



AEROSPACE INFORMATION REPORT

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Superseding AIR1664

Aircraft Flexible Tanks General Design and Installation Recommendations

RATIONALE

AIR1664A has been reaffirmed to comply with the SAE Five-Year Review policy.

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1. SCOPE:

This SAE Aerospace Information Report (AIR) includes general information about the various types and styles of flexible tanks and the tank-mounted fittings that adapt the tank to the surrounding structure and fluid-system plumbing.

Recommendations are given relative to the dimensional layout of the tank when these recommendations serve to avoid tank fabrication problems and tank/structure interface problems. As a part of these recommendations, critical dimensions of plumbing adapter fittings are discussed and recommendations made. Tank manufacturing tolerances are given.

Recommendations are made relative to cavity design and preparation to facilitate a reliable installation.

The special installation requirements of nonself-sealing, self-sealing, and crash-resistant tanks are discussed.

This document is not intended to replace the information or requirements of the military and commercial procurement specifications listed in Section 2. No attempt has been made, except in a very general way, to include physical property data such as weight and thickness of the composite materials available in the industry. Such materials are too numerous and vary too much between manufacturers.

Whenever specific data or advice is required, it is necessary that the tank manufacturers be consulted.

1.1 Purpose:

The purpose of this document is to supply aircraft fluid-system designers with baseline information pertinent to the application of flexible, removable tanks for power plant fluids without regard to the fluid in the tank.

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 each publication shall be that in effect on the date of this AIR unless otherwise specified in the manufacturer's model specification. 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 Nonself-Sealing Specifications:

MIL-T-6396	Tanks; Fuel, Oil, Water Alcohol Coolant Fluid, Aircraft, Nonself-Sealing, Removable, Internal
TSO-C80	Federal Aviation Agency Standard - Flexible Fuel and Oil Cell Material

2.1.2 Self-Sealing Specifications:

MIL-T-5578	Tank; Fuel, Aircraft, Self-Sealing
MIL-T-27422	Tank; Fuel, Crash Resistant Aircraft (Nonself-Sealing and Self-Sealing)

2.1.3 Other Related Documents:

MIL-C-5040	Cord, Nylon
MIL-C-5541	Chemical Conversion Coatings on Aluminum and Aluminum Alloys
MIL-P-8045	Plastic, Self-Sealing and Nonself-Sealing Tank Backing Material
MIL-B-83054	Baffle Material and Inerting, Aircraft Fuel Tank
MIL-F-87260	Foam Material, Explosion Suppression, Inherently Electrically Conductive, For Aircraft Fuel Tank and Dry Bay Areas
MIL-STD-801	Acceptance Standards for Flexible Tanks
MIL-STD-1290	Light Fixed and Rotary Wing Aircraft Crashworthiness
MIL-STD-1472	Human Engineering Design Criteria for Military Systems, Equipment and Facilities
MS29558	Tank Fitting "O" Ring - Center Bolt
MS29559	Tank Fitting "O" Ring - Through Hole
MS29560	Tank Fitting "O" Ring - Threaded Hole
TM-78-08	USAF Technical Memorandum - Foam Design
TR-89-D22E	USAAVSCOM Aircraft Crash Survival Design Guide Vol. V - Aircraft Post Crash Survival
AIR1662	Minimization of Electrostatic Hazards in Aircraft Fuel Systems
AIR4170	Reticulated Polyurethane Foam Explosion Suppression Material for Fuel Systems and Dry Bays
AS4873	Gland Design, Elastomeric O-ring Seals, Static Radial and Face, 800 psi, Maximum Service
FAR Part 23	Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes

2.2 Glossary:

BARRIER: A barrier is a film or material applied to the tank inner liner that resists fluid permeation. Used on nonself-sealing and self-sealing fluid tanks containing aviation fuels.

BUILDING FORM: A male shape duplicating the shape of the finished tank. The various plies of rubber-coated fabric or spray-on polyurethane are fabricated over this shape. The form maintains the tank shape during vulcanization and is removed after vulcanization.

CONVOLUTION: Generally, a recess projecting into the tank surface to clear structural ribs, formers, longerons, etc. Convolutions permit utilization of the maximum volume of the structure for fluid storage.

