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AEROSPACE INFORMATION REPORT

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Submitted for recognition as an American National Standard

AIRCRAFT FLEXIBLE TANKS
GENERAL DESIGN AND INSTALLATION RECOMMENDATIONS

TABLE OF CONTENTS

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ILLUSTRATIONS

1. SCOPE:

This 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 non-self-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 3. 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.

2. 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.

3. APPLICABLE DOCUMENTS:

The following documents shall form a part of this AIR to the extent specified herein. The applicable issue of each shall be that in effect on the date of this AIR unless otherwise specified in the manufacturer's model specification.

3.1 Non-Self-Sealing Specifications:

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

3.2 Self-Sealing Specifications:

MIL-T-5578	Tank; Fuel, Aircraft, Self-Sealing
MIL-T-5579	Tanks; Self-Sealing, Oil Aircraft
MIL-T-27422	Tank; Fuel, Crash Resistant Aircraft (Non-Self-Sealing and Self-Sealing)

3.3 Other Related Documents:

MIL-C-5040	Cord, Nylon
MIL-P-8045	Plastic, Self-Sealing and Non-Self-Sealing Tank Backing Material
MIL-B-83054	Baffle Material and Inerting, Aircraft Fuel Tank
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
DH1-6	AFSC Design Handbook, Systems Safety
DH2-3	AFSC Design Handbook, Propulsion and Power
TM-78-08	USAF Technical Memorandum - Foam Design
TO-1-1-3	USAF Technical Manual - Preparation, Inspection, Repair - Aircraft Fuel, Oil, Water Alcohol Tanks
TR-79-22E	USARTL Aircraft Crash Survival Design Guide Vol. V - Aircraft Post Crash Survival
01-1A-35	NAVAIR Technical Manual Maintenance Instruction Aircraft Fuel Cells and Internal/External Tanks Organizational, Intermediate and Depot
AIR4170	Reticulated Polyurethane Foam for Inerting Fuel Systems and Dry Bays
AMCP 706-202	Engineering Design Handbook, Part 2, Helicopter Detail Design

4. 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.

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 3.

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

4. (Continued):

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 the most 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 are also used with polyamide fabric. For special applications, fluorocarbon elastomers, as well as polyester and aramid fabrics, have been used.

5. DESIGN RECOMMENDATIONS:

The following recommendations apply to non-self-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 non-self-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 USARTL Technical Report 79-22 Volume TR79-22E. It is also recommended that MIL-STD-1290 be consulted.

5.1 Tank Configuration: The demand for maximum fluid storage capacity makes it desirable that flexible tanks conform to structure as closely as possible. This results 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 non-self-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.

5.1.1 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 Fig. 1 but may vary in accordance with the structure design.

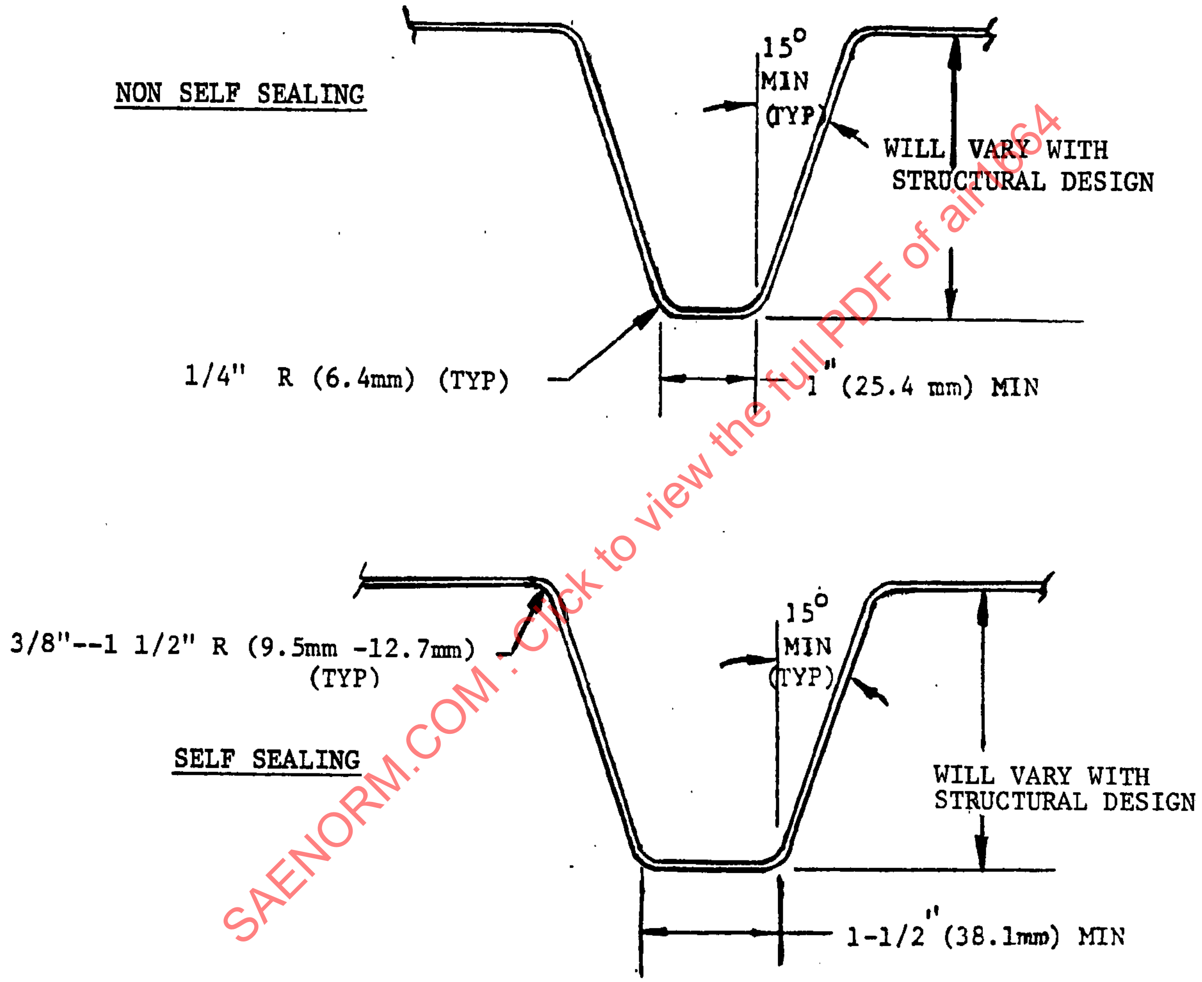


FIGURE 1 - Recommended Proportions for Convolutions

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

a. MIL-T-5578 and MIL-T-5579 Self-Sealing - 1 in (25.4 mm) min
b. MIL-T-27422 Self-Sealing - 2 in (50.8 mm) min
c. MIL-T-27422 Non-Self-Sealing - 0.75 in (19.1 mm) min
d. MIL-T-6396 Non-Self-Sealing 0.2 in (6.4 mm) min
e. To clear structure corner interferences, modify the tank shape. Bevels or radii may be used.

