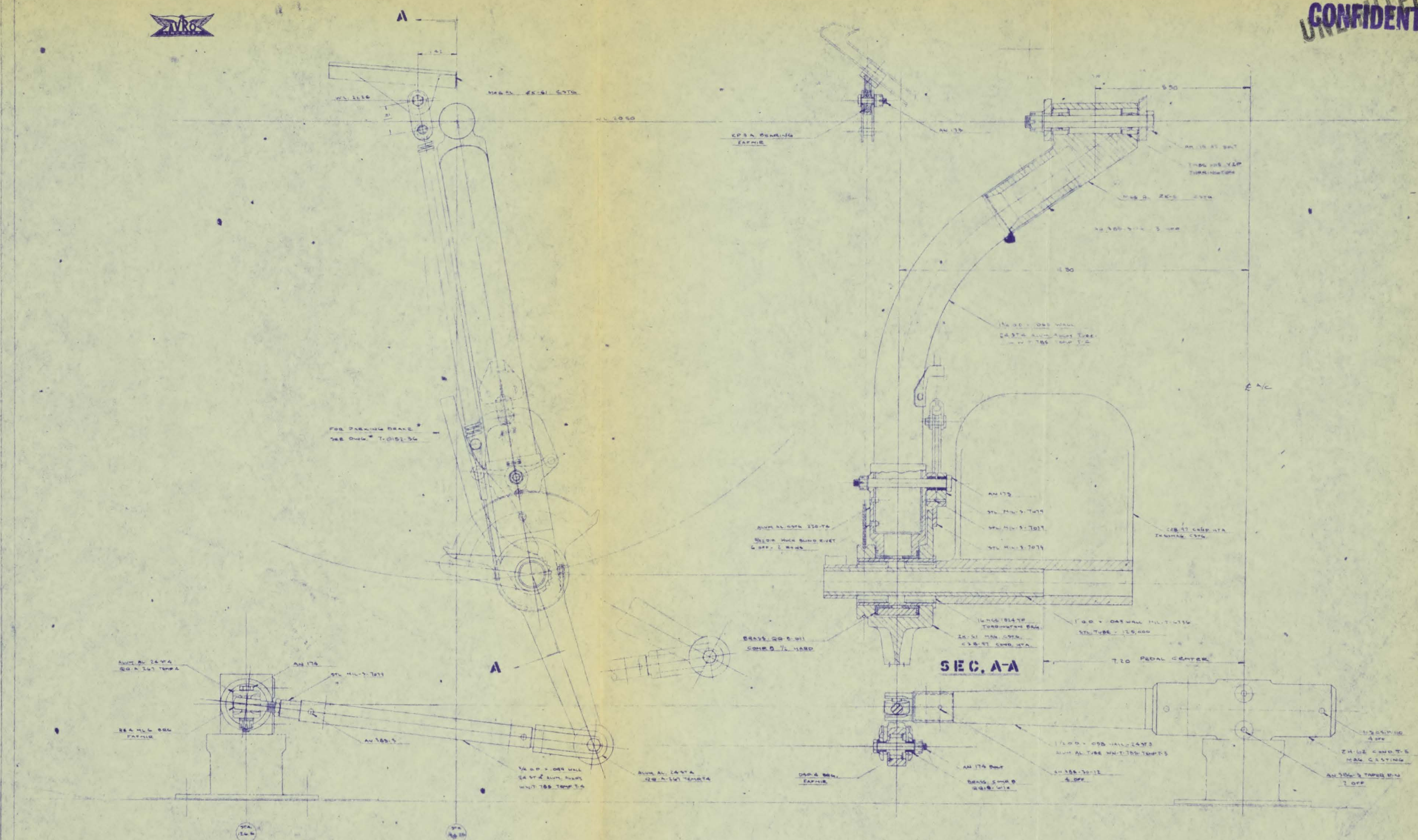
STIFFNESS OF SECTIONS A, B, C & D



RUDDER SYSTEM DATA

FIG. 6A

CONFIDENTIAL



RUDDER PEDALS

FIG. 9

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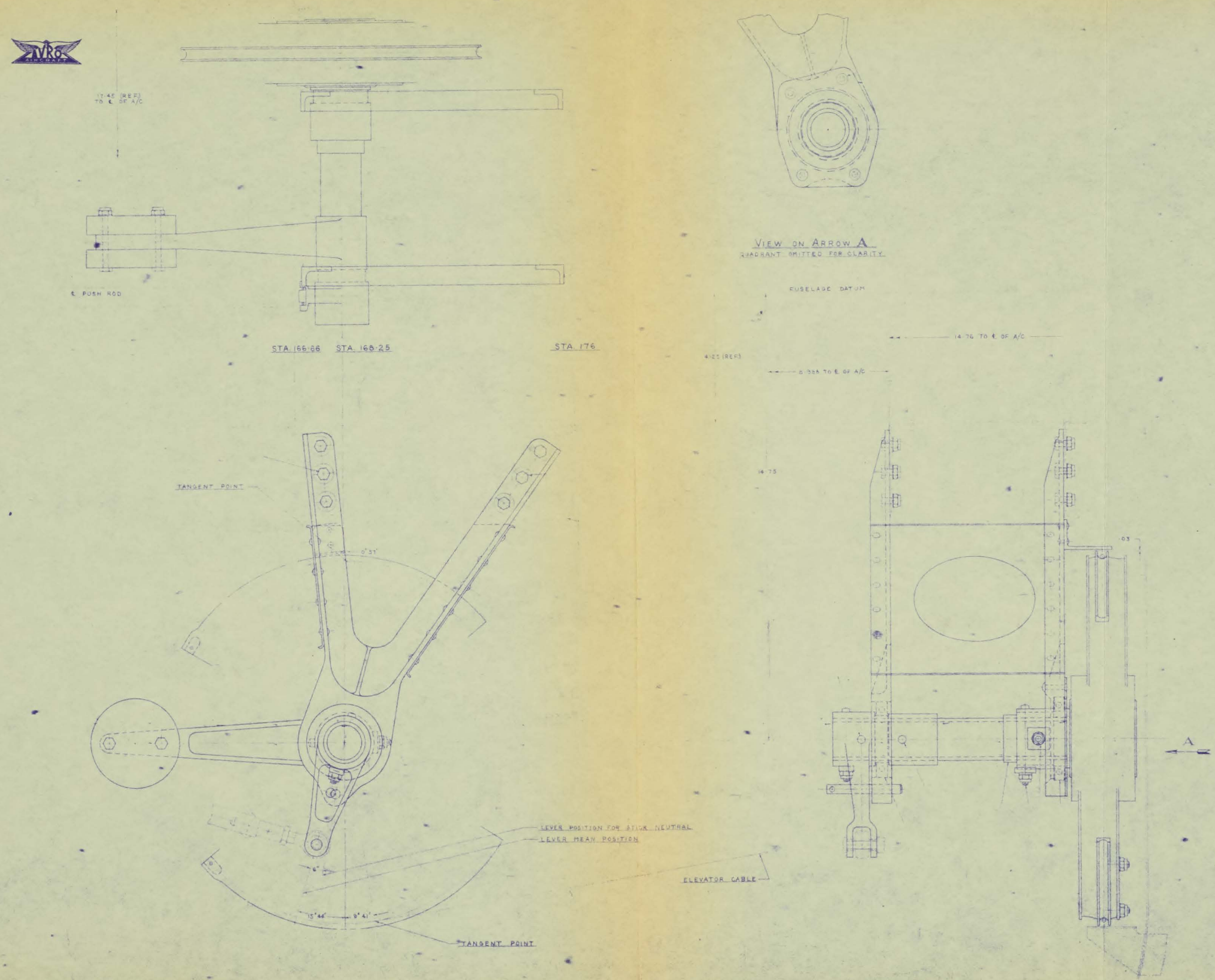
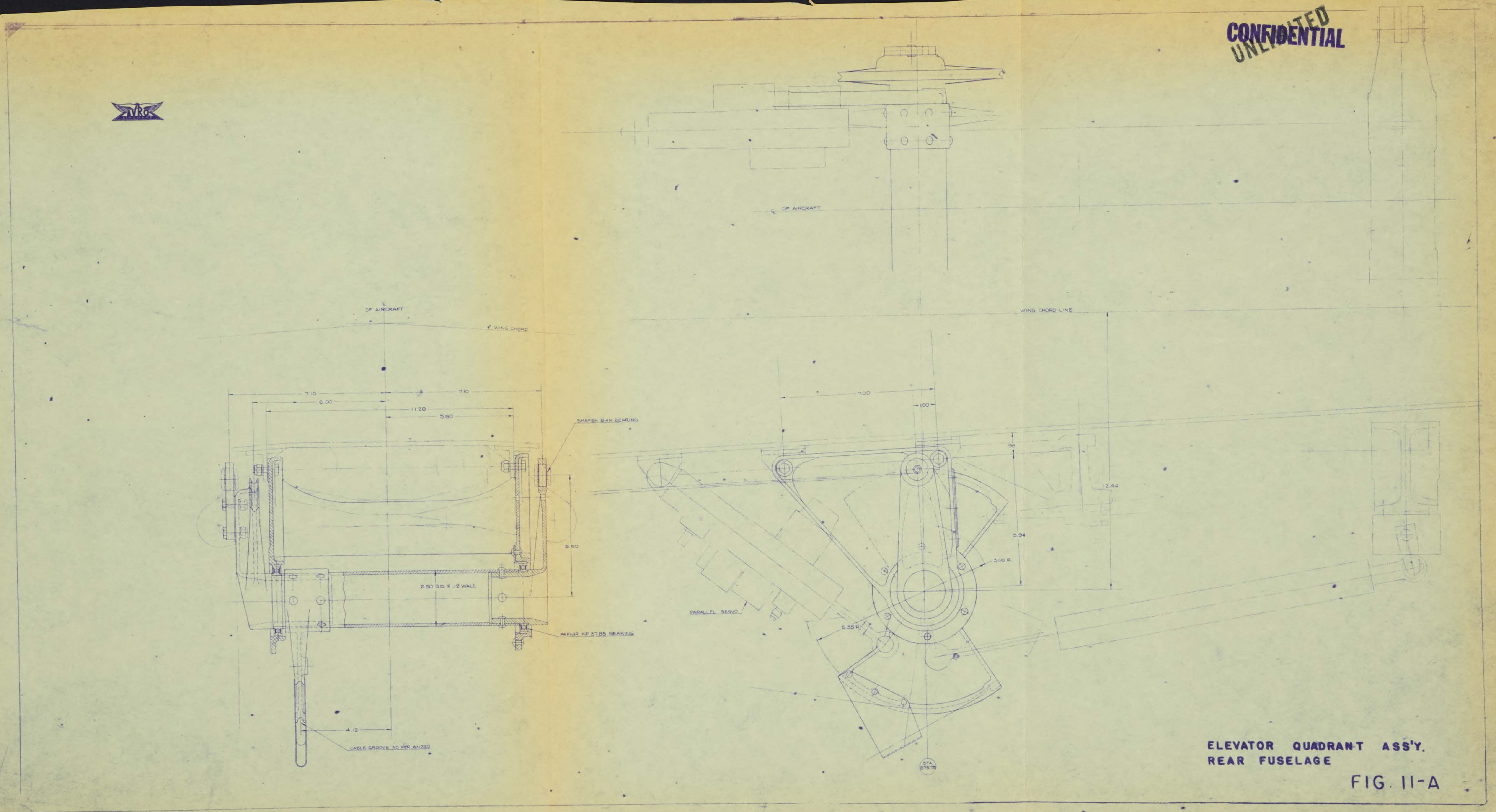
UNLIMITED



