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AEROSPACE INFORMATION REPORT

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SEALING INTEGRAL FUEL TANKS

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1. SCOPE:

This Aerospace Information Report (AIR) presents preferred practices for sealing and repairing integral fuel tanks. It addresses several basic fuel tank designs as they are currently found in practice and discusses the most practical and conservative methods for producing a reliable, sealed system. Design preferences for optimum sealing are not within the scope of this document. Such discussions can be found in the Air Force sponsored handbook entitled Aircraft Integral Fuel Tank Design Handbook, AFWAL-TR-87-3078.

The basic goal in sealing an integral fuel tank is to produce a system that is leak-free for the long term under the environmental and operational conditions expected. Factors that can influence the outcome are:

a. How well the basic design lends itself to good sealing (accessibility; minimal movement; other design factors)
b. The choice of sealant; where it is applied; how it is applied
c. How well the substrate surface is prepared
d. Whether the thickness and contour of sealant fillets and coatings are optimum for the configuration and flight dynamics
e. The degree of resistance of the sealant to the fluid and thermal environment
f. The degree of "insurance" employed (adhesion promoters, top coats over sealants, etc.)

Sealing the tank is a prime consideration. Sealant fillets inside the tanks are considered to be primary seals. Of nearly equal importance is corrosion control. Sealants are used for both, but the purpose of use should never be confused. It is generally accepted, for example, that a major purpose of faying-surface sealing is corrosion control. The faying-surface seal is not considered to be a primary seal except in adhesively sealed systems. It indeed plays an extremely important role as a secondary seal. It limits the length of a leak path and is a permanent, stable, and essentially dislodgeable, protected seal sandwiched between two surfaces. Extensive use is highly recommended.

Sealing philosophies differ within industry and government. There is, however, far more agreement than dispute. Where serious differences in philosophy prevail, they will be noted. If a particular approach appears to be clearly more protective, keeping time and costs in mind, it will be identified as a preferred method.

This document is a distillation of the considered opinions of a broad cross-section of experts in the private and public sector. The user is free to consider the options and plot his individual course from, perhaps, a somewhat more informed position.

2. SEALING PHILOSOPHY:

2.1 Sealing Basic Structural Configurations: The ultimate goal in sealing fuel tanks is to preclude the existence of leaks for the long term and to avoid the intrusion of moisture that can cause corrosion. Most designs fall short of this goal requiring that periodic repairs be made.

Integral fuel tank designs fall into two basic categories: those with full access to the interior of the tank and those with limited access. Those in the latter category are repaired either by injection of channel sealants from the exterior; by retightening or replacing certain types of fasteners from the exterior; by gaining access to the interior of the tank; or by disassembling the tank as necessary to reach the leak source. All sealing, with the exception of channel sealing, is done on the inside of the tank. Factors to be considered in sealing integral tanks for the two basic types are given in the following paragraphs.

2.1.1 Designs Providing Interior Access: Leak paths found in interior access designs originate from skin splice joints, spar to web joints, dry to wet bay interfaces, and access doors. Faying surfaces, lap joints, butt joints, fastener holes, and any other possible path from wet to dry side represent opportunities for fuel leakage and for moisture intrusion to produce corrosion. (Moisture from combined water in the fuel is also a potential source of corrosion.) It is generally accepted by the industry that the primary seal plane is formed by sealant applied inside the tanks at seams, lap edges, and fasteners.

Fay-surface sealing is also considered most important, limiting the length of leak paths, containing the fuel, and preventing corrosion. It is an essential adjunct to fillet sealing to produce a dependable, sealed system.

2.1.1.1 Fasteners and Joints: All fasteners and rivets (even interference fit fasteners) at tank boundaries should be wet installed and overcoated. Several major companies do not wet seal slug rivets or interference fit fasteners. All fasteners that penetrate dissimilar metals must be wet installed with a curing-type sealant. Fasteners and fastener holes shall be solvent cleaned when possible before installation occurs. Automatic installation sometimes precludes this step. Dry film lubricants need not be removed but adhesion promoters must be applied before wet installation. It is mandatory that cadmium fasteners be coated with epoxy before adhesion promoter is applied. MIL-L-8937 and MIL-L-46010 coatings need not be removed provided adhesion promoter is used. MIL-L-23398 coating, on the other hand, must be removed and adhesion promoter applied before sealant application. If a dry film lubricant is not removed, nor treated with adhesion promoter, it must be specifically tested for sealant adhesion. Corners and joggles shall be injected or wet packed except at a junction where three planes meet. Such a location shall be fitted with suitable reinforcement such as corner fittings or screens. Surge boxes and vent boxes should be sealed on both sides. Both sides of common fuel/pressure bulkheads should be sealed. All butt joints, lap joint, and seams should be fillet sealed.

2.1.1.2 Faying Surfaces: Fay-surface sealing should be employed on all lap joint surfaces in the fuel tank boundaries and under all attachments to the fuel tank. Some major examples include:

a. Skin to stringer interfaces
b. Web to spar chord
c. Spar chord to wing skin
d. Surface under any attachment to the skin
e. Shims installed in faying surfaces

After faying-surface sealant is applied and the two surfaces are pulled together in a 100% squeeze-out (i.e., the squeeze-out should be continuous around the entire periphery), the excess sealant is removed when still wet, the surface cleaned, and a fillet of a fuel-resistant sealant applied around the periphery. To simplify the manufacturing process, preassembly sealing should be done to the greatest extent possible. This would include the application of fillets around faying surfaces on subassemblies so that 90% of the sealing is complete on assembly. Remaining fillets are then applied. Pressure testing of faying surfaces of an assembled tank before fillets are applied reveal the effectiveness of the faying-surface seal. Repairs should be made, not by disassembly of the faying surface, but by fillet sealing the edges. Some of the subassemblies that are often "preassembled sealed" include: upper and lower wing panels, front and rear spars, all intermediate bulkheads and webs, and booster pump cover plates. Injection sealing can also be a form of "during assembly" sealing. Where possible, sealants should be injected while the faying-surface sealant in these locations is still in an uncured state. Final assembly sealing includes injection seals, hole and slot seals, brushcoat, and fillet seals. All leak path entry edges should be covered with a minimum of 0.15 in (3.8 mm) of sealant and the sealant should cover a minimum of 0.250 in (6.35 mm) on either side. It is important to note that a significant number of companies do not fillet seal subcomponents until after the final assembly pressure test for the very reason of monitoring sealing effectiveness.

2.1.2 Designs Providing Limited Access: Two types of integral fuel tank designs provide only limited access: The groove- or channel-sealed design and the adhesive-sealed design.

2.1.2.1 Consideration in Groove- or Channel-Sealing: Groove- or channel-sealed designs incorporate a continuous groove or channel in the faying surface around the entire seal plane of the tank. This allows injection of noncuring sealant from the outside by means of a series of ports spaced at 3 to 5 in (76 to 127 mm) intervals. Some groove designs have the groove adjacent to a fastener row or between two rows of fasteners; others have the groove in-line with the fasteners, surrounding each with sealant.

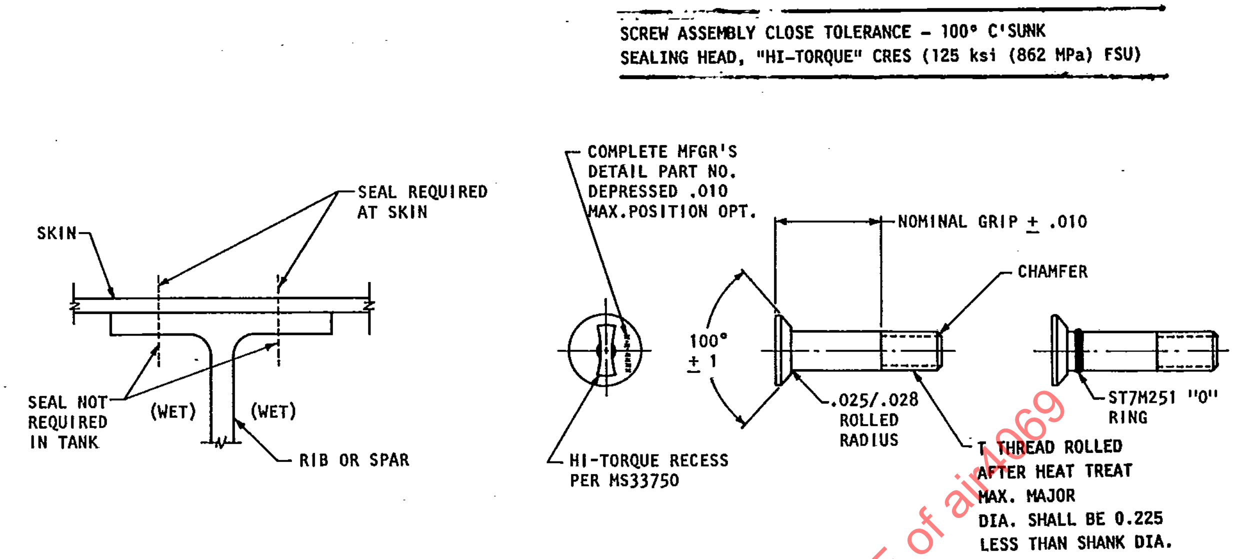


FIGURE 1 - Rib/Skin Asembly

2.1.2.1 (Continued):

The groove design offers distinct advantages in thin-winged aircraft where internal access is extremely limited or impossible. This design offers a major advantage to carrier aircraft since repairs can be made quickly under battle conditions using only a high-pressure sealant injection gun. The fuel tanks need not be emptied to repair the leak. This design is selected for other aircraft due to the simplicity of maintenance and repair.

Grooves are machined into aluminum or titanium alloy component parts of the fuel tank faying surfaces; they are molded into carbon epoxy, carbon-bismaleimide, or other composite parts. Fastener spacing in the channel groove is a maximum of six times the diameter of the fastener. The minimum diameter size of fastener used in channel seal grooves is 0.250 in (6.35 mm).

Ribs that do not assemble to skin splices, but which form the internal structure, do not normally require channel sealing. Self-sealing fasteners are used (Fig. 1). Fasteners not located in the groove path are of the self-sealing type and can be tightened or replaced from the outside.

The size of the groove, the distance between the injection ports, and design features that can inhibit the flow of sealant through the groove are factors related to design that greatly affect the ease of sealing and, eventually, seal integrity. In many groove designs, joint intersections produce voids or open spaces in the groove line. Restrictions, called dams, made of polysulfide sealant (MIL-S-8802 or MIL-S-83430) are formed in place to preserve the continuity of the groove. The configuration of the dam includes chamfered lands at the ends. Metal clips or retainers may also be used to hold the dams in place.

2.1.2.1 (Continued):

Liquid shims made of polysulfide or epoxy or adhesively bonded integral shims are used to improve the basic fit and may be used in integral fuel tanks unless specifically prohibited by design engineering. Gaps must be controlled to 0.005 in (0.127 mm) maximum.

Sealant-related factors concern both application (processing) and (operational) performance. Flow characteristics are important. Though it is noncuring, the groove sealant must seal all gaps and stay in place, yet be injectable. If the viscosity is too low, separation of filler from the sealant can occur, especially under high-injection pressures, resulting in sealant flowing into the tank. Bead-filled sealants appear to flow well and log jam to fill larger gaps.

Sealant is injected at pressures of several thousand psi by sealant guns designed to amplify plant air pressure of 80 to 100 psi (552 to 689 kPa) anywhere from 40 to 110 times. It is possible to damage the structure or distort the skin, losing sealant into the tank if pressures exceeding design structural limits are used. Minimum design thicknesses for tank components in the area of the channel seal are as follows:

a.	Aluminum alloys	0.190 in (4.8 mm)
b.	Titanium alloys	0.160 in (4.1 mm)
c.	Carbon epoxy composite	0.190 in (4.8 mm)

Pressure regulators on high-pressure channel sealant injection guns are essential. Sealers must be made aware of the injection pressure restrictions for the particular design they are servicing. Groove sealant can be extruded with as little as 40 psi (276 kPa) input pressure from plant air, using a 70:1 ratio.

Common failure mechanisms causing leaks in channel-sealed aircraft include:

a. Excessive mismatch of parts (greater than 0.005 in (0.127 mm))
b. Large joint deflections
c. Thermal expansion and contraction of both structure and sealant
d. Chemical degradation
e. Fuel swell of sealant
f. Vibration
g. Corrosion

Particular attention must be given to the selection of channel sealant to ensure good performance within the design configuration and operational environment expected.

2.1.2.2 Considerations in the Adhesive Sealing of Tanks: Adhesive sealing of faying surfaces of an integral fuel tank with a structural film adhesive requires particular design characteristics and special processes and equipment. Mating surfaces must not mismatch by more than 0.015 in (0.38 mm). Tooling must be proofed and verified periodically. After the film adhesive is applied, there must be a full clamp up of structural fasteners to produce the necessary bonding pressure. The entire unit must be placed in an oven for the cure of the adhesive at 300°F (149°C) for approximately 2 h. Structural voids at fuel tank boundaries are filled with polysulfide sealant after the oven cure is complete. Lock bolts, threaded fasteners, and crimp pins are installed with the seal washers on the fuel side. Some designs include a channel or groove between double rows of fasteners around the tank to provide for a future means of repair by injection. If partial access is possible, repairs can be made to the extent possible with polysulfide-curing sealants inside the tank. Other repairs not achievable by groove injection or by access can only be done by disassembly.

2.2 Redundancy in Sealing - Insurance: Fuel leaks have been one of the most serious of integral fuel tank problems and a very expensive item of operational maintenance and repair. A sealing plan that maximizes redundancy can be a source of great savings during the operational life of the aircraft. Several methods for introducing redundancy into the sealing plan are given in the following paragraphs.

2.2.1 Faying-Surface Sealing: Some companies use faying-surface sealing more extensively than others. It is strongly recommended for as extensive use as possible. It not only insures a good seal and minimizes corrosion, but it shortens leak paths, thus, making repairs easier and less expensive.

2.2.2 Wet Installation and Overcoating of Fasteners: Fasteners are the principal sources of leaks. An investigation by the AFWAL Flight Dynamics Laboratory in 1983 (Wright Patterson AFB, Ohio) revealed that even with interference fit fasteners, unless an interference of at least 0.003 in (0.08 mm) is present, acceptable sealing by the fastener alone could not be expected. Add to this, the frequent occurrence of out-of-round holes and other manufacturing glitches, and the value of wet installation of fasteners and overcoating of fasteners becomes an evident and inexpensive form of insurance. Overcoating can be accomplished by applying multiple brushcoats, by applying a brushcoat followed with an extrudable B overcoat, or by the application of a B coat alone.

2.2.3 Fillet Sealing - Extrudable Sealant (B) over Brushable (A): This practice is being questioned in many quarters, arguing that if the class B sealant is applied properly, the class A sealant is not needed. The fact remains that the close attention given to the application of class A material around all fasteners, joints and seams ensures that leak paths are closed. The heavier class B type sealant, applied with equal care, provides the thicknesses necessary for protection against joint movement, temperature cycling, and possible mechanical impact. Recent thinking favors the use of an adhesion promoter in place of the brushable class A sealant, then application of class B-type extrudable sealant.

2.2.4 Top Coats (MIL-S-4383 BUNA N or MIL-C-83019 Polyurethane) over Fuel-Tank Sealant: Top coats are used by a few companies. They are applied over fuel-tank sealant inside the tanks as a protective shield between the sealant and the fuel. Those who use it believe it is a necessary protection against the more chemically aggressive fuels used by some foreign countries. Extensive investigation of the chalking phenomenon with the USA fuels by the Air Force Materials Laboratory (AFML)/General Dynamics indicated that even heavy chalking represents only a cosmetic change with no detrimental effect on mechanical properties. Those who use top coatings reason that the damage can be significant on thin brushcoats. Such materials are available for use if desired. These topcoats are designed for long-term protection of the sealant surfaces. Other topcoats are available to preclude the accumulation of chips and dirt on the surface of uncured and still tacky sealant by causing a tack-free surface to form quickly (see 10.1.5).

2.2.5 Adhesion Promoters for Polysulfide Sealants: The use of adhesion promoters with polysulfide sealants for post-assembly seals in fuel tanks and in-service repairs have proven to be particularly effective. Extensive studies by the Air Force and private industry prove that with their use, good bonding is a fact if the substrate is cleaned properly, regardless of whether the surface is an old polyurethane or other normally hard-to-stick-to surface. Extensive use in both initial manufacture and later repair is highly recommended.

2.2.6 Redundancy in Sealing Groove Designs and Adhesively Sealed Designs: Polysulfide fillet sealing of all joints, voids, etc. in the lower skin area before the tank is finally assembled is strongly recommended. This is a one-time opportunity to add redundancy to the sealing of the portion of the tank that will be wet with fuel on a more or less continuous basis.

Some companies treat difficult areas in the upper skin by applying polysulfide sealant to the upper faying surfaces of groove-designed tanks as a back up to the noncuring channel sealant. Great care should be taken to avoid possible blocking of the channel with the sealant. In such cases, it is prudent to assume that the squeeze-out of faying-surface sealant is performed successfully and completely, having no more than a 0 to 0.003 in (0 to 0.08 mm) space in the mating surfaces, that space being occupied by the faying-surface sealant.

2.3 Composite Construction - Sealing Philosophy: All graphite/epoxy to metal joints must be fay-surface sealed. An exception - groove injection sealed joints. All graphite/epoxy to aluminum joints should be fillet sealed after assembly. All permanent fasteners penetrating the composite should be wet installed with corrosion-inhibiting sealant. Cut edges of fastener holes should be sealed with sealant. The sealant performs an important secondary role as a nonconductor between the graphite and aluminum preventing galvanic corrosion.

3. SUBSTRATES:

The possible metal surfaces present within an integral fuel tank include stainless steel, cadmium (must be coated), titanium, and aluminum (bare or treated). The surfaces, however, are almost always coated by a polyurethane or epoxy corrosion-preventing coating, (exception: titanium is not coated), thus, the sealant will be required to bond to the polymeric surface. When the corrosion-preventive coating and metal is scratched or damaged, the surface is smoothed, cleaned, and a chemical conversion coating is applied to the aluminum. If sealant will entirely cover the area, it is not necessary to reapply the urethane or epoxy coating before applying the sealant; otherwise, after chemical conversion coating application, the polymeric corrosion-preventing coating is reapplied. If only the polyurethane coating has been damaged, it can be touched up with an epoxy. Polysulfide sealants bond well to all the surfaces that might be encountered. Some companies merely cover the entire damaged area (after cleaning) with adhesion promoter and sealant.

Composite substrates are not coated with a corrosion-preventing coating. This surface is scuff sanded and cleaned with MIL-C-38736 cleaner in the areas where sealant is to be applied.

3.1 Corrosion-Preventive Coatings:

MIL-C-27725 fuel-resistant polyurethane corrosion-preventive coating is used almost universally to coat all of the inside aluminum surfaces of the integral fuel tank. It is applied before any sealing process, such as filleting, overcoating, or void filling, is accomplished. It will cure enough for handling in 24 h at 77°F (25°C) and 50% relative humidity (RH), but will not be fuel resistant for 3-1/2 days. It takes 14 days to become resistant to methylethyl ketone (MEK).

The exterior of the fuel tank is usually covered with an epoxy type corrosion-preventive coating such as epoxy-polyamide (MIL-P-23377).

3.2 Composite Surfaces:

Composites will be prevalent in fuel tanks in the future. It is beyond the scope of this document to review the status of present investigations regarding the bonding of sealants to composite surfaces; however, it is well known that graphite/epoxy structural materials, with its epoxy matrix, presents essentially an epoxy surface for bonding. Polysulfide sealants bond well to epoxy surfaces. Current studies will reveal whether there will be special idiosyncrasies that must be accommodated. It has been established, however, that the composite surface must be scuff sanded, then solvent cleaned. The sealant should be applied as soon as possible although tests have shown that properly protected, the surface is still bondable after 30 days.