5.2 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, 323.967(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.

5.2.1 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 non-self-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.

5.2.2 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.

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

5.2.3.1 In non-self-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.

5.2.3.2 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.

5.2.3.3 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 in 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.

5.2.3.4 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.

5.2.3.5 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.

5.3 <u>Plumbing Adapter Fittings</u>: 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.

5.3.1 <u>Nipple Type Fittings</u>:

5.3.1.1 Current military specifications do not permit the use of molded-rubber tubular nipple fittings; however, this type fitting is used in non-self-sealing, non-crash-resistant tanks used in certain general aviation type aircraft.

5.3.1.2 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.

5.3.1.3 Nipple fittings are simple, lightweight and cost effective. Flanges may be designed in one or two planes with the tubular section projecting inward or outward from the tank's outer surface. With a two-plane nipple fitting, the opening can be located closer to the tank bottom than with other type fittings. This often eliminates the need to locally lower the tank surface in the fitting area to obtain maximum liquid drainage.

5.3.1.4 Sealing the nipple-type fitting is accomplished by means of a hose clamp. Torque on the hose clamp should be controlled by the use of a torque wrench because excessive torque is a basic cause for fitting leakage. Controlled torque will avoid excessive compression of the molded rubber in the tubular section which could result in permanent distortion or tearing of the rubber tube.

5.3.1.5 Suggested torque values for various tubular nipple fittings are given below. These values apply to a rubber compound of approximately 50-65 Shore A durometer and a worm drive hose clamp with a 0.50-in (12.7-mm) wide band.

Rubber Tube Inside Dia. in (mm)	Torque lb·in (Nm)
0.25 - 0.62 (6.4 - 15.9)	12 - 16 (1.36 - 1.81)
0.75 - 1.0 (19.0 - 25.4)	15 - 20 (1.69 - 2.25)
1.5 (38.1)	25 - 30 (2.82 - 3.39)
2.0 (50.8)	30 - 35 (3.89 - 3.95)
3.0 (76.2)	35 - 40 (3.95 - 4.52)

The optimum sealing torque is influenced by the durometer of the fitting material, inside and outside diameter of the rubber nipple, and the hose clamp design. If these conditions vary considerably from those noted above, torque values should be established by test.

5.3.1.6 It is recommended when installing the metallic fluid line in the rubber tube, that the line extend through the fitting. By doing so, the tubular section is protected from distortion. As a result of the tubular section being stiffened, vibration loads will be transmitted to the relatively flexible fitting flanges. It is recommended that the metal line be secured to the adjacent structure as close as practical to the rubber fitting to avoid transferring the unsupported weight of the fluid line to the bladder.

Protection from cutting of the rubber tube by the hose clamp is attained by a fabric wrap on the outside of the tube. When the rubber tube of a nipple fitting extends outwardly from the tank surface through the bulkhead structure, the rubber tube should be centrally located in the clearance hole provided. This hole should be treated to eliminate cutting edges.

5.3.2 <u>Bolting Ring Type Fittings</u>:

5.3.2.1 In most instances, this type fitting consists of one or two metal parts bonded to rubber or rubber-coated fabric flanges to form a subassembly. The subassembly is subsequently fabricated into the tank wall. For maximum reliability, elastomeric O-ring gaskets are used as seals. Qualification is by compliance with the applicable tank specification.

5.3.2.2 Design standards MS29558, MS29559, and MS29560 should be followed whenever possible for MIL-T-5578, MIL-T-5579, MIL-T-6396, MIL-T-27422, and TSO-C80 tanks. These standards have been created with the assistance of the tank manufacturers and embody dimensional characteristics that assure cost effective productivity and reliability. Tooling is available for many fittings designed to these standards.

5.3.2.3 Crash-resistant tanks made to comply with MIL-T-27422 require very high-strength fittings in high-stress areas. These fittings must be qualified by compliance with test requirements in the specification. The dimensional envelopes of these fittings are different from MS types. See Fig. 2. In lower stress areas, consideration may be given to the use of MS type fittings as noted in 5.3.2.2. MS type fittings have application possibilities in commercial crash-resistant installations whenever performance requirements have been reduced below those of the military specification MIL-T-27422. Overall metal dimensions of standard MS fittings have been established within the following constraints:

a. Adequate space for replaceable thread inserts
b. Adequate adhesion area (flange to ring)
c. Adequate area for O-ring seal
d. Certain requirements for the diecasting process which is the preferential process for low-cost quantity production

5.3.2.4 Since these standards were established, designs have evolved based on machined rings, smaller OD thread inserts, and plain, no-groove seal surfaces.

These changes have resulted in potentially smaller envelope dimensions without violating the standards applying to minimum dimensions within the fitting such as adhesion area outside the bolt pattern.

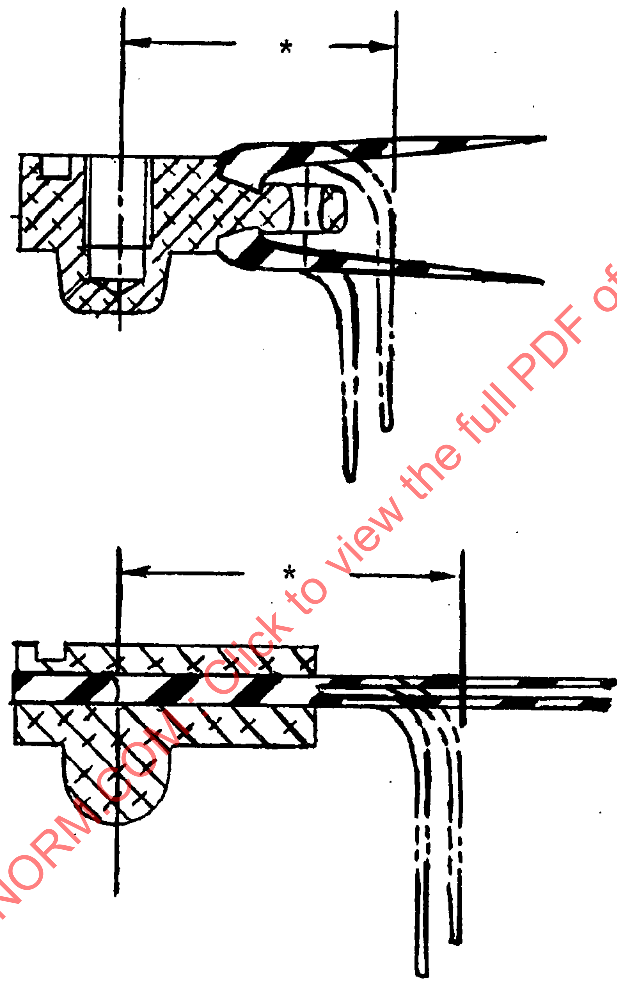
In two-part fitting designs, the outer part thicknesses may be reduced to 0.060 in (1.5 mm) if the O-ring is positioned in the mating part and the installation is such that distortion caused by assembly bolt torque cannot occur. The design of rectangular fittings should incorporate large, approximately 1 in (25.4 mm) corner radii. See Fig. 3.

