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TERMINATION REPORT
ON THE
BG93 AFCS AMPLIFIER CALIBRATOR

CR-ED 1058 June 1959

HONEYWELL
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TERMINATION REPORT

ON THE

6093 AFCS AMPLIFIER CALIBRATOR

Honeywell Controls
Military Products
Document CR-RD 1058.

June 1959

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FOREWORD

This report was prepared in accordance with the requirements of Contract CD/DRB 819009/0013/719-16-30-601 D.D.P. Serial Number 2-PF-8-13 as related to the Astra Automatic Flight Control System of the Avro Arrow.

Information on the related Function Selector is contained in Honeywell Controls Document CR-ED 1047, Astra Termination Report on the CG78 Panel Function Selector AFCS for the Astra System of the CF-105 Arrow Aircraft. It is recommended that this document be read in conjunction with the above.

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3 DESCRIPTION OF UNIT

3.1 General

3.1.1 Physical

The dimensions of the AFCS Amp Cal are 14.5 x 16.4 x 9.3 inches, including the mounting hardware. The calculated weight of the unit is 34 lbs.

The unit is attached to the shock-mounted portion of the mounting rack by two wing nuts. Six Pygmy bayonet-type connectors, ten adjustment potentiometers and test jacks J8 to J63 are mounted at the front of the unit, potentiometers and test jacks being normally under a hinged cover.

3.1.2 Electrical

The power inputs to the EG93 Amplifier Calibrator are 102 to 124 volts AC 400 ± 5% cps single phase and 26 to 30 V D.C. The signal outputs are the Roll and Pitch Axis signals to the Damper.

3.2 Component Parts

The D-EG93 Amplifier-Calibrator is an assembly of components fastened to a shock mounted chassis. The following components make up one D-EG93A-1 Amplifier-Calibrator.

Name	Quantity	Type No.
Transistor-Magnetic Amplifier	5	D-EG129A-1
Amplifier, Command Signal Limiter	1	D-EG152A-1
Characterizer, (qc)	1	D-DG33D-1
Signal Control, Heading	1	D-DG67A-2
Signal Control, Pitch	1	D-DG67A-3
Signal Control, Roll	1	D-DG67B-1
Signal Control, Lagged Pitch	1	AD-471802
Signal Control, Fader	1	D-DG68A-1
Signal Control, Engage Fader	1	AD-463550-1
Rack, Amplifier-Calibrator	1	D-QG92A-1

3.3 Theory of Operation

3.3.1 General

In the following the Automatic Flight Control System will be referred to as AFCS. The theory of operation will be described in terms of the

AFCS rather than in terms of its Amplifier-Calibrator, since very few additional components are involved and the gain in clarity resulting from a systems approach is appreciable.

3.3.1.1 AFCS Bridges - The AFCS has 2 control channels; on each for the control of the aircraft ailerons and elevators. Each channel consists of a series summing 400 cycle impedance bridge system. The operation of these bridges will be described for each of the applicable AFCS Modes.

3.3.1.2 Pre-Engage Configuration - The AFCS is operating in the pre-engage configuration when the Damper Function Selector Power Switch is on and the AFCS Function Selector Switch is in the Standby position. At this time AFCS Roll and Pitch bridges are continuously synchronized with the aircraft attitude signals received from the Platform Repeater.

3.3.1.3 Control Stick Steering Configuration (CSS)-The AFCS is operating in the CSS configuration when the AFCS is engaged and the Pilot is applying stick force. At this time the operation of the AFCS Roll and Pitch bridges is identical to the Pre-Engage configuration except for (1-cos Φ) and (SecΦ- 1) inputs to the Damper. The (1-cos Φ) signal is used to balance the normal accelerometer output when the aircraft is at some elevation angle other than zero. The up-elevator signal (Sec Φ-1) is used to maintain altitude when the aircraft is banking. These two signals provide pitch commands to the Damper in all AFCS Engage Modes except that in the Fire Control and Mach Hold modes, no up-elevator signal is fed to the Damper.