3.3 Dry Film Lubricants: In 1984, AFML tested seventeen dry film lubricants with polysulfide sealants for bonding characteristics with and without the use of adhesion promoters. It was concluded that adhesion promoters must be used with manganese-dioxide-cured polysulfide sealants in order to ensure 100% cohesive failure (tested after aging 7 days followed by 70 days at 140°F (60°C) in JRF/salt water). While the results were not as clear cut with dichromate-cured polysulfides, it left no doubt that it is highly desirable to use polysulfide adhesion promoters (AMS 3100) on parts containing dry film lubricant before the application of sealant if a good bond is to be expected. SAE AMS 3090 has been prepared for dry film lubricants to which sealants will adhere. An adhesion promoter is still needed.

4. SURFACE PREPARATION:

4.1 Cleaning: It is impossible to achieve a good sealant bond if the substrate has not been adequately cleaned. In general, all surfaces are cleaned in much the same way (i.e., first by cleaning with an aqueous, alkaline-detergent cleaner followed by organic solvent cleaning). In some cases the initial cleaning with aqueous alkaline cleaner is omitted. The steps involved in good cleaning practices are simple and logical but must be followed sequentially and completely.

a. Remove all chips and foreign material (use vacuum cleaners, not air pressure).

b. Prepare an aqueous solution of a detergent such as the MIL-C-25769 solution (superseded by MIL-C-87936).

c. Pour the detergent solution or squirt it from squirt bottles onto lint-free cloths (AMS 3819) or sponges and scrub the surface, working from the top down, and the inside out. Stiff bristle brushes can be used if necessary.

d. Rinse the cloth, brush, or sponge frequently in water (not in the detergent solution) to avoid the build-up of contaminants.

e. Rewet the cloth/sponge with detergent liquid and wipe until the surface appears clean.

f. Using a fresh lint-free cloth, thoroughly rinse with water and give a final wipe down.

g. Wipe dry with a dry cloth. Do not allow air evaporation - it would only redeposit dissolved materials on the surface.

h. Repeat the cleaning process using an approved organic solvent blend such as MIL-C-38736:

(1) Dispense the solvent blend from a polyethylene squeeze-bottle onto a clean lint-free cloth (do not dip wiper into solvent).

4.1 (Continued):

(2) Clean the surface thoroughly with the cloth, turning it frequently. Change to a new cloth as soil becomes evident.

(3) Clean from the top down and from the inside out.

(4) Continue cleaning. A brush may be used to apply solvent and to assist in cleaning. Rinse the brush by squirting bristles with solvent - not by dipping the brush into the solvent.

(5) Before the solvent has a chance to evaporate, rinse the section using a clean, solvent-wetted cloth.

(6) Finally, when there is no further evidence of soil, wipe the surface dry with a dry cloth.

If the surface is not sealed within 24 h, clean it again.

The MIL-C-38736 solvent blend is the solvent cleaner most used:

	PERCENT BY WT.	
	Type I	Type II*
Toluene	0	18.5
Aromatic naphtha containing 30 parts toluene	50	0
Ethyl acetate	20	35.5
Methyl ethyl ketone	20	36.0
Isopropyl alcohol	10	10.0

*Nonphotochemically reactive solvent blend.

Other solvents used successfully for cleaning are:

TT-M-261 Methyl ethyl ketone, technical grade

TT-N-95 Naphtha, aliphatic

TT-T-548 Toluene, technical grade

P-D-680 Dry cleaning solvent, high flash

O-T-620 Trichloroethane, -1,1,1 technical, inhibited.

NOTE 1: Trichloroethane solvent must not be used on titanium or titanium alloys if the surface may see temperatures above 400°F (204°C). Some use it at lower temperatures.

NOTE 2: Do not use methyl alcohol on titanium.

NOTE 3: Local air pollution regulations should be considered in selecting solvents.

4.1 (Continued):

IMPORTANT POINTS TO REMEMBER CONCERNING SURFACE CLEANING INCLUDE THE FOLLOWING:

a. Cleaning cloths should be lint-free and snag resistant and contain less than 0.5% extractable material (ASTM D 2257). The cloths should be open weave or nonwoven to allow for easier absorption of bulk contamination. AMS 3819 defines the properties and the allowable contamination levels of cleaning cloths.

b. All solvents shall be free of particulate matter and shall leave no residue on evaporation. Solvents shall be dispensed from clean, oil-free containers. The design of the containers should preclude the possibility of dipping cleaning cloths and brushes into the clean solvent.

c. Some question the use of chlorinated cleaners on titanium.

d. Titanium surfaces should be cleaned using both an aqueous alkaline detergent cleaner and an approved organic solvent blend.

e. General Cautions: Be aware of possible sources of surface contamination in the sealing area. These should be eliminated. Wind blown dust, unfiltered air from ventilators, air conditioners, fans, metal chips and metal or plastic dust from nearby drilling or sanding, are potential sources. Additional sources include contamination by personnel transmitting soaps, oils, grease from hands and clothing; contamination from equipment; moisture condensation on the surface if temperatures are allowed to drop while humidity is high; all are sources of contamination. Finally, do not touch cleaned surfaces with bare hands.

f. Never dispense silicone materials in the vicinity of sealing operations.

g. Filtered air should be used when forced into integral fuel tanks for ventilation, curing, drying or purging.

h. Very Important: If adhesion promoter or sealant is not applied within 24 h, clean the surface again.

i. Remember: once cleaned does not necessarily mean always clean. When in doubt, clean again.

4.2 Special Considerations Regarding Surface Preparation: Several points that affect the cleanliness of the surface are worthy of mention.

a. Lubricants containing silicones, molybdenum disulfide or graphite shall not be used in drilling, reaming, riveting, in machine operations, swaging, or in lubricating fasteners on any component of the integral fuel tank.

b. The preparation and use of silicone material should be isolated from the sealing area and from the area where sealants are prepared and handled.

4.2 (Continued):

c. Where fasteners are installed on automatic fastening machines or where tapered fasteners are used and detail parts cannot be disassembled after drilling of holes, the detail parts should be cleaned first, sealant applied to the faying surfaces, and the parts assembled and held together with sufficient clamping force to ensure intimate contact of the detail parts prior to and during the drilling or fastener holes. The permanent fasteners should be wet installed.

d. It is acceptable to apply sealant for wet installation to fasteners lubricated with cetyl alcohol or lauric acid lubricant.

4.3 Adhesion Promoters: Adhesion promoters for polysulfide sealants were developed primarily to ensure adhesion to aged, fuel soaked MIL-C-27725 polyurethane fuel tank corrosion coatings; however, they are extremely important in several applications and must be used properly in order to be effective, as indicated below:

1. They provide excellent insurance for sealant adhesion in new aircraft production and are strongly recommended for this purpose.

2. Their use should be considered mandatory in making in-service repairs to fuel tanks containing MIL-C-27725 polyurethane coatings.

3. Receiving inspection should conduct acceptance testing in accordance with AMS 3100. During use, it should be periodically retested.

In new aircraft production, some airframe manufacturers consider it mandatory to use adhesion promoters after cleaning and prior to post-assembly fillet and brushcoat polysulfide sealing of joints in integral fuel tanks. Adhesion promoters may also be used during assembly for faying-surface sealing, and on the surfaces under fasteners.

Repair of in-service aircraft dictates the mandatory use of adhesion promoters because the corrosion coating in the integral fuel tank is aged, fuel soaked, and has long since lost its chemically active groups on its surface. Sealants do not bond well to this surface. Adhesion promoters ensure excellent chemical bonding and provide an added degree of insurance of good bonding.

Adhesion promoters must be kept in closed, sealed containers at all times except when being used. They will absorb moisture from the air readily and will thereby become ineffective. If the material is transferred to smaller bottles for use on the line, the transfer should be made as quickly as possible and the bottles sealed. Small bottles with screw caps, once opened and in use on the line, should be discarded as follows: Red, chlorinated, after 7 days; Blue, non-chlorinated, after 24 h (or discarded earlier if the material appears cloudy). Always keep the container tightly capped when not removing material. It is important to know that, while absorption of moisture eventually renders the adhesion promoter ineffective, it is mandatory that some moisture be absorbed by the applied adhesion promoter to

4.3 (Continued):

activate it. For this reason, the applied adhesion promoter should be allowed to stand for a minimum of 30 min before sealant is applied. If the humidity level is excessively low, allow 1 h before sealant application. It is preferred that a thin coat be applied without a subsequent wipe-off of "excess" material.

If the sealant is not applied over the adhesion promoter within 24 h, reclean the surface and reapply the adhesion promoter. The adhesion promoter/cleaner product is available in two versions: one in a chlorinated solvent, the other in a nonchlorinated solvent. It is available in bottles and in aerosol cans.

5. SEALANT SELECTION:

Integral fuel tank sealants are available in several polymer types: polysulfides, polyurethanes, nitrile, fluoro-or cyano-silicones, and Buna-N rubber. Within the polymer types they are available in several forms: sprayable, brushable, extrudable, rollable, and in a number of cure rates, providing short or extended work lives and cure times. Nearly all of the sealants found within integral fuel tanks at the present time (1988) are polysulfides. Several decades ago, Buna-N rubber was used as a coating over the fuel tank sealant. This practice has been discontinued due to the excellent fuel resistance of present polysulfide sealants. Fuel resistant fluorosilicones are used in fairly rare instances where temperatures above 300°F (149°C) are expected on a fuel tank wall in high performance aircraft. Only fluorosilicones can be used to repair fluorosilicones because other sealants will not bond well to the fluorosilicone rubber surface. Fuel resistant polyurethane sealants are currently in development but are not yet available on the market. Fuel resistant polyurethane coatings have been recently qualified to several commercial specifications.

5.1 Polymer Types (Curing-Type Systems):

5.1.1 Polysulfide: Formulations used in integral fuel tanks are two-part materials consisting of a separately packaged base compound and a catalyst. The base compound contains the prepolymer and additives that influence viscosity, thixotropy, reaction rate, wettability, adhesion, tensile and peel strength, hardness, and, in some cases, the ability of the sealant to inhibit corrosion when moisture intrudes. The base compound may also contain a pigment and/or small amounts of solvents. The catalyst side contains the catalyst and its solvent or its inert carrier. The catalyst can be manganese dioxide (a black powder) or it can be a dichromate mixture.

The manganese dioxide is suspended in an inert organic plasticizer. The dichromate carrier contains water to solubilize some of the reactive materials. The catalyst side may also contain reaction modifiers and viscosity modifiers.

The base compound and catalyst are combined in a fixed and prescribed weight ratio to produce a sealant with the expected rheological and physical/mechanical properties.

5.1.1 (Continued):

Some polysulfide sealants contain corrosion inhibitors and are so identified in their accompanying data sheets and recognized by specifications designed for them (MIL-S-81733 for example). Corrosion inhibited sealants are used primarily in the faying surfaces of integral fuel tanks and in the wet installation of fasteners. Polysulfide sealants are available in several basic types for fuel tank application as listed below:

Fuel Tank Sealant	MIL-S-8802	-65° to +250°F	54° - 121°C
Fuel Tank Sealant (High Temp)	MIL-S-83430	-65° to +360°F	54° - 182°C
Corrosion Inhibiting Sealant	MIL-S-81733	-65° to +200°F	54° - 93°C
Corrosion Inhibiting Sealant (High Temp)	AMS 3268	-65° to +360°F	54° - 182°C
Quick Repair Sealant	MIL-S-83318	-65° to +250°F	54° - 121°C
Access Door Sealant (Low Adhesion)	MIL-S-8784	-65° to +180°F	54° - 82°C
Corrosion Inhibiting Access Door Sealant	AMS 3267	-65° to +250°F	54° - 121°C
Adhesion Promoter for Polysulfides	AMS 3100		

The viscosities of the polysulfide sealants are several and are designed for specific applications as indicated below:

BASE	VISCOSITY RANGE AT 77°F (25°C) (POISE)
Sprayable	50 - 150
Brushable (Class A)	100 - 500
Rollable (Faying Surface, Class C)	1 000 - 4 000
Extrudable/Trowelable (Class B)	6 000 - 16 000
CATALYST	700 - 1 600

5.1.1.1 Brush Coat Sealants: The Class A type or brushable sealants contain approximately 12 to 16% volatiles and flow more than the B or C types and are used around metal fasteners and over seams and often as a primer coat before the application of B type sealant. Class A type sealants are available in application times ranging from 1/2 to 4 h. They are applied with a stiff short brush. Since brushable sealants can contain as much as 16% volatile solvent, at least 1/2 h must be allowed after application for evaporation of solvent before a top coat of any kind is applied. Class A sealant thickness should not be greater than 0.125 in (3.18 mm) to allow for solvent evaporation.

5.1.1.2 Extrudable Sealants: The class B type thixotropic sealant has no more than 8% of volatile materials and is used primarily for fillets, but is also used for a wide variety of other applications such as hole filling, prepacking, injection sealing, and by some for top coating of fasteners after the class A material has been applied. The class B material is available in application times ranging from 10 to 15 min up to 12 h. The short application time material (10 to 15 min) is highly useful for quick repairs especially at low temperatures; of course, at the lower temperatures the application time and the cure time are longer. Most of the fuel tank sealing is accomplished with 2 h application time (B 2) material. For repairs, 1/2 h (B 1/2) material is used, and sometimes used during the winter when plant temperatures fall below 70°F (21°C). During hot summer months, 4 h material (B 4) is sometimes used. For faying-surface sealants, 4 h and 6 h materials (B 4 and B 6) are sometimes used.

It is important to note that humidity as well as temperature strongly affect the application time, tack-free time, and cure rate. Cure rates are accelerated by temperature and high humidity.

5.1.1.3 Rollable Sealants (long work life and open time): The class C sealant contains about 10% or less of volatiles with longer application times (8 to 48 h) and very long assembly times (ranging from 12 to 336 h) and are generally used for faying surfaces where, after sealant application, other work must be done before the two surfaces can be drawn together. At the time the two surfaces are pulled together tightly with fasteners, the sealant must still be sufficiently uncured to flow and "squeeze out". Generally, a 0.010 to 0.015 in (0.25 to 0.38 mm) thick coating is applied and is subsequently squeezed out to approximately 0 to 0.003 in (0 to 0.08 mm). The cure time can range from 5 to 14 weeks depending upon the assembly time of the product selected. Moisture cured, one-part sealants cannot be used as faying-surface sealants since moisture would not be available for the cure once the two surfaces are brought together.

Solvent from the class C sealant evaporates during the long assembly time before "squeeze-out" and surface mating occurs. If a short "open time" is expected, a slow curing class B sealant is used (such as a B 6, i.e., 6 h application time), since it has a lower volatile content - thus solvent would not be trapped when surfaces are mated. With any of the faying-surface sealants, a minimum of 1/2 h after application should be allowed before the surfaces are mated.

5.1.2 Polyurethanes: Polyurethanes have not been used as integral fuel tank sealants, since elastomeric urethanes of sufficient fuel resistance were not available. Highly crosslinked and rigid coatings are fuel resistant and are used almost exclusively in the form of a corrosion coatings over the metal inside the fuel tank. Such a product is described by MIL-C-27725. This material has been discussed in 3.1. A polyurethane coating (MIL-C-83019) over sealant is mentioned in 2.2.4. Fuel-resistant elastomeric polyurethanes are currently in advanced development and are expected to be available soon. They should be able to provide lower specific gravity products, a broad variety of viscosities and cure rates, and stronger materials, if desired.

5.1.3 Fuel Resistant Fluorosilicones (Curing Type): Fuel resistant fluorosilicones are used where temperatures up to 375°F (191°C) might be expected. Peel strengths are somewhat lower than polysulfides (approximately 10 lb/inch width (1.79 kg/cm width) versus 20 to 40 lb/in width) (3.6 to 7.2 kg/cm width) but are adequate. The peel strength is reduced to approximately 2 to 5 lb/in width (0.36 to 0.90 kg/cm width) at 400°F (204°C), but the bond remains intact. The only current usage is in the wing tank of the F-111. A small amount is also used in the F-14 wing. A primer must be used with the fluorosilicone to produce good adhesion. The one part sealant (moisture cured) produces acetic acid on cure. Bonding tests on various surfaces and fluid immersion tests of samples bonded to various surfaces were conducted during the 1984-85 time period in studies sponsored and/or conducted by the Air Force Materials Laboratory.

5.1.4 Buna-N Polymers: These polymers systems are used very infrequently and only as a protective overcoat (MIL-S-4383) over the integral fuel tank sealants. A totally different use of BUNA-N coatings is represented by Fill-and-Drain sealants. A tank is completely filled with a medium viscosity (high volatile content) BUNA-N sealant. It is then drained from the tank, leaving a coating over the entire surface of the interior. Solvents evaporate leaving a tough, durable coating. It is seldom used in large aircraft sealing due to the lack of control of thickness and weight and difficulty in removing cured materials for other repair work. Weight penalties resulting from coating surfaces in the tank that need no protection are also a factor.

5.2 Uncured Polymer Systems for Groove Design Sealing: Fuel-resistant channel or groove sealants are viscous, putty-like, one-part, uncrosslinked, nonvulcanizing polymeric formulations. They must be fuel resistant, self-healing and possess a tacky-type adhesion to the groove surfaces that prevents fuel from migrating by capillary action. They are produced from fluorosilicones, cyanosilicones, polysulfides and polyesters. Currently, both fluorosilicones and cyanosilicones are used. Two military specifications address channel sealants: MIL-S-81323 (now cancelled) and MIL-S 85334 (current military specification (Navy)). Fillers (often microspheres) are used in channel sealants for several reasons: to minimize thermal expansion, to modify viscosity, and to serve as a gap plugger by producing a log-jamming effect. A typical formulation is the following:

	% by weight
Noncuring polymer microspheres:	90.0
#20 to #50 mesh	6.0
#50 to #100 mesh	2.7
#200 to #400 mesh	1.3

Volume change from thermal expansion over the temperature range -65°F to +350°F (-54° to +177°C) is on the order of 15% with the better formulations and can be as high as 22% with some formulations. Such volume changes, plus volume increases of up to 25% (fluorosilicones) due to fuel swell, create tremendous pressures that can force sealants through the faying surfaces and can distort or damage structural members. Large viscosity changes with temperature also contribute to problems in maintaining a sealed tank.

5.2 (Continued):

The most common failure mode is gap extrusion caused by pressure build-up resulting from thermal expansion, fuel swell, internal tank pressure, and joint flexing.

SAE AMS 3376, issued in 1985, covers the requirements for channel-sealant properties.

Selection of the appropriate channel sealant involves consideration of the following factors:

a. Fuel resistance
b. Resistance to pressure rupture
c. Seal efficiency and flexibility at low temperature
d. Corrosion neutralizing or inhibition
e. Extrusion force
f. Degree of tack or adhesion to:
    1.) Anodized aluminum
    2.) Titanium
    3.) Aluminum and MIL-C-27725 - Tank coating
    4.) Aluminum and MIL-C-5541
g. Nonvolatile content
h. Specific gravity
i. Reinjection time

The following acceptance tests should be conducted on each lot of channel sealant received:

a. Nonvolatile content
b. Extrusion force
c. Pressure rupture
d. Fuel resistance

Sealant is supplied in both plastic cartridges and 5-gal pails.

5.3 <u>Selection of Polysulfide Sealant Types and Classes versus Application</u>: As mentioned previously, there is a wide variety of types and classes of polysulfide sealants available to choose from. The following table gives examples of the appropriate matching of sealant to application. It is not suggested that other types and classes cannot be used. Those given below are appropriate to the application indicated:

SEALANT CLASS VERSUS USE

Use/Application	Class	Method	Time (h) Application	Time (h) Assembly
Brushcoating of Fasteners, Seams	A-2, C-2	Brush	2	
Fillets, Overcoating Fasteners	B-2	Extrude	2	
Repair Fillets, Fasteners	B-1/2	Extrude	1/2	
Faying Surfaces	B-12	Roll/Spread	12	24
	C-20		8	20
	C-80		8	80
	C-168		48	168

NOTE: It is important to note that the assembly time will vary greatly with shop temperature.

5.4 Key Points Concerning the Curing of Polysulfide Sealants: The cure rates of polysulfide sealants are influenced greatly by temperature and humidity. At 55°F (13°C) and 40% RH a MIL-S-83430 B 2-type sealant requires nearly 100 h to cure, whereas, at 85°F (29°C) and 80% RH, the same material will cure in approximately 24 h.

