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TERMINATION REPORT
ON THE
GROUND TEST EQUIPMENT
FOR THE
FLIGHT CONTROL SYSTEM
OF THE
CF-105 ARROW AIRCRAFT

CR-ED 1048 August 1959

HONEYWELL
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Aero Document CR-ED 1048

August 1959

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Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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INTRODUCTION

This Document summarizes the work performed in designing the CF-105 Avro Arrow Flight Control System Test Equipment. It will consist of eight sections, each describing one aspect of the Test Equipment. This will permit the document to be broken up if necessary and distributed among the interested parties. For this reason each of the documents is self-contained, and on reading this document as a whole one will find a certain amount of repetition.

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TERMINATION REPORT

ON THE

GROUND TEST EQUIPMENT

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FLIGHT CONTROL SYSTEM

OF THE

CF-105 ARROW AIRCRAFT

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SECTION 1

GENERAL SYSTEM CONSIDERATIONS

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TERMINATION REPORT ON THE GROUND TEST EQUIPMENT FOR THE FLIGHT CONTROL SYSTEM OF THE CF-105 ARROW AIRCRAFT.

SECTION 1

GENERAL SYSTEM CONSIDERATIONS.

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1.1 GENERAL

The ground test equipment for the flight control system of the CF-105 Arrow Aircraft was designed to provide suitable testing facilities for the following items of Minneapolis-Honeywell designed equipment:

a) BG93 Automatic Flight Control System Amplifier Calibrator (AFCS Amp Cal)

b) DG63 Automatic Flight Control System Coupler (AFCS Coupler)

c) HG32 Air Data Computer (ADC)

d) YG720 Flight Director Attitude Indicator (FD/AI)

e) YG6000 Mach Indicator

f) Vertical and Heading Reference System (VHRS) consisting of the following:

(1) GG63 Stable Platform
(2) DG6000 Three A is Repeater
(3) EG151 Amplifier Assembly

g) CG78 Function Selector

The above items with the exception of the Three Axis Repeater, Function Selector and the Mach Indicator were developed at the Aeronautical Division of the Minneapolis-Honeywell Regulator Company in Minneapolis, Minnesota. The Three Axis Repeater, Function Selector and the Mach Indicator were developed in Toronto. As a result there were considerable liaison problems in producing a set of test equipment that would be compatible with the equipment to be tested. Further difficulties were introduced in that much of the design authority rested with RCA in Camden, New Jersey, and in many cases a three-way liaison problem resulted.

The equipment supplied as listed above provided the auto pilot with the heading reference and the air data necessary to operate the auto pilot. The AFCS Coupler provided those facilities necessary to couple the fire control system to the auto pilot. The Function Selector provided a means for the pilot to choose the mode of operation desired of the auto pilot. The Function Selector is described more fully in CR-ED 1047 "ASTRA TERMINATION REPORT ON THE CG78 PANEL FUNCTION SELECTOR AFCS FOR THE CF-105 ARROW AIRCRAFT".

The test equipment design was further complicated because the authority for test equipment development was not received until development of the actual flight control system was well under way. As a result, two compromises were necessary in order to produce equipment compatible with the Flight Control System equipment. These were an excessive number of connections to the equipment being tested rather than the provision of a single test connector; and the necessity of providing breadboard test equipment to provide interim test facilities for the early models of the Flight Control System equipment. Work on the Flight Control System test equipment began in January of 1958, although funding was not available until June of that year. As a result, the project was not fully active until funds were available to support the additional personnel required for an adequate design team. The work in the early stages, therefore, consisted principally of feasibility studies. The test equipment requirements were not defined until 9th. of June 1958. It was early decided that breadboard test equipment would be necessary to provide testing facilities for the initial sets of Flight Control Systems equipment provided to RCA. The Engineering or "D" models would follow later and were to be representative of a final model to be delivered to the RCAF as production test equipment.

Because components of the Flight Control System equipment were to be evaluated in Minneapolis, Camden (New Jersey) and Toronto, it was decided that the breadboard test equipment design would be such that one piece of test equipment would be furnished with each Flight Control System device to be tested.

These breadboard test sets were to have the capability of providing first and second line maintenance tests for the devices to be tested. This would permit the Honeywell Flight Test Engineers to evaluate the test philosophy and provide information on desirable modifications to the Honeywell Controls design team. The engineering or "D" models were to incorporate these improvements. These models were to be designed for separate first line and second line tests. It was a design aim that one portable box of equipment should permit a series of "go-no-go" tests to be performed on the complete Flight Control System mounted in the aircraft. A second box, which was to be used only if a series of "no-go" indications were obtained from the "go-no-go" tester, was to permit the technician to isolate the fault to a particular component (black box) in the Flight Control System. The faulty black box was then to be returned to the hangar, placed on the test stand and subjected to further tests. The test stand was to contain a complete operating flight control system, and the method of testing was to substitute the suspected component for the known good one on the test stand. A further set of "no-go" readings was to be considered as verification that the component was faulty.

No firm definition on the degree of maintenance was received from RCA but it was assumed that only plug-in components and those items that could be replaced without the use of a soldering iron or complex mechanical manipulation and adjustment would be replaced at the squadron level. Any maintenance beyond this was to be performed at a base workshop or at the factory. The maintenance problem was being resolved at the time the contract was cancelled.

As finally evolved, the test equipment was to be in accordance with the RCA statement of work dated 13 February 1958 as defined by RCA Astra Memo 637 dated 5 June 1958. The relevant paragraphs follow:

a) The breadboard and engineering Model #1 shall be electrically interchangeable and capable of testing the Flight Control Systems delivered to RCA for use on aircrafts 4 and 5 and on the spare. These systems consist of models 1, 2, and 3 of the AFCS Amp Cals, AFCS Coupler and the 3

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Axis Repeater; models 3, 4, and 6 of the FD/AI and its Amplifier Calibrator; models 2, 3, and 4 of the Mach Indicator and its Amplifier Calibrator; and models 3, 6, 7 of the Air Data Computer.

b) Engineering models #2 and #3 shall be electrically interchangeable and at least capable of testing the Flight Control Systems delivered to RCA for use in environmental testing and on aircraft #9 and its spare. These Systems consist of Models 4, 5, and 6 of the AFCS Amp Cal and the AFCS Coupler; models 1, 2, and 3 of te VHRS, models 7, 9 and 10 of the FD/AI and its Amplifier Calibrator; 8, 9 and 10 of the Mach Indicator and its Amplifier Calibrator; and models 1, 2 and 10 of the Air Data Computer.

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1.2 RELEVANT SPECIFICATIONS

a) RCA statement of work dated 13 February 1958, as amended by Astra memo 637 dated June 5 1958.

b) ASTRA 1 specification, Revision C.

c) RCA Specifications 5638 and 5375 governing finishes on front panel and external surfaces.

d) MIL-T-945A amendment 2 dated 14th of May 1953, "General Specifications for Test Equipment for use with Electronic Equipment".

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the ASTRA I Airborne Weapons Control System dated 19th of February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 "General Specification for Environmental Testing Ground Support Equipment".

h) MIL-E-5400 "General Specifications for Aircraft Electronic Equipment".

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1.3 DESCRIPTION OF UNIT

1.3.1 Breadboard Test Equipment

The Flight Control System Breadboard Test Sets consisted of 4 units:-

a) The Automatic Flight Control Systems Amplifier Calibrator Breadboard Test Set X1005 described in SECTION 2 of this document.

b) Automatic Flight Control System Coupler Breadboard Test Set X1002 as described in SECTION 3 of this document.

c) Air Data Computer and Mach Indicator Breadboard Test Set X1003 as described in SECTION 4 of this document. This unit tests not only the Air Data Computer but the Mach Indicator as well.

d) VHRS & FD/AI Breadboard Test Set X1004 as described in SECTION 5 of this document. This unit tests the Three Axis Repeater as well as the Flight Director Attitude Indicator.

The carrying cases in general consisted of a fibre-glass combination type case measuring 20" x 15" x 11"or 13". The breadboard test sets weighed approximately 50 pounds each.

1.3.2 Developmental Models

The developmental ("D") models of the Flight Control System test equipment were divided into 2 basic functions; first line maintenance and second line maintenance.

1.3.2.1 First Line Maintenance Equipment

First line maintenance was defined as that maintenance which could be performed in three hours or less; second line maintenance required more than three hours but less than eight hours. Any work requiring longer than eight hours was considered as base workshop or factory repair material. The first line maintenance equipment was divided into two units:

a) The UG6010 Flight Control System Test Set which performed "go-no-go" tests on the Flight Control System to determine its serviceability. This unit is described in SECTION 6 of this document.

b) The UG6011 Flight Control System Auxiliary Test Set. This unit was used when a series of "no-go" or bad indications were obtained with the Flight Control System Test Set to isolate the fault to a particular system component (black box). This unit is fully described in SECTION 7 of this document.

1.3.2.2 Second Line Maintenance Equipment

The second line maintenance equipment consisted of two sets of first line test equipment as described in 1.3.2.1 above, and two test stands. The test stands were to be:

a) The AFCS Test Stand which would provide the necessary cabling and mounting for the following:-

1) Automatic Flight Control System Amplifier Calibrator
2) Automatic Flight Control System Coupler
3) Air Data Computer
4) Mach Indicator and Mach Indicator Amplifier Calibrator
5) Function Selector

b) The Vertical and Heading Reference System Test Stand was to provide mounting facilities for the following:

1) Stable Platform
2) Amplifier Assembly
3) Three Axis Repeater
4) Flight Director Attitude Indicator and Flight Director Attitude Indicator Amplifier Calibrator.

The test equipment program had not proceeded far enough for the actual test stands to be completely defined. However, SECTION 8 of this document briefly outlines the course that the design was to have followed.

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1.4 STATUS AT CANCELLATION

When the ASTRA program was terminated in September 1958 the status of the Test Equipment was as follows:

a) Automatic Flight Control System Amplifier Calibrator Breadboard Test Set
The design was established, ordering was complete but fabrication had not yet begun.

b) Automatic Flight Control System Coupler Breadboard Test Set. A design was established, ordering was complete and mechanical assembly had begun. Wiring had not started because not all electrical components were in.

c) Air Data Computer Breadboard Test Set. The design was established and ordering was complete. Fabrication was nearly completed. Final assembly was delayed until the summing calculations for the Air Data Computer were received in order that the test set could be calibrated.

d) Three Axis Repeater Breadboard Test Set. The Three Axis Repeater Test Set design was complete. Ordering had begun but was not complete, consequently no fabrication had started.

e) UG6010 Flight Control System Test Set. The general design on this unit was established. Parts had not been ordered nor had fabrication begun. Drafting was about to begin.

f) UG6011 Flight Control System Auxiliary Test Set The general configuration of this unit was established but no layout or schematics had been developed. No drafting, procuring or fabrication had started.

g) <u>UG6012 Automatic Flight Control System Test Stand.</u> The general package of this unit was developed but no schematics or layouts had been developed. No drafting or ordering had begun.

h) <u>UG6013 Vertical & Heading Reference System Test Stand.</u> The general cabinet arrangement was established but no schematics, wiring diagrams or layouts had been evolved. Consequently, no drafting, procurement or fabrication was started.

1.5 PROPOSED FUTURE PROGRAMME

It was proposed to complete the fabrication of the breadboard test equipment with all possible speed in order to have suitable test equipment in the hands of field service engineering personnel in time for them to evaluate it. The first and second line maintenance equipment was to proceed at a somewhat slower pace but it was anticipated that fabrication would begin early in January of 1959 with delivery in August.

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1.6 CONCLUSIONS

The design of the Flight Control System test equipment produced a number of valuable lessons. These are as follows:-

a) It is possible to design related equipment in two widely separated plants providing close liaison is maintained.

b) Due to the increased complexity of airborne electronic systems, it is necessary to design test equipment concurrently with the system being tested. It is possible to design this test equipment for delivery with the device to be tested, providing that the penalty of additional cost in manpower and money is accepted.

c) Where test equipment design must be concurrent with the equipment design, it is necessary to design maximum flexibility into the test equipment. This flexibility can be removed once the equipment design is frozen.

d) It is highly desirable from a cost and delivery point of view to design developmental test equipment with a view to the ultimate use to which the test equipment is being placed without losing sight of the immediate objective of servicing the developmental equipment being tested.

e) As far as possible, the test equipment used on the test stand should be similar to that used on the aircraft in order that the time required to train technicians be kept to a minimum.

f) Because of tactical considerations, it is necessary that the test equipment check as many functions as possible in a minimum of time. These functions should be given the following priority:-

1) Safety of flight
2) Completion of mission
3) Crew Assist.

In all cases, safety of flight items should be checked. The time allowed for testing the equipment will determine whether or not (2) and (3) can be checked. In some cases where the equipment has a high degree of reliability, periodic checks may be sufficient for (2) and (3).

g) In order to reduce the amount of time spent checking equipment on the aircraft, consideration should be given to making the tests on the developmental equipment semi-automatic. This will simplify the problem of providing automatic test equipment at a later date.

The principal contribution of the Flight Control System test equipment to the state of the art has been the rather simple means used for checking complex equipment. In general, step functions have been applied to the Flight Control System and the resulting signal read at the output of the Flight Control System. With a properly integrated Flight Control System (and providing its location in the aircraft is judiciously chosen), it should be possible to apply signals to the input to the system and determine the effects of these signals, as a motion of the control surface. Rather simple means were found for checking for satisfactory operation of integrators. It was also proven during a similar program that it is possible to secure the help of the aircraft manufacturer by having him supply certain additional features on the aircraft to permit an easy checkout of the Flight Control System.

When proper project management is applied, no difficulty should be experienced in developing a weapons system that is completely integrated in that it will give the best possible performance with the least possible maintenance and the least amount of testing.

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TERMINATION REPORT

ON THE

GROUND TEST EQUIPMENT

FOR THE

FLIGHT CONTROL SYSTEM

OF THE

CF-105 ARROW AIRCRAFT

Honeywell Controls
Aero Document CR-ED 1048

SECTION 2

X-1005 AUTOMATIC FLIGHT CONTROL SYSTEM,
AMPLIFIER-CALIBRATOR BREADBOARD TEST SET.

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Aeronautical Division,
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ILLUSTRATIONS

TERMINATION REPORT ON THE GROUND TEST EQUIPMENT FOR THE FLIGHT CONTROL SYSTEM OF THE CF-105 ARROW AIRCRAFT.

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SECTION 2

X-1005 AUTOMATIC FLIGHT CONTROL SYSTEM AMPLIFIER CALIBRATOR BREADBOARD TEST SET.

2.1 GENERAL

The X-1005 Automatic Flight Control System Amplifier-Calibrator Breadboard Test Set was to be a part of the ground test equipment for the Flight Control System of the CF-105 ARROW aircraft, and was to perform First and Second Line tests on the BG93 Automatic Flight Control System Amplifier-Calibrator (AFCS Amp Cal).

The AFCS Breadboard Test Equipment was split into four separate pieces at an early stage to obtain easily portable equipment and uniform appearance. In addition, the size of the Breadboard Test Sets was restricted by the requirement that it be mountable in a standard 19" rack and have a weight limitation of 60 pounds. This rack mounting requirement was later dropped. The AFCS Amp Cal Breadboard Test Set was to be capable of testing any of the first six AFCS Amp Cals.

2.2 RELEVANT SPECIFICATIONS

a) RCA statement of work dated 13 February 1958, as amended by Astra memo 637 dated June 5, 1958.

b) ASTRA 1 specification, Revision C.

c) RCA Specifications 5638 and 5375 governing finishes on front panel and external surfaces.

d) MIL-T-945A amendment 2 dated 14th. of May 1953, "General Specifications for Test Equipment for use with Electronic Equipment".

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the ASTRA I Airborne Weapons Control System dated 19th of February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 "General Specification for Environmental Testing Ground Support Equipment".

h) MIL-E-5400 "General Specifications for Aircraft Electronic Equipment."

a) Fibreglass carrying case

b) Connecting cables

c) Chassis Assembly with following subassemblies:

1) Front Panel (See Figure 2.2)
2) Chassis Connectors
3) Chassis

2.3.3 Theory of Operation

2.3.3.1 First Line Tests

The AFCS Amp Cal Breadboard Test Set was to simulate all the inputs provided to the AFCS Amp Cal from other components of the Automatic Flight Control System.

These included:

a) Heading, Roll and Pitch output synchros in the AFCS Amp Cal.

b) Sec Ø-1 and 1-cosE potentiometers in the Three Axis Repeater (Ø is bank angle, E is elevator angle)

c) Angle of Attack (α), True Air Speed (V), Altitude (h) and Pitot differential pressure (q_c) in the Air Data Computer.

d) Signals from the AFCS Coupler and switching of the various coupler modes.

The input synchros for the AFCS Amplifier Calibrator were simulated by transformers tapped to give the voltages required in testing. Provision was to be made for changing the quantities simulated by a small step in order to observe the operation of various servos in the AFCS Amp Cal.

The following First Line Tests were to be performed on the AFCS Amplifier Calibrator:

a) Operation of the Roll Synchronizer Servo

b) Operation of the Heading Synchronizer Servo

c) Check of the "Gear Up" scheduled gain settings.

d) Check of the "Gear Down" scheduled gain settings.

e) Operation of the Pitch Synchronizer Servo.

f) Operation of the Lag Pitch Attitude Servo.

g) Operation of the Command Signal Limiter

h) Operation of the "q'_c Servo"

i) Operation of the Pitch Axis Fader.

j) Operation of the Anti-Engage Feature

If the "Go-No-Go" meter (Figure 2.3) read "go" for all the above tests the AFCS Amp Cal being tested was to be considered flightworthy, even though there was a small probability of the AFCS Amp Cal being incorrectly adjusted. As an example, the Command Signal Limiter (CSL) operation was only checked at a few points on its operating characteristic. However, a complete check of the CSL was to be regularly performed as part of the Second Line Tests, and any sudden deterioration of the CSL between the Second Line Tests had a very low probability. This approach to the testing problem was adopted in order to minimize the time required for performing the First Line Tests.

A typical "go-no-go" test arrangement is shown in Figure 2.3. The important features are:

a) A common voltage source for the output potentiometer and the bucking voltage potentiometer, making the balance point independent of the supply voltage;

b) Two resistors for setting the meter sensitivity to make the width of the "go" region correspond to the permissible output voltage range for this measurement.

A typical Gain Setting check is performed by providing predetermined inputs to all servos involved and reading the output of the AFCS Amp Cal with the "go-no-go" meter.

The servos contributing to an output being monitored by the "go-no-go" meter were checked operationally by slightly displacing the input to the servo in question. On returning the Servo input to its original value, the "go-no-go" meter should return to its original reading. This test ensured that the servo operated without an excessive dead zone.

In the Altitude and Mach Hold modes, the Pitch Synchronizer Servo was connected as an integrator, and it was desirable to form an estimate of the integrator drift without using accurate timing devices. Accordingly the integrator drift was considered to be caused by an equivalent input voltage, e_d, which would appear at the integrator input in series with a resistance R if the integrator input signal was zero. Now the integrator transfer function is approximately $-\frac{k}{S}$ and if a resistance of, say, 100 ohms was connected between output and input, the steady-state integrator output voltage due to the equivalent input drift voltage, e_d, would be $e_o = 100\ e_d$. This e_o was easily measured and provided a good estimate of drift rate of the integrator. The "go-no-go" meter was used for measuring e_o.

The Lag Pitch Attitude Servo was checked operationally by applying a step input to it. To keep the Pitch Synchronizer servo stationary during this test, the AFCS should be in the Mach Hold mode.

The Command Signal Limiter was checked by applying an input signal large enough to obtain limiting action. The limited output is checked with the "go-no-go" meter. The Pitch Axis Fader is checked by initiating a Fader cycle and simultaneously monitoring the AFCS Amp Cal Pitch Axis output with the "go-no-go" meter. At the completion of the Fader cycle, the meter reading should return to its previous value.

2.3.3.2 Second Line Tests

A number of test jacks were mounted on the front of the AFCS Amplifier Calibrator; these combined with the test jacks on the AFCS Amplifier Calibrator Breadboard Test Set panel provided access to all circuit points of interest for Second Line Tests. The remaining toggle switches located along the right-hand edge of the Test Set panel and numbered K1 to K25 were used to operate the AFCS Amp Cal relays for Second Line Tests.

2.4 DESCRIPTION OF PARTS

The Carrying Case was to be a 14" x 20" x 11" grey fibreglass instrument case, reinforced by an aluminum moulding which extended around the edges of the case and the lid. The carrying handle, latches and hinges were fastened to the case moulding which also held a gasket to render the case weatherproof. The brackets for mounting the panel were likewise fastened to the case moulding. The lid of the case was removable.

Six Test Set cables were to be used. The First Line Test Cable was to be 16 feet long and fixed to the Test Set at a terminal board. The three Second Line Test Cables were also to be 16 feet long and had identical connectors at either end (except one of the cables which was to have an extra connector for receiving aircraft power). In addition, two jumpered connectors without cables were to be provided for the Flight Test Panel connectors on the AFCS Amp Cal. All connectors for the AFCS Amp Cal Breadboard Tester were to be Pygmy PT bayonet type. Adapters for PT to PC connectors were to be provided, so that the Test Set could be used in conjunction with any of the First six Development Models of the AFCS Amplifier Calibrator. The Cables were to be stored in the Carrying Case, beside the Chassis.

The Tester Panel (Figure 2.2) was to be made of 1/8" aluminum. The markings were to be transferred from the X-1005 Panel Layout Drawing to a .01" sheet of photosensitized aluminum which was to be lacquered before placing on the Tester Panel.

The tester chassis was to carry the transformers for simulating synchro inputs, the potentiometers from which the bucking voltages were to be obtained, the remainder of the circuitry, internal cabling and the terminal boards required.

Figure 2 shows the Tester Panel layout. Mounted on the panel are:

a) AC and DC fuses and pilot lights.

b) Three Oak rotary switches - "Mode Selector", "Output Selector" and "Calibrated Inputs".

c) Three First-Line toggle switches: "$\Delta q'_c$", "$\Delta M/\Delta h$", "ζ_c".

d) Five Pygmy panel connectors J1 thru J5

e) Ten test jacks J6 thru J15.

f) Ten Second Line toggle switches beginning with K1 and ending with K25, numbers referring to the relays in the AFCS Amplifier Calibrator controlled by the toggle switches.

The "go-no-go" meter was to be a zero centre phase sensitive AC RMS meter, identical with the one in AFCS Coupler Breadboard Test Set. It was to be mounted in a cutout in the panel. The V.T.V.M. could be used for all first line and Auxiliary tests and for most of the second line tests, except those requiring quadrature voltage measurements. The "go-no-go" meter received power and signals from the AFCS Amplifier Calibrator Breadboard Test Set through a short cable.

The AFCS Amplifier Calibrator Breadboard Test Set Controls used for first line tests were as follows:

a) A four-position two-deck rotary "Mode Selector" switch.

b) A six-position three-deck rotary "Output Selector" switch.

c) Three toggle switches: $\Delta q_c'$, $\Delta M/\Delta h$, ρ_c.

d) A six-position two-deck rotary "Calibrated Inputs" switch.

The "Mode Selector" switch selected one of the following four modes:

a) Heading and Attitude Hold, Normal Flight (NF).

b) Control Stick Steering (CSS)

c) Mach Hold (MH)

d) Altitude Hold (AH)

The Output Selector Switch selected the AFCS Amp Cal Output to be monitored by the "go-no-go" meter. The "$\Delta M/\Delta h$" toggle switch introduced a test voltage into the Autopilot in either the Mach Hold or Altitude Hold mode, thereby simulating a Mach Deviation or an Altitude Displacement, as required.

The "q_c'" toggle switch belonged to the Auxiliary Test Set circuitry. It permitted rotation of the "q_c'" input synchros by a known amount which, provided information on the serviceability of the q_c' servo and the Command Signal Limiter.

The "S_c" toggle switch energized the "AFCS Engage" relay (K18) in the AFCS Amplifier Calibrator.

The "Calibrated Inputs" switch had one deck and six positions (one "off" and five "on" positions). Two of the five positions were used to provide input signals for checking the roll and pitch axis scheduled gains, the other three positions were for second-line tests.

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2.5 PERFORMANCE

The deviations from nominal output voltages appropriate for each test were to be observed as a deflection of the "go-no-go" meter. Because different deviations were permitted for different tests, the "go-no-go" region of the meter would correspond to the acceptable output voltage ranges by virtue of resistors arranged to suitably change the sensitivity of the "go-no-go" meter for each particular test.

The bucking voltages could be set to within .5% of nominal and the meter sensitivity could be set to within 1% of desired sensitivity. Variations in supply voltage also effected the "go-no-go" measurements. A 10% change in supply voltage would cause a change of 10% in the indicated reading on the meter. Where the meter was set for a 15% tolerance this error would be a maximum of 1.5%. The error decreased as null was approached.

It would be necessary, therefore, to check the supply voltage subsequent to each marginal reading. With this provision the overall accuracy expected from the First Line Tester was 2% or better. There are no experimental data on tester performance, since the tester construction was not sufficiently far advanced to permit evaluation.

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2.6 STATUS AT CANCELLATION

All parts had been ordered (except small items, locally available from stock) and about 50% of the parts were on hand (primarily connectors and rotary switches). Panel layout was completed.

Fabrication of panel and chassis had been initiated; work on cables was not initiated.

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2.7 PROPOSED FUTURE PROGRAMME

It was proposed to complete the design of the Breadboard Test Set and to deliver it to Minneapolis-Honeywell, Minneapolis, Minnesota for evaluation with developmental AFCS Amplifier Calibrators. Results of this evaluation and reports from the users were to form the basis for modification to the test procedure on the Flight Control System Test Set as described in Section 6 of this document.

2.8 CONCLUSION

The problem of devising first line checks adequate for determining the flightworthiness of the AFCS and simultaneously minimizing the testing time required was solved by adopting a combination of steady-state quantitative tests and transient qualitative tests. All transient quantitative tests and the time-consuming steady-state tests were scheduled for Second Line Maintenance.

The liaison problem was appreciably simplified by an early decision by AFCS Amplifier Calibrator designers in Minneapolis to incorporate both a test connector and a number of strategically located test jacks.

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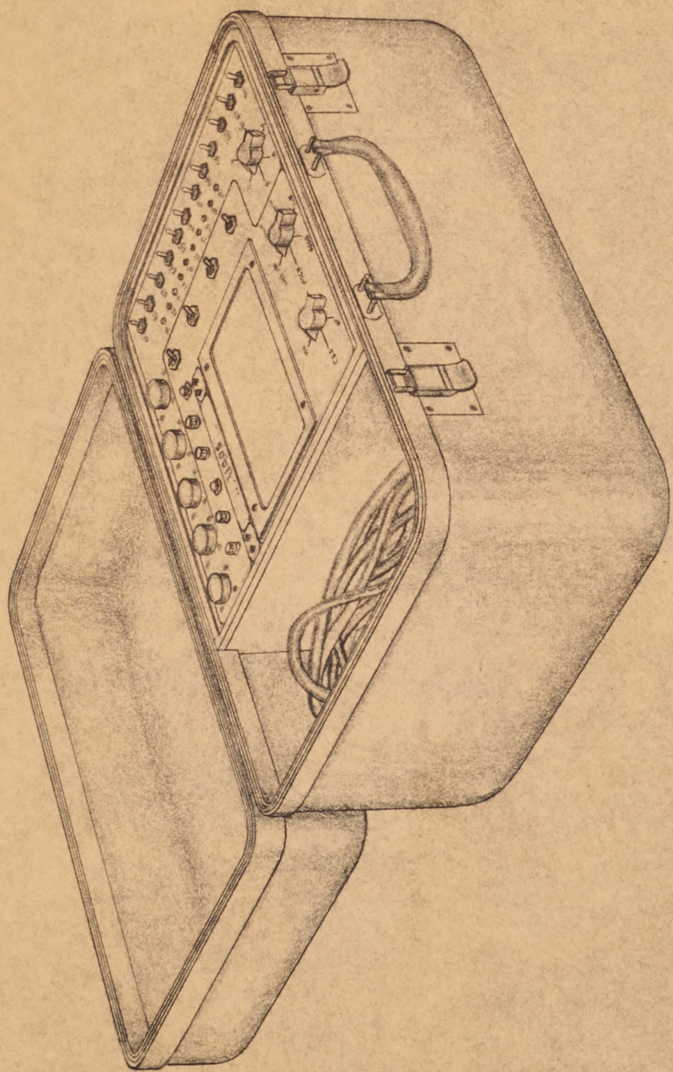

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FIG 2·1
AFCS AMP CAL
BREADBOARD TEST SET

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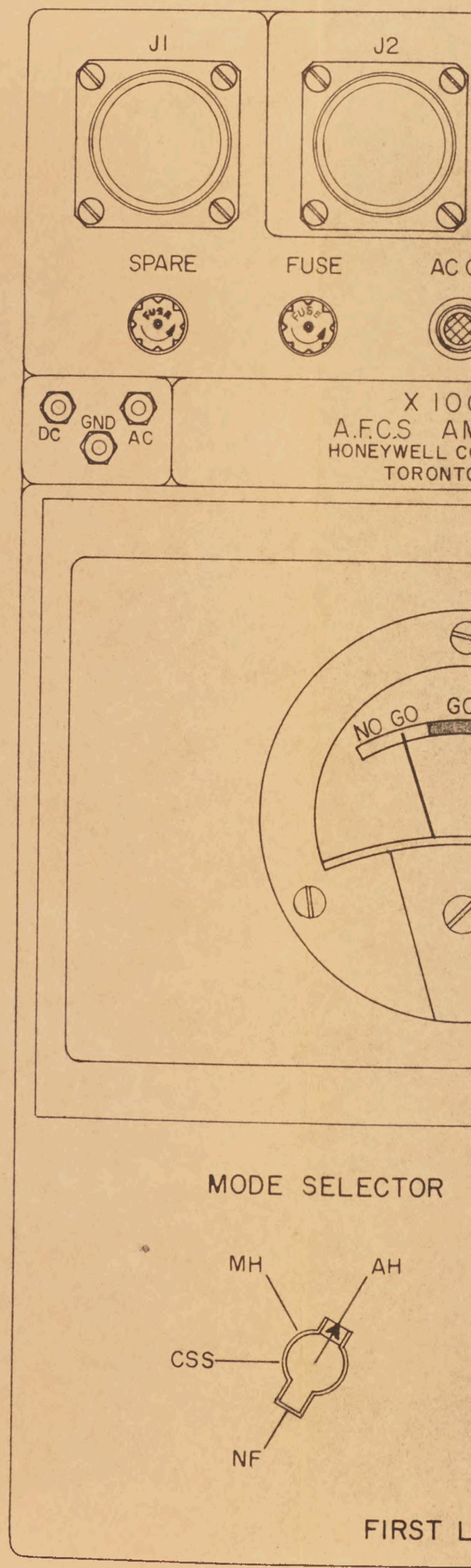

J1
J2
SPARE
FUSE
DC
GND
AC
X 10
A.F.C.S AM
HONEYWELL C
TORONT
NO GO
MODE SELECTOR
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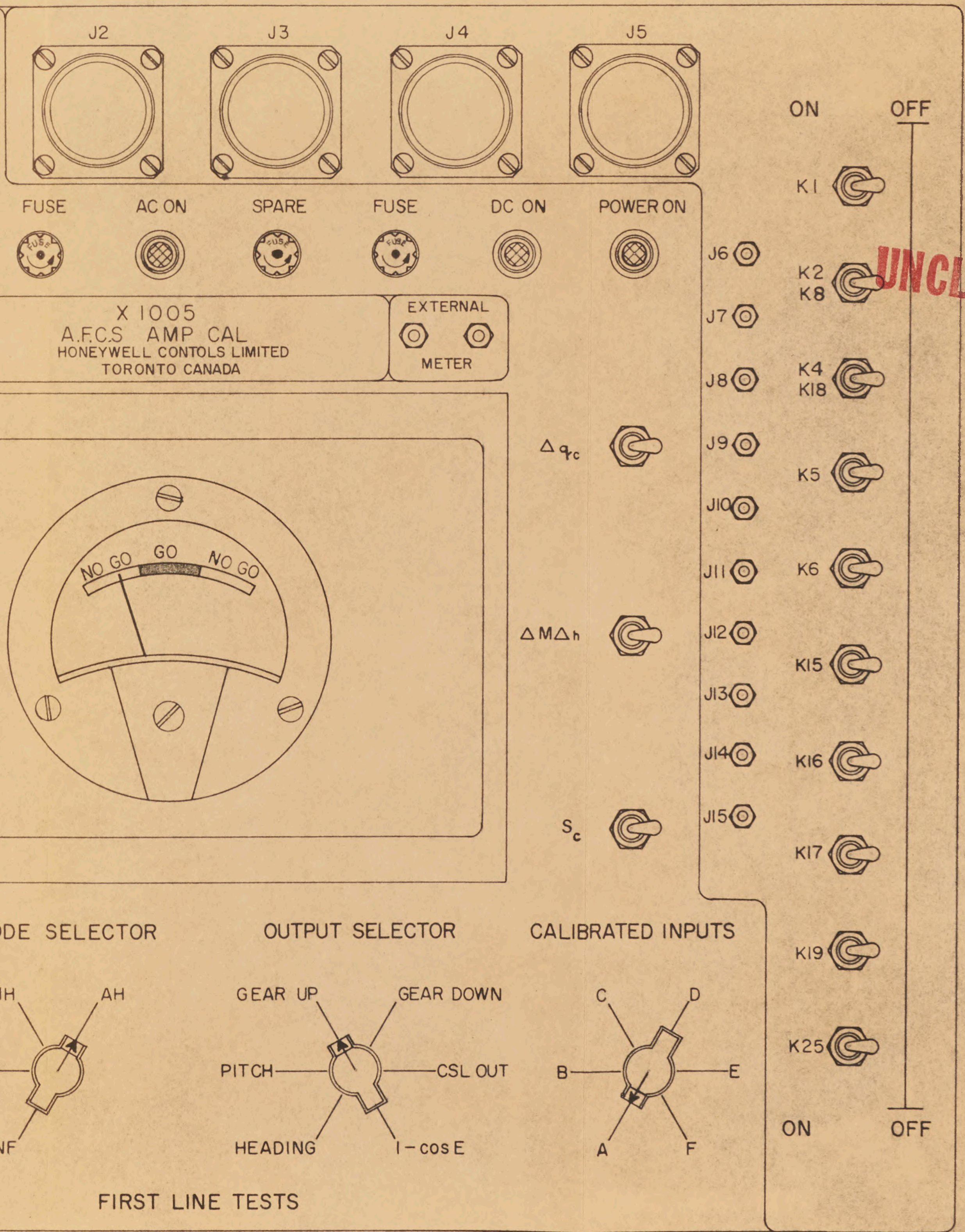

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A.F.C.S. AMP CAL BREADBOARD TEST SET.
FIG. 2·2

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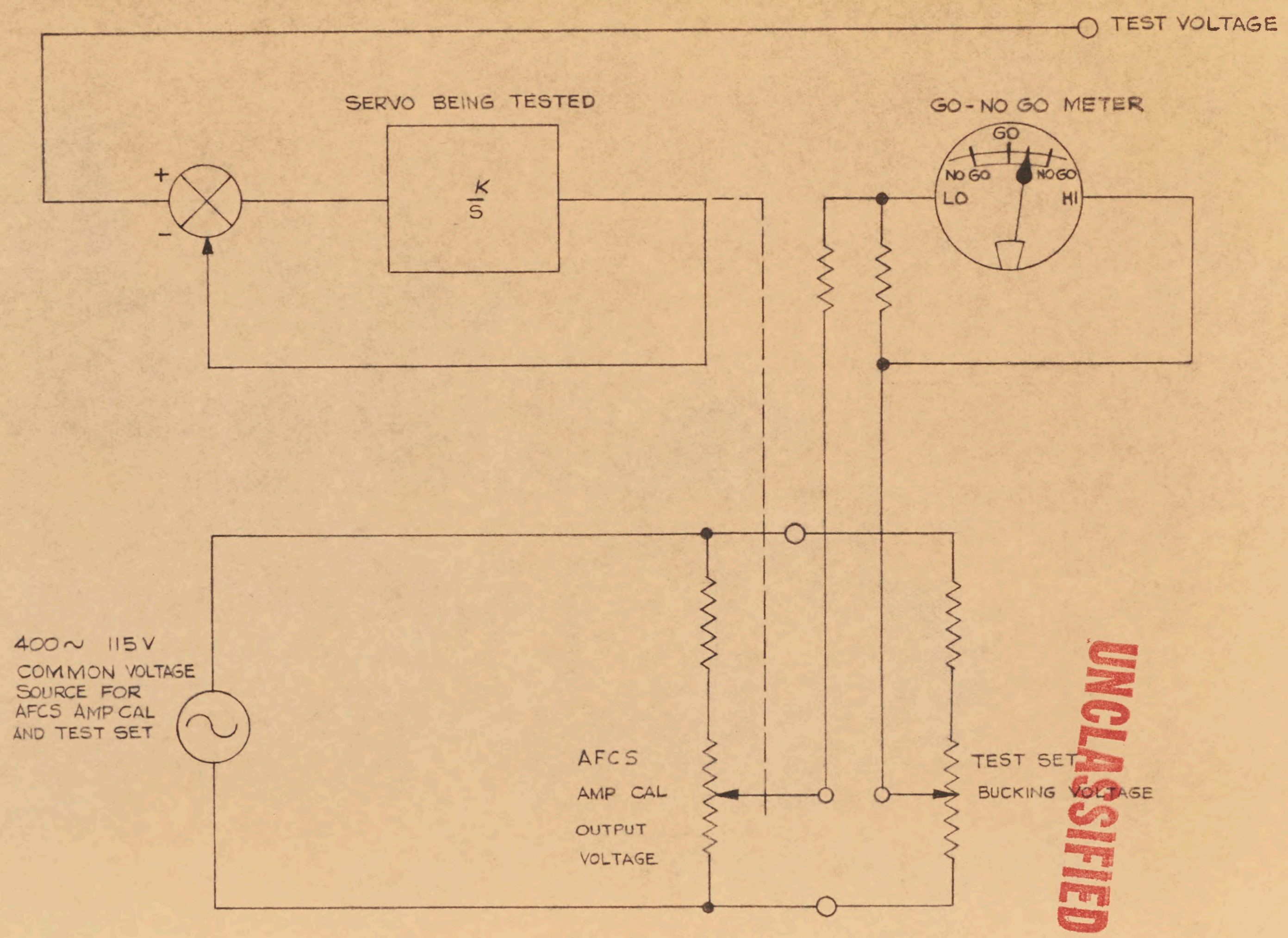

A TYPICAL CIRCUIT FOR A "GO-NO GO" CHECK ON A SERVO

FIG 2·3

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TERMINATION REPORT
ON THE
GROUND TEST EQUIPMENT
FOR THE
FLIGHT CONTROL SYSTEM
OF THE
CF-105 ARROW AIRCRAFT

Honeywell Controls
Aero Document CR-ED 1048

SECTION 3

X-1002 AUTOMATIC FLIGHT CONTROL SYSTEM
COUPLER BREADBOARD TEST SET.