5.3.2.5 The large radius will reduce stress concentration in the tank to fitting bond which occurs as a result of handling.

5.3.2.6 Seals should be O-rings installed with controlled compression. Molded-in-place seals are also useful. Seal material should be that recommended by the airframe contractor for the service environment. Bulkhead type seal designs may be incorporated into two-part fittings. These may be useful for tank drain installations.

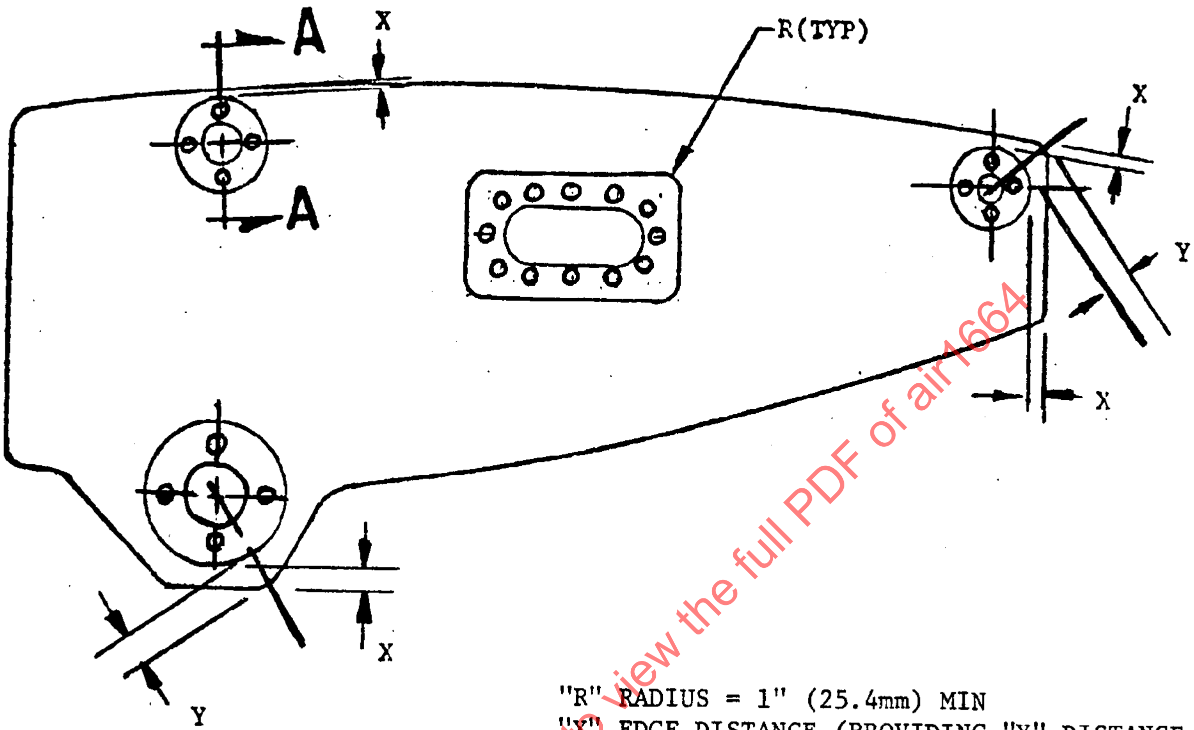
O-ring groove design shall be per MS standard fitting drawings MS33581 or other approved design standards. To facilitate retention of the O-ring during complex installations, undercut type O-ring grip grooves are preferred.

5.3.2.7 Threads shall be in accordance with accepted standards. Assembly bolts should be no smaller than 1/4 in (6.4 mm) to avoid breaking of bolts and subsequent maintenance action. Threaded holes are to have replaceable, self-locking threaded steel inserts to permit replacement of damaged threads in the field or at a maintenance depot. Threaded holes shall meet the test requirements of MIL-T-6396.



*Single plane fittings vary in design as illustrated. Generally such a fitting can be located as close as 1 1/2" to the outer mold line of the tank (as measured from the bolt circle). Since dimensions do vary among the manufacturers, they should be consulted if a closer distance is required. One alternate solution to a closer location is a two plane fitting.

FIGURE 2 - Typical Crash-Resistant Tank Fitting
Bolt Center Line to Mold Line Distance



"R" RADIUS = 1" (25.4mm) MIN
"X" EDGE DISTANCE (PROVIDING "Y" DISTANCE IS MET) 3/8" (9.5mm) NONSELF-SEALING 5/8" (15.9mm) SELF-SEALING
"Y" EDGE DISTANCE = 1 1/2" (38.1mm) MIN

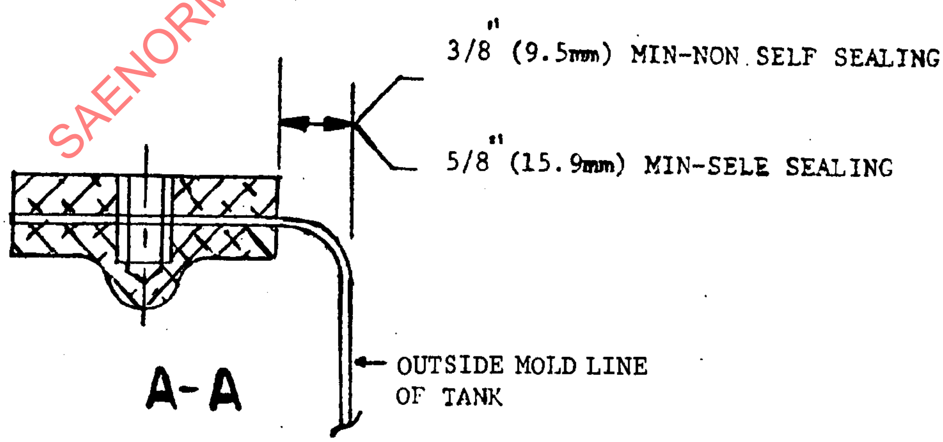


FIGURE 3 - Recommended Dimensions for Fuel Tank Fabrication

5.3.2.8 The fitting ring materials shall be suited to the tank supplier's manufacturing process and the intended use of the fitting. Fitting rings are generally aluminum alloy.

5.3.2.9 When the aluminum ring has integral, nonremovable steel inserts, the preferred corrosion protection treatment is a chemical dip per MIL-C-5541 rather than anodize.

5.3.2.10 Fitting design is very flexible and need not follow standard design in all details. However, installation within the tank envelope requires that adequate clearance be allotted between the metal parts of adjacent fittings and between the fitting metal and the tank mold line.

5.3.2.10.1 When it is desired to locate two adapter fittings close together, consider locating the two bolt patterns in one ring rather than two separate rings. This will facilitate fitting fabrication, reduce tolerances between centers, improve tank reliability, and may reduce envelope size.