The work lives assigned to particular products are stated for a reaction temperature of 77°F (25°C) and 50% relative humidity (standard conditions). Plant conditions are practically never at standard conditions; thus, the sealant cure rates will be faster or slower than the stated ideal. A rough rule of thumb is that for every 18°F (10°C) increase in temperature the reaction rate will double. Experiments with variations in humidity, holding the temperature at 77°F (25°C) showed that a B 2 sealant (i.e., 2 h worklife) acted like a B 1 when the humidity was raised to 65% RH, and acted like a B 3 when the humidity was lowered to 35% RH.

Anticipation of weather conditions can permit the selection of faster or slower curing sealants to fit the occasion. Moderate acceleration of cure after sealant application can be accomplished by the use of heat lamps if surface temperatures are monitored closely to 140°F (60°C) or less. Increasing the humidity artificially will also increase the cure rate.

Changing the ratio of catalyst to base is not recommended. Such modifications are possible with some products but only under instructions from the sealant supplier. Large increases in manganese dioxide catalyst bring with it its organic plasticizer carrier that can soften the sealant and make adhesion more difficult.

6. SEALANT PACKAGING:

Two-part polysulfide sealants can be purchased from suppliers in a variety of package sizes. The sizes are: 1/2 pint (0.24 L), pint (0.47 L), quart (0.9 L), gallon (3.8 L), and 5-gal (19-L) can kits, as well as in 50-gal (189-L) drum kits. The can kits, through the gallon sizes, are 3/4 quantities of base compound to allow room for the addition of the catalyst and mixing within the base compound container. Sealant is also available in two component plastic injection kits with the 2-1/2 fl oz (74 mL) and 6 fl oz (177 mL) sizes being the most popular. Where large quantities will be used, 50-gal (189-L) drums of base materials with its accompanying 5 gal (19 L) pail of catalyst are purchased and later repackaged by machine mixing and freezing in 2-1/2, 6, and 12 fl oz (74, 177, and 355 mL) polyethylene cartridges for later thawing and use in sealant guns.

Field repairs are generally accomplished through the use of a two-component plastic injection kit (MIL-C-38714). The base material is contained in the cartridge, and the catalyst in a hollow dasher rod that extends into the cartridge. The rod serves as a shaft for a dasher (agitator blade) for mixing base and catalyst once they are combined. The catalyst is forced out of the dasher rod and into the base material through the use of a ram rod. The dasher rod, after mixing is complete, is removed and nozzle installed on the end of the cartridge. The cartridge is then placed in a pneumatic or manual sealant gun for use by the sealer. These kits eliminate the necessity of mix/freezing cartridges of sealant and storing frozen tubes. It eliminates the need for weighing out base and catalyst in the proper ratio from a larger quantity in a two-part kit. It is convenient to use for both production plant and field repairs.

Sealants can also be purchased from the sealant manufacturer already mixed and frozen in 2-1/2 fl oz (74 mL) and 6 fl oz (177 mL) polyethylene cartridges. It is a cost-saving convenience for those end-users who have no facilities and equipment for meter mixing and freezing sealant. This also shifts to the sealant supplier the responsibility for supplying a properly mixed and frozen product.

7. STORAGE OF SEALANT BEFORE USE:

7.1 Uncured Two Part Sealant Kits: Uncured sealants are chemically reactive systems. They are perishable. Both the sealant manufacturer and the user share a responsibility for protecting the shelf life of the sealant. The manufacturer will formulate the most chemically compatible and stable system possible and package it in sealed containers under an inert atmosphere to maximize its shelf life. The user must recognize the activating effect of temperature and exercise appropriate temperature control in storage to ensure that the full shelf life expected will be realized. The user must also appreciate the fact that when containers are opened (cans, foil bags, drums), the inert atmosphere is lost. If only partial use of the material is made, the inert atmosphere (dry nitrogen purge or carbon dioxide) should be restored.

7.1 (Continued):

The shelf life quoted on the labels of most sealant suppliers are based on a recommended storage temperature of no more than 80°F (27°C). Many user storage facilities have no air conditioning. Temperatures can reach 130° to 150° (54° to 66°C) in the summer months. Both base and catalyst can increase in viscosity; a skin can form over the base compound and the resultant changes will cause rejection upon inspection.

Users may extend the useful life of the sealant significantly by merely storing the sealants at 60°F (16°C) rather than 80°F (27°C). A very broad rule of thumb with chemical systems states that an 18°F (10°C) reduction in temperature reduces reaction rates by 50%. It is obvious then that the lower the storage temperature, the less change will occur in the unmixed kits in storage. Storage of unmixed kits at 32°F (0°C) or below should be done only on instructions from sealant manufacturer.

7.2 Storage of Mixed and Frozen Tubes: The reactivity of mixed and frozen polysulfide sealant can be essentially suspended by storage at -40°F (-40°C) or below. Such is not the case for mixed and frozen polyurethanes, which will begin to show significant loss of work life after 30 days at -40°F (-40°C). While polyurethanes are not currently available as fuel tank sealants, it is important to note this difference between polysulfide and polyurethane sealants. It is recommended that mixed and frozen polysulfide be stored at -40°F (-40°C) or below.

Data from the industry indicate that class B polysulfides (2 h work life) can be stored approximately 10 days at -10°F (-23°C), maintaining an acceptable work life. Class A (2 h work life) polysulfides can be stored no longer than 48 h at 0°F (-18°C). Unfortunately, there is no bank of data available to show the effects of intermediate subzero storage temperatures upon the slow loss of work of frozen sealant. Suffice it to say that -40°F (-40°C) is a safe storage temperature. It should be noted that frequent opening of the freezer door or cold room door will affect the inside temperature. Setting racks of frozen cartridges outside the box or room to rearrange inventories will also cause the sealant cartridges to increase in temperature and lose work life. Awareness and good practice will protect the shelf life. Most users of frozen cartridges have established shelf life limits for frozen cartridges (many use 30 days as the limit). Rather than scrap the cartridges at the end of the period, it is practical and worthwhile to conduct a work life test to determine acceptability. It is then at the discretion of the user to extend the shelf life, maintaining production continuity and reducing waste.

7.3 Storage of Elastomeric One Part Fluorosilicones (Fuel Resistant): Currently, one military aircraft (F-111) uses significant quantities of fluorosilicone elastomeric, fuel resistant integral fuel tank sealant. The one-part sealant is used in the lower part of the wing tank and on the sides. It is a one-part, moisture-cured system. Dow Corning Q4-2817 is used. Its shelf life is six months at 80°F (27°C). General Electric produces a similar material, FRV1106 and recommends low temperature storage (0° to 20°F) (-18° to -6.7°C).

7.4 Storage of Channel Sealants: Both the noncuring high viscosity fluorosilicones and the noncuring polysulfide channel sealants are stored at ambient temperature and have a one year shelf life.

The channel sealants referred to in this group are:

MATERIAL	SPEC.	MANUFACT.	PRODUCT#	COMMENT
Polysulfide (noncuring)	MIL-S-85312	Products Research	PR-702	
Fluorosilicones	MIL-S-81323	Dow Corning	94-011	(Spec. cancelled)
	MIL-S-81323	Dow Corning	94-031	
	MIL-S-85334	General Electric	G651 A	Contains plastic beads
	MIL-S-85334	Dow Corning	Q4-2805	Contains plastic beads
	AMS 3376	(No Qualified Products List)		

8. SEALANT MIXING:

Each individual batch of a two-part polysulfide integral fuel tank sealant has a custom matched catalyst system to produce the properties required by the specification. A particular batch of base must be used only with its matched batch of catalyst if the expected properties are to be realized. Catalyst of different batches of the same product shall not be interchanged.

Catalyst and base must be mixed thoroughly to produce the expected properties in the cured sealant. The class A brushable and class C rollable products are quite viscous; the class B extrudable type is thixotropic. In all cases, no swirling motion can be produced through stirring to aid in the mixing, thus every bit of base and catalyst must be moved physically by the stirring instrument and the container walls should be scraped frequently during the mixing process in order to blend the two parts together. A vital factor in the proper use of sealants is sufficient, effective blending to produce a uniform mixture -- and to produce that uniform mixture without stirring in air.

8.1 Hand Mixing: Small two-part can kits (up to and including gallon sizes) provide enough space above the base compound in the container to permit all of the catalyst to be transferred into the base container for blending in that container. Sufficient "extra" catalyst is included to accommodate normal transfer losses and still produce the correct ratio of base to catalyst in the mixed sealant. It is recommended that the full kit be catalyzed to ensure that the proper ratio is obtained rather than using small portions of a kit, weighing out partial amounts and encountering the dangers of incorrect weighing.

It also precludes other sources of error from entering (such as the removal of nonuniform catalyst from its container by failing to stir before removal). There is the added danger of not purging the remainder with an inert gas nor sealing the lid tightly.

8.1 (Continued):

A useful technique in the transfer of catalyst is to invert the closed can and cut out the bottom with a can opener. This produces a smooth side all the way to the top of the can rather than having to manipulate around the rim of the can if removal were attempted with the can right side up.

Hand mix the base and catalyst thoroughly for 5 min with frequent scrape down of the walls. Fold the material over itself. Don't whip it, incorporating air. If the warehouse storage temperature is greatly different from standard temperature (77°F) (25°C), bring kits into temperature controlled (standard temperature) range well in advance of mixing to assure that the application time and extrusion rates will be in the range expected.

Hand mixing does not necessarily mean that all mixing is achieved by hand with a spatula. It also refers to mixing through the use of hand held or mounted lighting mixers or similar motor driven agitators. In all cases the movement of the mixer blade throughout the material and frequent scrape down will aid immeasurably in producing a uniform mix. WARNING: Extremely fast stirring can cause vortexing, resulting in the incorporation of air; it can also heat up the sealant, change its viscosity, and shorten its work life.

Hand mixing of small quantities of two part sealant in specially designed two component polyethylene plastic injection kits is described in 10.1.3.1.

8.2 Machine Mixing: This type of mixing refers to small batch mixing on a special piece of equipment called a Dasher Mixer. It also refers to continuous mixing on a meter/mixer machine.

8.2.1 Dasher Mixer/Filler (Batch): Small batches of material (1 qt (0.9 L); 5 qt (4.7 L)) are sometimes mixed in a Dasher Mixer (SEMCO Models #1350 and 1378), Fig. 2.

There are no other similar or equivalent products on the market. An air cylinder forces the dasher agitator to make full strokes up and down, top to bottom, through the material, mixing it thoroughly without incorporating air. The top of the mixer is in contact with the surface of the sealant. A counter registers the dasher cycles, ensuring cycle uniformity batch to batch. A machine adjustment converts the agitator to a pressure disc forcing the material out through a port into low density cartridges for quick freezing or for immediate use.

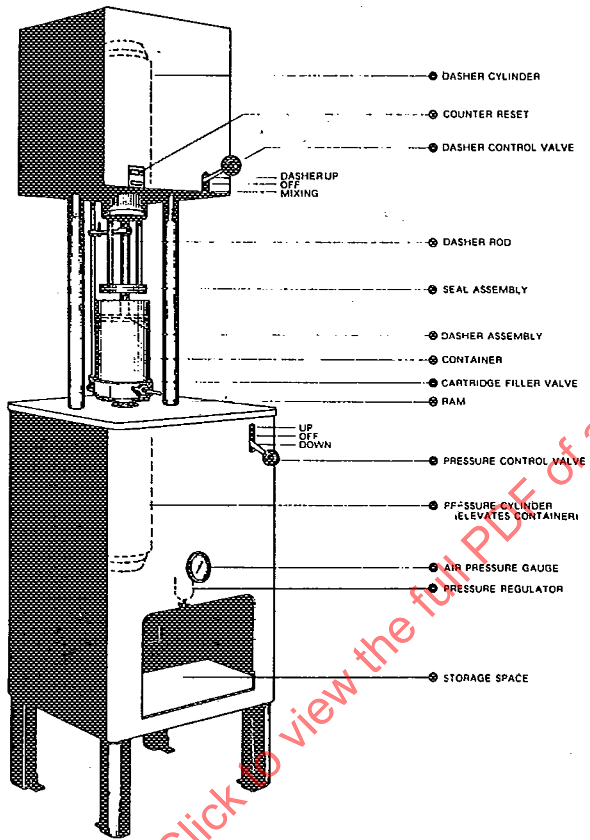


FIGURE 2 - Dasher Mixer

8.2.2 Meter Mix Machines (Continuous Mixing): Two-part sealant is mixed with a meter/mix machine when large quantities of cartridges of mixed sealant are required. The cartridges are filled and immediately quick frozen to -40°F (-40°C) or below for storage until use. A diagram of a typical 5-gal (19-L) catalyst pump and a 50-gal (189-L) base compound pump with proportioning and mixing equipment mounted on its stand is shown in Figs. 3 and 4. Generally, a 50-gal (189-L) drum of base material is positioned on a sealant pump. A follower plate is positioned in the drum on the surface of the sealant.

The follower plate stays in contact with the surface as the positive action of the pump moves the material through hoses to the metering system and to the mix head and delivery valves. The catalyst, in a 5-gal (19-L) pail, is fitted with a 5-gal (19-L) pump that operates in similar fashion. The separate streams of catalyst and base exit the metering system in the proper ratio and are fed into either a static or dynamic mix head, where a uniform mixture is produced. (Fig. 5.)

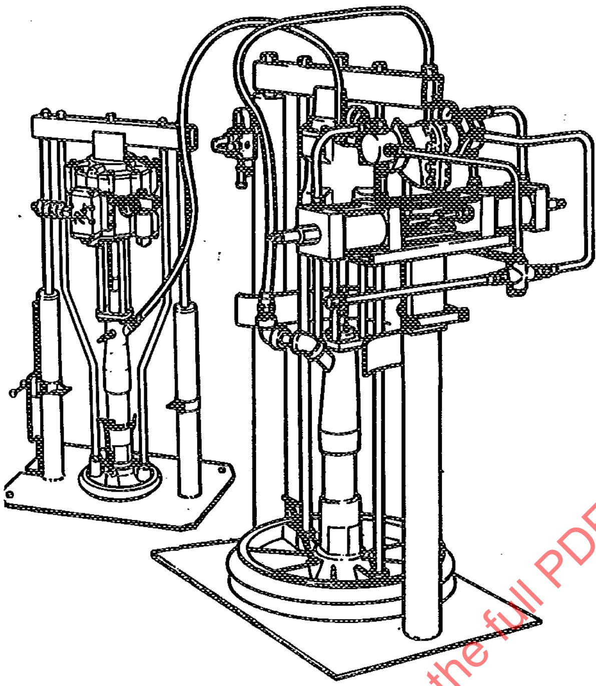


FIGURE 3 - Diagram of 5-Gal (19-L) Catalyst Pump, 50-Gal (189-L) Base Pump, Proportioning Device, and Mix Head

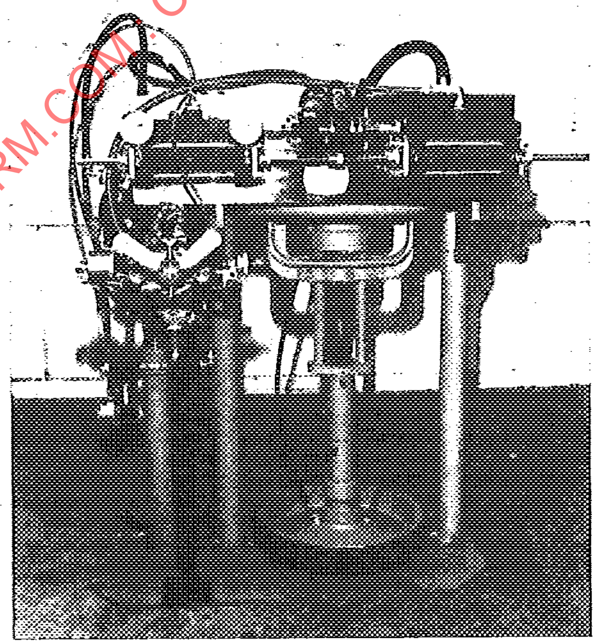


FIGURE 4 - Photo of 5-Gal (19-L) and 50-Gal (189-L) Pumps, Proportioning Device, Mix Head, and Fill Valves

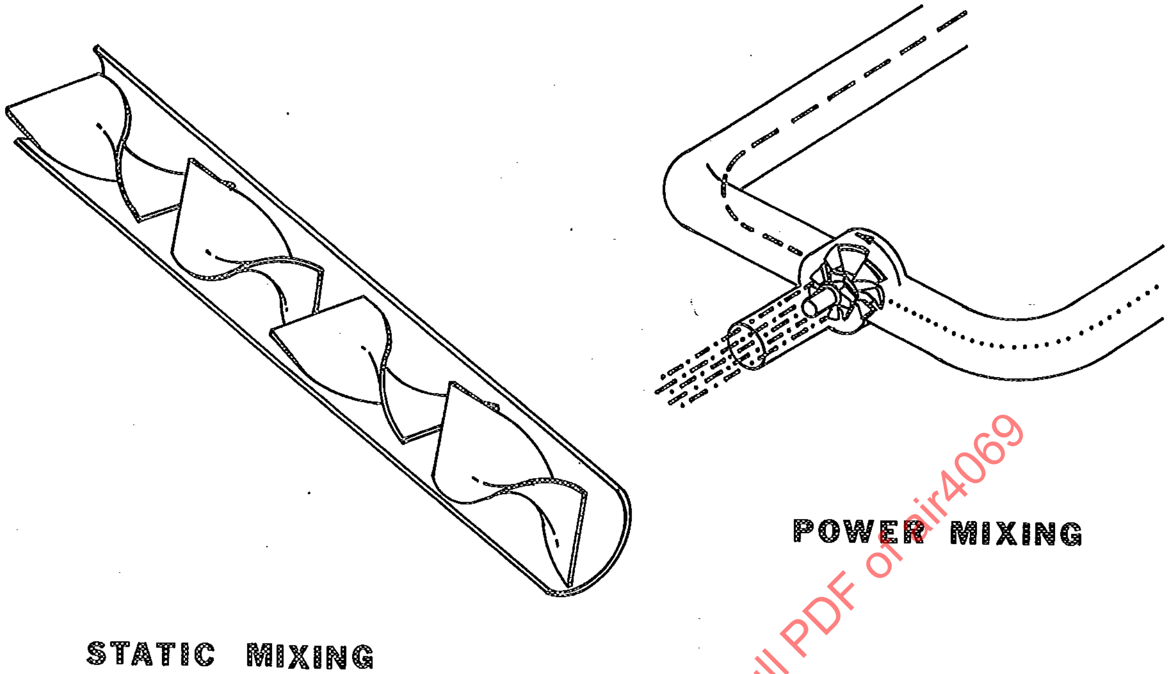


FIGURE 5 - Static and Dynamic Mix Heads

8.2.2 (Continued):

The sealant exits the mix head and passes through a valve into a 2 1/2, 6, or 12 fl oz (74, 177, and 355 mL) polyethylene cartridge, which after filling, is immediately submerged into a cold bath of methanol and dry ice (CO_2) at -100°F (-73°C), where the temperature of the cartridge should be reduced to -40°F (-40°C) or below before moving it to a -40°F (-40°C) storage box.

8.2.2.1 Dynamic Mix Heads: The separate streams of base and catalyst are fed into a dynamic mix head where a low speed impeller (approximately 300 rpm) provides good shearing action, mixing the two materials as they pass through the 1 to 2 in (25 to 51 mm) long x 2-1/2 in (63.5 mm) diameter chamber. The opening/closing of the fill valve downstream of the mix head controls the entire meter/mix system including the supply pumps, pressures, material flow, and mix rpm. This single valve action provides uniform operation of all the systems and a positive shut off with the absence of back pressure. The mix head is double walled and may be cooled by refrigerated water. Positive shut off valves, positioned at the mixing head inlets, prevent compounds from entering the mixing chamber unless the fill nozzle valve is activated.

Dynamic mix heads are far more expensive than static mix heads and more complicated with drive motors, impellers, heat exchangers, and refrigeration systems. The residence time in the small mixing chamber is only a matter of seconds. The sealant is not heated appreciably if refrigerant is continuously passed through the heat exchanger in the mix head. Build-up of sealant on the impeller is very slow, so downtime for cleaning is infrequent. It is generally cleaned only by circulation of solvent through the head -- not by disassembly. The drive motor for the

8.2.2.1 (Continued):

dynamic mix head is powered by plant air [20 cfm (566 L/m) at 90 psi (620 kPa)]. The meter/mix system (pumps, metering system, and mix head) are all pneumatically driven and, therefore, can be used in areas where explosion proof equipment is required.