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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SECTION 3

X-1002 AUTOMATIC FLIGHT CONTROL SYSTEM COUPLER BREADBOARD TEST SET.

3.1 GENERAL

The X-1002 AFCS Coupler Breadboard Test Set was part of the Test Equipment designed to check the operation of the MH 65 Automatic Flight Control Subsystem for the CF-105 aircraft.

The purpose of the Coupler Breadboard Test Set was to check the operation of the D-DG63A AFCS Coupler as an independent unit both on the bench and in the aircraft.

Phasing of various equipments into the flight test programme dictated separate sets of Test Equipment. As a result, one Breadboard Test Set was required for the first Developmental("D") Model Couplers used in the Flight Test Programme on the partial AFCS.

When design of the Coupler Breadboard Test Set commenced, fabrication of the "D" Model Couplers was largely in progress. The test connector on the Coupler was used entirely for Flight Test instrumentation, hence it was not possible to provide the desirable parallel connected test connector(s) and relay(s) for the Test Set. This was not considered a serious difficulty as these facilities could be provided in the preproduction models. It was intended that the Breadboard Test Set should be adaptable for testing preproduction Couplers as well as the "D" models.

During the design of the Test Set, certain Coupler modes were discontinued.

a) The Automatic Ground Controlled Approach was no longer required.

b) The requirement for a Breakaway and Rollout manoeuvre was dropped.

The status of two other features of Coupler operation was somewhat dubious throughout the development. These were Integral Control and Bank Limit. In the case where a mode has been deleted, it was felt that the Test Set should have provision for incorporating this or another mode should the requirement be later raised. It was considered that provision should be made for switching the "optional" features "in" or "out" at will.

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3.2 RELEVANT SPECIFICATIONS

a) RCA statment of work dated 13 February 1958. as amended by Astra memo 637 dated 5 June 1958.

b) ASTRA I specification, Revision C.

c) RCA Specifications 5638 and 5375 - governing finishes on front panel and external surfaces.

d) MIL-T-945A amendment 2 dated 14 of May, 1953, "General Specification for Test Equipment for use with Electronic Equipment."

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the ASTRA I Airborne Weapons Control System dated 19th of February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 - "General Specification for Environmental Testing Ground Support Equipment."

h) MIL-E-5400 "General Specification for Aircraft Electronic Equipment."

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3.3 DESCRIPTION OF UNIT

3.3.1 General

3.3.1.1 Physical

The X-1002 AFCS Coupler Breadboard Test Set was contained in a drip-proof grey fibreglass carrying case measuring approximately 20" x 15" x 13" and weighing approximately 50 pounds. The necessary interconnecting cables were stored in the lid.

3.3.1.2 Electrical

a) Inputs. The AFCS Coupler Breadboard Test Set required two electrical inputs, viz:

(i) 115V ± 10%, 400 ± 20 cps single phase per MIL-E-7894A.

(ii) 26.5V DC ± 10%.

b) Outputs.

(i) The Breadboard Test Set provided direct current and 400 cycle and 500 cycle signals to the DG63 AFCS Coupler, simulating the inputs from the Fire Control Computer, the Data Link Coupler and the Navigation Computer.

(ii) The Test Set supplied the networks required for some of the analogue computations normally performed in the HG32 Air Data Computer.

(iii) The Test Set provided the 28V DC relay switching power required for energizing the various coupler modes.

(iv) The Test Set supplied appropriate 400 cps reference voltages for each test.

(v) The 400 cps power to the Coupler was supplied and adjusted from the Test Set.

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3.3.2 Component Parts

The Test Set consisted of the following assemblies and sub-assemblies:

a) Carrying Case (Figure 3.1)

b) Cable Harness

c) Panel Assembly

d) VTVM Sub-Assembly

3.3.3 Theory of Operation

3.3.3.1 Coupler Operation

The Coupler consists principally of two d.c. servos. The only inter-action between the two servo loops is via the Azimuth Gain Scheduling Potentiometer (this is actually a sector switch with resistors connected from sector to sector). The Azimuth Gain Scheduling Potentiometer is characterized to attenuate the d.c. signal input to the Azimuth Servo Differential Amplifier for "up elevator" outputs from the Elevation Servo.

The Coupler inputs are dc, 400 and 500 cycle voltages and potentiometer positions (analogue resistance inputs). Amplifiers, demodulators, computing networks, and filters operate on the input signals to provide suitable d.c. voltages to the differential amplifiers. The signal to the differential amplifiers is selected by switching circuits in the Coupler. The 28 V. DC for switching to the appropriate Coupler mode is supplied externally or internally, depending on the particular case. The Coupler Outputs are all 400 cycle voltages (phase reversible) from potentiometers located on the servo output shafts. The roll (azimuth) signal output may be modified by selecting the Bank Limit or Rollover position. Both azimuth and elevation axes may be switched to integral control by the Integral Control Switch.

3.3.3.2 Test Set Operation

For test purposes the Coupler is electrically disconnected from the Aircraft and connected in series with the Test Set (Figure 3.2). Power (400 and 28V DC) is applied to the Coupler from the Test Set, and the 400 cycle voltage is adjustable from the Test Set (Figure 3.3) The Test Set contains a 400 cycle transformer with multiple secondaries to provide 400 cycle signals to the input of both servos (or the Nav-AGCI attenuator). A plus and minus 10 V DC power supply in the Test Set provides the necessary d.c. steering error signals. A 500 cycle oscillator - power amplifier produces signals for the Lead Pursuit inputs and square wave excitation for the demodulator. Relay switching is accomplished from the Test Set by supplying 28V DC to the appropriate relays for the Coupler mode selected by the Function Selector Switch. Suitable positions of the AFCS Function Selector are duplicated in the Test Set along with pilot lights to indicate visually the Coupler status.

The selected 400 cycle output from the Coupler is applied to one input terminal of the AC, V.T.V.M. in the Test Set and the other terminal is provided with a voltage corresponding to the proper coupler output. The difference between these two voltages is amplified and displayed as a deviation on the zero centre A.C., V.T.V.M. which has "good" and "bad" sections marked on it. The proper A.C., V.T.V.M. range for any test condition will be indicated by the lighted V.T.V.M. Range Indicator Lamp.

If desired, the actual voltage output from the Coupler may be read by rotating the Indicator Function Switch (S4) to the "VOLTS OUT" position. This connects the second input terminal of the A.C., V.T.V.M. to signal ground. The A.C., V.T.V.M. range indicated by the panel lamp is selected and the 400 cycle VOLTAGE ADJUST knob is rotated until the pointer on the D.C., V.T.V.M. reads zero.

The ZERO pushbutton on the Test Set shorts all inputs to the Coupler and indicates the offset and/or zero drift at the coupler outputs.

The AZ-EL (Azimuth Elevation) switch selects the Coupler output to be displayed on the "go-no-go" meter (A.C., V.T.V.M.). Both V.T.V.M.'s are provided with INT-EXT (Internal-External) switches and connectors to facilitate trouble-shooting the Coupler and checking the calibration of the Test Set. For the latter purpose, the Test Set provides test points and adjustment pots on the front panel by means of which the signals or bucking voltages etc., may be changed if required.

To use the Test Set with a pre-production Coupler it is necessary to replace the cable harness provided in the Test Set. In addition, several switching functions are accomplished by operating switches on the Armament Panel in the cockpit when testing pre-production models. When this is required, a red indicator lamp on the Test Set will light indicating the cockpit switch to be operated. The lamp will extinguish when the switch is "made".

3.4 DESCRIPTION OF PARTS

3.4.1 Carrying Case

A moulded fiberglass instrument case measuring approximately 20" x 15" x 13" was selected since it was a stock item and fulfilled the requirements of being light, rugged and rainproof. A gasketed panel mounting angle was fitted inside the flange of the case. The gasket permitted a wider tolerance on the mounting angle dimensions and provided a rain-proof seal between the panel and carrying case. The lid of the carrying case was provided with compartments for stowing the cable harness, test leads and instruction manual.

3.4.2 Cable Harness

Bendix Pygmy connectors with integral strain relief fittings were used throughout. For economy and ease of fabrication, flexible sleeving was used on the wires. Any necessary wiring changes are more easily accomodated with this method of cable construction.

3.4.3 Panel Assembly

This panel was of 1/8" thick aluminum. All necessary brackets for component mounting were fastened with flat head screws from the front of the panel. Panel lettering and component mounting centres were transferred from an ink tracing to a thin (0.010") sheet of photosensitive aluminum. This sheet of aluminum then covered the bracket mounting screws when cemented to the 1/8" panel. Also, a full size template was provided for front panel holes. This method has the advantages of ease and economy over etched panels but the durability is not as good even when lacquered. It is, however, a suitable method of development equipment because panel lettering may be readily changed.

3.4.4 V.T.V.M. Assembly

Two V.T.V.M.'s were provided mounted in a front removable box. One V.T.V.M. was a zero centre A.C. RMS - phase sensitive type, the function of which was selected by a toggle switch on the front V.T.V.M. mounting bracket. The other V.T.V.M. was a zero centre DC V.T.V.M. Separate range selector switches were provided for each V.T.V.M. The complete V.T.V.M. assembly plugs into a connector beneath the panel on the Test Set.

The phase sensitive AC, V.T.V.M. was used as a "go-no-go" indicator for it could provide information on direction of the error as well as its magnitude.

The second V.T.V.M. (d.c. zero-centre) was used for troubleshooting, field calibration checks and for monitoring the d.c. and a.c. supply voltages. The latter was continuously monitored during test on the D.C., V.T.V.M. The 400 cycle voltage was rectified and a portion of it was compared with a reference voltage, and the deviation was displayed on the D.C., V.T.V.M. Adjustment of 400 cycle voltage was accomplished as described in 3.3.3.2.

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3.5 PERFORMANCE

The A.F.C.S. Coupler was designed to have a static accuracy of ± 10% with nominal inputs and supply voltage.

For use as a "go-no-go" checker, the Test Set had the central 50% of the A.C., V.T.V.M. scale representing this ± 10% deviation from the nominal Coupler output, and hence the "go" sector. The errors which could accrue due to the Test Set were due to several different causes viz:

a) Line Voltage. Line voltage variations affect the coupler output and the bucking voltage equally. At null, therefore, line voltage would have no effect. At the outer limits of the "go" sector with 10% high line voltage, the width of the "go" sector would be increased by 10%, or 1% of the output voltage. Similarly with 10% low line voltage the width of the "go" sector should be decreased by 10% or 1% of the output voltage. To reduce this "grey" region the Test Set permitted the line voltage to be adjusted to within ± 2% of the nominal value. Hence, the uncertainty in reading a marginal output became ± 0.2%.

b) Analogue Computing Networks. Each of the lead pursuit computing networks in the aircraft consisted of three potentiometers and two fixed resistors. If the network was simulated by four fixed ± 1% resistors the error could be ± 2%. However, using potentiometers in the Test Set, the voltage ratio of the network could be set to 0.4%.

c) Voltage Outputs. The d.c. voltage outputs could be set to 0.4%. The 400 and 500 c.p.s. voltage outputs may be set to ± 1%. Phase shift between the 500 c.p.s. signal and demodulator excitation is not considered. The 400 c.p.s. reference voltage may be set to ± 1%.

d) V.T.V.M. At null, the V.T.V.M. error should be negligible. The accuracy of the A.C., V.T.V.M. is ± 3% of full scale. Since the scale is zero centre the maximum error becomes ± 6% of the scale reading. The scale represents ± 20% of the output voltage, therefore, the peak V.T.V.M. error is 1.2%.

The maximum possible Test Set error in indication will occur when reading the Azimuth Axis Fire Control Output in the Lead Pursuit Mode, because in this case the contributing factors are two d.c. voltages, two 500 c.p.s. voltages, two computing networks, the line voltage, the bucking voltage, and the V.T.V.M. error.

Maximum error is $\pm(2 \times 0.4 + 2 \times 1.0 + 2 \times 0.4 + 0.2 + 1 + 1.2) = \pm 6\%$.

The R.S.S. is

$$\sqrt{2 \times .4^2 + 2 \times 1^2 + 2 \times .4^2 + .2^2 + 1^2 + 1.2^2} = \pm 2.3\%$$

NOTE: The aforementioned Maximum R.S.S. errors apply for indicated deviations around the limits of the "go" sector.

If it is desired to use the Test Set to calibrate the Coupler, then the line voltage and meter errors may be neglected as the Coupler would be adjusted to null out the bucking voltage.

For the same case as considered previously, the maximum error is

$$6.0 -(0.2 \times 1.2) = \pm 4.6\%$$

The R.S.S. error is

$$\sqrt{2. \times .4^2 + 2 \times 1^2 \times 2 \times .4^2 + 1^2} = \pm 1.9\%$$

In a more usual case e.g., Lead Collision'the maximum and R.S.S. error (near null) become 1.4% and 1.1% respectively, the chief sources of error being limited principally by the accuracy of the a.c. meters used in calibration.

3.6 STATUS AT CANCELLATION

At cut-off, the test set was being assembled, and most bought-out components had been received. The front panel assembly was 90% complete and mounted in a suitably modified carrying case, but components behind the panel were not mounted, and wiring was not started.

3.7 PROPOSED FUTURE PROGRAMME

The Breadboard Test Set was to have been completely assembled, wired, tested, calibrated and shipped to AVRO by the 15 of November 1958.

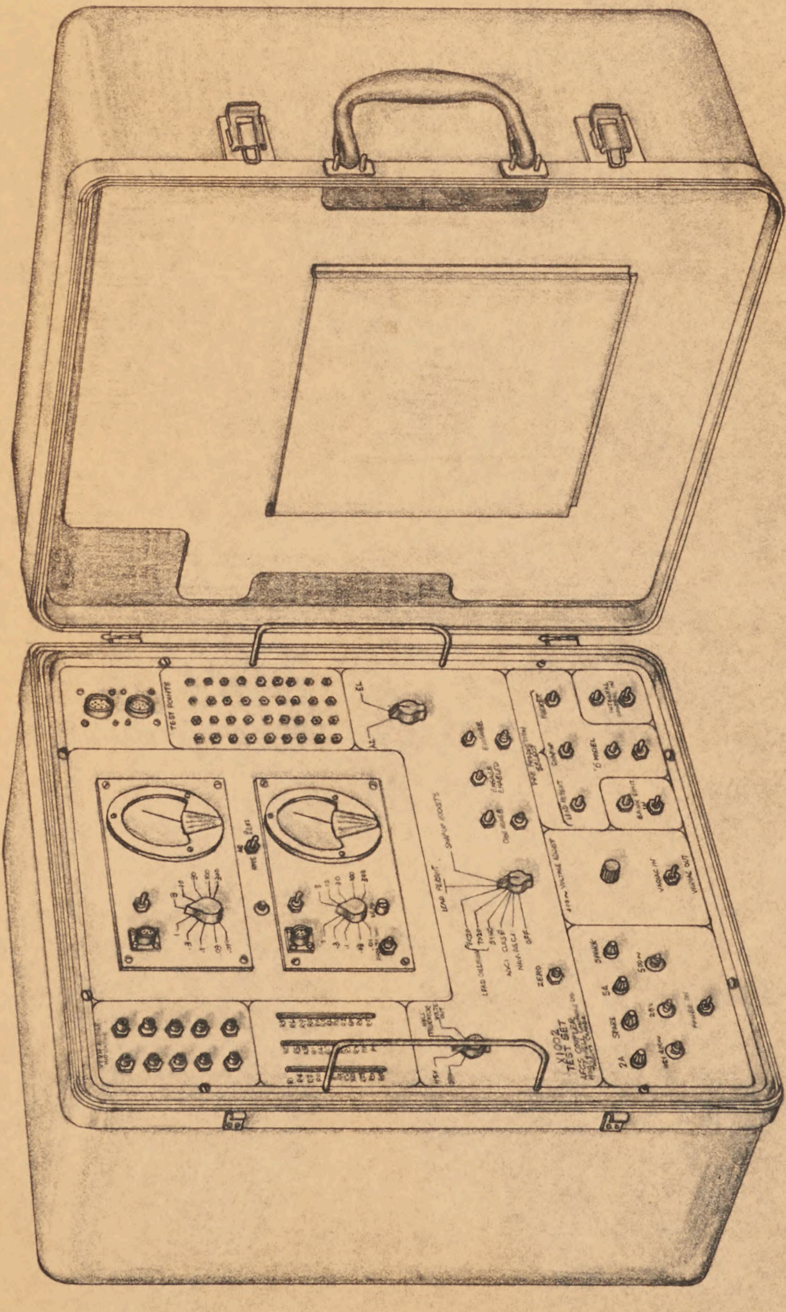
It was anticipated that delivery would be delayed approximately two weeks pending arrival of the V.T.V.M.'s. During this period it would have been possible to use the Test Set with externally connected laboratory type V.T.V.M.'s. A modification of the Breadboard Test Set circuit was to have been incorporated in the "D" Model AFCS Test Set.

3.8 CONCLUSIONS

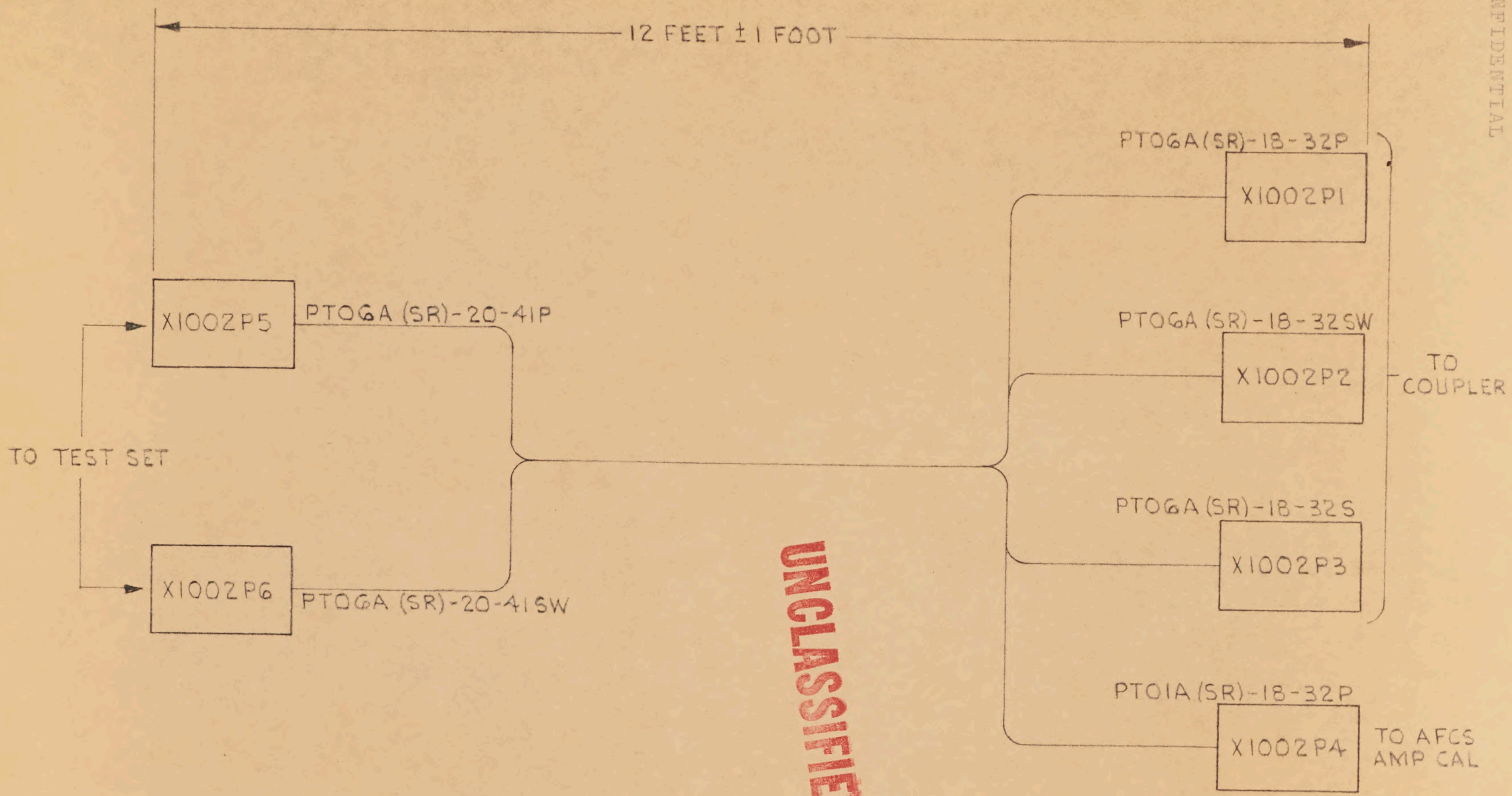
a) The purpose of the Breadboard Test Set to provide facilities to Flight Test Engineers to test and/or adjust the "D" Model AFCS Couplers, would have been fulfilled.

b) A further aim of the Breadboard Test Set was to provide simplicity of operation so that a low skill level technician would be able to perform "go-no-go" tests with a minimum of instruction or experience. It is considered that the small number of operating controls fulfill this objective.

c) The Test Set was designed and built in the four months preceding cut-off, and, although full co-operation was received from Minneapolis Aero, it is felt that the design of the Test Set and the test procedures could have been simplified considerably had the test equipment design started earlier in the programme. e.g., had it been possible to excite the Coupler F/C pots with D.C. rather than A.C., a V.T.V.M. would not have been required for "go-no-go" tests, and the use of a d.c. microammeter as a null indicator would have permitted automatic range selection to be incorporated in the Test Set.



COUPLER BREADBOARD
TEST SET
FIG 3.1



CABLE HARNESS
FIG 3·2

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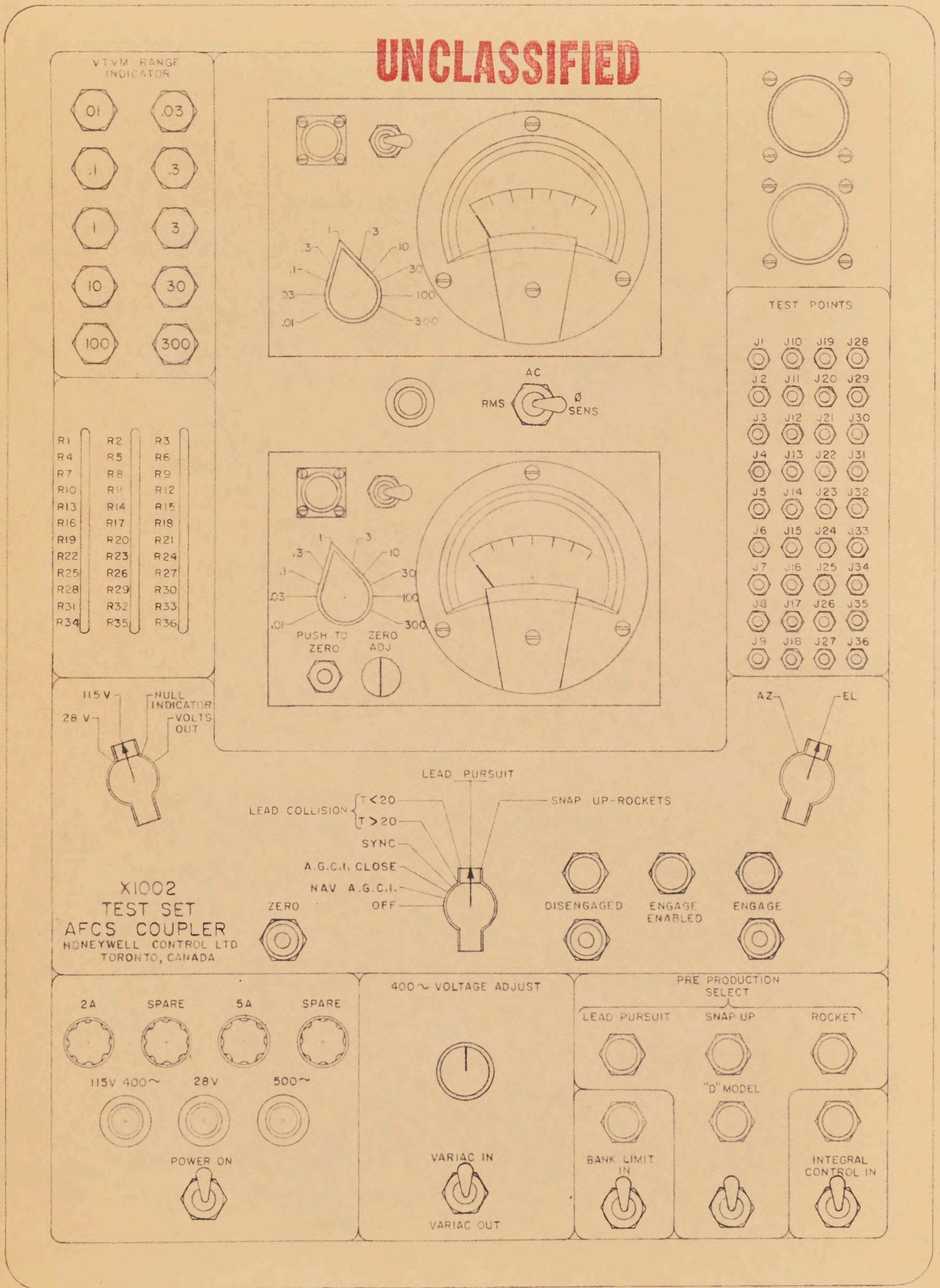

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A.F.C.S. COUPLER TEST SET
FIG. 3·3

DATE
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TERMINATION REPORT

ON THE

GROUND TEST EQUIPMENT

FOR THE

FLIGHT CONTROL SYSTEM

OF THE

CF-105 ARROW AIRCRAFT

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Honeywell Controls
Aero Document CR-ED 1048

SECTION 4

X-1003 AIR DATA COMPUTER AND MACH
INDICATOR, BREADBOARD TEST SET.

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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X-1003 AIR DATA COMPUTER AND MACH INDICATOR, BREADBOARD TEST SET

4.1 GENERAL

The X-1003 Air Data Computer and Mach Indicator Breadboard Test Set was part of the Arrow Electronics System Test Equipment and was designed to test the D-YG 6000A-1 Mach Indicator System and the D-HG32A-2 Air Data Computer. This breadboard model test set was being designed coincidentally with the Air Data Computer development.

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4.2 RELEVANT SPECIFICATIONS

a) RCA statement of work dated 13 February 1958, as amended by Astra memo 637 dated June 5, 1958.

b) ASTRA I specification, Revision C.

c) RCA Specifications 5638 and 5375 governing finishes on front panel and external surfaces.

d) MIL-T-945A amendment 2 dated 14th of May 1953, "General Specifications for Test Equipment for use with Electronic Equipment".

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the ASTRA I Airborne Weapons Control System dated 19th. of February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 "General Specification for Environmental Testing Ground Support Equipment."

h) MIL-E-5400 "General Specifications for Aircraft Electronic Equipment."

Because this test set was meant to be used only as an interim measure until the integrated test equipment could be designed and built, the specifications were used as guides only. In all cases, however, good commercial and military design practices were followed.

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4.3 DESCRIPTION OF UNIT

4.3.1 General

4.3.1.1 Physical

The X-1003 Breadboard Air Data Computer and Mach Indicator Test Set and associated cables were to fit inside a 20" x 15" x 11" reinforced fibreglass instrument case. With the case open, it is seen that the Test Set was mounted in the lower section and the upper section was used for the storage of cables and instruction manuals (Figure 4.1).

Because the Test Set was designed to perform both first and second line tests, test cables were provided for both functions. First line test cables were to be sixteen feet long to enable placing the Test Set on the ground under the electronics bay of the aircraft, and connecting to the Air Data Computer above it. Second line test cables were six feet long for use on a work bench when the Air Data Computer had been removed from the aircraft.

4.3.1.2 Electrical

The Test Set was designed to obtain its power from the Air Data Computer via the test connector, J29, on the A.D.C. The power supply built into the Test Set required 113V ± 11V, 400 cps at 100 ma and supplied 27.5V D.C. at about 300 ma., to operate the test relay and the clutches for the Mach Hold and Altitude Hold functions in the Air Data Computer.

The inputs which the Test Set could measure were of two types:

1. Voltage outputs from the Altitude Rate, Mach Error, Altitude Error and Differential Pressure signal sources.

2. Potentiometer ratios or resistances of all output potentiometers.

The test set had output terminals to which a phase sensitive AC VTVM having a floating ground must be connected for use as a "go-no-go" indicator.

4.3.2 Component Parts

The X-1003 Breadboard Air Data Computer and

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Mach Indicator Test Set consisted of the following parts.

a) Case

b) Main chassis Assembly consisting of

1) Test Panel including switches, knobs, lights, etc.
2) Chassis with connectors
3) Trimpot Assembly
4) Resistor board assemblies

c) Cable compartment assembly

d) Cables (seven)

4.3.3 Theory of Operation

The Air Data Computer Test Set was divided functionally into three sections:

a) A.D.C. First Line tests

b) A.D.C. Second Line Tests

c) Mach Indicator tests

In order to facilitate first line testing, the Air Data Computer had a built-in self-test feature. The self-test feature was activated by supplying 27.5V. D.C. to the self-test relay K1 via the test connector J29. When K1 was powered it set up simulated air data conditions corresponding to values of speed (M) of 1.550M, altitude (h) of 50,000 feet, angle of attack (α) of 0 degrees and total temperature (T_T) of 573.6°R. These values were sufficient to determine shaft positions, and hence output potentiometer ratios, or synchro output voltages, of all output shafts in the A.D.C.

Three of the output shafts had potentiometers brought out through the test connector J29. These were R33 on the true air speed (V) shaft, R20 on air density (ρ) shaft, and R61 on the angle of attack (α_i) shaft. In addition, the first line portion of the test set had facilities for applying 28V. D.C. to the Mach Hold and Altitude Hold solenoids. The A.D.C. had leads brought out to J29 to permit the measurement of Altitude Rate, Altitude Error and Mach Error voltages when these solenoids were powered. The differential pressure (q_c) synchro also had leads brought out to J29.

Because the values of the voltage outputs and their tolerances for the various functions were known the Test Set was designed to connect each voltage into the simple bridge circuit shown in Figure 4.2. The bucking voltage was supplied by the Test Set and the Meter with the divider network to select the proper "go-no-go" range was connected between the output device and the voltage divider.

In the cases where a potentiometer position (or ratio) was to be measured, the bridge circuit was modified slightly so that the Test Set supplied both a fixed voltage across the whole potentiometer and the proper bucking voltage. This is shown in Figure 4.3. Included in the Test Set was a precision potentiometer, with a fixed voltage across it, which could be used as a calibration reference for the remainder of the test circuitry.

In the second line portion of the Test Set, provision was made for checking the potentiometer ratios of all the output potentiometers on all the A.D.C. output shafts, with the exception of those checked on first line tests. In addition it was possible to check the voltage at every pin of connectors J3 and J4 (which connect the pressure data module to the other modules) by "teeing in" with the cables supplied.

Mach Indicator tests were to be performed by switching the amplifiers in the Mach Indicator Amplifier Calibrator from one channel to another by means of the switch in the Test Set. Thus, for example, if a fault appeared in the Command Mach channel, it would be possible to switch the amplifier from the Mach Limit servo or the Actual Mach servo into the circuit and so isolate the fault to the amplifier or the external circuitry.

4.4 DESCRIPTION OF PARTS

4.4.1 Case

In order to meet the requirements of MIL-T-945A, as far as ruggedness was concerned, a fibreglass reinforced epoxy case was chosen. This case is comparatively light in weight for its strength and is rainproof. The case size was dictated by the panel size as described in a further paragraph. A cable compartment with a hinged cover was riveted to the lid portion of the case. The seven cable assemblies were stowed in this compartment.

4.4.2 Main Chassis Assembly

One of the design objectives for the A.D.C. Test Set was that the method of construction be such that the unit could be mounted in a portable carrying case for first line tests, and, also be capable of being installed permanently in a standard type of mounting rack for second line use. The two requirements were not entirely compatible because the carrying case mounting required connectors on the side of the chassis (the bottom being inaccessible) whereas the rack mounting required no obstructions on the sides to permit passing the assembly through an opening the size of the panel. The objective was met, however, by designing for a rack type mounting with the connector mounting easily changed to permit carrying case mounting.

The main chassis assembly consisted of the front panel of 3/32" steel with the chassis side and end panels of 1/16" aluminum. The chassis sides are formed to shallow channel or Z sections for stiffness. A recessed side panel is provided for eight adjustment potentiometers. Miscellaneous circuit resistors are collected together on terminal boards which are mounted at convenient places on the chassis.

