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Automatic Pilot Installations

RATIONALE

This Technical Report contains no changes from the previous revision, other than the addition of a Stabilization Notice Page. This document has been determined to contain stable technical information which is not dynamic in nature.

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FOREWORD

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1. SCOPE:

These recommendations cover the mechanical and electrical installation and installation test procedures for automatic pilots of the type normally used in transport type aircraft. The material in this ARP does not supercede any airworthiness requirement in the Civil Air Regulations.

1.1 Purpose:

This Aeronautical Recommended Practice is intended to outline Automatic Pilot installation design, performance, and test recommendations for use as a guide by the aircraft industry.

2. REFERENCES:

"Design Manual on Aircraft Electrical Installations - Available from: Aircraft Industries Assn., 610 Shoreham Building, Washington 5, D.C.

Specification MIL-W-5088B (ASG) "Installation of Aircraft Wiring" - Available from: Commanding Officer, U.S. Naval Air Station, Johnsville, Pennsylvania

Specification MIL-E-7894A (ASG) "Characteristics of Aircraft Electric Power" - Available from: Commanding Officer, U.S. Naval Air Station, Johnsville, Pennsylvania, Attention: Technical Records Division

Civil Aeronautics Manual 4 "Aircraft Airworthiness" - Available from: The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

Specification ANC-5 "Strength of Metal Aircraft Elements" - Available from: The Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C.

SAE Aeronautical Standard AS402A "Automatic Pilots" - Available from: Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE Aeronautical Recommended Practice ARP268A "Location and Actuation of Cockpit Controls for Commercial Transport type Aircraft" - Available from: Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, PA 15096-0001.

RTCA Paper 151-56/DO-74 "Automatic Flight" - Available from: Radio Technical Commission for Aeronautics., Room 2036, Building T-5, 16th & Constitution Ave. NW, Washington 25, D.C.

2.1 Glossary of Terms:

AIRSPEED CONTROL: A function, or mode of operation, which provides constant airspeed by regulating the throttles in response to signals from an airspeed sensor.

AIRSPEED SENSOR: A device which provides output signals proportional to airspeed pitot-static pressures.

2.1 (Continued):

ALTITUDE CONTROL: A function, or mode of operation which provides constant altitude by controlling the pitch attitude of the aircraft in response to signals from an altitude sensor.

ALTITUDE SENSOR: A barometric device which provides output signals proportional to the deviation from a reference pressure-altitude.

ATTITUDE GYRO: A gyroscope which provides an output signal which is a measure of the aircraft's attitude with respect to a gravitational reference. (Also called vertical gyro)

CONTROL VALVE: A valve used to control the fluid flow of a hydraulic type servo. It operates in response to signals from a controller, selector, or sensor. (Also called a Boost Control Valve, or Power Boost Control Valve).

CONTROLLER: A device which permits the human pilot to initiate Turn, Pitch, and Bank Signals in the Automatic Pilot.

FOLLOW-UP CONTROL UNIT: A device which provides an output signal proportional to the displacement, or rate of movement, of that which is being driven by the servo. (Also called a Feedback or Repeatback Control unit.)

FOLLOW-UP SIGNAL: A signal produced by a Follow-Up Control unit. (Also called a Feedback or Repeatback Control Unit.)

FUNCTION SELECTOR: A device which permits the human pilot to select automatic pilot functions or modes of operation.

GLIDE PATH: The path used by an aircraft in approach procedures as defined by an instrument landing facility.

GLIDE SLOPE: An included path in space which is defined by radio signals emanating from an instrument landing facility.

LOCALIZER: A radio facility which provides signals for use in lateral guidance of aircraft with respect to a runway centerline.

OVERSHOOT: Movement of the aircraft whereby it coasts past the commanded reference altitude, attitude, or flight path before settling out.

RATE GYRO: A gyroscope which provides an output signal proportional to the turning rate about a given axis.

SERVO: The actuating device which positions the aircraft control surfaces in response to a commanded signal from a controller, selector or sensor. (Also called a servomotor or servo actuator.)

2.1 (Continued):

SERVO ENGAGE DISENGAGE: The process of connecting or disconnecting the servo motor and gear train from the cable drum or sector through a mechanical or electrical clutch in the servo.

SERVO OVERPOWER: The act of overpowering the servo by applying an appropriate pilot force at the control column or rudder pedals.

SIGNAL: A measure or quantity of the medium used to communicate a condition, effect, or other desired intelligence from one point in the system to another. In an electrical system this may be a voltage; in a hydraulic system, a pressure. A signal may be generated by a sensor, controller or selector or other such reference device.