The metal parts of any two adjacent MS type fittings should not be closer than 1.25 in (31.8 mm). If fittings are designed to be closer than this, the tank manufacturer may elect to provide a fitting having two bolt patterns in a common flange or two bolt patterns in a single ring.

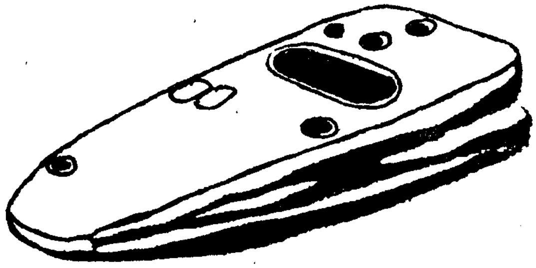
5.3.2.10.2 Fittings shall not be located so close to any edge of the tank that a tank fabrication problem results. For fabric flange fittings, the distance from the OD of the fitting ring to the tank edge should not be less than the following dimensions:

MIL-T-6396 Tanks	3/8 in (9.5 mm)	See Fig. 3
MIL-T-5578 Tanks	*5/8 in (15.9 mm)	See Fig. 3
MIL-T-5579	*5/8 in	
MIL-T-27422		See Fig. 2

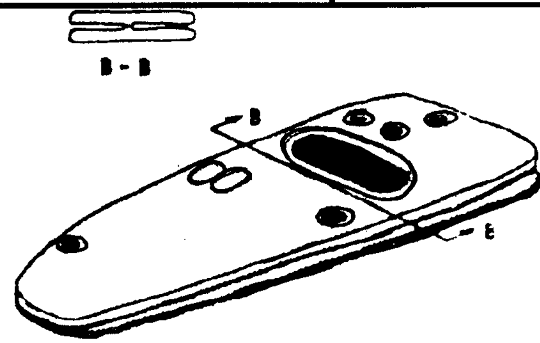
*Can be less if sealing materials are eliminated.

The center line of an interconnector may be lowered by using a small sump directly below the fitting. The edge distances noted above should be observed. For fabrication reasons, a flat bottom sump is preferred to a cylindrical or conical shaped bottom. See Fig. 4.

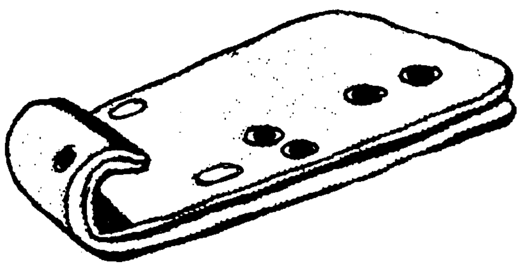
5.3.2.10.3 Whenever special size fittings are needed, bolt pattern spacing should follow the MS standards as closely as practicable. When a circle is not listed in the MS standards, the ID and OD edge distances of the standard MS design should normally be observed although variation may be feasible for certain fitting designs. This is especially important where space is restricted.



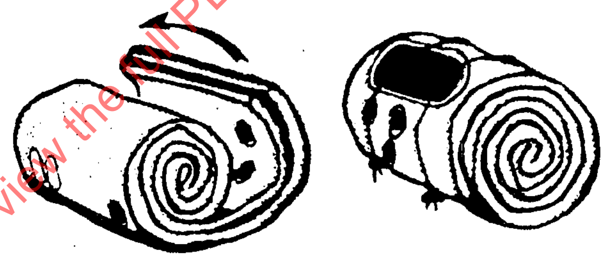
Place the outboard bladder cell on a clean surface with no sharp obstructions.



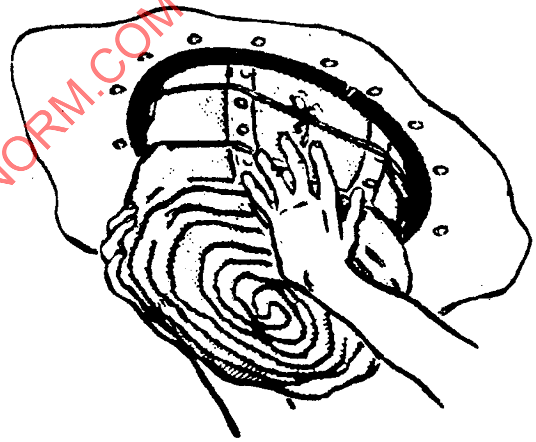
Fold in the sides of the cell and flatten as shown in Section B-B.



Carefully dust the upper and lower surface of the folded cell with powdered soapstone.



Roll the cell as shown and tie with nylon cord.



CAUTION

AVOID ANY CONTACT OF CELL SURFACE WITH THE ACCESS OPENING.

Avoid any contact of cell surface with the access opening.

FIGURE 4 - Installation Procedure

5.3.2.10.4 The tank manufacturing process requires access openings to permit fabrication mandrel removal, adequate cleaning, inspection, and repair of the inner surfaces. When personnel access is required, the mandatory minimum size fitting is the standard 10 in x 16 in (254 mm x 406 mm) clear opening, either oval or rectangular in shape. In smaller tanks where a 10 in x 16 in (254 mm x 406 mm) fitting cannot be used, smaller openings, minimum 8 in ID (203 mm), may be used. To determine the required number of access fittings, human factors must be considered.

These tank openings may coincide with structure installation access panels or may be located in bulkhead areas between tanks, where they may be used as openings through which internal plumbing may pass.

5.3.2.10.5 If the inner surface of a tank must be electrically bonded to the structure to bleed static electrical charges from the tank, the inner liner must be conductive and the fitting design should be reviewed. Some adhesives used to bond plumbing adapter fittings to the tank wall have electrical insulation properties, hence, it should not be assumed that an electrical path exists from the inner surface of the tank to the metallic fitting ring. A fitting, immersed in fuel, will generally provide an electrical path from the fuel to the inner ring and to the assembly bolt, and from there to the structure.

5.3.2.10.6 With respect to crash-resistant tanks, the location of fittings is more critical than in noncrashworthy installations. The favored locations are in those surfaces that will experience the lowest stress in a crash situation.

Differences exist between fixed-wing and rotary-wing aircraft with regard to impact direction. Hence, the orientation of the more highly stressed panels in a fixed-wing aircraft will be different from those in a rotary-wing aircraft.

Fittings located in the highest stressed panels will, of course, experience the greatest loads. In addition, fittings located in a high-stress panel effectively reduce the stress energy capacity of the tank wall in that area and the stress level in the remaining tank wall is increased. Large access fittings in particular should be located, if possible, in the low-stress panels. The designer is referred to USARTL TR79-22E Volume V for additional guidance on crash-resistant fuel system design.

5.3.3 <u>Fitting/Structure-Interface</u>:

5.3.3.1 Engineering drawings should define the desired location of the fitting's outer surface (structure seal surface) with respect to the tank's outer mold line.