3.3.2 Aileron Axis

3.3.2.1 Heading Hold - Heading Hold is automatically selected when the pilot releases the Control Stick with the aircraft in a bank angle of 7.5° or less. At this time the Heading Synchronizer locks on to the reference heading and any aircraft deviation from the heading produces a signal which is fed through the Roll Synchronizer to the Damper. The Roll Synchronizer provides the bank limit function on all Heading Modes.

3.3.2.2 Bank Hold - Bank Hold is automatically selected

when the pilot releases the Control Stick with the aircraft in a bank angle of less than 63° and greater than 7.5°. At this time the Roll Synchronizer Locks-on to the reference bank angle and any aircraft deviation produces a proportional roll command which is fed into the Damper.

3.3.2.3 Automatic Ground Controlled Intercept or Navigation (AGCI) - The AGCI or Navigation Mode is engaged when the pilot selects the Auto-Steer Mode and the AFCS Coupler is receiving enabling signals from the Navigation Computer or the Data Link Coupler. At this time the aircraft is directed to the desired flight path vector by a heading error signal from the AFCS Coupler. This signal is fed through the Heading Synchroniser (which provides a lag in all Auto-Steer Modes except Fire Control) to the Roll Synchronizer. The Roll Synchroniser in turn feeds a roll command signal into the Damper and provides the bank limiting function.

3.3.2.4 Automatic Ground Controlled Approach (AGCA) - The AGCA Mode is engaged when the pilot selects the Auto-Steer Mode and the AFCS Coupler is receiving enabling signals from the Data Link Coupler. The operation is identical to AGCI except for the following:

a) In addition to receiving Heading error signals, the roll bridge receives roll command signals from the AFCS Coupler.

b) The bank limit fader control provides a smaller bank limit and further decreases the bank limit when the glide slope path is intercepted.

3.3.2.5. Fire Control - The inputs for the Fire Control mode are also obtained from the AFCS Coupler. The Fire Control Mode is engaged when the Pilot selects the Auto-Steer Mode and the AFCS Coupler is receiving enabling signals from the Fire Control Computer. At this time the flight path of the aircraft is controlled by roll command signals from the AFCS Coupler which are fed directly into the Damper. The remainder of the roll bridge is synchronized to the Platform Repeater signals as on Control Stick Steering and Pre-Engage.

3.3.3 Elevator Axis

3.3.3.1 Pitch Hold - Pitch Hold is automatically selected when the pilot releases the Control Stick with the aircraft in an elevation angle less than ± 55°. At this time the Pitch Synchronizer locks-on to the reference elevation angle and any aircraft deviation from the reference produces a proportional pitch command which is fed through the Lagged Pitch Signal Control to the Damper.

3.3.3.2 Altitude Hold - Altitude Hold is engaged when the Pilot selects this mode on the Function Selector. At this time the pitch bridge is synchronized to the reference altitude and any aircraft deviation from this reference produces a pitch command to the Damper consisting of the following signals:

a) A signal which is the sum of an altitude error and an altitude rate signal.

b) A signal which is obtained by feeding a portion of the above mentioned sum through the Pitch Integrator and the Lagged Pitch Signal Control.

3.3.3.3 Mach Hold - Mach Hold is engaged when the pilot selects this mode on the Function Selector. At this time the pitch bridge is synchronized to the reference Mach and any deviation from this reference produces a pitch command which is fed through the Lagged Pitch Signal Control and which consists of the following signals:

a) Mach error

b) A portion of mach error which is fed through the Pitch Integrator.

