

UNIFIED FACILITIES CRITERIA (UFC)

JOINT SEALING FOR BUILDINGS



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JOINT SEALING FOR BUILDINGS

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U.S. ARMY CORPS OF ENGINEERS (Preparing Activity)

NAVAL FACILITIES ENGINEERING COMMAND

AIR FORCE CIVIL ENGINEER SUPPORT AGENCY

Record of Changes (changes are indicated by \1\ ... /1/)

Change No.	Date	Location

This UFC supersedes TM 5-805-6, dated 16 September 1994. The format of this UFC does not conform to UFC 1-300-01; however, the format will be adjusted to conform at the next revision. The body of this UFC is the previous TM 5-805-6, dated 16 September 1994.

FOREWORD

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The Unified Facilities Criteria (UFC) system is prescribed by MIL-STD 3007 and provides planning, design, construction, sustainment, restoration, and modernization criteria, and applies to the Military Departments, the Defense Agencies, and the DoD Field Activities in accordance with [USD\(AT&L\) Memorandum](#) dated 29 May 2002. UFC will be used for all DoD projects and work for other customers where appropriate. All construction outside of the United States is also governed by Status of forces Agreements (SOFA), Host Nation Funded Construction Agreements (HNFA), and in some instances, Bilateral Infrastructure Agreements (BIA.) Therefore, the acquisition team must ensure compliance with the more stringent of the UFC, the SOFA, the HNFA, and the BIA, as applicable.

UFC are living documents and will be periodically reviewed, updated, and made available to users as part of the Services' responsibility for providing technical criteria for military construction. Headquarters, U.S. Army Corps of Engineers (HQUSACE), Naval Facilities Engineering Command (NAVFAC), and Air Force Civil Engineer Support Agency (AFCEA) are responsible for administration of the UFC system. Defense agencies should contact the preparing service for document interpretation and improvements. Technical content of UFC is the responsibility of the cognizant DoD working group. Recommended changes with supporting rationale should be sent to the respective service proponent office by the following electronic form: [Criteria Change Request \(CCR\)](#). The form is also accessible from the Internet sites listed below.

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- Whole Building Design Guide web site <http://dod.wbdg.org/>.

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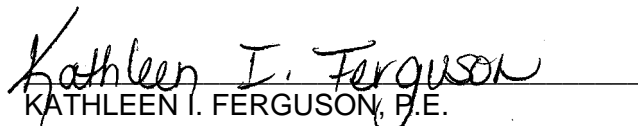
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TECHNICAL MANUAL

JOINT SEALING
FOR
BUILDINGS

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CHANGE

HEADQUARTERS
DEPARTMENT OF THE ARMY
Washington, DC 15 May 1995

No. 1

JOINT SEALING FOR BUILDINGS

TM 5-805-6, 16 September 1994, is changed as follows:

1. New or changed material is indicated by a vertical bar in the margin of the page.
2. Remove old pages and insert new pages as indicated below:

<i>Remove Pages</i>	<i>Insert Pages</i>
TOC	TOC
13	13, 14, 15, 16, 17, 18

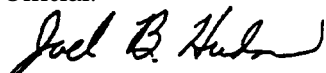
3. File This sheet in front of the publication for reference purposes.

The proponent agency of this publication is the Office of the Chief of Engineers United States Army. Users are invited to send comments and suggested improvements on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to HQUSACE, (CEMP-EA) WASH, DC 20314-1000.

By Order of the Secretary of the Army:

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General, United States Army
Chief of Staff

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Secretary of the Army*

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TECHNICAL MANUAL }
 No. 5-805-6 }

HEADQUARTERS
 DEPARTMENT OF THE ARMY
 WASHINGTON, DC, 16 September 1994

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***This manual supersedes TM 5-805-6 dated 31 January 1985**

1. Purpose. This manual provides criteria for the design of building joints and for the selection of sealants to prevent entry of water, air, dust, light, or sound through the joints.

2. Scope. This manual describes joint configurations and the selection and use of sealants, backing, bond breakers and primers for joints in various construction materials and in various environments. Design procedure is limited to joints between parallel materials and does not include structural design of joints. This manual supplements ASTM C 1193 which covers joint design, sealants, primers, backing and bond breakers, as well as the application and tooling of sealants.

3. References. Appendix A contains a list of references used in this manual.

4. Terms. A joint consists of a space between two or more adjacent materials. The joint is sealed when filled with a caulking or sealant. The terms "caulking" and "sealant" are often used interchangeably in the construction industry. Technically, a "sealant" is anything that "seals," and this includes caulking compounds.

a. Caulking. In this manual, the term "caulking" is limited to oil-and resin-based caulking which hardens as it cures and will accommodate little or no joint movement.

b. Sealants. In contrast to caulking, the more resilient "sealants" are rated to stand joint movements of 12.5, 25, or 50 percent of the joint width.

c. The sealant system. A sealant is usually installed as a system which includes a bond breaker or backing, and sometimes requires a primer. The adjacent materials are the substrates to which the caulking or sealant must adhere. A bond breaker may be required to prevent the sealant from bonding to the bottom of the joint. The backing supports the sealant from penetrating too far into the joint and may also act as a bond breaker.

d. Field formed and preformed. Both caulking and sealants may be "field-formed" from a liquid or paste, or they may be "preformed" as beads, strips or molded parts. Cure time and pot life of field-formed materials are shortened by increasing temperatures.

5. Joint Movement. Joints must be designed to allow for both cyclical and permanent changes in the length, volume, and plane of building materials abutting the joints. A properly designed joint, with an appropriate sealant, will accommodate movement of the adjacent (or substrate) building materials with no loss of adhesion or cohesion of

the sealant; i.e., the sealant will remain bonded to the substrate and to itself for the expected service life. Joints open and close as the adjacent materials are moved by structural instability, thermal expansion and contraction or (sometimes) changing moisture content.

a. Structural movement. The scope of this manual does not include calculation of movements due to structural loads and moisture changes. However, the extent of such movements can be used to calculate the joint size and to determine the proper sealant.

b. Temperature movement. For temperature changes, joint movement depends on the temperature change and effective length of the adjacent material from the anchor, i.e., the part of the material free to move in the direction of the joint. When no anchor exists, the joint should accommodate the movement of both adjoining materials.

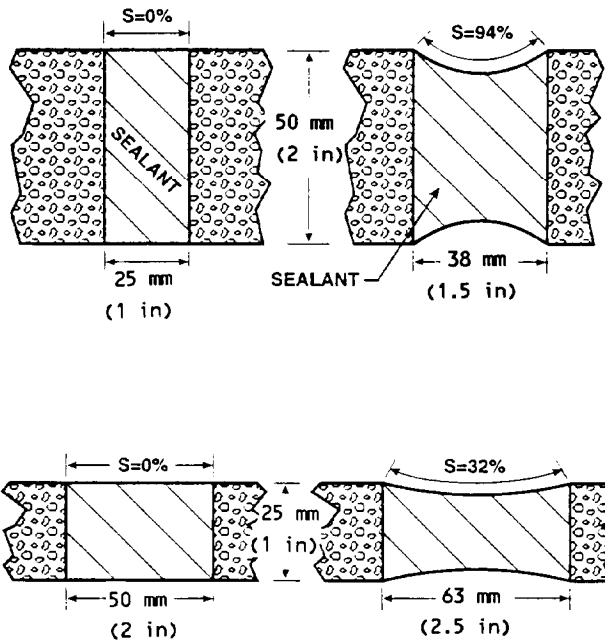
c. Butt and shear joints. Butt joints are designed to allow movement at right angles to the plane of the joint faces. When the plane of movement is skewed or deflected, shear forces must be considered in the joint design. A shear joint will hide and protect the sealant and will put less strain on the sealant as the joint moves. Shear joints are difficult to design, prepare, prime, seal, and repair; however, a shear joint may move laterally a distance equal to the joint width when an elastomeric sealant is used.

d. Width to depth ratio. The general rule is that a joint should be at least twice as wide as it is deep, and never less than 6 mm ($\frac{1}{4}$ inch) deep. A joint that moves should be wider than it is deep because the sealant must move to, or away from the edges as the joint opens or closes. The effect can be seen for joint extension in figure 1 and for joint compression in figure 2. In both cases, joints with the same cross-sectional area and different width-to-depth ratios each move 13 mm ($\frac{1}{2}$ -inch), either elongating or compressing the sealant.

(1) In figures 1 and 2, two joints are shown with the same cross-section of 1290 sq. mm. (2 square inches). As the joint extends or compresses, the faces, or outer edges of the sealant, are pulled in or pushed out by the movement of the sealant. In either case the faces are elongated. However, the different width-to-depth ratios produce very different surface elongations.

(2) Figure 1 shows how a 13 mm ($\frac{1}{2}$ inch) extension of a narrow joint elongates the sealant surface about 3 times as much as a similar extension in a wide joint.

(3) The difference is even greater when the joint is compressed 13 mm ($\frac{1}{2}$ inch) as shown in figure 2. Here the surface elongates about 250



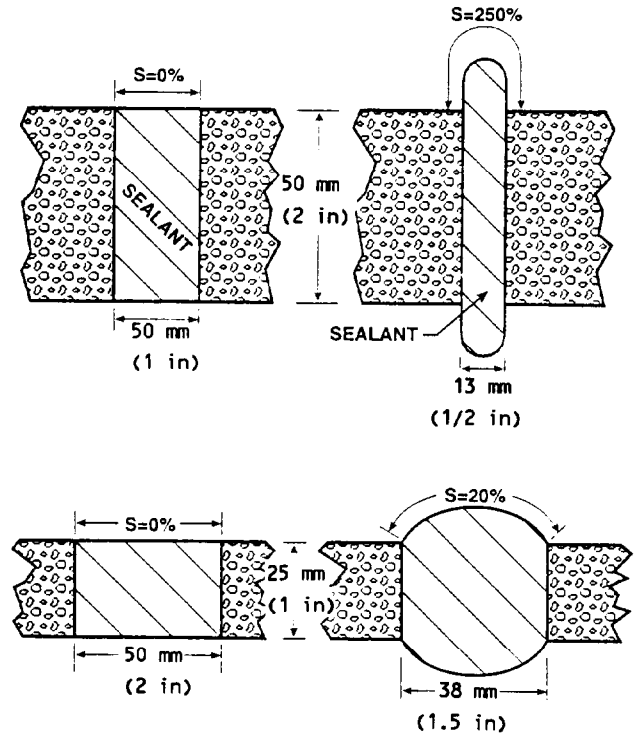
S = SURFACE ELONGATION

Figure 1. Joint Extension.

percent in the narrow joint, but only 20 percent in the wide joint.

