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Safety Criteria for Pneumatic Starting Systems

FOREWORD

Changes in this revision are format/editorial only.

1. SCOPE:

This SAE Aerospace Information Report (AIR) presents safety criteria for pneumatic type engine starting system design and component hardware. Included are safety criteria in design of both starter control valves and starters as well as in design of airframe control systems. Safety topics concern starter valve operation and material application, airframe controls and instrumentation installations and starter rotor integrity and containment.

2. REFERENCES:

2.1 Applicable Documents:

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order. In the event of conflict between the text of this document and references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

2.1.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AIR1467 Gas Engine Limited Starting Systems

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2.2 Definitions:

ROTOR: The entire rotating assembly with the exception of accessory drive shafts and gears.

HUB: The inner portion of the rotor.

BLADE: Elements of the turbine rotor which convert gas energy to mechanical energy.

MAXIMUM NORMAL OPERATING SPEED: The maximum defined cutout speed including all tolerances and overshoot.

MAXIMUM FREE RUN SPEED: Maximum free run is the operation of the starter with no-load on the output shaft in combination with any single failure of the intended pneumatic power source or starter control system which produces the highest free run speed including the effects of altitude. Any speed limiting device which is uncheckable shall be considered as having already failed when determining the maximum possible free run speed. The no-load condition can occur due to failure of the starter control valve to close because of a valve or system malfunction, a sheared output shaft, or by opening the starter control valve while the engine is operating with the clutch disengaged.

LOW CYCLE FATIGUE: Low cycle fatigue results from high stress which can be below or above the proportional limit of the material but higher than its endurance strength.

HIGH ENERGY FRAGMENTS: A high energy fragment is considered as any fragment which has sufficient energy to pass through a shield of soft aluminum with a thickness of 0.040 inch (1.016 mm) maximum during the test demonstration.

OVERSPEED: The speed at which a rotor exceeds its yield limit.

3. GENERAL:

Several methods of starting and motoring turbine engines are available. Some of the more common methods include hydraulic, electric, and pneumatic starting. This report presents the safety guidelines for design of a pneumatic system. A pneumatic system basically consists of an air turbine mounted on the engine accessory gearbox which is supplied compressed air from either an onboard or external compressed air source. A pneumatic shutoff valve is normally installed in the airframe to control operation of the starter.

The most effective method to improve starting system design safety is to minimize or eliminate those system or component failures which have been shown to be the major contributors to unsafe failures of the starter turbine. Most unsafe failures of the starter are caused by unwanted and undetected rotation of the air turbine and/or the inability to isolate the air turbine if unwanted rotation occurs. Uncontrolled rotation of the turbine can be a result of failure of the pneumatic valve in the open position, failure of the starter over-running clutch (if equipped) which causes the starter to be driven by the engine, or failure of the cutout switch (if equipped) to terminate the start cycle. Undetected turbine rotation can be a result of insufficient or unreliable instrumentation to provide a warning of a system or component failure.

4. STARTER VALVE DESIGN CONSIDERATIONS:

The starter valve should be designed to the maximum extent possible to assure that it closes in the event of a failure. Precautions which should be considered include (1) use of anti-corrosive material for moving parts, (2) dynamic studies of valve operation, (3) arrangements which do not expose the solenoid and its poppet to system pressure and contamination and (4) a design which minimizes contamination effects upon the valve actuator components.

Methods which are effective in assuring that the valve will be closed in the event of failure include designs where (1) the valve is spring loaded closed, (2) inlet pressure aids in closing the valve with the solenoid de-energized, (3) use of mechanical advantage techniques for multiplication of forces between actuator and valve element, and (4) if the valve is a butterfly type, the butterfly is aerodynamically loaded to the closed position. The valve should include a valve position indicator switch which accurately provides a signal when the valve is in the “not closed” position. Actuation of the switch should be mechanical and detect valve position rather than a signal which only senses that the valve is told to go close.

5. AIRFRAME DESIGN CONSIDERATION:

5.1 Controls and Instrumentation:

The airframe controls should be reviewed for failure which would permit the starter to remain energized when not selected. Separation of electrical leads (to prevent shorting) and methods employed in soldering and insulating are also important design review details. Instrumentation should be provided to indicate when the pneumatic shutoff valve is “not closed”. Also, if the start system is such that the failure of any single component may activate the starter, a warning device should be provided to alert the crew to failure of a component or starter activation.

5.2 Installation:

Combustible fluid lines should be located as far as practical from the starter to minimize the possibility of combustible fluid contact with the starter in the event of failure. Precautions should be taken to minimize starter exhaust impingement in the vicinity of combustible fluids or vapor. The exhaust gases should be ducted outside the engine compartment if they are corrosive or exceed 700 °F (371 °C).

6. STARTER DESIGN CONSIDERATIONS:

In addition to the measures taken to minimize starting system failures, precautions should be taken to insure that in the event of a failure the effects will not be hazardous to personnel or equipment. The precautions taken in starter design often vary depending on the intended source of compressed air as related to maximum operating temperature. For the purpose of this report, design safety considerations will be shown separately for moderate temperature applications (below 1000 °F [538 °C]) and for high temperature application (above 1000 °F [538 °C]). It is often not practical for cost and weight considerations to apply the same criteria for high temperature applications that are used in moderate temperature applications. Moderate temperature air sources include most ground carts, onboard APU's and moderate temperature engine bleed air. Sources for high temperature compressed air may include hydrazine gas, solid propellant cartridge gas or high temperature (over 1000 °F [538 °C]) engine bleed air.

6.1 Moderate Temperature Applications:

6.1.1 Parts Containment: The starter should be capable of containing all high energy fragments within its envelope and remain on its mount should a failure of any of its components occur. Other containment criteria are:

- Any fragments emitted from the starter exhaust should not constitute a fire hazard nor have sufficient energy to harm equipment, structure, or personnel.
- If failure of the rotor bearing(s) will allow an axial shift of the rotor such that containment provisions are negated, a means should be provided to prevent this occurrence.
- The design should be such that rotation of the outer case of the starter which could shear ducts or other attachments is prevented.
- Containment devices (rotating or stationary) should not require maintenance for proper operation.
- A failure of a complete rotor (maximum energy tri-hub burst) should be contained at any speed up to maximum operating speed.

6.1.2 Rotor Integrity:

6.1.2.1 Low Cycle Fatigue: The starter rotor should be designed to and constructed to minimize the probability of low cycle fatigue. As a minimum, the rotor hub must be designed to withstand stresses which occur during cycling from rest up to the maximum normal operating speed with maximum inlet temperature for two times the number of start cycles which can occur throughout the operational life of the starter. The rotor hub must also withstand 5 percent of the number of operational life start cycles when cycled from rest to the maximum free-run.