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CONTINUOUS SPARK IGHITION FOR RAPID RELIGHT AFTER FLAMEOUT OF GAS TURBINE ENGINES.

John J. Rose
Propulsion Laboratory

WADEC-TR-51-64

STATEMENT #5 UNCLASSIFIED

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I. PURPOSE

1. To present information regarding results attained in efforts to establish rapid relight of gas turbine engines after flameout with continuous operation of the spark ignition system.

II. FACTUAL DATA

1. The in-flight flameout of gas turbine engines, in many instances, is the result of transient reductions in engine airflow caused by many possible conditions such as particular aircraft maneuvers, contamination of intake airflow by exhaust products of self-propelled ordnance launched from aircraft, and severe ice ingestion by the engine. If the aircraft loses altitude or flight speed due to the engine flameout, or must be piloted to lower altitude in order to relight the engine, the mission of that particular aircraft is either compromised or completely aborted.

2. The first major effort on rapid relight of gas turbine engines appears to have been accomplished by the British. In early 1956, Proteous engines of the Bristol Britannia Commercial Aircraft experienced flameout while flying through heavy precipitation of small ice crystals at very low air temperature. The British were successful in obtaining rapid relights under these icing conditions by inserting into the combustion chamber of the Proteous engine, a platinum glow plug. Apparently the platinum rod is heated to incandescence during normal engine operation, and this heat is retained sufficiently after flameout to relight the engine. The catalytic effects of platinum upon mixtures of hydrocarbon fuels and air probably aid the relight process also; British references are listed in Appendix A.

4. The Propulsion Laboratory, Wright Air Development Center, approached the rapid relight problem quite differently than the British. In late 1957, the continuous use of spark ignition, or intermittent use of spark ignition during critical periods of flight was proposed as the most straightforward method for rapid relight of gas turbine engines. The Propulsion Laboratory itself was unable to perform rapid relight testing due to limited engine test facilities. Arnold Engineering Development Center (AEDC) undertook rapid relight tests on a YJ79-GA-3A engine at the request of the Propulsion Laboratory. Tests were conducted between 19 December 1957 and 28 April 1958 comparing the engine's spark ignition system and a platinum glow plug for rapid relight. At the conditions tested, the continuous spark ignition system was a more effective and reliable method of producing engine re-ignition following compressor stall-induced flameout than the glow plug system. AEDC reference is listed in Appendix A.
5. From the conclusions as reported by AEDC and other ground test facilities, it became increasingly obvious that the biggest problem is resolving rapid relight after flameout was to get actual simulation of conditions as experienced in-flight, i.e., short time air reduction transients through the engine. Therefore, at the request of the Propulsion Laboratory and the Weapon Systems Project Office, AEDC, the Directorate of Flight and All-Weather Testing, AEDC, over the period from June through October 1958 performed flight tests with continuous spark ignition on FIQl aircraft under icing conditions. The FIQlA and FIQlB aircraft were both tested in order to check rapid relight capabilities with the two different ignition systems. FIQlA aircraft have an ignition system with approximately four (4) joules stored energy and 12 sparks per second firing rate, while the FIQlB has an ignition system with approximately <4 joules stored energy and four (4) sparks per second firing rate. The aircraft were flown behind the KB-9 tanker plane in such a position that water from the tanker boom sprayed onto the left inlet. After accumulating 1" to 1 1/2" of ice on the engine inlet lip, the aircraft were removed from the icing spray and flown to warmer altitudes to dislodge the inlet ice for ingestion by the engine. Results of the tests showed that sustained engine operation could be maintained with the spark ignition system turned on during ice ingestion. The tests also showed that a flameout was possible, during ice ingestions with the spark ignition system turned off. Flight test reports are listed in Appendix A.