5.3.3.2 Control the location of rivets, cavity-sealing materials, doublers, etc., that would prevent proper assembly of the seal interfaces. A 1-in (25.4 mm) minimum constant width area outside the seal area in the structure should be kept clear of any protuberances extending above the seal surface plane. This is particularly important at interconnector locations or other edge locations where structure design may call for application of cavity sealants and rivets between structural components. See Fig. 5. Also, see comments on backing board in 5.5.5.3.

5.3.3.3 Avoid installing fittings in convoluted locations. Tank fabrication problems are severe. To avoid severe tank fabrication problems, keep interconnector fittings or similar edge mounted fittings away from three plane intersections. The ring OD generally should be at least 1.5 in (38 mm) from any edge. See Fig. 3.

5.3.3.4 Fittings are not designed to carry structural loads.

5.3.3.5 For maintenance reduction it is desirable to design fitting installations so that an individual tank of an interconnected group can be disassembled without disturbing the seals in the adjacent tanks.

5.3.3.6 If baffles are considered necessary for slosh control, flight loads should be carried through the tank wall - not into the tank wall - and then into the structure. Special fittings will facilitate this. Horizontal rather than vertical baffles may be effective and will impose less load on the tank wall if designed to deflect fluid rather than confine the fuel.

5.3.3.7 Providing access for installing plumbing, particularly internal assemblies, is important. Difficult installations adversely affect installation time and often result in handling damage. Blind installations are particularly bad. Scuff patches or pads should be added to the tank's interior in areas where there is a probability of impact damage from dropped tools or plumbing equipment.

5.4 Tank/Structure Interface: Cavity liners, sometimes referred to as backing board, are often used to bridge stringers, ribs, or other structural members to provide a smooth contour and to prevent skin loading in fluid tank areas. Reinforced polymeric materials are commonly used. However, metal liners are sometimes used for structural reasons. The polymeric type backing board may add significant ballistic performance to the fluid tank.

It is pertinent to note that the design of structures adjacent to a flexible fluid tank should take into account the existence of hydrodynamic loads when the tank is penetrated by projectiles. A portion of these loads can be absorbed by the wall and cavity liner if the tank and liner bridges the structural members. Conversely, a skin or bulkhead panel in direct contact with the tank will experience a greater percentage of the hydrodynamic load. Thus, structure design may be influenced by the type of tank and cavity liner selected.

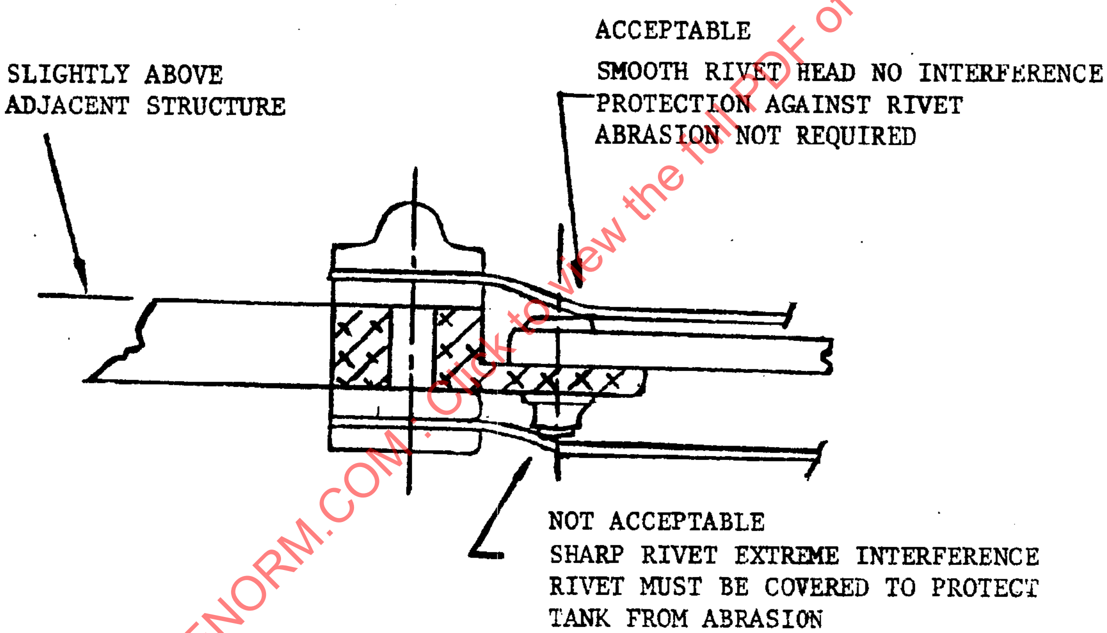


FIGURE 5 - Fitting/Structure-Interface

5.4.1 The size of the structure opening for tank installation is dependent on several factors; namely, flexibility of the tank material, number, size, and location of fittings with respect to each other, the installation opening, and the size and configuration of the tank, particularly self-sealing types, normal and crash resistant. When personnel must enter the cavity, the recommended minimum size opening has been 10 in x 16 in (254 mm x 406 mm), either oval or rectangular. However, where MIL-STD-1472 applies, larger minimum sizes are specified based on access location. Other than this, it is not possible to specify the dimensions of the structure's installation opening prior to having established a tank design.

It may be necessary to create a simulated tank installation to establish the structure installation opening size for tanks of complex configuration.

Self-sealing tanks meeting Protection Level B .30 caliber (7.6 mm) are usually more flexible than .50 caliber (12.7 mm) tanks and can often be installed through openings 2 in to 3 in (51 mm to 76 mm) larger than the largest fitting in the tank. Orientation of large fittings can be very influential on the tank's folding pattern.

5.4.2 Self-sealing tanks resistant to .50 caliber (12.7 mm) gunfire - MIL-T-5578 Protection Level A or MIL-T-27422 Protection Level A (crash resistant) - are quite stiff and resistant to collapse. A general installation procedure would call for the tank to be collapsed by folding two opposite panels inwardly and collapsing the tank in a direction at 90 deg to the plane of the fold. One dimension of the tank would be reduced. It is recommended that the structure installation opening in one direction be at least equivalent to the width of the unfolded tank panel. The size of the opening in the other direction would depend on the amount the tank had been collapsed.

Fitting location must be considered for effect on tank collapse. The orientation of the tank configuration to the structure access location is critical.

Shallow, flat tanks will not be susceptible to collapsing. Self-sealing tanks with numerous and deep convolutions on side panels cannot be readily collapsed and could be damaged as a result of severe distortion.

The use of removable straps to hold the tank in the collapsed position is feasible and may be necessary; however, consideration must be given to the possibility of damaging the tank. The use of vacuum or heat (up to 150°F) is sometimes helpful in collapsing the tank.

In certain aircraft designs, the availability and accessibility of working space outside the cavity must be considered.