(4) Effect of bond-breaker and backing. Figure 3 shows how the top surface elongation is greatly increased when the sealant is bonded to the bottom of the joint and the joint is elongated or compressed. Figure 4 shows the location of a bond breaker which prevents the sealant from adhering to the bottom of the joint. Where the joint is deeper than the sealant, a backing material is used to support the sealant as shown in figure 5. The backing may prevent adhesion, thus acting as a bond breaker, or it may be sufficiently flexible to move with the sealant.

e. *Temperature.* The maximum temperature range that a joint must withstand depends on the service temperature of the adjacent materials. Service temperatures may exceed ambient, as discussed below. Coefficients of thermal linear expansion are quite different for various materials, as listed in ASTM C 1193. Thermal expansion also varies at different parts of the temperature range and is affected by variations in thickness or composition. As a result, when calculations require an exact coefficient of thermal expansion of a material, it is best obtained from the manufacturer of that specific material and for the exact thickness and expected temperature range to be



S = SURFACE ELONGATION

Figure 2. Joint Compression.

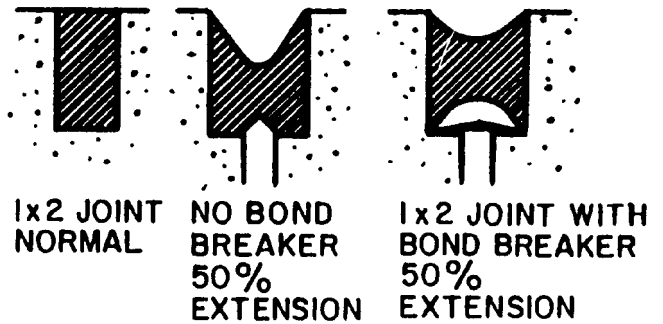


Figure 3. Effect of Bond-Breaker.

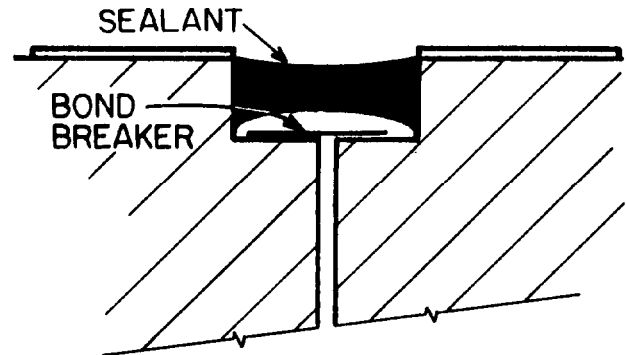


Figure 4. Bond-Breaker in Shallow Joint.

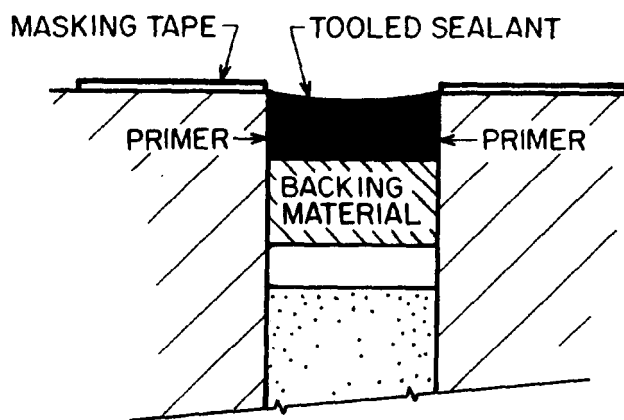


Figure 5. Backing Material in a Deep Joint.

used in the project. Where temperature ranges are moderate, as for most building interiors (and some sheltered exteriors), thermal movement will be limited. In general, plastics and metals have more thermal movement than stone, glass, masonry, and concrete.

(1) In cold regions, the joint expands as the temperature falls and the substrate materials contract. More often in the rest of the world, the joint is compressed as the temperature rises.

(2) The service temperature of the substrate material is not limited by the ambient temperature but may be increased by solar absorption or decreased by radiation to a clear cold night sky. Thus, service temperature is the extreme highest or lowest temperature experienced by the material during its service life. For most joints, this extreme temperature change causes the maximum joint movement.

(3) A range of application temperatures is specified by the manufacturer for each sealant, and either the low or high end of this range is selected as needed to produce the greatest temperature range, i.e., the greatest difference, or change, between application and extreme service temperature. This temperature change is used for calculating the joint width.

6. Approximate Joint Dimensions. The following guidelines provide approximate joint dimensions for use when anticipated temperature ranges and joint movement are limited. A detailed design procedure is recommended when temperature ranges are large or where other factors contribute to joint movement.

a. For side-bonding field-formed sealants, a relatively shallow joint is better and usually more economical than a deep joint.

b. The minimum joint width should always be 6 mm (¼ inch).

c. For oil-and resin-based caulking, the depth should be one to three times the width, and the joint should be subject to very little movement.

d. For elastomeric sealants, when the joint is wider than 13 mm (½ inch), the depth should be ½ the width but never less than 13 mm (½ inch). For widths in excess of 50 mm (2 inches), the depth should be as specified in the sealant manufacturer's recommendations.

7. Calculation of Joint Size. Sizes of most butt joints can be determined using one of the procedures in ASTM C 1193; one of these procedures makes use of a nomogram to approximate joint width requirements for various combinations of substrate materials and sealants; a method is also provided for calculating the joint-width (compression) based on expansion of adjacent materials. Similar calculations are described below for both compression and for extension of joints. Calculations are more complicated for configurations such as overlaps, fillets, or corners; these joints should be designed as recommended by the sealant or substrate manufacturer.

a. *Substrate service temperature.* Joint size should be based on the largest change in temperature expected for the service life of the joint and its adjacent materials.

b. *Compression.* When materials next to a joint are heated, they expand and compress the sealant in the joint. This compression is often the most severe distortion that the sealant must tolerate. The temperature range for the maximum expansion of the materials is the difference between the highest service temperature and the lowest sealant application temperature.

(1) In direct solar radiation, the highest service temperature will exceed the ambient temperature, roughly in proportion to the solar absorption coefficient of the surface, unless limited by the material's heat capacity. For example, a black surface may absorb as much as 95 percent of the solar radiation, and an exterior insulation and finish system or insulated metal panel will have low heat capacity, i.e., the heat cannot be readily absorbed or dissipated. Reflected solar radiation from adjacent surfaces may also have to be considered.

(2) The maximum substrate material temperature $T(\max)$ is determined by adding the hottest ambient summer temperature $T_a(\max)$ to the radiative heat gain XC using equation 1:

$$T(\max) = T_a(\max) + XC \quad (\text{eq. 1})$$

Where $X = 100$ for low heat capacity substrate material

$X = 75$ for high heat capacity substrate material

$C =$ Coefficient of solar absorption for the substrate material.

Some example coefficients of solar absorption are:

Almost any flat black color:	0.95
Bare galvanized steel:	0.90
Tarnished copper:	0.80
Bare concrete:	0.65
Clear-finish aluminum:	0.60
Aluminum paint:	0.40
Clear glass:	0.15.

(3) The maximum substrate material temperature T(max) minus the application temperature T(app) can then be used to estimate the joint movement in compression due to temperature increases as follows:

$$MC = L \times C \times [T(\text{max}) - T(\text{app})] \quad (\text{eq. 2})$$

Where MC = Estimated joint compression in inches

L = Length in inches of substrate material

C = Coefficient of expansion

T(max) = Maximum substrate material temperature

T(app) = Application temperature

(4) When the material is thin or readily absorbs solar radiation, and solar radiation is not a major factor, the maximum material temperature can be approximated by adding 20 degrees C (30 degrees F) to the maximum ambient temperature. Ambient predicted temperature ranges may be obtained from table 1, chapter 24, of the ASHRAE Handbook of Fundamentals.

c. Extension. The temperature range that will cause the maximum amount of joint extension (or joint-expansion due to contraction of the substrate material) is the difference between the highest application temperature and the material's lowest service temperature. The lowest ambient temperature Ta is usually nearly the same as the lowest material temperature T(min). Some joints experience lower temperatures, e.g., from artificial cooling or by radiation of an insulated surface to a cold night sky. The material will change in temperature from the application T(app) temperature to the lowest ambient temperature; consequently, the expansion of the joint movement can be expressed as Me where:

$$Me = L \times C \times [T(\text{app}) - T(\text{min})] \quad (\text{eq. 3})$$

Where Me = Estimated joint expansion

L = Length of substrate material

C = Coefficient of expansion

T(min) = Minimum material temperature

T(app) = Application temperature

d. Joint width. The maximum joint width W is calculated as the greater of either the width for compression Wc or width for expansion We:

$$Wc = (1/MS) \times Mc \quad (\text{eq. 4})$$

and

$$We = (1/MS) \times Me$$

Where MS = 1/2 of total movement capacity of the sealant in combined compression and tension. For example, if a sealant is rated for a maximum total joint movement of 50 percent, MS is 25 percent or 0.25.

e. Joint depth. Determine the joint depth as recommended by the sealant manufacturer (espe-

cially for silicone sealants) or according to the general guidelines described above.

f. Example. Following is an example of the above calculations in inch-pound units:

Determine the joint size for expansion joints spaced at 20-ft. intervals for a concrete masonry unit wall (C = 5.2 x 10⁻⁶ inch/inch/degree F) in which vertical joints are to be sealed. An elastomeric sealant with a movement capacity of plus or minus 25 percent is to be used and a maximum temperature gradient of 100 degrees F is anticipated.

$$\text{Joint movement } M = (20 \text{ ft.} \times 12 \text{ in./ft.}) \times (5.2 \times 10^{-6} \text{ inch/inch/degree F}) \times 100 \text{ degrees F} = 0.125 \text{ inch.}$$

$$\text{Joint width } W = (1/.25) \times M = 0.125/.25 = 0.5 \text{ inch.}$$

Therefore, assuming zero construction tolerance, the joint width should be 1/2 inch and the joint depth should be 1/4-inch.