Several important points are worth mentioning concerning the use of meter/mix equipment:

a. Stir the 5 gal (19 L) pail of catalyst thoroughly with a mechanical agitator.

b. Do not whip air into the catalyst (i.e., do not raise the blade too close to the surface; don't form a vortex by stirring too rapidly).

c. Scrape down the walls frequently.

d. If the catalyst sits for 48 h after stirring, stir it again.

e. Either start with clean hoses for base and catalyst and with an empty meter/mix machine or purge the lines and meter/mix equipment with at least 2 gal (7.6 L) of base and equivalent catalyst.

f. Purge air from the equipment as well as the lines, otherwise a large number of sealant cartridges will contain air in the mixed sealant. Bleeder valves are available in appropriate locations.

g. Calibrate a variable ratio machine initially, and frequently thereafter. Check a fixed ratio machine frequently: i.e., start of each shift and with change of containers.

h. Collect button samples from each cartridge. Number the cartridges and corresponding buttons. This will reveal unexpected or undetected changes in ratio by differences in cure rate of the buttons. It is also an indicator of the uniformity of mixing (observation of streaks or homogeneous color) and whether there is excessive air entrapment.

i. If operations are to be shut down temporarily, the mix head can be removed, sealed, and frozen. The base and catalyst lines should be sealed.

j. If a static mix head is used, clean it if the flow rate decreases substantially.

k. Air pressure to the meter mix equipment should be sufficient in volume as well as pressure. 60 cu ft/min (1700 L/min) at 90 psi (621 kPa) is standard.

An automated mixer for mixing a small amount of sealant in a two component polyethylene plastic injection kit is discussed in 10.1.3.1.

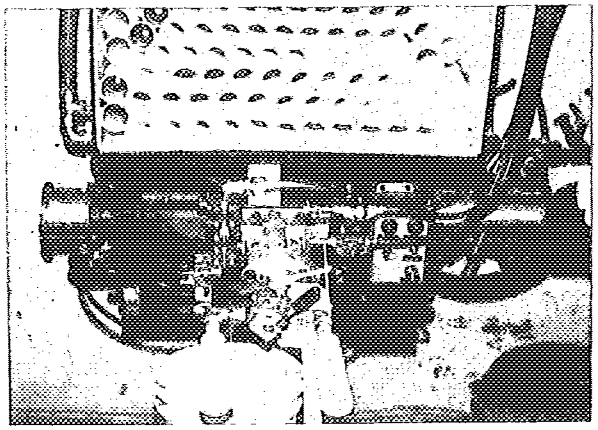


FIGURE 6 - Meter/Mix and Dispensing Equipment

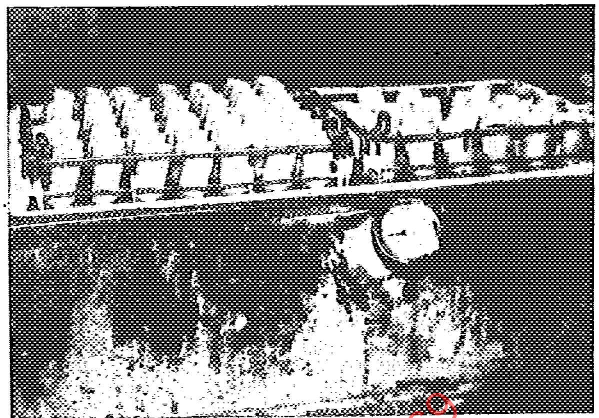


FIGURE 7 - Quick Freezing of Cartridges of Sealant in a Cold Bath

8.2.2.2 Static Mix Heads: A static mix head is a tube containing an internal metal ribbon or containing a series of cylindrical elements with drilled holes that cause catalyst and base to fold over many thousands of times to achieve the uniform mix. There are no moving parts. The tube can be 2 to 4 ft (610 to 1219 mm) long and 2 to 8 in (51 to 203 mm) in diameter depending upon the degree of mixing required and the rate of throughput required.

Static mix heads are available from several manufacturers and in several basically different designs. The appropriate diameter and length must be selected in relation to the viscosities of the materials involved, the ease with which they combine, and the flow rates desired.

A major consideration in the selection of a static mix head is its ease of disassembly and ease of cleaning. Partially cured sealant tends to build up on the internal elements due to the frictional heat developed through forcing the material through the unit. A design containing a permanently installed metallic ribbon can be difficult to clean. Circulating solvent through the unit is a slow process. In some cases, it is necessary to heat the mix head with a torch, incinerating the residual sealant. Mix heads containing a series of removable plastic or metallic cylindrical elements is easier to clean but often the elements must be forced out of the tube with a mechanical press. The elements once removed are soaked in solvent and cleaned with brushes.

9. FREEZING AND THAWING OF MIXED CARTRIDGES:

9.1 Freezing: Once the base compound and catalyst are mixed, Fig. 6, the application time will slip away rapidly unless the temperature of the 2-1/2, 6, or 12 fl oz (74, 177, or 354 mL) cartridge of mixed sealant is reduced rapidly to -40°F (-40°C) or below. The preferred practice is to position the mixing/filling equipment immediately adjacent to a cold bath of methanol/dry ice at -100°F (-73°C). Metal baskets containing 30 to 48 open compartments are submerged in the coolant to receive the cartridges immediately after filling., (Fig. 7). The cartridges are capped on the nozzle end and placed in the basket, nozzle end down. The plunger end is up, with the top 1-1/2 to 2 in (38 to 51 mm) of the cartridge remaining above the surface of the liquid.

9.1 (Continued):

Another technique is to place the cartridges in the freezer bath in thin-walled aluminum sleeves that are closed at the bottom, thus, eliminating any possibility of contamination from the coolant. After 10 min, the basket of cartridges can be removed from the bath and transferred to a cold box or cold room for storage at -40°F (-40°C) below. At this temperature, there is, essentially, no loss of application time. Cartridges have been held as long as 6 months at -40°F (-40°C) without noticeable loss of application time.

Another approved but less used method of quick freezing is to place the freshly-filled low-density cartridge into a nitrogen chamber for approximately 2 min to reduce the temperature to -40°F (-40°C) or below.

9.2 Thawing: Frozen cartridges of mixed sealant are thawed by three approved methods. These methods are discussed in the following paragraphs.

9.2.1 Ambient Air: Frozen cartridges are laid on a bench or table top and allowed to warm at room temperature. The rate of warm up is variable depending upon the temperature of the cartridge, the temperature of the ambient air, the closeness of one cartridge to another, and whether they are standing vertically or lying horizontally. Ambient thaw usually takes about 30 min. The core of the cartridge should reach 60°F (16°C) before application is started.

9.2.2 Enclosed or Open Water Bath: Two approaches are used with hot water baths:

a. An enclosed metal water bath with metal sleeves welded in place top and bottom provides a dry cylinder into which the cartridges fit snugly. Heat transfer from the water through the metal sleeve and polyethylene cartridge is good. With the water bath at 120°F (49°C) the thaw takes about 4 min.

b. Frozen cartridges are placed directly into heated or unheated water. The cartridges are closed with caps on both ends. As the cartridge warms, the material inside expands slightly, and water is not drawn into the container. Thus, the approach is acceptable.

9.2.3 Microwaves: The use of a carousel microwave oven is fairly common. The power level should be on the order of 650 W; there should be an interrupted defrost cycle (i.e., 20 s of heat, 20 s of soak). A 6-fl oz (177 mL) cartridge can be thawed in approximately 2 min. This method is fairly reproducible if the same number and size of cartridges are used each time. It is most important that the carousel feature be used to produce uniform radiation and to avoid hot spots.

In summary, there are several acceptable methods for thawing frozen cartridges. Hot spots can be produced by microwaves; they can also be produced by electrical cartridge heating jackets (not mentioned previously) that can produce very high skin temperatures and cause partial cure of the outer diameter while the heat is penetrating to the core. These heat guns should be used with extreme caution.

10. SEALANT APPLICATION:

Aircraft designs produce a variety of configurations of integral fuel tanks and a variety of subassemblies, attachments, and fit ups associated with each design. In all cases, two-part, curing-type sealants are utilized in several of four general forms: sprayable, brushable, extrudable, and rollable. This document cannot specifically address each of the many individual designs. It can, however, recommend preferred practices in the application of sprayable, brushable, extrudable, and rollable sealants and point out the more desirable contours and thickness to be used in the application of sealant in seams, joints, fastener heads, voids, in faying surfaces, and in types of configurations that are common to all designs. This section on two-part sealant appliction will, therefore, address first the techniques for applying these four forms of sealant, then discuss several specific configurations where additional comment is appropriate. It will also mention methods of protecting applied sealant in its early, tacky state of cure. The application of groove/channel sealant (uncuring type) will be discussed, focusing on key factors necessary for proper application.

10.1 Two-Part Curing Type Sealant: Sealant is applied with two goals in mind: achieving a good bond with the substrate and producing a long-term seal through proper thickness and contour. Achieving a good bond requires a clean surface, sealant with the proper adhesion characteristics for that surface (or use of an appropriate adhesion promoter), and application of the sealant during its application time when it is still capable of wetting the surface. It is well to state again that the use of adhesion promoters for polysulfide sealants during the initial production as well as in later repair is highly recommended. Experience has shown that even though acceptance tests are conducted on every batch of sealant and on a variety of coated panels, the production surface can be different and the production cleaning may not be as thorough or complete as that produced under laboratory conditions. Extensive tests with adhesion promoters have proven that whether the surface is old or new, clean or partially dirty, and be it acrylic, polyurethane or treated aluminum, a good bond is produced through its use with polysulfide sealants. A discussion of adhesion promoters is given in 4.3. The adhesion promoter may be applied by aerosol spray, brush, or by wiping it on with a clean cloth saturated with the materials. It is preferred that a thin coat be applied without a subsequent wipe-off of "excess" material. The adhesion promoter is slightly colored, permitting visual examination to ensure that the entire surface has been coated. The applied adhesion promoter should be allowed to stand for at least 30 min (1 h when the humidity is low) to permit activation of the promoter and evaporation of the solvent. Sealant can then be applied. If sealant is not applied to the (protected)* surface within 24 h the surface should be recleaned and the adhesion promoter reapplied. Adhesion promoters are available in both chlorinated and nonchlorinated solvents. Local company policies dictate which can be used. Adhesion promoters with chlorinated solvents should never be used on titanium or titanium alloy surfaces.

*A surface, after cleaning and application of adhesion promoters, should be protected from airborne debris if there is a delay in the application of sealant.

10.1.1 Sprayable Sealants: Two-part sprayable polysulfides are used by a few commercial companies for corrosion control on the outside of the fuel tank.* Pint, quart, and gallon (0.47 L, 0.95 L, and 3.8 L) sizes can be mixed by transferring all the catalyst for the kit into the base compound container, replacing the lid on the base compound container and shaking it on a standard gallon (3.8 L) capacity paint shaker at 1350 vibrations per minute in the upright position for 3 min followed by 3 min in the inverted position. Larger quantities such as 5 gal (19 L) are generally mixed in 10 gal (38 L) pressure pots using an air driven agitator.

When a paint shaker is not available for the 1 gal (3.8 L) and smaller can kits, they can be mixed mechanically with a Jiffy mixer (air motor, Jiffy blade, T-blade, or flat blade). Limit the speed to 80 rpm to avoid whipping air into the mix and to avoid temperature rise from frictional heat. Scrape down the sides frequently during the 5 to 6 minute mix period.

Thinning (reducing the viscosity of) the material, unless specifically spelled out in processing instructions from the sealant manufacturer, should not be done.

The following types are examples of spray equipment that perform satisfactorily:

1. DeVilbiss gun MBC-510 with nozzle combination 704-E Fluid tip 0.070 in (1.8 mm) I. D., AV-601 Air cap AV-1239 #704 Fluid needle MBC-444-E.

2. Binks Model 18 spray gun 62B tip, 01046 orifice 83A needle 63PB air cap, 3/8 in (9.5 mm) fluid lines.

A line pressure of 45 psi (310 kPa) and a pot pressure of 5 psi (34.5 kPa) is recommended. Sprayable sealants are generally applied to a thickness of 0.003 to 0.007 in (0.08 to 0.18 mm) wet (approximately 0.0015 to 0.025 in (0.038 to 0.06 mm) dry). The application of sprayable sealant is usually of the corrosion inhibitive (chromate) type, used for over-coating slots and depressions and for smoothing gaps. It is important to note that sprayable polysulfide sealants are seldom, if ever, used within the integral fuel tanks. MIL-C-27725 polyurethane is used as a corrosion coating on the inside of the tank and MIL-P-23377 epoxy-polyamide is used on the outside. Normal techniques for spray painting apply. The gun should be moved parallel to the work. Find the proper distance and speed to avoid running or orange peel effects. The orange peel effect can be produced by being too far away as well as too close. Second coats should not be applied until the first coat is tack free.

*Advanced development successes have been realized in spraying polysulfides inside fuel tanks.

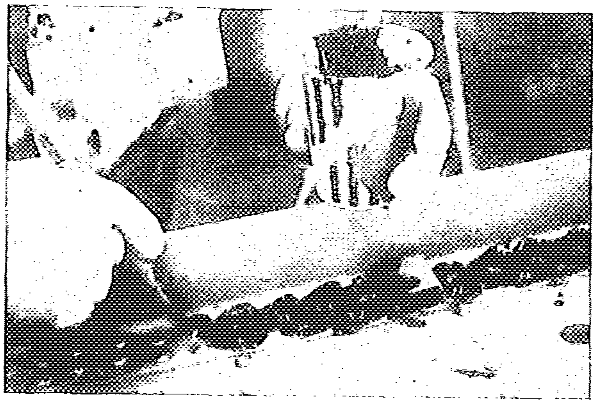


FIGURE 8 - Application of Brushable Sealant

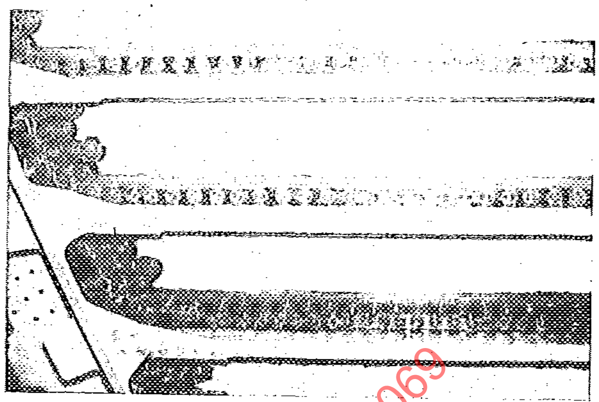


FIGURE 9 - Brushable Sealant Applied

10.1.2 Brushable-Sealant Application: The class A, brushable sealants are applied as brush-coat seals on fasteners and in locations when a flowable material is needed. The first coat is worked in and around all leak source areas with a short stiff brush. The second brush coat is applied after the first coat is tack-free. Overcoats on fasteners are built up to a thickness of 0.030 to 0.060 in (0.76 to 1.52 mm). Brushable sealant is used around crevices, holes, seams, fasteners, and, in some companies, on seams and surfaces to be later covered with the thicker class B extruded fillet of sealant.

It is important that, in applying, the brushable sealant be scrubbed thoroughly into the various crevices and seams (some use a circular motion on surface to ensure that good wetting of the surface has been achieved). Such attentive application prevents the occurrence of voids and, with proper application, minimizes the presence of air bubbles.

Figs. 8 and 9 illustrate the application of the brush-coat sealant over rows of fasteners prior to the application of the class B extrudable material.

Brush coats are applied to a thickness of 0.030 to 0.060 in (0.76 to 1.52 mm) depending upon the location and configuration. The sealant should be applied only within its application time to ensure good wetting of the surface. Because the coating by definition is thin, the presence of air bubbles is unacceptable. The width of the brushcoat should exceed the width of the fillet to be applied by at least 0.10 in (2.5 mm) on each side. Thinning of the brushable sealant should not be attempted unless the sealant supplier provides specific instructions regarding the type and grade of solvent to be used and the allowable amount of solvent to add. Restating an earlier recommendation, an adhesion promoter should be applied to the clean surface before the base coat is applied, whether it be initial production or repair. A brush coat is used as a primary seal only when built-up with multiple coats, such as in the overcoating of fasteners.

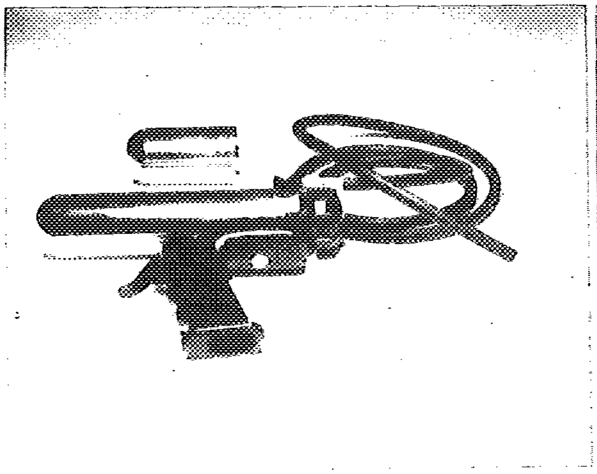


FIGURE 10 - Sealant Gun

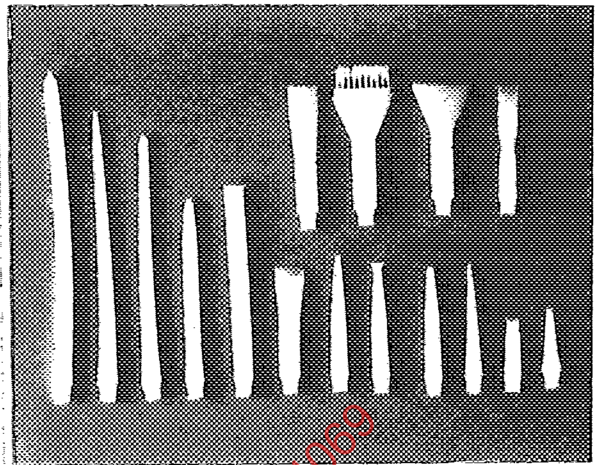


FIGURE 11 - Several Cartridges and Nozzle Sizes and Shapes

10.1.3 Extrudable Sealant Application:

10.1.3.1 General: Extrudable class B sealants are used for filleting over joints, splices and seams, injecting slots and joggles, filling corner closeout cups, and are also used by some for overcoating and crowning fastener heads, bolts, and rivets. They are also used for hole filling and, in some cases, for faying surface applications.

The class B sealants are distinguished by their nonsag or low block flow characteristics and their thixotropic nature, both of which permit the easy extrusion of a very viscous material.

While both the A and B classes of integral fuel tank sealants are equally resistant to jet fuel, the nonsag class B, which contains fewer volatile solvents, is used to provide the required dimensional thickness without the fear of trapping solvents.

The mixed sealant is generally applied from a 2-1/2, 6, or 12 fl oz (74, 177, or 355 mL) low-density polyethylene cartridge contained in a sealant gun powered by plant air 80 to 90 psi (552 to 621 kPa). Manual guns are also available. Use of greater pressure may cause a high incidence of plunger flipping (overturning) resulting in air being blown directly through the cartridge of sealant. A sealant gun with cartridge and nozzle is shown in Figs. 10 and 11.

The handle of the sealant gun is removable. A trigger mechanism, which extends parallel with the barrel, is available for use in restricted areas. More than fifty nozzle shapes and sizes are available from several manufacturers to accommodate most sealing situations. For another view of the gun and nozzle, see Appendix 2, Fig. A2.

10.1.3.1 (Continued):

For field repair and for repairs or sealing where frozen cartridges of mixed sealant are not available, small quantities of sealant [2 1/2 fl oz or 6 fl oz) (74 mL, 177 mL)] can be mixed on site using the two-component polyethylene plastic injection kit illustrated in Fig. 12.

The base compound is contained in the cartridge, the catalyst in the hollow stem (dasher rod). A ram rod is used to force the catalyst into the body of the base compound as shown in Fig. 13.

An open spoke agitator on the end of the dasher rod is used to mix the catalyst and base as the dasher rod is pushed and pulled, rotating clockwise slightly each time. Automated equipment is also available to do the mixing (Fig. 14).