2.2 (Continued):

CRASH-RESISTANT TANK: A variation of either a nonself-sealing tank or self-sealing flexible tank fabricated of very strong elastomer coated fabric and high-strength fittings. It is intended that this tank retain fluid without leakage under impact-survivable crash conditions. This type of tank is procured to MIL-T-27422 for military applications and to the airframe designer's specifications supplemented by TSO-C80 for commercial applications.

FIT CHECK FIXTURE: A fixture accurately simulating the size and shape of the aircraft flexible tank cavity. It is used as a quality assurance acceptance test tool.

FITTINGS - TANK MOUNTED: Fittings are subassemblies fabricated into the tank wall for the purpose of:

- a. Attaching the tank to structure
- b. Providing a sealing surface for and a means of attaching equipment items to the tank
- c. Providing for the attachment and sealing of vent lines and fluid flow lines to the tank

They are an integral part of the tank assembly. Fittings generally consist of metal rings. See "Nipple Fitting."

FITTING FLANGE: Some fitting subassemblies are attached to the flexible tank wall by means of plies of rubber-coated fabric or molded rubber that are called flanges. These flanges are bonded to the metal rings of the fitting and also to the tank wall and become an integral part of the tank assembly during vulcanization.

FIBER-LOCK FITTING: This is a fitting design developed under the auspices of the U.S. Army specifically for crash-resistant tanks. It uses numerous individual fibers fabricated radially into the tank wall as means of retaining the metal fitting in the tank. See also Wedge-Lock for crash-resistant fittings.

HANGER FITTINGS: Various designs of fittings have single bolts, fabric loops, and formed wire rings which are fabricated into the flexible tank wall. Generally, they provide a means of externally attaching or supporting the flexible tank to the aircraft structure. However, the term is also applied to fittings used on the inside of the tank to support items of equipment and fluid flow lines.

HYDRODYNAMIC RAM: Hydrodynamic ram refers to the pressure loads that develop in a fluid filled tank as a result of shock loading or the penetration and travel of a projectile through the fluid. The loads can be such as to cause structural failure.

LACE LINE: A high-strength, nylon cord used to support a flexible tank to the structure. It is used in conjunction with attach point on the external surface of the cell and on the structure. The type of material is parachute shroud line procured to MIL-C-5040 Type III.

2.2 (Continued):

LINER (INNER LINER): The innermost ply of a flexible fluid tank. It can be either a rubber layer, a rubber-coated fabric, or a spray-on polyurethane.

MOLDED IN PLACE SEAL: A proprietary commercial sealing gasket in which a partial O-ring is molded and retained in grooves positioned on both sides of a thin metal ring. The metal ring is designed to be installed in the interface of the tank mounted fitting and the structure or item of equipment.

NIPPLE FITTING: A fitting generally molded entirely of rubber but can contain fabric. The fitting consists of a tubular section whose inside diameter is sized to match standard aluminum tubing. A seal is obtained using a hose clamp assembled to the outside of the molded tube. The molded tube may extend outwardly or inwardly from the tank external surface. The tubular section is adapted to the flexible tank by means of molded flanges. This type fitting is used primarily in general aviation nonself-sealing tanks.

NONSELF-SEALING TANK: A tank having no ballistic sealing properties. It can, however, possess tear-resistant characteristics. These tanks are procured to MIL-T-6396, MIL-T-27422 and commercially modified MIL-T-27422/TSO-C80 specifications.

RETICULATED FOAM: A three-dimensional, net-like, open-cell material, made of a flexible polyurethane compound. It is useful for explosion suppression and slosh attenuation in aircraft fluid tanks. Procured to MIL-B-83054 or MIL-F-87260. Design with reference to USAF Technical Memorandum ASD/AENFEF-TM-78-08 and AIR4170.

SCUFF PATCH OR PAD: An additional thickness of material designed to prevent tank wall damage from any anticipated source. The material can be rubber-coated fabric or molded rubber applied to either the inside or outside surface of the tank. Also may be called a wear patch.

SELF-SEALING TANK: A tank in which construction is such that an automatic sealing action occurs when penetrated by a projectile. The weight and thickness of constructions is adjusted to the ballistic threat anticipated for the aircraft. These tanks are procured to MIL-T-5578 or MIL-T-27422.