8. Materials.

a. Bond-breaker. If sealant adheres to the bottom of the joint, subsequent movement of the joint will cause substantial distortion of the sealant cross-section as shown in figure 3. Consequently, when movement is anticipated, a bond breaker must be applied to the bottom of the joint. A liquid breaker should not be used because it will interfere with adhesion of the sealant to the sides of the joint. A typical bond breaker is a self-adhesive polyethylene or polytetrafluoroethylene tape which is placed, adhesive-side down, in the bottom of the joint. A backing material may be treated to act as a bond breaker. However, a bond breaker is not required if the backing material is soft enough to allow movement of the sealant. Figure 4 shows a typical bond breaker application in a shallow joint.

b. Backing. Joints are frequently deeper than the allowed depth of sealant as a result of structural requirements or convenience of construction. If these joints will have any motion, a backing is required to control the depth and shape of the sealant and, sometimes, to act as a "secondary seal." When the sealant is "tooled," the backing provides support needed to assure uniform sealant depth and full wetting of the substrate surfaces.

(1) *Secondary seal.* When used as a secondary seal, the backing should be an elastomeric closed-cell foam, installed in compression as specified by the manufacturer. Uncompressed closed-cell backing should have a diameter 25 to 33 percent greater than the joint width, while open cell backing should be 40 to 50 percent greater. The backing must be compatible with the substrate,

primer, and sealant materials which constitute the joint. Backing may be a combination of materials, e.g., when fiberboard is cast between two concrete structures and the opening to the fiberboard is filled with a foam backing to adjust the sealant depth. The backing may have its own bond breaker surface; it may be covered with a separate bond breaker; or the backing may be flexible enough to move with the sealant as the joint changes shape. Backings come in a variety of shapes and are often called "backer-rose."

cal sealant and backing configuration is shown in figure 5. Applications of sealant and backing are shown in figure 6.

(2) *Omission of backing.* Shallow interior joints with little or no motion may be sealed without a bond breaker, but unless the joint is shallow enough to prevent sealant from sagging into the joint, a backing should be installed to hold the sealant in place while it is tooled. Doors and thresholds are often sealed without backing as shown in figure 7.

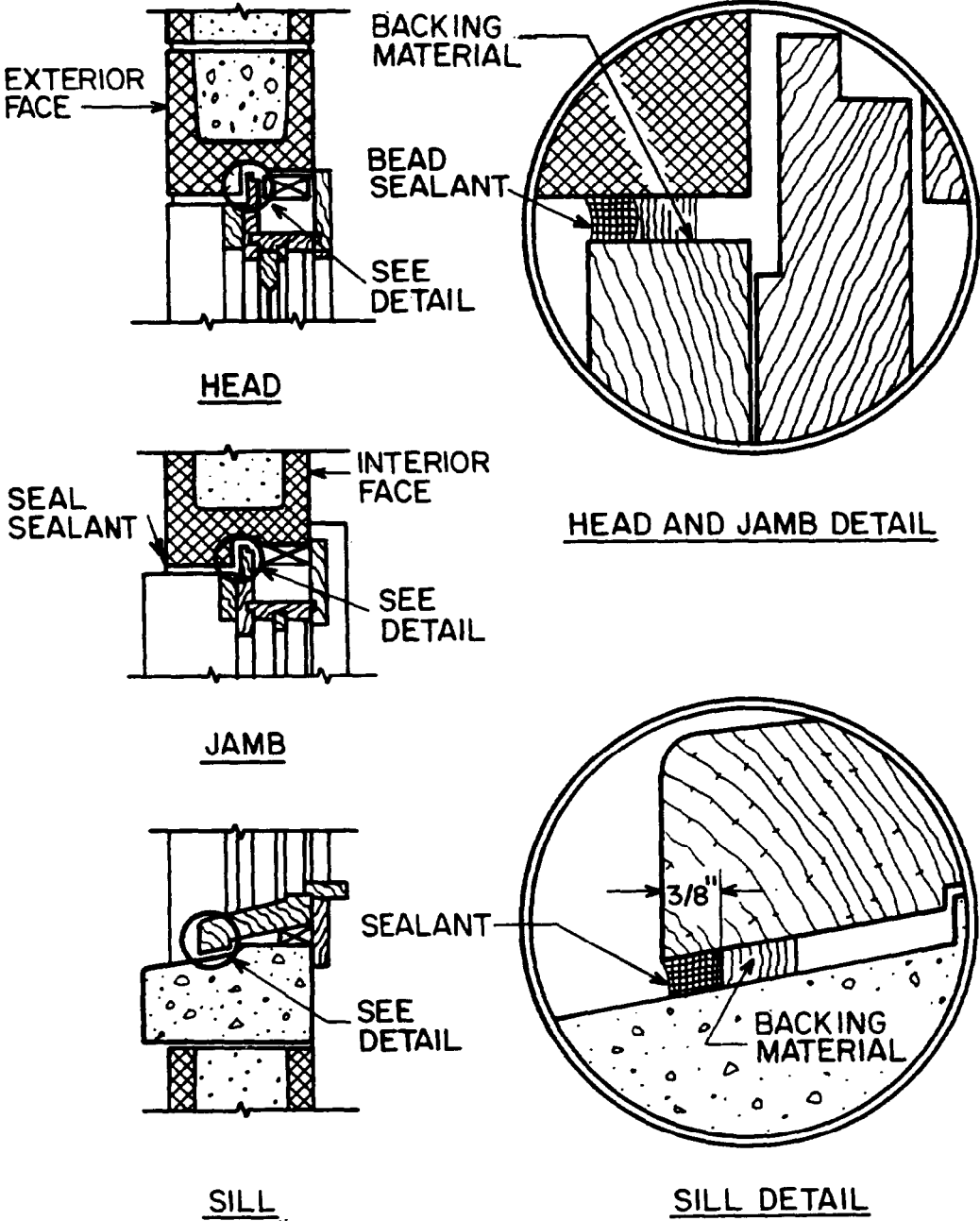


Figure 6. Wood Window in Masonry.

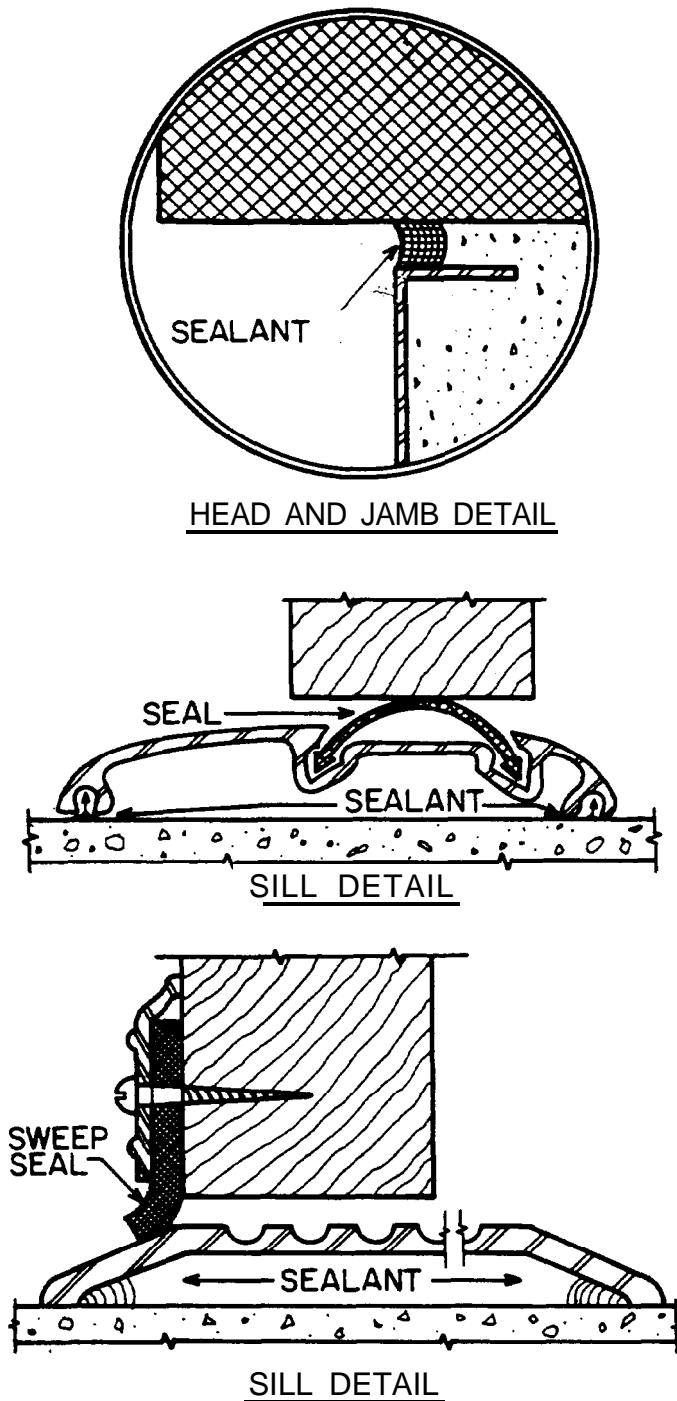


Figure 7. Exterior Door and Threshold.

c. *Primer.* Some sealants require a primer to promote adhesion to all substrates. More often, a primer is only needed on a non-porous substrate such as glass or metal. A primer is generally designed for use with a particular commercial sealant and may be restricted to specified substrates. Primers should be provided (and used as recommended) by the sealant manufacturer.

d. *Caulking.* Oil- and resin-based caulking is inexpensive and oxidizes to form a tack-free surface skin that can be painted.

