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Standard Guide for Use of Joint Sealants¹

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1. Scope

1.1 This guide describes the use of a cold liquid-applied sealant for joint sealing applications. Including joints on buildings and related adjacent areas, such as plazas, decks, and pavements for vehicular or pedestrian use, and types of construction other than highways and airfield pavements and bridges. Information in this guide is primarily applicable to a single and multi-component, cold liquid-applied joint sealant and secondarily to a pre-cured sealant when used with a properly prepared joint opening and substrate surfaces.

1.2 An elastomeric or non-elastomeric sealant described by this guide should meet the requirements of Specification C 834, C 920, or C 1311.

1.3 This guide does not provide information or guidelines for the use of a sealant in a structural sealant glazing application. Guide C 1401 should be consulted for this information. Additionally, it also does not provide information or guidelines for the use of a sealant in an insulating glass unit edge seal used in a structural sealant glazing application. Guide C 1249 should be consulted for this information.

1.4 Practice C 919 should be consulted for information and guidelines for the use of a sealant in an application where an acoustic joint seal is required.

1.5 This guide also does not provide information relative to the numerous types of sealant that are available nor specific generic sealant properties, such as hardness, tack-free time, or curing process, among others. Guide C 1299 should be consulted for information on generally accepted comparative values for the characteristics and properties of the more common generic types of liquid-applied sealant.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parenthesis are provided for information only.

1.7 The Committee with jurisdiction for this standard is not aware of any comparable standards published by other organizations.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices, and determine the applicability of regulatory limitations prior to use.*

1.9 The committee with jurisdiction over this standard is not aware of any comparable standards published by other organizations.

2. Referenced Documents

2.1 ASTM Standards:²

C 510 Test Method for Staining and Color Change of Single- or Multicomponent Joint Sealants

C 717 Terminology of Building Seals and Sealants

C 719 Test Method for Adhesion and Cohesion of Elastomeric Joint Sealants Under Cyclic Movement (Hockman Cycle)

C 792 Test Method for Effects of Heat Aging on Weight Loss, Cracking, and Chalking of Elastomeric Sealants

C 794 Test Method for Adhesion-in-Peel of Elastomeric Joint Sealants

C 834 Specification for Latex Sealants

C 919 Practice for Use of Sealants in Acoustical Applications

C 920 Specification for Elastomeric Joint Sealants

C 1083 Test Method for Water Absorption of Cellular Elastomeric Gaskets and Sealing Materials

C 1087 Test Method for Determining Compatibility of Liquid-Applied Sealants with Accessories Used in Structural Glazing Systems

¹ This standard is under the jurisdiction of ASTM Committee C24 on Building Seals and Sealants and is the direct responsibility of Subcommittee C24.10 on Specifications, Guides and Practices.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- C 1135 [Test Method for Determining Tensile Adhesion Properties of Structural sealantsSealants](#)
- C 1247 [Test Method for Durability of Sealants Exposed to Continuous Immersion in Liquids](#)
- C 1248 [Test Method for Staining of Porous Substrate by Joint Sealants](#)
- C 1249 [Guide for Secondary Seal for Sealed Insulating Glass Units for Structural Sealant Glazing aApplications](#)
- C 1253 [Test Method for Determining the Outgassing Potential of Sealant backingBacking](#)
- C 1299 [Guide for Use in Selection of Liquid-Applied Sealants](#)
- C 1311 [Specification for Solvent Release Sealants](#)
- C 1330 [Specification for Cylindrical Sealant Backing for Use with Cold Liquid-Applied Sealants](#)
- C 1382 [Guide-Test Method for Determining Tensile Adhesion Properties of Sealants When Used in Exterior Insulation and Finish Systems \(EIFS\) SystemsJoints](#)
- C 1401 [Guide for Structural Sealant Glazing](#)
- C 1442 [Practice for Conducting Tests on Sealants Using Artificial Weathering Apparatus](#)
- C 1472 [Guide for Calculating Movement and Other Effects When Establishing Sealant Joint Width](#)
- D 2203 [Test Method for Staining from Sealants](#)

3. Terminology

3.1 *Definitions*— Refer to Terminology C 717 for definitions of the following terms used in this guide: adhesive failure, bicellular sealant backing, blooming, bond-breaker, bridge sealant joint, butt sealant joint, cell, cellular material, chalk, chalking, chemically curing sealant, closed cell, closed cell material, closed cell sealant backing, cohesive failure, compatibility, compatible materials, compound, control joint, creep, cure, cured, dirt pick-up, durability, durability limit, elastomeric, elongation, expansion joint, fillet sealant joint, gasket, hydrostatic pressure, isolation joint, fluid migration, joint filler, laitance, latex sealant, modulus, non-sag sealant, open cell, open cell material, open cell outgassing, premature deterioration, primer, reversion, rundown, seal, sealant, sealant backing, self-leveling sealant, service life, shelf-life, shrinkage, silicone sealant, skin, solvent release sealant, structural sealant, substrate, tooling, tooling time, weathertight, working life (pot life).

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *pre-cured sealant, n*—a preformed, factory cured, elastomeric material.