WEDGE LOCK FITTING: A fitting design developed under the auspices of the U.S. Army specifically for use in crash-resistant fuel tanks. The fitting gains its name from the use of a wedging action to retain the metal fitting rings to the flexible tank materials.

3. BACKGROUND:

The primary function of a flexible tank, regardless of any subclassification of types, is to provide a means for fluid storage. After it has been determined that a flexible, removable tank will be used, the airframe fluid system designer will determine the type of flexible tank that will satisfy the requirements.

3. (Continued):

Since there are limits to the configurations that can be fabricated, it is necessary that consultation with the tank manufacturers be established early in the design stages to avoid unacceptable designs.

Flexible tanks are generally classified in terms of their secondary functional capability. These secondary capabilities supplement the primary function of fluid storage. Typical secondary capabilities are self-sealing ability, crash resistance, high temperature resistance, and tear resistance. Appropriate performance type procurement specifications are available for each of these basic types as noted in Section 2.

Vulnerability/survivability studies are helpful in determining the type tank (i.e., self-sealing, nonself-sealing, tear-resistant) and the necessity for inerting materials. For weight savings, some installations use tanks with a combination of self-sealing and nonself-sealing materials. This type tank is procured to specification MIL-T-5578, Protection Levels C or D, or MIL-T-27422, Protection Level B.

A flexible tank is essentially a handmade article and is therefore relatively expensive. Experience indicates that the more complex a configuration becomes, the more costly it is in terms of unit cost. Reliability and maintainability can be compromised by excessive complexity in the total design.

Materials utilizing nitrile elastomers and polyamide fabrics are commonly used construction materials for flexible tanks. These materials have been used since the early 1950s and have no serious shortcomings even though the operating environment of military aircraft is varied and severe. Compounds of urethane and polyester fabrics are also commonly used in both military and commercial flexible tanks. For special applications, fluorocarbon elastomers, as well as aramid fabrics, have been used.

4. DESIGN RECOMMENDATIONS:

The following recommendations apply to nonself-sealing tanks procured to MIL-T-6396, MIL-T-27422, and TSO-C80 and self-sealing tanks procured to MIL-T-5578 or MIL-T-27422. With respect to crash-resistant flexible tank installations, military applications require that tanks be procured according to MIL-T-27422 which defines the performance of the end product and materials. However, for commercial applications of higher-strength flexible tanks, those requirements that are not established by specification are determined by the aircraft manufacturer. A flexible, crash-resistant tank may be required to withstand high, internal hydrodynamic loading without failure. In addition, the tank must perform those functions associated with a nonself-sealing installation as required.

To be effective, a crash-resistant tank must be designed as part of a system. Thus, system design requirements must be considered. The designer is advised to consult USAAVSCOM Technical Report TR-89-D22E Volume V. It is also recommended that MIL-STD-1290 be consulted.

4.1 Tank Configuration:

The demand for maximum fluid storage capacity makes it desirable that flexible tanks conform to structure as closely as possible. This may result in the tank being convoluted. Convolutions present fabrication problems and should be limited as much as possible. In most cases, unsupported areas are unacceptable in self-sealing tank installations. However, unsupported areas in nonself-sealing installations may be specified. Tank wall strength will generally be adjusted to match the installation situation. It is recommended that contact be established with tank manufacturers early in the design phase to establish the practicality of the planned configuration.

4.1.1 Where convolutions must be used, the shape and size of the convolution is of importance to the tank manufacturer. Recommended cross sections are shown in Figure 1 but may vary in accordance with the structure design.

4.1.2 Tank edge radii are significant from the tank fabrication standpoint. The following sizes are recommended.

- a. MIL-T-5578 Self-Sealing - 1 in (25.4 mm) min
- b. MIL-T-27422 Self-Sealing - 2 in (50.8 mm) min
- c. MIL-T-27422 Nonself-Sealing - 0.75 in (19.1 mm) min
- d. MIL-T-6396 Nonself-Sealing 0.2 in (6.4 mm) min
- e. To clear structure corner interferences, modify the tank shape. Bevels or radii may be used.