5.4.3 Non-self-sealing tanks are generally flexible enough to be folded into a roughly tubular shape and inserted through an opening 2 in to 3 in (51 mm to 76 mm) larger than the largest fitting in the tank (see Fig. 4). On large non-self-sealing tanks, fitting locations generally determine the tank's folding pattern and should be considered carefully when establishing access for installation. Judicious use of straps, which are subsequently removed, can aid the installation of large non-self-sealing cells, particularly those fabricated from heavier materials.

If the tank is supported by a lace line system, the outside of the tank must be accessible; consequently, the access opening(s) in the structure must be of a sufficient size and number to permit this.

5.5 <u>Cavity Configuration and Preparation</u>:

5.5.1 Most flexible tanks of the non-self-sealing type are installed directly against metal structure on which sharp corners are created by three plane intersections. Formed structural shapes such as "Z" sections, which the tank is designed to clear but to which the tank may partially conform, often present sharp edges. These conditions should be treated to provide protection for the tank. Regardless of the tank thickness, cutting edges must be avoided especially when the fluid weight will force the tank wall against the edge.

5.5.1.1 Tape is useful to cover thin structure and shallow height rivet heads. However, the tape and the adhesive on the tape must be compatible with the total aircraft environment in order to avoid deterioration of the tape.

Various elastomeric sealant materials are useful in protecting any type of flexible tanks from the effects of sharp edges by filling in the stepoff at the structure edges. Other common conditions are bucked heads on larger rivets and broken shanks on Huck-type bolts, etc. The sealant shall be compatible with the total environment of the aircraft.

5.5.1.2 To avoid assembly problems and problems with weight and volume, sealant application must be controlled in all areas and in particular in the vicinity of fitting sealing surfaces and in cavity corners. In particularly severe conditions, a large radius on the tank resulting in the tank bridging the corner may be useful. However, to avoid stressing the tank wall unduly, consideration shall be given to the flight loads, both positive and negative, and the strength of available tank materials. The tank wall can be reinforced locally as necessary.

5.5.1.3 When laying out lace line patterns, avoid the possibility of lacing across a fitting seal area (see Fig. 6).

5.5.2 In some areas other than the bottom surface, the use of cavity liners may be eliminated from non-self-sealing tank cavities as a cost- and weight-saving design. As an example, consider an intermittently supported top panel. Consider the need for a stronger, heavier tank material if this is done. (See MIL-T-6396 Class C.)

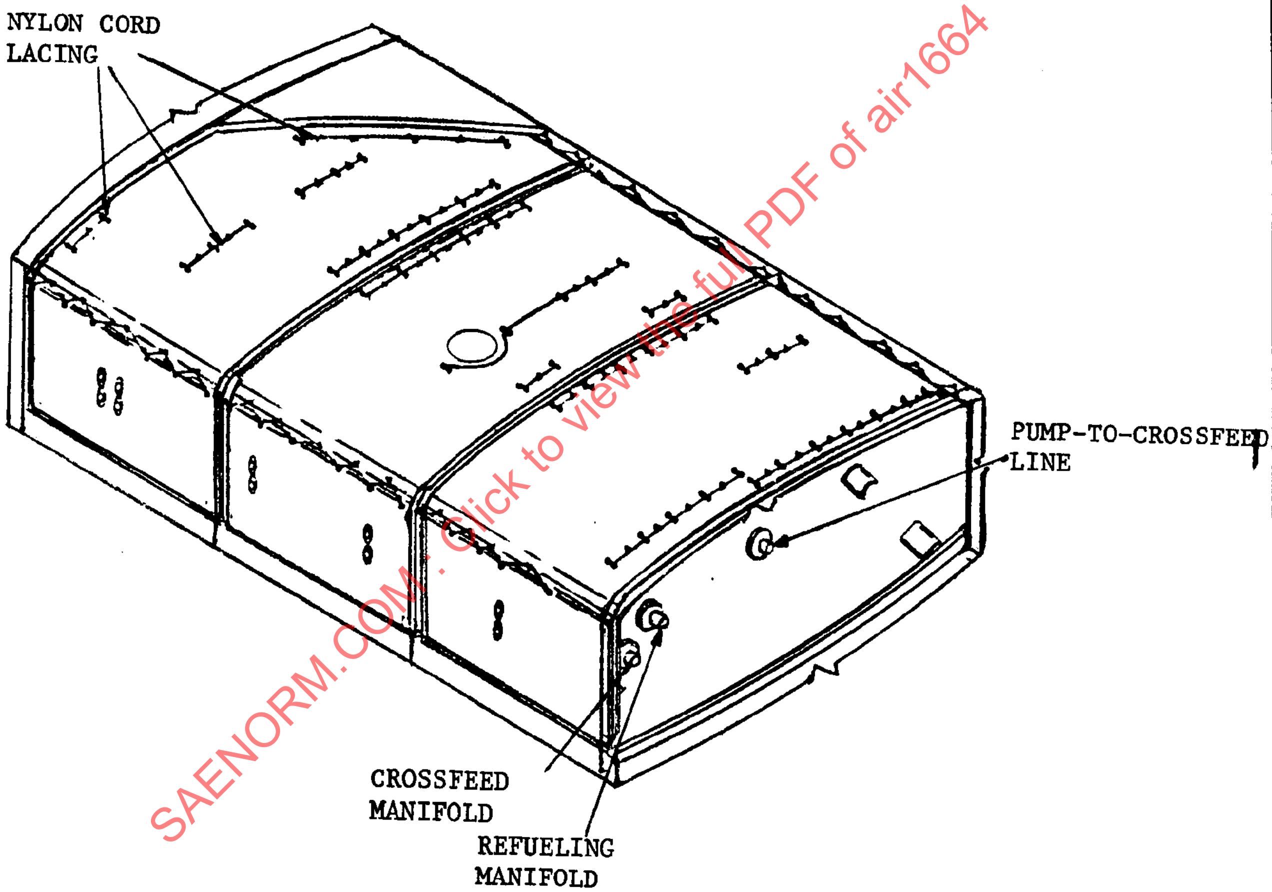


FIGURE 6 - Installed Tanks Showing Lacing

5.5.3 For maximum gunfire resistance when designing a Class B (tear-resistant installation), utilize the maximum support available by locating the tank wall against the structure preferably with backing board between the tank and structure.

5.5.4 The use of filler blocks to prevent trapping of fuel should be confined to the aircraft cavity since locating them within the tank increases package size and adds to the problem of installing the tank through small access openings.

5.5.5 Self-sealing tanks require the use of ballistic resistant backing materials installed between the tank wall and metallic structure. The backing serves to protect the tank against the effects of shrapnel and the flowering of adjacent metal. Backing board also supports the tank wall before and after projectile penetration. Support for the walls of self-sealing tanks under fluid loads is important since tension loads induced in the deflected tank wall by hydraulic loading during gunfire cause misalignment of the wound edges and, thus, adversely affects sealing performance. See 5.6 for additional discussion on backing materials and Fig. 7.

In the event convolutions are designed into self-sealing tanks, the backing board must also be convoluted. Special support for the backing board should be provided at edges parallel to basic structure members when the board extends beyond them (see Fig. 7).