THROTTLE CONTROL: A function or mode of operation which provides power or throttle control in response to pitch attitude, glide slope, or airspeed signals.

TRANSIENT: A temporary deviation of the aircraft from its normal attitude produced by momentarily overpowering the automatic controls or by momentarily injecting a signal to cause a deviation.

TRIM INDICATOR: An instrument used to indicate the relative amount of servo effort being used to maintain the aircraft trim.

UNDERSHOOT: Movement of the aircraft whereby it stops short of the commanded reference altitude, attitude or flight path, before settling out.

3. GENERAL REQUIREMENTS:

3.1 Equipment:

The automatic pilots referred to herein should conform to Aeronautical Standard AS402A.

3.2 Materials:

Materials should be of a quality which experience and/or tests have demonstrated to be suitable and dependable for aircraft use.

3.3 Workmanship:

Workmanship should be consistent with high grade aircraft manufacturing practice.

3.4 Environmental Conditions:

The design of the installation should be such that satisfactory performance may be obtained under the environmental conditions to which the aircraft may be subjected.

3.5 Installation Survey and Component Selection:

In order to provide information relative to the aircraft aerodynamic and structural characteristics, an "Installation Survey" form is included as Appendix "A" of this ARP. The aircraft manufacturer should, to the best of his ability with respect to the aircraft design status, supply the automatic pilot manufacturer with the information called for on this form. Along with this survey the aircraft manufacturer should also specify any automatic pilot component characteristics which may be deemed necessary to provide a closer integration of the automatic pilot with the basic aircraft control system.

On the basis of this information, the automatic pilot manufacturer should then design, select, and combine the necessary components into a comprehensive system which can be expected to perform the desired and necessary functions in accordance with AS402A, and not induce aerodynamic or structural loads in excess of the design limits specified by the aircraft manufacturer. Final values of maximum servo forces and signal calibration should be checked and determined on the basis of flight tests of the initial installation.

4. DETAIL REQUIREMENTS:

4.1 Mechanical:

4.1.1 Control Surface Actuators (Servos):

- 4.1.1.1 Location and Mounting: The location and mounting of the servo should be carefully considered from the standpoint of control system friction, preloads, lost motion, and other such characteristics which would tend to cause automatic control difficulties.

Locations should also be chosen to permit the shortest practicable connecting cables or links. Adequate clearance should be provided between the moving parts of the servo and adjacent structure to prevent possible jamming by foreign objects.

The servo mounting bracket should be designed with sufficient rigidity to prevent any detrimental deflection under conditions of maximum servo force. The use of vibration isolators should not be considered.

- 4.1.1.2 Connections and Rigging: The servo should be connected to the main control system so that it will produce uniform force and displacement in both directions of operation. In servo installations utilizing cable control, a parallel cable installation is preferred over the series installation. Cable installations designed for direct attachment to a bell crank or surface horn should be made through a suitable sector designed as an integral part of the horn or bell crank. The design of the sector should be such that full travel of the control system will provide a negligible change in servo cable tension. Where the cable runs over the servo drum, and has an angular motion with respect to the plane of the drum, the maximum misalignment resulting from this motion should not exceed 1 degree for the neutral position of the controls nor 3 degrees for any position between half and full movement of the controls. Each servo cable keeper should be positioned as close as possible to the point of tangency between the servo drum and cable.

4.1.1.2 (Continued):

Care should be taken in the design of the cable routing to prevent the possibility of foreign objects from lodging between the cable and the drum. If necessary, a suitable guard should be installed.

All control routing to the servos should be designed such that the minimum amount of friction will be added to the aircraft control system. Cabling details should be consistent with the general design practices which have been carried out in the manual control system. (See references 4 and 5).

4.1.2 Engaging Systems:

4.1.2.1 Cockpit Controls: If mechanical engaging and/or disengaging is utilized, the cockpit control handle should be so located that it is readily accessible to both pilot and copilot and as close to the flight controller and as distinctive in method and direction of operation as practicable. Forward or upward motion of the cockpit control should engage the automatic pilot system while motion in the opposite directions should disengage. (If engaging and disengaging is accomplished electrically the motion of the control switch handle shall be similar.) If necessary, the control handle should be provided with suitable guard to prevent inadvertent operation of the automatic pilot. The handle should be so located to enable a force not to exceed 35 pounds to be readily applied.

4.1.2.2 Cables or Rod Controls: All Control Cables and/or Control Rods used in a mechanical engaging system should be routed that they provide the minimum of friction. A maximum load of 35 pounds should be presented to the pilot at the cockpit control. This load should be the total of the friction plus disconnect load.