6. Prior to initiation of the continuous ignition flight test by Directorate of Flight and All-Weather Test, the Propulsion Laboratory performed endurance testing on several spark ignition systems to determine the suitability of present intermittent duty systems for continuous duty operation. The present duty cycle requirement for spark ignition systems is two minutes on, three minutes off, two minutes on, and twenty-three (<3) minutes off as called out in Specification MIL-E-5007A. The results of tests conducted by an engine manufacturer, an ignition system manufacturer, and the Propulsion Laboratory show that present spark ignition systems are adequate for duty cycles considerably in excess of the requirements of MIL-E-5007A, with time of operation to failure dependent upon the environmental temperature of the system.

7. Since present spark ignition systems operating on direct current are not capable of continuous operation over long periods of time, the Propulsion Laboratory designed a continuous duty system using components presently available which does not have the limitations of the ignition systems of present engines, but does retain the high energy levels required for ground starting. A detailed review of this design is included in Appendix B. This ignition system is to be flight-tested by Directorate of Flight and All-Weather Test in the near future.

III. CONCLUSIONS

8. Rapid relights are obtainable utilizing continuous ignition on FIQlA and FIQlB aircraft under artificially induced ice ingestion.

9. Direct current ignition systems tested are satisfactory for longer duty cycles than presently required by MIL-E-5007A, however, are not adequate for extended continuous duty.

10. Under conditions tested, the spark ignition is capable of more satisfactory rapid relights than the platinum glow plug.
IV. RECOMMENDATIONS

11. The use of continuous spark ignition be thoroughly investigated for specific applications which are prone to flameout under certain flight conditions.

12. The continuous ignition system designed by the Propulsion Laboratory be flight tested in F101B aircraft under ice ingestion conditions.

13. Engine manufacturers develop continuous ignition systems during the development phases of new gas turbine engines as a means of reducing the probability of engine flameout during flight.

14. Determine minimum spark energy and voltage required for rapid relight with the view toward reducing stress and wear on components of a continuously operating ignition system.

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PUBLICATION REVIEW

This report has been reviewed and is approved.

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Propulsion Laboratory

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March 1959
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Bureau of Aeronautics
Navy Department
ATTN: IP-32b, Mr. R. Brown
Washington 25, D. C.

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Philadelphia, Pennsylvania

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1 National Aeronautics & Space Administration
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Washington 25, D. C.

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1

Lewis Research Center
National Aeronautics & Space Administration
1000 Brookpark Road
Cleveland 3, Ohio

CONTRACTORS

1

AC Spark Plug Division
General Motors Corporation
1300 Detroit Highway
Flint 2, Michigan

1

Allison Division
General Motors Corporation
Attention: Mr. Fred Sietz
Indianapolis 6, Indiana

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B. G. Spark Plug Corporation
341 Broad Avenue
Ridgefield, New Jersey

1

Boeing Airplane Company
Post Office Box 3707
Seattle 24, Washington

1

Boeing Airplane Company
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AVCO Manufacturing Company
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1 Douglas Aircraft Company
   3000 Ocean Park Blvd.
   Santa Monica, California

1 Fairchild Engine Division
   Fairchild Engine & Airplane Corporation
   Farmingdale, Long Island
   New York

1 General Electric Company
   Missile & Ordnance Department
   Attention: C. J. Watters
   Lakeside Avenue
   Burlington, Vermont

1 General Electric Company
   Jet Engine Division - J93 Project
   Evendale Plant
   Post Office Box 196
   Cincinnati 19, Ohio

1 General Electric Company
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   Evendale Plant
   Post Office Box 196
   Cincinnati 19, Ohio

1 General Electric Company
   Jet Engine Division - J47 Project
   Evendale Plant
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   Cincinnati 19, Ohio

1 General Electric Company
   Small Aircraft Engine Department
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   West Lynn 5, Massachusetts

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   Norwich, New York

1 Glenn L. Martin Company
   Baltimore, Maryland

1 Grumman Engineering Corporation
   Beth Page, Long Island,
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1 Lockheed Aircraft Corporation
   Post Office Box 551
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   Columbus 15, Ohio