(1) Oil- and resin-based caulking must be used with caution because it shrinks while curing, hardens with aging, cannot be immersed in water, and has limited resistance to joint movement. Applications should be limited to rigid interior joints not more than 6.3 mm (1/4 inch) wide because the caulking lacks elasticity and may shrink as much as 20 percent. Paint will extend the service life of caulking and will protect the material from occasional exposure to water.

(2) Oil- and resin-based caulking should be applied at temperatures between 4 and 38 degrees C (40 and 100 degrees F). The service temperature range is from -30 to 39 degrees C (-20 to +150 degrees F). Type I is used in caulking guns and Type II is applied with a putty knife.

e. *Latex sealants.* Latex sealants adhere well to wood, masonry, and concrete. Depending on the grade of material, these sealants have varied weather resistance which is improved by applying a coat of paint.

(1) Latex sealants may shrink as much as 30 percent while curing and have limited resilience when cured. Consequently, latex sealants should be used only for temporary or low budget construction where joint movement does not exceed 15 percent of the joint width.

(2) Many acoustic applications can be satisfied with latex sealants, as shown in ASTM C 919.

(3) The binder in a latex sealant may be natural rubber or a synthetic polymer. The most common latex sealants are based on a water-dispersed acrylic polymer, thus the terms "latex" and "acrylic" are often used interchangeably.

f. *Acrylic sealants.* Acrylic sealants are widely used because they are inexpensive and adhere well to most porous surfaces. Most acrylic sealants are water dispersed ("latex") but they are also available in solvent dispersions. These sealants usually shrink up to 30 percent during the curing process. The service temperature range for acrylic sealants is from -30 to +84 degrees C (-20 to +180 degrees F). A quality acrylic sealant may have a life expectancy up to 20 years.

(1) The quality of acrylic sealants varies; the higher the acrylic polymer content, the better the flexibility and resistance to weathering (and the higher the cost). Solvent based systems often have better water resistance than those dispersed in water.

(2) Acrylic sealants should not be exposed to standing water and they do not bond well to bare metal or glass unless a primer is applied first.

Special "siliconized acrylic" sealants will adhere to metals and glass. The comparatively inexpensive vinyl acetate-acrylic copolymer sealants have poor resistance to water and ultraviolet and they are limited to near-zero joint movement.

(3) Uncured acrylic latex sealants clean up readily with water. During the relatively slow curing time, acrylic sealants are susceptible to dirt pickup. Acrylic sealants resist attack by ultraviolet, salt spray, and weathering. They are vulnerable to attack by esters, ketones, aromatic hydrocarbons, petroleum products, and oxidizing chemicals. Acrylic sealants are generally limited to a total joint movement of plus or minus 12.5 percent, although silicone-acrylics can resist joint movement as high as 50 percent.

(4) Acrylics are available "clear" and in colors, and they may be painted, although joint movement may crack the paint.

g. Elastomeric sealants. An elastomeric sealant is one which will withstand a joint movement of at least 25 percent (plus or minus 12.5 percent). Elastomeric sealants are classified as single- or multi-(usually two-) component; pourable or non-sag; allowable joint movement (plus or minus 25 or 12.5 percent); for use in traffic or no traffic; and for use on mortar, glass, aluminum, or "other" substrate. Paint should be applied to elastomeric sealants only when the joint has little or no movement; otherwise, when the sealant elongates, the paint surface will crack. Most of the elastomeric sealants will provide good service in severe weather exposures and can be used in place of oil- and resin-based caulking or acrylic sealants. Elastomeric sealants may lack sufficient strength or durability for use as structural (load-bearing) sealants. Performance characteristics vary, depending on the type and amount of polymer and other ingredients.

(1) *Polysulfide sealants.* Polysulfides react with strong oxidizers and may ignite in presence of liquid oxygen or concentrated hydrogen peroxide. Polysulfide sealants can be used in joints that move as much as 50 percent (plus or minus 25 percent). Polysulfide sealants are available in colors and will accept paint. The service temperature range for polysulfide sealants is from -30 to + 65 degrees C (-20 to 150 degrees F), except for aircraft sealants which are specially compounded to permit operation at -40 degrees (C or F). Polysulfide sealants hold up well when fully immersed, as in swimming pools. At one time, polysulfide sealants dominated the market for high performance sealants for buildings.

(a) Polysulfide single-component sealants are usually latex dispersions which were among

the first fuel resistant sealants. The loss of water when curing causes these sealants to shrink, and their physical properties have been surpassed by those of the silicones and polyurethanes.

(b) Two-component polysulfide sealants were first developed for sealing integral tanks in aircraft in the early 1950's. They provide high solids content (thus little or no shrinkage) and good adhesion to most construction materials. Early applications were limited because of the high cost of the polymer, but their good performance in a few high quality architectural applications resulted in a larger market and reduced costs. Two-component polysulfides are widely used in building construction. The cure rate can be adjusted to provide adequate pot life and short cure time.

(2) *Polyurethane sealants.* Tough, flexible polyurethane sealants are often used on sidewalks and industrial floors. Clear polyurethanes have poor resistance to ultra violet light, but pigments provide considerable protection. Polyurethanes are available in colors and can be painted. Polyurethane is also used with several co-polymers; an epoxy co-polymer, for example, will enhance hardness and water resistance. The service temperature range for polyurethane sealants is from -40 to 83 degrees C (-40 to + 180 degrees F). Life expectancy of a quality urethane sealant may be as high as 20 years.

(a) Polyurethane sealants can withstand joint movement of 50 percent (plus or minus 25 percent).

(b) Specially compounded polyurethane sealants may be used in areas exposed to liquid oxygen (LOX). Many polyurethane sealants have good resistance to petroleum products; however, manufacturer's data should be consulted for specific exposures.

(c) Unopened containers of single-component polyurethanes have a relatively short shelf life of 6 months to a year. An open container of polyurethane sealant will soon increase in viscosity until it is no longer usable.

(d) Increased temperature and humidity will shorten the pot life. Polyurethane foam sealant and foam insulation are produced by adding a blowing agent, e.g., an aerosol in a can or two parts mixed in a spray. The resulting foam must be protected from ultra violet exposure.

(3) *Silicone sealants.* Silicone sealants have excellent weather resistance and a service temperature range from -54 to + 204 degrees C (-65 to + 400 degrees F). Good quality silicones are superior to most other types of sealants with regard to flexibility, elongation, capacity to absorb joint

movement, resistance to temperature extremes, and resistance to weather and ultra violet light. Quality silicone sealants have a life expectancy up to 50 years and are often specified in place of polysulfide or polyurethane sealants. Silicones should not be exposed to abuse or traffic; they are generally less resistant to abrasion and penetration than polyurethane or epoxy sealants.

(a) Silicone sealants are vulnerable to attack by solvents, petroleum products, and some oxidizing chemicals. Prolonged immersion in water degrades silicone sealants, and chlorine, as in swimming pool water, accelerates the degradation.

(b) Physical properties of silicone vary from high-strength low-elongation to low-strength high-elongation; the stronger materials are used for structural bonding of glass and thin stone while the high-elongation silicones can withstand joint movement from plus 100 to minus 50 percent. Properties of two-component and single-component silicones are similar except that two-component systems provide an adjustable pot life (10 minutes to 3 hours) and cure time (4 hours to 7 days). The two components may be two polymers or, more commonly, a polymer and a curing agent which reacts with the polymer or acts as a catalyst to promote polymerization. Curing is accelerated by higher temperature but is not usually affected by ambient relative humidity. Additionally, some two-component silicones are not compatible with some acetoxyl single-component silicones as discussed in following paragraph 8.g.(4).

(c) Special silicone sealants are available for solar collectors, sanitary sealing, and glazing.

(d) Silicone sealants usually have high solids content (low shrinkage), are available in colors, and will not accept paint unless formulated to do so, e.g., silicone-polyether copolymers will accept paint.

(4) *Acid-curing silicone sealants.* (Note: See following paragraph 9 for general curing properties of sealants.) In acid or "acetoxyl" curing sealants, moisture from the air reacts with the polymer to produce acetic acid; as a result, the curing process is accelerated by increased humidity. The acetic acid byproduct can migrate into, and react with, porous substrates or it will eventually evaporate into the surrounding air. Some acid-curing silicones have high strength, but they are not recommended for use with concrete, masonry, or insulating glass and may be incompatible with some two-component silicone sealants. This incompatibility can cause a structural failure, e.g., a field-applied single component silicone can damage a two-component structural silicone sealant in a factory-made window assembly.

(5) *Neutral curing silicone sealants.* (Note: See following paragraph 9 for general curing properties of sealants.) These sealants also cure by reacting with moisture from the air, but the resulting by-product may be an alcohol or ammonia, depending on the nature of the polymer. Neutral-curing sealants are compatible with most building materials and other types of silicone sealants.

h. Structural silicone sealants. These sealants have minimum tensile, rheological, and aging-resistance values which exceed those required for silicones classed as elastomeric sealants. The structural silicones are available in either one- or two-component systems and are used to support and retain glazing or other types of panels, sometimes with no structural support visible on the outside of the building. Design of such structures requires a rigorous structural analysis beyond the scope of this manual. Due to their premium costs, structural silicone sealants are usually limited to applications where high strength is required. However, they can generally be used in place of any of the sealants described above, except that, like other silicones, they will not accept paint and are more easily damaged than polyurethane sealants.

i. Preformed sealants. Preformed sealants depend on continuous, positive compression rather than adhesion for their sealing action. They are generally designed for specific uses and fixed geometry joints in contrast to the more versatile field-formed sealants. Preformed sealants are available as beads, tape, or special shapes for specific tasks, and they may be either plain or reinforced. Preformed sealants should be used in joints that are subject to little or no movement. The service temperature ranges of common preformed sealants are: from -30 to +70 C (-20 to +160 F) for vinyl chloride; from -40 to +107 C (-40 to +225 F) for polychloroprene; from -35 to +148 C (-30 to +300 F) for isobutylene-isoprene copolymers (butyl) or polyurethane; from -30 to +70 C (-20 to +160 F) for polyethylene or styrene-butadiene (SBR); and from -54 to +204 C (-65 to +400 F) for silicone sealants. Some compounds based on polytetrafluoroethylene will survive extended service at degrees 260 C (500 F). Figure 8 shows an application of a preformed sealant.