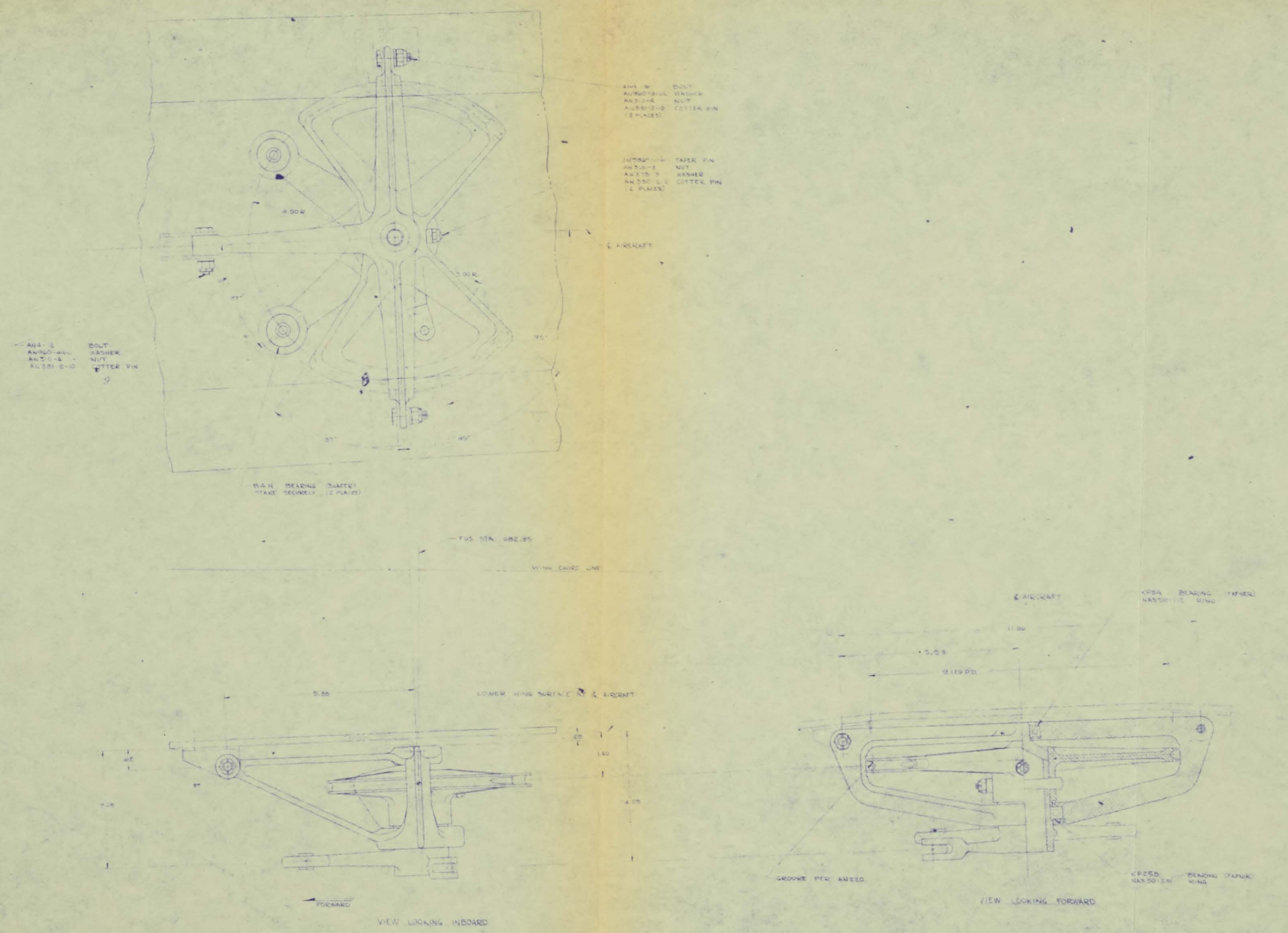
ELEVATOR QUADRANT ASS'Y.
FRONT FUSELAGE

FIG. 10



ELEVATOR QUADRANT ASS'Y.
REAR FUSELAGE

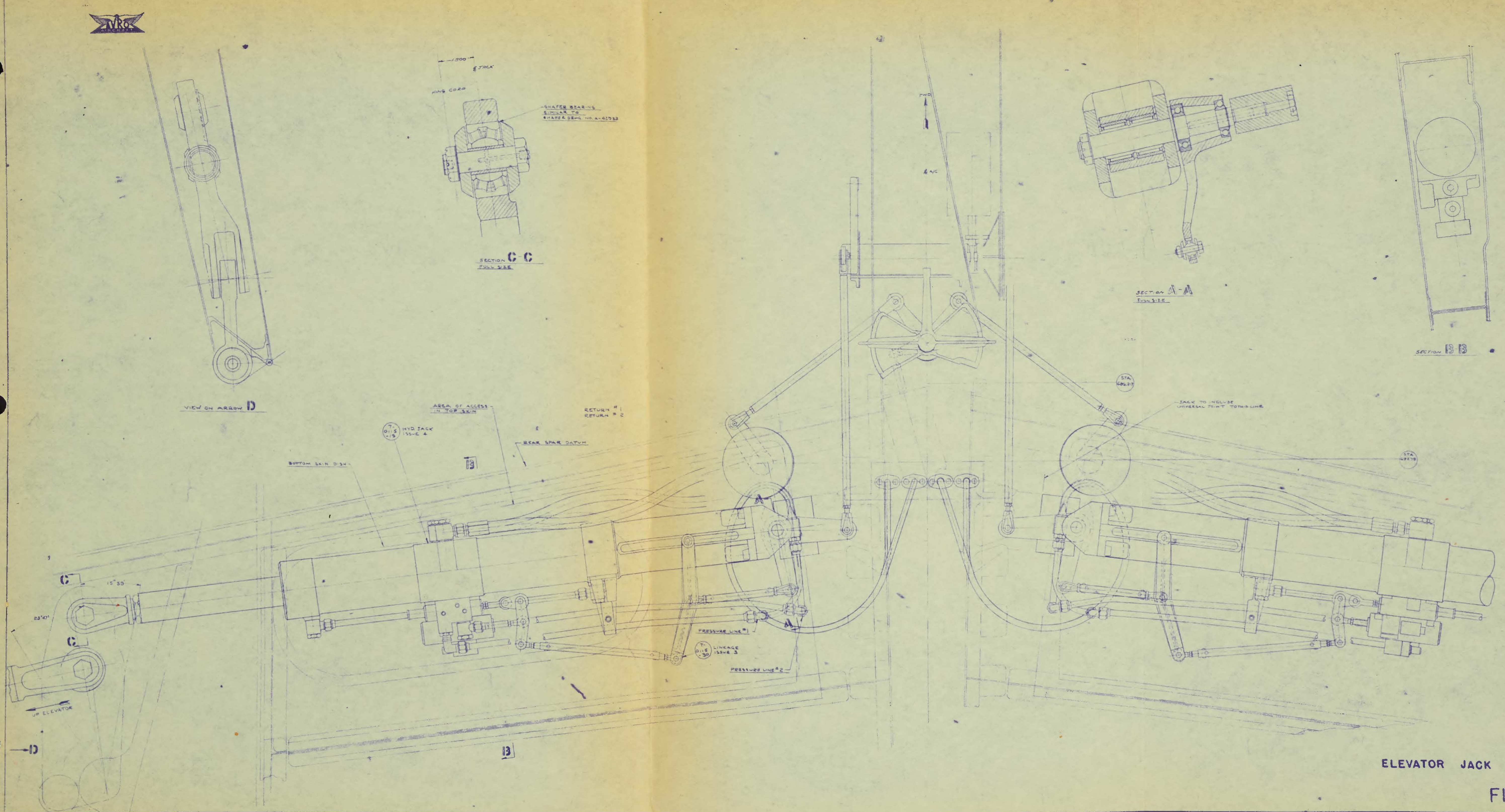
FIG. 11-A



ADVANCE PRINT

AILERON QUADRANT ASS'Y.
REAR FUSELAGE

FIG 11-B



ELEVATOR JACK ASS'Y.

FIG. 12

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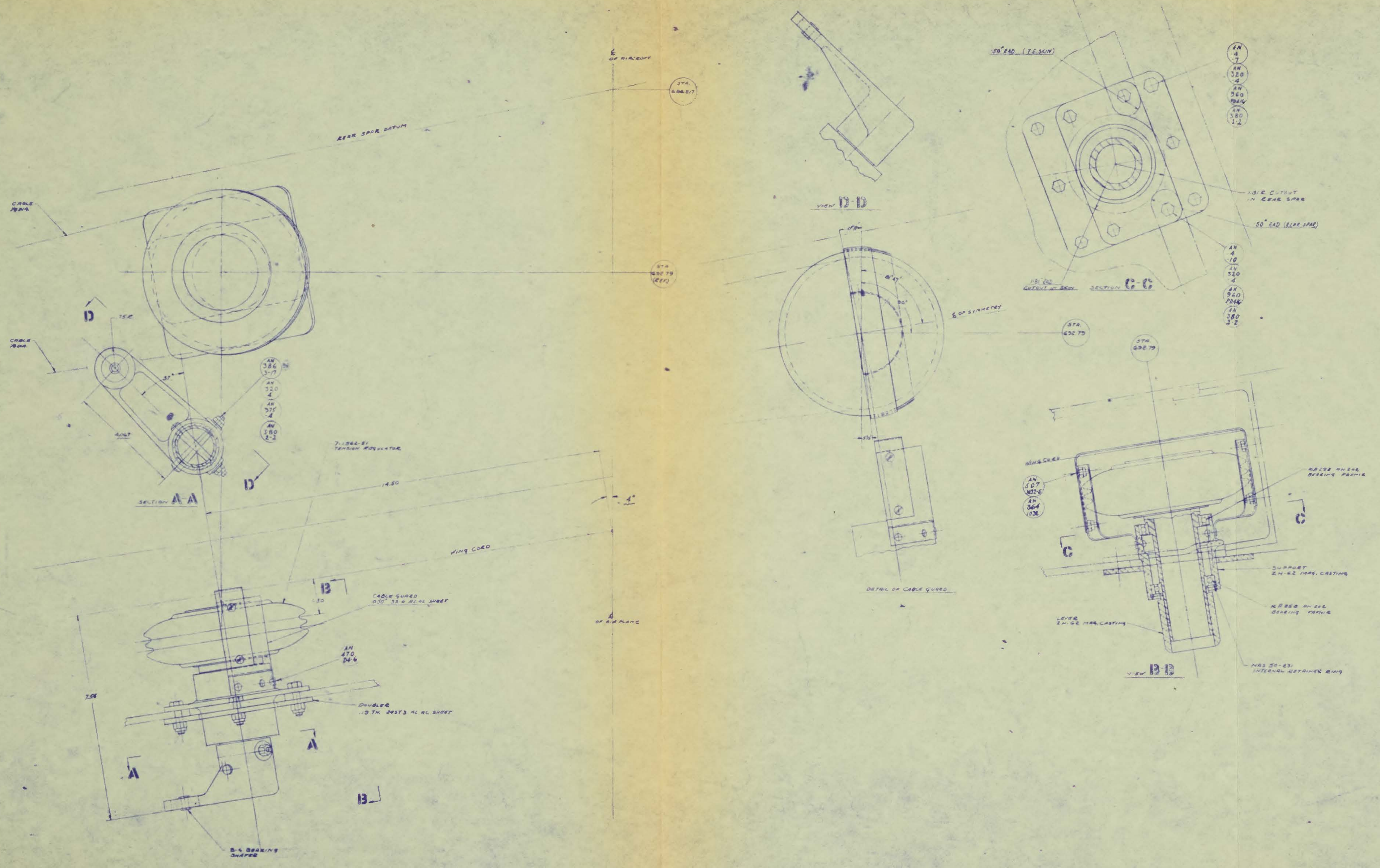
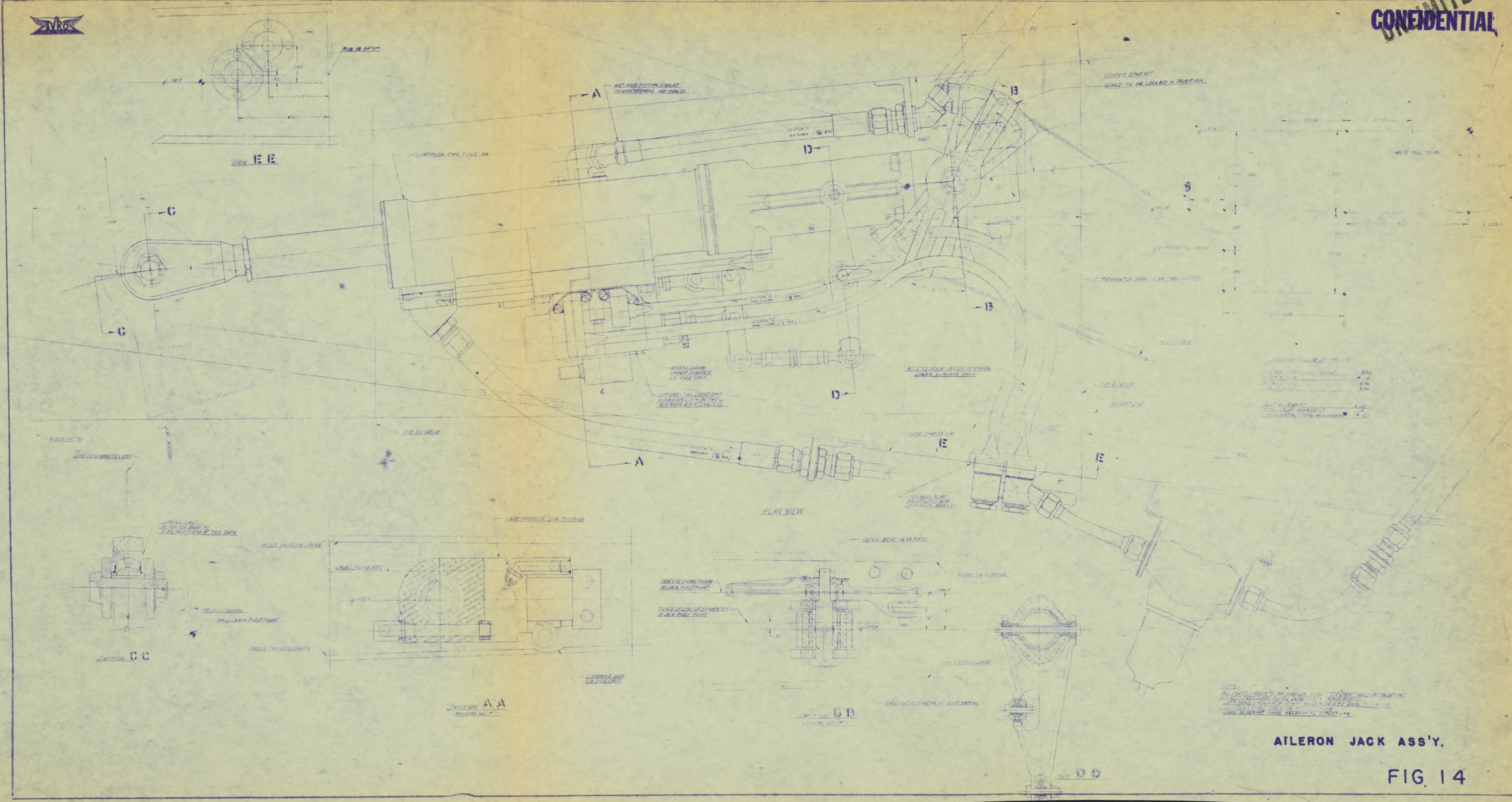
UNLIMITED