4.1.3 Follow-up Controls:

4.1.3.1 Location: To permit the minimum of lost motion or deadspot to be maintained in the connecting linkage the follow-up control unit, if not a part of the servo, should be located in the control cable system as near as possible to the servo drum or other portion of the control system, the movement of which is being measured.

4.1.3.2 Connection and Mounting: Follow-up control units may be mounted in any position, but provisions should be made to enable either the shaft or the housing of the unit to be rotated for orientations of the electrical signal element. Connections should be made to the control system by means of push-pull rods and ball joints, control cables, or other suitable means which will transmit motion of the control system to the follow-up control unit shaft without lost motion. The connecting linkage should be such that the movement of the control system through its full travel will rotate the follow-up control shaft safely within the limits of its mechanical range, and in a manner compatible with system requirements (e.g., a linear or non-linear function).

- 4.1.4 Control Valves and Piping: Electro-hydraulic control valves should be located immediately adjacent to their respective hydraulic boost or power control valves on the pilot's side of the boost, where applicable. They should be mounted securely in such a manner so as to prevent misalignment and/or twisting of any actuated parts.

All hydraulic piping and valves should be kept out of the cockpit area and away from oxygen lines or equipment, wherever possible.

- 4.1.5 Reference Components and Amplifiers: Accelerometers, pendulums, rate and displacement gyros, or other such reference devices should be installed such that their orientation, and location with respect to the aircraft's axes and center of gravity, will be in accordance with the manufacturer's recommendations.

The altitude sensor should be located as near as practicable to the source of static pressure, and suitably shock-mounted and oriented in a manner to preclude any undesirable effects of vibration and acceleration.

Amplifiers and coupling units should be mounted so as to allow accessibility to all tap switch or potentiometer adjustments.

- 4.1.6 Controller and Function Selector Panel: These units should be situated side by side and located in a position that is visible and readily accessible for operation by both pilot and copilot in their normal positions. The axes of the controller knobs or wheels should be oriented with those of the aircraft.

The function selector panel should be adequately lighted for night use. Where toggle switches are used, the function should be switched "ON" by a forward, or upward motion of the switch handle.

4.1.7 General:

- 4.1.7.1 Mounting Brackets: All mounting brackets should be designed to provide adequate strength, freedom from vibration and flexing that would interfere with the satisfactory operation of the automatic pilot under any flight conditions encountered in service.
- 4.1.7.2 Ventilation: All components should be installed in accordance with the temperature requirements of the equipment. If it is impossible to so locate the equipment in the aircraft which has temperature similar to that required, then provisions to direct cooling air to this equipment must be made.
- 4.1.7.3 Safety: All attaching fittings and fasteners such as bolts, nuts, clevis pins, etc., if not of the self locking type should be locked with safety wire or cotter pins.
- 4.1.7.4 Bonding: The chassis or mounting frames of all components should be electrically bonded to the aircraft structure. All mating surfaces which conduct a ground return should be clear of paint, anodized coating or other non-conducting materials.

- 4.1.7.5 Shock Mounts: The installation of connectors and connecting cables should be designed to minimize the effect of their added weight on vibration-isolated equipment. This item assumes greater importance where light-weight components are shock-mounted and the added weight of the attached cable and connector constitutes a significant part of the shock-mount load.

4.2 Electrical:

- 4.2.1 Power Supplies: The design of the electrical installation and the selection of the power supply components should conform to the best aeronautical practice and shall have ample capacity for cold starts to be encountered in service. Intermittent loads, other than the automatic pilot should be carefully considered with regard to automatic pilot performance. Where variations in voltage and frequency critically affect automatic pilot performance indicating meters should be provided for these functions.

- 4.2.1.1 A.C. and D.C.: Voltages and frequencies supplied to the automatic pilot should be in accordance with its established design ratings.

- 4.2.2 Wiring: Connections should be made in accordance with the wiring diagrams supplied by the automatic pilot manufacturer. Power leads and circuit protective devices should be installed in accordance with standard practices or as recommended by the automatic pilot manufacturer.

Electrical cabling and wiring should be adequate to meet such requirements as maximum allowable voltage drop, lead resistance, and current as recommended for the automatic pilot installation. References 1 and 2 may be used as a guide for aircraft wiring.