(1) *Non-resilient tapes and beads.* These sealants are essentially preformed strips of non-curing sealant. They are generally made from uncured butyl or polybutene mixed with fillers such as clay, calcium carbonate, and other fillers or pigments which help to hold the shape of the tape before it is applied. Non-resilient tapes are really

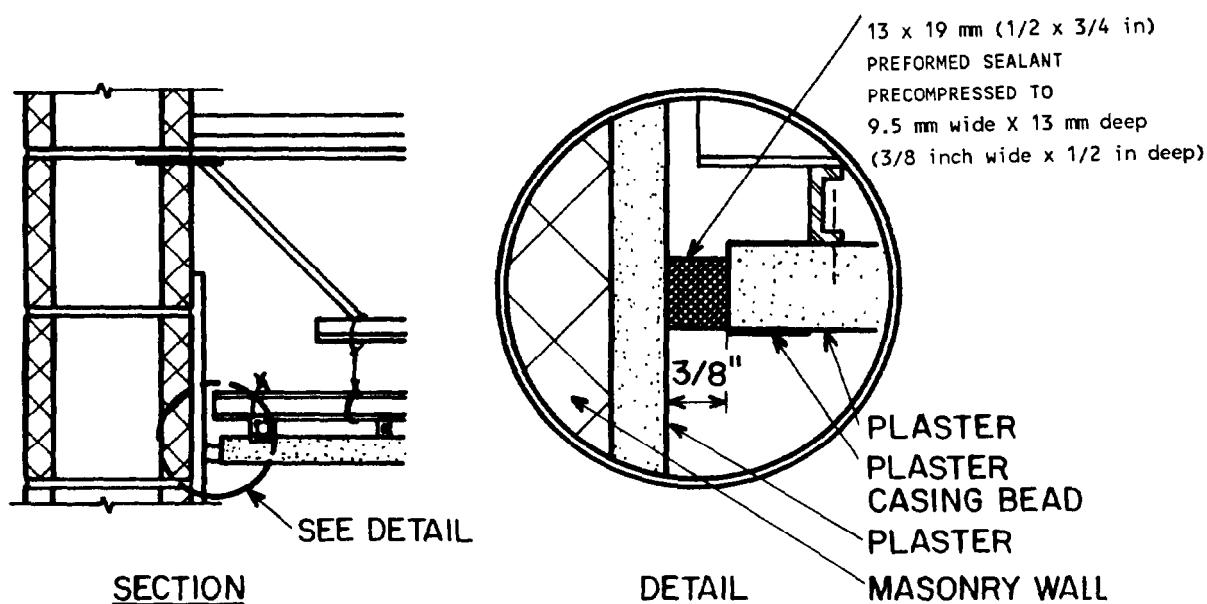


Figure 8. Preformed Sealant at Ceiling to Wall Joint

joint tillers because they are tacky enough to produce a seal but have little true adhesion and little recovery after being deformed. Non-resilient tapes are used for hidden joints, often with a cap bead of a compatible sealant. These sealants should not be used in working joints or in visible exterior joints.

(2) *Resilient tapes, beads, and gaskets.* These resilient materials are generally made of cured butyl, polyisobutene, or other synthetic rubber and fillers. They stay tacky, are harder than non-resilient tapes, and have greater recovery after deformation. Resilient gaskets are used for seals in glazing and exterior panels and as structural gaskets.

j. Wool felt. This sealant is a wool felt impregnated with a non-hardening anti-corrosive compound. Wool felt sealant is brown in color, is not affected by heat below its ignition temperature, and is available with adhesive on one side.

k. Resilient foam. These sealants are preformed polyurethane foam strips that are waterproofed with a coating such as asphalt or polybutylene. To be effective, the sealants must be used under compression. The percentage of compression determines the joint's capacity and varies with the sealant's manufacturer. For example, to weatherproof a joint, one sealant may have to be compressed 75 percent while another material may be effective when compressed 50 percent. The service temperature of resilient foam is limited by the waterproofing material and ranges from -40 to +93 degrees C (-40 to +200 degrees F). Polyurethane foam without waterproofing can be used in

temperatures ranging from -40 to 145 degrees C (-40 to +275 degrees F). Dry foam is available with an adhesive to hold the sealant in place during application.

l. Acoustic sealants. ASTM C 919 describes the use of sealants in acoustical applications. An acoustical sealant can be almost any sealant that maintains sufficient adhesion and cohesion to hold it in place, keep it from falling apart, and block the path of sound. The prevention of air penetration is more critical to sound attenuation than the actual sound deadening of the sealant itself. Non-skinning sealants are most often used because they are least expensive. Following are acoustic considerations for various types of sealants, which, except for the "non-skinning," are described in more detail elsewhere in this manual.

(1) *Non-skinning sealants.* These sealants remain soft and pliable because of their butyl, polybutene, or polyisobutylene polymer base. They are gun-grade, non-curing, ready for immediate use, can be applied at temperatures ranging from -18 to +38 degrees C (0 to 100 degrees F), and will stand service temperatures ranging from -52 to +93 degrees C (-60 to 200 degrees F). Non-skinning sealants are used in fixed joints between metals and glass and may be capped with a bead of compatible elastomeric sealant. Non-skinning sealants may stain porous surfaces and should not be used on exposed masonry. They are subject to attack by petroleum products; do not provide a good base for paint, and may retain dirt. While recommended only for use in fixed (non-moving) hidden joints, non-skinning sealants have

enough resilience to withstand limited displacement vibration.

(2) *Prefomed sealants.* Gaskets, tapes, and prefomed foams are effective in sealing wall penetrations such as telephone, television, and electrical outlets.

(3) *Asphalt or oil- and resin-based sealants.* These sealants perform well at first, but they shrink, harden, crack, and lost adhesion which may cause air gaps that will transmit sound.

(4) *Latex and acrylic sealants.* In joints which have little or no movement, latex and acrylic sealants are effective in stopping sound transmission.

(5) *Elastomeric sealants.* The elastomeric sealants discussed in this manual are good acoustic sealants, especially for joints that move.

(6) *Other types of sealants.* High costs limit acoustic applications of otherwise suitable sealants based on butyl rubber or polymers of polychloroprene or chlorosulfonated polyethylene.

m. Butyl sealants. Solvent-based butyl sealants are used where good water resistance is needed, their dark color is acceptable, solvent release is not a problem, and the joints move less than 10 percent of the joint width. A few specially formulated butyl sealants will tolerate joint movement as high as 20 percent.

(1) Butyl sealants consist essentially of butyl rubber and other materials dispersed, and at least partially dissolved, in an organic solvent.

(2) Applications include joints between doors or windows and masonry and between cap flashings and parapet walls. Butyl sealants cure by evaporation of the solvent with little shrinkage. The presence of solvent precludes most butyl sealants from applications where volatile organic compounds are severely restricted. Butyl sealants are very flexible, have excellent resistance to water and weather, and bond well to masonry and metals; consequently, butyl sealants are often used in joints between dissimilar materials.

(3) Some butyl sealants are available in colors. Butyl sealants are vulnerable to attack by petroleum products and oxidizing chemicals, including ozone. Butyl sealants can be painted and are available in cartridges for caulking guns, in containers for putty knife application, and in prefomed beads, tapes, and extrusions.

n. Chlorosulfonated polyethylene (CSPE) and polychloroprene sealants. These materials are available as sealants and as fluid-applied membranes, both of which provide good resistance to water and many chemicals, including most petroleum products. CSPE is often used in roofing, while polychloroprene is used underwater, e.g., in

swimming pools. These sealants have a low solids content (about 20 percent) and cure by evaporation of solvent; consequently, they shrink too much for many types of joints. After application, some of these sealants may become tack-free in 24 hours and then take 1 to 3 months to cure. During the cure time, movement of the joint can damage the seal.

(1) *CSPE.* An example of CSPE is hypalon. CSPE is more often found in roofing as a membrane than as a sealant in building joints. Cured CSPE sealants can withstand a joint movement of 25 percent. They have good resistance to most acids, alkalis, and petroleum products. CSPE sealants are available in colors and will accept oil-based paints, but they are better left uncoated.

(2) *Polychloroprene.* Polychloroprene (Neoprene) sealants can withstand joint movement up to 25 percent and provide excellent resistance to many chemicals, most petroleum products, and water. Polychloroprene sealants are used to seal joints in swimming pools and joints between concrete and asphalt.

9. Curing. Caulking may be slow curing; some caulkins and acoustic sealants never fully cure. Most sealants must cure to be strong enough to absorb the joint's motion and to resist stresses imposed by outside forces. The sealant cure must be slow enough to permit the material to be applied and fast enough to complete the cure before the sealant is stressed by temperature changes or by its intended usage.

a. Single-component sealants. Single-component sealants cure by absorbing moisture from the air or by evaporating solvent or water from the sealant into the air. Silicone and polyurethane single-component sealants cure by acquiring moisture from the air, so shrinkage is minimal or none. Sealants dispersed in water or solvent cure by the loss of the water or solvent which causes some shrinking during the cure. Single-component systems are slow to cure and may require several months to develop their full strength. High temperature and humidity will hasten the slow cure. A thick bead cures slowly and may remain permanently soft near the middle.

b. Multi-component sealants. Rather than depend on moisture for curing, these sealants cure by the reaction of two or more components, each of which has a long shelf life. When the components are mixed together the resulting sealant cures in a short time. The components may be two or more polymers, a curing agent, or a catalyst to promote polymerization. Increased temperature and humidity will shorten the cure time. Additionally, the

high-solids content of these sealants minimizes shrinkage during the curing process.