The front panel was a standard rack size of 8 3/4" by 19" notched for rack mounting. Rather than engraving the panel itself, the panel markings were reproduced on .010" thick sensitized aluminum sheet which was exposed and developed by a photographic process. The aluminum sheet was then glued to the steel panel with a contact adhesive. A sprayed coat of lacquer protects the markings from abrasion. This method resulted in a professional appearance and was considerably less expensive than engraving. Panel markings are easily changed by making a new sheet.

A sub-assembly holds twenty-nine miniature trimmer potentiometers which were used in the bucking voltage circuit. These trimpots were accessible through slots in the panel. Rubber gaskets are provided to make the slots rainproof.

4.5 PERFORMANCE

It was anticipated that the X-1003 Test Set would be capable of testing the various Air Data Computer outputs (voltage outputs and potentiometer ratios) within fourteen per cent of the tolerance on each individual output. Since there are separate tolerance figures on each output, the test set accuracy is different for each measurement. Thus, a 1% output may be tested with an accuracy of 0.14%.

Because the construction of the Test Set had not been completed, there was no opportunity to prove its performance and accuracy in practice.

4.6 STATUS AT CANCELLATION

At the time of cancellation of the Astra System the design of the A.D.C. Test Set was within a few days of completion. All that remained was the calculation of some of the resistance values in the bridge circuits. We were waiting to receive a document from Minneapolis, which would have given the tolerances on some of the A.D.C. output potentiometers. This information was necessary to complete the calculations.

The construction of the Test Set had reached the stage where all mechanical assemblies had been made and mounted. The chassis wiring was approximately half completed. Six of the seven cable assemblies were completed. The remaining cable lacked two connectors, which had not been received from the vendor. The purhcase order for the connectors was subsequently cancelled.

4.7 PROPOSED FUTURE PROGRAM

It had been proposed, of course, that the design and construction of the X-1003 Test Set be carried to completion under the original contract arrangements for A.E.S. Test Equipment. The cancellation of the program ended all work on the project.

4.8 CONCLUSIONS

The program for the development of this Test Set has demonstrated that it is possible to design and produce test equipment simultaneously with the development of equipment to be tested. Furthermore, efficient liaison has made it possible to carry out the two programmes in companies separated by an international boundary and distant geographical locations.

The one difficulty encountered in this programme was extreme time lag in the transfer of classified information. This lag was caused by the complex channel of flow required for all engineering documents and drawings.

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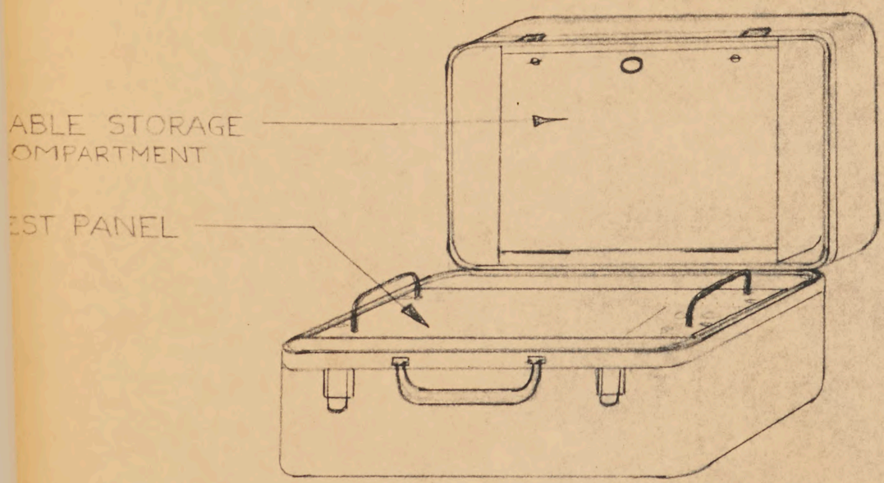

FIG. 4·1

GENERAL ARRANGEMENT OF X 1003 TEST SET.

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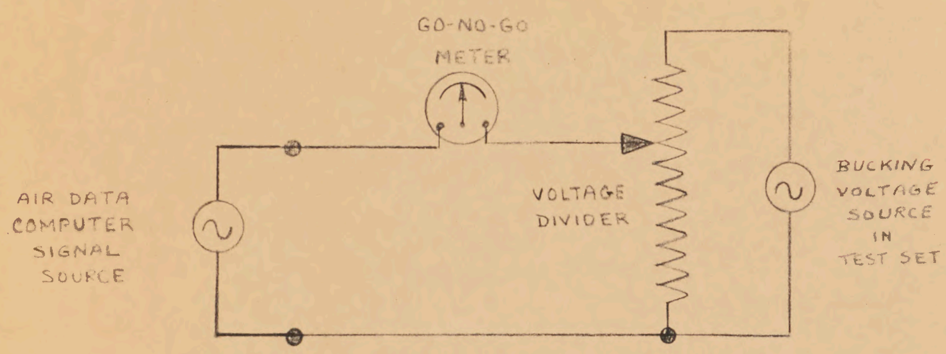
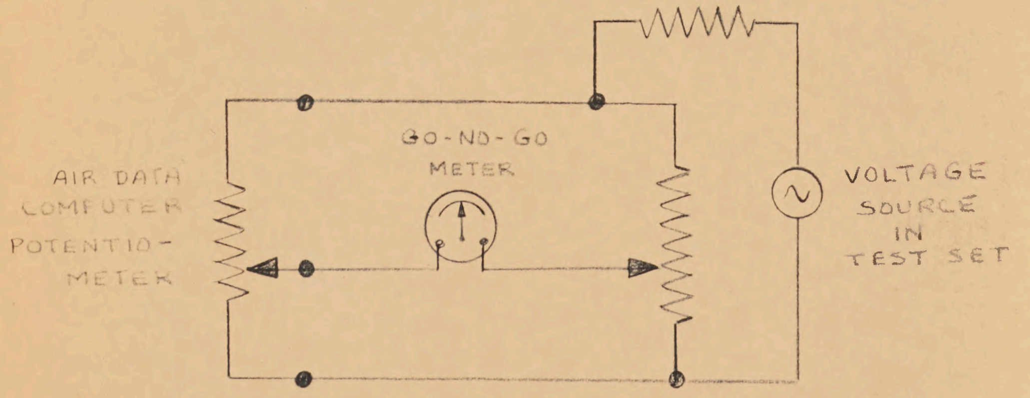


TEST CIRCUIT FOR ADC VOLTAGE OUTPUTS

FIG. 4·2



TEST CIRCUIT FOR A·D·C· POTENTIOMETER RATIO MEASUREMENTS

FIG. 4·3

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TERMINATION REPORT
ON THE
GROUND TEST EQUIPMENT
FOR THE
FLIGHT CONTROL SYSTEM
OF THE
CF-105 ARROW AIRCRAFT

Honeywell Controls
Aero Document CR-ED 1048.

SECTION 5

X-1004 VERTICAL AND HEADING REFERENCE SYSTEM AND FLIGHT DIRECTOR/ATTITUDE INDICATOR, BREADBOARD TEST SET

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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X-1004 VERTICAL AND HEADING REFERENCE SYSTEM AND FLIGHT DIRECTOR/ATTITUDE INDICATOR, BREADBOARD TEST SET.

5.1 GENERAL

The X-1004 Vertical and Heading Reference System (VHRS) and Flight Director Attitude Indicator (FD/AI) Breadboard Test Set was part of the Arrow Electronic System (AES) Test Equipment. It was designed to perform "go-no-go" and fault isolation tests on the JG227B-1 FD/AI, the BG114A-1 Amplifier Calibrator and the Interim VHRS part of the Arrow Electronic System (AES), and was to be used only with Aircraft 4, 5, and spare for Flight Test purposes.

The Interim VHRS did not use the GG63 Stable Platform, but comprised instead a GG48B-3 Vertical Gyro (and its Amplifier Calibrator, the BG121A-1) a J-4 Compass and the DG6000A-1 Three Axis Repeater. The J-4 Compass was to have been supplied by RCA to provide the heading reference for the Interim system. Proper operation of both the Vertical and Directional Gyro systems was to have been confirmed by direct observation of their outputs on the Test Set angle monitor. Because the test procedure was well developed for testing the J-4 Compass, no special provision was made in the Test Set for it. Any trouble detected by observation of faulty attitude information from the Vertical gyro was to be remedied by changing first the BG121A-1 Amplifier Calibrator (Amp Cal) and, if this did not remedy the situation, by changing the Vertical gyro assembly itself. The GG48 is hermetically sealed.

The Three-Axis Repeater comprised a rack and junction box on which were mounted the Heading, Roll, and Elevation Repeater Servo Modules. Each of the Repeater Servos contained ten output devices, which provided angle information, or functions thereof, to other subsystems within the Arrow Electronic System (AES.) The output devices were a combination of synchros, characterized potentiometers and sector switches. The Three-Axis Repeater was located in the Electronics Bay, and the Vertical and Directional Gyro systems in the Aircraft Duct Bay. Individual Repeater-Servo modules could only be removed if the rack was removed from the aircraft.

The JG227A-1 FD/AI provided a 'moving horizon' type of attitude presentation and lateral and vertical steering information. Associated with the JG227A-1 was the BG114A-1 Amplifier Calibrator, which contained the associated electronics. In addition to providing a continuous display of aircraft attitude, the indicator provided lateral and vertical rate-corrected error (deviation), and lateral and vertical displacement (directions).

Testing of the two sub-systems was broken down into First and Second Line Maintenance. Both were to have been performed by the Breadboard Test Set, the selector switches for each being clearly marked.

First line testing was to have involved a simple "go-no-go" test of both units, with an additional fault isolation feature available for the FD/AI to provide isolation of a fault to either the Indicator or the Amplifier Calibrator (Amp Cal).

"Go-no-go" performance tests on the FD/AI involved simply slewing of each of the three axes to a predetermined angle and observing the Indicator for the proper values. Fault isolation to either the Indicator or its Amp Cal was to have been accomplished by driving the indicator motors directly from a source in the Test Set with the Amp-Cal disconnected, and measuring the corresponding tachometer voltage.

Details of the theory behind the tests are outlined in a later section.

It must be emphasized that the Breadboard Test Set described herein was a "one of a kind" item. It was designed only for use with the Interim VERS. Described in Section 6 is the complete Flight Control System Test Set which included many of the tests performed by this Breadboard, and which was to have been used with the whole Flight Control System (including the Stable Platform).

5.2 RELEVANT SPECIFICATIONS

a) RCA statement of work dated 13 February 1958 as amended by Astra memo 637 dated 5 June 1958.

b) ASTRA 1 specification, Revision C.

c) RCA Specification 5638 and 5375 - Governing finishes on front panels and external surfaces.

d) MIL-T-945A amendment 2 dated 14 of May 1953. "General Specification for Test Equipment for use with Electronic Equipment."

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the Astra 1 Airborne Weapons Control System dated 19 of February 1958.

f) MIL-STD-108C. Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 - "General Specification for Environmental Testing Ground Support Equipment"

h) MIL-E-5400 "General Specification for Aircraft Electronic Equipment."

5.3 DESCRIPTION OF UNIT

5.3.1 General

5.3.1.1 Physical

Reference is made to Figure 5.1 where the general configuration of the overall Test Set is illustrated. The carrying case was to be of fibreglass, grey in colour and about 20" x 15" x 13" deep when closed. Two handles were to be provided for carrying purposes. The top, which contained all cabling coiled about a framework, was to be removable for the sake of convenience in use. Two suitcase type fasteners were to provide the means for securely fastening the lid to the bottom. The whole unit would have weighed between 50 and 60 pounds. The general layout of the panel can be seen in Figure 5.2.

5.3.1.2 Electrical

It will be noted from Figures 5.1, 5.2 and 5.3, that all connections to and from the Test Set were to be made through a set of nine connectors arranged in a line along the top of the panel. Power and output signals from the Interim VHRS were to have been brought in on one of the connectors. Two others were to have been connected to test connections located on the Three-Axis Re--peater and the FD/AI Amp Cal. Another was to go in series with the FD/AI. The remaining five were to have been connected to the output connections of the Repeater, thus giving access to all output devices.

Such a situation in a production test set, where existing connectors had to be removed in order to allow connection of the Test Set Connectors, would be intolerable from the reliability standpoint. However, because this Breadboard was to be used for flight tests only and it would be ridiculous to demand parallel connections to all signals desired on a "one-off" basis, the situation was considered acceptable. The cabling necessary for connection to the components under test was to have been permanently connected to the Test Set, and stored in the lid, as indicated previously.

For First Line "go-no-go" tests, three of the nine cables were connected. For Fault Isolation an additional connection was required. Second Line testing required that all cables be connected.

With the exception of the angles, which were to have been read directly on an output single monitor in the Test Set, all readings were to have been taken on a null-reading A.C., V.T.V.M.

5.3.2 Component Parts

The Breadboard Test Set consisted of the following:

a) Panel, mounting all switches and meters.

b) Carrying case containing the panel and interconnecting cables.

c) Interconnecting cables for joining the Test Set to the VHRS and FD/AI.

5.3.3 Theory of Operation

This section will be broken down into two parts, Section 5.3.3.1 and Section 5.3.3.2. Section 5.3.3.1 will describe the basic theory involved behind the slewing of the Three-Axis Repeater by a perfect input angle simulator, testing of output devices on the Repeaters and tests involving the FD/AI. Section 5.3.3.2 will describe the test procedure with reference to Figures 5.2 and 5.3.

5.3.3.1 Basic Theory

5.3.3.1.1 Perfect Angle Simulation

As was mentioned previously, the Repeater Servo Control Transformers (CT's) were to serve as the command points for all angle inputs. Perfect input angles can be simulated very easily, as can be seen from Figure 5.4.

In Figure 5.4a the typical repeater servo connection is shown, where CX is the control transmitter, and CT the control transformer. Figure 5.4b shows the CX replaced by a single voltage source E and a network which is usually a low impedance voltage divider.

Figure 5.4c indicates that the maximum induced voltage E across any two of the stator windings occurs at maximum coupling. The source E in Figure 5.4b will then have the value $E = E_{max} \cos 30°$. For example, $E = 11.8 \cos 30° = 10.2V$ for a 11.8V CT. Figure 5.4d defines the conventional direction of the rotor angle for positive rotation for the indicated lead designations.

The general relationship between the voltages produced by three independent sources and a required angle θ is given in Figure 5.4e. By grounding the appropriate terminal, the required network for a desired angle command will reduce to the forms shown in Figure 5.4f. For negative angles between 0° and -180°, leads 1 and 3 need only be interchanged. Trim-pots usually suffice for the voltage dividers. Synchro tuning capacitors are usually required. If extreme accuracy is required pot-loading corrections may be necessary.

By means of the above method of angle simulation it is possible to use switching to command various desired angles from the repeater for test purposes. If, for example, a test is to be made on a certain output device at a specific angle, both the command and test functions can be combined on a single rotary switch. This is essentially what was to be done in the Breadboard Test Set for most of the tests.

It will be readily seen that the method described above also lends itself to testing of any CX's and CT's on the output shafts of the Three-Axis Repeater.

5.3.3.1.2 Repeater Servo Performance Tests

The simple "go-no-go" check of each of the Repeater Servos was to have been achieved by introducing perfect angle inputs of 0°, 120° and 240°. These were to be observed on the Output Angle Monitor, which was a pointer on a Torque Receiver (TR) shaft mounted on the Test Set front panel. The TR's were connected to corresponding Torque Transmitters (TX's) on the Repeater Servos. These TX's, which ordinarily went to the Flight Director Attitude Indicator (FD/AI CT's) were disconnected from the FD/AI for the repeater tests.

In addition to the visual check (which gave no indication of accuracy), a null reading was to be made using the Instrumentation CT's provided as one of the Repeater outputs for Flight Test Purposes. By connecting them in Perfect Angle configurations corresponding to 0°, 120° and 240° a null reading on the VTVM would be obtained which would be a measure of the Repeater

Servo accuracy. This is illustrated in Figure 5.5a for the Zero degree case. Any deviation in the null reading obtained for the three test angles indicates excessive gear train wear, or synchro misalignment.

Indication of the dynamic performance of the Repeater Servos was to have been accomplished on a Second Line Maintenance basis by the transient response test illustrated in Figure 5.5b. With the switch in the 0° position, the CT is connected in a 0° configuration. Thus, the shaft output position corresponds to 0°. Instrumentation CT_2 is connected in a 15° configuration and hence gives an output corresponding to a 15° error, (about 5 volts).

When the switch is turned to the 15° position, CT_1 is connected in a 15° configuration, and slews the servo through an angle of 15° This corresponds to a 15° step input. During the transient period the output of CT_2 decreases from the 5 volts to zero. When displayed on a recorder the response should indicate about .6 damping ratio.

5.3.3.1.3 Three Axis Repeater Output Devices Tests

Four basic steps were to be involved in the testing of each of the output devices on the Three-Axis Repeater, namely:

a) Connecting and exciting the output device under test in an active, working configuration.

b) Commanding a specific angle into the appropriate Repeater servo which will give a known output from the device under test in accordance with step a.

c) Supplying a bucking voltage equal to the known output obtained in step b.

d) Comparing the voltage obtained from steps b and c by means of a V.T.V.M.

All of these steps would be taken simultaneously by turning the selector switch to the position corresponding to the output to be tested. Repeater output devices were to be checked on a Second Line Maintenance basis. Figure 5.6a illustrates the procedure.

The following five different types of output devices required testing:

1. Sector Switches
2. Control or Torque Transmitters (CX and TX)
3. Control Transformers (CT)
4. Co-ordinate Resolvers (B)
5. Characterized potentiometers.

Sector switches were to be checked at angles of 0° and 180° because they were all symmetrical about the axis so defined. They were to be tested by a simple lamp circuit energized by the 28 volt line. Changes in the sector angles due to dirt, arcing over at high altitudes, etc., were not checked because the tolerances were quite loose, and the switch reliability was found to be quite high. See Figure 5.6b.

Control and Torque Transmitters were to have been checked at a command angle $\theta c = 0°$, and with the synchro connected in a 0° configuration. See Figure 5.6c. It should be noted that all devices were checked in such a way that a definite value of bucking voltage was required to produce a null. Thus, there was little danger that a null reading could occur on the test of one of the devices unless its performance was acceptable.

Control Transformers required $\theta c = 60°$, and were connected in a 0° configuration. See Figure 5.6d.

The command angle for Resolvers was 30°. The connections of the terminals depended on the terminals which were made available at the connectors. See Figure 5.6e for typical connection.

5.3.3.1.4 FD/AI Performance Checks

The "go-no-go" check planned for the Indicator portion of the Flight Director Attitude Indicator (FD/AI) involved visual inspection of the Three-Axis Ball Indicator by an observer in the cockpit. By means of the Three-Axis Repeater, all axes were first to be slewed to zero. Each axis in succession was then to be slewed to an angle of 60°. If the ball indicated the above readings, it was assumed to be operational, provided, of course, that there was not evidence of sluggishness or oscillation about the equilibrium position.

Testing of the Director portion was to have been achieved by inserting a D.C. test signal and noting a deflection on both the Deviation and Director Needles. Even though there was no provision for AGCA on ILS on the Arrow at the time, the above simple test of the needles was incorporated in the Test Set.

5.3.3.2 Test Procedure

In giving the following brief description of the procedure in using the Breadboard Test Set, reference is made to Figures 5.2 and 5.3.

5.3.3.2.1 First line maintenance testing

"Go-no-go" tests, and any required fault isolation was to be performed in First Line Maintenance Testing. Cables from J1, J7 and J8 of the Test Set were connected as indicated in Figure 5.3 for the "go-no-go" tests. The cable from J9 was connected in place of J1 on the FD/AI only for fault isolation purposes.

The Main Selector Switch is shown with its five positions in the middle of the panel (Figure 5.2). This switch controls the whole operation of the Test Set. The first three active portions of this switch were to be used in First Line. A pilot light arrangement provided visual indication of the test being performed. For example, on the position shown as "Repeater Performance" the pilot light in the column under the heading "Repeater Performance" would light up. Similarly, the light in the column under the heading "FD/AI Performance" would light up indicating that the Test Set was ready to check the performance of the FD/AI when the Main Selector Switch was in the FD/AI Performance position.

The Output Angle Monitor and VTVM were automatically connected so that angle and null voltages for a given test in progress were available.

5.3.3.2.2 Second line maintenance testing

The last position of the Main Selector represented Second Line Maintenance Tests. This amounted to checking all the output devices on the Three Axis Repeater. For these tests, all the connections indicated in Figure 5.3 were required.

Pilot lights were arranged so that the Heading, Roll and Elevation Axes were checked in succession, the pilot lights shown in Figure 5.2 opposite the "S" numbers on the switch (indicating sector switches) provided indication of switch continuity as indicated in a previous section.

The two switch positions shown as "Transient Response" in the "Repeater Performance" Column provided the means of introducing a 15° step into each axis, as explained in Section 5.3.3.1.2. This is really a Second Line Test, since a recorder would be required for reading. It is an omission that it was not so indicated.

Four pin jacks were to be provided for observation of the Repeater Servo error signals and Instrumentation CT's. These would have application in the "Transient Response" test for recorder readout and for general troubleshooting.

If the existence of a fault was discovered in the "go-no-go" tests on the FD/AI as indicated in Section 5.3.3.1.4 above, the problem of isolation to either the FD/AI or its Amplifier Calibrator (Amp Cal) remained. The Amp Cal, which was located in the Electronics Bay, was relatively accessible; the FD/AI located in the cockpit, was not. It was, therefore, important to provide fault isolation in order to allow removal of the defective component.

The procedure used was to be that of simulation. The Amp Cal was to be disconnected from the FD/AI and simulated by three voltage sources in the Test Set. These sources provided the proper voltage to drive the motors in the FD/AI at a known speed.

The corresponding tachometer voltage outputs were to be compared with a bucking voltage in the Test Set producing a null if the motors and the tachometers were operating properly. If so, the Amp Cal was concluded to be at fault, and replaced. If not, then the FD/AI was to be replaced.

5.4 DESCRIPTION OF PARTS

5.4.1 Panel

The panel was to be mounted on the lower case and support the VTVM, controls, angle monitor and all the components necessary to generate signals and monitor outputs.

5.4.2 Carrying Case

The carrying case was to be made of fibreglass and was of weatherproof construction. It was to provide accommodation for the panel assembly, and the interconnecting cables.

5.4.3 Interconnecting Cables

The interconnecting cables were to be of sufficient length to permit the test set to be placed on the ground while performing tests. They were to be a collection of #20 teflon covered wire sheathed in a close-fitting vinyl sleeve.

5.5 PERFORMANCE

Since the Breadboard Test Set described herein was not constructed there is no performance data available.

5.6 STATUS AT CANCELLATION

At cut-off, all components were on order, and most had arrived. Construction had just begun. The panel master, from which the panel was to have been made by a photographic process, was completed (Figure 5.2 is a reduced drawing thereof, with knobs, Dial Indicator and VTVM drawn in).

5.7 PROPOSED FUTURE PROGRAMME

No future programme was envisioned for this Breadboard since it was one-of-a-kind item, and was built for testing of interim equipment.

5.8 CONCLUSIONS

The concepts used in the design of the Breadboard Test Set are simple and straightforward and are common knowledge to all those skilled in the art.

There is one idea which came up during the design of the Breadboard Test Set which is of some interest. It was not incorporated because it was untried and it was felt that further development time was not possible because of the tight schedule, and because the Breadboard was only required to fill an interim need. The idea involved the "Transient Response" test referred to earlier. It was proposed that the test be made "go-no-go" by replacing the recorder by the simple circuitry shown in Figure 5.7.

The upper part of Figure 5.7a is identical to Figure 5.5b. Instead of the recorder a simple phase-sensitive demodulator, rectifier and RC filter is used with a DC. V.T.V.M.

In Figure 5.7b the envelope of the voltage output from CT2 is shown during the transient due to the 15° step. (This could just as well be the servo error signal). This wave is essentially what comes out of the demodulator. The diode D can be arranged to have polarity such that only the shaded portions are fed into the RC filter. The filter time constant can be adjusted so that the reading on the DC VTVM is a measure of the number of overshoots. If the reading persists, the servo is oscillating. If the reading is below a predetermined reference value the servo is too sluggish, and if the reading is higher than the reference, the servo is underdamped.

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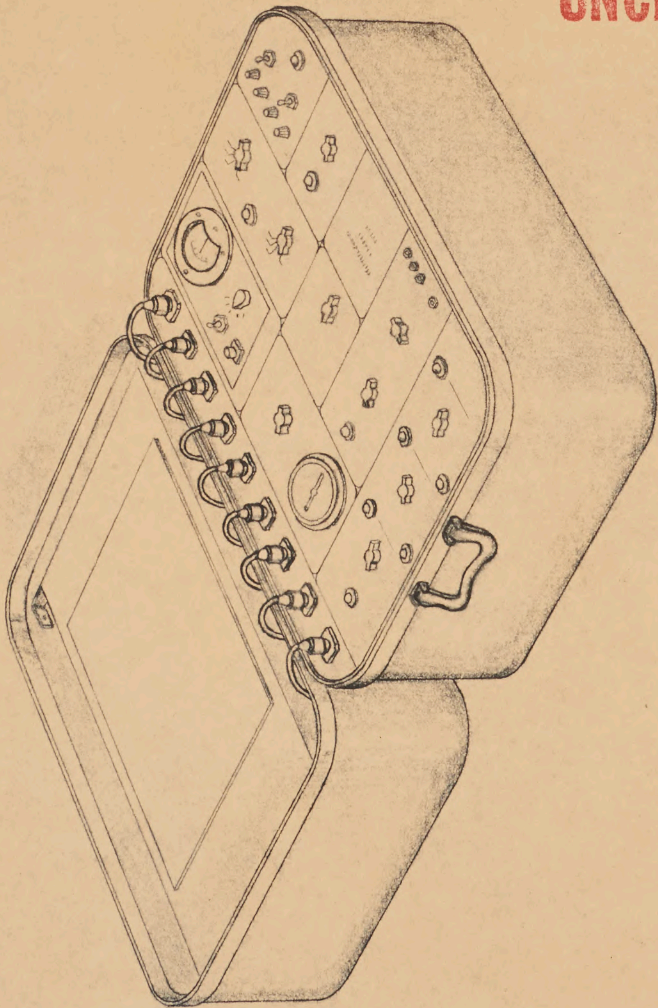

BREADBOARD TEST SET ASSEMBLY

FIG. 5·1

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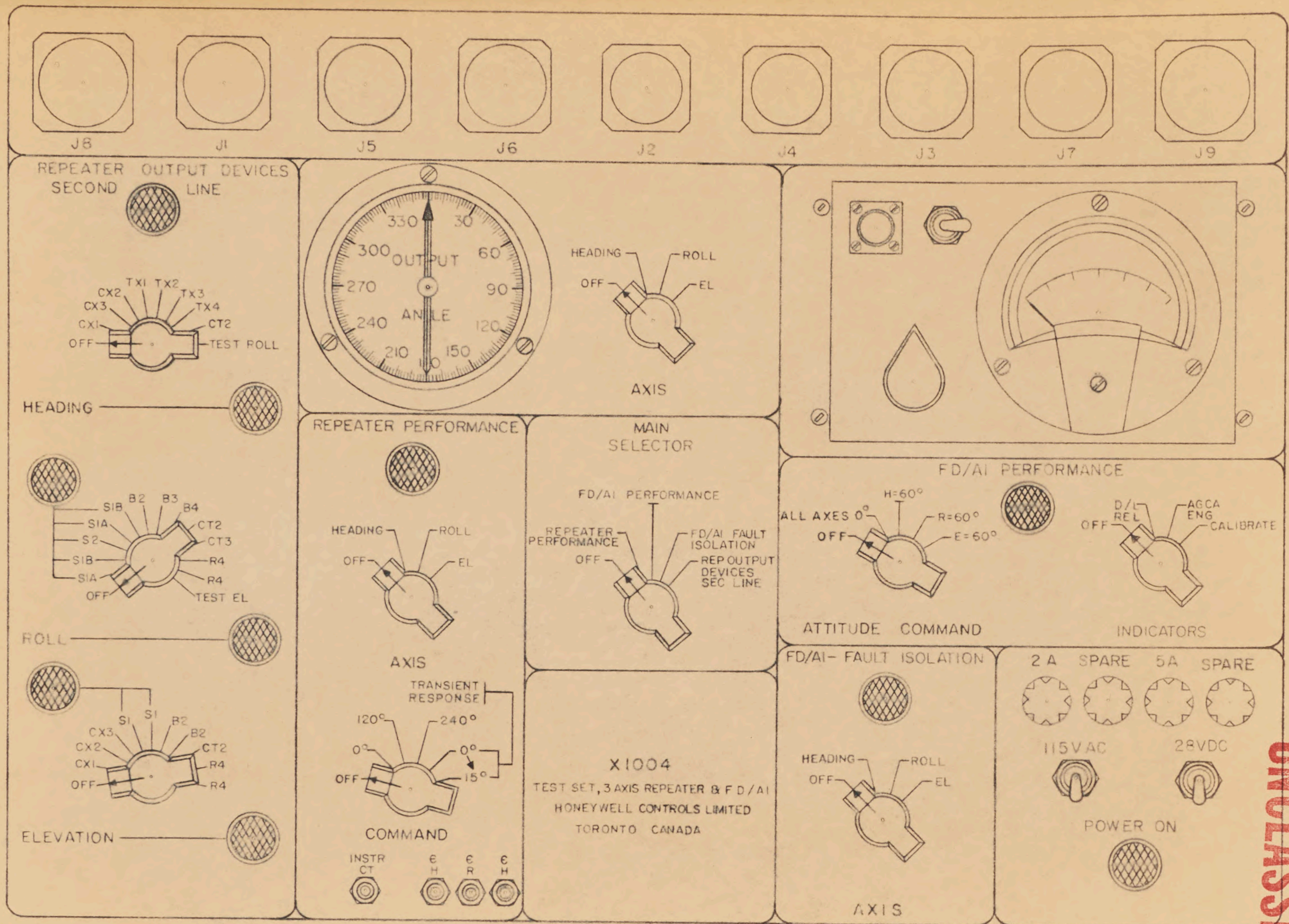


BREADBOARD TEST SET PANEL LAYOUT
FIG. 5·2

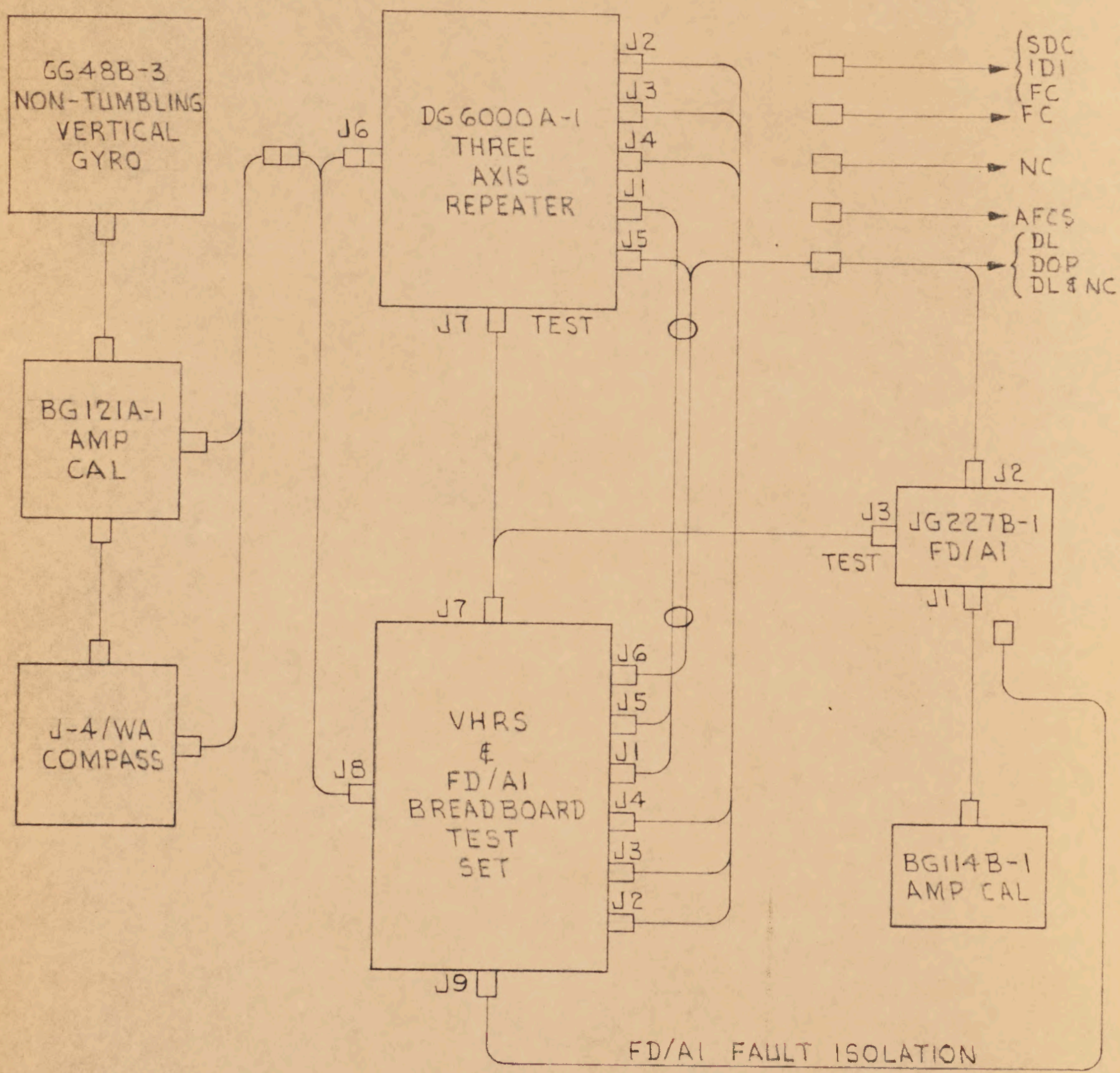
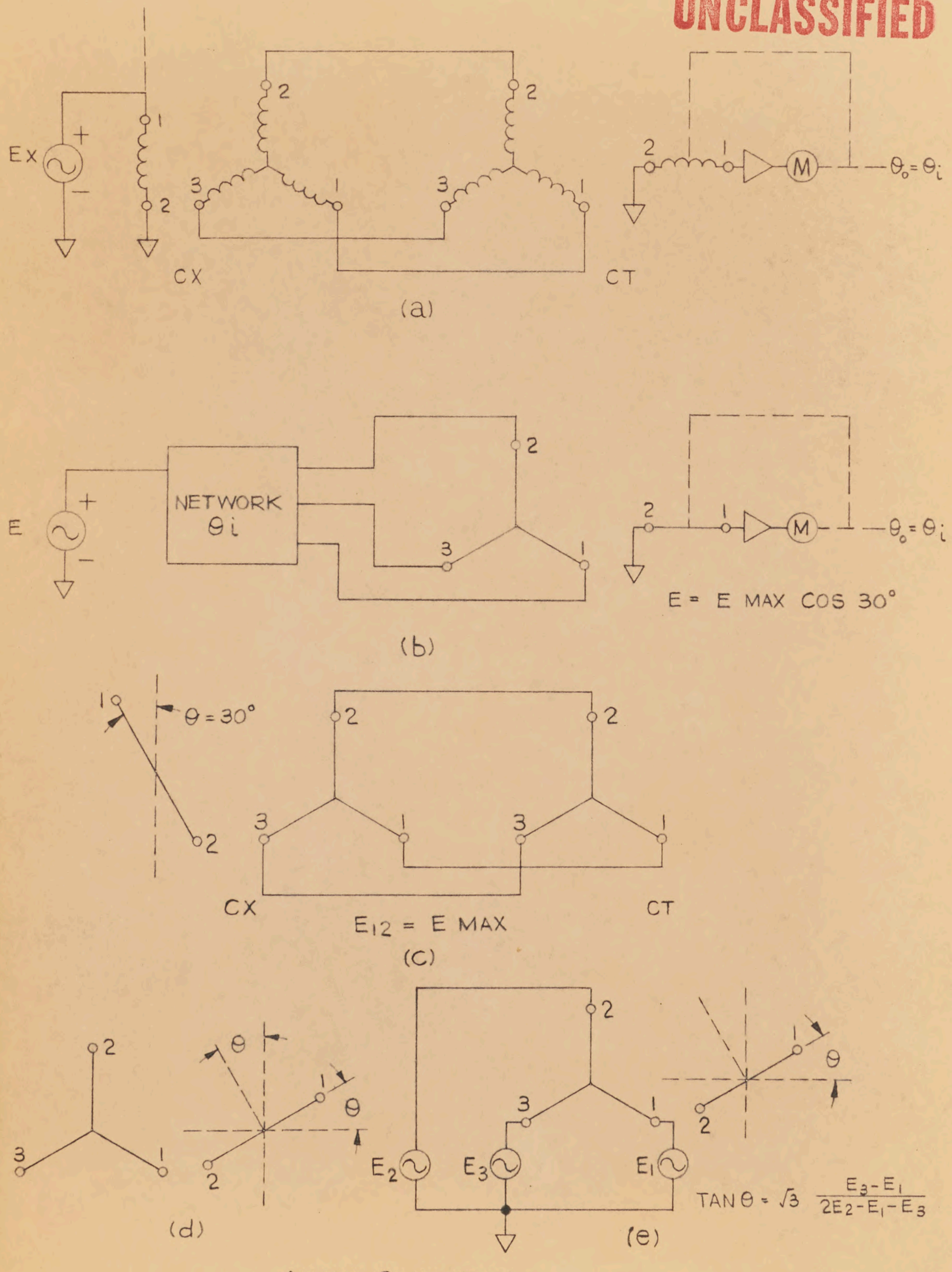