AILERON TENSION REGULATOR
QUADRANT ASS'Y. INNER WING

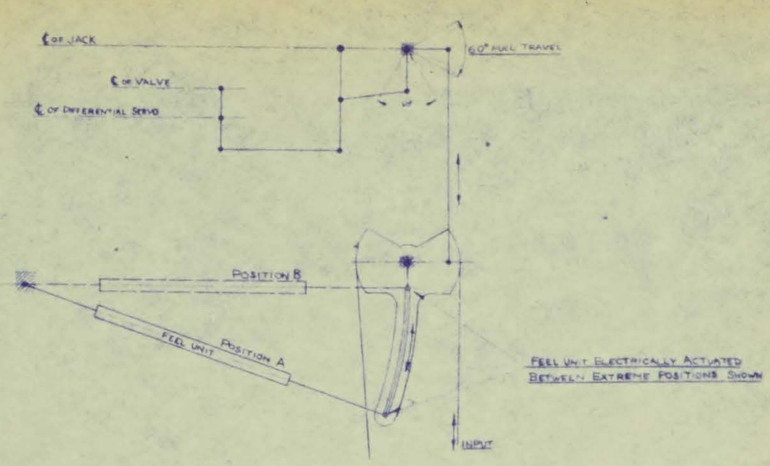
FIG. 13

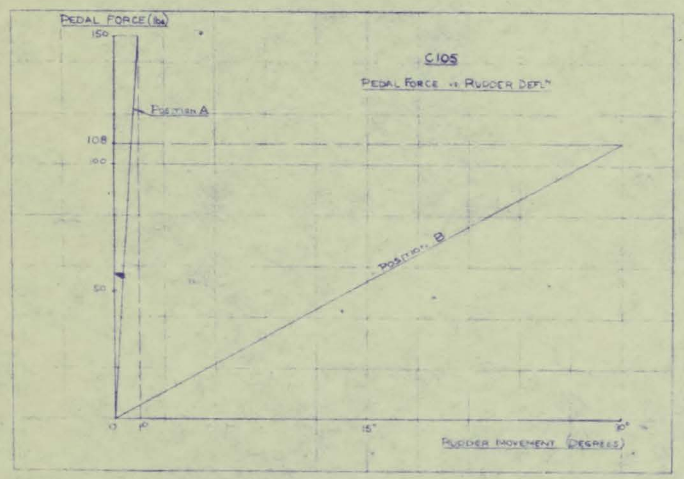
UNLIMITED
CONFIDENTIAL

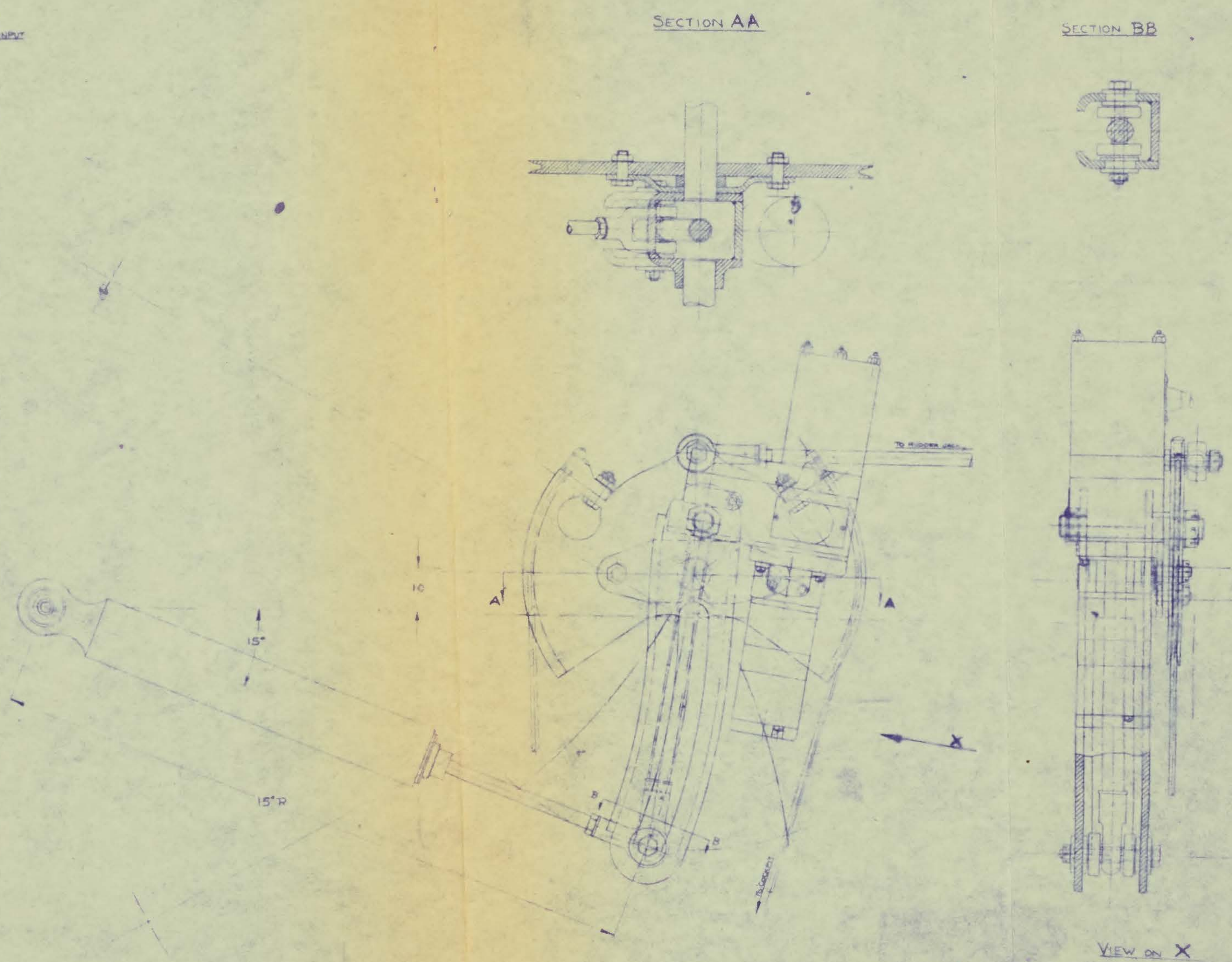


AILERON JACK ASS'Y.