The stroking of the dasher rod is accomplished by means of a reversing air cylinder, and rotation of the dasher rod is accomplished by a low speed electric gear motor. The service requirements are compressed air [approximately 90 psi (621 kPa)] and 110 V AC, 60 cycle (or 220 V, 50 cycle). The most effective stroking speed is between 16 and 22 strokes per minute. When the sealant has been mixed uniformly, the dasher rod is unscrewed from the agitator and removed. The cartridge is fitted with a nozzle and placed in a pneumatic or hand operated sealant gun for application. Dispensing the fillet from the nozzle (i. e., applying the fillet to a seam or joint) in aerospace work is done in an opposite fashion from construction caulking where a trail of sealant is deposited as the delivery tip of the gun points to the rear of the direction of travel. Air can be trapped under the bead as it is laid.

It is not necessary to lay an undersize fillet then apply a large fillet over it if a large fillet bead is called for. While this technique is practiced by some, it introduces an unnecessary step and creates yet another interface where a new bond line must be established. It is preferred that a larger nozzle orifice be used initially and that only one fillet be applied, then tooled. The preferred technique in the aerospace industry is to hold the gun about 30° off perpendicular pointing the nozzle in the direction of travel as the fillet is laid in the joint or seam. This forces sealant into the crevice and minimizes the possibility of air entrapment. Some hold the gun nearly perpendicular to the work. Do not apply sealant with the tip pointing opposite the direction of travel. After the bead of sealant is applied, the sealant is tooled as shown in Figs. 15 and 16. This produces a faired configuration, eliminating the possibility of reentrant edges and trapped air, and ensuring good surface contact.

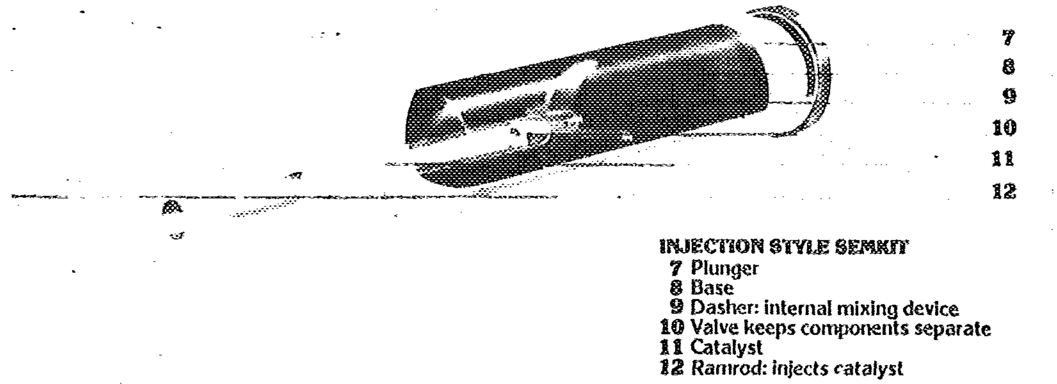


FIGURE 12 - Two-Component Plastic Injection Kit

FIGURE 13 - Catalyzing the Base Compound: Two-Component Plastic Injection Kit

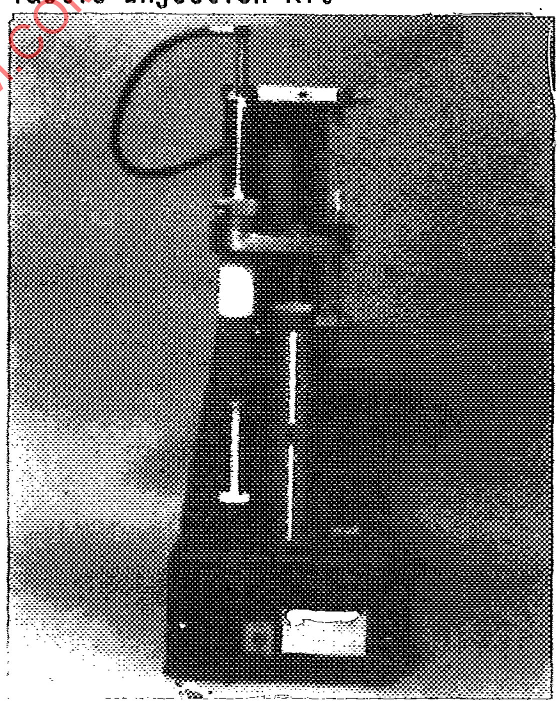


FIGURE 14 - Automated Mixer for the Two-Component Injection Kit

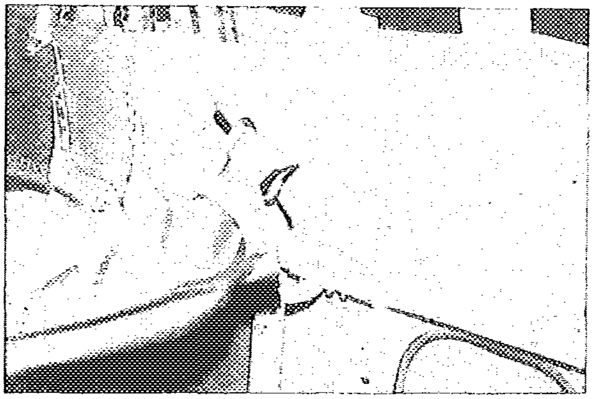
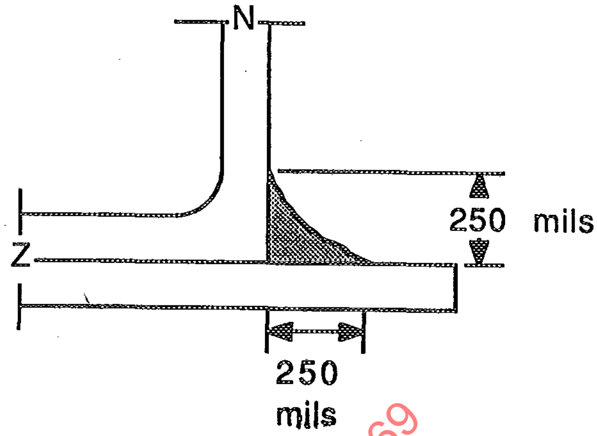


FIGURE 15 - Tooling a Fillet



Note: 250 mils = 0.250 in

FIGURE 16 - Fillet Contour

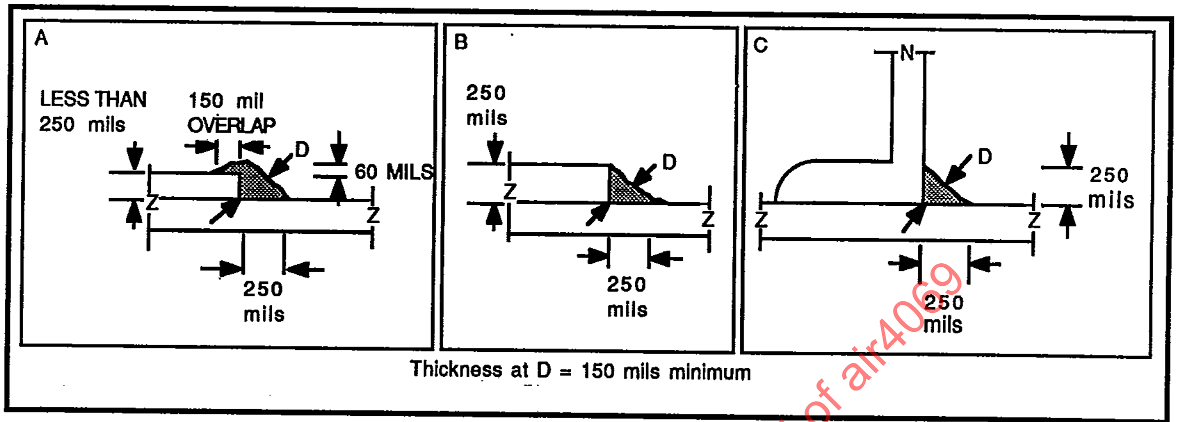
10.1.3.1 (Continued):

The principal goal in applying the appropriate thickness and contour of sealant at any potential leak source is to use a thickness, relative to the sealant elongation that will allow joint movement under operational conditions without tearing the sealant. For example, if a sealant with an elongation of 100% were used to seal a joint, and the thickness of the sealant at the joint were only 0.001 in (0.025 mm), the maximum allowable movement at that interface would be only 0.001 in after which sealant failure would occur. A thickness of 0.003 in (0.08 mm) on the other hand, with the same 100% elongation, would permit 3 times that amount of joint movement without failure. There are numerous joint and gap configurations and a preferred sealant configuration for each. The major types are illustrated in Figs. 17 and 18.

10.1.3.2 Offsets and Joints: The application of fillets to offsets and joints is illustrated in Fig. 17.

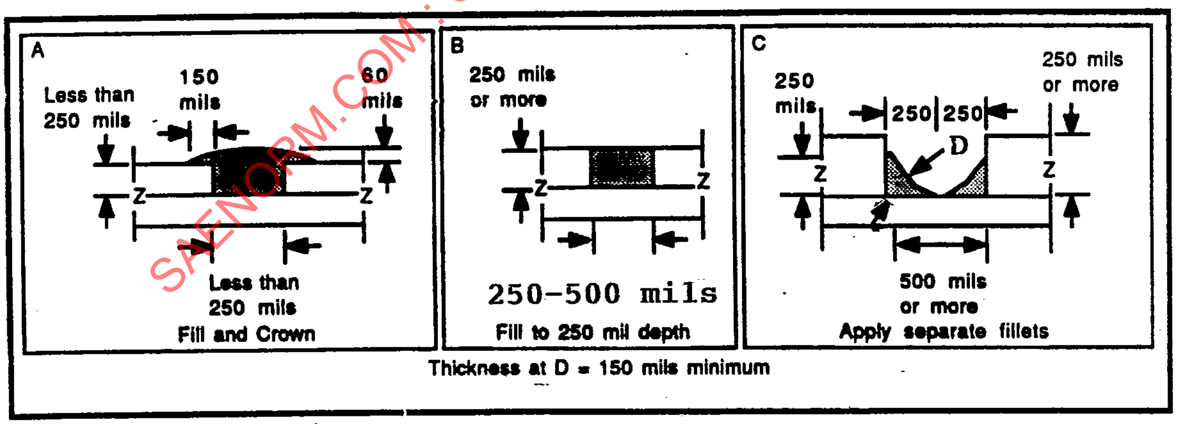
10.1.3.3 Butt Gaps: Butt gaps vary in width and height. The preferred method for sealing them is shown in Fig. 18.

Preferred sealant configurations vary company to company and with various government documents. The dimensions given in Figs. 17 and 18 present a safe average. Two major factors govern the sealant contour: Sealant should extend at least 0.250 in (6.35 mm) from the potential leak source, and the diagonal thickness from the leak source should be at least 0.150 in (3.81 mm). If the thickness of a plate or offset is less than 0.250 in (6.35 mm), it should be crowned. Extreme care must be taken to ensure that butt gaps are not bridged rather than filled. When a butt gap is wider than 0.500 in (12.7 mm), two separate fillets can be laid, each extending from its potential leak path 0.250 in (6.35 mm).



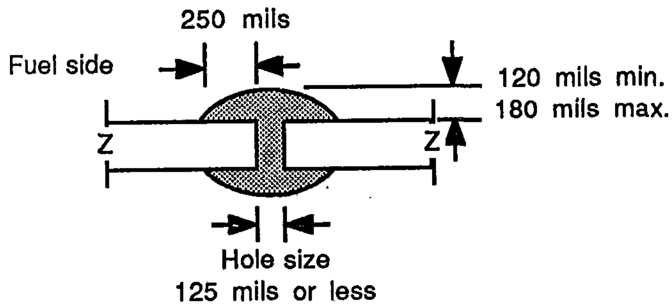
Note: 60 mils = 0.060 in (1.52 mm)
150 mils = 0.150 in (3.81 mm)
250 mils = 0.250 in (6.35 mm)

FIGURE 17 - Sealing Offsets and Joints



Note: 60 mils = 0.060 in (1.52 mm)
150 mils = 0.150 in (3.81 mm)
250 mils = 0.250 in (6.35 mm)
500 mils = 0.500 in (12.7 mm)

FIGURE 18 - Sealing Butt Gaps



Note: 120 mils = 0.120 in (3.05 mm)
125 mils = 0.125 in (3.18 mm)
180 mils = 0.180 in (4.57 mm)
250 mils = 0.250 in (6.35 mm)

FIGURE 19 - Sealing a Small Hole

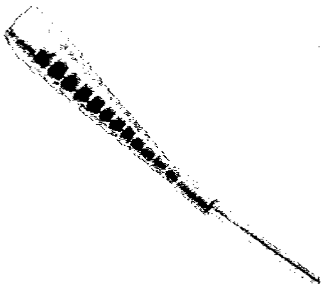


Figure 20a

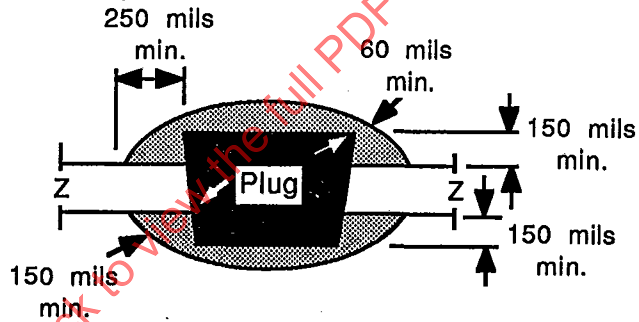


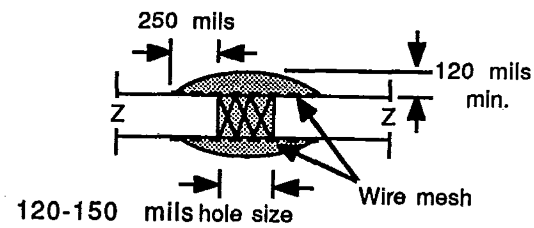
Figure 20b

Note: 60 mils = 0.060 in (1.52 mm)
150 mils = 0.150 in (3.81 mm)
250 mils = 0.250 in (6.35 mm)

FIGURE 20 - Sealing a Large Hole Slot with a Plug and Sealant

10.1.3.4 Holes and Slots: Holes and slots in the integral fuel tank may be sealed with class B extrudable sealant alone if the opening is less than 0.125 in (3.18 mm). Longer openings to 0.250 in (6.35 mm) may be accommodated if the slot is sufficient to give adequate surface area for adhesion. The sealant should protrude through the hole and be tooled on both sides to the dimensions shown in Fig. 19.

If the opening is between 0.125 in (3.2 mm) and 0.500 in (12.7 mm), it can be sealed with a combination of sealant plug and sealant (Fig. 20) or a combination of annealed aluminum wire screen and sealant.



Note: 120 mils = 0.120 in (3.05 mm)
150 mils = 0.150 in (3.81 mm)
250 mils = 0.250 in (6.35 mm)

FIGURE 21 - Sealing a Large Hole or Slot with Screen and Sealant

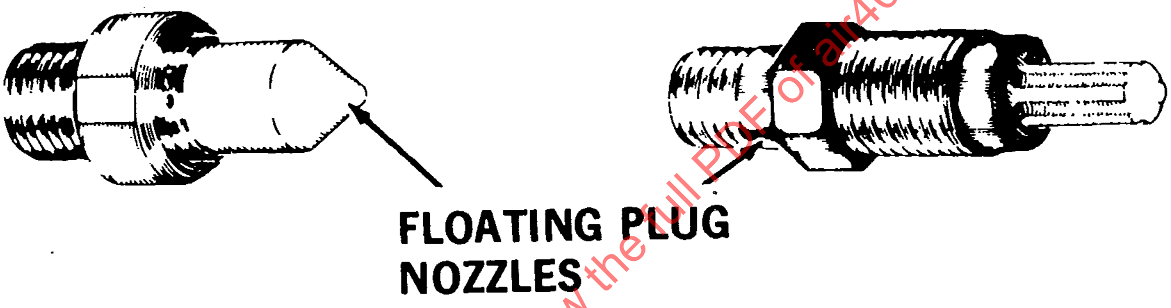


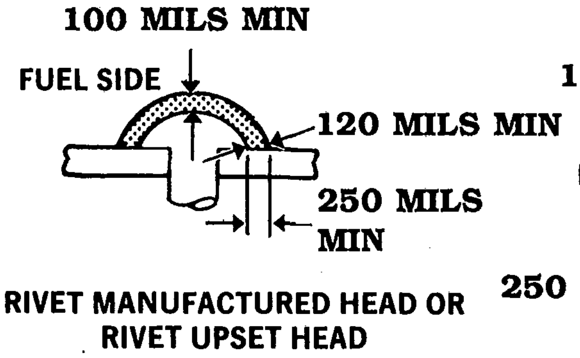
FIGURE 22 - Floating Plug Nozzle

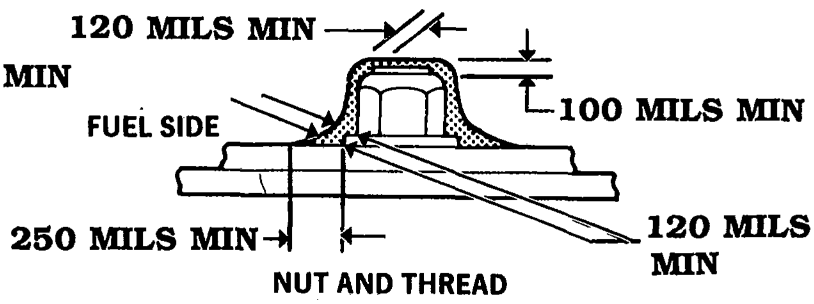
10.1.3.4 (Continued):

Metal clips or plastic blocks can be used to reduce the hole size before sealing. When wire screen is used (Fig. 21) it must be trimmed to overlap the hole or slot by approximately 0.250 in (6.35 mm).

A thin layer (1/16 in (1.6 mm) of sealant is applied around the opening first. The screen is then embedded in the sealant. A tie wire is laced to the screen and put through the hole. The hole is then filled with sealant from the opposite side. A second piece of screen of similar size is similarly positioned in sealant over the hole on the opposite side. The tie wire is laced to the second screen. The screens are then further impregnated with sealant completely crowning them on both sides and fairing the sealant edges approximately 0.100 in (2.54 mm) beyond the edge of the screen, completing the seal.

10.1.3.5 Fastener Sealing: It is recommended that all fasteners penetrating the fuel boundary be wet installed. The use of adhesion promoters is recommended. Sealant can be extruded into the hole and around the surface to be under the head of fastener. An alternate approach is to use a special floating plug nozzle on the sealant gun, injecting sealant into the hole as shown in Fig. 22.





Note: 100 mils = 0.100 in (2.54 mm)
120 mils = 0.120 in (3.05 mm)
250 mils = 0.250 in (6.35 mm)

FIGURE 23 - Overcoating a Fastener

FIGURE 24 - Overcoating a Rivet

10.1.3.5 (Continued):

Once fasteners and bolts are installed and tightened they must be overcoated with sealant. It has been mentioned previously that an overcoat can be built up from multiple layers of class A sealant, or can consist of an A coat followed by an overcoat of B sealant or B sealant alone can be used. When brush coats are applied, wait until the surface is tack-free before applying the next layer of material. Note that multiple layers of class A can be considered a primary seal. It is well to overcoat all fasteners. Slug rivets, on the other hand, are considered absolute seals on their own.

Fasteners are overcoated by several techniques:

a. Artist's Brush - Starting at the base of the fastener, rotate the brush around the head and adjacent surface until it is coated and surrounded by faired fillet, as shown in Figs. 23 and 24.

b. Beehive Technique - Start the application of sealant from the nozzle of the sealant gun at the base of the fastener head. Rotate the nozzle in a spiral motion until the head is completely covered. Tool to the proper configuration.

