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AEROSPACE INFORMATION REPORT

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LONG-TERM STORAGE RELIABILITY OF HIGH PRESSURE GAS CONTAINERS FOR PNEUMATIC ACTUATION SYSTEMS

FOREWORD

The purpose of this AIR is to provide information relative to the long-term storage reliability of cold gas containers for pneumatic actuation systems. It is intended to aid in the selection of a pneumatically powered system for control of a tactical missile or guided projectile that must survive up to 30 years of nonoperating storage before operational use.

1. SCOPE:

This SAE Aerospace Information Report (AIR) provides design data reliability information relative to the long-term storage of gas containers or pressure vessels charged with nitrogen or helium at pressures ranging from 6000 to 12 000 psi. The gas containers are cylindrical, spherical, or toroidal in shape. Internal volumes range up to 1385 in^3. Applications for this type cold gas actuation system include tactical missiles, guided projectiles, and smart bombs. A typical system is described.

2. REFERENCES:

The following publications form a part of this specification to the extent specified herein. The applicable issue shall be the issue in effect on the date of the purchase order.

2.1 DOD Publications:

Available from Reliability Analysis Center, RADC/RAC Griffis AFB, NY 13441-5700.

NONOP-1 Nonoperating Reliability Databook 1987
DSR-4 Discrete Semiconductor Device Reliability 1988

3. DISCUSSION:

3.1 Background:

Actuation systems currently installed in many tactical missiles and guided projectiles are required to be able to meet performance specifications after dormant storage periods of up to 20 years, without checkout or maintenance. Longer storage times, up to 30 years, are currently being specified for new applications.

From a reliability standpoint, these long nonoperating storage requirements are recognized as being more difficult to design to and satisfy than the significantly shorter launch and flight requirements of the mission. This appears to be the case whether the system is hydraulic, pneumatic, or electromechanical. Reliability comparison between actuation system types has been difficult, because the necessary information has not been readily obtainable on pneumatic systems primarily due to the scarcity of gas container nonoperating storage data. This AIR provides gas container storage information and gives details on a number of typical gas container designs.

3.2 System Description:

A typical actuation system in which a cold gas container is utilized is comprised of a control system which receives power from stored gas to control an output load. Actuation systems include the following components assembled in one or more housings with appropriate gas manifolding:

a. Power supply
b. Controller
c. Power modulator
d. Actuator
e. Feedback elements

A brief description of each of these follows.

3.2.1 Power Supply: The cold gas power supply consists of four major components:

1. A high pressure gas container, typically sealed by a metal-to-metal seal/weld to survive long-term storage
2. A device to release the gas from the sealed container when operation is initiated
3. A pressure reducing and regulating device to provide the source gas to the power modulators at the design operating pressure
4. An integral filter to facilitate system acceptance test from an external gas source, through an exercise port, and the reducing and regulating device

3.2.2 Controller: The electronics portion of the system that controls the power modulator as a function of the command or error signal between the actuator load position and the commanded position.

3.2.3 Power Modulator: The component of the actuation system that regulates the potential energy of the power source to the actuator as a function of controller output. Typically, these are electrically powered control valves which let gas flow into or out of the actuator piston chambers as required to control the actuator output position.

3.2.4 Actuator: The component of the actuation system that does work or dissipates energy to control a load. The actuators are typically piston type actuators controlled by power modulators to position fins, jet vanes, or thrust vector control (TVC) nozzles.

3.2.5 Feedback Elements: The component of the actuation system that senses the actuator output and transforms it into a form compatible with the command signal. Typically, the actuator load position is measured by a feedback sensor which indicates the fin, vane, or TVC nozzle position relative to the airframe.

3.3 Long-Term Storage:

Cold gas pneumatic actuation systems are stored at a number of manufacturers' facilities and military supply depots, as components of weapons assemblies, throughout this country and in other countries of the world. The actuation system manufacturers often conduct reliability verification programs to check the systems at prescribed intervals to substantiate reliability estimates and verify long-term storage capability.

Typical of some of these continuing programs, the storage components are subjected to environments in which the variations in ambient temperature and relative humidity are characteristic of the local climate. The test specimens are housed in vented containers that protect them from direct solar radiation and precipitation. Periodically, all components are subjected to verification tests to ascertain that failures have not occurred.

High pressure stored gas containers are the major concern from a reliability standpoint, and comprise the largest group of components in these storage programs. The other components of the actuation systems are relatively insignificantly affected by the long-term storage and are fewer in number in the ongoing storage program. Table 1 summarizes design characteristics of a variety of gas containers or pressure vessels for military applications. Where data on multiple units are grouped, the tabulated weight is the average of the two or three grouped units and the leakage rate entry is the highest individual rate noted for the group.