(1) A catalytic curing reaction uses a catalyst or “activator” which triggers the polymerization of the sealant. Small quantities of catalyst will promote the reaction which may be accelerated when very little additional catalyst is added to the mix.

(2) Co-polymerization results when two or more different polymers react to produce a third polymer (or co-polymer) system.

(3) Mixing is done just before or during the application so that the “pot life” is long enough to allow the sealant to be placed in the joints. The mix ratio is tailored to allow control of the cure time, sometimes progressing to an early-strength tack-free stage in as little as 1 hour.

(4) Mix-proportions must be closely controlled, mixing must be thorough, and the mixed sealant must be used before expiration of its pot life and shelf life. These sealants may be mixed with special equipment as they are applied or pre-mixed and loaded into sealant gun cartridges. The cartridges are sometimes frozen to extend the pot life of the material. Curing is always accelerated by increased temperature and sometimes by increased humidity.

(5) The properties of two-component sealants are generally similar to the one-component seal-

ants based on the same type of polymer; the primary difference is the curing time.

10. Selection of Sealants. The applications listed below range from the least demanding interior caulking to the most demanding exterior structural sealants. Table 1 provides a general comparison of sealants.

a. Interior joints in wood, masonry, concrete, and metal. Joints with short life, no movement, and no exposure to standing water can be filled with inexpensive oil-and-resin-based caulking. Paint will extend the service life by protecting the caulking from occasional water exposure, retarding loss of volatile constituents, and filling small cracks in the caulking.

b. Interior acoustic joints. Non-skinning or pre-formed sealants are used to fill interior joints that will not move and where the soft sealant will not be disturbed (usually hidden from view).

c. Exterior joints protected from standing water or severe weather. Acrylic sealants are suitable where joint movements do not exceed 15 percent, and water exposure is limited. Quality varies; increased acrylic content improves performance and increases cost. The solvent-based acrylics are generally superior to those with a water base. Paint will help protect acrylic sealants. Elastomeric and structural silicone sealants are also suitable for these applications.

Table 1. General Guide to Sealant Selection

Sealant/ Primary Use	* Substrates	Cure Time	Shrink	Total Joint Movement	Design Life/Comments
Acrylic latex Interior, Non-moving joints.	Porous	Slow	Yes	15%	5 to 20 yrs. Paint will help protect. No standing water.
Polysulfide Single	All	Slow	Yes	25%	5 to 20 yrs.
Multi- All joints except traffic.	All	Variable	No	50%	5 to 20 yrs.
Polyurethane Single	All	Slow	No	50%	Resists traffic abuse. 5 to 20 yrs.
Multi- All joints.	All	Variable	No	50%	5 to 20 yrs.
Silicone Single	All	(Resists high & low temperatures. Slow	No	50%	Will not accept paint.) 10 to 20 yrs.
Multi- All joints except traffic.	All	Variable	No	50%	10 to 20 yrs.
Structural Silicone Single	All	Slow	No	50%	Will not accept paint. 20 yrs.
Multi- Used to support smooth-faced exterior glass & panels.	All	Variable	No	50%	20 yrs.

Table 1. General Guide to Sealant Selection-Continued

Sealant/ Primary Use	* Substrates	Cure Time	Shrink	Total Joint Movement	Design Life/Comments
CSPE Chemical resistant membrane or coating	Porous	Slow	Yes	25%	5 to 20 yrs. Resists water, chemicals, & petroleum products.
Chloroprene Swimming pools	Porous	Slow	Yes	25%	5 to 20 yrs. See CSPE.
Non-skinning Acoustic seals	Porous	None	No	None	2 to 5 yrs. Do not paint.
Butyl Water seal, Small joint movement	All	Slow	Yes	10%	5 to 20 yrs. Protect from UV & ozone; good water resistance
Preformed & Resilient Sealants	All	None	No	100%	Up to 20 yrs. All types of joints.

* NOTE: "All" substrates include glass, metal, finished wood, and porous materials. "Porous" materials are concrete, masonry and unfinished wood.

d. Exterior moving joints. The elastomeric sealants based on polysulfide, polyurethane, and silicone provide excellent resistance to weather. Standard classes are 12.5 and 25 percent joint movement. Sealants capable of 50 percent joint movement are available.

e. Exterior joints, heavy abuse. Of the elastomeric sealants, polyurethane usually provides the best resistance to abrasion or penetration as required for a sealant exposed to abuse and traffic.

f. Joints in exterior insulation and finish systems (EIFS). Most types of EIFS will deteriorate quickly if moisture penetrates into the layers of insulation, base coat, and top coat. Properly sealed joints prevent moisture from entering the EIFS joints and exposed edges. When the finish coat is coarse, the sealant must be adhered to the base coat which is turned down into the joint; otherwise, moisture will migrate through the edges of the finish coat, release the sealant's adhesion, and enter through the joint into the EIFS and underlying structures. Manufacturers provide or specify sealants and details for sealing each EIFS system.

g. Joints subjected to chemical exposure. Use CSPE or polychloroprene (Neoprene) sealants when exposures are anticipated to aliphatic solvents, petroleum products, water, and numerous other chemicals. Preformed sealants made from fluoro- or fluoro-chloro-carbon polymers (such as teflon and kynar) will resist many very active chemicals.

h. Joints subjected to temperature extremes. Most (but not all) silicone sealants retain good flexibility at temperatures as low as -54 degrees C (-65 degrees F); and will not deteriorate when exposed to temperatures as high as +204 C (400 F). Polytetrafluoroethylene (Teflon) sealants will resist higher temperatures but are generally only

available as preformed sealants.

11. Radon. For controlling radon in low rise buildings, ASTM E 1465 provides design options for sealing and ventilating slabs, basements, and crawl spaces. When applied, these "options" should incorporate the joint designs and sealant selections established in this manual.

12. Fire Resistance. Most sealants are combustible. Exceptions to this are teflon and kynar sealants which will break down at temperatures in excess of 700 degrees F. Polychloroprene, CSPE, and some silicone sealants are generally "self-extinguishing." Sealants for fireproofing are specially formulated to pass flame spread and smoke requirements. Control and expansion joints in fire rated construction will be designed in accordance with Series J900, U900, and U400 of the UL Fire Resistance Directory; firestopping will be in accordance with Military Handbook MIL-HDBK-1008.

13. Joint Details. Most joints will be configured as shown in figures 4 and 5. One of the adjacent materials may extend beyond the face of the joint (e.g., when a window casing is sealed to masonry, or when a pipe is sealed in a sleeve and the sleeve is sealed in a wall), but this does not affect the basic joint configuration. In deep joints, a backing material should always be required to hold the sealant in place while it is being inserted and tooled. Without backing, tooling can dislodge the sealant. If a sealant is not tooled, it may not fill the joint, and air bubbles may penetrate the sealant, form blisters, or mar the surface.

a. Stationary joints. A joint is stationary (or fixed) where the adjoining materials are not free to

move independently of each other. Stationary joints can be configured as shown in figures 4 and 5, except that a bond-breaker is not needed because there will be no deformation of the sealant (or caulking). In a stationary joint, the backing may be rigid material.

b. Moving joints. Joints that move are generally configured as shown in figures 4 or 5, and in every case the bottom of a moving joint should be protected by a bond-breaker or by a backing material which can move with the sealant.

c. Expansion and control joints. Expansion and control joints should be treated as moving joints, including those control joints that do not penetrate the material but provide a weak place where a crack can develop in the material beneath the joint. A control or expansion joint in tile is shown in figure 9.

d. Pipe and round duct penetrations. A pipe or round duct must be protected with a sleeve when penetrating a floor, wall, ceiling or roof. The gap between pipe and sleeve should be a minimum of 6 mm (1/4 inch) and the gap between duct and sleeve should be 25 mm (1 inch) or more. Sealants for these gaps may be selected from table 2. A resilient sealant may be required to absorb movement due to thermal expansion or to dampen

vibration from operating components connected to the pipe or duct. In fire resistant structures, the gap must be filled with fireproofing material and a sealant may be required to protect the fireproofing from traffic or water.

(1) *Bare Pipe Sleeve.* A bare pipe may penetrate a wall through a sleeve with sealant in the exterior wall and an escutcheon on the interior as shown in figure 10.

(2) *Above Grade Insulated Pipe.* Pipe insulation should be protected by a metal jacket which may be sealed to the sleeve as shown in figure 11.

(3) *Exterior Wall Penetration.* Protection from exterior moisture may be required above or below grade. The penetration may be isolated from the waterproofing membrane by a clamping flange which also serves to protect the sealant as shown in figure 12.

(4) *Floor Penetration.* Sealant around a pipe penetrating through a floor should be sloped to avoid trapping water or dirt at the pipe to sealant interface as shown in figure 13.

e. Typical joints. Table 2 lists typical joints used in construction and provides sealant selection criteria depending on the anticipated requirements for movement, cure time, paint acceptance, and resistance to traffic or standing water.