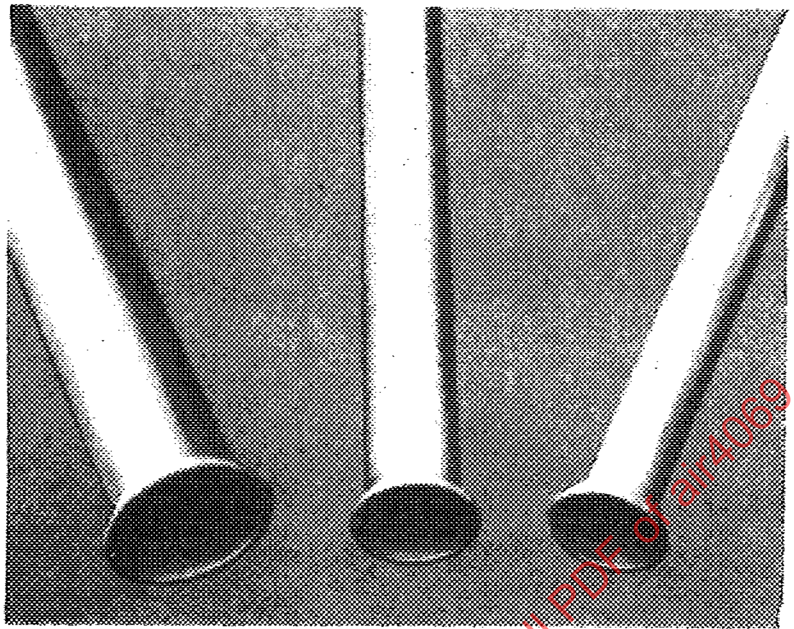


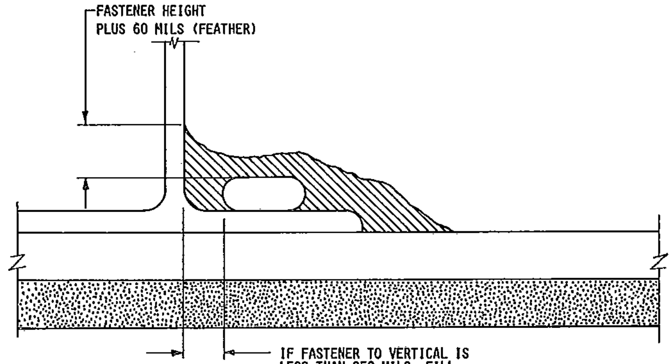
FIGURE 25 - Fastener Sealing Applicator

10.1.3.5 (Continued):

c. Flared Tube Applicator (Daubing) - The flared tube applicator is a beveled or flared copper or aluminum tube (Fig. 25) that is closed at one end. It is filled with sealant from the sealant gun, pressed over the fastener head to the base surface, rotated slowly as it is withdrawn.

d. Seal Caps - A variety of sizes of aluminum caps are available to the sealer. Caps of the proper size are selected, filled with class B sealant from the sealant gun and pressed in place. Excess sealant squeezes out at the base and is formed into a fillet around the base of the cap. The cap is left in place permanently. Seal caps can also be filled and frozen for later use. On thawing, care must be taken (by covering the open end) to avoid accumulation of water condensate on the surface of the sealant.

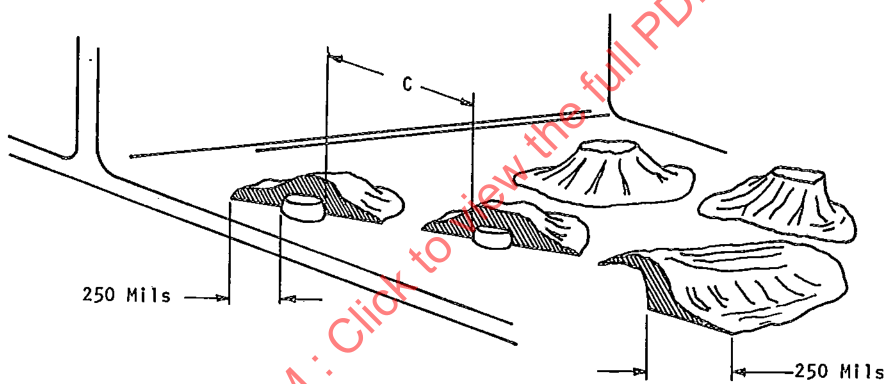
Some companies use seal caps only at lower levels where foot traffic during production operations may bump and scuff coated fasteners. Others use seal caps because they are quick and convenient and do not limit their use to special areas. Plastic caps and caps cast from MIL-S-8802 type sealant are also used. Caps are being developed for rivets as well. Adhesion promoter should be applied to the inside of the cap before it is filled with sealant to ensure that a good bond forms with no chance for dislodgement later. Nylon caps are not recommended at this point due to difficulty in bonding to the surface and lack of a sufficiently broad data base to recommend it.



Note: 60 mils = 0.060 in (1.5 mm)
120 mils = 0.250 in (6.4 mm)

FIGURE 26 - Sealing Fastener Near a Vertical Surface

SEALING INDIVIDUAL FASTENERS



IF "C" IS GREATER THAN 500 MILS
FASTENERS CAN BE INDIVIDUALLY SEALED.

Note: 250 mils = 0.250 in (6.35 mm)
500 mils = 0.500 in (12.70 mm)

FIGURE 27 - Sealing Individual Fasteners

10.1.3.5 (Continued):

e. Miscellaneous - All of the techniques mentioned are acceptable if care is taken to exclude air bubbles, to avoid air entrapment, to avoid bridging, and to tool or shape the configuration to provide the faired edges and the thickness indicated. When fasteners are overcoated or filleted near a vertical obstruction, care must be taken that no bridging of sealant will occur. If the fastener is closer than 0.250 in (6.35 mm) to the vertical structure, apply sealant completely around the fastener. Wait until the sealant gels, then fill in the space between the fastener and the vertical and fair the sealant up the side as shown in Fig. 26.

If fasteners are widely separated (i.e., greater than 0.500 in (12.7 mm) mils apart), they can be overcoated (filleted) individually as shown in Fig. 27.

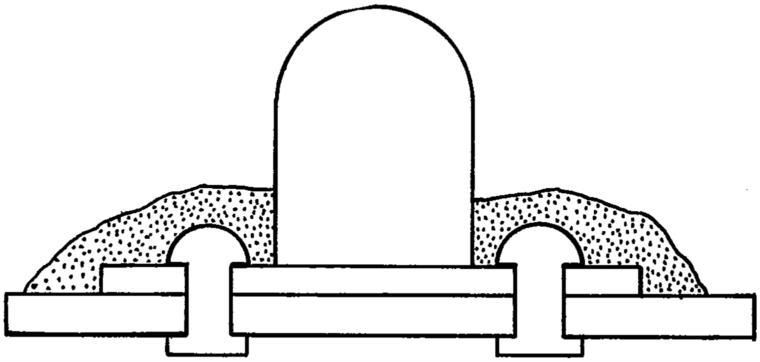


FIGURE 28 - Dome Nut Sealing

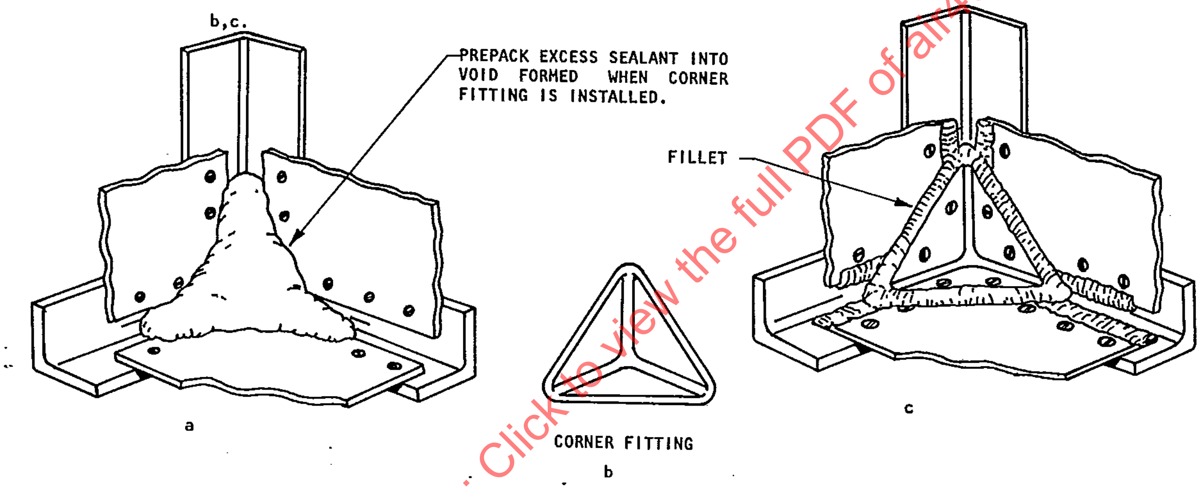


FIGURE 29 - Prepack Sealing

10.1.3.6 Dome Nut Sealing: Extrudable sealant is applied around the base of dome nuts as shown in Fig. 28. Some completely encapsulate the dome nut with two coats of brushable sealant. Sealant is applied around the base of the dome nut, encapsulating the fasteners used to hold it in place. The thicknesses of sealant and tooling requirements described earlier apply to this sealing operation.

10.1.3.7 Prepacking: Extrudable sealant is also used for prepacking voids created at structural intersections. Sealant is packed into the void area and onto the surfaces that will enclose it. The parts are then joined together, avoiding the possible trapping of air. Sealant must squeeze out from all edges of the part. After securing in place, remove excess sealant using a nonmetallic tool and fair the material as fillets around the edges. An example of prepacking is given in Fig. 29. When prepacking a gap is impossible or inappropriate, injection sealing is used.

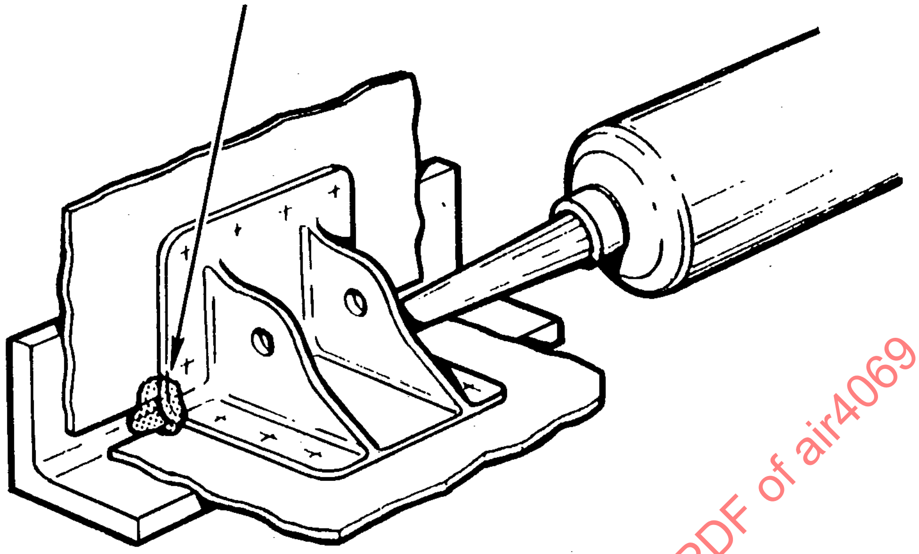


FIGURE 30 - Injection Sealing

10.1.3.8 Injection Sealing: After assembly, various channels, crevices, and holes result from the fastening of sections and subassemblies together. Such voids cannot be left open to collect debris or to become unobserved areas for degradation. All voids and channels must be filled. Pipe cleaners can be used with solvent cleaners to clean the areas. Adhesion promoter is then applied with clean pipe cleaners. Finally, class B extrudable sealant is injected, using an appropriate nozzle shape and length. Inject sealant until it extrudes from the other side. If there is more than one opening, plug the other until the first is full, then unplug each of the others in turn. When each is full, withdraw the nozzle, filling the entrance. Remove the excess with a nonmetallic tool and fair the sealant at the exit areas. Injection sealing is illustrated in Fig. 30.

10.1.3.9 Access Door Sealing: There are three types of access door seals: molded-in-place seals, bonded-in-place seals, and formed-in-place seals (form-in-place gaskets are generally not used due to permanent compression set of the polysulfide). The formed-in-place seal is produced through the use of a two-part polysulfide sealant. Three types of sealant are used:

a. Low peel strength [2 lb/in (350 N/m) of width] MIL-S-8784 or AMS 3267.

10.1.3.9 (Continued):

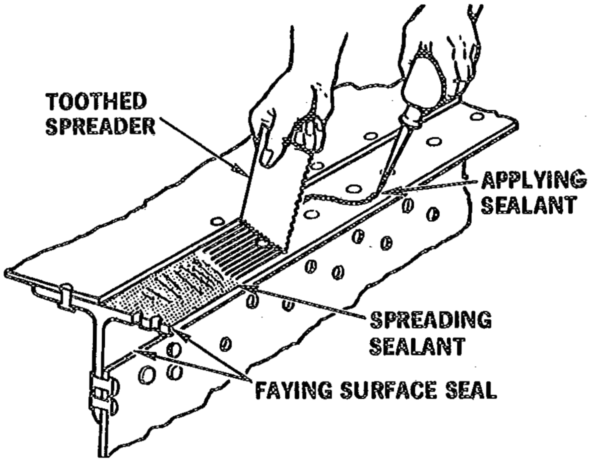
b. MIL-S-8802 sealant with a nonsilicone parting agent on the door. The sealant (class B) is applied to the door frame and smoothed uniformly over the surface to a thickness of approximately 0.020 in (0.51 mm). The door is installed while the sealant is still tacky. The fastener should be tightened sufficiently to obtain a continuous squeeze out of sealant. After the sealant has become tack free (approximately 24 h or less at standard conditions), the specified torque can be applied to the fasteners. It is understood, of course, that the faying surface should be wide enough (i.e. greater than 1/4 in (6.4 mm) to form a good seal.

c. AMS 3267 corrosion-inhibiting access door sealant.

10.1.4 Faying-Surface Sealant Application: Faying-surface sealants are applied between overlapping surfaces (See 2.1.1.2 and 2.2.1). Since those surfaces will be drawn tightly together by fasteners, rivets, bolts, and screws, most of the applied sealant will be squeezed out. The squeeze out must occur during the assembly time or "open time" of the sealant, while the sealant is still sufficiently uncured to flow. After surface cleaning and application of adhesion promoter, the sealant is applied by extruding several beads in a wavy pattern across the surface to be coated. The sealant is then spread to a uniform thickness of approximately 0.010 in (0.25 mm) by a spreader or roller as shown in Fig. 31.

An alternative method of application is through the use of a roller nozzle assembly that attaches to the threaded end of a standard cartridge in a sealant gun (Fig. 32).

When the two surfaces are fastened together, the sealant squeezes out uniformly around the periphery of the overlap. (If permanent fasteners are not installed within the assembly time, temporary fasteners should be installed in every other hole and final torqued within the assembly time). If a continuous squeeze out is not achieved, the panels must be opened and sealant reapplied. For maximum structural strength and to minimize later metal fatigue, the two surfaces are fastened together with the goal of achieving metal to metal contact. The sealant remaining is a thin film 0.003 to 0.005 in (0.08 to 0.13 mm) thick and only a stain in the immediate area of the fastener.



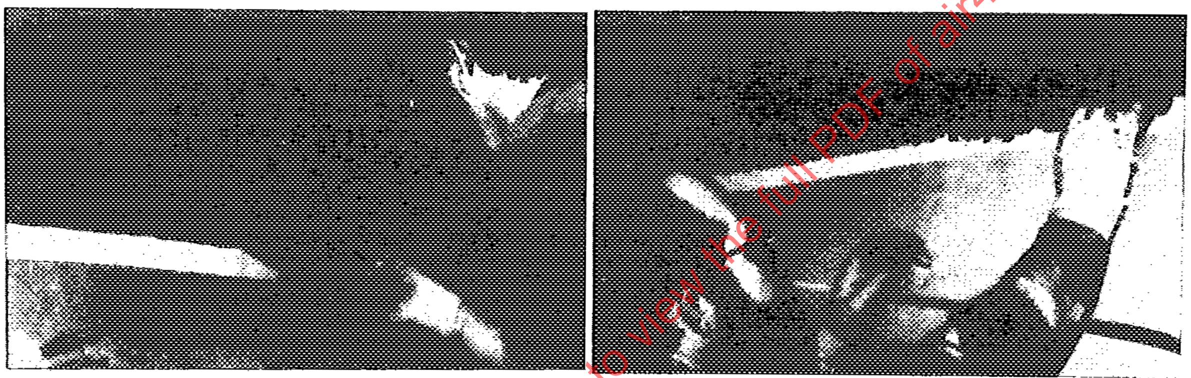


FIGURE 31 - Application of Sealant to Faying Surface

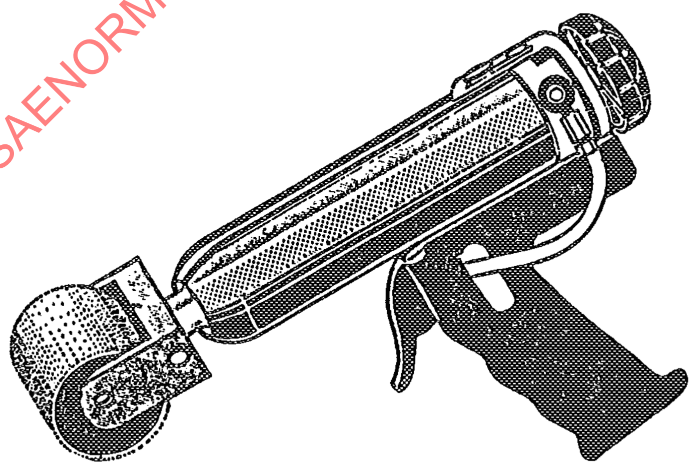


FIGURE 32 - Roller Nozzle for Faying-Surface Sealing Application

10.1.4 (Continued):

Several alternative approaches are taken after squeeze out, depending upon the company:

a. Wipe off the excess and apply a fillet

b. Wipe off the excess and do not apply a fillet until after final assembly and after pressure testing for faying-surface leaks

c. Wipe off the excess, retaining enough to form and tool a fillet; apply a tack free time accelerator to avoid the embedment of chips and accumulation of dirt

d. If the faying-surface sealant is a corrosion-inhibited one, wipe off the excess and apply a fillet of MIL-S-8802 or MIL-S-83430 type sealant

Most companies favor application of the fillet at the subassembly stage at the time the faying surface is closed.

10.1.5 <u>Protection of Sealant During the Tacky State</u>: After sealant application, be it brush coat, fillet, or faying-surface sealant, the sealant surface is quite tacky, eventually becoming tack free usually within the first 7 to 24 h. During this period, it is vulnerable to the collection of metal chips, dust, and other airborne debris that is carried in the air from other work being done in the area. Too much surface contamination will require that the sealant be removed, the surface recleaned, and sealant reapplied.

Three techniques are used for protecting the tacky sealant:

a. Physical protection by polyethylene plastic sheet, paper, cardboard, etc.

b. Application of a quick drying overcoat

c. Application of a fog of tack-free time accelerator

Sealing should be performed in a facility where the air is filtered if at all possible. it is also desirable that no drilling or sanding be done in the area during the tacky period. Since this is not always possible, protection must be provided. Draping plastic sheets is not without problems including the risk of marring the sealant surface.

The use of a quick drying, sprayable overcoat will protect the surface of the sealant. Sometimes a chromate primer is used. A one-part polyurethane (PRC's PR-1062) is the only material currently available that was designed for this purpose. It is tack-free in 1 h.

10.1.5 (Continued):

It is applied with a soft, camel's hair brush to avoid disturbing the surface of the sealant. Do not apply by spraying and restrict overlap to 1/4 in (6.4 mm). The third method mentioned above, a tack free time accelerator, is not a coating, it is a mixture of accelerators normally used in polysulfide sealants. It is sprayed lightly on the surface as a fog or mist. It merely accelerates the polymeric reaction on the surface of the sealant, forming a thin, tough skin in 1 to 2 h. It is preferred because it does not introduce a foreign substance or change the surface characteristics in any way. It is easy to apply from an aerosol can (PRC's Pro-Seal 815). It also is the only product of its kind on the market currently. It is important to note that only the surface is tough and tack free; the remaining body of sealant under the surface continues to cure at its normal rate. The sealant is not cured sufficiently for pressure testing or fuel on-loading; thus when a sealant is made tack free by the tack-free time accelerator, it should be done only for surface protection -- not for quicker refueling or pressure testing.