FIG 5·3

INTERCONNECTION DIAGRAM



ANGLE SIMULATION

FIG. 5·4

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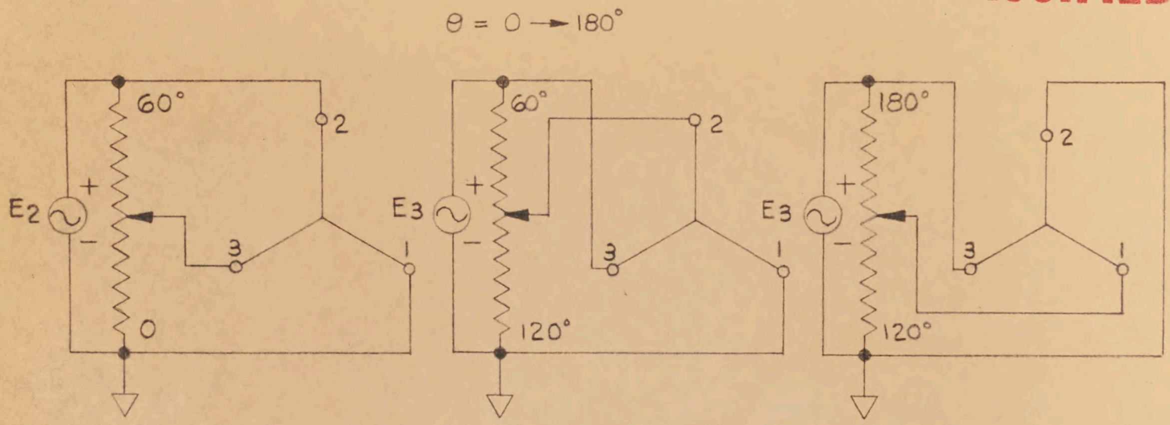


(f)

ANGLE SIMULATION
FIG. 4 (CONT'D)

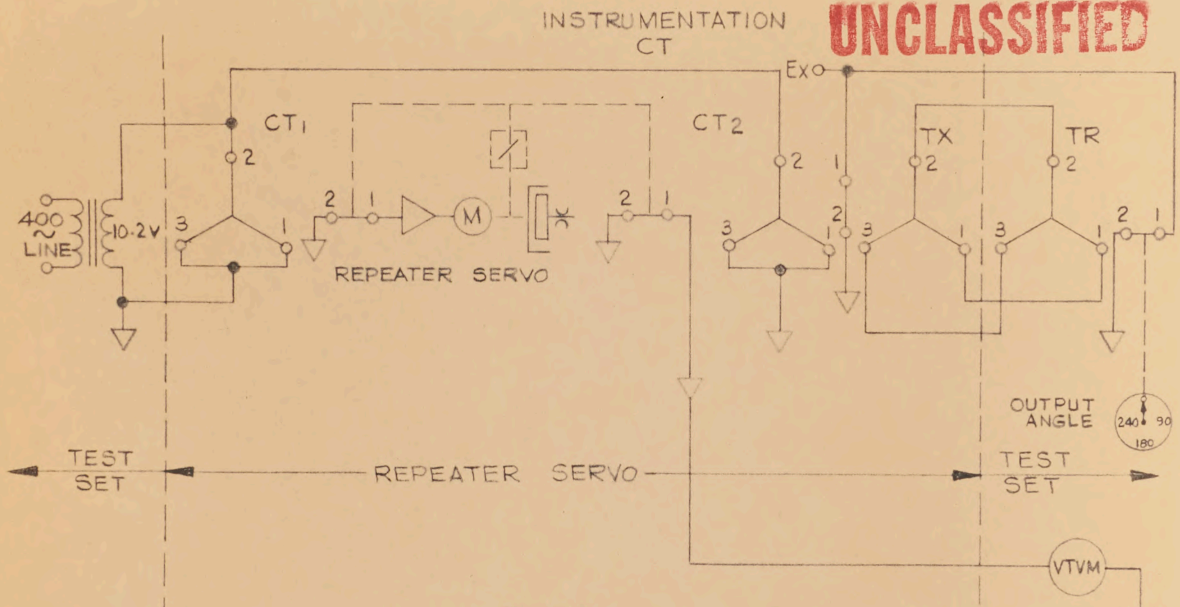


FIG 5 a
REPEATER PERFORMANCE CHECK

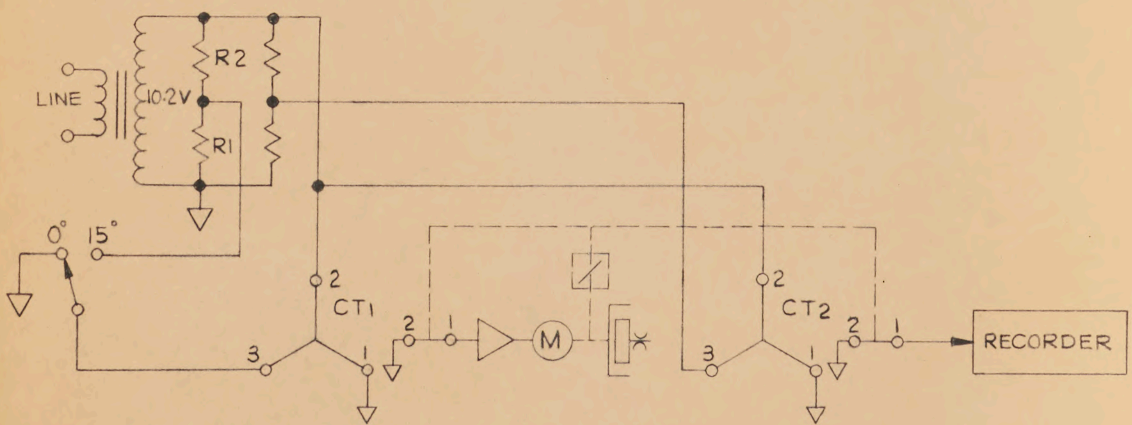


FIG 5·5 b
TRANSIENT RESPONSE CHECK

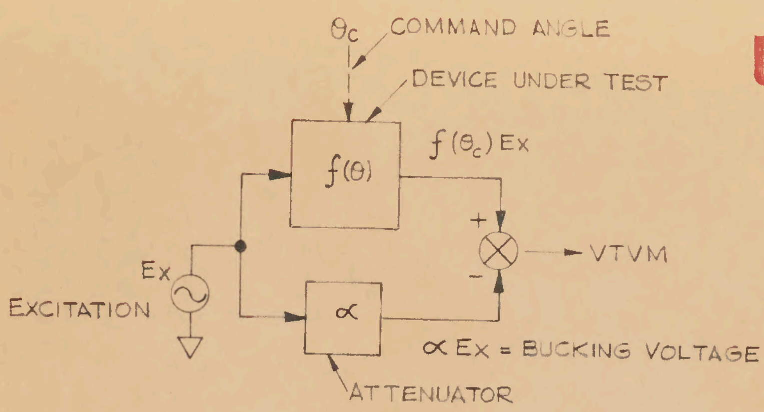


FIG 6a
BASIC TEST

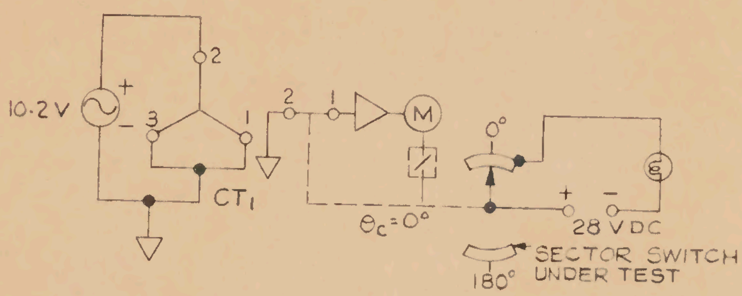


FIG 6b
SECTOR SWITCH TEST

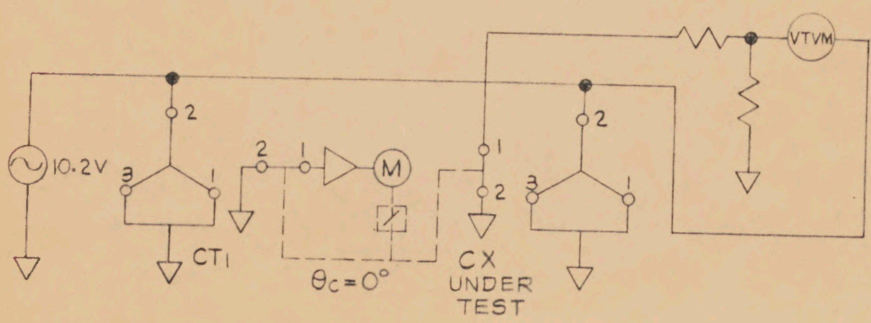
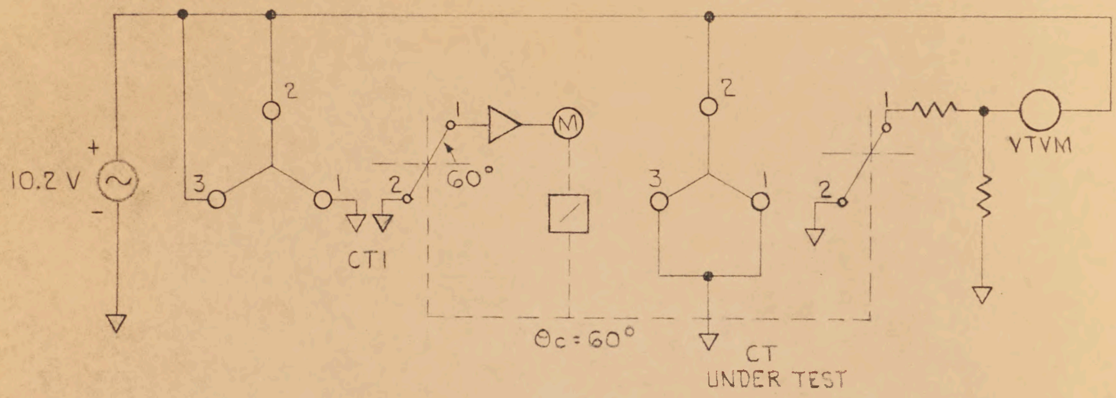
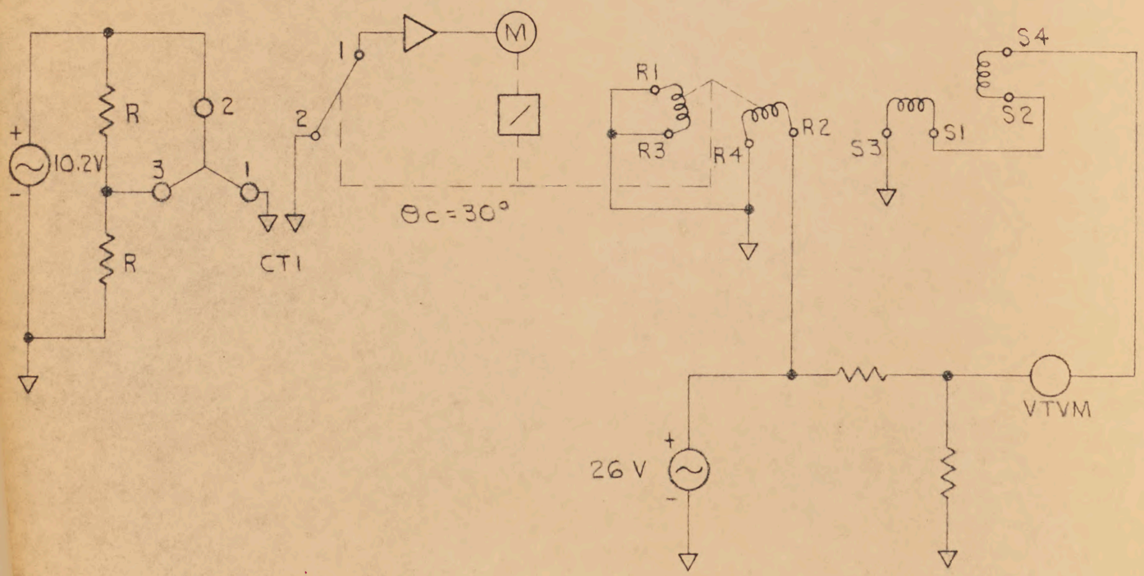


FIG5·6c
CONTROL TRANSMITTER TEST



CONTROL TRANSFORMER TEST

FIG. 6 (d)



CO-ORDINATE RESOLVER TEST

FIG.5-6(e)

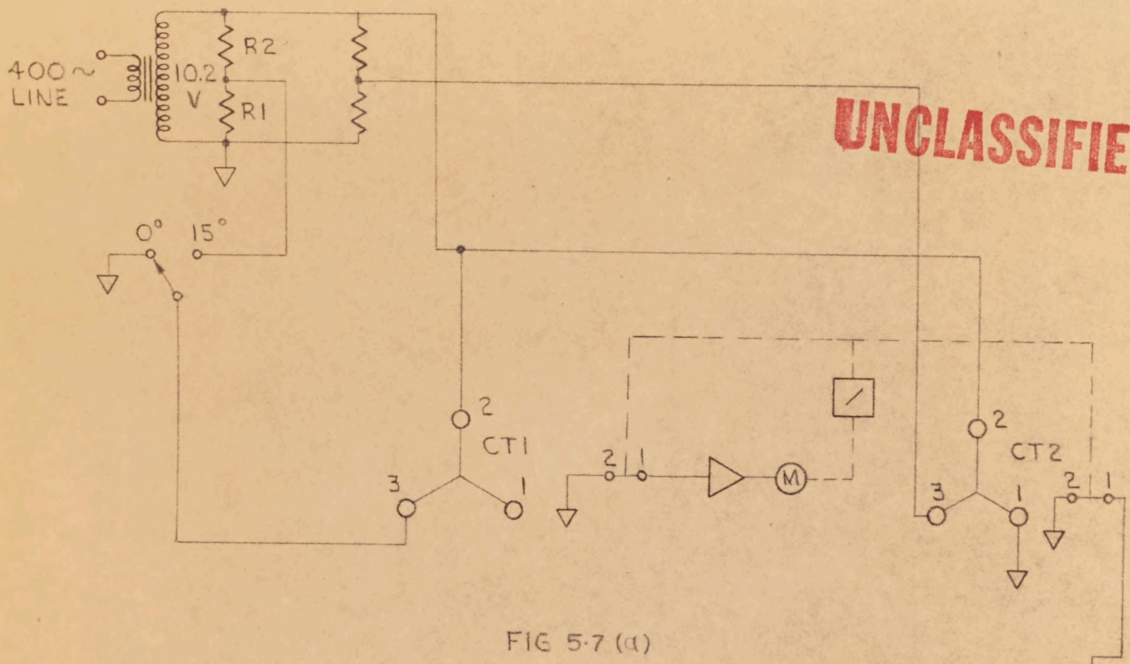


FIG 5·7 (a)
TRANSIENT RESPONSE TEST

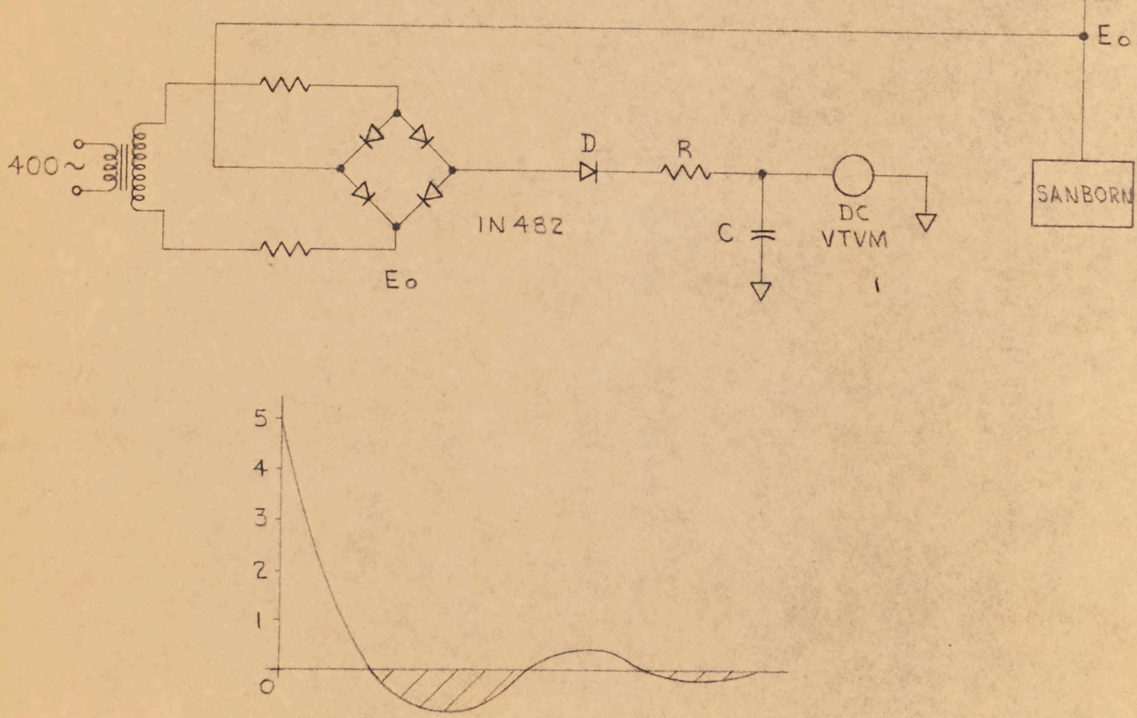


FIG 5·7 (b)
PROPOSED TRANSIENT RESPONSE CHECK

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TERMINATION REPORT ON THE GROUND TEST EQUIPMENT FOR THE FLIGHT CONTROL SYSTEM OF THE CF-105 ARROW AIRCRAFT

Honeywell Controls
Aero Document CR-ED 1048

SECTION 6

UG-6010 FLIGHT CONTROL SYSTEM TEST SET

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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ILLUSTRATIONS

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TERMINATION REPORT ON THE GROUND TEST EQUIPMENT FOR THE FLIGHT CONTROL SYSTEM OF THE CF-105 ARROW AIRCRAFT.

SECTION 6

UG-6010 FLIGHT CONTROL TEST SET

6.1 GENERAL

The UG-6010 Flight Control System Test Set was part of the test equipment provided in accordance with the R.C.A. Statement of Work dated 13 February 1958 (as amended by Astra Project memo 637 dated 5 June 1958), and was to be used to check the operation of the MH65 Automatic Flight Control Subsystem of the ASTRA I System.

The UG-6010 used alone performed first line maintenance functions on the Flight Control System in the aircraft. When used in conjunction with the other units of the Flight Control System test equipment, the UG-6010 permitted second line maintenance on the Flight Control System components on the bench.

The UG-6010 Flight Control System Test Set integrated the various Breadboard Test Sets for the Flight Control System. Primarily it was designed to permit the performance of a series of simple "go-no-go" tests to determine the serviceability of the Flight Control System.

In the normal modes of operation of the Flight Control System, some of the inputs to the AFCS Amplifier-Calibrator and/or Coupler were outputs from the other components of the Flight Control System. By a judicious selection of tests, not only could "go-no-go" tests be performed, but a substantial degree of fault isolation was possible merely by interpreting the results of the "go-no-go" tests. Further fault isolating facilities where required were provided by the UG-6011 Flight Control System Auxiliary Test Set described in Section 7 of this document.

In the earlier stages of development, it was anticipated that all the functions of both the UG-6010 and UG-6011 Test Sets might be incorporated into one 15" x 20" x 13" equipment case. The test harnesses and instruction manual were to be stowed in the lid of the equipment case. Figure 6.1 shows the Flight Control System Test Set as visualized at this early stage of development.

The disadvantages of this configuration which led to its ultimate abandonment were:

a) The overall weight of the Test Set including cable harness would have been approximately 60 to 70 pounds.

b) The capacity for cable stowage in the lid was somewhat marginal.

c) The platform simulator would have been somewhat larger than originally envisaged.

d) A D.C. Vacuum Tube Voltmeter was required for use in some of the VHRS fault isolation tests rather than the D.C. Voltmeter function provided by the one V.T.V.M.

e) Two Test Sets were considered more adaptable for use with the AFCS & VHRS Test Stands UG-6012 and UG-6013, than a single Test Set.

In view of the aforementioned reasons it was intended that two separate Test Sets with an interconnecting cable be constructed.

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6.2 RELEVANT SPECIFICATIONS

a) MIL-T-945A Amendment 2, 14 May 1953, "General Specification for Test Equipment for Use with Electronic Equipment"

b) R.C.A. Specifications 5638 and 5375-1 governing finishes required for the external surfaces of the carrying case and front panel respectively.

c) R.C.A. Specification 8958509, 19 February 1958, "Specification for the Ground Equipment for the Flight Control System of the Astra I Airborne Weapons Control System"

d) Astra I Standards - Relating to selection of parts, materials and processes.

e) MIL-STD-108C "Definitions of and Basic Requirements for Enclosures for Electric and Electronic Equipment."

f) MIL-E-4970 - "General Specification for Environmental Testing Ground Support Equipment".

g) MIL-E-5400 "General Specification for Aircraft Electronic Equipment".

6.3 DESCRIPTION OF UNIT

6.3.1 General

6.3.1.1 Physical

The Test Set and Cable Harness were to be contained in a 15" x 20" x 13" drip-proof fibre-glass carrying case finished in dark cobalt grey. The case had handles on both 15 inch sides and weighed between 50 and 60 pounds complete with Test Set and Harness.

The Test Set proper was to be mountable on a modified 19" rack panel and finished in light blue-grey.

6.3.1.2 Electrical

The Test Set required 115V ± 10% line to neutral, neutral grounded, 400 ± 20 cps, single phase power as per MIL-E-7894A and 26.5V ± 10% D.C.

6.3.2 Component Parts

The Flight Control System Test Set consisted of the following:

a) Carrying Case which contains the Panel Assembly and the Cable harness.

b) Cable Harness for connecting the Test Set to the Flight Control System.

c) Panel Assembly which supports all the components and circuits.

6.3.3 General Theory of Operation

The components of the Automatic Flight Control System to be tested by the UG-6010 Test Set were:

a) DG6000 Three-Axis Repeater (4440)

b) HG32 Air Data Computer (4310)

c) JG168 Mach Indicator (4230)

d) BG94 Mach Indicator Amplifier Calibrator (4240)

e) JG227 Flight Director and Attitude Indicator (4210)

f) BG114 Flight Director & Attitude Indicator Amplifier Calibrator (4220)

g) BG93 Automatic Flight Control System Amplifier Calibrator (4110)

h) DG63 Automatic Flight Control System Integrated Coupler (4120)

i) CG78 AFCS Function Selector

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6.3.3.1 VHRS Tests

The following comprise the intended "go-no-go" tests for the Vertical and Heading Reference System:

a) Cage the Heading Alignment Unit on the reference pylon and wheel out to the aircraft. Remove the Heading Alignment Unit from its cart and place it on the aircraft reference plate in the nosewheel well. Connect the Heading Alignment Unit to the connector provided. Align the Heading Alignment servo in the Platform Amplifier to the Heading Alignment Unit. Simultaneously apply a signal from the UG-6010 Flight Control System Test Set to the EG151 Amplifier Assembly Test connector 4420J6 to introduce a 45° heading error. Note that the only test connectors which need be connected in order to perform the Vertical Heading and Reference System "go-no-go" tests are the test connectors to the Amplifier Assembly 4420J6 and the test connector to the Three-Axis Repeater 4440J7.

b) Turn on the Automatic Flight Control System (AFCS) power from the cockpit and monitor the erection sequence. This will be indicated by six indicator lamps on the Test Set. As each lamp extinguishes it will indicate that the respective circuitry is operating satisfactorily. The modes indicated are as follows:

Mode 1: Warm-up

a) VHRS "ON" Lamp. This serves to indicate the over-temperature condition as well as the "off-on" condition.

b) Platform Heater Lamp. This will extinguish when the Platform thermostat opens at 160°F.

c) Temperature Control Circuitry Lamp. This lamp will cycle two or three times per minute.

Mode 2: Fast Erection Lamp

Mode 3: Drift Trim Lamp

Mode 4: Normal Lamp

NOTE: A timer in the Test Set will automatically force the system into the normal mode after five minute period in the Drift Trim Mode has elapsed.

c) Monitor the aircraft attitude and modified heading on the Angle Indicator located on the Test Set panel. The Three-Axis Repeater may now be disconnected from the Amplifier Assembly by means of its test relay 4440K1 and the other Flight Control System tests commenced.

d) When the VHRS is switched to the normal mode the 15 minute timer is started. At the completion of this timer cycle an indicator lamp on the VHRS sub-panel will light indicating that a reading of the Platform Drift Rate should be taken. A reading corresponding to a Drift Rate of less than 0.8° per hour will indicate that the Vertical and Heading Reference System is operating satisfactorily.

The remainder of the system is checked in the following manner (See Figure 6.5)

6.3.3.2 Three Axis Repeater (4440)

The Three-Axis Repeater is checked by applying electrical signals simulating the outputs of the Platform Transmitters to the Three-Axis Repeater Control Transformers. Outputs from the Three-Axis Repeater are supplied to the following units:

a) The Flight Director and Attitude Indicator (4210). The three outputs are displayed on the pitch, roll and heading indicators in the cockpit.

b) AFCS Amplifier Calibrator (4110). Malfunctions of the Three-Axis Repeater will be indicated as a "no-go" reading at the output of the AFCS Amplifier Calibrator.

c) AFCS Coupler (4120). A malfunction of the Three-Axis Repeater will be indicated as a "no-go" reading at the output of the AFCS Amplifier Calibrator.

6.3.3.3 Air Data Computer (4310)

Energizing the Air Data Computer test relay 4310K1 causes the Air Data Computer to run to the following fixed test conditions.

a) Mach (M) = 1.55M

b) Temperature (T_{T_i}) = 573.5°R

c) True Air Speed (V_a) = 500 yds. per sec.

d) Altitude (h) = 50,000 ft.

e) Indicated Angle of Attack (α_i) = 0 degrees

f) Differential Pressure (q_c) = 631.1 lbs. per square foot.

g) Log Static Pressure (log P_s) = 2.384

Of the outputs listed above, a, b, c, d, are checked by visual indication on the cockpit instruments.

The remainder of the Air Data Computer outputs, that is e, f, g, are supplied as inputs to the AFCS Amplifier Calibrator (4110) and the AFCS Coupler (4120). A malfunction of the Air Data Computer will be indicated as a "no-go" reading at one or more of the outputs of the AFCS Amplifier Calibrator and/or the AFCS Coupler.

6.3.3.4 Flight Director/Attitude Indicator and its Amplifier Calibrator

The Flight Director/Attitude Indicator is checked by applying three known inputs from the Three-Axis Repeater to the Flight Director/Attitude Indicator Amplifier Calibrator and observing the orientation of the indicators in the cockpit.

6.3.3.5 Mach Indicator and its Amplifier Calibrator

Actual Mach and Mach Limit signals are supplied to the Mach Indicator Amplifier Calibrator from the ADC when the test relay in the latter is energized and the readouts are observed in the cockpit.

6.3.3.6 Automatic Flight Control System Amplifier Calibrator.

Tests on the AFCS Amplifier Calibrator are divided into:

a) Pitch axis tests

b) Roll axis tests.

6.3.3.6.1 Pitch Axis Tests

The following modes are checked on the pitch axis:

a) Pre-engage

b) Mach hold

c) Altitude hold

d) Normal flight

e) Control stick steering

f) Fire control

g) Fader circuitry

NOTE: The Command Signal Limiter is not checked in the gear down mode.

6.3.3.6.2 Roll Axis Tests

The following modes are checked on the Roll Axis:

a) Pre-engage

b) Navigation-automatic ground control interception.

c) Normal flight

d) Control stick steering

e) Fire Control

Signal inputs to the Automatic Flight Control System Amplifier Calibrator are from the UG-6010 Automatic Flight Control System Test Set directly or from the following parts of the sub-system under test.

a) Air Data Computer

b) Three-Axis Repeater

c) Automatic Flight Control System Coupler.

Relay operation in the AFCS Amplifier Calibrator is accomplished directly from the test set or indirectly via the AFCS Coupler.

Outputs from the AFCS Amplifier-Calibrator are applied to the "go-no-go" meter of the UG-6010 Automatic Flight Control System Test Set. Interpretation of one or more "no-go" readings will be covered later under "Fault Isolation".

6.3.3.7 Automatic Flight Control System Integrated Coupler

The following Coupler modes will be checked:

a) Synchronization circuit

b) Lead-collision circuit

c) + 3db gain

d) Lead pursuit

e) Snap up

f) Collision warning

g) Breakaway

6.3.4 Test Procedure

6.3.4.1 General

Turn the ROLL AXIS TEST SELECTOR switch to "PITCH AXIS" test. The switch remains in this position for all the pitch axis tests (6.3.4.1 to 6.3.4.8 inclusive). Turn the PITCH AXIS TEST SELECTOR switch to position "a" "PITCH SYNCHRONIZER" test. This engages the Automatic Flight Control System in the Fire Control mode and is applied as test voltage to the Integrated Coupler in parallel with the output "n" from the normal accelerometer. The "go-no-go" meter checks the **pitch output to the Damper.**

NOTE: See Figure 6.5 for system blocks tested by the PITCH AND ROLL TEST SELECTOR switch. The switch position (a, b, etc.) is referenced on the block diagram switches indicating the path taken by the test signal.

6.3.4.2 Mach Hold Test

Turn the PITCH AXIS TEST SELECTOR switch to position "b" "MACH HOLD" test. This engages the Automatic Flight Control System in the Mach Hold mode, connects negative feedback from pitch synchronizer and integrator servo output to input and applies a test voltage at the Mach deviation input to the Automatic Flight Control System Amplifier Calibrator. This also commands a roll angle to set the "secant Ø-1" Potentiometer and a pitch angle to set the "1 - cosine E" potentiometer. The "go-no-go" meter checks the pitch output to the Damper.

6.3.4.3 Command Signal Limiter Test

Turn the PITCH AXIS TEST SELECTOR switch to position "c" "COMMAND SIGNAL LIMITER" test. This sets up a test identical to the Mach Hold test except for the Mach deviation input signal which is now large enough to cause limiting in the Command Signal Limiter. The "go-no-go" meter checks the pitch output to the Damper.

6.3.4.4 Altitude Hold Test

Turn the PITCH AXIS TEST SELECTOR switch to position "D" "ALTITUDE HOLD". This engages the AFCS in the Altitude Hold mode, connects negative feedback around the pitch synchronizer and integrator and applies a test voltage at the Altitude Rate and Altitude Displacement inputs to the AFCS Amplifier Calibrator pitch axis. This also commands a roll angle to set the "secant Ø - 1" potentiometer and a pitch angle to set the "1 - cosine E" potentiometer. The "go-no-go" meter checks the pitch output to the Damper.

6.3.4.5 Control Stick Steering and Normal Flight and Fader Test

Turn the "PITCH AXIS TEST SELECTOR switch to position "E" "CONTROL STICK STEERING AND NORMAL FLIGHT AND FADER" test. This engages the Automatic

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Flight Control System in the Control Stick Steering mode and also commands a roll and pitch test angle. A toggle switch is provided for switching the Automatic Flight Control System Amplifier Calibrator to Normal Flight mode. The "go-no-go" meter checks the pitch output to the Damper. Another toggle switch is provided for changing the pitch command angle in the Normal Flight mode. A pushbutton is provided for de-energizing the Automatic Flight Control System in order to check the Fader operation. When the pitch command angle is changed or when the Fader is operated the "go-no-go" meter acts as a monitor.

6.3.4.6 Lead Pursuit (T less than 20 seconds)

Turn the PITCH AXIS TEST SELECTOR switch to position "f" "LEAD PURSUIT". This engages the Automatic Flight Control System in the Lead Pursuit mode with time to go less than 20 seconds, simulates the 4/T input to the Integrated Coupler and applies test voltages to the Elevation Steering Error input and the Lead Pursuit Compensation input. The "go-no-go" meter checks the gear up pitch output to the Damper.

6.3.4.7 Armament Selection Integral Control & Snap-up Test

Turn the PITCH AXIS TEST SELECTOR switch to position "g" "ARMAMENT SELECTION INTEGRAL CONTROL AND SNAP-UP" test. This switches the Automatic Flight Control System from Lead Pursuit with time to go less than 20 seconds to Lead Collision with time to go greater than 20 seconds. Inputs are in 6.3.4.6. The "go-no-go" meter checks the pitch output to the Damper. A toggle switch is provided for switching the Coupler to the Integral Control mode. The "go-no-go" meter will now drift off the "GOOD" sector. Releasing the Integral Control toggle switch will cause the "go-no-go" meter to return to the "GOOD" sector. Another toggle switch is provided to check the Snap-up mode. Operating this switch will cause the "go-no-go" meter to move off scale and return to the "GOOD" sector.

6.3.4.8 Breakaway Test

Turn the PITCH AXIS TEST SELECTOR switch to position "h" "BREAKAWAY TEST". This initiates the breakaway and rollout maneouvres. The "go-no-go" meter checks the pitch output to the Damper during:-

a) The breakaway maneouvre

b) Rollout

At the completion of these maneouvres the Coupler Disengaged light will come on.

6.3.4.9 NAV-AGCI Test

Turn the PITCH AXIS TEST SELECTOR switch to "ROLL AXIS TEST". The switch remains in this position for the remainder of the roll axis tests. Turn the ROLL AXIS TEST SELECTOR switch to position "i" "NAV-AGCI" test. This engages the Automatic Flight Control System in the NAV-AGCI mode and applies a test voltage to the Integrated Coupler at the Coupler Heading Error input. The "go-no-go" meter checks the output from the Coupler Roll Axis.