FIG. 14







RUDDER FEEL SYSTEM &
QUADRANT ASS'Y. IN FIN

FIG. 15

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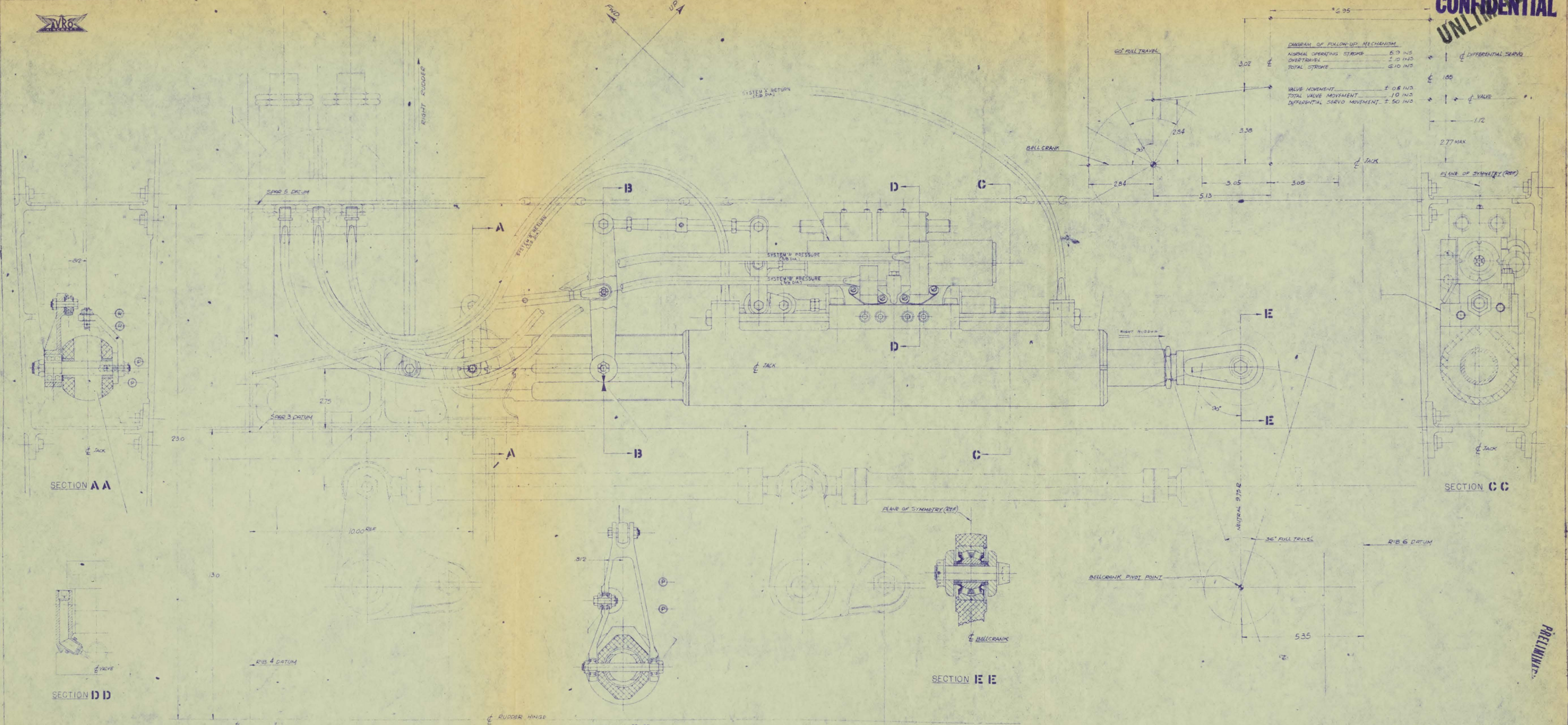
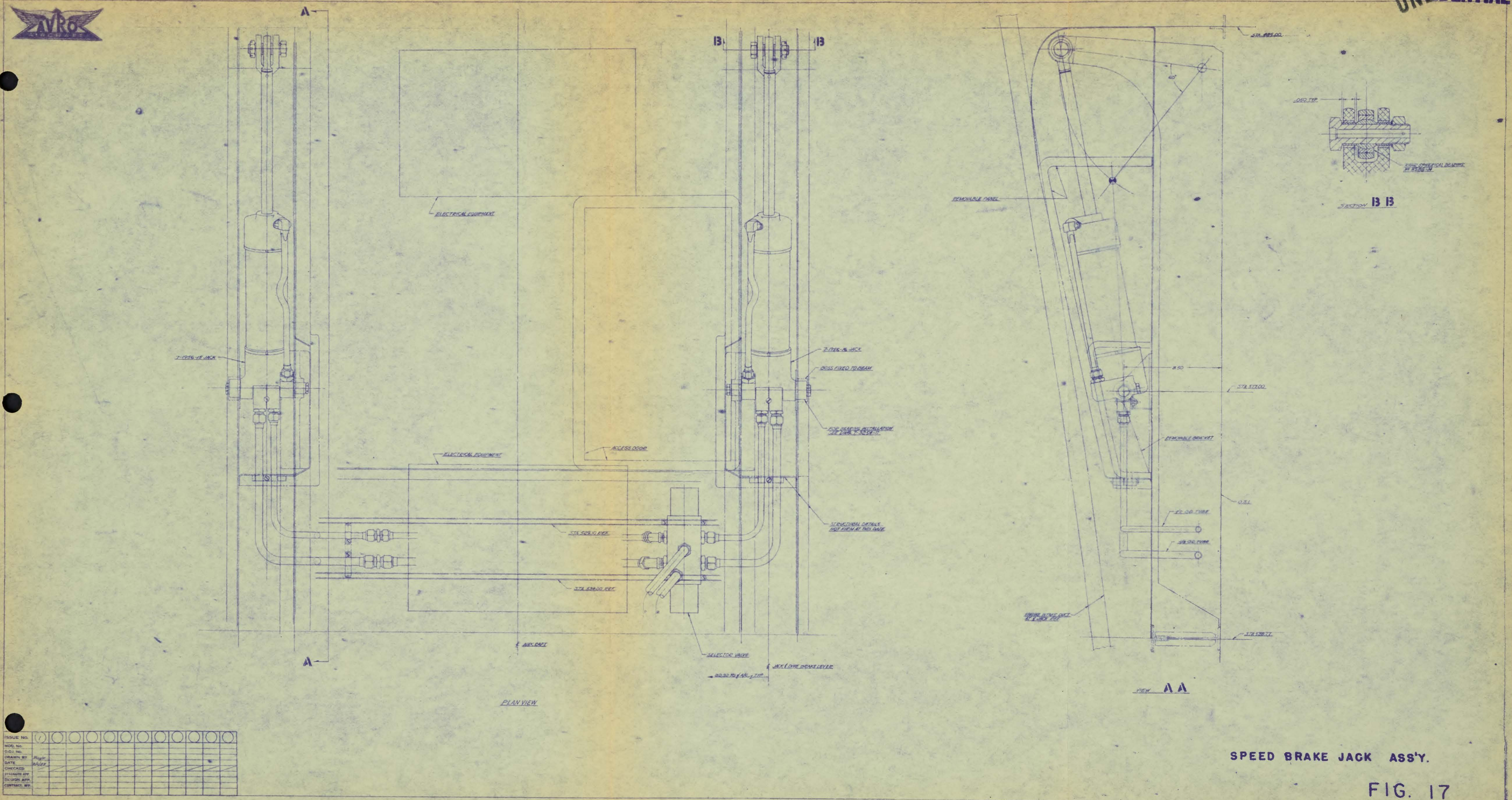
UNLIMITED



RUDDER JACK ASS'Y.

FIG. 16

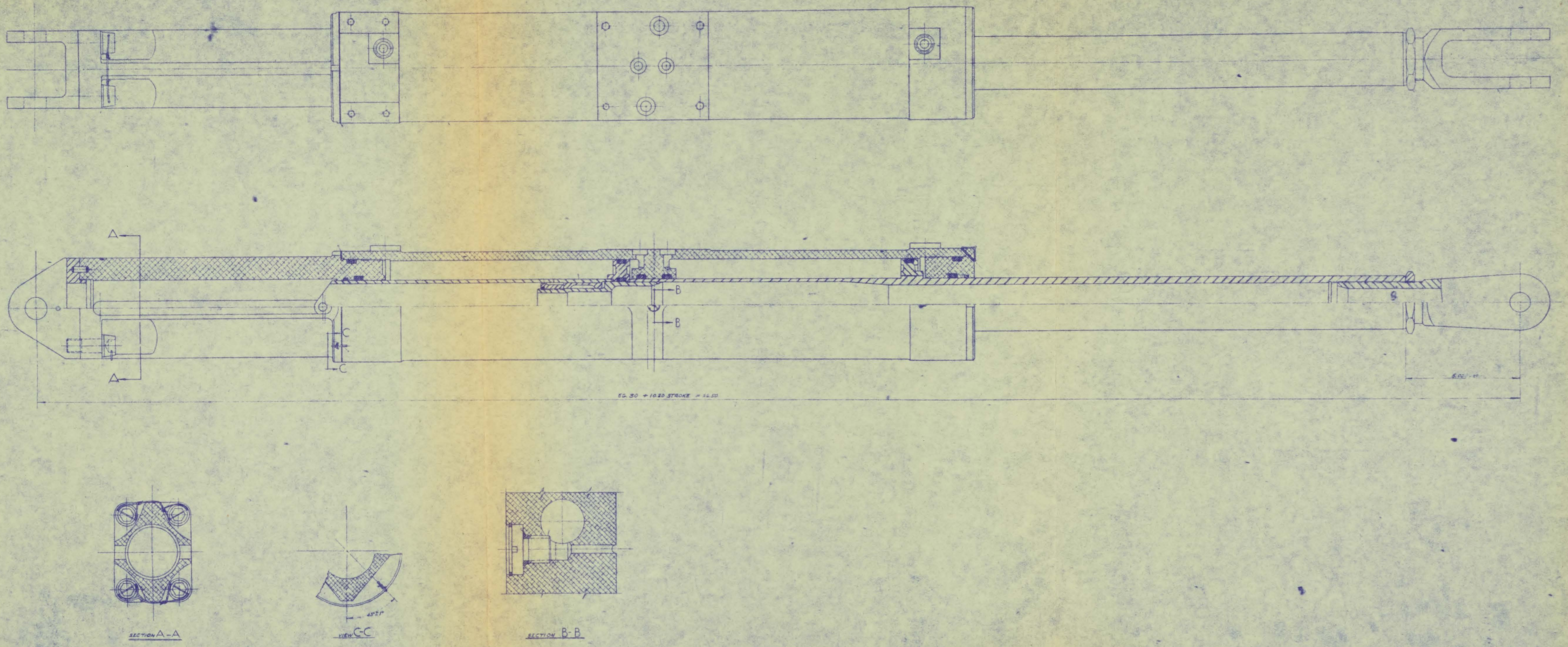


SPEED BRAKE JACK ASS'Y.