- 4.2.3 Shielding and Grounding: Strict conformance to the shielding recommendations supplied by the automatic pilot manufacturer should be followed in all installations to eliminate any possibility of spurious control signals. Where shielding is grounded at specified locations, the signal leads should be enclosed in sleeving to insulate the shielding from other circuits and ground contacts with the aircraft structure.

- 4.2.4 Switches, Signal Devices, and Interlocks: These items should be installed and electrically interconnected into the system, in accordance with the instructions of the automatic pilot manufacturer to insure that adequate protection of the aircraft and the automatic pilot is maintained.

- 4.2.5 Engaging System:

- 4.2.6 Cockpit Control: Both pilot and copilot should have an electrical push button for instant deactivation of all servos. Each switch should be located on the wheel side opposite the throttle hand. The electrical power or Autopilot "ON-OFF" switch should be located in a position easily accessible to both pilots.

4.3 Maintenance:

- 4.3.1 Accessibility: Ready access should be provided for service points such as lubrication, adjustment, dehydrators, and other items requiring attention while the automatic pilot is installed in the airplane. Units requiring frequent replacement should be located to provide for ease of removal. The installation of such units behind stress panels, and other units which require prior removal for access should be avoided wherever possible. Where units are located behind non-stressed panels, the use of quick-fasteners is recommended for attaching the panel.
- 4.3.2 Clearances: Adequate clearance should be provided for:
- (1) Normal movement of the unit during flexing of shock mounts.
 - (2) Removal of electrical or mechanical connections.
 - (3) The use of tools required for removing and installing attachments.
 - (4) Removing the unit completely from the aircraft, through openings and around other items.
- 4.3.3 Replaceability: Location of mounting nuts, bolt holes, and other such fasteners that are required should be governed by the tolerances of the matching unit being installed. The alteration of a component to match the aircraft fittings should be avoided in the interests of interchangeability. Where shims are required to align the unit they should be attached to, and become a permanent part of the aircraft. Use of the following devices is recommended wherever possible to facilitate replaceability:
- (1) Vibration-proof nuts.
 - (2) Nut plates attached to mounting brackets.
 - (3) Mounting subplates equipped with quick fasteners.
 - (4) Electrical disconnect plugs in lieu of terminal strips. (Except in low current carrying circuits such as those found in the compass transmitter leads in which case the number of disconnect plugs should be kept to a minimum.)
- 4.3.3.1 Hardware: The use of standard aircraft hardware ("AN" or "NAS") is recommended wherever possible.
- 4.3.4 Interchangeability: All components of a like type and function should be interchangeable with no further field modifications or internal adjustments at the time the unit is installed.

4.3.4 (Continued):

Where external adjustments are required to permit components to be used in different type aircraft or different portions of the system, it is recommended that instructions for making the adjustment be placed on the unit wherever possible. Where two units appear identical but produce different operating characteristics which, if misplaced, would tend to cause malfunctioning, means should be provided, such as dowel locating pins, or other such devices to physically prevent the components from being improperly installed. Where two or more components, having different functions but possessing identical connectors, are adjacent, means should be provided to physically prevent crossed connections. Example: Two different gyro units or servo units located side-by-side and having the same type of electrical connectors. Each connector cable should be clamped close enough to the proper unit to prevent it from being cross connected to the wrong unit. The use of placards, color coding, and other marking can be used but should not be relied upon for complete protection.

4.3.5 Field Tester Provisions: Consideration should be given for providing suitable test receptacles for the attachment of field test equipment without removal of the units under test.

5. TESTS:

The manufacturer's recommendations regarding any special test equipment required, and specific tests to be performed, should be utilized in conjunction with the following:

5.1 Ground Tests:

5.1.1 Mechanical Installation:

- 5.1.1.1 Mounting: All component mounting bases and brackets should be inspected for security of attachment to the basic structure and the components themselves for security of attachment to their respective mounting bases. Servo mounting brackets should be inspected under maximum load conditions for any excessive flexing or deformation.
- 5.1.1.2 Rigging: All servo cable leads and linkages should be checked for proper tension tightness and inspected for clearance and friction through the full throw of the controls. Turnbuckles and fittings should be checked for safetying and tightness.
- 5.1.1.3 Static and Dynamic Pressure Source Leak Test: The static and dynamic pressure systems to which the air data sensors are connected should be tested for leaks by use of a sensitive manometer and suitable fittings. Test pressures should be determined for the particular installation depending on whether or not cabin pressurization exists on the aircraft.

CAUTION: EVERY PRECAUTION SHOULD BE TAKEN TO PREVENT DAMAGE TO THE SENSITIVE DIAPHRAGM MECHANISMS OF THE DATA SENSORS.