5.5.5.1 Backing board panels may be held in place with adhesives, rivets, or sheet metal screws. Use only enough fasteners to position the board to the structure and minimize deflection under fluid loads. If the backing board can deflect with the tank wall under hydrodynamic ram and return to its original position, the gunfire performance of the installation will be improved. Consult with tank manufacturers for additional backing board installation data as the characteristics of available materials are considerably different.

5.5.5.2 Where it is planned to install the tank against a flat metal structural panel such as a bulkhead, a sheet of backing material is required between the tank and the structure to protect against petalling and spalling of metal (see Fig. 8).

If a thin metal liner is used in the cavity as shown in Fig. 8, an alloy that will tend to resist catastrophic splitting and tearing, (often occurs as a result of hydrodynamic ram) should be specified. Failure of the metallic liner increases the probability of tank failure, particularly at low temperatures.

5.5.5.3 When designing a backing board installation, attention should be given to the possibility that the backing material will rest on top of rivet or bolt heads, structure doublers, etc., which may extend inside the basic mold line of the cavity. The effect of these conditions on the fit of the fluid tank must be assessed by the design engineer and reflected in tank configuration data.

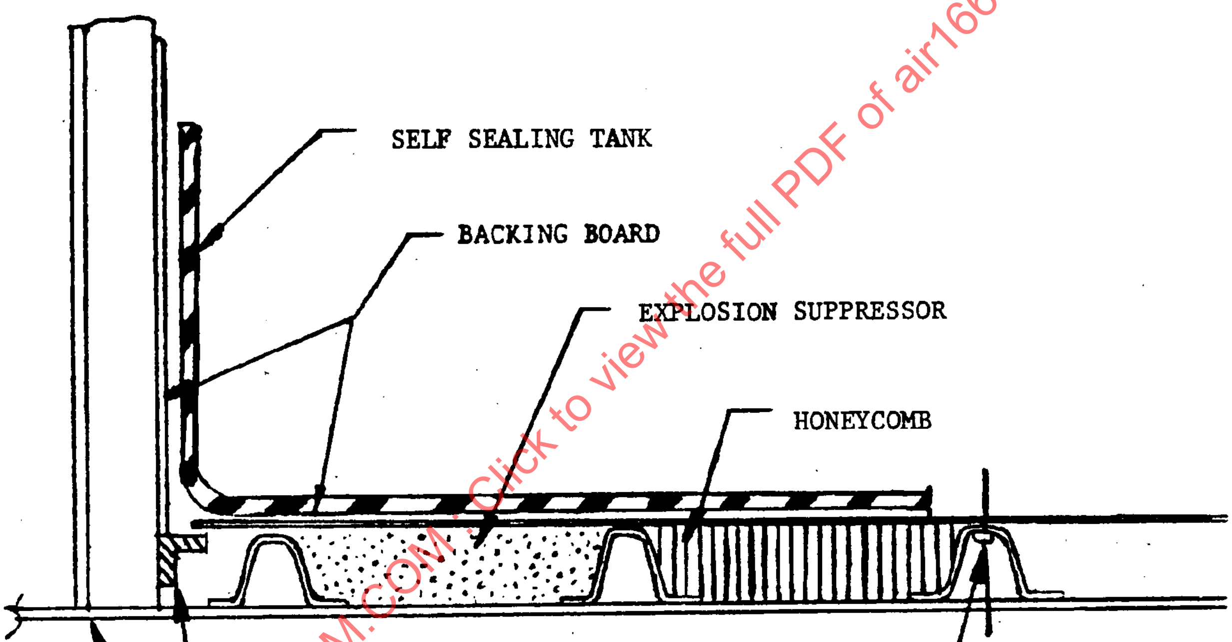


FIGURE 7 - Typical Self-Sealing Tank Installation

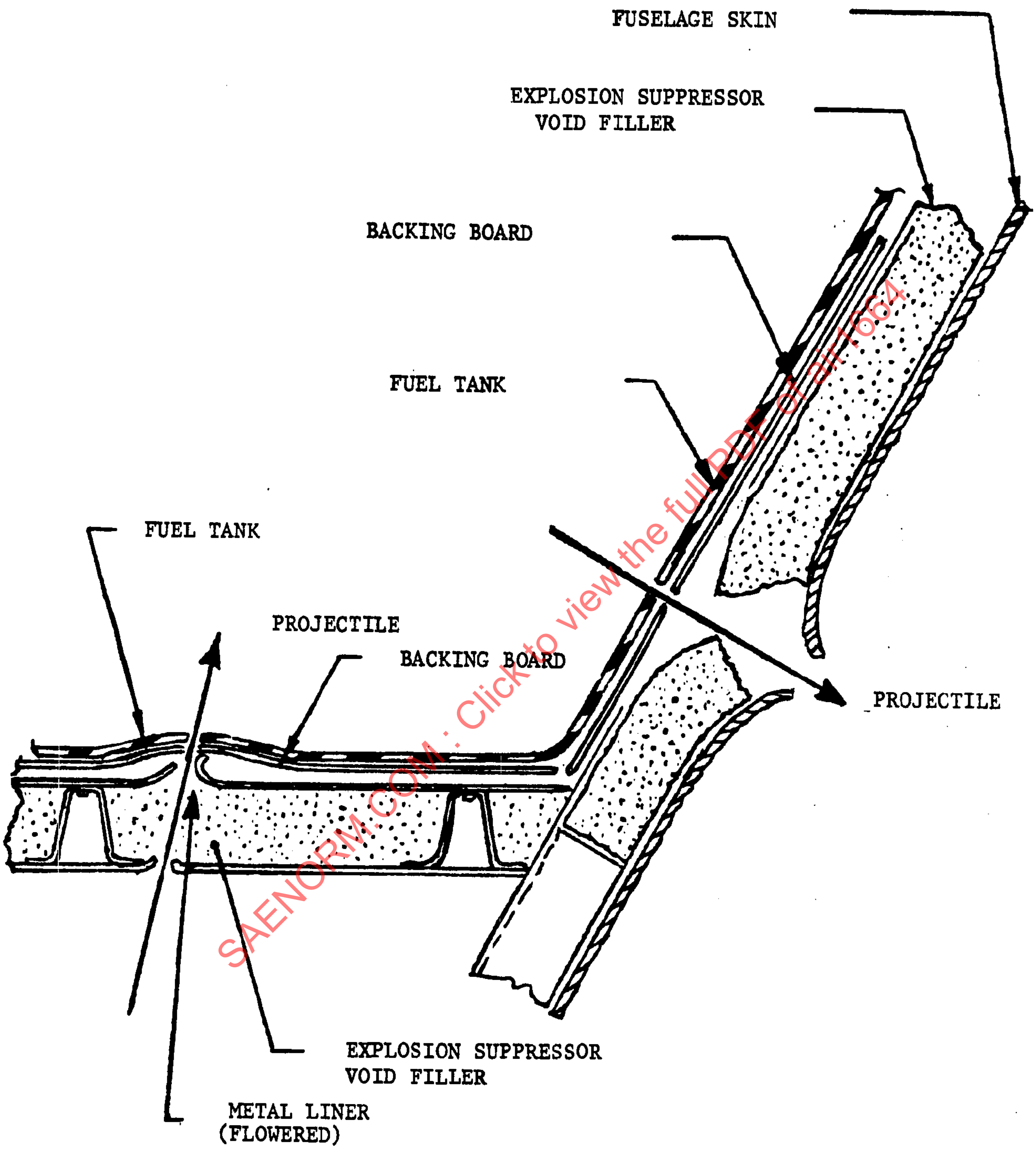


FIGURE 8 - Ballistic Penetration of Self-Sealing Tank Installation

5.5.5.3 (Continued):

In large panel areas, away from tank edges, these conditions may have no significant effect on fit. However, in areas near tank edges and adjacent to plumbing attach points, the added thickness of fastener heads plus the backing board may displace the tank sufficiently to prevent a proper installation.