FIG. 17

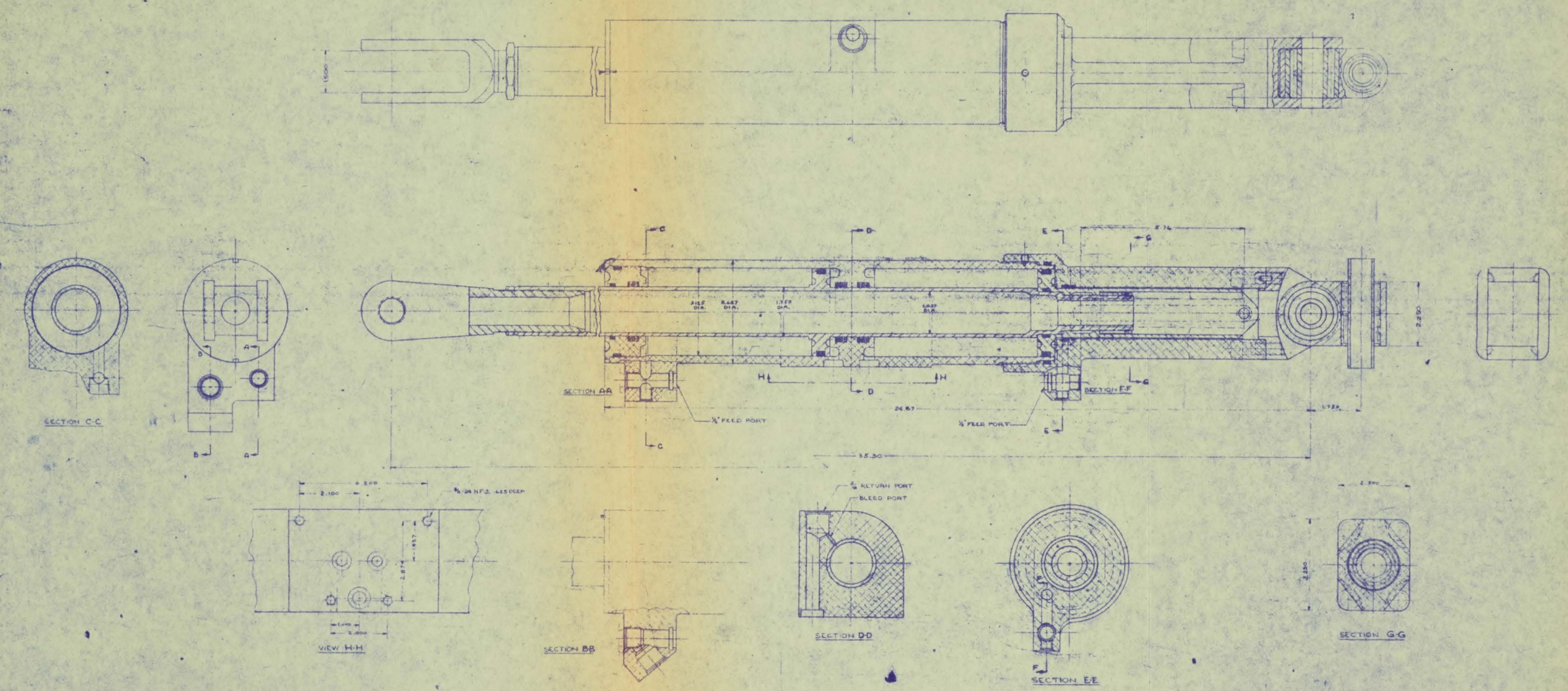
CONFIDENTIAL

UNLIMITED



ELEVATOR JACK

FIG. 18

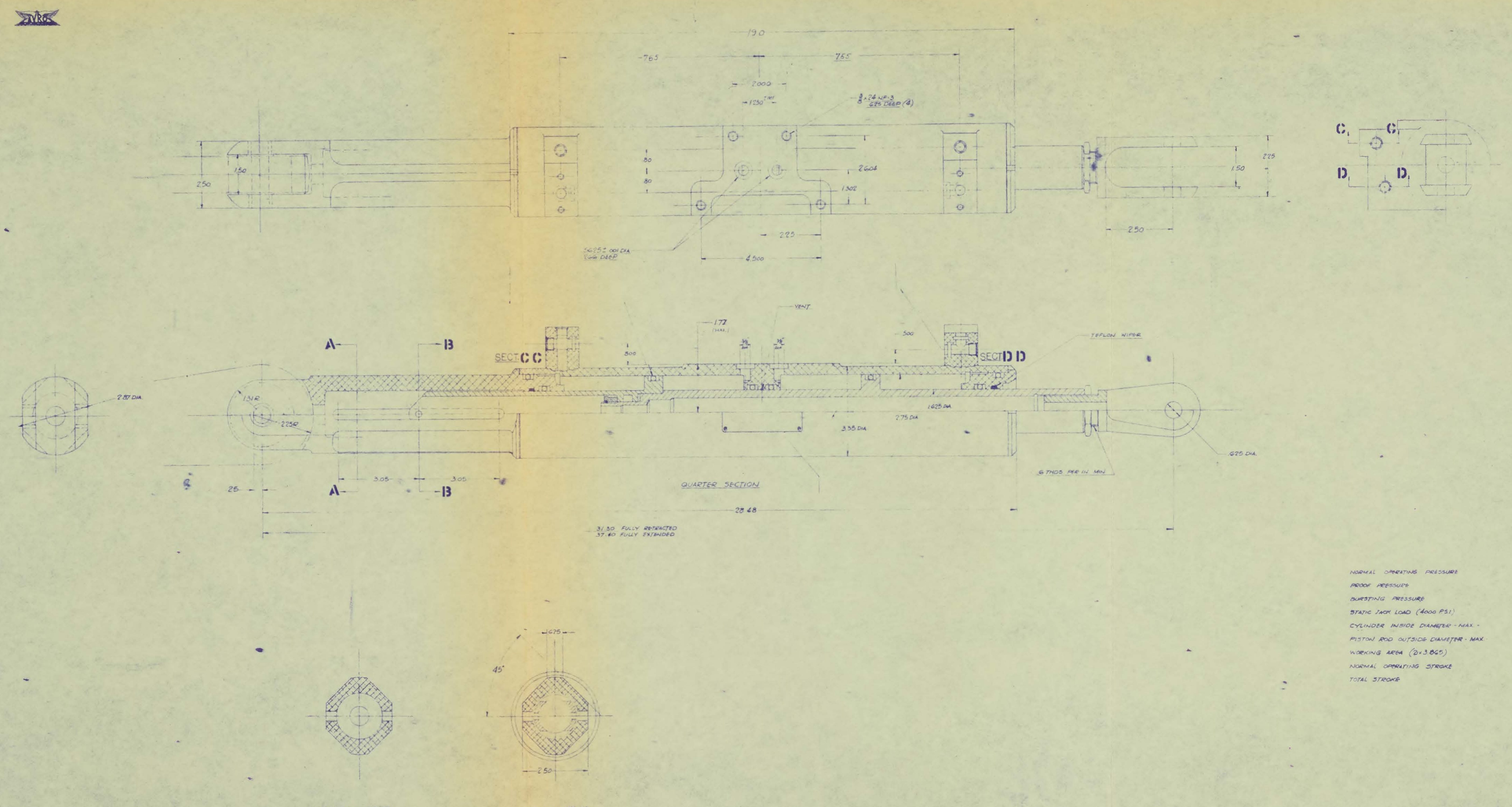


NOTES:
1. ALL BACK-UP RINGS TEFLON.
2. ALL "O" RINGS "PRECISION RUBBER" COMPOUND #711-70 OR "PARKER" #890-5

AILERON JACK

FIG. 19

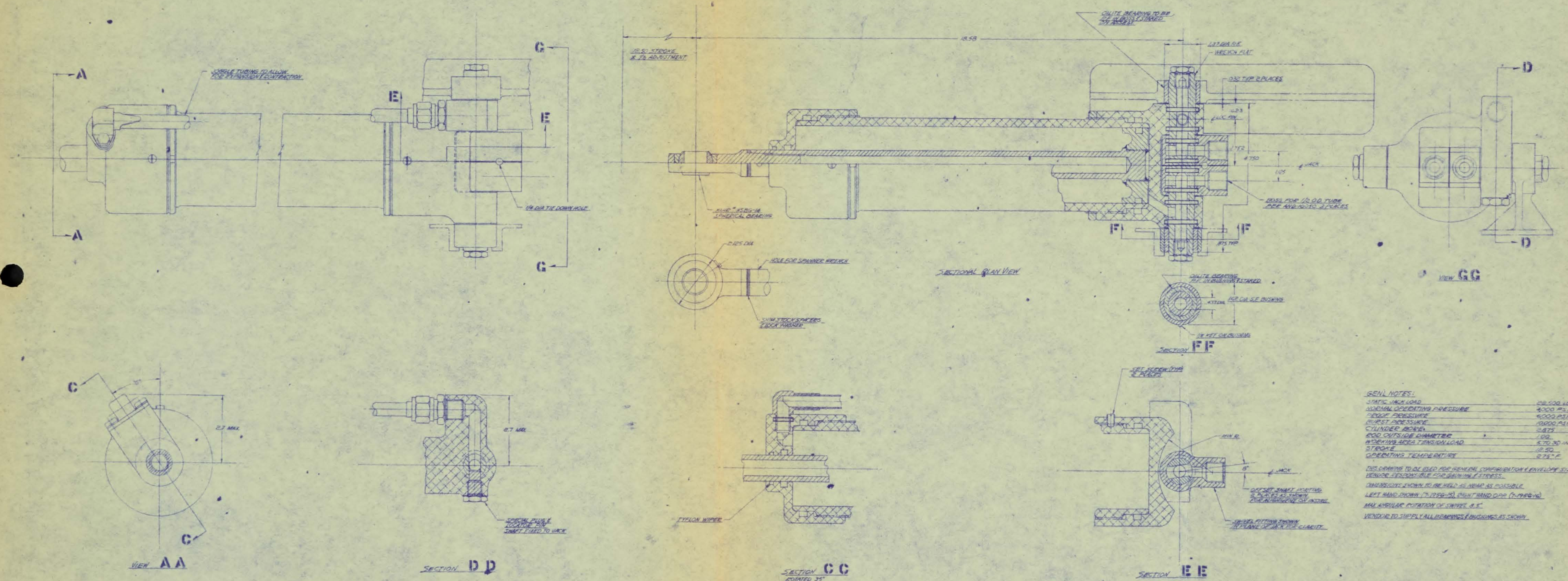
CONFIDENTIAL
UNLIMITED



NORMAL OPERATING PRESSURE	4000 PSI
PROOF PRESSURE	6000 PSI
BURSTING PRESSURE	10,000 PSI.
STATIC JACK LOAD (4000 PSI)	30,900 LBS
CYLINDER INSIDE DIAMETER - MAX. -	2.750 INS.
PISTON ROD OUTSIDE DIAMETER - MAX.	1.625 INS.
WORKING AREA (2×3.865)	7.73 SQ INS.
NORMAL OPERATING STROKE	5.9 INS.
TOTAL STROKE	6.10 INS

RUDDER JACK

FIG. 20



GENL NOTES:

STATIC JACK LOAD	28,500 LBS
NORMAL OPERATING PRESSURE	4000 PSI
PROOF PRESSURE	6000 PSI
BURST PRESSURE	10,000 PSI
CYLINDER BORE	2.875
ROD OUTSIDE DIAMETER	1.00
WORKING AREA TENSION LOAD	5.70 SQ IN
STROKE	12.50
OPERATING TEMPERATURE	275° F

THIS DRAWING TO BE USED FOR GENERAL CONFIGURATION & ENVELOPE SIZE ONLY
VENDOR RESPONSIBLE FOR GAUGING & STRESS.

DIMENSIONS SHOWN TO BE HELD AS NEAR AS POSSIBLE

LEFT HAND SHOWN (7-1956-15), RIGHT HAND OPP (7-1956-16)

MAX ANGULAR ROTATION OF SWIVEL 8.5°

VENDOR TO SUPPLY ALL BEARINGS & BUSHINGS AS SHOWN

[redacted]

SPEED BRAKE JACK

FIG. 21

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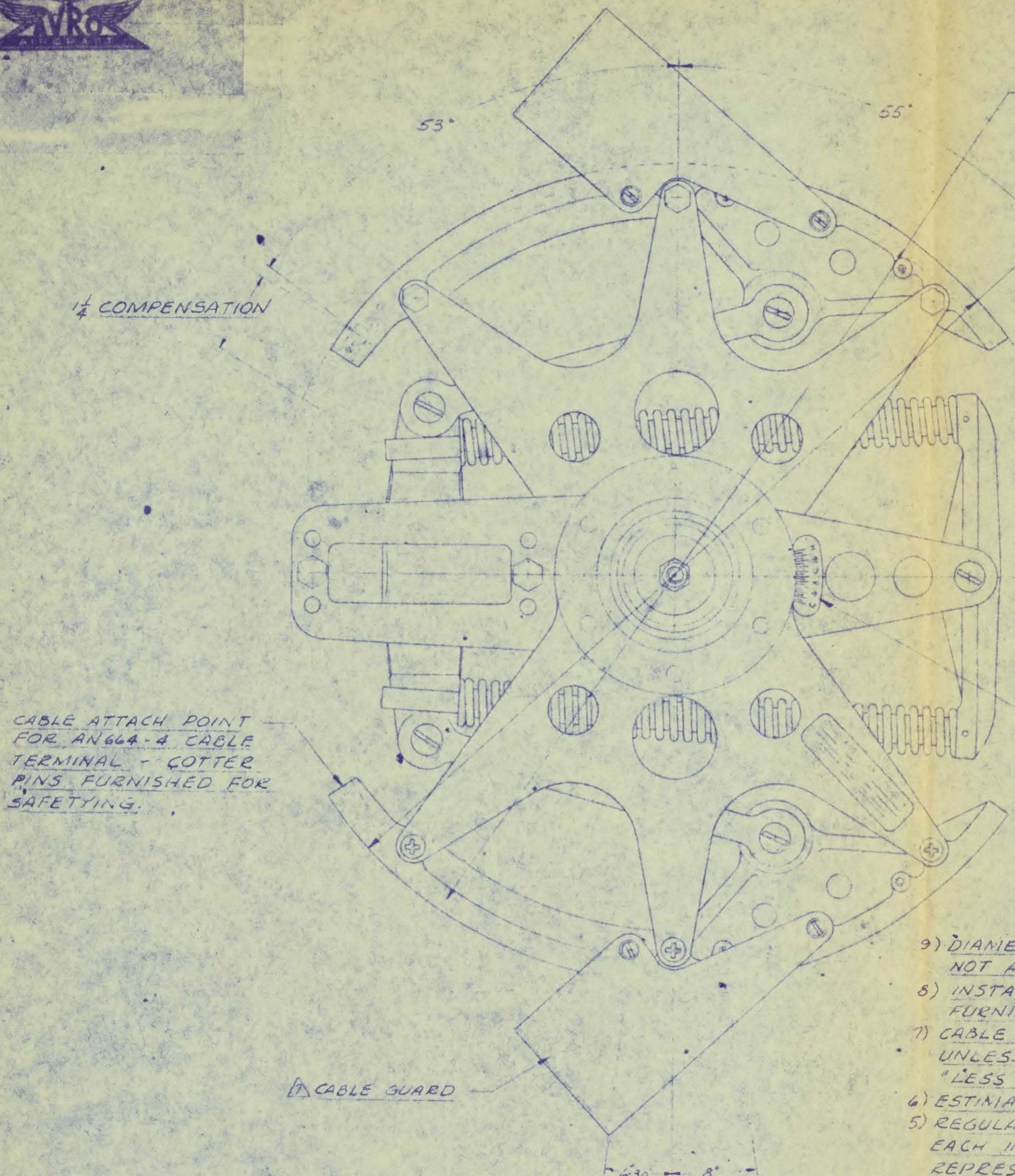