6.3.4.10 Amplifier Calibrator Roll Axis Test

Turn the ROLL AXIS TEST SELECTOR switch to position "j" "AMPLIFIER CALIBRATOR ROLL AXIS" test. This engages the Automatic Flight Control System in the NAV-AGCI mode and applies a test voltage to the Integrated Coupler at the Coupler Heading Error Input. The "go-no-go" meter checks the gear up roll output to the Damper.

6.3.4.11 AGCI Close Control Test

Turn the ROLL AXIS TEST SELECTOR switch to position "k" "AGCI CLOSE TEST". This engages the Automatic Flight Control System in the AGCI Close Control mode and also applies a test voltage to the Integrated Coupler at the Coupler Heading Error input. The "go-no-go" meter checks the Integrated Coupler output.

6.3.4.12 Roll Synchronizer Test

Turn the ROLL AXIS TEST SELECTOR switch to position "l" "ROLL SYNCHRONIZER" test. This engages the Automatic Flight Control System in the Fire Control mode and commands roll and pitch axis test angles from the Three-Axis Repeater. The "go-no-go" meter checks the gear down roll output to the Damper.

6.3.4.13 Lead Pursuit Test

Turn the ROLL AXIS TEST SELECTOR switch to position "m" "LEAD PURSUIT" test. This engages the Automatic Flight Control System in the Lead Pursuit mode, simulates 4/T inputs to the Integrated Coupler, and applies a test voltage to the Integrated Coupler Lead Pursuit input. The "go-no-go" meter checks the gear up roll output to the Damper. A push button is provided for checking the Collision Warning circuitry during this test. Depressing this pushbutton will cause the Coupler Disengaged lamp to light.

6.3.4.14 Armament Selection and Integral Control Test

Turn the ROLL AXIS TEST SELECTOR switch to position "n" "ARMAMENT SELECTION AND INTEGRAL CONTROL" test. This engages the Automatic Flight Control System in the Lead Collision mode with time to go greater than 20 seconds and applies test voltages to the Azimuth Steering Error input, in addition to the inputs described in 6.3.4.13. The "go-no-go" meter checks the gear up roll output to the Damper. Operate the Integral Control toggle switch as in 6.3.4.7. The "go-no-go" meter will now drift off the "GOOD" sector.

6.3.4.15. Breakaway Test

Turn the ROLL AXIS TEST SELECTOR switch to position "o" "BREAKAWAY" test. This initiates the Breakaway and Rollout maneouvre. The "go-no-go" meter checks the Roll output to the Damper during

a) The Breakaway maneouvre

b) Roll out

At the completion of these maneouvres the Coupler Disengaged lamp will light.

6.3.4.16 Control Stick Steering and Normal Flight Test

Turn the ROLL AXIS TEST SELECTOR switch to position "p" "CONTROL STICK STEERING AND NORMAL FLIGHT" test. This engages the Automatic Flight Control System in the Control Stick Steering mode and also commands a roll and a heading test angle from the Three-Axis Repeater. The "go-no-go" meter checks the gear up roll output to the Damper. A toggle switch is provided to switch the Automatic Flight Control System into the Normal Flight mode. Two pushbuttons are provided for changing the commanded roll and heading angles respectively.

With the Automatic Flight Control System in the Normal Flight mode, the "go-no-go" meter acts as a monitor.

6.3.4.17 Command Signal Limiter Output Tests

Turn the ROLL AXIS TEST SELECTOR switch to "PITCH AXIS" test. Turn the PITCH AXIS TEST SELECTOR switch to position "r" "COMMAND SIGNAL LIMITER OUTPUT" test. This will engage the Automatic Fire Control System in the Fire Control mode, and will duplicate the conditions for 6.3.4.1 "Pitch Synchronizer" test. The "go-no-go" meter will check the output of the Command Signal Limiter; the 1-cosE potentiometer is not involved.

6.3.4.18 Flight Director/Attitude Indicator Test

NOTE: a) This test and those following require an operator in the cockpit.

b) Communication between the cockpit operator and the Test Set operator is required by the aircraft intercommunication system.

c) The Test Set operator will operate the Test Set under instructions from the cockpit operator.

6.3.4.18.1 The Test Set operator will turn the PITCH and ROLL AXIS TEST SELECTOR switches to the positions "t" and "u" "FLIGHT DIRECTOR/ATTITUDE INDICATOR ATTITUDE" test. This will command the Three-Axis Repeater to zero degrees. The cockpit operator will observe the indicator for zero and check elevation trim by turning the knob provided on the indicator and observing the deflection of the elevation axis. The elevation axis is returned to zero and each axis in turn is commanded to 30° by the Heading, Roll and Elevation pushbuttons on the Test Set while the cockpit operator observes the indicator.

6.3.4.18.2 The Test Set operator turns the PITCH and ROLL AXIS TEST SELECTOR switches to positions "v" and "w" "FD/AI DIRECTOR" test. This engages the AGCA mode and applies simulated AGCA Vertical and Lateral displacement signals to the FD/AI. The cockpit operator will observe the Vertical and Lateral displacement and deviation needles for proper calibration. He will also observe the Data Link reliability and power failure flags and check the panel lighting.

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6.3.4.19 Mach Indicator Test

The cockpit operator will observe the Mach Indicator Actual Mach and the Mach Limit pointers and the power failure flag. He will also check the Mach Indicator panel lighting and observe the Total Temperature and True Air Speed Indicators.

The Test Set cable harness is now disconnected and all aircraft cabling and jumper caps, if any, replaced.

6.3.4.20 Function Selector Test

The cockpit operator will check the Function Selector as follows:

a) The AFCS toggle switch is moved to the "ENGAGE" position. The solenoid will hold it in this position.

b) The MACH-ALTITUDE HOLD switch is turned to the "MACH HOLD" position. The solenoid will hold it in this position. Turn this switch to the "ALTITUDE HOLD" position where it will be solenoid held.

c) Turn the AUTO STEER NORMAL switch to "AUTO STEER". Now all three switches will be solenoid held.

d) Turn the AFCS switch from "ENGAGE" to "STANDBY". The remaining two switches will return to "NORMAL" position.

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6.4 DESCRIPTION OF PARTS

6.4.1 Carrying Case

A moulded fibreglass instrument case was selected to fulfill the requirements of being light, rugged and rainproof.

Originally it was felt that a case approximately 20" x 15" x 10 1/2" deep with a single carrying handle on the 20" side would suffice; but inadequate cable stowage space necessitated later adoption of a 13" deep case. This necessitated using two handles on the 15" side of the case since the overall weight of Test Set had also increased. (Figure 6.2)

A gasketed panel mounting angle was fitted to the flange of the case. The gasket permitted a wider tolerance on the mounting angle dimensions and, in conjunction with the gasket around the panel, provided a rainproof seal between the carrying case and panel.

6.4.2 Cable Harness

Bendix Pygmy connectors with integral strain relief fittings were used throughout and flexible sleeving was used on all cables. Moulded cable harnesses might conceivably be used on the production models. This method of cable construction was not favoured for developmental or preproduction test equipment since any wiring change necessitated scrapping all affected cables.

Test leads were provided for the VTVM and voltmeter.

6.4.3 Panel Assembly

A composite type of construction was selected for the panel assembly, viz:

a) Front Panel The front panel was a flat sheet of .032" aluminum, with a light blue anodized finish.

b) Sub Panel The sub panel was of .091" aluminum. All mounting brackets are flush riveted to the sub panel. This procedure was followed to simplify the assembly of the panel and bracket modules. Previous experience has indicated that welding on the panel produced excessive distortion.

Components were mounted on the sub-panel brackets as required and then the front panel was placed over the sub panel and all controls, switches and indicators mounted through the composite panel. The rubber channel was fitted around the edges of the panel and the composite panel was almost as rigid as a solid panel.

c) VTVM The VTVM was a purchased component and was packaged ready for mounting in a rectangular cutout in the panel by means of four screws.

All necessary terminals for connecting the VTVM to the Test Set were brought out on the back of the instrument.

The VTVM was designed for mounting on a one-eighth inch panel and hence was flush with the front panel.

The VTVM panel included a three inch zero centre meter with 3-0-3, 10-0-10 scale and red and green "GOOD" and "BAD" sectors. The central half of the scale constituted the "GOOD" sector.

A ten position Range Switch was provided, with ranges from 10 mv to 300 v full scale.

An INTernal - EXTernal toggle switch permitted the VTVM to be used as an integral part of the Test Set or independently by connecting the test leads to the coaxial connector adjacent to the toggle switch.

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6.5 PREDICTED PERFORMANCE

The overall accuracy of a test result was to be indicated by the Test Set Null Indicator and would have varied widely depending on the number of test set inputs required, and the number of AFCS components involved and the accuracy of their respective outputs.

Aside from the errors due to tolerance build-up in the equipment under test, there were several possible sources of error inherent in the Test Set itself, viz:

a) Line Voltage

Line voltage variations would have affected both the AFCS output being checked and its bucking voltage equally. At null, therefore, line voltage would not be a source of error.

At the limit of the "GOOD" sector a line voltage variation of 10% would cause a 1% error in Test Set indication.

b) Fixed Resistive Networks

Fixed resistive networks could be factory adjusted to within ± 0.5% of nominal or better.

c) Voltage Outputs

D.C. voltages could be set to ± 0.5% and A.C. voltages to ± 1% of nominal. The errors introduced by this means would never be greater than the setting error.

d) VTVM

At null the VTVM error was negligible. When used as a null indicator the maximum error was ± 1.2% of the output voltage for an indication at the edge of the GOOD sector.

e) Other Sources of Error

In some tests, several components of the AFCS were in cascade. The accuracy of a particular component - e.g., the coupler might have contributed an error of ± 10% without being out of tolerance, and there are several components in series, hence the accuracy of the system might be ± 25%.

Test Set caused error might reach a maximum of ± 7 to 8% but normally would be less than ± 3%. (based on the error analysis for the breadboard test sets.)

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6.6 STATUS AT CANCELLATION

At cancellation on fabrication had been done on the Test Set but the majority of components were on order. The front panel layout had been completed and all test procedures had been established.

6.7 PROPOSED FUTURE PROGRAMME

The first Automatic Flight Control System Test Set was to have been completed by November 1959 with subsequent units to be delivered in January of 1960.

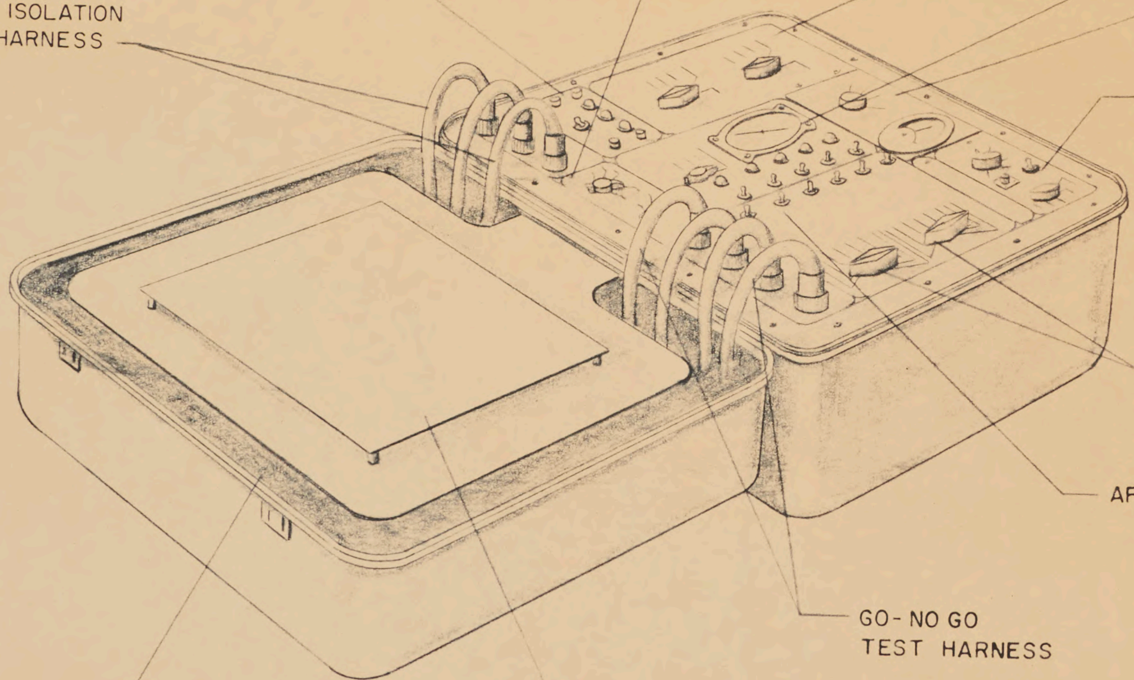
6.8 CONCLUSIONS

a) It is felt that the AFCS Test Set as outlined represents the simplest approach to the performance of go-no-go system tests.

More exotic and more nearly automatic check-out equipment could be provided, but the savings in time required to perform the tests would be small and the increase in complexity and required lead time would be very considerable.

b) The degree of fault isolation provided was greater than originally anticipated and would require the use of the Auxiliary Test Set on first line maintenance less frequently than might be expected.

c) It would be desirable to provide a single large test connector for the Test Set rather than several smaller connectors on the individual components. This would eliminate the necessity for opening numerous access doors and panels and making multiple connection for routine checks.



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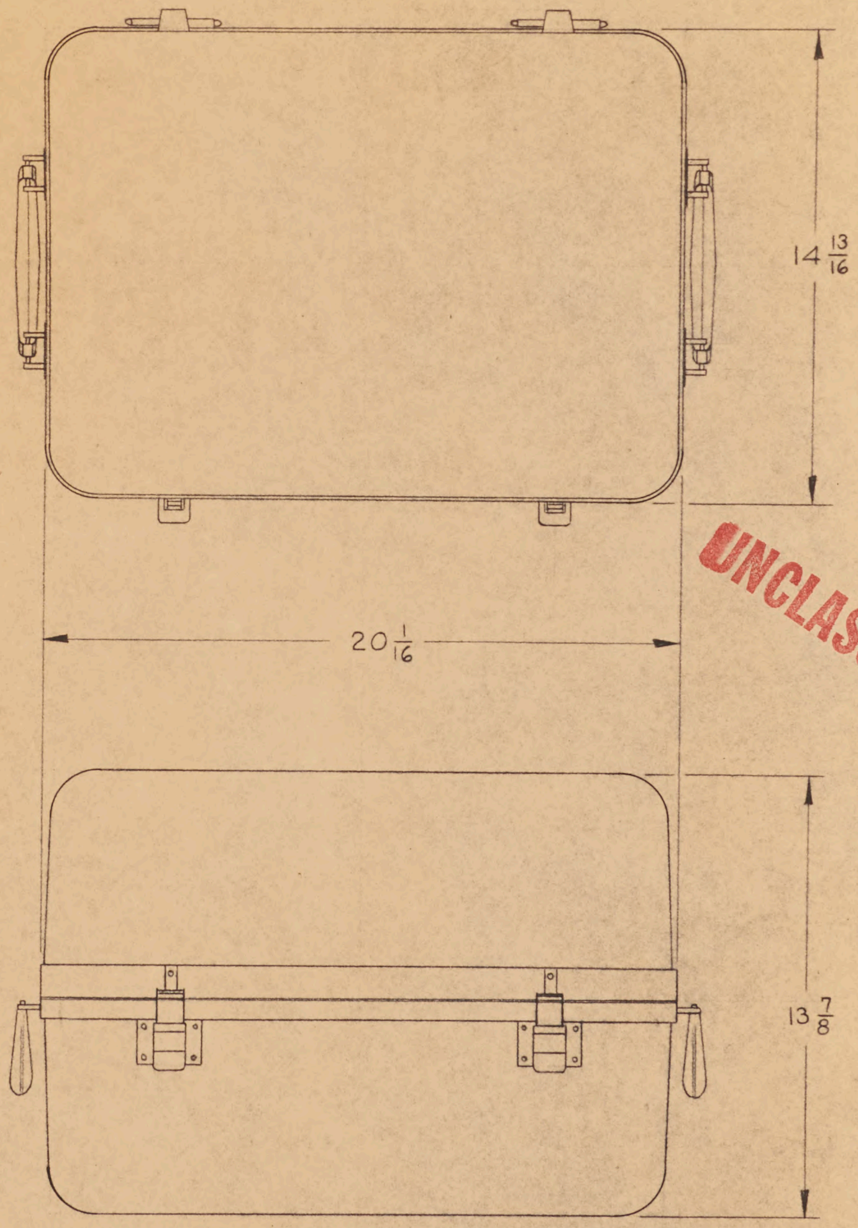
AERO ENGINEERING TORONTO CANADA	DATE 8·25·58	BY	CLASSIFICATION	TITLE FLIGHT CONTROL SYSTEM TEST SET	FIG. NO 6·1



COMBINATION CASE

FIG. 6·2

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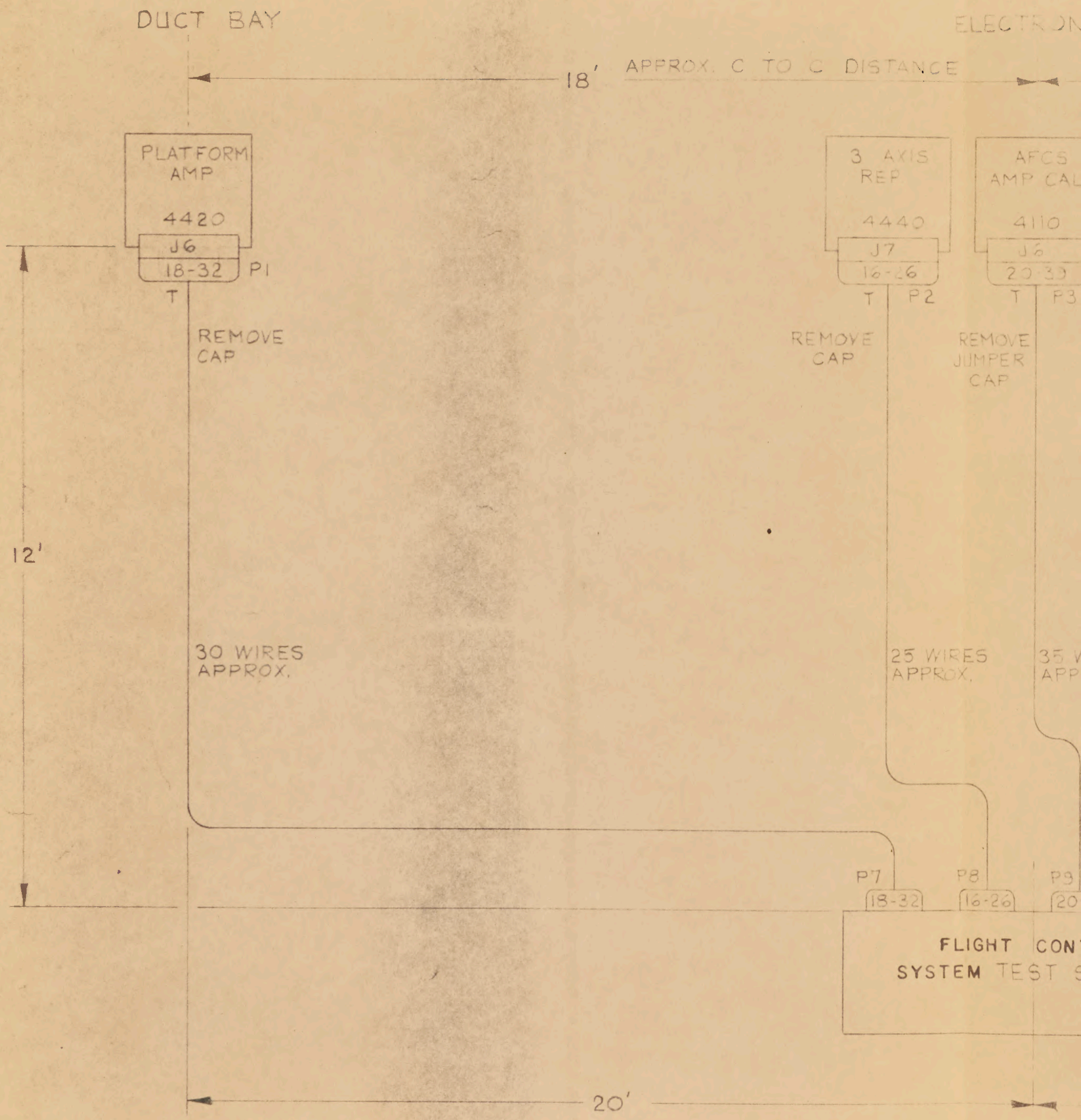
SCALE 1:5



DUCT BAY
ELECTRON
18' APPROX. C TO C DISTANCE
PLATFORM AMP
4420
J6
18-32
P1
T
REMOVE CAP
3 AXIS REP
4440
J7
16-26
T
P2
REMOVE CAP
AFCS AMP CAL
4110
J6
20-39
T
P3
REMOVE JUMPER CAP
12'
30 WIRES APPROX.
25 WIRES APPROX.
35 W
APP
P7
18-32
P8
16-26
P9
20
FLIGHT CONT
SYSTEM TEST S
20'

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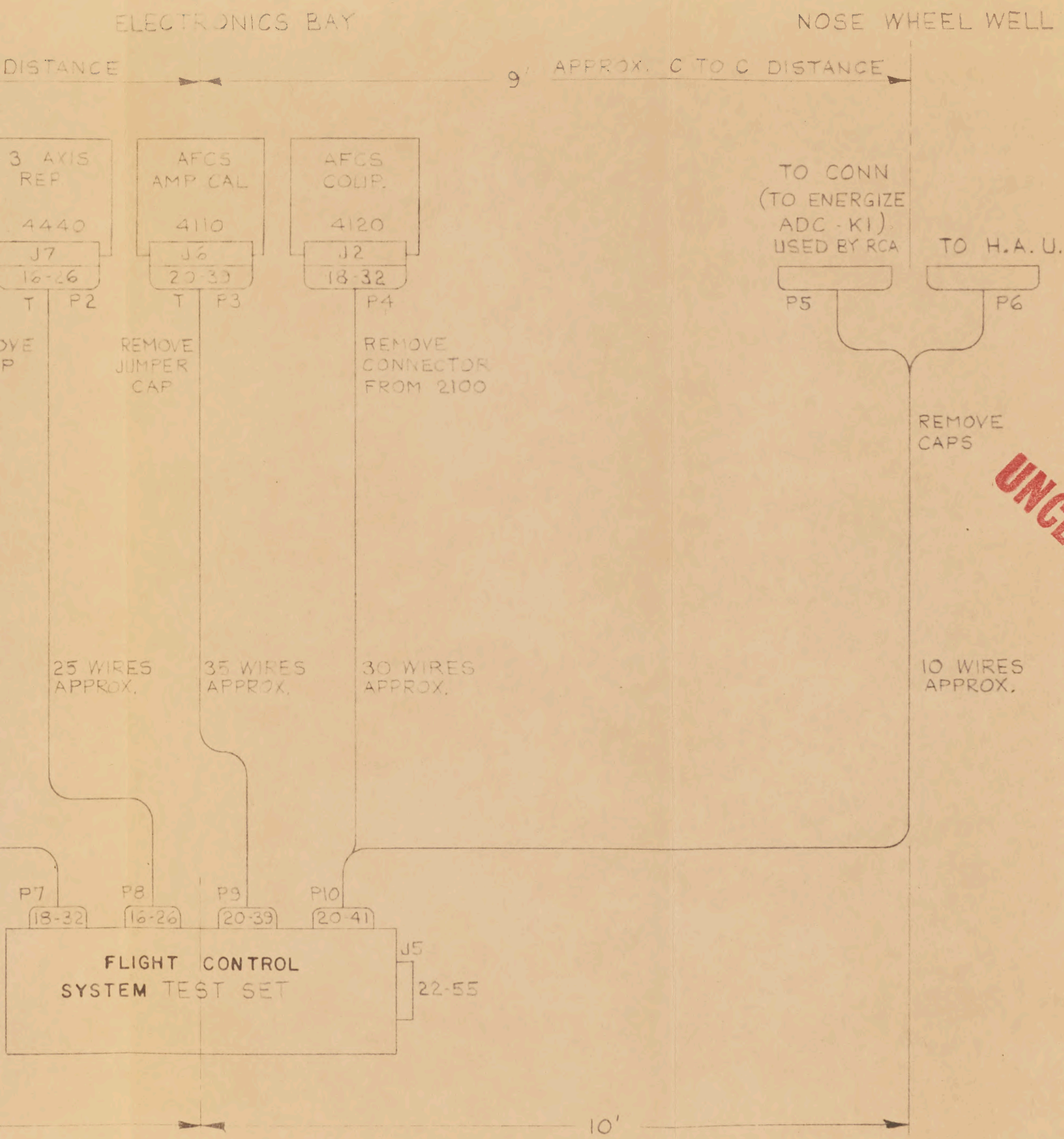

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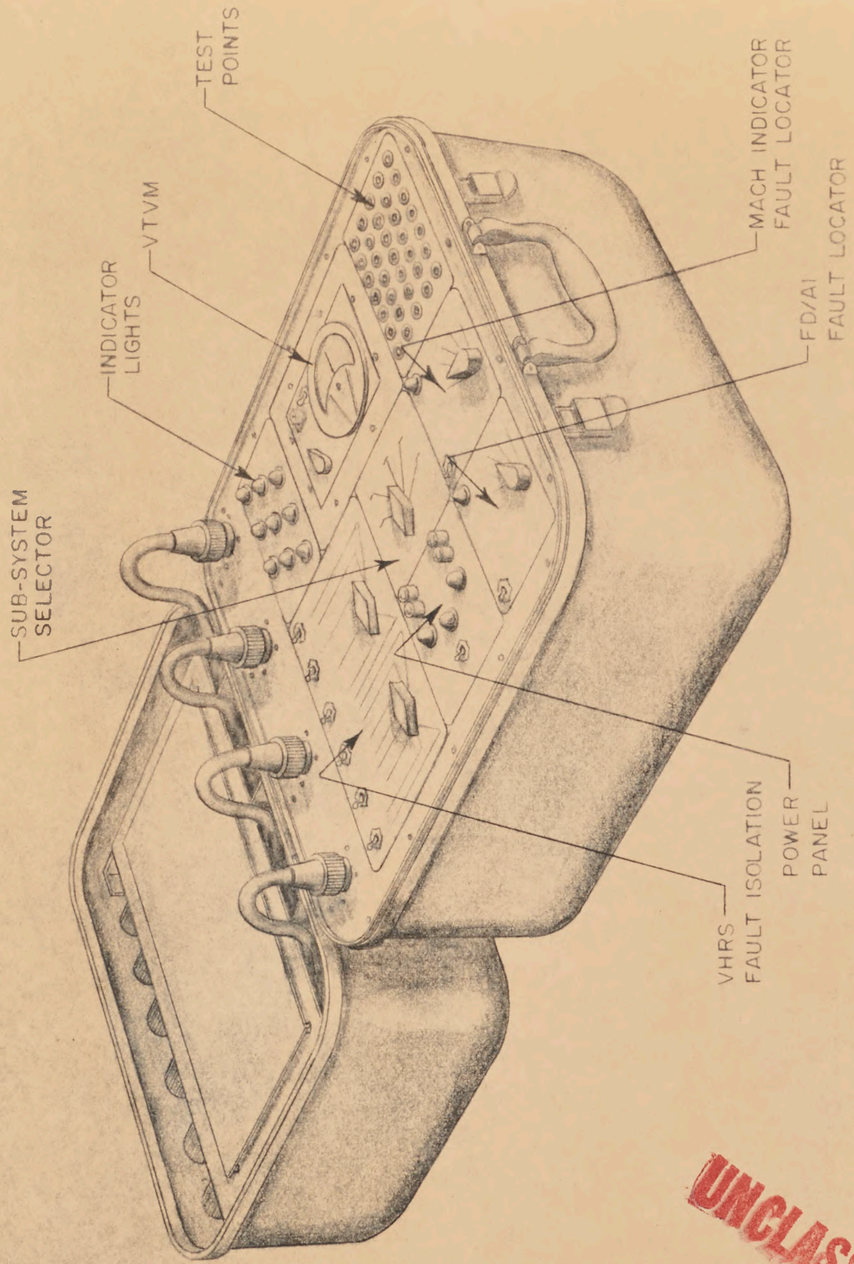
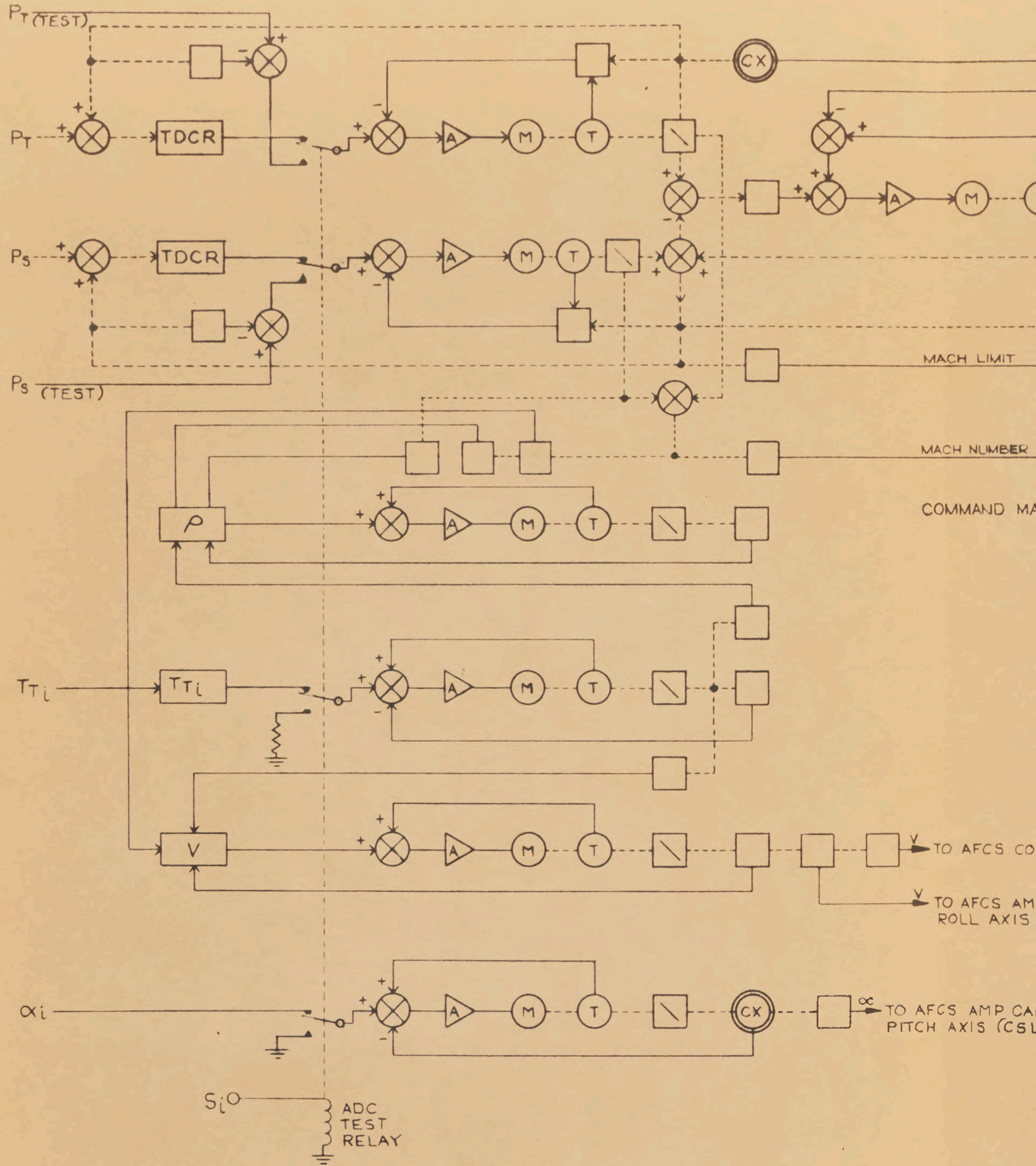
AERO ENGINEERING TORONTO CANADA	8/25/53	BY	CLASSIFICATION	TITLE FLIGHT CONTROL SYSTEM TEST HARNESS	FIG. NO. 6·3



CSK1752

AERO ENGINEERING TORONTO CANADA	DATE	BY	CLASSIFICATION	TITLE	FIG. NO.
	9/24/58	[illegible signature]		UG6011 AFCS AUX TEST SET	6·4