Tanks having narrow, cross-section areas are particularly sensitive to undersize cavity conditions because these narrow sections tend to be stiff and unyielding. The tank size can be adjusted in a localized area to provide a proper fit; also fastener configuration may be changed or the backing board may be cut away to clear. The conditions should be known before hard tooling for the tank has been manufactured.

5.5.6 Honeycomb panels provide an excellent cavity for a flexible tank. In addition, honeycomb provides excellent localized support to the damaged area of a self-sealing tank penetrated by gunfire provided the panel is of sufficient strength to resist splitting. If the honeycomb skin in contact with the tank is nonmetallic, a backing board is not required. A properly designed cavity of honeycomb panels can therefore provide good gunfire resistance. However, such a structure does not provide hydrodynamic ram relief and must therefore be designed to withstand the loads without major failure of panel skins and edge fasteners.

5.5.7 In the event high-strength, low-elongation composite materials are considered for use in a tank cavity, the resistance to gunfire of the particular composite should be investigated. The test setup should include a flexible container to simulate the distribution of hydrodynamic ram load transmitted by the flexible tank.

5.5.8 The cavity must be drained overboard so as to prevent an accumulation of fuel in the event of tank leakage and to alert maintenance personnel. Check that fluid will flow to the drain point from all cavity locations and will not be blocked by the tank outer wall. The cavity must be vented to prevent buildup of fuel vapors which may constitute a fire hazard. Particular care should be taken to seal the tank compartment from adjacent compartments where higher air pressure may prevail in flight due to ram air effects. If air outlets are provided to relieve such unwanted pressure buildup, then they must be protected so that they are not plugged by the tank wall.

Except for overboard drainage, structures for tank cavities should be sealed not only to prevent fuel from leaking from the cavity into the surrounding structure, but they should be sealed to prevent fuel from any source outside the cavity from entering the cavity and contacting the external surface of the tank. Over a long period of time, fuel in contact with the tank exterior can result in tank deterioration.

5.5.9 Suggested Fuel Tank Installation Procedure: Before any attempt is made to install a tank, the cavity shall be inspected and prepared as follows:

a. Inspect all tank fitting mating surfaces for cracks, scratches, distortion, and damages that will cause mismating or prevent proper sealing. Replace all defective fittings or any suspected of contributing to a leak.

b. Inspect all tank fitting mating surfaces and tank connections for dirt, paint, grease, thread, or other foreign materials that would prevent a proper seal. To avoid scratches on metal surfaces, do not use a metal scraper to remove paint or other foreign matter. Clean all fittings and connections with a clean lint-free cloth moistened with naphtha.

c. Inspect backing boards (where applicable) for cracks, chipping, crazing, or other damage that may cause injury to the tank during or after its installation. Replace all defective backing boards.

d. Inspect tank attaching points for damage or missing parts, and repair or replace as necessary.

e. Assure that all vent or interconnect lines are in their proper positions and that hose clamps are in position and readily accessible.

f. Remove all dirt, grease, and grime from the tank cavity and clean it with a cloth moistened with naphtha.

g. Inspect the entire cavity for nicks, burrs, sharp edges, etc., that could cause tank injury, and smooth in accordance with the applicable aircraft technical manual.

h. Visually inspect fluid tank cavity during all maintenance when the tank is removed and the cavity is accessible for evidence of corrosion, and treat corroded areas as necessary prior to installation of the fluid cell.

5.5.9.1 Self-Sealing Tank Handling Precautions:

a. Transport cells by truck or dolly. Do not use tank fittings for handholds.

b. Do not drag or tumble a fluid tank.

c. Before placing a tank on the floor, spread heavy paper or canvas and keep the exterior surface of the tank clean.

d. Do not place a tank on benches or tables where parts of it will overhang.

e. Before collapsing or folding a fuel tank for installation, warm it to 70°F. In cold weather the cavity shall also be heated before installing the tank.

5.5.9.1 (Continued):

f. The maximum time permitted for a self-sealing tank to remain in a collapsed or folded condition is 1 h. Folding for installation should be accomplished just prior to inserting or removing the tank from its cavity. New tanks that are boxed or crated and stored for 1 year or more may have a tendency to shrink and may be soaked in water after removal from the boxes or crate prior to air testing and installation in the aircraft. Exterior wiping with a damp cloth is usually sufficient to restore design dimensions.

g. Do not rest a tank on sharp objects, a table corner, tapes, edges of a cavity, or on its own fittings.

h. All metal fittings, such as hangers that extend from tanks, shall be provided with rubber protective caps when the tank is out of the cavity.

5.5.9.2 <u>Non-Self-Sealing Tank Handling Precautions</u>: Non-self-sealing tank handling precautions are the same as for self-sealing tanks with the following additional precautions:

a. A bladder tank may be left collapsed indefinitely.

b. Always fold or unfold a tank on a smooth, clean, padded surface that has been covered with canvas or rubberized fabric. When canvas is used, it shall be covered with waxpaper.

5.5.9.3 <u>Tank Installation</u>:

a. After the tank cavity has been properly prepared and inspected, remove any stickers, tapes, tags, or shipping protective devices from the tank. On tanks having metal-to-metal fittings, make sure that the O-rings and grooves are free of dirt, paint, etc., and are not nicked or scratched. Remove contaminants with a clean, lint-free cloth moistened with naphtha. Do not use any lubricant.

b. Fold the tank being careful not to pinch it between the fittings, and gently ease it into the cavity so as not to damage it on the cavity openings or other protrusions of the aircraft.

c. Attach the tank to the structure of the aircraft in accordance with the applicable aircraft technical order.

d. Align tank fittings and interconnects with their mating parts. On fittings that use O-rings, properly seat the O-ring in the groove so as not to pinch it between the fitting surfaces. Some fittings require the use of clamping rings to hold the fittings together and the O-ring in its groove. Consult the aircraft technical manual for applicability and procedures.

e. On bolted fittings assure that the bolts are the proper length. Insert all bolts finger-tight before torquing.