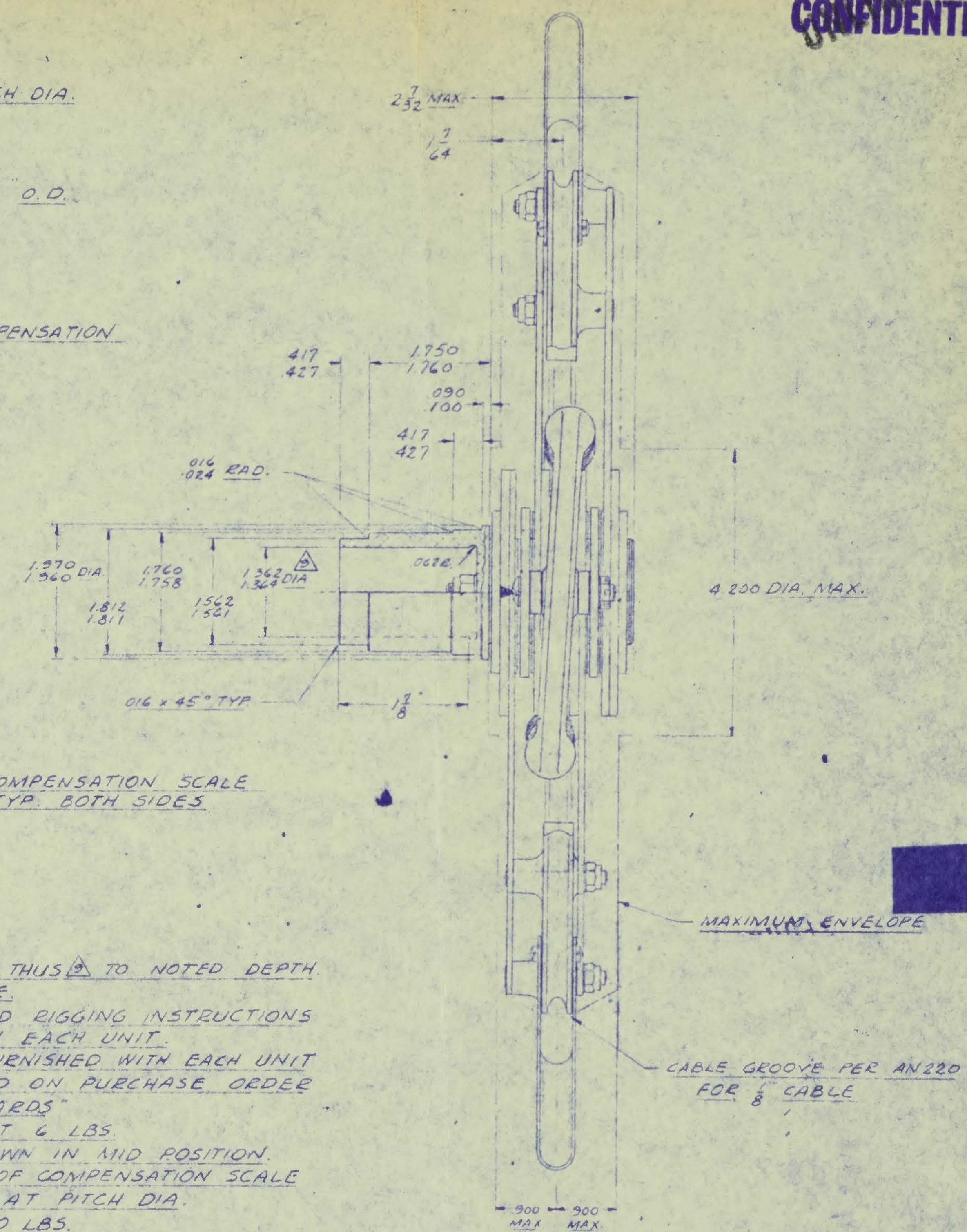

NOTE:-

9) DIAMETER NOTED THUS △ TO NOTED DEPTH NOT A THRU BORE.

8) INSTALLATION AND RIGGING INSTRUCTIONS FURNISHED WITH EACH UNIT.

7) CABLE GUARDS FURNISHED WITH EACH UNIT UNLESS SPECIFIED ON PURCHASE ORDER "LESS CABLE GUARDS"

6) ESTIMATED WEIGHT 6 LBS.

5) REGULATOR IS SHOWN IN MID POSITION. EACH INCREMENT OF COMPENSATION SCALE REPRESENTS 1/8" AT PITCH DIA.

4) ULTIMATE LOAD 820 LBS.

3) RIG LOAD VARIATION FOR FULL RANGE OF COMPENSATION 40 LBS MIN., 60 LBS. MAX.

2) COMPENSATION PER CABLE 2 1/2" MIN.

1) UNIT DESIGNED TO MEET THE REQUIREMENTS OF AV. ROE SPEC. E222 (8) AND CONTROL DWG. NO 7-0115-95 . SEE PACIFIC SCIENTIFIC CO. DATA REPORT NO. 102 FOR SUMMARY OF COMPLIANCE.

TENSION REGULATOR QUADRANT FRONT FUSELAGE

FIG. 22

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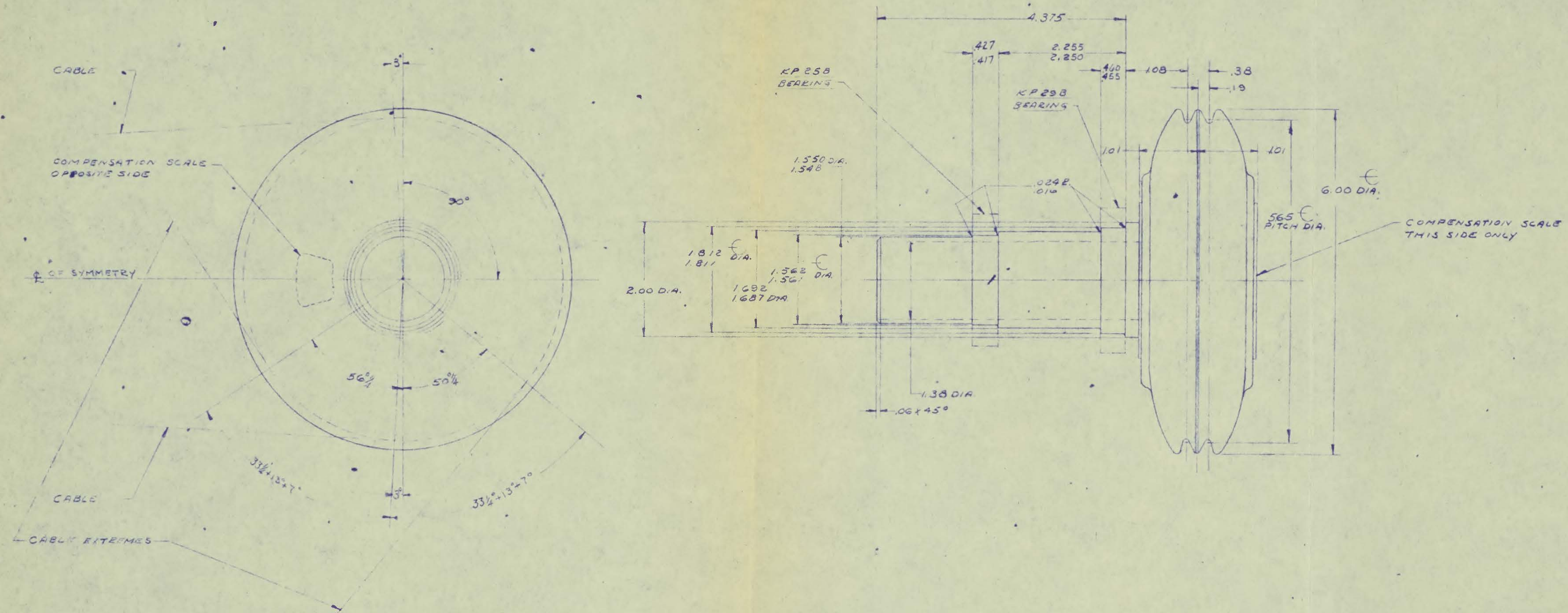


NOTES:

1 CABLE DIA 1/8
2 RIG TENSION 40# TO 60#
3 - MOVEMENT OF SECTOR: FROM TANGENT POINT
OPERATING RANGE ± 33¼° OVERTRAVEL ± 7°, COMPENSATION ± 13°
4 - REGULATOR SHOWN IN MID POSITION OF COMPENSATION
5 CABLE LOAD 680# ULT
6 DIAMETERS MARKED THUS ℄ MUST BE CONCENTRIC WITHIN .010 F.I.R.