PT (TEST)
PT
TDCR
PS
TDCR
PS (TEST)
CX
MACH LIMIT
MACH NUMBER
COMMAND MA
ρ
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TO AFCS CO
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ROLL AXIS
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CX
TO AFCS AMP CA
PITCH AXIS (CSL
Si
ADC
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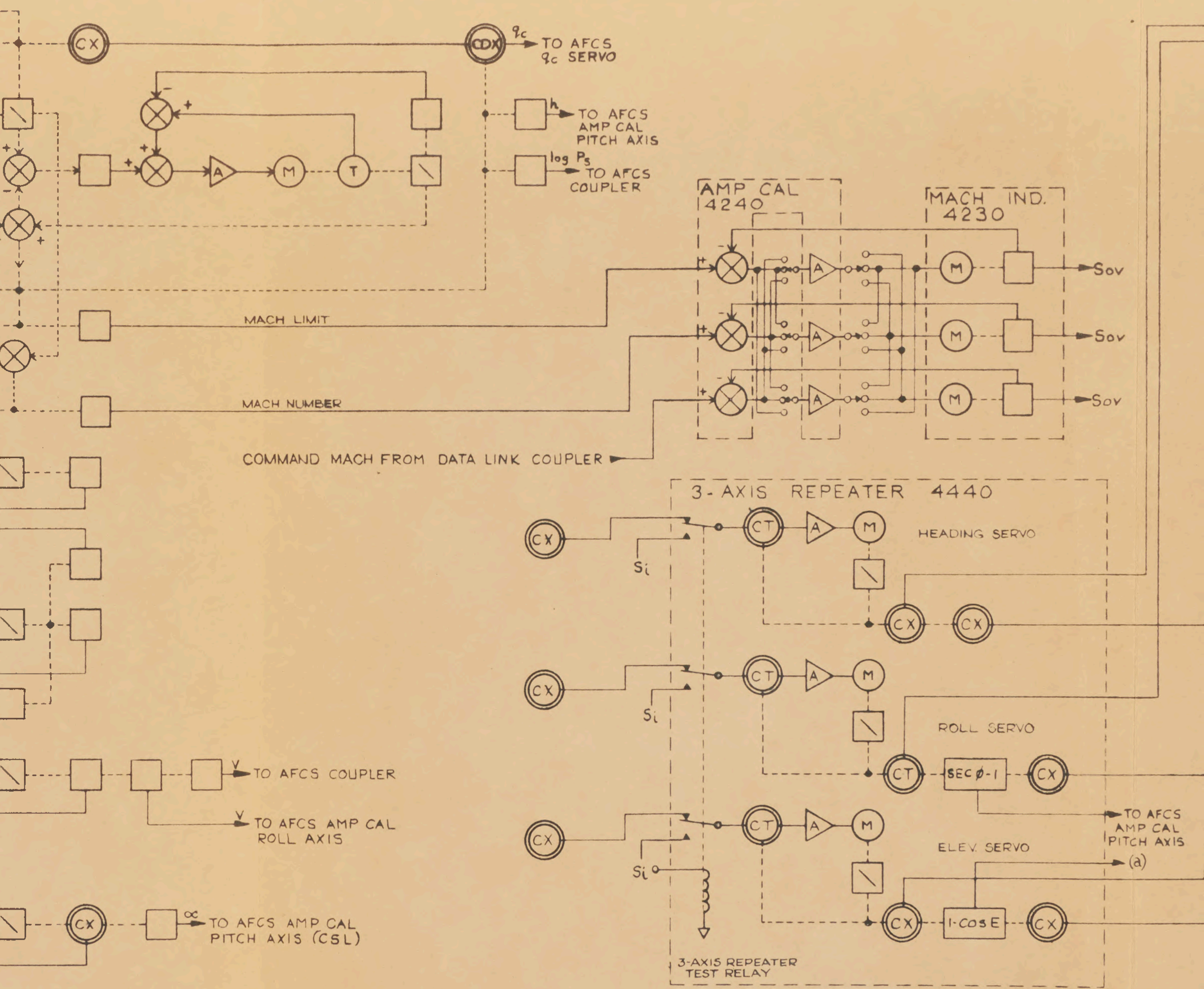
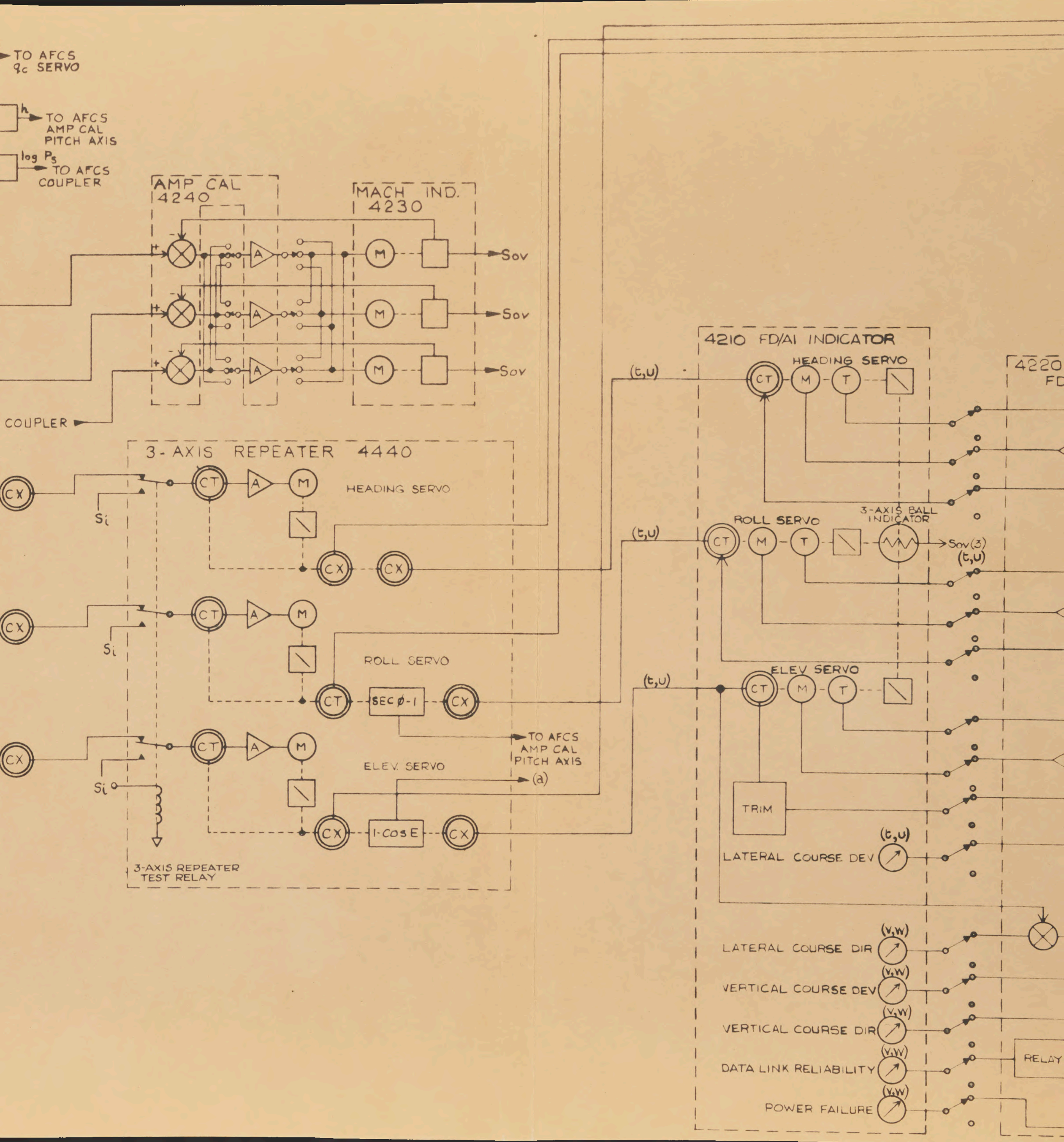
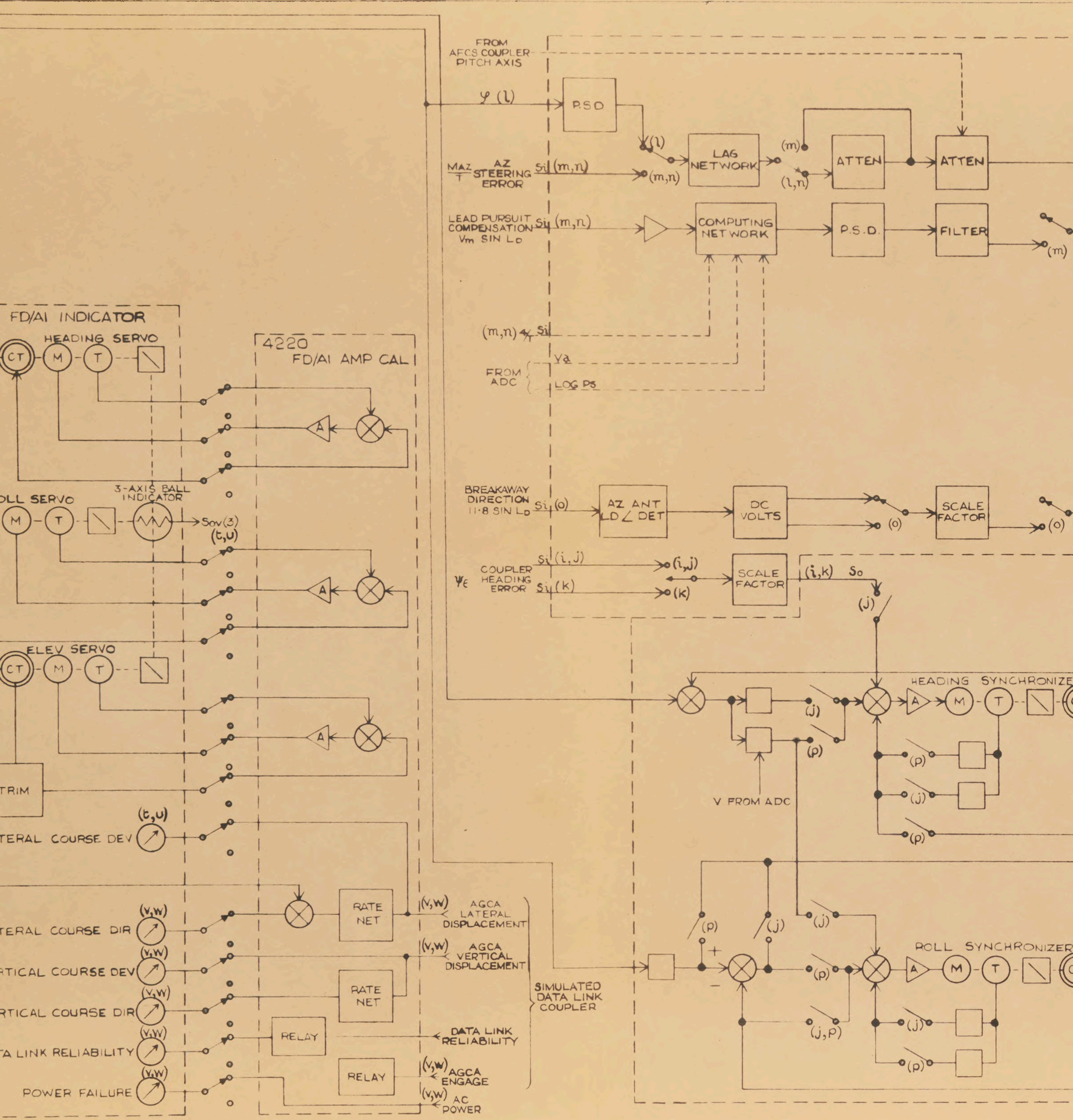
RELAY



TO AFCS q_c SERVO
TO AFCS AMP CAL PITCH AXIS
TO AFCS COUPLER
AMP CAL 4240
MACH IND. 4230
MACH LIMIT
MACH NUMBER
COMMAND MACH FROM DATA LINK COUPLER
3-AXIS REPEATER 4440
HEADING SERVO
ROLL SERVO
ELEV. SERVO
SEC Ø-1
1-COS E
TO AFCS AMP CAL PITCH AXIS
(a)
3-AXIS REPEATER TEST RELAY
TO AFCS COUPLER
TO AFCS AMP CAL ROLL AXIS
TO AFCS AMP CAL PITCH AXIS (CSL)



TO AFCS
q_c SERVO
TO AFCS
AMP CAL
PITCH AXIS
log P_s
TO AFCS
COUPLER
AMP CAL
4240
MACH IND.
4230
Sov
Sov
Sov
COUPLER
3-AXIS REPEATER 4440
HEADING SERVO
ROLL SERVO
SEC φ-1
TO AFCS
AMP CAL
PITCH AXIS
ELEV. SERVO
(a)
1-COS E
3-AXIS REPEATER
TEST RELAY
4210 FD/AI INDICATOR
HEADING SERVO
ROLL SERVO
3-AXIS BALL
INDICATOR
Sov(3)
ELEV SERVO
TRIM
LATERAL COURSE DEV
LATERAL COURSE DIR
VERTICAL COURSE DEV
VERTICAL COURSE DIR
DATA LINK RELIABILITY
POWER FAILURE
4220
RELAY



FROM AFCS COUPLER PITCH AXIS
ψ (l)
P.S.D
AZ STEERING ERROR
Si (m,n)
(l)
(m,n)
LAG NETWORK
(m)
(l,n)
ATTEN
ATTEN
LEAD PURSUIT COMPENSATION Vm SIN LD
Si (m,n)
COMPUTING NETWORK
P.S.D.
FILTER
(m)
FD/AI INDICATOR
HEADING SERVO
CT
M
T
4220
FD/AI AMP CAL
(m,n)
Si
Va
FROM ADC
LOG PS
A
3-AXIS BALL INDICATOR
ROLL SERVO
Sov(3)
(t,u)
BREAKAWAY DIRECTION 11·8 SIN LD
Si (o)
AZ ANT LD∠ DET
DC VOLTS
(o)
SCALE FACTOR
(o)
Si (i,j)
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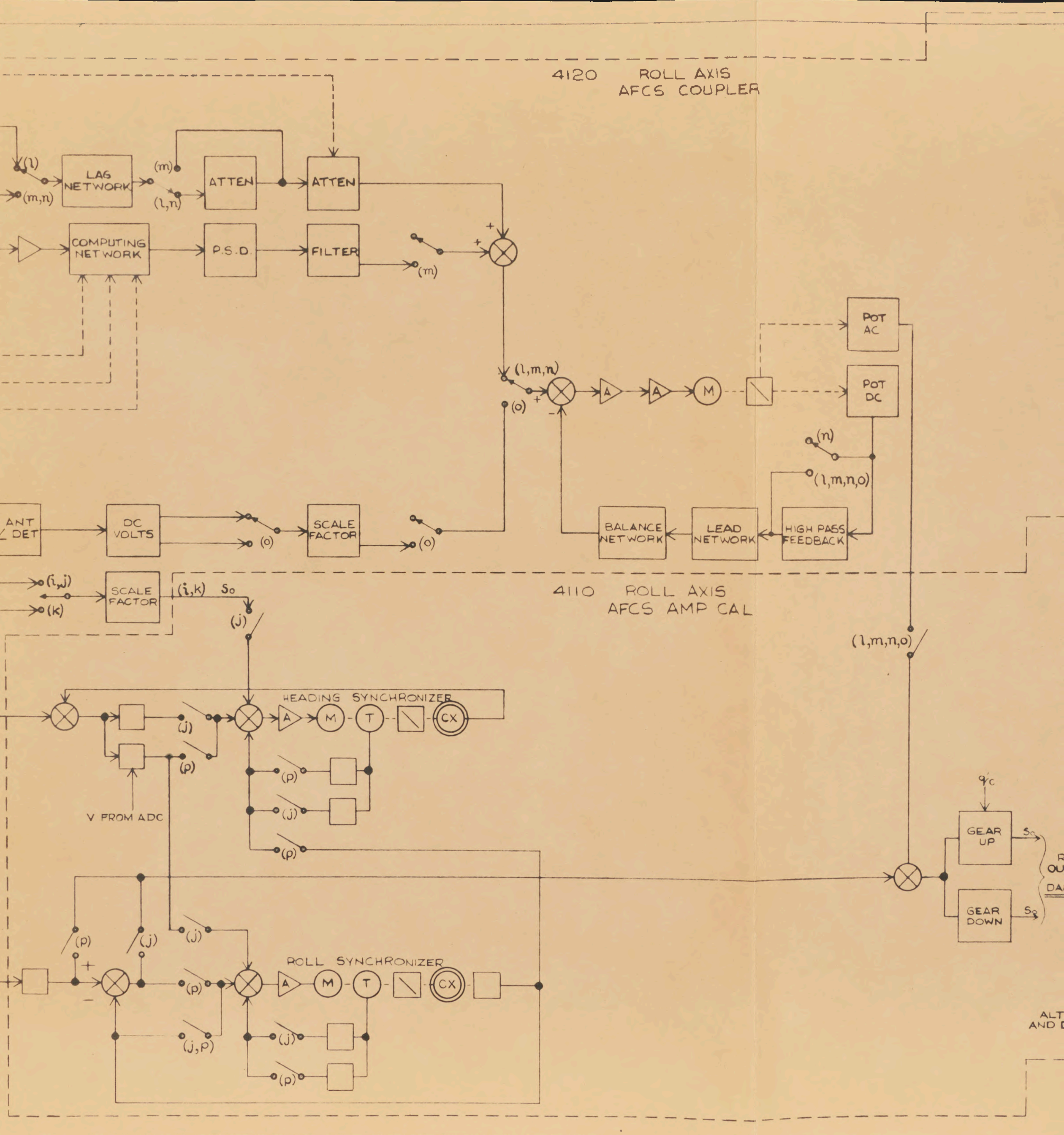
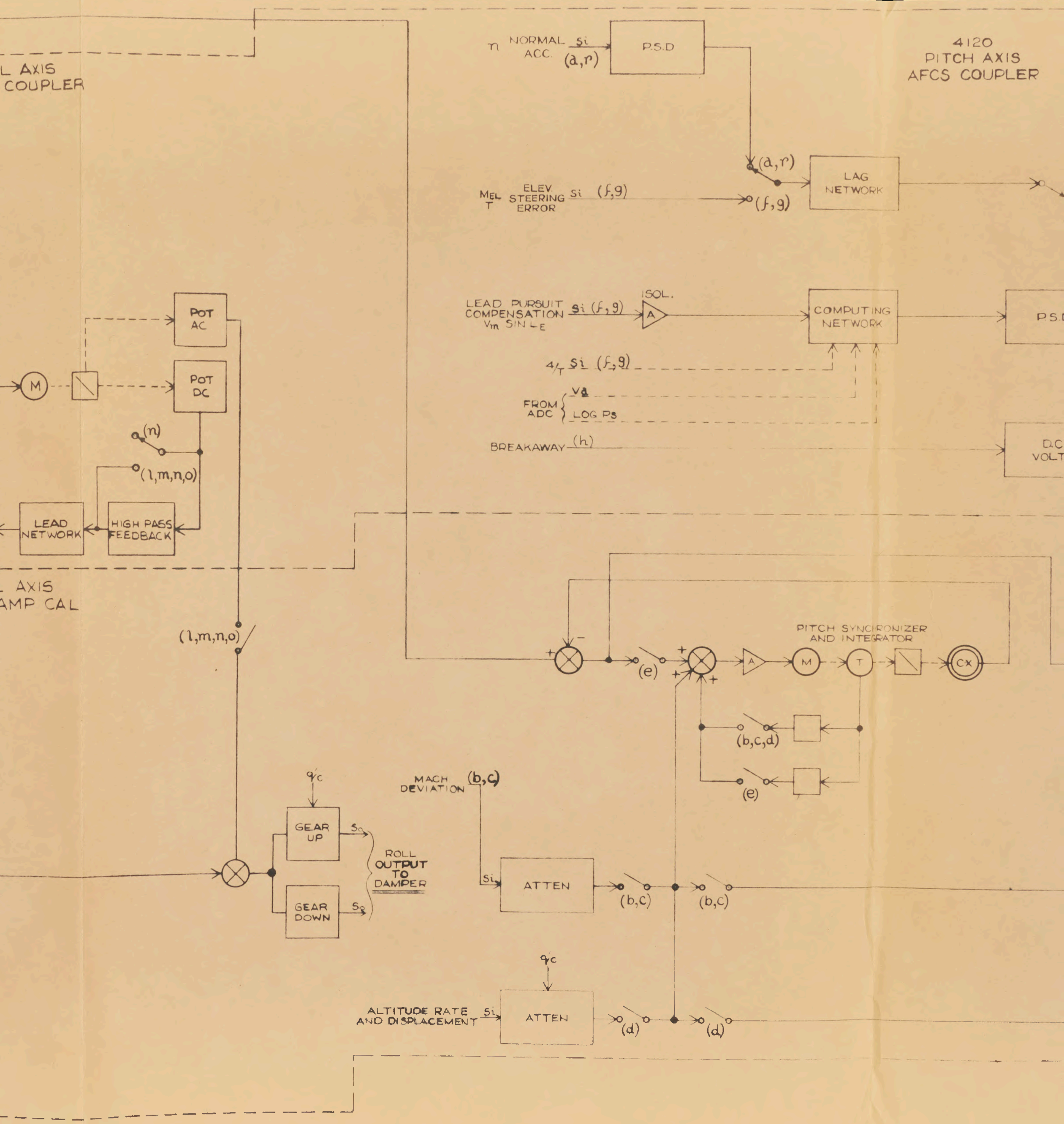
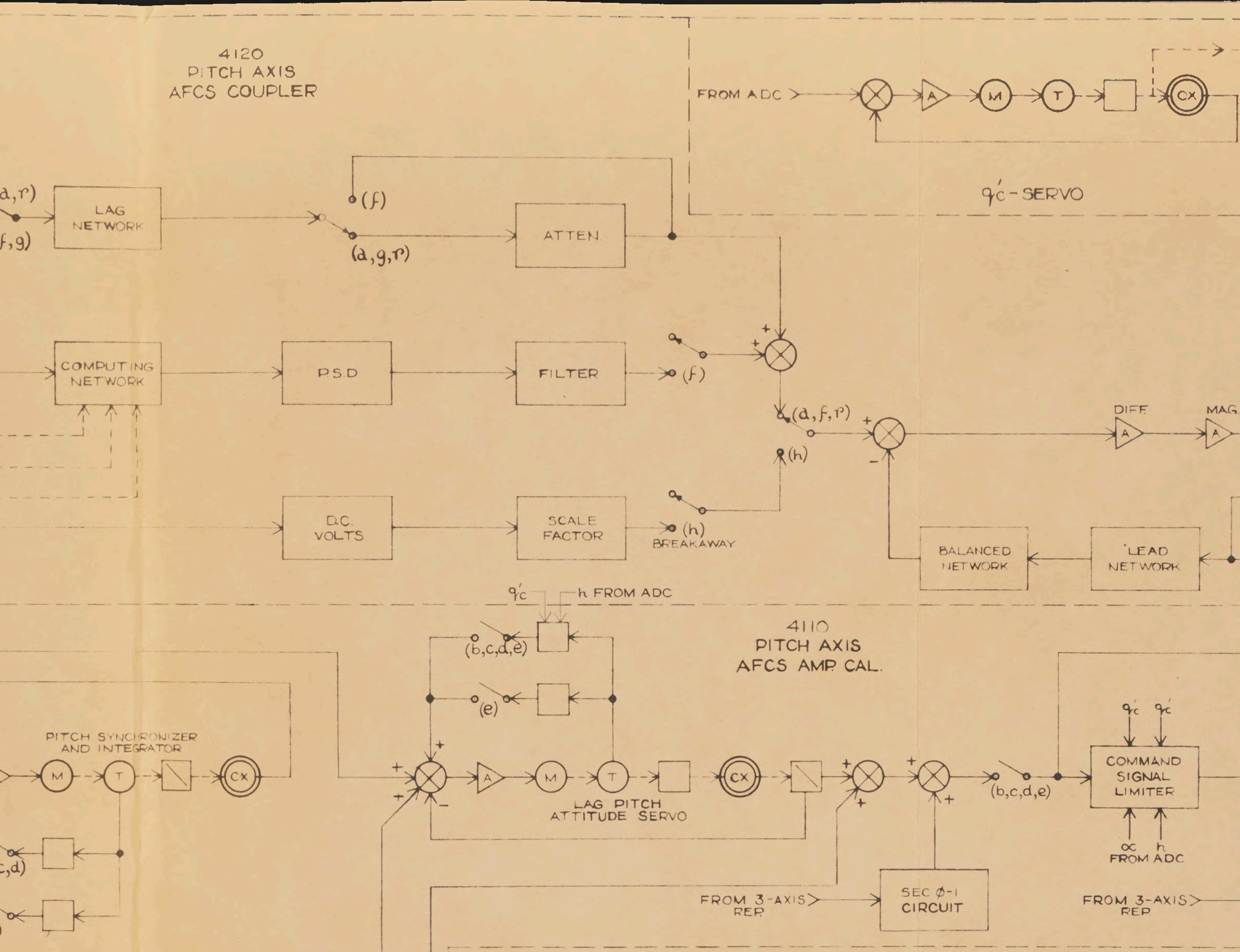
COUPLER HEADING ERROR
Si (k)
(k)
SCALE FACTOR
(i,k)
So
(j)
ELEV SERVO
HEADING SYNCHRONIZER
(j)
(p)
V FROM ADC
TRIM
(t,u)
LATERAL COURSE DEV
(v,w)
LATERAL COURSE DIR
RATE NET
(v,w)
AGCA LATERAL DISPLACEMENT
(v,w)
VERTICAL COURSE DEV
(v,w)
AGCA VERTICAL DISPLACEMENT
(v,w)
VERTICAL COURSE DIR
RATE NET
SIMULATED DATA LINK COUPLER
(v,w)
DATA LINK RELIABILITY
RELAY
DATA LINK RELIABILITY
(v,w)
POWER FAILURE
RELAY
(v,w)
AGCA ENGAGE
(v,w)
AC POWER
ROLL SYNCHRONIZER
(j,p)


4120 ROLL AXIS
AFCS COUPLER
LAG NETWORK
ATTEN
ATTEN
COMPUTING NETWORK
P.S.D.
FILTER
(l)
(m,n)
(m)
(l,n)
(m)
(l,m,n)
(o)
POT AC
POT DC
M
A
A
(n)
(l,m,n,o)
BALANCE NETWORK
LEAD NETWORK
HIGH PASS FEEDBACK
ANT
DET
DC VOLTS
SCALE FACTOR
(o)
(o)
(i,j)
(k)
SCALE FACTOR
(i,k)
So
(j)
4110 ROLL AXIS
AFCS AMP CAL
(l,m,n,o)
HEADING SYNCHRONIZER
CX
T
V FROM ADC
(p)
(j)
GEAR UP
GEAR DOWN
ROLL SYNCHRONIZER
(j,p)
ALT
AND D



L AXIS
COUPLER
4120
PITCH AXIS
AFCS COUPLER
NORMAL ACC.
Si
(a,r)
P.S.D
(a,r)
LAG NETWORK
ELEV STEERING ERROR
Si (f,g)
(f,g)
ISOL.
LEAD PURSUIT COMPENSATION
Vm SIN LE
Si (f,g)
A
COMPUTING NETWORK
P.S.
Si (f,g)
FROM ADC
LOG Ps
BREAKAWAY
(h)
D.C. VOLT
POT AC
POT DC
M
(n)
(l,m,n,o)
LEAD NETWORK
HIGH PASS FEEDBACK
L AXIS
AMP CAL
(l,m,n,o)
PITCH SYNCHRONIZER AND INTEGRATOR
A
M
T
CX
(e)
(b,c,d)
(e)
MACH DEVIATION
(b,c)
GEAR UP
GEAR DOWN
ROLL OUTPUT TO DAMPER
Si
ATTEN
(b,c)
(b,c)
ALTITUDE RATE AND DISPLACEMENT
Si
ATTEN
(d)
(d)



LEGEND

Si - INPUT TEST SIGNAL
So - OUTPUT TEST SIGNAL
Sov - OUTPUT TEST SIGNAL, VISUAL

PITCH AXIS

a - PITCH SYNCHRO
b - MACH HOLD
c - C.S.L. LIMIT
d - ALTITUDE HOLD
e - CSS. & NF & FADER
f - LEAD PURSUIT (T < 20)
g - ARMAMENT SELECTION (LEAD COLLISION T > 20) & SNAP-UP & INTEGRAL CONTROL
h - BREAKAWAY

ROLL AXIS

i - NAV. AGCI
j - AMP. CAL. ROLL AXIS
k - AGCI CLOSE
l - ROLL SYNCHRO
m - LEAD PURSUIT & COLLISION WARNING & REENGAGE COUPLER
n - ARMAMENT SELECTION & INTEGRAL CONTROL & WEAPONS FIRED & REENGAGE
o - BREAKAWAY
p - NF & CSS.
r - CSL OUTPUT
t,u - FD/AI INDICATOR
v,w - FD/AI DIRECTOR

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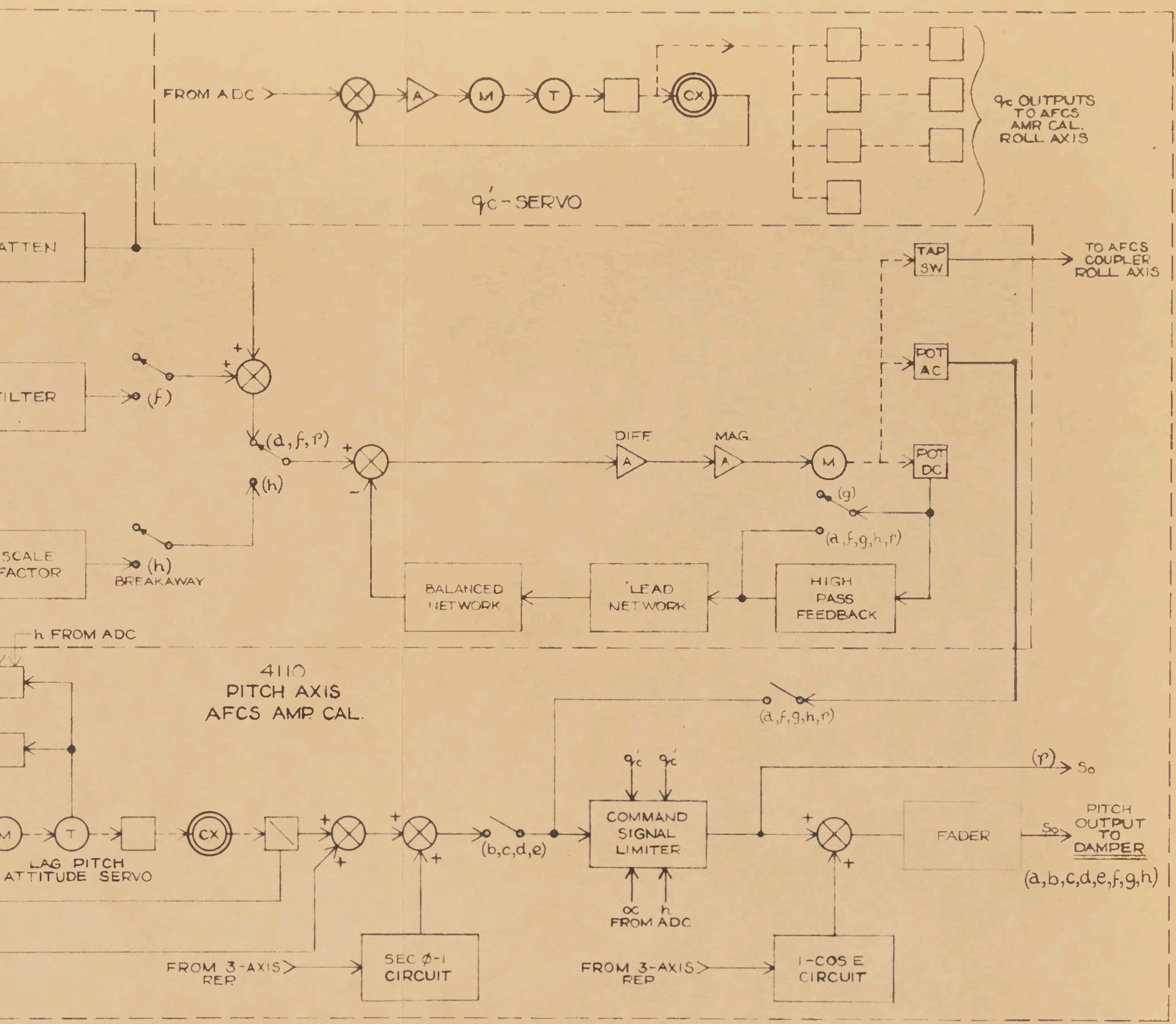

LEGEND

T TEST SIGNAL
UT TEST SIGNAL
UT TEST SIGNAL, VISUAL
PITCH AXIS
H SYNCHRO
H HOLD
. LIMIT
TUDE HOLD
& NF & FADER
D PURSUIT (T < 20)
MENT SELECTION (LEAD COLLISION T > 20)
AP-UP & INTEGRAL CONTROL
KAWAY
ROLL AXIS
AGCI
CAL. ROLL AXIS
CLOSE
SYNCHRO.
PURSUIT & COLLISION WARNING
ENGAGE COUPLER
AMENT SELECTION & INTEGRAL CONTROL
APONS FIRED & REENGAGE.
KAWAY
CSS.
OUTPUT
I INDICATOR
I DIRECTOR

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AERO ENGINEERING TORONTO CANADA	DATE 9-26-58	BY D.GOLSBY	CLASSIFICATION	TITLE FLIGHT CONTROL SYSTEM 1ST LINE MAINTENANCE	FIG. 5

TERMINATION REPORT
ON THE
GROUND TEST EQUIPMENT
FOR THE
FLIGHT CONTROL SYSTEM
OF THE
CF-105 ARROW AIRCRAFT.

UNCLASSIFIED

Honeywell Controls
Aero Division CR-ED 1048

SECTION 7

UG 6011 FLIGHT CONTROL SYSTEM
AUXILIARY TEST SET.

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

TABLE OF CONTENTS

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ILLUSTRATIONS

TERMINATION REPORT ON THE GROUND TEST EQUIPMENT FOR THE FLIGHT CONTROL SYSTEM OF THE CF-105 ARROW AIRCRAFT

SECTION 7

UG 6011 FLIGHT CONTROL SYSTEM AUXILIARY TEST SET

7.1 GENERAL

The UG 6011 Flight Control System Auxiliary Test Set was a part of the ground test equipment for the Flight Control System of the CF-105 Arrow Aircraft and was provided in accordance with R.C.A. Statement of Work dated 13 Feb. 1958, as amended by Astra Project memo 637 dated 5 June 1958. It was designed to augment the UG 6010 Flight Control System Test Set in carrying out First and Second Line tests. In First Line tests the UG 6010 System Test Set was used to determine if the Flight Control System was flightworthy. If it was non-flightworthy, the UG 6011 Auxiliary Test Set together with UG 6010 were used to locate the fault to a replaceable system component. Both the UG 6010 System Test Set and the UG6011 Auxiliary Test Set were to be used in conjunction with the UG 6012 and UG 6013 Test Stands to provide complete facilities for operation and calibration of the whole CF-105 Arrow Aircraft Flight Control System.

The various Flight Control System Breadboard Test Sets were functionally combined into the UG 6010 System Test Set and the UG 6011 Auxiliary Test Set.

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7.2 RELEVANT SPECIFICATIONS

a) RCA Statement of Work dated 13 February 1958, as amended by Astra memo 637 dated June 5, 1958.

b) ASTRA 1 specification, Revision C.

c) RCA Specifications 5638 and 5375 governing finishes on front panel and external surfaces.

d) MIL-T-945A amendment 2 dated 14 of May 1953, "General Specifications for Test Equipment for use with Electronic Equipment."

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the ASTRA I Airborne Weapons Control System dated 19th of February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 "General Specification for Environmental Testing Ground Support Equipment."

h) MIL-E-5400 "General Specifications for Aircraft Electronic Equipment."

7.3 DESCRIPTION OF UNIT

7.3.1 General

The UG-6011 Flight Control System Auxiliary Test Set and associated cables were to fit inside a 20" x 15" x 14" reinforced fibreglass instrument case, the cables being stowed in the lid (Fig. 7.1). The weight of the Test Set was to be approximately 50 pounds. The Test Set proper was to be mounted on a modified 19 inch rack panel and finished in light blue-gray.

7.3.1.2 Electrical

The UG-6011 Test Set required the following electrical power inputs from the Flight Control System being tested:

115 volts ± 10% AC 400 cycles ± 20 cps single phase. 27.5 V. D.C. ± 10%.

The remainder of the electrical connections between the Test Set and the Flight Control System permitted simulation, electrical interchanging and monitoring of certain Flight Control System outputs and components.

7.3.2 Component Parts

The component parts of the UG-6011 Flight Control System Auxiliary Test Set were:

a) Carrying case (with cable stowage facility and panel mounting flanges.)

b) Test cables.

c) Panel Assembly, with the following sub-panels: Power, V.T.V.M., VHRS Fault Isolation, Indicator Lights, Test Points, Mach Indicator, Fault Locator Flight Director - Attitude Indicator Fault Locator and sub-system Selector.

d) Chassis Assembly, holding various circuit components and internal cabling.

7.3.3 Theory of Operation

7.3.3.1 General

The UG-6011 Flight Control System Auxiliary Test Set isolated faults to a particular component (black box) of the following sub-systems:

The Vertical & Heading Reference System, consisting of:

a) GG63 Stable Platform (4410)

b) EG151 Platform Amplifier Assembly (4420)

Mach Indicator Sub-system, consisting of:

a) JG168 Mach Indicator (42[illegible]0)

b) BG94 Mach Indicator Amplifier Calibrator (4240)

Flight Director/Attitude Indicator Sub-system, consisting of:

a) JG227 Flight Director/Attitude Indicator (4210)

b) BG114 Flight Director/Attitude Indicator Amplifier Calibrator (4220)

A multipole, multiposition rotary subsystem selector switch selected a suitable low voltage from a tapped step-down transformer. This voltage was applied to the subsystem and was also read on the V.T.V.M. A series of satisfactory readings indicated a good Amplifier Assembly and a probable faulty Platform.

7.3.3.2 Purpose of Tests

The following were the Fault Location tests performed on the Vertical and Heading Reference Sub-system.

The UG-6011 Auxiliary Test Set located faults within the Vertical and Heading Reference Sub-system by simulating the GG63 Stable Platform and checking the operation of EG151 Platform Amplifier Assembly. If the EG151 Platform Amplifier was found to be operational, the GG63 Stable Platform required replacement.