10.2 Groove- and Channel-Sealant Application: Groove and channel design and sealants were discussed in 2.1.2.1 and 5.2. The preparation of surfaces and application of sealant (and equipment used) is the subject of this section.

10.2.1 Surface Preparation and Pretreatment:

10.2.1.1 Substrates: Substrates may be aluminum alloys, titanium, or composites. Aluminum alloys are either MIL-A-8625, Type 1, Class 1, chromic acid anodized or MIL-A-8625, Type II, Class 1, sulfuric acid anodized or ion vapor deposition aluminum coated in accordance with MIL-C-83488, Type II, Class 1. The latter surface treatment is more often adopted for fatigue and fracture critical parts. Occasionally, MIL-C-5541, Type 1A, chromate conversion coating will be employed for fatigue-critical reasons, but this is actually less desirable because of reduced corrosion resistance.

The fuel wetted aluminum surfaces and the aluminum faying surfaces are normally coated (0.001 in (0.025 mm) thickness) with MIL-C-27725 polyurethane corrosion coating. Titanium and composite surfaces are coated only if they are to interface with dissimilar metals. Grooves in titanium or composites are normally not coated.

The application of the polyurethane coating to detail parts can be performed either before or after fitting, drilling, and reaming operations, provided the surfaces are clean, scratch free, and chip free prior to assembly. Subsequently, any scratched or damaged areas of the coating can be locally repaired. Injection grooves in carbon-epoxy, carbon-bismaleimide, and other composite laminates do not normally require finish treatments other than cleaning to remove parting agents.

10.2.1.2 Substrate Cleaning: After the initial assembly of all parts forming the fuel containment area and all fitting, filling, drilling, reaming, and countersinking is completed, parts are disassembled and all chips and burrs removed.

Prior to reassembly of the skins to the substructure, faying surfaces and channel grooves and all of the tank interior surfaces are cleaned using a cleaning solvent (MIL-C-38736; or O-T-620 1,1,1-trichloroethane*; or TT-M-261 methyl ethyl ketone (technical grade), applied with an absorbent, lint-free, low extractable cloth (See 4.1). The cleaned surface should be given a final wipe with a clean cloth, not allowing the rinse-solvent to evaporate to dryness on the substrate.

Protect the surface from recontamination after cleaning. Paper masking tape or masking discs can be applied to the exterior of all fastener holes designated as injection or observation ports if they are to be left open for any length of time.

Wherever there are discontinuities in the channel or openings or mismatches where sealant can escape, the openings must be closed by liquid shims, using two part polysulfide sealant (MIL-S-8802 or MIL-S-83430) or one of several epoxies, such as Hysol's EA-934 NA. No remaining gap should exceed 5 mils (0.13 mm). Dams (made of MIL-S-8802 or MIL-S-83430 sealant) can be put in place at this time or later during the prepacking operation if the manufacturing plan calls for prepacking the grooves prior to assembly.

10.2.1.3 Prepacking and Clean Up: The grooves may be prepacked with channel sealant before assembly or the structure can be assembled then injected with channel sealant. In the former case, it is still necessary to inject after assembly to ensure that no voids remain.

To prepack the grooves, place a plastic cartridge of channel sealant in a standard (not high pressure) sealant extrusion gun. Do not fit the cartridge with a nozzle. Hold the gun perpendicular to the surface with the cartridge opening pressed against the groove edges. Inject the sealant, moving the gun along the groove at a rate sufficient to continuously fill the channel groove. (Note: Terminate prepacking within 1 in (25 mm) of any dam area, if the dam has not yet been installed).

Install the dam by injecting MIL-S-8802 or MIL-S-83430 polysulfide sealant using a standard (not high pressure) sealant extrusion gun fitted with a plastic nozzle. The injection is accomplished by inserting the nozzle into the dam area with the initial nozzle position at the edge of the channel, withdrawing it slowly as sealant is extruded, filling the dam area. No polysulfide sealant should enter the channel groove itself. Once the polysulfide sealant has cured completely, the prepacking with channel sealant can be completed (or can be started, if the dam is built first, before any prepacking has been accomplished).

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*Many do not use chlorinated solvents with titanium.

10.2.1.3 (Continued):

Once the channel has been filled, the prepacked sealant should be troweled level with the groove edges using a plastic (or other non-metallic) scraper. If necessary, fill any voids or low spots with channel sealant. Ensure that all corners are filled. Excess sealant should be cleaned from the adjacent mating surfaces. Solvent-wetted cloths should be used.

It is important to note that joints and overlap edges of the lower skins are fillet sealed and other appropriate sealing is done with MIL-S-8802 or MIL-S-83430 polysulfide sealant while access is still available inside the tank. Some companies also apply faying-surface sealant in selected areas before tank components are reassembled. All permanent type fasteners are installed and torqued per engineering drawing requirements. Injection fittings are installed and torqued. The assembly is now ready for the injection of channel sealant. Channel sealant is injected through external ports spaced at 3 to 5 in (76 to 127 mm) intervals around the periphery of the tank by means of a high-pressure injection gun.

10.2.2 Equipment for Groove Injection: Equipment used for injecting channel sealant is radically different from the standard sealant extrusion guns used in fillet application.

Several brand names and models must be mentioned as examples of the type of equipment necessary to perform this task. This discussion in no way means to imply that this is the only equipment capable of doing the job. The equipment to be mentioned are those most widely used however.

The Grover #223 injection gun (Fig. 33) magnifies the plant air pressure by a ratio of 70:1. Since tip injection pressures required for the various groove sealants range from 2000 to 6000 psi (13 790 to 41 369 kPa) the plant air pressure must be regulated down from 80 to 90 psi (552 to 621 kPa) to a level of 25 to 60 psi (172 to 414 kPa).

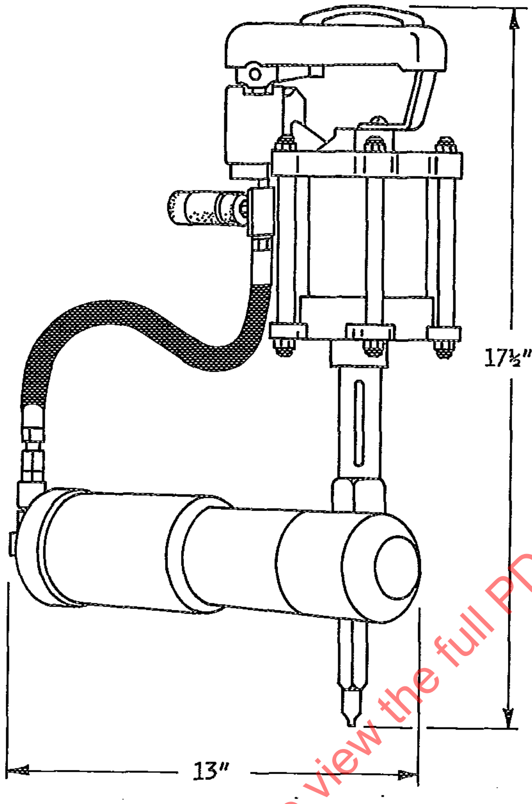

FIGURE 33 - Groover #223 High Pressure Injection Gun

10.2.2 (Continued):

Tip pressures are kept under 3000 psi (20 684 kPa) [air pressure at 27 to 29 psi (186 to 200 kPa)] for thin-skinned aircraft like the F-4 and but can be as high as 6000 psi (41 369 kPa) for heavier-winged aircraft. It is critical to the success of the sealant application that the operator be acutely aware of the limitation on line pressure since the structure can be damaged, panels can be distorted or rippled, and sealant can be forced into the tank itself.

The Grover #223 gun utilizes a #226358 SEMCO cartridge adapter to permit the use of a 6-fl oz (177 mL) plastic cartridge of channel sealant. The Products Research & Chemical Corporation SEMCO Model #510 injection gun (Fig. 34) provides a 110:1 ratio of line pressure magnification. It can accept 6, 8, or 20 fl oz (177, 237, or 591 mL) cartridges of channel sealant. It provides a continuous bead of material when actuated. It is fitted with a regulator for adjusting to the viscosities of various channel sealants and for controlling tip pressure. Again, line pressure limits must be a part of the process instruction to ensure that design structure channel width and cross-section, sealant viscosity, and injection gun prssure are compatible.

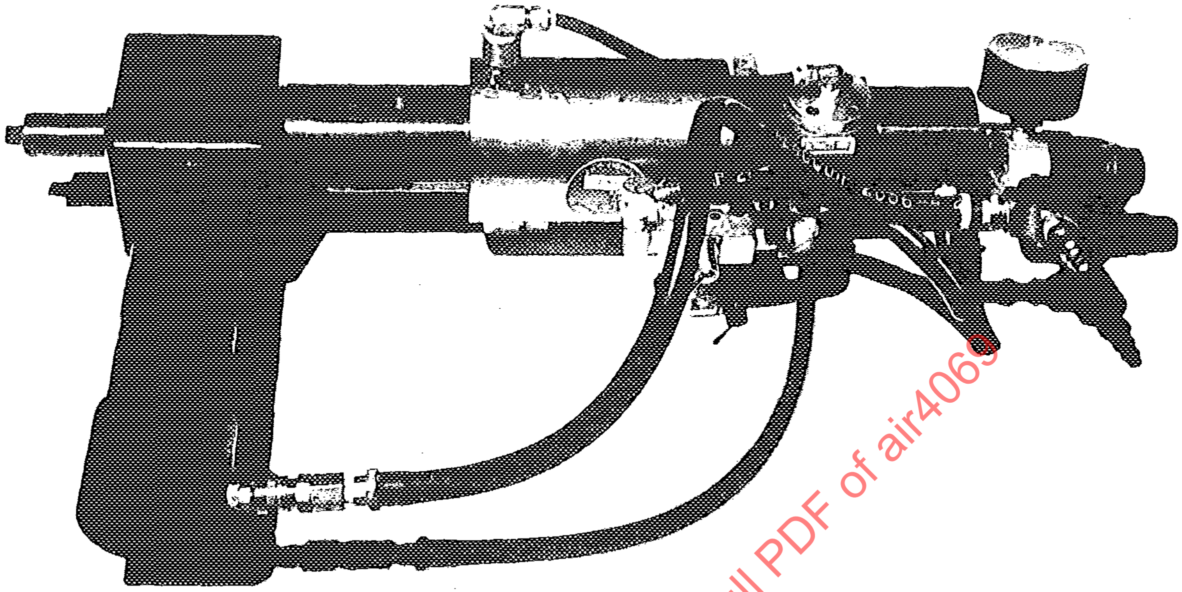

FIGURE 34 - SEMCO Model #510 High Pressure Injection Gun

10.2.2 (Continued):

Another method of injecting channel sealant is from equipment that contains the sealant in bulk [5 gal (19 L)] rather than through the use of small plastic cartridges. The equipment that pumps from a 5 gal (19 L) container generates the 3000+ psi (20 684 kPa) of tip pressure from the pump itself. The application gun is therefore quite small.

The Pyles Dispenser System Model 710018-462-000 is connected to the shop air pressure supply. The equipment has a 38:1 pressure multiplier ratio. When the air pressure setting is 100 psi (689 kPa) the tip pressure will be on the order of 3700 psi (25 511 kPa); when the air pressure is 50 psi (345 kPa) the injection pressure is approximately 1900 psi (13 100 kPa). The lower pressure is used for the injection sealing of thin carbon-epoxy skins to metal or carbon-epoxy substructure.

10.2.3 Injecting the Channel Sealant: The injection procedure can be started at any point on the tank. Local process specifications or engineering drawings will indicate where the injection process will start. The starting point is not critical. It is critical, however, that the port adjacent to the port in which the injection fitting is installed is open for the sealant to exit indicating that the channel in between has been filled.

It is necessary to provide proper clamp up of the seal-groove structure throughout the injection phase. Only the fasteners from the injection port in use and its adjacent port are removed. All other fasteners must be installed and torqued.

10.2.3 (Continued):

When removable fasteners are involved in the peripheral sealing, injection fittings should be torqued into both the injection and exit holes. It is necessary to measure the depth of the sealant groove and match it to the port injection fitting. (Some permanent fasteners have a set screw in the fastener. It can be removed to attach the injection fitting).

Injection fittings are installed and torqued so that the slot in the fitting is aligned with the direction of the sealant groove, being careful not to exceed the torque range for the fitting. With the adjacent exit hole open, the gun is attached to the injection fitting and the sealant flow started. When sealant appears at the level of the skin or spar or at the bottom of the countersink, the sealant flow is stopped. The injection fitting is then installed in the hole previously used for sealant exit and the next adjacent fastener is removed to permit exit of sealant when the process is systematically repeated. Continuity is thus ensured, port to port. The sealant gun is hand held and pressed against the injection fitting while sealant is injected. Fixtures are also available for supporting the weight of the gun when overhead parts are injected.

Some noncuring sealants are stiff when cold and extrude at a much lower rate producing more back pressure. Local heating of the structure with heating pads will aid in the movement of the sealant.

Once the sealing operation is completed all accessible excess sealant should be removed from the tank's interior and exterior surfaces.

Fasteners used in addition to those in the groove path must be of the self-sealing type (O-rings) and capable of being replaced from the outside of the tank.

11. LEAK REPAIR:

11.1 Repair Philosophy: During initial manufacture, leaks are repaired when they are discovered. When the aircraft is in operational use, repairs may be noted but deferred for action at the time of scheduled maintenance. If the leak is significant, it may be downgraded by the use of a temporary repair, with permanent repair deferred until the time of scheduled maintenance. If a significant leak cannot be downgraded to a no leak or small leak condition, the plane must be grounded. Temporary repairs are made to the outside of the integral fuel tank sometimes without defueling. Such a repair can never be accepted as a permanent repair. Permanent repairs are made inside the tank. Leaks are caused by design deficiencies, material deficiencies, poor workmanship, and flight environment, which can produce bond failures, structural cracks, corrosion, and loosening of fasteners. The most common leak sources are non-self-sealing fasteners penetrating the fuel barrier walls. Proper initial sealing of all fasteners is imperative. Repairing leaking fasteners in the field is more difficult since some types may require somewhat different sealing contours and dimensions, and repair personnel must recognize the differences in the sealing requirements of each type.

11.1 (Continued):

Fuel tank leaks have been classified by the military and by commercial industry in much the same way, recognizing that internal, nonvented leaks are more serious than internal vented ones, which in turn are more serious than external leaks. Rate of leaking is a second element determining the seriousness of the leak.

11.2 Leak Classification: The seriousness of leaks is broken into four categories by the Air Force* A=slow seep, B=seep, C=heavy seep, D=running leak. These leaks are quantified in the following table. The level of action to be taken depends upon how much of a leak it is and where it is located. There are three levels of action: A and B are essentially the same - the small leak is documented to be periodically inspected for leak growth. Under level A, it is not mandatory to repair when the tank is opened for inspection or other repair. Under level B, repair should be scheduled when the aircraft is down for maintenance or when it is opened for another inspection or repair. Level C requires documentation and repair to a no leakage or small leakage condition (level A or B).

Leak Category	6-Minute Leak Limit JP-4	Location & Action External	Internal Vented	Internal Unvented
A- Slow Seep	0 to 1/4 in stain	1	1	2
B- Seep	> 1/4 - 3/4 in stain	1	2	3
C- Heavy Seep	> 3/4 - 6 in stain	2	3	3
D- Running Leak	> 6 in or drips and runs	3	3	3

Note: 1/4 in (6.4 mm) ; 3/4 in (19.0 mm); 6 in (152 mm)

Slightly different stain areas and drip rates are spelled out for AV Gas and for JP-5 and JP-8. JP-5 and 8 are categorized the same.

11.3 Temporary Repairs: External repairs (except for groove injection) are considered temporary. Temporary repairs are designed to downgrade the leak classification to a flyable condition until scheduled permanent repairs can be accomplished. Several types of patch kits are available.

Groove injection repairs are permanent. In groove designed tanks, if a sealant dam fails, large losses of channel seal to the exterior will be observed. Fasteners occurring outside the groove path will be dealt with as with other designs in using sealing washers or O-rings.

11.3.1 Aluminum Foil Patch Kit: Leaking fasteners are repaired most effectively by the application of an aluminum foil patch, bonded with an extra fast setting epoxy or polysulfide sealant. A kit, such as a SEMCO 400A1 (Fig. 35) or equivalent, containing essentially all of the items needed, is used.

*Air Force Technical Manual T.O.1-1-3

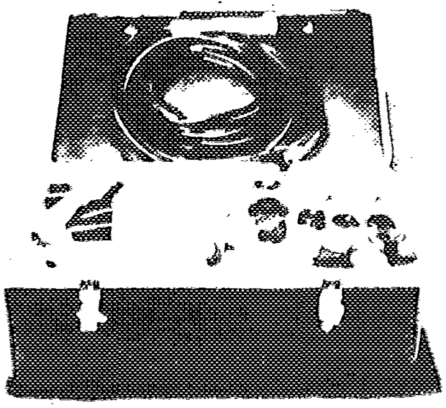

FIGURE 35 - Aluminum Foil Patch Kit
(National Stock No. 4920-450-6925)

11.3.1 (Continued):

The aircraft does not need to be defueled if the fast setting epoxy is used. The procedure for use is:

1. Clean the fastener area with MIL-C-38736 cleaner. Note: Do not remove the original sealant topcoat on the fastener before applying the patch.

2. Use a patch cut from the 0.002 in (0.05 mm) thick aluminum foil supplied in the repair kit. The diameter should cover the head of the fastener and extend 1/2 in (12.7 mm) beyond the head of the fastener.

3. Clean the surface of the foil patch with MIL-C-38736 cleaner.

4. Mix and apply the quick setting epoxy to the cleaned side of the aluminum patch. Apply it to a thickness 0.015 to 0.020 in (0.38 to 0.51 mm).

5. Press the patch into place over the fastener head. Hold in place with the kit fixture provided. Cure time: approximately 15 min at 75°F (24°C).

6. CAUTION: Do not heat to accelerate cure. Heat curing causes the epoxy to become brittle and fail.

7. To remove the patch (when a permanent repair is to be made), heat the patch to 200° to 250°F (93° to 121°C) with a heat gun. Use a plastic scraper to pry up the patch. Use needle-nosed pliers to remove the patch. Heat and scrape until epoxy is removed.

11.3.1 (Continued):

NOTE: If MIL-S-8802 two-part polysulfide sealant is used in place of the fast setting epoxy, the plane must be defueled to a level below that of the leak. Proceed as above. After the patch is applied, apply heat to the patch using the heat applicator in the repair kit. Cure for approximately 30 min at 140°F (60°C). At temperatures below 50°F (10°C), preheat the surface around the fasteners for a few minutes before the patch is applied.

Several other less favored types of externally applied patches are available, utilizing epoxy or polysulfide sealants and using unique application fixtures.

11.3.2 Injection of Sealant Around Flush Fasteners: Flush fasteners can be resealed (temporary repair) without defueling through the injection of MIL-S-46163 (previously MIL-S-22473) Loctite sealant at a pressure of approximately 900 psi (6205 kPa). (Paint will have been removed from around the fastener and the surface cleaned.) After the Compressed Air Injector Kit has been used, the head of the fastener is covered with aluminum tape and the sealant is heat cured (heating iron, 140°F (60°C), 5 to 10 min) to stop the leak. (NOTE: When the aircraft employs Buna-N seals in faying surfaces, high pressure injection repair should not be used.)

The equipment required is a part of the kit and includes a position locator, suction cups, cylinders, and jacks for holding the assembly to lower-wing surfaces. After the sealant is cured the tape is removed.

11.3.3 Application of Quick Hardening Material: A simple method for the temporary repair of fastener leaks requires first cleaning the surface around the fastener with methyl ethyl ketone (MEK), then applying a material that will harden over the fastener head.

a. Use Oyltite Stik (Air Force I.D. is D-103). Soften it by dipping the end into methyl ethyl ketone

b. Firmly apply around the fastener head until the leak stops

c. Remove excess

11.4 Permanent Repairs: Permanent repairs are made from inside the tank (exception: groove-sealant injection). Each leak requires a leak path analysis to identify the leak exit point, the leak path, and the leak source. The appropriate aircraft manual will identify the sealants used on the structure, fasteners, access doors, and components.

The types of seals made with curing-type sealant are:

a. Prepacked and injection seals - Inject if possible and add a fillet seal around the periphery and any other opening.