1 North American Aviation, Inc.
   Los Angeles International Airport
   Los Angeles 45, California

1 Northrop Aircraft Inc.
   Northrop Field
   Hawthorne, California

1 Pratt & Whitney Aircraft Division
   United Aircraft Corporation
   East Hartford 8, Connecticut

1 Pratt & Whitney Aircraft Division
   United Aircraft Corporation
   Research & Development Center
   United, Florida

1 Scintilla Division
   Bendix Aviation Corporation
   Sidney, New York

1 Westinghouse Electric Company
   Aviation Gas Turbine Division
   32 North Main Street
   Dayton 2, Ohio

1 Wright Aeronautical Division
   Curtiss-Wright Corporation
   Woodridge, New Jersey

1 Champion Spark Plug Company
   ATTN: Fr. L. R. Lentz
   900 Upton Avenue
   Toledo 1, Ohio
APPENDIX "A"

BIBLIOGRAPHY

A. British Platinum Glove Plug

1. U.S. Navy, Bureau of Aeronautics, Aer FP-323 correspondence dtd 24 May 1957 to Commander, Wright Air Development Center, ATTN: WCLP-7, Subject: "Technical Data, forwarding of".


B. Arnold Engineering Development Center


C. Wright Air Development Center Flight Testing


7. AEDC Form 56, Flight Test Request #CLP 53-39 "Rapid Relight Test After Flameout J57-1-43 Engine, F101B" 19 September 1958 - Propulsion Laboratory


9. AEDC Form 56, Flight Test Request #CTE 53-4 "Flight Test of Continuous Ignition During Icing" 30 January 1958 - Directorate of Flight & All-Weather Testing

D. Ignition System Endurance Testing


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APPENDIX "A" (cont'd)

11. Scintilla Division, Bendix Aviation Corporation, correspondence to 4ADC
    Subject: "Continuous Duty Operation for IGN-1C (10-3770-1) Ignition Unit
            Used on (AF) J57-P-13 Engine" - 31 March 1958

12. Propulsion Laboratory, 4ADC, Test data "J57 Engine Ignition Endurance Test"
    31 March 1958 through 16 April 1958

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**APPENDIX “B”**

**A CONTINUOUS IGNITION SYSTEM NOW UNDER CONSIDERATION FOR A.F. USE**

**A. INTRODUCTION:**

1. The ignition systems presently in use on turbojet engines use 24 volt direct current. This is necessary because alternating current is not always available at the engine starting RPM of a winmilling air start. However, with the rapid relight and higher RPM of the engine, the AC is available and is the most desirable for a continuous operating ignition system. It eliminates the need for electromechanical devices, such as vibrators, used in DC systems which have definite limitations for continuous operation. Also considerable higher voltages will be required for rapid relight due to the high pressures in the combustors. However, the spark energy of the continuous system can be a fraction of present ignition systems, since rapid relight is accomplished under ideal conditions of high pressure and temperature. This can be understood from the fact that glow plugs are producing ignition for rapid relight.

**B. DEVELOPMENT AND TEST:**

2. Visioning these facts, the Propulsion Laboratory initiated a work program to develop a continuous system which could be readily made available and installed on present aircraft with a minimum of modification to the engine and at the same time keep the present ignition system intact for ground and air winmilling restarts.

3. As a result of this effort, a system shown in Exhibit A and B was devised which can be installed on engines without the installation of additional igniter plugs. Components with continuous capability and which are presently in production were selected for the system. The continuous system parallels the present ignition system to spark a single igniter plug and either system can be selected by switching only the low voltage of each system.
EXHIBIT "B"

LABORATORY PROTOTYPE SYSTEM
TWO INDIVIDUAL IGNITION SYSTEMS
TO OPERATE ON A SINGLE IGNITER PLUG.

WADC-43   WADC TN 59-64   -13-
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