TENSION REGULATOR QUADRANT
INNER WING

FIG. 23

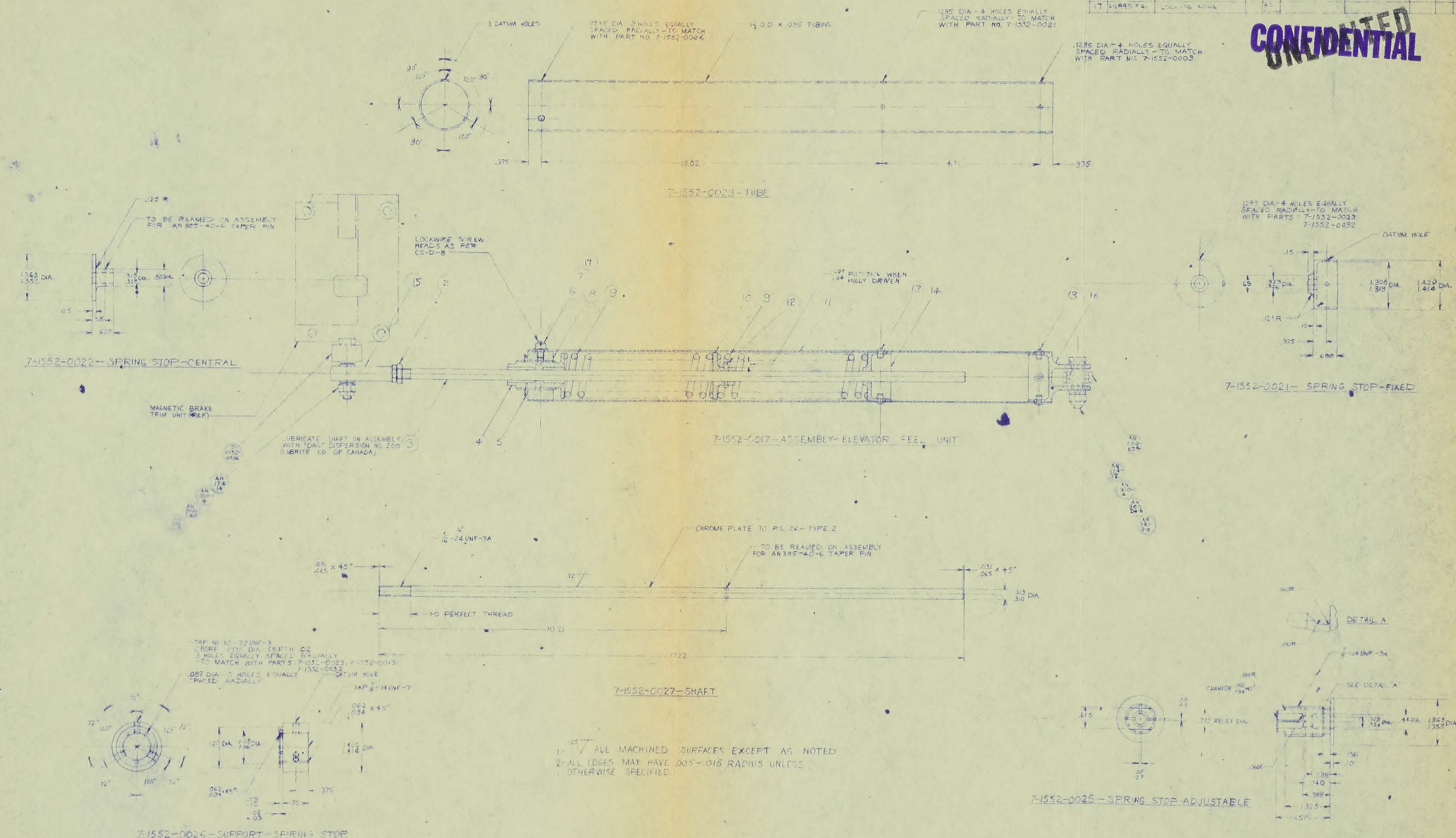
AVRO AIRCRAFT

CONFIDENTIAL

UNLIMITED

DRAWING PARTS LIST

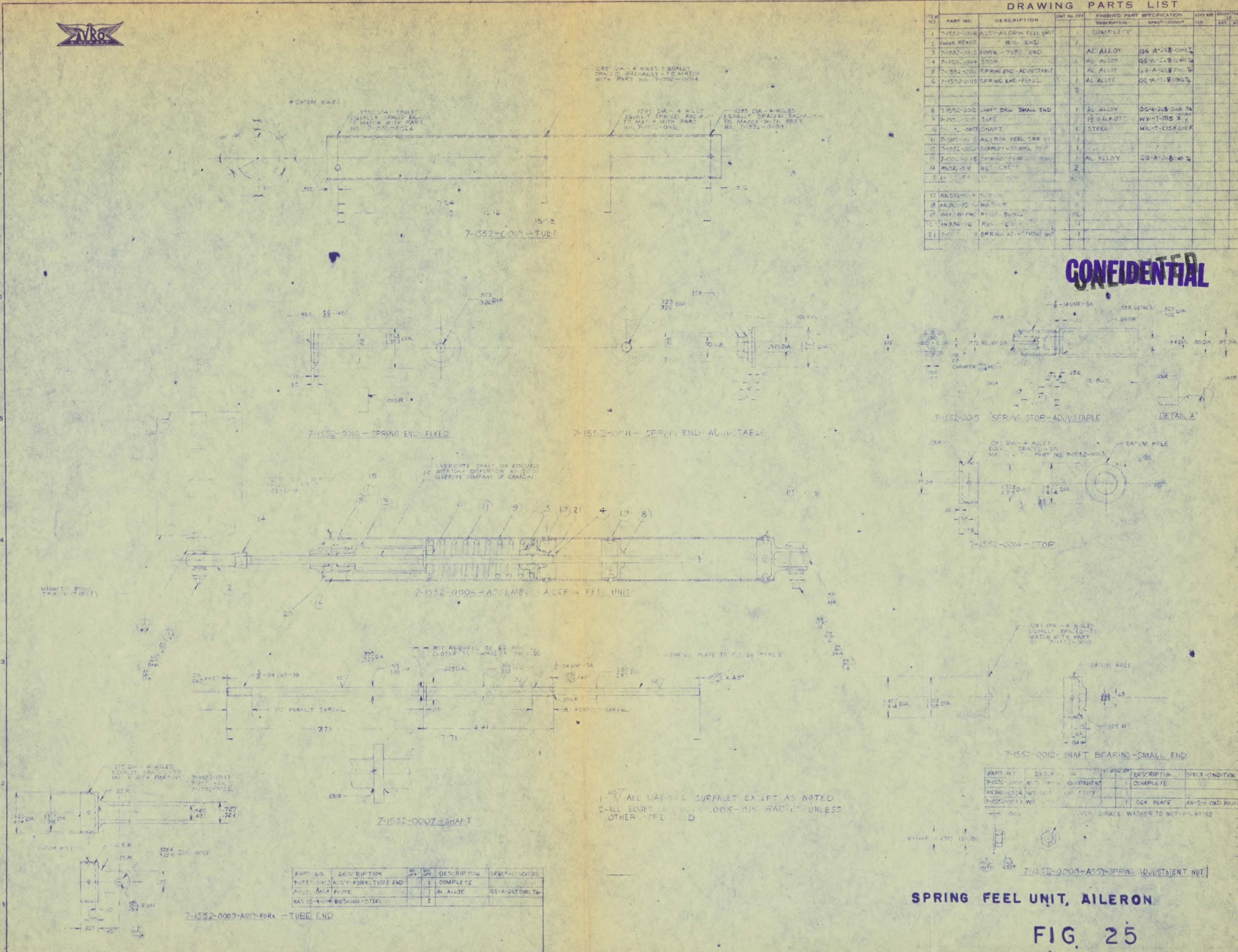
ITEM NO.	PART No.	DESCRIPTION	UNIT No. OFF		FINISHED PART SPECIFICATION DESCRIPTION	SPEC^N - COND^N	LOFT REF CLD.	WEIGHT/PART LB EST.	ACT.
1	7-1552-0017	ASS'Y-COMPLETE		1					
2	AN316-5R	NUT-CHECK		1					
3	7-1552-0027	SHAFT		1	STEEL	MIL-S-6758 COND F			
4	7-1552-0025	SPRING STOP-ADJUSTABLE		1	AL ALLOY	QQ-A-268 COND T4			
5	AN936-16	RING-LOCK		1					
6	AN512-10-4	SCREW		3					
7	AN960PD10L	WASHER		3					
8	7-1552-0026	SUPPORT-SPRING STOP		1	AL ALLOY	QQ-A-268-COND T4			
9	7-0115-0017	ELEVATOR FEEL SPRING		2					
10	7-1552-0022	SPRING STOP-CENTRAL		1	AL ALLOY	QQ-A-268-COND T4			
11	7-1552-0023	TUBE		1	AL ALLOY	WW-T-785 [illegible]			
12	AN385-40-6	PIN-TAPERED PLAIN		1					
13	HUCK CKL-P+C	RIVET-BLIND		8					
14	7-1552-0021	SPRING STOP-FIXED		1	AL ALLOY	QQ-A-268-COND T4			
15	FAFNIR RE4F5	ROD END		1					
16	7-1552-0009	FORK-TUBE END		1	[illegible] 7-1552-0006				
17	AN995-F41	LOCKING WIRE		A/R					



1- ALL MACHINED SURFACES EXCEPT AS NOTED
2- ALL EDGES MAY HAVE .005-.015 RADIUS UNLESS OTHERWISE SPECIFIED

SPRING FEEL UNIT, ELEVATOR

FIG. 24



DRAWING PARTS LIST

ITEM NO.	PART NO.	DESCRIPTION	UNIT No. OFF		FINISHED PART SPECIFICATION DESCRIPTION	SPEC. – COND.	LOFT REF. CLD.	WEIGHT/PART LB EST.	ACT.
1	7-1552-0006	ASSY-AILERON FEEL UNIT		1	COMPLETE				
2	[illegible]	[illegible] END		1					
3	7-1552-00[illegible]	FORK – [illegible] END			AL ALLOY	QQ-A-268-COND. T4			
4	7-155[illegible]	STOP		1	AL ALLOY	QQ-A-268-COND. T4			
5	7-1552-0011	SPRING END – ADJUSTABLE		1	AL ALLOY	QQ-A-268 COND. T4			
6	7-1552-0010	SPRING END – FIXED		1	AL ALLOY	QQ-A-268 COND. T4			
				2					
8	7-1552-0012	SHAFT BRG. SMALL END		1	AL ALLOY	QQ-A-268-COND. T4			
9	7-155[illegible]	TUBE		1	1½ O.D. x .03[illegible]	WW-T-785 [illegible]			
10	[illegible]-0007	SHAFT		1	STEEL	MIL-S-[illegible] COND F			
11	7-[illegible]	AILERON FEEL SPR[illegible]		1					
12	7-1552-[illegible]	SUPPORT – SPRING [illegible]		1					
13	7-1552-0015	SPRING STOP – [illegible]		1	AL ALLOY	QQ-A-268 COND T4			
14	AN[illegible]	NUT – CHECK		2					
15	[illegible]	[illegible]							
17	AN[illegible]	SCREW							
18	AN[illegible]	WASHER							
19	[illegible]	RIVET – BLIND		12					
20	AN396-16	[illegible]		1					
21	7-15[illegible]8	SPRING ADJUSTMENT NUT		1					

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7-1552-0009 – TUBE

7-1552-0010 – SPRING END FIXED

7-1552-0011 – SPRING END ADJUSTABLE

7-1552-0015 SPRING STOP-ADJUSTABLE

DETAIL "A"

7-1552-0014 – STOP

7-1552-0006 – ASSEMBLY – AILERON FEEL UNIT

7-1552-0007 – SHAFT

7-1552-0012 – SHAFT BEARING – SMALL END

7-1552-0008 – ASSY – SPRING ADJUSTMENT NUT

7-1552-0003 – ASSY – FORK – TUBE END

PART NO.	DESCRIPTION			DESCRIPTION	SPEC. – CONDITION
7-1552-0003	ASSY-FORK, TUBE END		1	COMPLETE	
7-1552-0013	FORK		1	AL ALLOY	QQ-A-267 COND. T4
NAS 75-4-[illegible]	BUSHING – STEEL		2		

