

AEROSPACE INFORMATION REPORT

Submitted for recognition as an American National Standard

SAE AIR947

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Engine Erosion Protection

FOREWORD

Changes in this reaffirm are format/editorial only.

1. SCOPE:

This Aerospace Information Report deals with protection of helicopter aircraft engines against erosion. Applicability is restricted to aircraft having a disc loading of less than 15 pounds per square foot.

2. BACKGROUND:

Historically, the responsibility for providing the means of handling the problem of entrainment of undesired substances in the inlet air of aircraft gas turbines has been an interface problem between the engine and airframe manufacturer; however, the trend has clearly been in accordance with two basic principles:

- (a) Whatever substances can possibly be tolerated in the air should be allowed to remain, and the engine designer is responsible to allow for them. Examples of such substances are snow, rain, hail, supercooled water droplets, and reasonable quantities of small, solid particules such as sand, dust, foliage, etc. Tolerance of the engine is optimized in design and development (i.e., an anti-icing system is provided, and erosion resistant materials are used in engine construction).
- (b) Whatever substance cannot be tolerated in the air must be removed by an airframe part or an engine accessory, if available. Examples of such substances are bolts, nuts, rags, hay, and large quantities of sand and dust.

A more fundamental underlying principle from which the foregoing are derived is that the solution for any problem associated with entrainment should be undertaken by whichever manufacturer can provide the best solution to the problem from an overall aspect.

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3. QUANTITY OF SAND AND DUST WHICH CAN BE TOLERATED IN ENGINE INLET AIR:

Determination of the quantity of sand and dust which can be tolerated in any given engine is a complex problem. Generation of this answer poses a major difficulty inasmuch as the tolerance of an engine for sands of different chemical composition, different particle size, and size distribution has not yet been predicted analytically. Furthermore, the experimental determination of the effects of these variables is a very costly proposition. One practical approach is the use of a standard test sand which can be used to define the tolerance of a given engine. The various branches of the Government are attempting to develop such a standard and contract for a defined tolerance in the procurement of new engine models. Specifications must be established for materials to be used as design criteria for engines and inlet systems. There is considerable variation in tolerance of one engine design to another, and there are trade-offs in performance in selecting a design. Thus, it is not desirable to impose an overly stringent tolerance on the engine (which is likely to be at the expense of performance) when a less stringent engine tolerance requirement could result in a better aircraft by the inclusion of a sand separator. On the other hand, a minimum engine tolerance is necessary.

4. TEST CONCEPTS FOR EROSION TOLERANCE:

In view of the fact that the concept of a representative "test sand" is strongly entrenched in Industry and Government thinking, it is expedient to further this concept to the point that sufficient understanding is achieved to result in an agreeable standard.

Choice of "Test Sand"

Military specifications for gas turbines have recognized two standard sands for a number of years. These are known as "Coarse Arizona Road Dust" and "Fine Arizona Road Dust". They have been used for environmental testing, and have been found satisfactory for most purposes. However, it has been established that they are not representative of helicopter environments in many operating areas. The reason is two-fold: First, they consist of particles which are considerably smaller than those contained in sandy soil. Second, the chemical composition, being only 68% Silica, is not as abrasive as pure quartz found in beach sand. Helicopters (depending on design and disc loading) have been shown to be capable of stirring up an entire soil spectrum of particle sizes, and the engines have ingested almost the entire spectrum, with very little selectivity for the finer particles, as would normally be expected. Particles of 500 microns and above can be so ingested.

Because of the shortcomings of "coarse" and "fine" Arizona Road Dust, as test sands for helicopters, there has been increasing effort to find a new standard consisting of larger particle size and more abrasive material. Several are under study. Figure 1 shows the particle size distribution of four samples of sandy soil from widely scattered areas of the world. Figure 2 represents two test sands. One of these, which contains some larger particle sizes, is defined in Military Specification MIL-E-5007C (Engines, Aircraft, Turbojet and Turbofan, General Specification for, Paragraph 3.25). The material is crushed quartz, a more abrasive material than that found in "Coarse Arizona Road Dust." This test material is more representative of sandy soils, and thus simulates the type of environment which would be experienced by a helicopter engine operating without any protection such as a barrier filter or sand separator. It would also represent the best simulation of the operating environment of a combined engine-separator package.

4. (Continued):

Small engines used in small aircraft do not appear to be subjected to the large particle sizes which constitute the largest fraction of MIL-E-5007C contaminant. In order to simulate the environment for these engines, the use of Arizona Coarse Road Dust is recommended. The choice of test sand should hinge on the size and expected environment of the aircraft.

As an objective, the following degree of tolerance is recommended:

1. For engine-separator packages:

- (a) MIL-E-5007C test sand at a rate of ingestion of .006 grams per cubic foot of total aspirated air for a duration of 50 hours minimum, from uneroded engine condition, and
- (b) "Coarse Arizona Road Dust" at a rate of ingestion of .006 grams per cubic foot of total aspirated air for a duration of 50 hours minimum, from uneroded engine condition.

2. For bare engines:

- (a) MIL-E-5007C test sand at a rate of ingestion of .0015 grams per cubic foot of air for a duration of 3 hours 20 minutes minimum, from uneroded engine condition, or
- (b) "Coarse Arizona Road Dust" at a rate of ingestion of .0015 grams per cubic foot of air for a duration of 10 hours minimum, from uneroded engine condition.

5. ESTABLISHING THE REQUIREMENTS FOR A SEPARATOR:

Tolerance of a given engine against sand ingestion can best be presented in the form of performance change plotted against weight of sand ingested for each test sand. Rate of ingestion should be specified, as well as any limiting failure criteria, such as surge or part failure. Knowing the tolerance of a given engine, the aircraft designer can define the requirements for a separator (or no separator, as the case may be). This determination must be made with the knowledge of the conditions under which the aircraft will operate, and how long it will be exposed to sand and dust during each mission. Unfortunately, data is not available on how much sand will become suspended in the air and taken into the engine inlets. This depends on the downwash, flow pattern, and relative location of cowling and engine inlet. Until these influences are better understood, the selection of separator requirements will have to be partly based on experience with similar type aircraft.