Bendix Fluid Power Division

Report No. 8720-3173U
Component Improvement Program
Task 83-01
36E133 Air Turbine Starter
February, 1986
Contract No. N00019-80-G-0607-XU04

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Component Improvement Program
Task 83-01
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Prepared for:
Department of the Navy
Naval Air Systems Command
Washington, DC

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SCOPE

This report describes the analysis and results of the first half of Task 83-01, "Solid State Electronic Cutout Switch for the 36E123 (A-29) and 36E133 (A-28) Starters", conducted in accordance with NAVAIR Contract No. N00019-80-G-0607-XU04.

All analysis and initial phase testing was performed by the Engineering Department of Allied Signal Corporation, Bendix Fluid Power Division at Utica, New York.

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1.0 INTRODUCTION

The subject air turbine starters (ATS), Bendix Type 36E133 ATS and Type 36E123 ATS were designed to comply with MIL-S-19557, 8 and 9, respectively. The automatic cutoff control for both starters, as permitted by Paragraph 3.5.7 of the aforementioned specification, was designed to sense the speed of the starter's output drive. The existing control is a fly-weight type governor which acts to open an electrical switch at the predetermined cutout speed.

While the device has some definite advantages, field service has demonstrated that they are overridden by the following:

- The location of the governor (buried in the front end of the starter) makes it very difficult to service in the field.

- The mechanical elements are negatively influenced by the vibrational environment of the starter and engine.

- The electrical leads, which must be snaked through "tortuous" paths and small holes from the external connector to the switch, has caused insulation to be stripped from the leads, shorting out the switch.

In the recent past, Bendix has designed and developed an electronic solid-state "cutout switch" for turbine starters. This totally electronic device, typically monitors starter turbine speed and acts to terminate the start cycle at the turbine equivalent to the specified cutout speed.
These electronic devices are potted to isolate the components from environmental affects and the devices can be mounted externally of the starter to permit easy replacement, if necessary, or to put them in an environmentally favorable location.

Field experience has demonstrated that these electronic cutout switches are far superior to the mechanical devices.

The effort described herein was performed to adapt an existing, service proven, switch to the 36E133-4A starter, S/N 1501, supplied by the NAVY. The new starter configuration is a 36E133-6A (reference Figure 3).
2.0 TASK DESCRIPTION

2.1 Objective
Replace mechanical cutout switch with a solid-state electronic cutout switch to improve accuracy and reliability of the automatic start cycle termination in the S-3A and F-14A aircraft.

2.2 Work Statement
The program consisted of the following steps:

1. Evaluate feasibility of adapting a production Bendix solid state electronic switch for this application.

2. Propose design changes necessary to adopt electronic switch.

3. Prepare detail drawings of proposed switch and modified/new parts.

4. Fabricate one set of parts for test evaluation. Would include breadboard switch assembly.

5. Run development test on breadboard system.

6. Fabricate cutout switch mockup and check installation of starter on aircraft.

7. Complete design changes/detail drawings of proposed switch.
8. Fabricate final design of switch and associated hardware. (Reference Appendix 2).

9. Perform qualification test on final design. Test would include environmental tests.

10. Prepare final reports, to include ECP submittal.
3.0 ANALYSIS

The 36E133-4A starter (see Figure 1) is the latest Bendix configuration starter being used on the F-14A aircraft. This starter has a fly weight governor-type cutout (c/o) switch. (See Figure 2).

A more recently designed Bendix starter, currently in use on the KC-135R aircraft re-engined with the CFM56-2 engine, uses an electronic cutout switch on a highly similar turbine and gear reduction system. The high degree of similarity between this starter and the subject starters (36E123 ATS and 36E133 ATS) make the electronic device a prime candidate for adapting to subject units.

3.1 The following is a list of advantages of the electronic cutout switch over the mechanical/governor type cutout switch.

3.1.1 The electronic switch selected for the 36E133 starter is the same proven circuit presently being used on the Bendix KC-135R starter. Only a minor resistor change needed to be made.