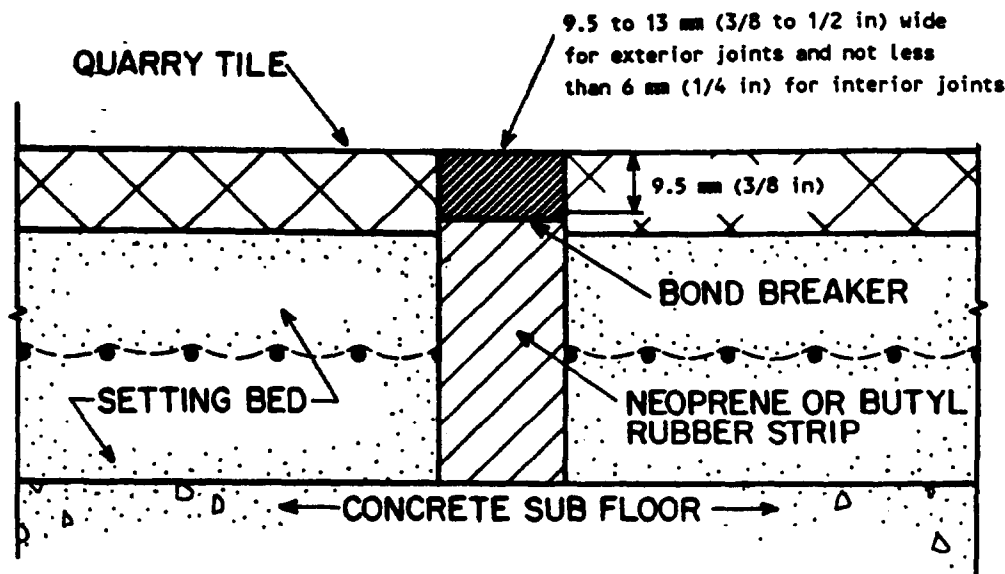


Figure 9. Control or Expansion Joint in Tile.

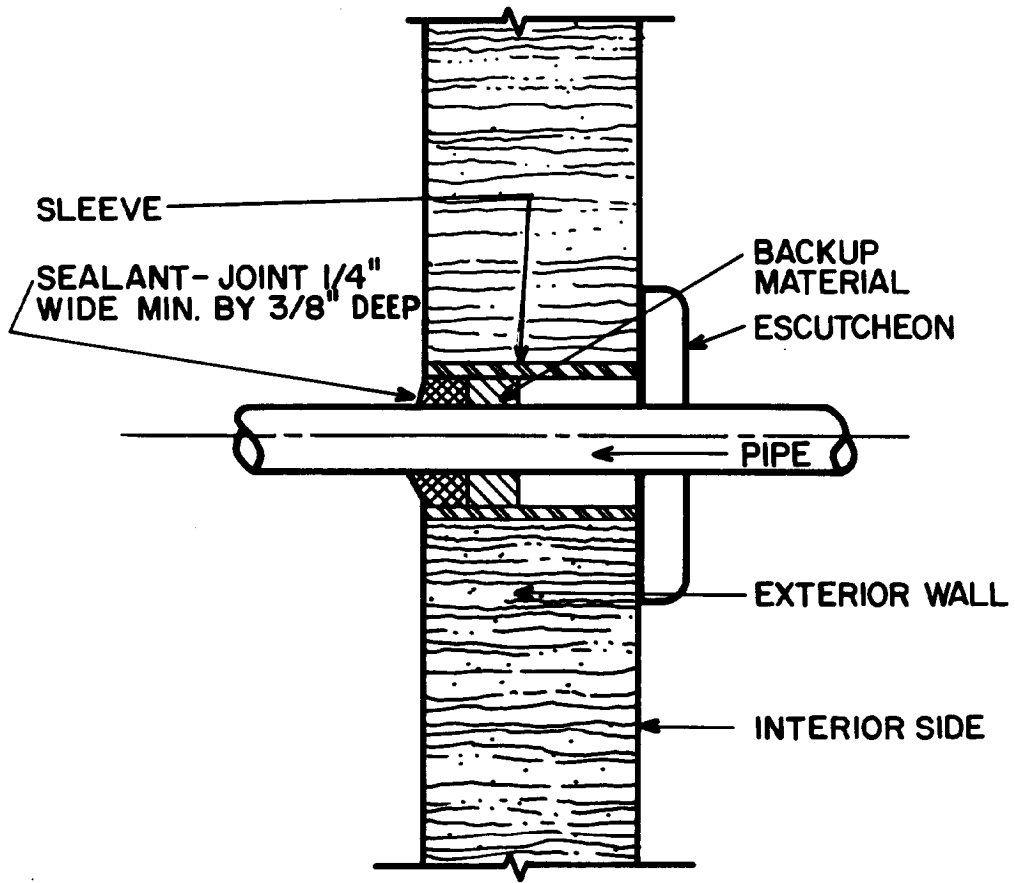


Figure 10. Pipe Sleeve for Bare Pipe - Above Grade.

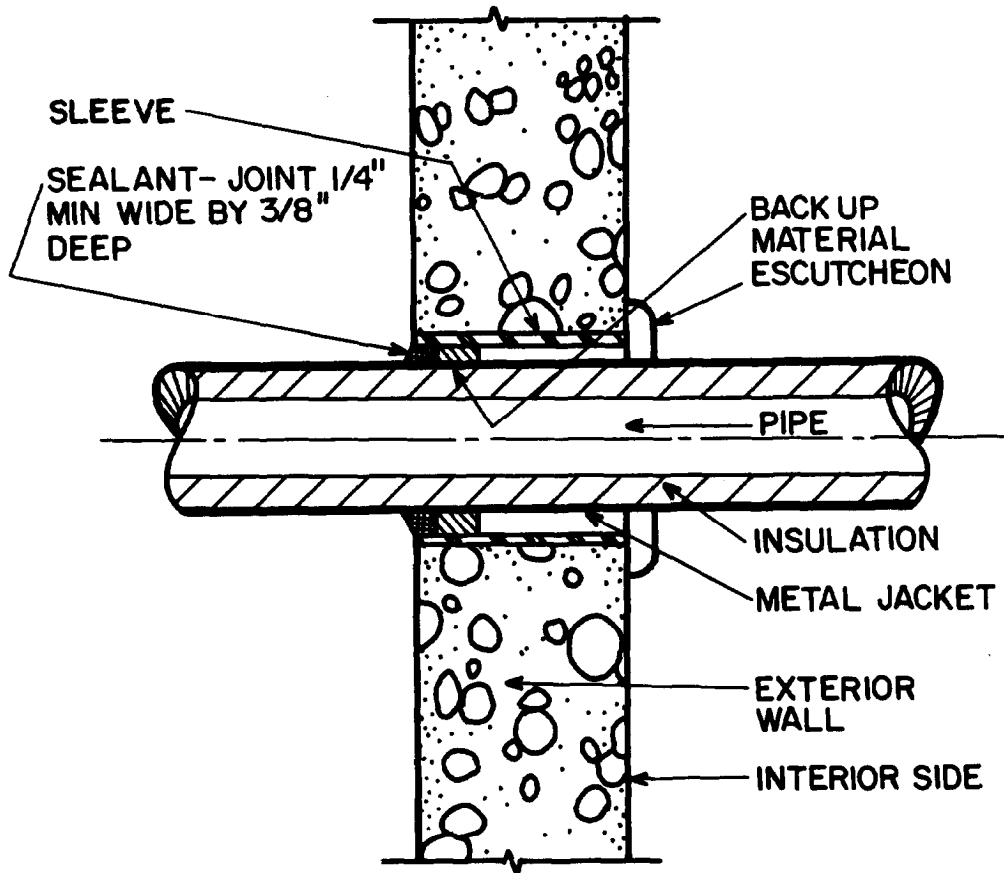


Figure 11. Pipe Sleeve for Insulated Pipe - Above Grade.

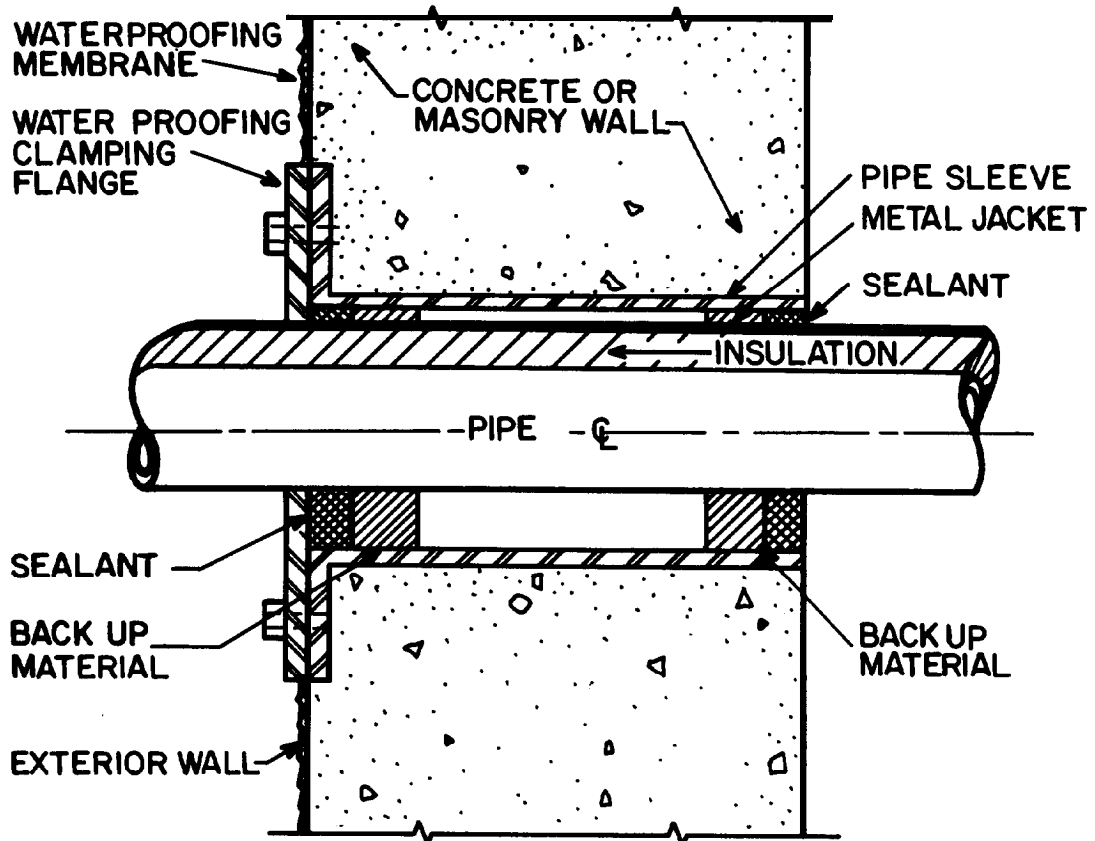


Figure 12. Pipe Skew Through an Outside Wall.