3.3.3.4 Automatic Ground Controlled Approach (AGCA) - The inputs for this mode are obtained from the AFCS Coupler. The AGCA model is engaged when the pilot selects the Auto-Steer Mode, the AFCS Coupler is receiving enabling signals from the Data Link Coupler, and the glide slope is intercepted. At this time the flight path of the aircraft is controlled by Pitch Command Signals from the AFCS Coupler. The pitch command signal consists of an AGCA Pitch Signal Control and fixes the rate of descent of the aircraft and an AGCA displacement signal which holds the aircraft on the desired glide slope path.

3.3.3.5 **Fire Control** - The Fire Control Mode is engaged when the pilot selects the Auto-Steer Mode and the AFCS Coupler is receiving enabling signals from the Fire Control Computer. At this time the flight path of the aircraft is controlled by pitch command signals from the AFCS Coupler which are fed directly into the Damper. The remainder of the pitch bridge is synchronized to the Platform Repeater signals as on Control Stick Steering and Pre-Engage.

3.3.4 Engagement

It is impossible to engage the AFCS unless the Normal Damper is engaged, the YG709A-2 Vertical and Heading Reference System is energized and ready for automatic operation, and the AFCS roll and pitch bridges are properly synchronized with aircraft attitude and the command signal limiter output is zero.

4 DESCRIPTION OF PARTS

4.1 Main Assembly, D-EG93

The Amplifier Calibrator is an assembly of components which mounts on a shock mounted chassis. It provides the calibration potentiometers for adjusting the parameters in the bridge circuitry to obtain desired aircraft response and performance. Test points are furnished for trouble shooting purposes and making measurements. A separate description of the sub-components is given below:

4.2 Sub-assemblies

4.2.1 Transistor-Magnetic Amplifier, D-EG129A-1

The transistor-magnetic amplifier provides the power for the signal controls and the D-DG33D-1 Characterizer.

The amplifier consists of two stages of voltage amplification followed by a full wave discriminator which drives a self-saturating magnetic amplifier with a full-wave push-pull output.

4.2.2 Amplifier, Command Signal Limiter, D-EG152A-1

The amplifier is used to limit the pitch command signals to the damper, and consists of full wave diode networks followed by a transistor-amplifier with push-pull output. Its inputs consist of the pitch command signal and the reference signals which are scheduled with angle of attack, altitude, and dynamic pressure.

4.2.3 qc - characterizer, D-DG33D-1

The qc servo drives synchro to null input. The characterizer consists of 7 potentiometers, motor driven by the output from an EG129A-1 amplifier which in turn receives its inputs from the Air Data Computer. The unit consists of a motor, velocity generator, gear train, slip clutch, angular position potentiometer, and 6 scheduling potentiometers having gain scheduling functions as follows:

1. Roll Command to Damper
2. Pitch Command to Damper
3. Positive Reference Signal to Command Signal Limiter.

4. Lagged Pitch Attitude Gain
5. Altitude Gain
6. Negative Reference Signal to Command Signal Limiter.

4.2.4 Heading Signal Control, D-DG67A-2

The Heading Signal Control consists of a motor, velocity generator, gear train, and synchro output. The unit responds to signals from a synchro transmitter in the Platform Repeater and provides the synchronization function for the attitude hold modes. The unit also responds to signals from the AFCS Coupler and provides a lag in the Auto-Steer modes.

4.2.5 Pitch Signal Control, D-DG67A-3

The Pitch Signal Control consists of a motor, velocity generator, gear train, and synchro output. The unit responds to signals from a synchro transmitter in the Platform Repeater and provides the synchronization function for the attitude hold modes. It also serves to provide an integration on Mach and Altitude Hold.

4.2.6 Roll Signal Control, D-DG67B-1

The Roll Signal Control consists of a motor, velocity generator, gear train, clutch mechanism, and synchro output. The unit responds to signals from a synchro transformer and provides the synchronization function for the attitude hold modes. The unit also operates with the Fader Signal Control to provide the Bank Limit function. The synchro output shaft travel is controlled by mechanized stops.