4.2 Tank to Structure Support (Hangers):

Hanger systems should be designed primarily to position the tank to the cavity contour and secure the tank to the structure under normal flight loads. The fuel tank cavity vent and drain systems should be designed so that the pressure inside the tank is positive in relation to the outside of the tank. If this cannot be done and the tank pressure is negative, hangers may be used to prevent the tank from collapsing. For tanks that will experience negative pressure, the qualification program must address hanger integrity during service.

NOTE: FAR Part 23, paragraph 23.967(a)(5) does not allow bladder collapse in small airplanes.

Hanger systems must also be designed to prevent interference between the tank and internal plumbing that might cause damage to the tank.

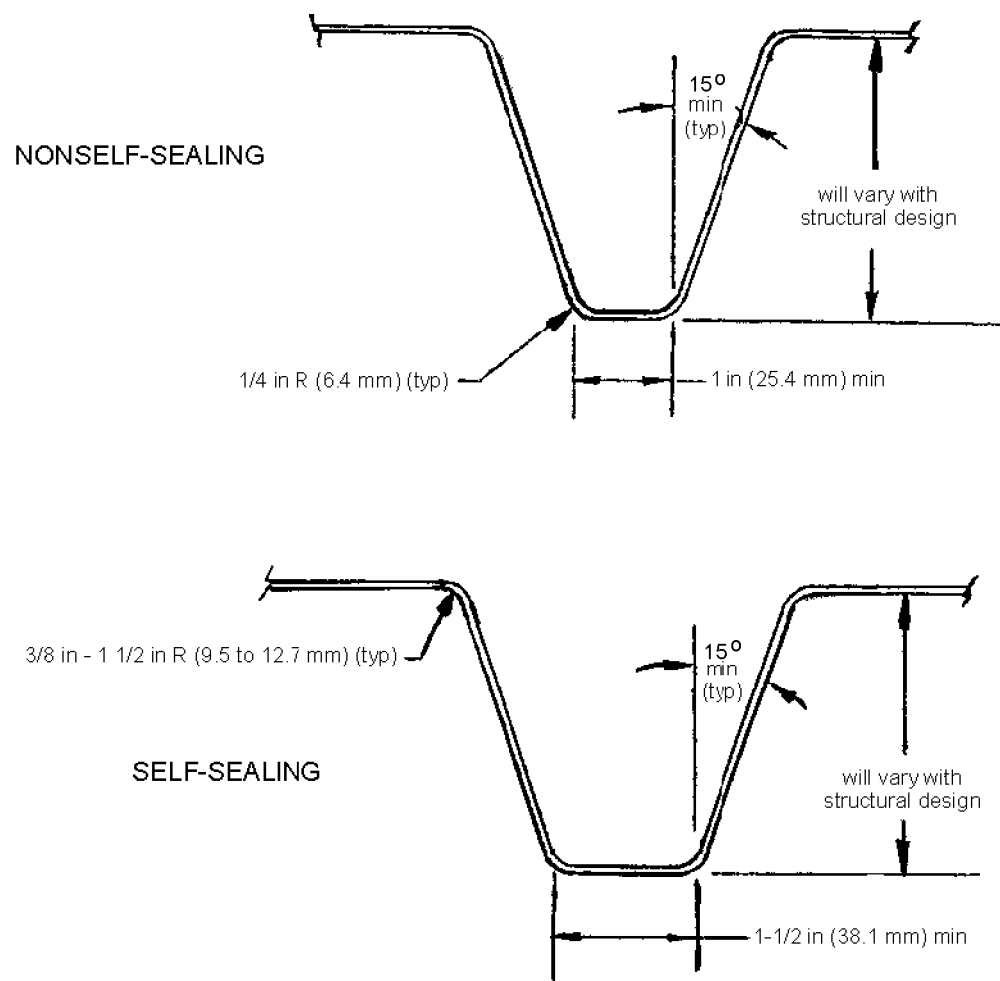


FIGURE 1 - Recommended Proportions for Convolutions

- 4.2.1 Two commonly used hanger systems are "single-point direct attachment" suitable for all types of tanks and the lace line system in which the tank is suspended from a tensioned nylon cord. The lace line system is generally useful only on flexible nonself-sealing tanks and very lightweight self-sealing tanks made to MIL-T-5578 Protection Level B. Tank mounted parts include fabric loops, bent wire rings, nonmetallic ferrules, tapped holes, studs, and buttons. Consult tank manufacturers for various types. Through bolt-type hangers are not desirable because of the leakage potential. Structure mounted parts can be eye bolts, bent wire loops, keyhole plates, etc.