The containers in Table 1 are part of an ongoing storage program in Arizona, USA. The effects of long-term storage in this environment are indicated in Table 2. The gas leakage rates tabulated alongside the specification requirements illustrate the very low gas loss rates characteristic of these high pressure containers over relatively long storage times. The gas weight entries are the differences between container before fill and after fill weights.

3.3 (Continued):

In another storage program, started in 1964, the environmental variations are typical of the climate of central Connecticut, USA.

a. Temperature Range: -26 to +102 °F
b. Relative Humidity Range: 30 to 100%

The stored containers are fully charged and accurately weighed to establish the basis for the annual weight comparison. The annual weight check is followed by an update of the accumulated storage hours and the reliability data. Figure 1 illustrates the yearly buildup of storage time from the 1960's to the 1990's.

Prior to 1980 three containers were found to have developed leaks. The causes of the leaks were identified and corrective action was instituted. Modifications to items such as material grain direction, material specifications/quality control, and process specifications now assure that a storage life of 30 years or more can be satisfied with reasonable reliability.

Other control system components such as explosive cutters, solenoids, electronic control packages, and complete control systems are also included in the storage program. The quantities of these other components, however, are considerably less than the quantity of gas containers in storage. Consequently, the storage hours for reliability prediction purposes have not accumulated as rapidly.

Reliability information on the other components is normally available from other sources such as the Reliability Analysis Center, RADC. The actuator components and the power supply components, other than the container, are similar to hydraulic system components for which reliability data exists. (However, where appropriate, accountability is required for the different effects of long-term exposure to a hydraulic fluid as opposed to a pneumatic fluid.) Electronics data also tends to be more readily available than similar reliability data on gas containers.

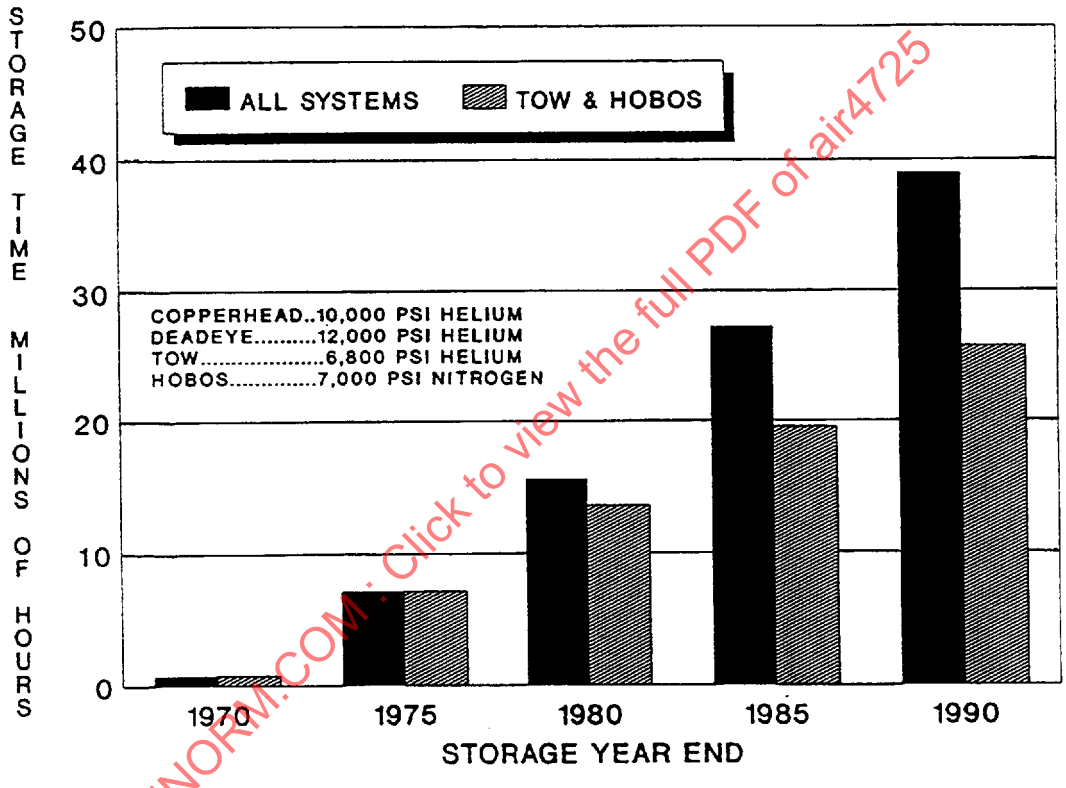

FIGURE 1 - Gas Container Cumulative Storage Hours