1 – ALL MACHINED SURFACES EXCEPT AS NOTED
2 – ALL EDGES [illegible] .005 – .015 RADIUS UNLESS OTHERWISE SPECIFIED

SPRING FEEL UNIT, AILERON

FIG. 25

AVRO AIRCRAFT

AVAILABLE ELEVATOR HINGE MOMENT

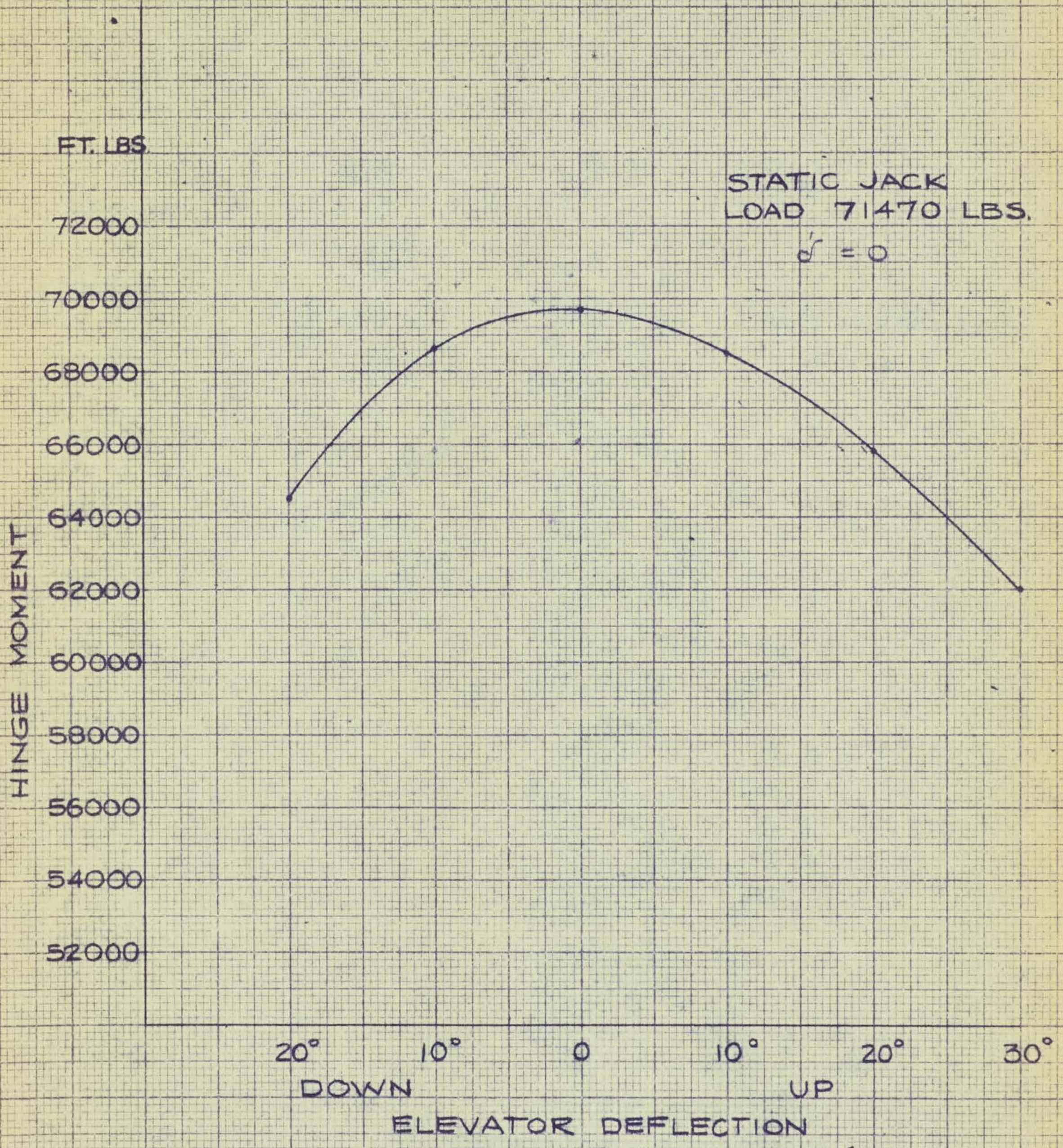


FIG. 27

C-105 MAR. 17, 1955 BIRCKHOLTZ

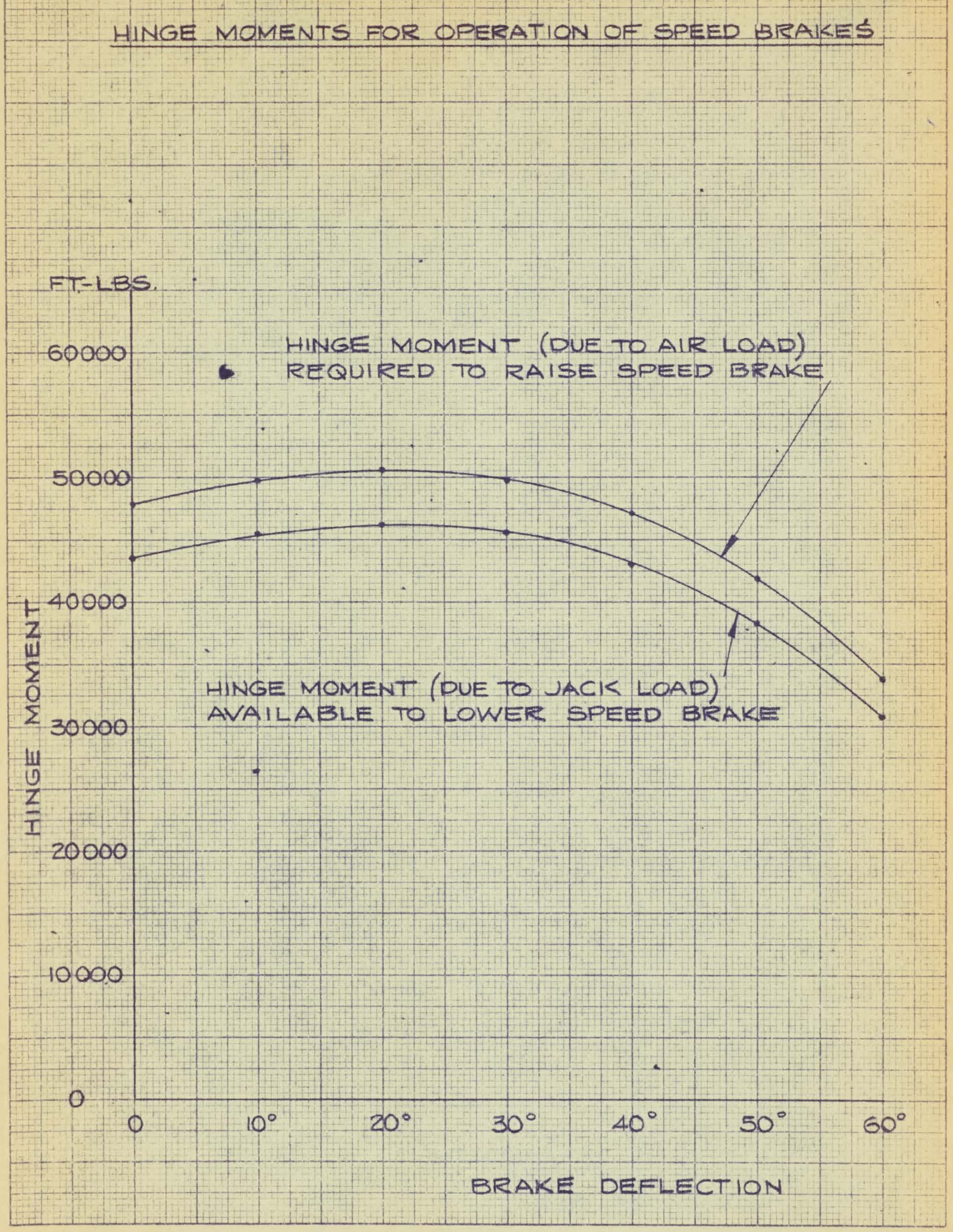
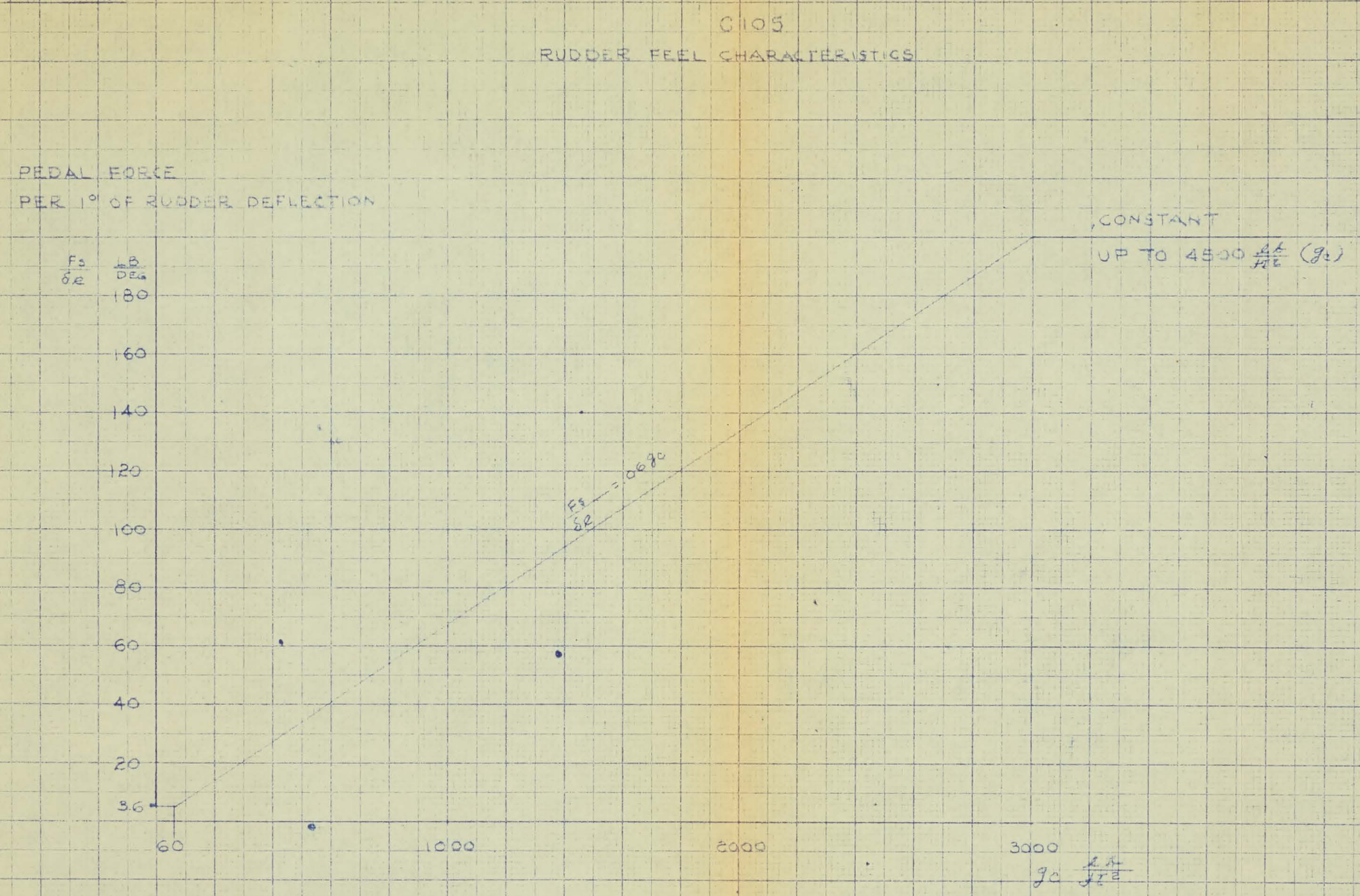
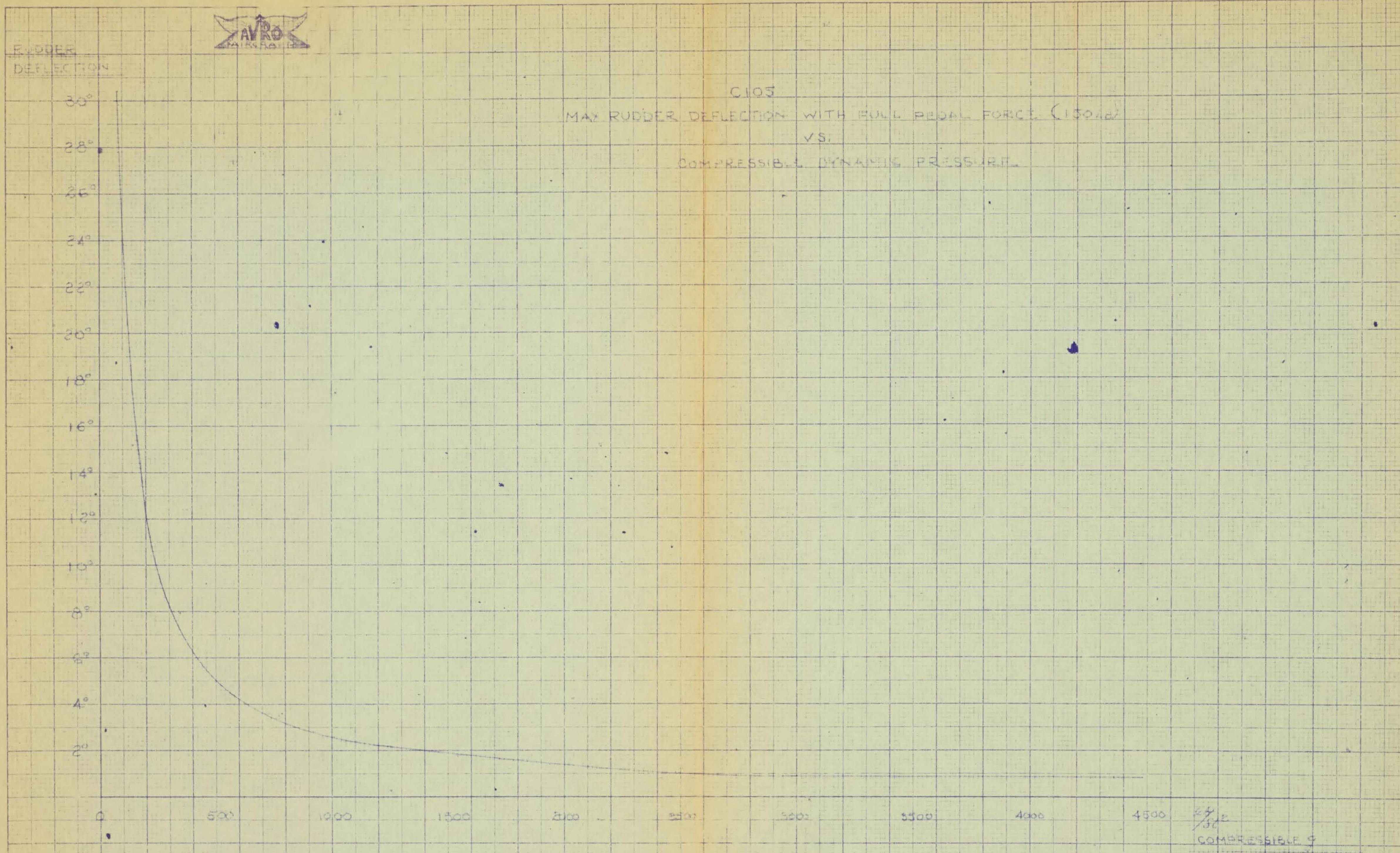


FIG. 30



RUDDER FEEL CHARACTERISTICS

FIG. 31



RUDDER DEFLECTION– COMPRESSIBLE DYNAMIC PRESSURE

FIG. 32