External or internal support frames made of metal, wood, or plastic can also provide support when attachments to the structure are desirable. Relatively small areas of the tank wall can be stiffened by various methods and attached to the structure as required. This can be useful to prevent the normal drape in the tank top panel from causing interference with equipment items such as level control valves. A local concentration of hangers of various types will also accomplish the same result. For small areas, hook and pile materials might also be usable.

- 4.2.2 The choice of systems is often related to the accessibility of the tank's external surface while in the structure. Also the weight and flexibility of the tank material will influence the choice. Hangers for normal and crash-resistant self-sealing tanks can be identical.

If attach points are not accessible on the outside of the tank, a single-point direct attachment hanger system may be used. A "handle" should be provided on the cell inner surface to facilitate positioning the external attach point.

If a single-bolt attachment is to be made from the outside, provide a means to prevent fitting rotation when torquing the assembly bolt.

- 4.2.3 The number and location of hangers is influenced by tank materials, tank size and shape, fitting locations, and aircraft operational environment.

- 4.2.3.1 In nonself-sealing tanks, an occasional attach point on the bottom edges near the corners assures that the tank shape is fully developed and aligned to the structure. If the tank is wider at the bottom than the top, the bottom edge must be positioned and secured to the structure. Fluid interconnector fittings will often serve this function.

A cylindrical tank requires hangers along the maximum breadth line.

- 4.2.3.2 Tank attach points ideally should be located as near the top edge as possible. The objective is to support the side panel in the plane of the panel. Large tanks and complex shapes may require hangers on or near vertical edges and at various points in the end and side panels. Aircraft subjected to catapult take-off and arrested landing should have tank hangers located on the fore and aft panels to resist the effect of fluid sloshing; namely, the creation of negative pressures in the tanks.

Top panels in excess of 3-ft wide should have additional support to avoid excessive drape. This is particularly desirable on self-sealing tanks because of the greater weight of the material. Fittings used to attach equipment items to the structure will serve the same purpose.

- 4.2.3.3 Hanger attach point spacing on the tank varies. Lighter weight materials have no inherent self-supporting properties. Self-sealing materials exhibit a degree of self-support which is enhanced in smaller tanks.

On those tanks where the lace line system is used, tank attach points must be located so as to prevent the tank from moving along the lace line and flexing as a result of fluid slosh. Spacing of 6 to 15 in is recommended on the lightest weight constructions starting as near as practical to three plane surface intersections. A tie point should be provided between the tank and structure at the end of each support line to prevent movement. Plumbing adapter fittings in the tank wall will provide support; therefore, supplemental hangers may not be needed.

- 4.2.3.4 Reticulated foam or similar explosion-suppressant materials may support the tank walls unless negative pressure is involved. However, these materials shall not replace hangers inasmuch as a supply shortage might require operation without suppressant materials.
- 4.2.3.5 Various types of hangers may be used to support internal plumbing. It is recommended that these hangers be secured to the structure to support the plumbing. Scuff patches may be used to prevent equipment and internal plumbing from damaging the tank wall.

4.3 Plumbing Adapter Fittings:

The aircraft plumbing is interfaced with the container by adapters called fittings. Such fittings interface with surfaces provided on the structure or on equipment items. Most are designed to provide for a fluid seal.

When metal fittings are attached to the tank wall by flexible flanges, these flanges are either molded rubber or rubber-coated fabric.

There are basically two configurations of fittings; namely, molded-rubber tubes (nipples) and metal bolting rings having integral gasket surfaces or replaceable gaskets. The bolting rings may have through holes or blind threaded inserts.

Through bolt fittings should be used only for connections where leakage along the bolt would not result in leakage outside the fluid containment system.

4.3.1 Nipple Type Fittings:

- 4.3.1.1 Current military specifications do not permit the use of molded-rubber tubular nipple fittings; however, this type fitting is used in nonself-sealing, noncrash-resistant tanks used in certain general aviation type aircraft.
- 4.3.1.2 Industry design standards controlling envelope sizes for rubber nipples do not exist. Nipple fittings to accommodate many common diameters of metal tubing are currently available from tank manufacturers.