11.4 (Continued):

b. Faying surface - Disassembly would be necessary. Normally leaks are repaired by the use of fillet seals. In some cases hollow bolts can be used for injecting faying-surface sealant to effect repair. Hand held pressure will provide an adequate "pressure release system" to prevent panel distortion. The fastener is then reinstalled and sealed.

c. Fillet Seals - Repaired by removal of the fillet in the affected area, tapering the remaining ends to an approximate 30° angle. Abrade 1/2 in (12.7 mm) on each end, clean, apply adhesion promoter, apply brushcoat class A sealant, then apply fillet.

d. Brush coats - The brush coat is recommended for fillets and is applied before the fillet is deposited. It is never applied over fillet seals as a leak repair.

e. Hole and slot - Repaired by removing old sealant and seals, and reapplying sealant.

f. Overcoat Seals - As previously mentioned four approaches are acceptable:

(1) Multiple layers of class A material if each layer is applied after the prior layer surface is tack free.

(2) Class A sealant layer followed by class B sealants applied after the A material is tack free.

(3) Class B material applied alone.

(4) It is recommended that, with any of these approaches given above, adhesion promoter be applied first.

11.4.1 <u>Leak Path Analysis</u>: There is a leak source inside the tank, a leak path to the outside of the tank, and a leak exit point. A leak can occur directly through (beside) a fastener to the outside or it can travel many feet through crevices in assembled structure before appearing at an exit point. The task consists of tying the leak exit to the leak source. Study of the tank design drawings and the method by which it was sealed can give valuable clues as to the probable path from exit to source. Locating all leak exits and tying them to their leak sources is a necessary prerequisite to making permanent repairs. When the tank is opened, all the leak sources must be identified and repaired and other defects corrected to make the total effort cost effective. For this reason, the value of leak path analysis cannot be overstated.

11.4.1.1 <u>Finding the Leak Exit</u>: There are four widely used methods for determining the leak exit: (1) red talcum powder, which turns bright red wetted by fuel; (2) torn paper - absorption on paper reveals a leak; (3) tank pressurization with gas/soap bubbles on the outside and (4) helium, argon, ammonia, or nitrous oxide pressurization; outside detection.

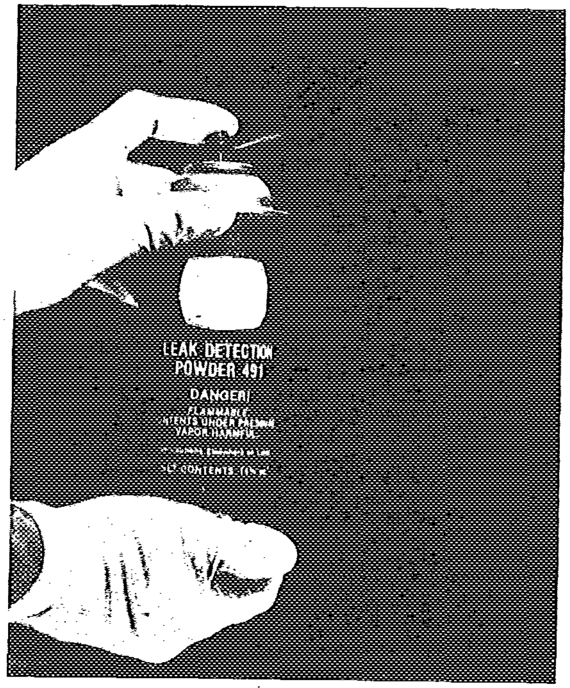

FIGURE 36a - Plastic Powder Dispenser

FIGURE 36b - Spray Can Dispenser for Powder

FIGURE 36 - Red Leak Detection Powder

11.4.1.1 (Continued):

The more recent method is dyed fuel; detection by U.V. light.

a. Red Talcum Powder (Figs. 36 a,b) - A recommended method.

Conditions: Used only external to the tank
Used before defueling
Used where leaks are observed or suspected

1. Strip any exterior sealant from the seams in the suspected area.

2. Wipe off the leak area thoroughly with cotton wipes (3 to 4 changes or turns).

3. Blow out all seams and corners with compressed air 100 psi (689 kPa) max: hold nozzle at least 1/2 in (12.7 mm) away from all sealant and structures).

4. Dust immediately; use thick camel's hair brush or aerosol dust spray. Wetted powder will turn bright red.

5. Observe long enough to detect sequence if other leak exits are to appear.

6. Identify (mark) exit point(s) with a marking pencil and wipe off the remaining talc.

11.4.1.1 (Continued):

b. Torn Paper - A recommended method.

Conditions: Used only external to the tank
Used before defueling
Used where leaks are observed or suspected

1. Strip any exterior sealant from the seams in the suspected area.

2. Wipe off the leak area thoroughly with cotton wipes (3 to 4 changes or turns).

3. Blow out all seams and corners with compressed air 100 psi (689 kPa) max: hold nozzle at least 1/2 in (12.7 mm) away from all sealant and structures).

4. Apply fuzzy edge of torn paper (an absorbing type) to the suspect area.

5. Move the fuzzy edge slowly along the suspect area.

6. Mark the spots where liquid is absorbed.

c. Gas Pressure - This method is to be used with caution, but it is necessary in order to find elusive leaks. Observe all safety precautions for dealing with pressurized systems. Establish what the pressure limits are for the tank. Be aware of the aircraft vent system. Make a check list of all plugs, cover plates, and caps installed during the test. After the test, review and remove.

1. Defuel and purge tanks to a fire-safe condition.

2. Install plates to all fittings.

3. Attach the air supply and water manometer.

4. Pressurize tank.

5. Apply a noncorrosive soap bubble solution (MIL-L-25567 or equivalent) to the tank exterior.

6. Mark all leaks with a marking pencil.

7. Relieve pressure slowly over at least a 15-min period.

d. Helium or Argon Gas Pressure/Detector - Conditions and steps through (c4) above are the same except that the tank is pressurized with helium or argon. A helium or argon leak detector is used to scan the exterior surface to find the leak exits. Mark them with a marking pencil. Relieve pressure slowly over at least a 15-min period.

11.4.1.1 (Continued):

When the leak exit is found near two adjacent tanks, it is necessary to establish which tank is leaking, or if both are leaking. The procedure is straight forward. A brief summary is given below:

1. Defuel outboard tank and let drain. If leak stops - this tank is the leaker. If not, proceed to 2.

2. Defuel the other tank and refuel the first one. If the leak stops, the defueled tank is the leaker. If not, either both tanks are leaking or residual fuel is giving the indication of leak.

3. If residual fuel is suspected, defuel both tanks and drain all residual fuel to stop the leak.

4. Fill one tank. If no leak appears, the other is the leak.

5. If a leak appears, drain the fueled tank; wait for the leak to stop, then fuel the other tank. If a leak shows, both are leaking.

e. Dyed Fuel and Detection by Ultraviolet Light - The Widger Chemical Dye-Lite leak detection system has been adopted by several major airframe manufacturers and air carriers for fuel tank leak detection. A dye which fluoresces in ultraviolet light is added to the jet fuel. The exterior is then examined with the light. Procedures control the concentration of the dye, the method of dispersing in the fuel, the time before detection scanning starts, and the specifications for the ultra violet lamp.

11.4.1.2 <u>Finding the Leak Source</u>: The leak source can be (1) the sealant, (2) loose, cracked, or missing fasteners, or (3) a structural failure. A structural failure can produce an early invisible crack. Standard procedural steps for defueling and opening a tank for access should be taken. Several dependable methods for finding a leak source are summarized below. It is important to emphasize that structural drawings must be studied and the original sealing plan considered in order to determine the most likely paths from source to exit. It is also important to reemphasize that every leak exit be positively identified to its leak source before permanent repairs begin. After analysis of structural drawings and sealing procedures, inspect the interior of the tank.

a. Inspection - Start at points opposite the leak exits. Look for:

1. Defective sealant - cracks, air bubbles, soft spots, shrinkage, scars, discoloration, chalking, loss of elasticity

11.4.1.2 (Continued):

2. Loss of adhesive bond - apply plant air [100 psi (689 kPa) max] with an air gun placed approximately 1/2 in (12.7 mm) from the sealant; if debonded sealant is found, the sealant should be stripped away without damaging the corrosion coating

3. Missing, cracked, loose fasteners

The most likely leak paths should be inspected carefully, using mirrors where direct viewing is not possible.

b. Test Methods for Finding the Leak Source

1. Blow Back Method - One worker with a compressed air hose inside the tank applies the nozzle (pressure 100 psi (689 kPa) max) approximately 1/2 in (12.7 mm) from the suspected sealant or site. A second worker on the outside applies a soap bubble solution (MIL-L-25567) to the suspected area. Bubbles should reveal leaks which are then marked. This ties leak exit with leak source. The same test is applied to all suspect areas. Then recheck by applying the air at the outside and the soap bubble solution on the inside.

2. Dye Injection Method - (Use if (1) above fails to reveal the source/exit). This procedure, summarized briefly, consists of injecting a small quantity of dyed fuel through the leak exit then entering the tank to observe the suspected leak source areas for evidence of the dye. An alternate approach employs a hollow hole installed in a fastener hole near the leak exit. Dye injection and pressurization may cause the dye to follow the leak path to the source. Other techniques using dyed fuel (vacuum cup, pressure box) are also used to move the dye along the leak path.

3. Vacuum - Negative Pressurization of Fuel Tank Summary: An approved negative pressure is applied to the fuel tank. Dyed fuel is applied to the outside of the tank at the leak exit. The vacuum is released slowly, then the inside of the tank is inspected for evidence of dye which reveals the leak source.

It must be stated strongly that structural cracks cannot be repaired by the use of sealant. It must be structurally repaired, thus, such leak sources must be treated differently in planning permanent repairs.

11.4.2 <u>Permanent Repairs with Two-Part Curing Sealant</u>:

11.4.2.1 <u>Prepacked Seals</u>: Without disassembly, remove peripheral sealant, clean, apply adhesion promoter, and repair with a fillet. Tool the fillet.

11.4.2.2 Injection Seals: Without disassembly, remove peripheral sealant, clean, apply adhesion promoter (use a pipe cleaner if necessary), reinject, tool the outer surface.

11.4.2.3 Faying-Surface Seals: Remove the fillet around the edge, clean, apply adhesion promoter, apply brushcoat, apply fillet, tool. More extensive repair (i.e., replacement of the faying-surface sealant) would require disassembly, involving significant time and cost. In some cases hollow bolts can be used for injecting faying-surface sealant to effect a repair.

11.4.2.4 Fillet Seals: The repair of a fillet seal involves the following steps:

a. Remove the defective sealant using nonmetallic tools, (steel knives or scrapers must not be used).

b. Cut the remaining ends of fillets, tapering them to approximately 30°. At least 1/2 in (12.7 mm) on each filler end should be abraded.

c. Clean the surface. (See Section 4.)

d. Repair the corrosion coating with an epoxy. (See Section 3.)

e. Apply adhesion promoter (allow 30 min for activation). At this point, there are two methods for proceeding, both acceptable.

Method 1 - Apply a brushcoat of class A polysulfide sealant at a sufficient width along the seam or joint that, after the filler is applied and tooled, the "A" material extends 0.100 in (2.54 mm) wider on each side of the fillet.

Apply the class B extrudable fillet sealant and tool it. In those companies which use this technique, the "B" is applied any time after the "A" material is tack free. (If more than 24 h passes without applying the "B" material, the "A" surface would have to be cleaned.)

Those companies which do not use this technique fear that, unless the solvent from the class A brushcoat has a chance to evaporate (they consider the time to be significantly longer than the time to become tack free) it can be a source of bond failure between A and B. Such has not been the experience of those using this method. There is not a strong bank of data to prove the superiority of the "B" over "A" technique.

Method 2 - Apply the class B extrudable polysulfide fillet directly to the freshly applied adhesion promoter (no sooner than 30 min after the adhesion promoter was applied and no later than 24 h). Tool the fillet. While some also apply a brushcoat of class A sealant over the fillet, it is not recommended since the brushable "A" sealant alone does not produce a primary seal and could mask a leak in the fillet.

11.4.2.4 (Continued):

There is a body of opinion favoring elimination of the brushcoat under the fillet as well. By cleaning the surface, applying adhesion promoter, applying the extrudable class B sealant, and tooling it, there is no need for the extra step of applying a brushcoat.

11.4.2.5 Brushcoats: Brushcoats of class A polysulfide sealant are applied by stiff brush, working in a close circular motion into and around crevices, holes, seams, around and over fasteners and on surfaces to be sealed with a fillet of class B material. It is recommended that after cleaning the surface, adhesion promoter should be applied before the brushcoat is applied.

11.4.2.6 Fasteners: Since there are several types of fasteners, the major types should be addressed.

a. Interference Fit Fasteners - Leaks in interference fit fasteners are repaired by removing the sealant fillet or overcoat if any; cleaning the surface, applying adhesion promoter; overcoating with class B polysulfide, using either a brush or an extrusion gun (other techniques previously mentioned in 10.1.3.5 are acceptable); and fairing/feathering the edges.

b. Fastener with Sealing Washer or O-Ring - Retighten; if leak persists, remove the fastener, clean the surface, replace the sealing washer, replace the fastener, tighten. An alternative method: after retightening the existing fastener if leaking persists, clean the surface of the fastener thoroughly (inside the tank) with an acceptable solvent cleaner and overcoat with a class B extrudable sealant, observing the thickness and dimensions described in 10.1.3.5.

c. Fasteners Sealed with a Brushcoat/Fillet - Repair as in 11.4.2.6a.

11.4.2.7 Access Doors Previously Sealed with Polysulfide Sealant:

a. Retighten fasteners

b. Remove leaking screw or bolt, clean it, apply class A or B sealant to the shank and under the screw or bolt head, reinstall. If leak persists, remove door, remove seal, clean, reapply access door sealant as described in 10.1.3.9.

11.4.3 Permanent Repairs with Groove/Channel Sealant: Leaks occur at times in difficult-to-reach areas requiring the removal of equipment before repairs can be made. The most common failure mode is gap extrusion from pressure build-up due to thermal expansion, fuel swell,and other factors.

Thermal expansion and contraction can also cause void formation. Other causes of leaks include leaching of the lower molecular weight polymers by the fuel, polymer chain scission from vibration and shearing action, and hydrolysis of the polymer from absorbed water in the fuel.

11.4.3 (Continued):

Finding the leak source is the first order of business. This can mean removing access panels and wiping out the area of the suspected leak source to identify it. Once found, the channel in that area must be reinjected. The fuel level can be lowered below that of the leak to avoid spillage when the injection and observation ports are opened.

Repair personnel must be alert to the temperature of the aircraft and the sealant since the sealant extrudability varies greatly with temperature requiring significantly different tip injection pressures.

It may be necessary in some cases to warm the aircraft in the vicinity of the injection ports to be used.

Starting with the first and second cover screws to the left of the leak exit, inject channel sealant until it exits the second port in a length equivalent to the distance between the ports [3 to 5 in (76 to 127 mm)] and/or until no voids or fuel is observed. Close the first port, open the third port. Inject into the second port. Again observe sealant exiting the third port until that segment between has been replaced. Close the second port and inject into the third port, opening the fourth port for exiting of old sealant. Close the third and fourth ports.

In the event that the design includes fasteners not located in the channel, they are generally of the self-sealing type which are replaceable from outside the tank. Other fasteners that are accessible from inside the tank (if any) are repaired as described in 11.4.2.6.

If a fuel leak is observed near a dam location and the leak cannot be stopped by injecting sealant across the dam area, the cause could be a failed dam. If large amounts of channel sealant escape to the exterior of the tank, a ruptured dam is confirmed. The aircraft then must be defueled before repair. After access is gained to the area, remove any extruded groove sealant; then remove any residual dam material (MIL-S-8802 or MIL-S-83430 sealant) using small probes or drills (drills should be hand or air operated only).

CAUTION

Follow the configuration of the structural gap - Avoid damage to metal or composite surface.

Clean the dam gap of all debris and contamination using small wire bottle brushes wetted with solvent and rotated in a drill motor.

Clean the brushes frequently. Cleaning is completed by wiping the surfaces with clean, wetted cotton swabs. The adjacent surfaces of the repair site should also be cleaned for a distance of 2-in (51-mm) minimum in all directions. Wipe the surface dry with an approved lint and oil-free cloth wetted with methyl ethyl ketone (MEK). Wipe the surface dry with a dry wiper.

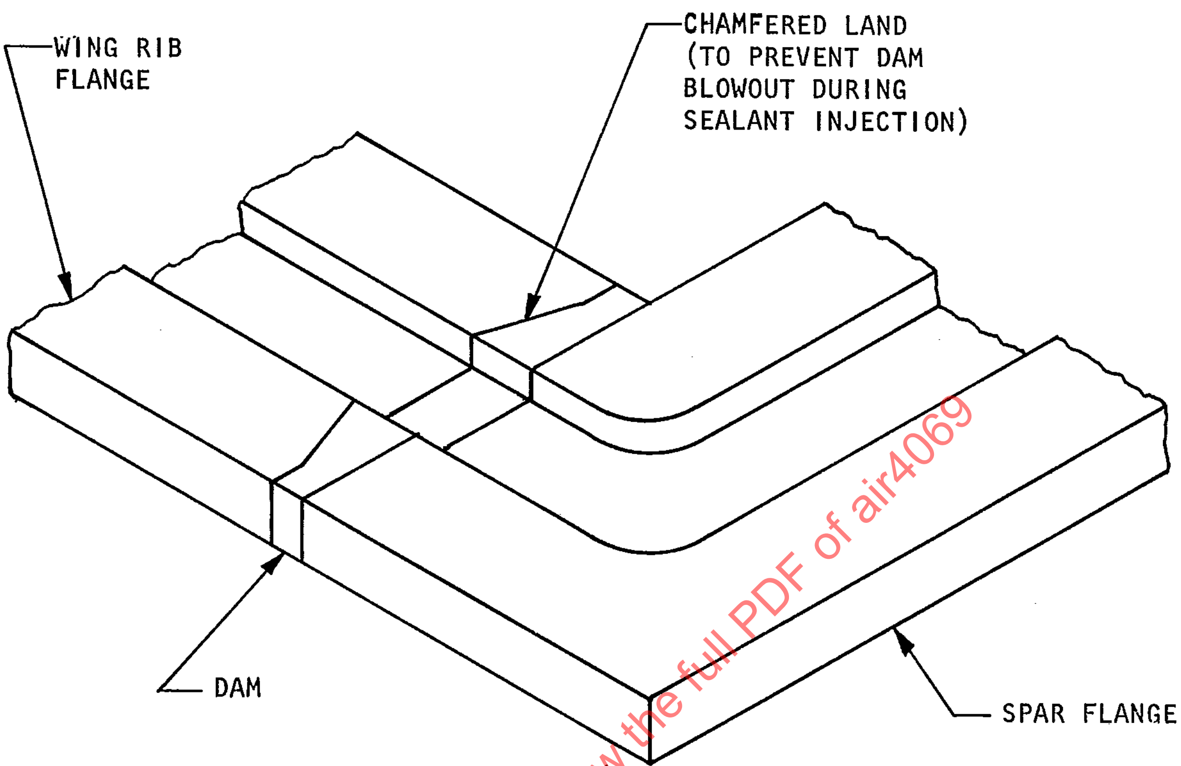

FIGURE 37 - A Typical Dam

11.4.3 (Continued):

Rebuild the dam using MIL-S-8802 or MIL-S-83430 polysulfide sealant (B 1/2). Apply with a sealant gun by inserting the nozzle into the dam area to the groove channel and slowly withdrawing the tip as the dam area is filled. Also apply sealant on the outside of the repair. After complete cure of the polysulfide sealant, the channel can be reinjected with groove sealant.

11.4.4 <u>Permanent Repairs in Adhesively Bonded Tanks</u>: Such tanks often combine adhesively bonded faying-surface sealing with groove and conventional sealing. Leakage in adhesively bonded faying surface areas are repaired by applying curable sealants as fillets or brushcoat plus fillet to the interior of the tank. Where design permits, inject sealant into the available channel in leak areas. Any leaks not accessible otherwise will require disassembly. Attempting to make a repair by application of sealant on the outside of the tank is not acceptable and is not an option.

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