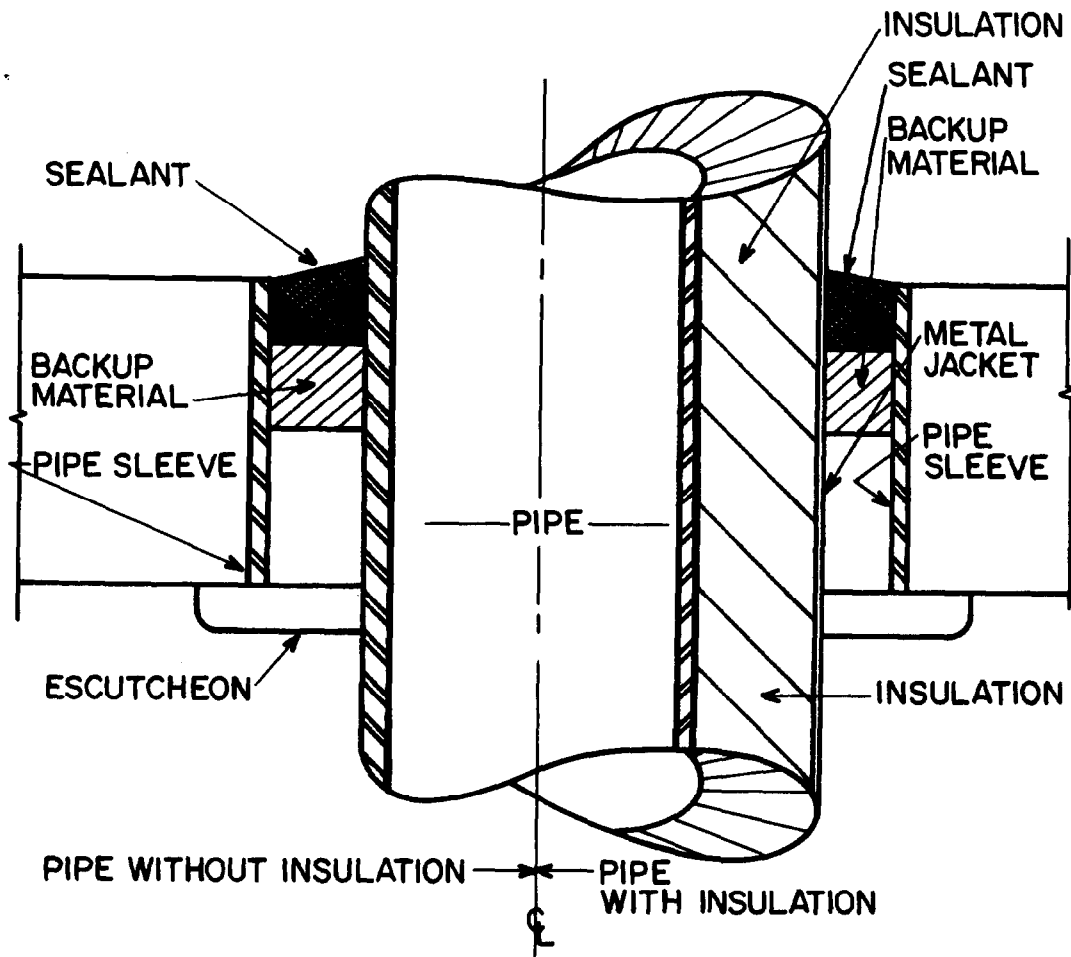


Figure 13. Pipe Sleeve Through Floor.

Table 2. Typical Joints

A. MOVING JOINTS

<u>TYPE OF JOINT</u>	<u>FIGURES</u>
EXPANSION & CONTROL	4, 5, 7, & 9
PIPE & DUCT PENETRATION	10, 11 & 12

SELECT SEALANT FOR MOVING JOINT TO MEET THE FOLLOWING CRITERIA:

<u>TRAFFIC</u>	<u>PAINT OVER</u>	<u>CURE TIME</u>	<u>STANDING WATER</u>	<u>SUGGESTED SEALANTS</u>
NO	NO	DAY	NO	1-COMPONENT SILICONE
NO	NO	HOURS	NO	2-COMPONENT SILICONE
NO	YES	DAY	YES	1-COMPONENT POLYSULFIDE
NO	YES	HOURS	YES	2-COMPONENT POLYSULFIDE
YES	YES	DAY	NO	1-COMPONENT POLYURETHANE
YES	YES	HOURS	NO	2-COMPONENT POLYURETHANE

B. STATIONARY JOINTS NOT SUBJECT TO THERMAL EXPANSION OR OTHER MOTION

<u>TYPE OF JOINT</u>	<u>FIGURES</u>
DOORS & WINDOWS	6
CEILINGTO-WALL	8
PIPE & DUCT PENETRATIONS	10, 11, 12

Any sealant listed in part A above may be used in a stationary joint, subject to restrictions noted.

The following sealants should be used in stationary joints only; these sealants lack the resilience necessary to perform in a moving joint:

<u>TRAFFIC</u>	<u>PAINT OVER</u>	<u>CURE TIME</u>	<u>SUGGESTED SEALANTS</u>
NO	YES	HOURS	ACRYLIC LATEX
NO	YES	NONE	PREFORMED
NO	YES	DAY	OIL & RESIN CAULK

move independently of each other. Stationary joints can be configured as shown in figures 4 and 5, except that a bond-breaker is not needed because there will be no deformation of the sealant (or caulking). In a stationary joint, the backing may be a rigid material.

b. *Moving joints.* Joints that move are generally configured as shown in figures 4 or 5, and in every case the bottom of a moving joint should be protected by a bond-breaker or by a backing

material which can move with the sealant.

c. *Expansion and control joints.* Expansion and control joints should be treated as moving joints, including those control joints that do not penetrate the material but provide a weak place where a crack can develop in the material beneath the joint. A control or expansion joint in tile is shown in figure 9.

d. Table 2 lists typical joints used in construction.

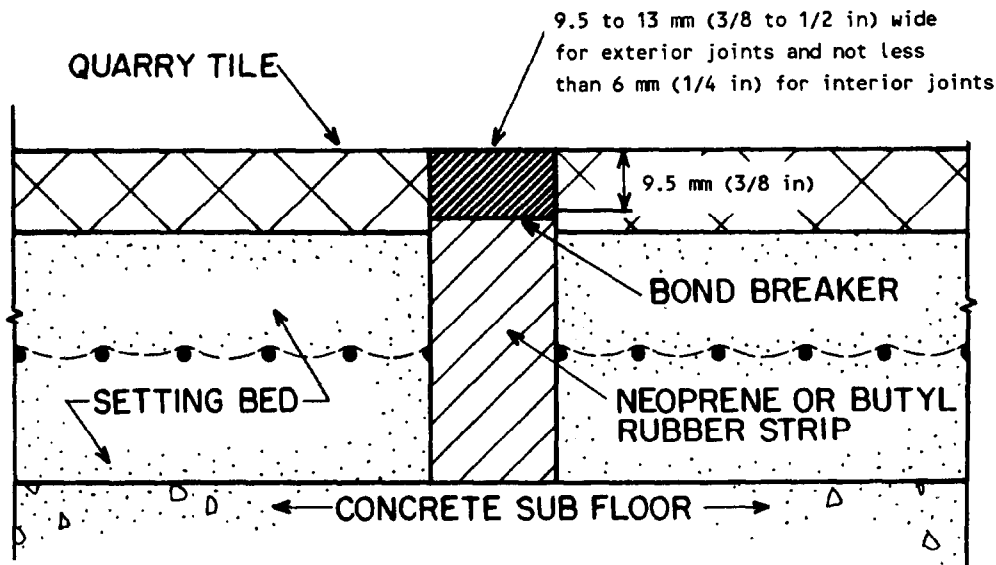


Figure 9. Control or Expansion Joint in Tile.

Table 2. Typical Joints

Joint Type	Traffic	Paint Over	Cure Time	Suggested Sealants	Figures
CONTROL	NO	NO	DAY	1-COMPONENT SILICONE	4,5
CONTROL	NO	YES	DAY	1-COMPONENT POLYSULFIDE	4,5
CONTROL	YES	YES	DAY	1-COMPONENT POLYURETHANE	4,5,7,9
CONTROL	NO	NO	HOURS	2-COMPONENT SILICONE	4,5
CONTROL	NO	YES	HOURS	2-COMPONENT POLYSULFIDE	4,5
CONTROL	YES	YES	HOURS	2-COMPONENT POLYURETHANE	4,5,7,9
DOORS AND WINDOWS	NO	YES	DAY	OIL- & RESIN CAULK	6
	NO	YES	HOURS	2-COMPONENT POLYSULFIDE	6
	YES	YES	HOURS	2-COMPONENT POLYURETHANE	6
CEILING TO WALL	NO	YES	NONE	PREFORMED SEALANT	8

APPENDIX A REFERENCES

Government Publications

Department of Defense

MILK-HDBK-1008 Fire Protection for Facilities, Engineering, Design,
and Construction

Nongovernment Publications

American Society for Testing and Materials (ASTM) 1916 Race Street,
Philadelphia, PA 19103

C 919-84 Standard Practice for Use of Sealants in Acoustical
Applications

C 1193-91 Standard Guide for Use of Joint Sealants

E 1465-92 Guide for Radon Control Options for the Design and
Construction of New Low Rise Residential Build-
ings

*American Society of Heating, Refrigeration and Air-Conditioning Engineers
(ASHRAE)* 1791 Tullie Circle NE, Atlanta GA 30329

1993 Handbook Fundamentals, (I-P or SI Edition)

Underwriters Laboratories (UL) 333 Pfingston Road, Northbrook, IL 60062

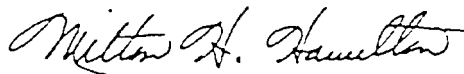
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