3.1.2 The electronic cutout switch is bench set and tested easily and accurately before being installed in the starter. Conversely, the mechanical switch normally requires an adjustment involving a disassembly of the starter output spline. This is an unreliable, awkward and time consuming procedure.
3.1.3 The electronic device provides a positive, sharp and consistent break in the electrical circuit, while that provided by the mechanical governor is highly influenced by the varying friction of it's mechanical components.

3.1.4 Should the electronic switch need to be replaced, that can be done easily without removing the starter from the engine.
4.0 ELECTRONIC SWITCH DESCRIPTION

The function of the cutout switch is to terminate the start cycle at a predetermined speed. An electromechanical speed sensing device is used to terminate the start cycle. The device is similar to many we have and are currently providing on other military aircraft start systems. Experience has demonstrated that the electronic devices are more reliable than the mechanical, lightweight devices.

The device consists of the following major elements:

- An electric relay - aircraft power is connected to the contacts only. The relay coil is powered by a small fixed stator coil generator in the starter.

- A single pole, magnet-fastened to the starter turbine shaft, rotated in the generator stator coil.

- A small electronic package - also powered by the generator, encapsulated in a potting compound and mounted in a small metal box, fastened to the starter gear housing. (See Figures 3, 4 and 5).

In operation, airframe power is applied to the starter control valve through the normally closed contacts of the relay. This arrangement permits the use of existing airframe wiring.

The small generator incorporated in the starter manifold produces an electric output in terms of power and frequency that is a direct function of turbine rotative speed and is more than ample to power the circuit and relay.
The output of the generator is directed to the electronic package through a short length of shielded cable furnished with the starter.

The output of the generator:

- Powers the electronic circuit in which the instantaneous turbine speed in terms of frequency is compared to a frequency equivalent to starter cutout speed.

- Powers the coil of the relay (normally de-energized - see Figure 6) when the electronic circuit switches it on at cutout speed.

Essentially, a part of the circuit develops a fixed pulse signal, whose frequency is equivalent to starter cutout speed relative to the starter turbine. This signal is compared to the varying frequency equivalent to the instantaneous turbine speed.

When that signal from the turbine is equal to, or less than that of the fixed pulse generator, the relay is switched on, opening the airframe circuit to the starter valve and terminating the start cycle. The relay will remain "on" with its contacts open for a short period as the starter turbine begins to coast down in speed. Latching circuits typically provided in the airframe prevent inadvertent recycling of the starter.
5.0 CONCLUSIONS

5.1 The existing electronic circuit can be used for the 36E133/123 with only a minor resistor change to accommodate the subject unit's cutout speed.

5.1 Breadboard testing was successfully completed and satisfactorily demonstrated feasibility.

5.3 The suitability of the configuration selected was demonstrated by a successful mock-up on F-14A at Oceana Naval Air Station.

5.4 A failure, which occurred at about the eight hundredth cycle of a two thousand start cycle test, was not the fault of the cutout switch. The switch was found to be in excellent condition.

5.5 The electronic switch is available to complete the endurance evaluation program.
6.0 RECOMMENDATIONS

6.1 Accept that steps 1 through 8 of the work statement (reference para. 2.2, pg. 3) have been satisfactorily completed.

6.2 Complete the remaining defined test program, using the starter that will be employed in accomplishing the objectives of TASK 85-01, Bearing Improvement, as the test vehicle.
APPENDIX 1

FIGURES 1 through 6
Figure 2 - 36E133-4A Governor
Type: Cutout Switch
P/N 2491553 Assembly
FILL BOX WITH "EMERSON" AND LUMINOS STYCAST

*2651 RESIN & CATALYST II
PER ESI-01382 - FILL TO TOP OF STIFFENER

BOND IN PLACE
(SEE NOTE)

BOND AS FOLLOWS:
APPLY THIN COAT OF 3M TYPE EC1357 TO BONDING SURFACES OF BOTH PARTS - PRESS FIRMLY TOGETHER

CONNECTION AS SHOWN AND TEST PER TS-11142 BEFORE FILLING WITH "STYCAST"
APPENDIX 2

PARTS LISTS
### Reworked Parts for 36E133-6A ATS

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### New Parts for 36E133-6A ATS

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### ATS Parts

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