The UG-6011 Auxiliary Test Set located faults in the Mach Indicator Sub-system by simulating the Mach Limit and Actual Mach inputs from the Air Data Computer. If the Mach Indicator Sub-system was found to be operational, the Air Data Computer was to be replaced; if not, the Mach Indicator Fault Locator switch was used to interchange servo amplifiers in the BG94 Mach Indicator Amplifier Calibrator thereby isolating the fault to the Indicator or to the Amplifier Calibrator.

The UG-6011 Auxiliary Test Set located faults within the Flight Director/Attitude Indicator Subsystem by simulating the Flight Director/Attitude Indicator Amplifier Calibrator. If this substitution resulted in an operational sub-system the BG114 Flight Director/Attitude Indicator Amplifier Calibrator was to be replaced; if not, the JG227 Flight Director and Attitude Indicator was to be replaced.

7.3.3.3 Details of Tests

7.3.3.3.1 VHRS Fault Isolation (Figure 7.2)

The procedure to be used in testing the various equipment was as follows:

Turn SUB-SYSTEM SELECTOR switch to VHRS position. Turn PLATFORM AMPLIFIER ELECTRONICS switch to Mode Selector Position. Rotate the MODE SELECTOR switch through the positions corresponding to the VHRS modes. Outputs are monitored on the UG-6010 Flight Control System Test Set.

With SUB SYSTEM SELECTOR switch set at VHRS position and MODE SELECTOR switch at Platform Amplifier Electronics position, rotate the AMPLIFIER ELECTRONICS swithh through the summing and alignment amplifier and drift time servo check positions. Outputs are measured across dummy loads in the DC V.T.V.M. in the Auxiliary Test Set (UG-6011) and/or the AC V.T.V.M. in the Test Set (UG-6010).

7.3.3.3.2 Flight Director/Attitude Indicator Fault Isolation.

a) Heading Axis Test Turn the SUB-SYSTEM TEST SELECTOR switch to FD/AI. Turn the FD/AI FAULT ISOLATION switch to "HEADING". A voltage corresponding to a pre-determined motor speed is applied to the control phase of the servo motor and the velocity generator voltage is compared with a reference voltage and the deviation is displayed on theAC V.T.V.M. on the UG6010.

b) Roll Axis Test Turn the FD/AI FAULT ISOLATION switch to "ROLL" and read the output as in 7.3.3.3.2(a)

c) Elevation Axis Test   Turn the FD/AI FAULT ISOLATION switch to "ELEVATION" and read the output as in 7.3.3.3.2(a)

7.4 DESCRIPTION OF PARTS

7.4.1 Carrying Case

The Carrying Case was a 20" x 15" x 14" grey fibreglass instrument case, reinforced by an aluminum moulding which extended around the edges of the case and the lid (Figure 7.3). Two carrying handles - one at each end of the case were attached to this moulding, as well as latches, hinges and a rubber gasket to render the case weatherproof. The lid of the case was removable.

7.4.2 Test Cables

The Test Cables were 16 feet long to allow the connections to the Flight Control System components to be made with the tester on the ground (Figure 7.4). The cables had transflex jackets and identical strain-relief connectors at either end (Pygmy type PT bayonet connectors).

Connections were to be made from the UG-6011 Flight Control System Auxiliary Test Set to the UG-6010 Flight Control System Test Set and to selected connections in the Flight Control System. This would involve interrupting the aircraft wiring but this is necessary for fault isolation.

7.4.3 Tester Panel

The Tester Panel was a modified 19" panel supporting all the necessary switches, meters and controls, and all mounting brackets for circuit components and cabling located underneath the panel.

7.4.3.1 Tester Panel Subdivisions

The UG-6011 Flight Control System Auxiliary Test Set had the following functional divisions on the front panel:-

a) Metering Circuitry - The Vacuum Tube Voltmeter had overlapping ranges from 10 millivolts to 300 volts. It was a conventional DC instrument and requires no further description.

b) Subsystem Selector - The sub-system selector switch provided simulated signal voltages to the Flight Control Sub-system under test.

c) V.H.R.S. Fault Isolation - The Vertical and Heading Reference System isolation function provided a convenient means of determining if a faulty VHRS was due to a faulty GG63 Platform or a faulty EG151 AmplifierAssembly. (The DG6000 Three-Axis Repeater was tested along with the rest of the Flight Control System.)

In the actual fault isolation the UG-6011 was connected to the EG151 Amplifier Assembly in place of the GG63 Platform. It provided loads and signal sources corresponding to some conditions of a serviceable platform. As the selector switches were rotated, voltages were applied to the Amplifier Assembly and the output was read on the VTVM. A series of satisfactory readings indicated a good Amplifier Assembly and a probable faulty Platform.

d) Indicator Subsystem - The Indicator Subsystem consisted of a series of lamps connected in series with relays and/or switches and a voltage source. Satisfactory operation of the relay or switch indicated proper operation of the VHRS EG151 Amplifier by lighting a lamp. The lamps were self-testing so that their proper operation could be checked.

e) Mach Indicator Fault Locator - The Mach Indicator Fault Locator Switch permitted the interchange of the servo amplifiers in the three Mach Indicator servos. If the particular fault moved with the amplifier, the amplifier must be faulty, otherwise the Mach Indicator was faulty.

f) Flight Director-Attitude Indicator Sub Panel - The rotary switch on the FD/AI sub-panel tested the Heading, Roll and Elevation axes of the FD/AI by applying a voltage corresponding to a pre-determined motor speed to the control phase of the servo motor for the axis being tested, and comparing the velocity generator voltage with a reference voltage.

g) Test Points Sub Panel - A number of Test Points were available on the front panel for Second Line tests.

h) Power Sub-Panel - The Power Sub-panel contained the power on-off toggle switch, pilot lights, fuses and spares.

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7.5 PERFORMANCE

The function of the UG-6011 Flight Control System Auxiliary Test Set was largely that of simulating certain inputs and outputs of the Flight Control System. The accuracy expected from the tests, therefore, depended on the accuracy of the simulated voltages and resistances, which was .5%, and the accuracy of the "go-no-go" metering circuitry in the UG-6010 Flight Control System Test Set. There were no experimental data on Auxiliary Test Set performance because the Test Set construction was not initiated.

7.6 STATUS AT CANCELLATION

The tests to be performed with the UG-6011 Test Set had been chosen; the front panel of the Test Set was laid out; long lead-time components, such as connectors and rotary switches, had been ordered. Construction had not been initiated.

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7.7 PROPOSED FUTURE PROGRAMME

The first UG 6011 Flight Control System Auxiliary Test Set was to have been completed by November 1959 with subsequent units to be delivered in January of 1960.

7.8 CONCLUSIONS

a) It is felt that the AFCS Auxiliary Test Set as outlined represents the simplest approach to the performance of go-no-go system tests.

More exotic and more nearly automatic check-out equipment could be provided, but the savings in time required to perform the tests would be small and the increase in complexity and required lead time would be very considerable.

b) The degree of fault isolation provided was greater than originally anticipated and would require the use of the Auxiliary Test Set on first line maintenance less frequently than might be expected.

c) It would be desirable to provide a single large test connector for the Auxiliary Test Set rather than several smaller connectors on the individual components. This would eliminate the necessity for opening numerous access doors and panels and making multiple connection for routine checks.

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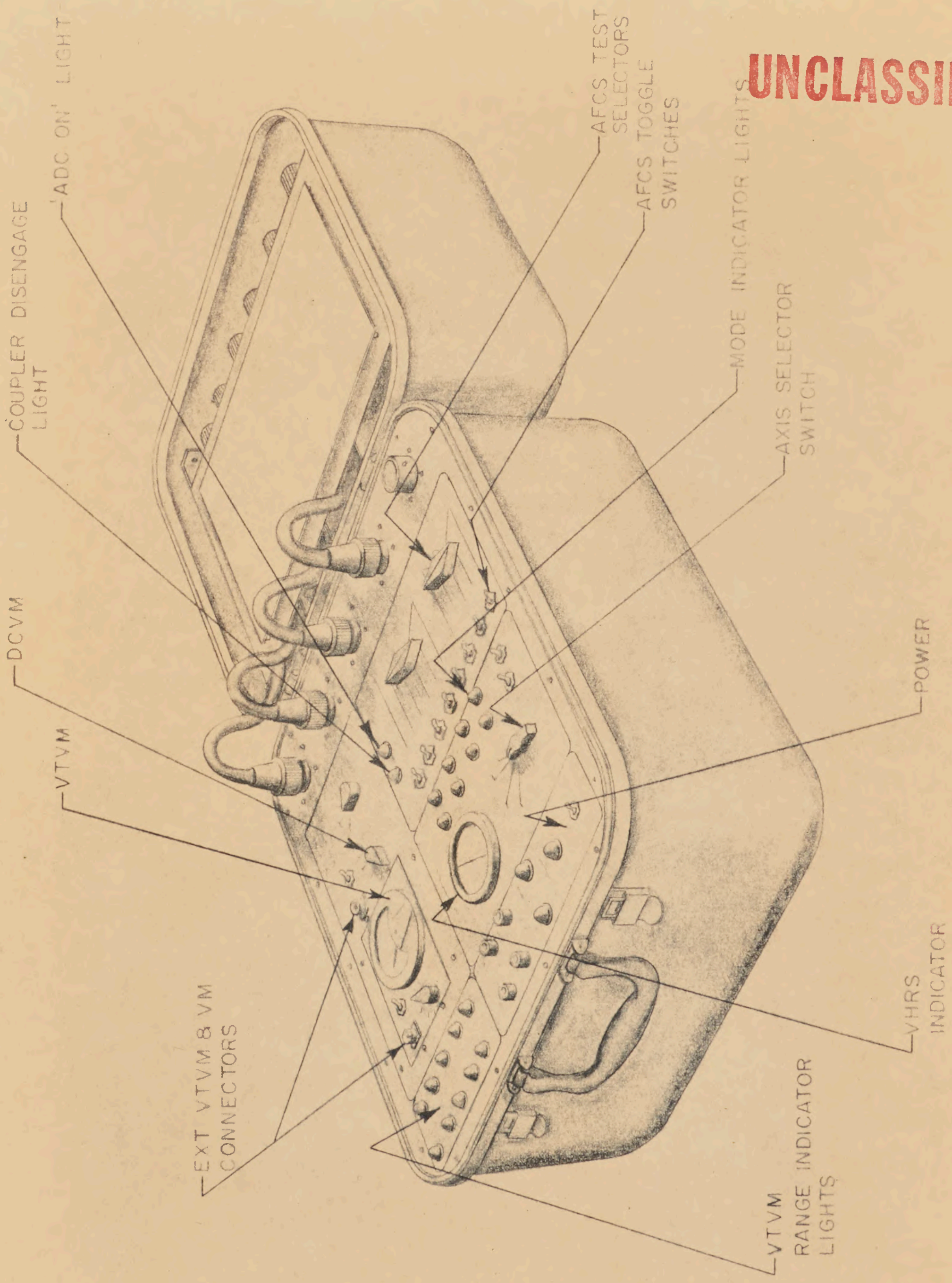

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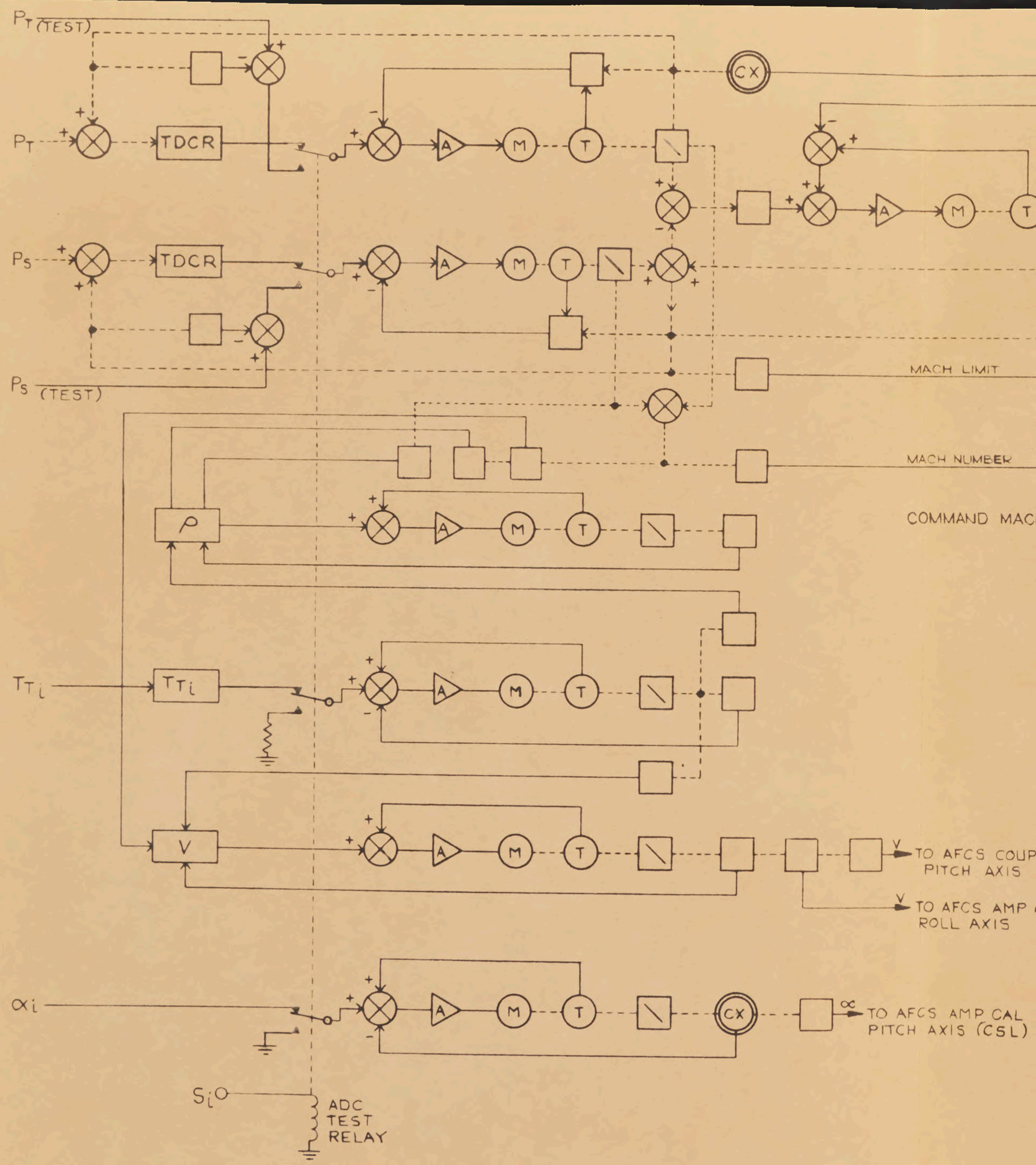
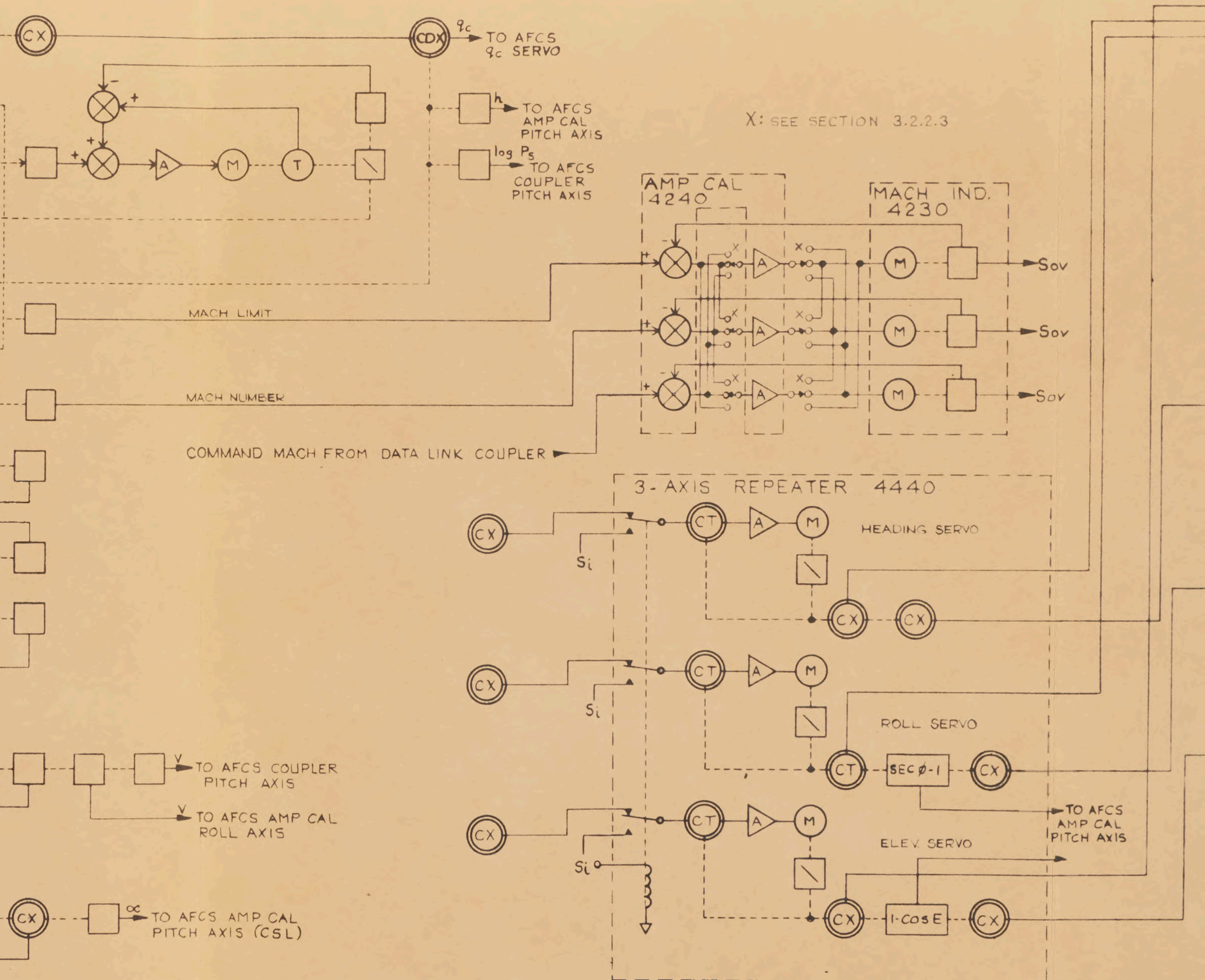
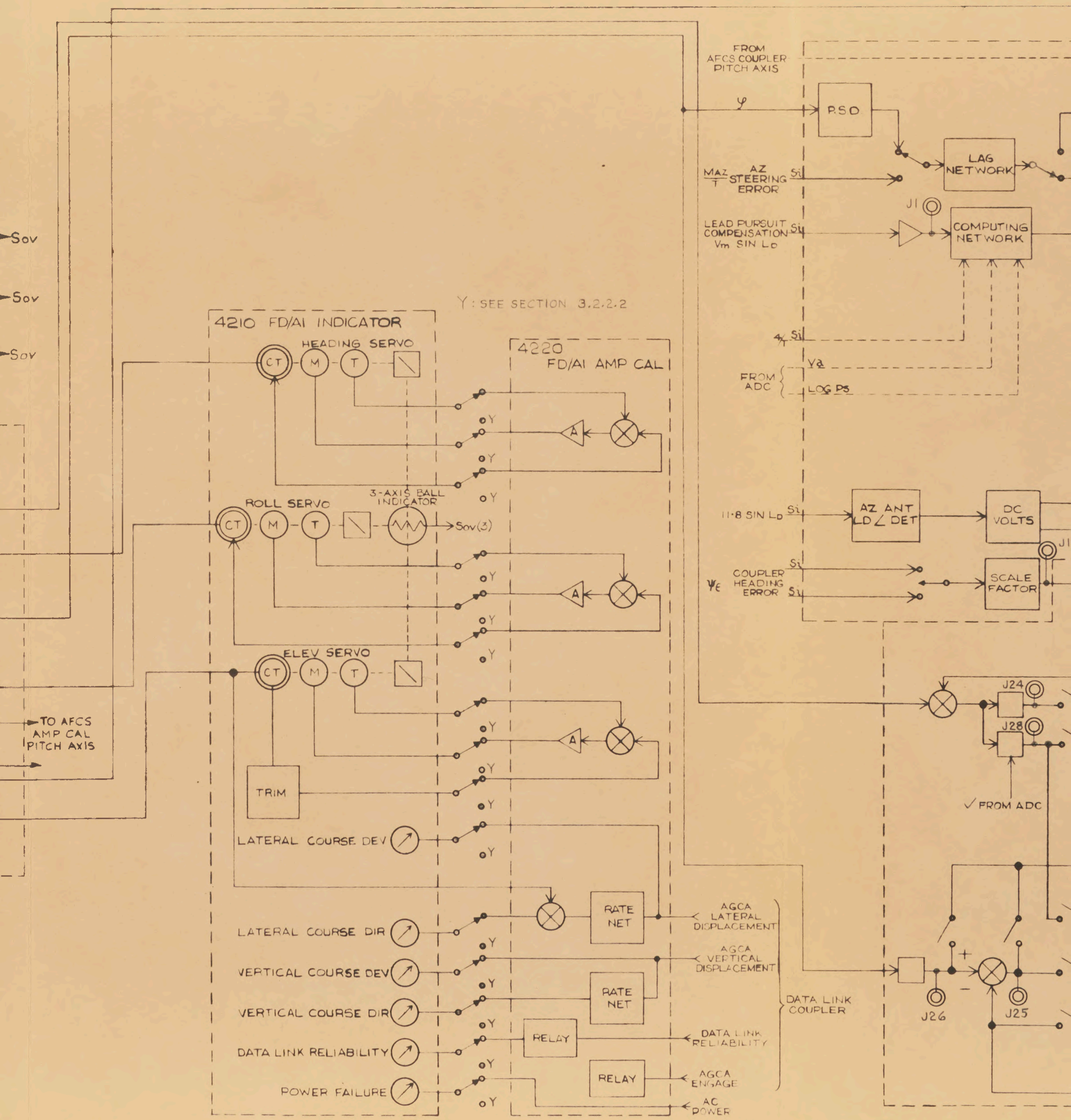
AERO ENGINEERING TORONTO CANADA	DATE 4/25/58	BY [illegible]	CLASSIFICATION	TITLE UG6010 AFCS TEST SET	FIG. NO. 7·1

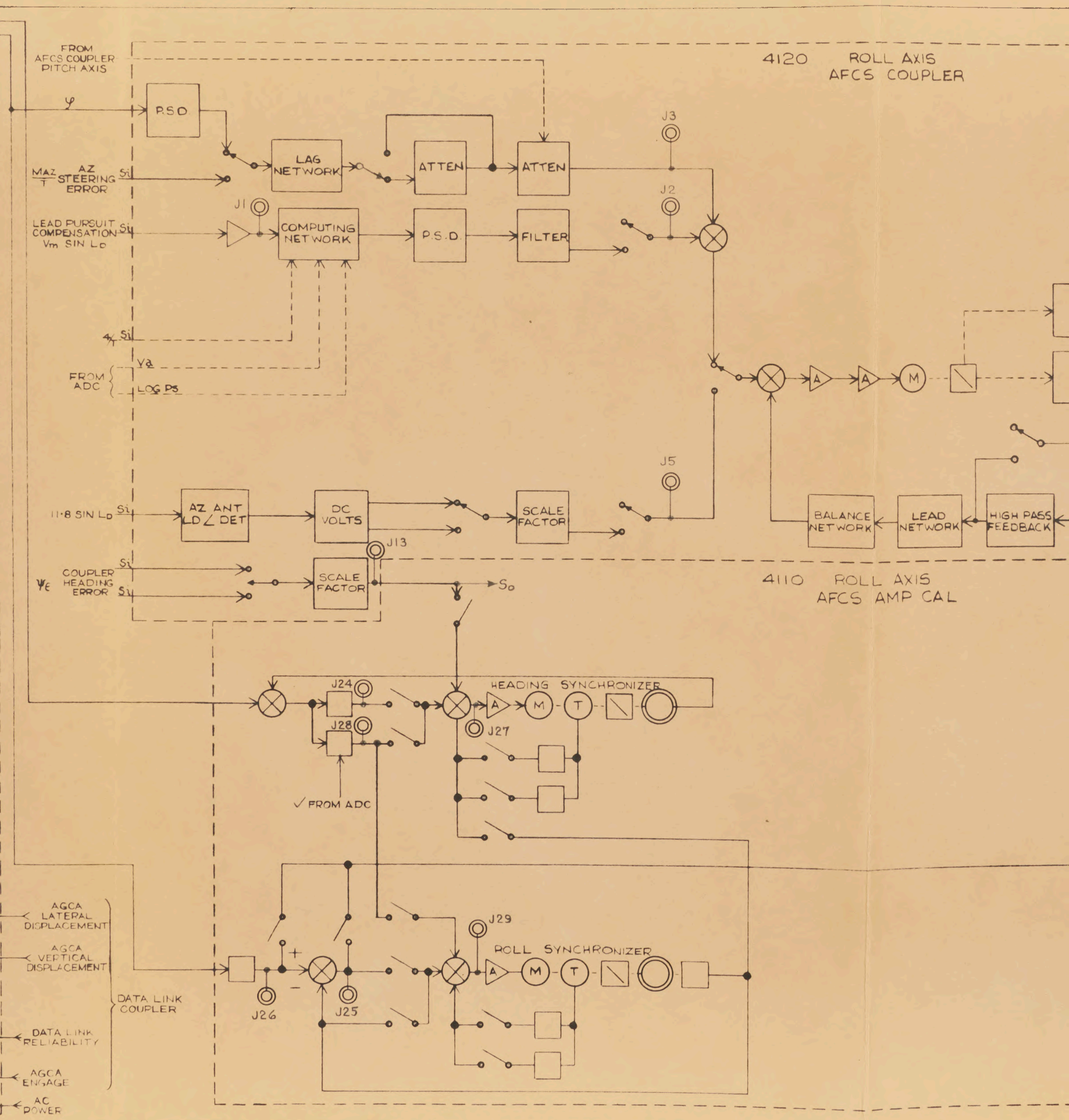


PT (TEST)
PT
TDCR
CX
PS
PS (TEST)
MACH LIMIT
MACH NUMBER
COMMAND MAC
ρ
TTi
V
TO AFCS COUP
PITCH AXIS
TO AFCS AMP
ROLL AXIS
αi
TO AFCS AMP CAL
PITCH AXIS (CSL)
Si
ADC
TEST
RELAY

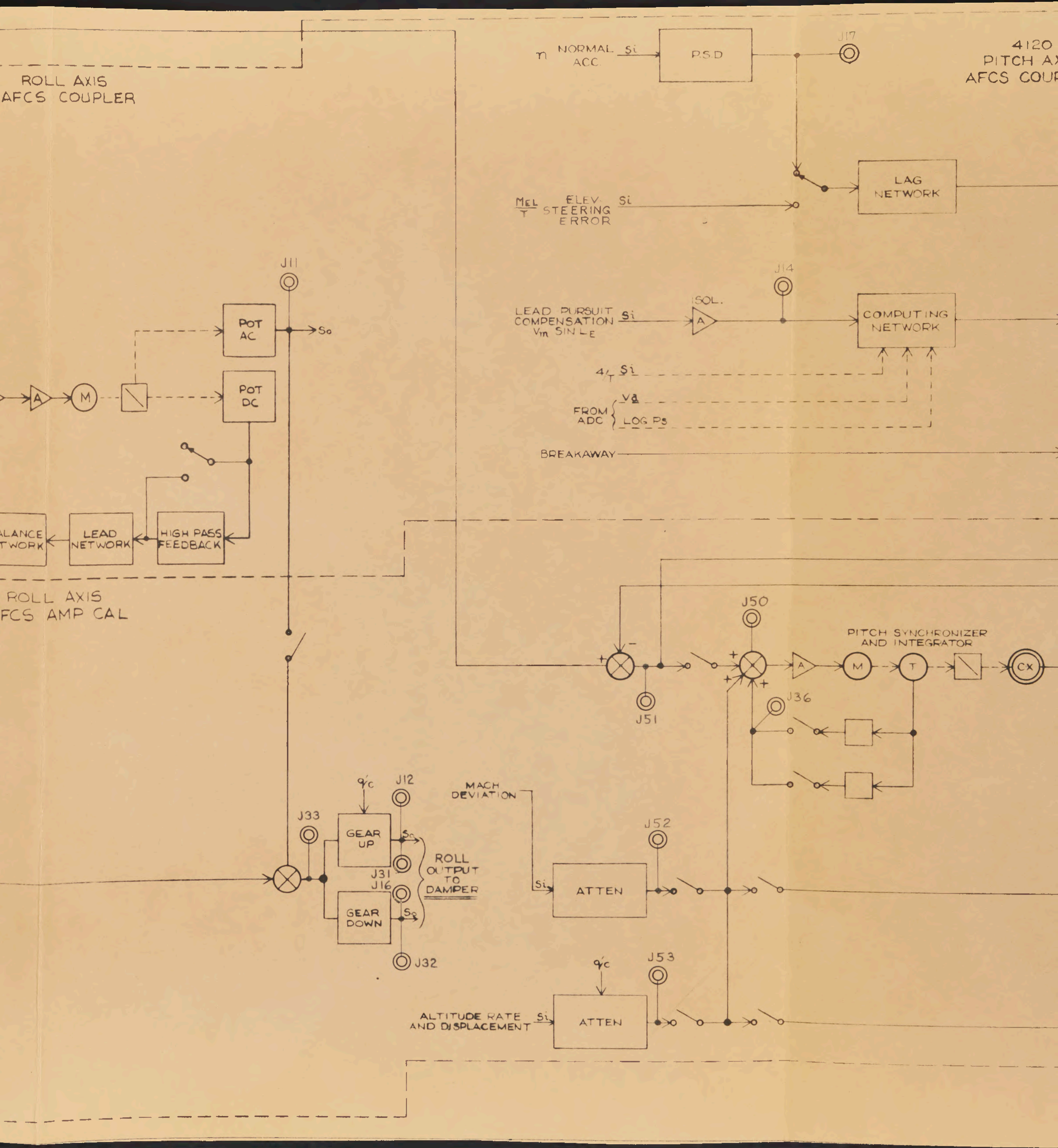

CX
CDX
q_c TO AFCS q_c SERVO
h TO AFCS AMP CAL PITCH AXIS
log P_s TO AFCS COUPLER PITCH AXIS
X: SEE SECTION 3.2.2.3
AMP CAL 4240
MACH IND. 4230
Sov
MACH LIMIT
MACH NUMBER
COMMAND MACH FROM DATA LINK COUPLER
3-AXIS REPEATER 4440
HEADING SERVO
ROLL SERVO
ELEV. SERVO
SEC φ-1
1-COS E
TO AFCS AMP CAL PITCH AXIS
V TO AFCS COUPLER PITCH AXIS
V TO AFCS AMP CAL ROLL AXIS
∝ TO AFCS AMP CAL PITCH AXIS (CSL)

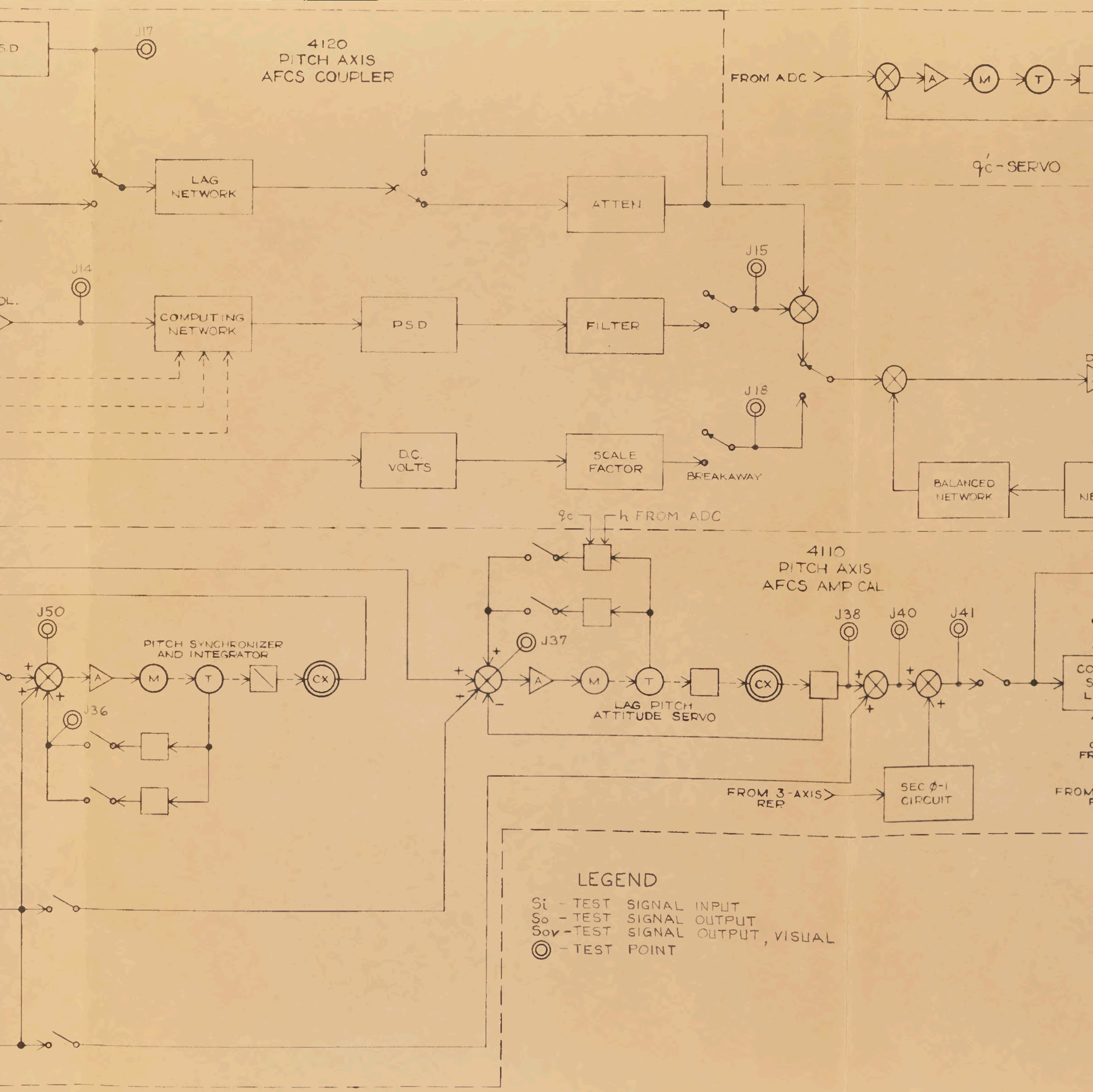


FROM AFCS COUPLER PITCH AXIS
PSD
LAG NETWORK
AZ STEERING ERROR
LEAD PURSUIT COMPENSATION Vm SIN Lo
J1
COMPUTING NETWORK
Y: SEE SECTION 3.2.2.2
4210 FD/AI INDICATOR
HEADING SERVO
CT
M
T
4220 FD/AI AMP CAL
FROM ADC
LOG PS
A
ROLL SERVO
3-AXIS BALL INDICATOR
Sov(3)
Sov
11·8 SIN Lo
AZ ANT LD∠ DET
DC VOLTS
COUPLER HEADING ERROR
SCALE FACTOR
ELEV SERVO
TO AFCS AMP CAL PITCH AXIS
J24
J28
TRIM
✓ FROM ADC
LATERAL COURSE DEV
LATERAL COURSE DIR
RATE NET
AGCA LATERAL DISPLACEMENT
AGCA VERTICAL DISPLACEMENT
VERTICAL COURSE DEV
VERTICAL COURSE DIR
DATA LINK COUPLER
J26
J25
DATA LINK RELIABILITY
RELAY
AGCA ENGAGE
POWER FAILURE
AC POWER