4.2.7 Lagged Pitch Signal Control - AD 471802

Lagged Pitch Signal Control consists of a motor, velocity generator, gear train, clutch mechanism, sector switch and synchro output. The unit provides a lag for the pitch command signal on all attitude hold modes. The unit also performs an Anti-Engage Function by sensing error signals from the Compass, Pitch, and Roll Synchronizers, and the Command Signal Limiter Output. The Synchro output shaft travel is controlled by mechanized stops.

4.2.8 Fader Signal Control, D-DG68A-1

The Fader Signal Control consists of a motor, gear train, clutch mechanism, 2 sector switches, and an output potentiometer. This unit provides the Bank Limit function and also provides for fading action between bank limits.

4.2.9 Engage Fader Signal Control, AD463550-1

The Engage Fader Signal Control consists of a motor, gear train, clutch mechanism, limit switches, sector switch, and two potentiometers. The unit performs a dual fading action when the AFCS is engaged. It fades out the Damper Pitch Trim signal and fades in the AFCS Pitch Command.

5 PERFORMANCE

5.1 Predicted Performance

The performance specifications, regarding the three synchronizer servos and the Lagged Pitch Attitude servo were as follows:

a) Heading Synchronizer

Follow-up rate Output Shaft: 10°/sec with less than 1° lag.

Resolution: 1/15°
Angular Accuracy: .5°
Gear Train: 3294:1

b) Pitch Synchronizer - Integrator

Follow-up rate, Output Shaft: 20°/sec. with less than 1° lag.

Resolution: 1/20°
Angular Accuracy: .5°
Gear Train: 1600:1
Used as an integrator shall be capable of having an output of .2 volts/sec for a 1 volt input.

c) Roll Synchronizer

Follow-up rate, Output Shaft: 150°/sec with less than 5° lag.

Resolution: 1/15°
Angular Accuracy: .5°
Gear Train: 207:1
By adjusting velocity generator feedback and/or input connections the roll synchronizer shall be capable of running at a rate of 144°/second.

d) Lagged Pitch Attitude

Time constant adjustable from 1 to 2 seconds by varying velocity generator feedback. May be scheduled as a function of qc Gear Train - 3294:1

An additional facet of performance is the fail-safety improvement obtained by virtue of utilizing series-running bridge networks in both Pitch and Roll channels.

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Resolution: 1/20°
Angular Accuracy: .5°
Gear Train: 1600:1
Used as an integrator shall be capable of having an output of .2 volts/sec for a 1 volt input.

c) Roll Synchroniser

Follow-up rate, Output Shaft: 150°/sec with less than 5° lag.

Resolution: 1/15°
Angular Accuracy: .5°
Gear Train: 207:1
By adjusting velocity generator feedback and/or input connections the roll synchronizer shall be capable of running at a rate of 1440°/second.

d) Lagged Pitch Attitude

Time constant adjustable from 1 to 2 seconds by varying velocity generator feedback. May be scheduled as a function of qc Gear Train - 3294:1

An additional facet of performance is the fail-safety improvement obtained by virtue of utilizing series-running bridge networks in both Pitch and Roll channels.

5.2 Actual Performance

No data is available on the actual performance of the AFCS because the ARROW programme was cancelled before tests could be performed.

6 PRESENT STATUS AT CUT-OFF

The six developmental models of the BC93 Amplifier Calibrator were in the process of fabrication. Test connections were provided although provision for completely testing the unit could not be provided on the early models. The models completed and the component parts are now in storage in Minneapolis awaiting the disposal instructions from the prime contractor.

7 PROPOSED FUTURE PROGRAMME

The programme is completed and it is anticipated that no further work will be performed on it.

8 CONCLUSIONS

The work on the AFCS represented a high degree of liaison between AVRO Aircraft Limited, RCA Camden, New Jersey and Honeywell Controls Limited, Toronto. Unfortunately the experience gained on this programme cannot be put to any immediate use in Canada.