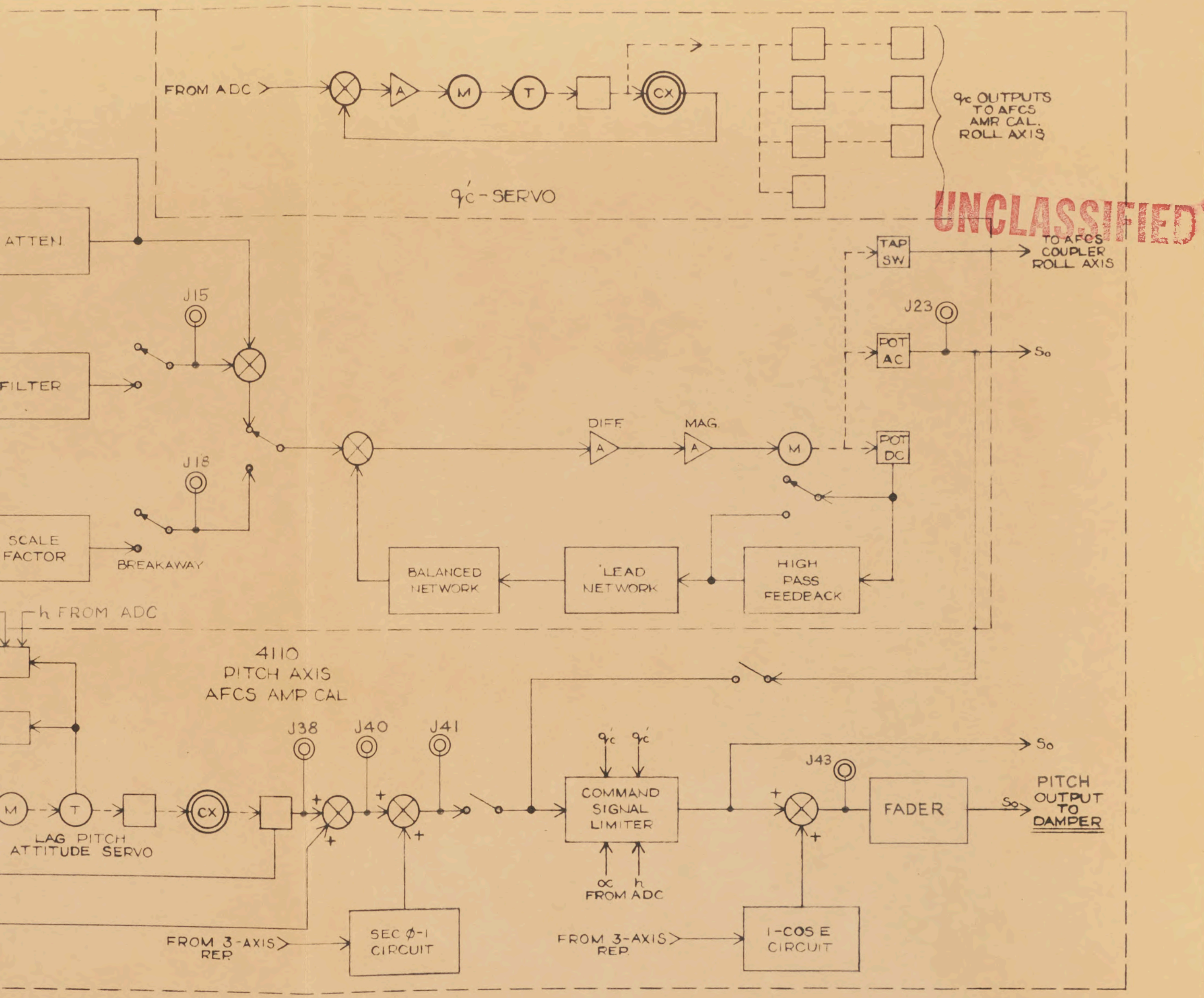


FROM AFCS COUPLER PITCH AXIS
4120 ROLL AXIS AFCS COUPLER
P.S.D.
LAG NETWORK
ATTEN
ATTEN
J3
J2
J1
AZ STEERING ERROR
LEAD PURSUIT COMPENSATION Vm SIN Lp
COMPUTING NETWORK
P.S.D.
FILTER
FROM ADC
Va
LOG PS
J5
11·8 SIN Lp
AZ ANT LD∠ DET
DC VOLTS
SCALE FACTOR
BALANCE NETWORK
LEAD NETWORK
HIGH PASS FEEDBACK
J13
COUPLER HEADING ERROR
SCALE FACTOR
So
4110 ROLL AXIS AFCS AMP CAL
J24
HEADING SYNCHRONIZER
J28
J27
FROM ADC
AGCA LATERAL DISPLACEMENT
AGCA VERTICAL DISPLACEMENT
DATA LINK COUPLER
DATA LINK RELIABILITY
AGCA ENGAGE
AC POWER
J29
ROLL SYNCHRONIZER
J26
J25


ROLL AXIS
AFCS COUPLER
4120
PITCH AX
AFCS COUP
NORMAL ACC
Si
P.S.D
J17
LAG NETWORK
ELEV. STEERING ERROR
Si
J11
POT AC
So
POT DC
A
M
J14
ISOL.
LEAD PURSUIT COMPENSATION
Si
A
COMPUTING NETWORK
4/T Si
FROM ADC
LOG Ps
BREAKAWAY
ALANCE
TWORK
LEAD NETWORK
HIGH PASS FEEDBACK
ROLL AXIS
FCS AMP CAL
J50
PITCH SYNCHRONIZER AND INTEGRATOR
A
M
T
CX
J51
J36
J12
J33
GEAR UP
So
J31
J16
GEAR DOWN
So
J32
ROLL OUTPUT TO DAMPER
MACH DEVIATION
Si
ATTEN
J52
J53
ALTITUDE RATE AND DISPLACEMENT
Si
ATTEN


4120
PITCH AXIS
AFCS COUPLER
J17
FROM ADC
A
M
T
q'_c - SERVO
LAG NETWORK
ATTEN
J14
J15
COMPUTING NETWORK
PSD
FILTER
J18
D.C. VOLTS
SCALE FACTOR
BREAKAWAY
BALANCED NETWORK
q_c
h FROM ADC
4110
PITCH AXIS
AFCS AMP CAL
J50
PITCH SYNCHRONIZER AND INTEGRATOR
CX
J36
J37
LAG PITCH ATTITUDE SERVO
J38
J40
J41
FROM 3-AXIS REP
SEC Ø-1 CIRCUIT
LEGEND
Si - TEST SIGNAL INPUT
So - TEST SIGNAL OUTPUT
Sov - TEST SIGNAL OUTPUT, VISUAL
◎ - TEST POINT

9/26/58



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LEGEND

EST SIGNAL INPUT
EST SIGNAL OUTPUT
EST SIGNAL OUTPUT, VISUAL
EST POINT

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C-SK 1759

9/26/58 H. Kear

FLIGHT CONTROL SYS.
SECOND LINE MAINTENANCE

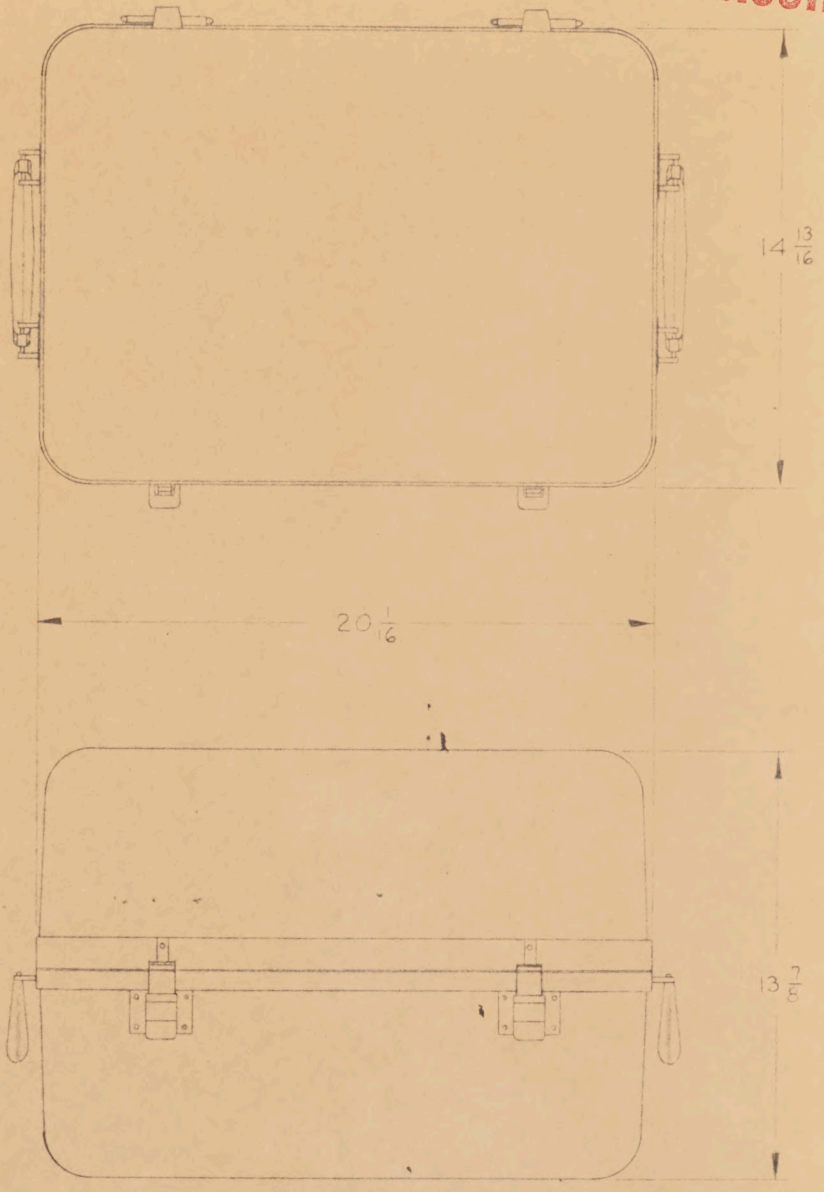

FIG. 7·3

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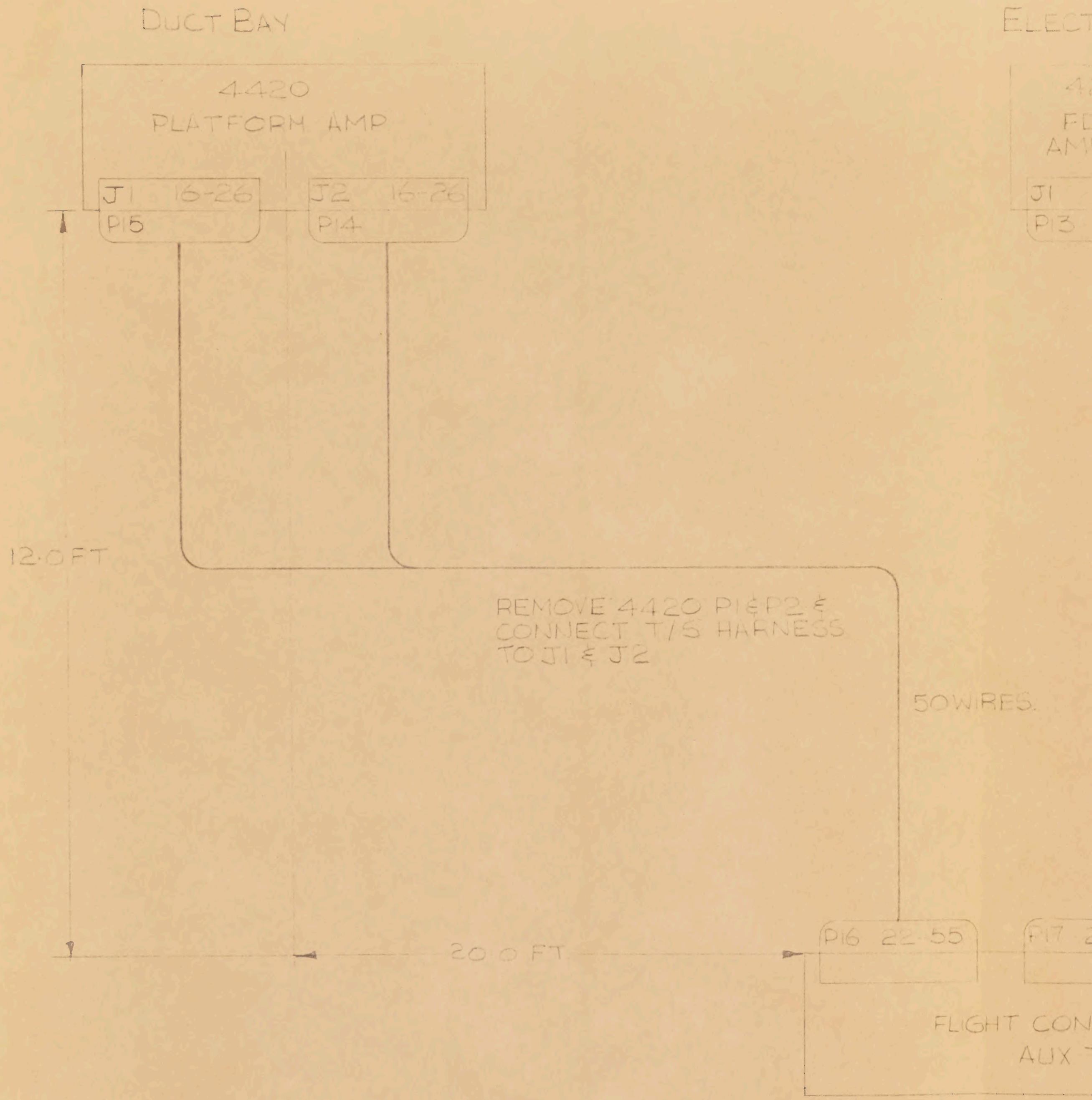
SCALE 1:5


DUCT BAY
4420
PLATFORM AMP
J1 16-26
P15
J2 16-26
P14
12.0 FT
REMOVE 4420 P1 & P2 &
CONNECT T/S HARNESS
TO J1 & J2
50 WIRES.
P16 22-55
20.0 FT
FLIGHT CON
AUX

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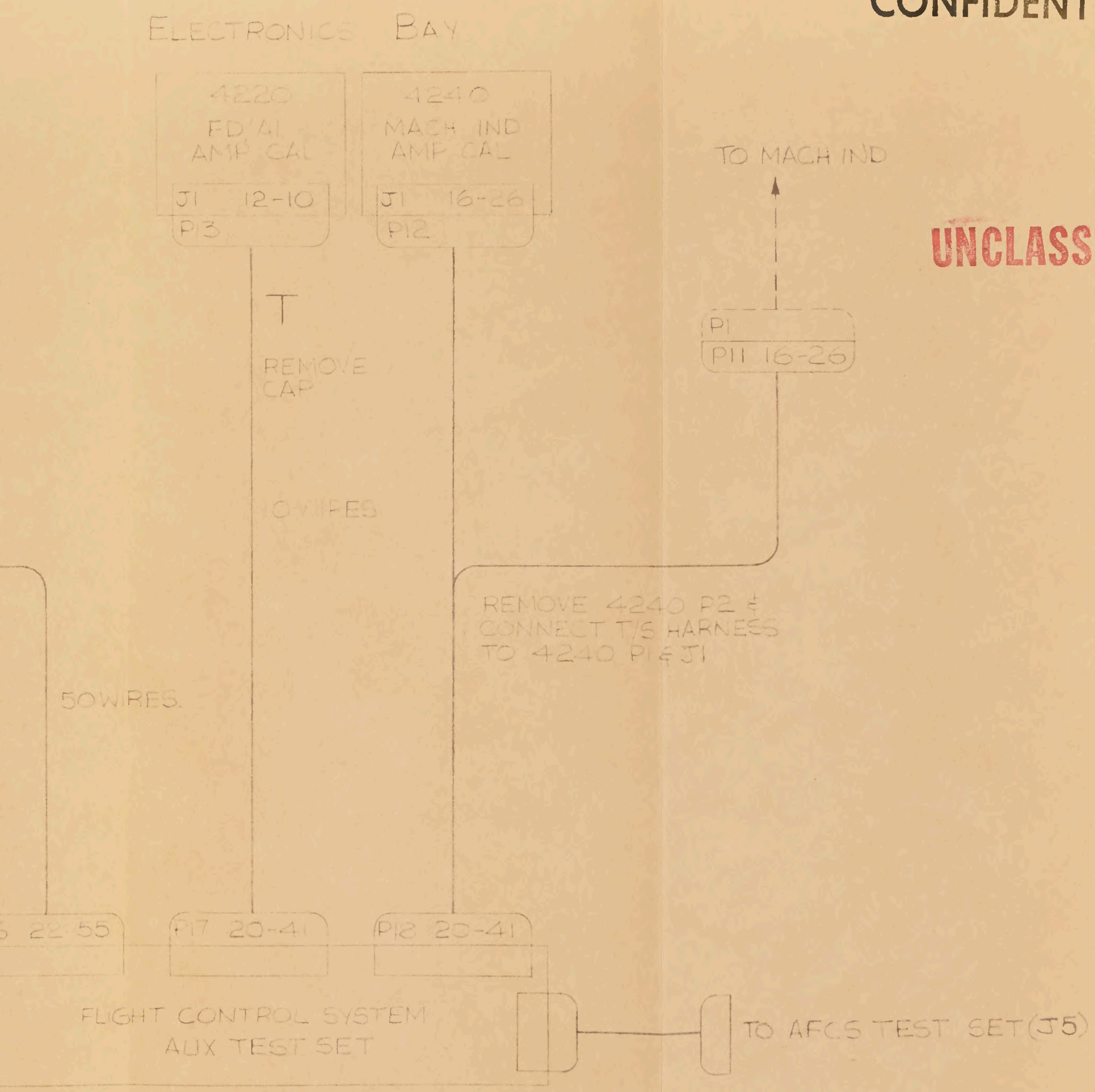

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AERO ENGINEERING TORONTO CANADA	DATE 8-25-58	BY	CLASSIFICATION	TITLE FLIGHT CONTROL SYSTEM AUX TEST HARN	FIG NO 7·4

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TERMINATION REPORT

ON THE

GROUND TEST EQUIPMENT

FOR THE

FLIGHT CONTROL SYSTEM

OF THE

CF-105 AVRO AIRCRAFT

Honeywell Controls
Aero Document CR-ED 1048

SECTION 8

SECOND LINE MAINTENANCE EQUIPMENT
FOR THE ARROW ELECTRONIC SYSTEM.

Honeywell Controls Limited,
Aeronautical Division,
Toronto, Ontario.

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SECTION 8

SECOND LINE MAINTENANCE EQUIPMENT FOR THE ARROW ELECTRONIC SYSTEM

8.1 GENERAL

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The Second Line Maintenance Equipment for the Arrow Electronics System was to consist of two units the UG-6012 Automatic Flight Control System Test Stand (AFCS Test Stand) and the UG-6013 Vertical and Heading Reference System Test Stand (VHRS Test Stand). These two test stands were to be used in conjunction with one set of first line test equipment consisting of the UG-6010 Flight Control System Test Set and the UG-6011 Flight Control System Auxiliary Test Set.

The Second Line Maintenance Equipment was to be designed to perform the following functions:

a) Verification by substitution of a faulty component and the repair of that component if it was within the scope of second line maintenance.

b) Calibration and harmonization (if necessary) of all subsystems prior to installation in the aircraft.

c) Training technicians on the Automatic Flight Control System equipment.

d) Training technicians on the use of the Automatic Flight Control System test equipment.

In order to accomplish the above functions the test stand was to provide the necessary interconnecting cables, mounting racks, junction panels and controls for operating the complete flight control system.

The design of the second line test stands was delayed due to the delay in receiving a contract from RCA. The schedule for the development called for the design of the Second Line Maintenance Equipment immediately after the design of the First Line Equipment was completed. This design was to be carried out by the personnel who had designed the First Line Equipment. This provided the most economical means of providing Second Line Maintenance Equipment. Further delays were encountered however in the choice of the final configuration for the test stand. It was a requirement that these stands be air transportable with a complete complement of the flight control system mounted on them. Sketches of several configurations were prepared by Honeywell Controls for submission to RCA in March of 1958. As it turned out RCA had already decided on a test stand configuration and Honeywell Controls were asked to comment on any necessary modifications required to accommodate the Honeywell portion of the Arrow Electronic System. No modifications were necessary although personnel in general were not in total accord with the test stand configuration. In April of 1958 the first drawings of the test stand were received by Honeywell Controls from RCA. Sufficient information was contained in these to enable the Honeywell Engineers to begin considering replacement of equipment on the test stand. However, the drawings were not complete enough to enable cable routings to be decided upon. It was felt by the Honeywell personnel that cable locations were going to be a considerable problem. Work had proceeded to the point where a general configuration in the form of artist sketches had been prepared for the test stand and these were submitted to RCA September 1958 in the form of a Honeywell Aero Document CR-ED 1029 entitled "Model Specification Flight Control System Test Equipment." Shortly after the issue of this document the Astra programme was cancelled and no further work was done on the test equipment.

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8.2 RELEVANT SPECIFICATIONS

a) RCA statement of work dated 13 February 1958 as amended by Astra memo 637 dated 5 June 1958.

b) Astra I Specification, Revision C.

c) CR-ED 1029 entitled "Model Specification Flight Control System Test Equipment", dated 29 September 1958.

d) MIL-T-945A Amendment 2 dated 14 May 1953, "General Specification for Test Equipment for use with Electronic Equipment."

e) RCA Specification 8958509 - Specification for the Ground Equipment for Flight Control System of the Astra I Airborne Weapons Control System dated 19 February 1958.

f) MIL-STD-108C Definitions of and basic requirements for enclosures for electric and electronic equipment.

g) MIL-E-4970 "General Specification for Environmental Testing Ground Support Equipment".

h) MIL-E-5400 "General Specification for Aircraft Electronic Equipment".

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8.3 DESCRIPTION OF UNIT

8.3.1 General

The test stands were to measure approximately 114 inches by 56 inches by 19 inches wide in the closed position and 114 inches by 56 inches by 38 inches when open. The weight of the test stand was to be a minimum consistent with the requirements of strength and rigidity. The colour of the test stand was to be in accord with RCA Specifications 5638 and 5375 governing finishes on front panels and external surfaces.

8.3.1.1 Electrical

The test stand was to operate from the following sources of power:

a) 108 to 121 volts line to neutral (neutral grounded) 400 cycles ± 20 cycles 3 phase AC at 3 amperes per phase.

b) 24 volts to 29 volts DC at 6 amperes.

c) 115 volts ± 10% 60 ± 6 cycles at 10 amperes for energizing convenient outlets on the test stand.

Outputs from the test stands were to be applied to the automatic flight control systems under test and were to be derived from sources within the test stand or from the first line test equipment that was to be provided with the test stands.

8.3.2 Component Parts

Second Line Maintenance Equipment was to consist of two units; the UG-6012 Automatic Flight Control System Test Stand (AFCS Test Stand) and the UG-6013 Vertical and Heading Reference System Test Stand (VHRS Test Stand)

8.3.2.1 AFCS Test Stand (Figure 8.1)

The AFCS Test Stand was to consist of the following:

a) The Test Stand proper.

b) Junction panels and controls for operating the components of the automatic flight control system.

The isolation of faults to a particular black box on the Flight Control System was to be undertaken by the substitution method. This consisted of placing the suspected black box in the test stand in place of the known good one that was to be part of the test stand and performing the series of go-no-go checks again using the First Line Test Equipment as described in Sections 6 and 7 of this document. If a series of no-go readings were obtained, indicating a fault in the black box, this was to be considered sufficient indication that the black box was at fault. Fault isolation would then be undertaken to confirm the location of the fault by substituting it for a good unit on the Test Stand. Where repairs to a component were beyond the capabilities of the Second Line Maintenance organization the component was to be returned to the Fourth Line facility for repair and a spare unit obtained from stores.

In addition to the signal sources and indicators mounted on the First Line Test Equipment, auxiliary signal sources were to be provided in the Test Stands to assist in the fault isolation. Consideration was to be given to the provision of facilities for operating a particular black box independently of the other sub-systems. This was considered desirable in that the amount of running time on the equipment would then be kept to a minimum. Some units, however, were not adaptable to this type of operation namely the JG227 Flight Director Attitude Indicator and the BG114 Flight Director Attitude Indicator Amplifier Calibrator which had to be tested jointly. The GG63 Platform and EG151 Amplifier Assembly the BG94 Mach Indicator Amplifier Calibrator and the JG168 Mach Indicator also had to be tested jointly. All other units were able to be tested as individual entities.

The operation of the equipment was to consist of the application of signals of known magnitude and phase to the input of the suspected unit or system and to read the output on either the go-no-go meters or the vacuum tube voltmeters provided with the First Line Test Equipment. The skill level for performing such functions was to be kept to a minimum.

c) The necessary interconnecting cables and mounting racks for mounting the following components of the Automatic Flight Control System.

1) BG93 Automatic Flight Control System Amplifier Calibrator.

2) DG63 Automatic Flight Control System Coupler.

3) HG32 Air Data Computer

4) JG168 Mach Indicator

5) BG94 Mach Indicator Amplifier Calibrator.

6) CG78 Function Selector

8.3.2.2 UG 6013 VHRS Test Stand

The UG-6013 VHRS Test Stand was to consist of the following major components:

a) The Test Stand proper

b) The Junction Panel

c) Interconnecting cables for joining the VHRS components.

d) Mounting racks for the following:

1) VHRS consisting of:

i) GG63 Platform
ii) EG151 Amplifier Assembly
iii) DG6000 Three Axis Repeater.

2) JG227 Flight Director/Attitude Indicator (FD/AI)

3) BG114 Flight Director/Attitude Indicator Amplifier Calibrator.

8.3.3 <u>Theory of Operation</u>

The Second Line Maintenance Equipment was designed to be used in conjunction with one set of First Line Maintenance Equipment, namely the UG-6010 Flight Control System Test Set and the UG-6011 Flight Control System Auxiliary Test Set.

8.4 DESCRIPTION OF PARTS

Figure 1 illustrates the Second Line Maintenance Assembly. The UG-6012 AFCS Test Stand and the UG-6013 VHRS Test Stand were essentially identical with the exception of the mount of the Flight Control System components on the control panel. In the stored condition the bench portion folded up to form the front of the cabinet. The legs and outriggers were folded into recesses in the front and corners of the cabinet so that the unit presented a reasonably clean configuration. The mounting was to be such that the equipment could be manhandled using a fork lift truck. The test stands themselves were to be of a frame construction with a welded aluminum skin. Folding doors were to be provided at the rear to provide access to the wiring and to power supply. Folding doors at the front provided access to additional wiring and power supplies. The mounting racks for equipment were to be provided with slides to allow them to be pulled out to the work surface of the equipment. The mounting racks and slides were to be sufficiently rigid to support the equipment at any altitude. Control panels were to be provided that were easily read and as far as possible were to be self-explanatory. A roll chart was to be provided on each of the control panels showing the schematics for each of the sub-systems mounted on the test stand. Provision was to be made for stowing handbooks and cables.

Shown in Figure 1 is a concrete pylon for mounting the GG63 Stable Platform on its tilt table. Space was also provided for supporting the reference gyro which was to be used in the calibration of the GG63.

As can be seen in the diagram the UG-6010 Flight Control System Test Set and the UG-6011 Flight Control System Auxiliary Test Set were to be mounted separately from the test stand. This provided a maximum degree of flexibility in the test equipment for these units could also be used at the aircraft as First Line Test Sets.

8.5 PERFORMANCE

Because the design had not progressed beyond the stage of defining the functions of the Test Stands no performance figures are available.

8.6 STATUS AT CANCELLATION

The location of second Line Test points had been decided upon and provision had been made for including these in the Flight Control System proper. A general configuration of the test equipment had been decided upon but drawing had not begun except the sketches shown in Figure 8.1.

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8.7 PROPOSED FUTURE PROGRAMME

Because of the cancellation of the Arrow program no future work will be performed on the Second Line Maintenance Equipment.

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8.8 CONCLUSIONS

Work had not progressed far enough to warrant drawing any conclusions from this portion of the programme.

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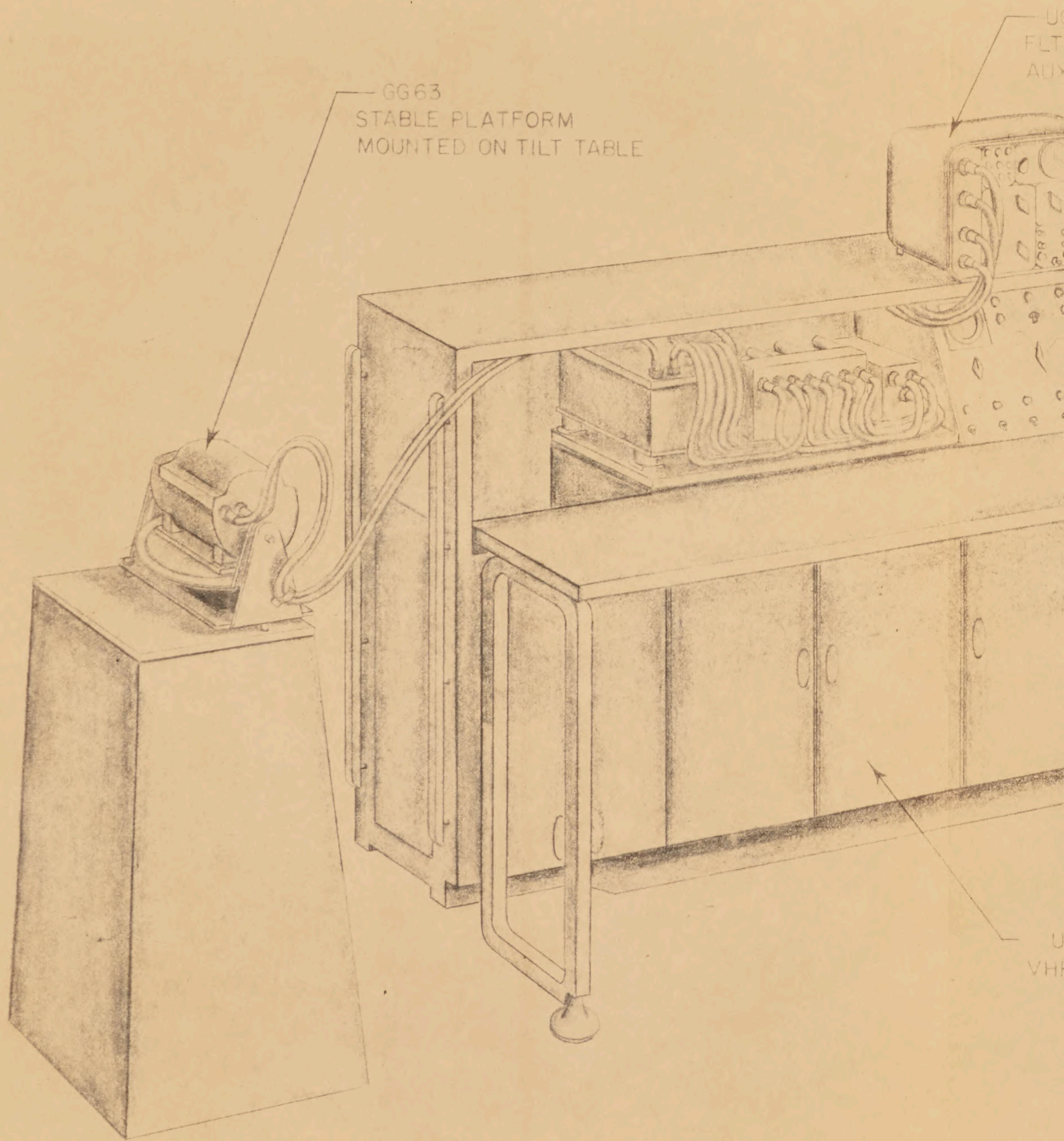
GG63
STABLE PLATFORM
MOUNTED ON TILT TABLE

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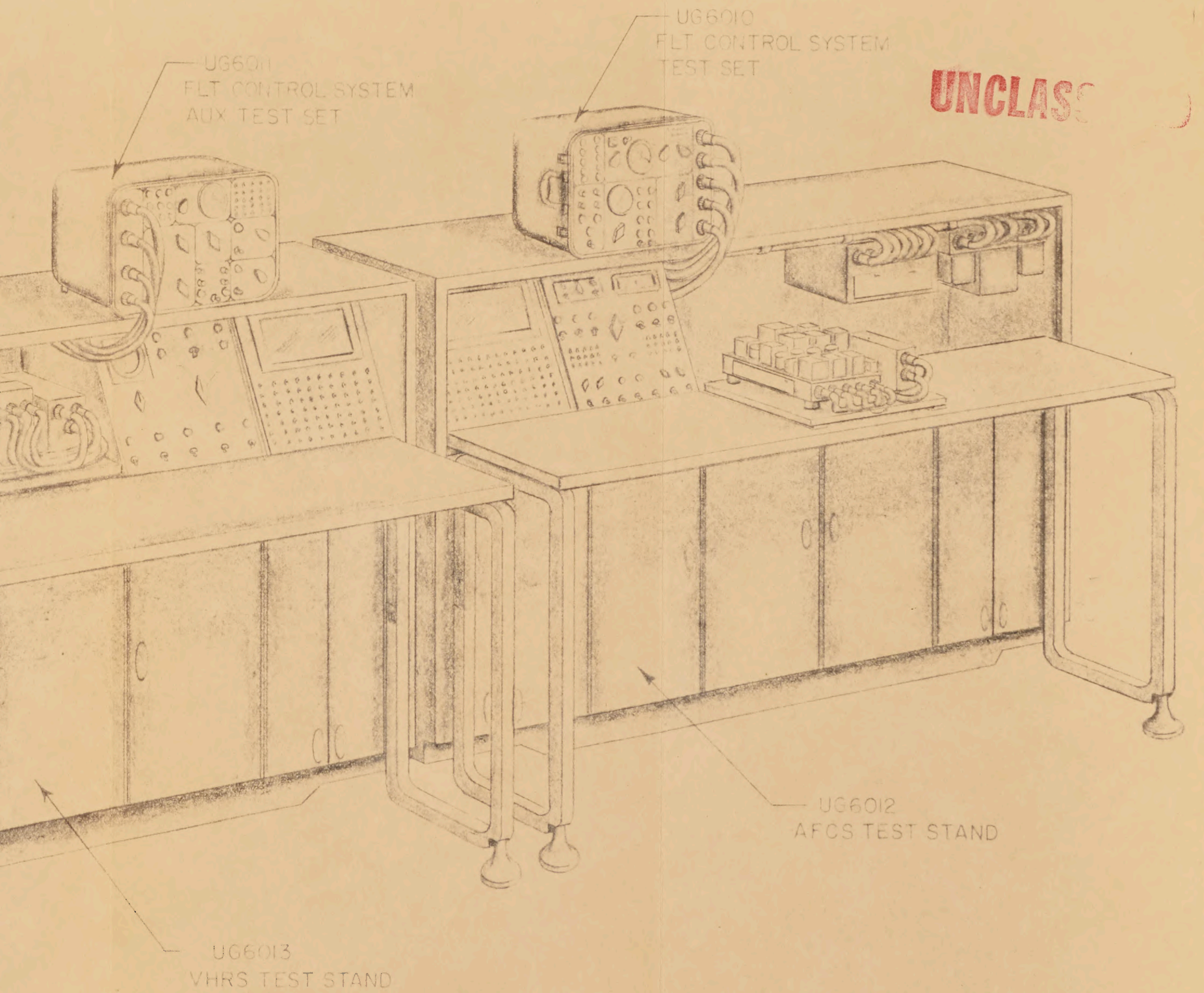

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