4. Significance and Use

4.1 This guide provides information and guidelines for consideration by the designer or applicator of a joint seal. It explains the properties and functions of various materials, such as sealant, sealant backing, and primer, among others; and, procedures such as, substrate cleaning and priming, and installation of the components of a sealed joint. It presents guidelines for the use and application of the various materials, design of a sealant joint for a specific application, and environmental conditions and effects that are known to detrimentally affect a sealant joint. The information and guidelines are also useful for those that supply accessories to the sealant industry and for those that install sealants and accessory materials associated with sealant use.

4.2 In addition to the design and installation data in this guide, consult the sealant manufacturer about applications for its products and their proper use and installation. Considering the range of properties of commercially available sealants, the variety of joint designs possible, and the many conditions of use, the information contained herein is general in nature.

4.3 To assist the user of the guide in locating specific information, a detailed listing of guide numbered sections and their descriptors are included in Appendix X2.

5. General Considerations

5.1 *General*—Proper selection and use of a sealant is fundamental to its ultimate performance, service life, and durability. A sealant joint subjected to movement and other similar performance factors should be designed for the particular application to avoid compromising its performance capability and causing failure (See 15). If not designed for the particular application, failure is a distinct probability. Equally important is the proper selection and use of other materials and products associated with sealant use. These include substrate cleaner, surface conditioner or primer, type of sealant backing material, bond-breaker, and joint filler, among others. The ability of a sealant installation to remain weathertight is critically dependent on proper preparation, continuity, and durability of the substrates to which the sealant will adhere, and compatibility of the sealant with the materials it will contact, including the substrates. The proper application and installation of the various materials and products, following the established joint design criteria, avoids premature deterioration of the sealant joint. For a sealant joint that is difficult or expensive to access (for example, tall buildings and certain roofs) a sealant should be selected that will have excellent environmental weathering characteristics to minimize maintenance. The following sections describe joint design guidelines and the properties and use of a sealant and its associated materials.

5.2 *Durability*—The durability of a sealant and a sealant joint is related to many factors. For example, environmental exposure to solar radiation, ozone, heat-aging, and atmospheric contaminants can lessen sealant durability. Inadequate construction tolerances and improper sealant joint design for movement and other effects can contribute to sealant joint failure, which is usually expressed as adhesive or cohesive failure of the sealant. Inadequate installation (for example, where the sealant profile is inappropriate for movement, where substrates have not been properly cleaned and, if required, primed, and the sealant inadequately tooled, among others) is a common cause of failure. Conditions of exposure and design (where, for example, a sealant joint is

exposed to constant wetting or to pedestrian or other traffic) can lessen sealant and sealant joint durability. The type of sealant, its primary polymer backbone, and the particular sealant formulation can also contribute to lessened durability, especially if a sealant is used in an application, or under conditions of use, not appropriate for it. Frequently, various combinations of environmental exposure and conditions of use occur which can result in lessened durability. For example, depending on sealant type, joint movement combined with heat aging and cold weather exposure or joint movement combined with heat aging and moisture can result in failure. To enhance durability, it is important that the sealant type is matched to the conditions of use and exposure and that the sealant joint is of proper design for those conditions of use and exposure. In any event, eventual replacement of a sealant that has reached its durability limit must be planned for in the initial design and installation to facilitate future remedial work.

5.2.1 Durability Testing—Presently, testing for sealant durability consists of exposing small-scale sealant samples to conditions intended to simulate the effects of movements (as in Practice C 719), and to artificial weathering by actinic radiation, moisture, and heat, without cycling movement, in a laboratory accelerated weathering device according to Practice C 1442. Additionally, environmental exposure at various locations (for example Florida, Arizona, Texas, and certain sites in northern latitudes) is also conducted. Correlation of artificial weathering to environmental exposure is important to assess the relevance of laboratory test results to predicting sealant performance during environmental use (**1, 2**). Laboratory tests to date indicate that at least several thousand hours of artificial weathering exposure is necessary to adequately predict a minimum level of environmental performance. For example, if changes occur five times faster in a laboratory device than under environmental conditions (a typical average acceleration factor for a number of materials), and the desired lifetime of a material is about five years, as much as one year of artificial weathering may be necessary to qualify a material for the application. The latest ASTM weathering standards recommend as a minimum exposure time that necessary to produce a substantial change in the property of interest for the least stable material being evaluated. However, this may not be long enough to qualify a material for the desired application. Environmental performance will vary with latitude. For example, a sealant used in Chicago will perform differently than the same sealant used in Florida for a similar application. Compass orientation also has an effect, with a northerly exposure sealant tending to last longer than a southerly. The incident solar radiation is a primary contributing factor, among others, to lessened durability. Other conditions being equal, the sealant in Chicago will in general perform for a longer time period than the same sealant used in Florida.

5.2.1.1 The latest durability testing programs indicate that artificial weathering performed concurrently with movement of a sealant joint sample seems to more realistically predict sealant and sealant joint environmental performance (**3, 4, 5, 6**). Current ASTM laboratory test methods, that include a durability component, such as C 719, do not provide an adequate prediction of sealant long-term environmental performance and therefore potential sealant and joint durability.

5.2.1.2 Test method C 719 evaluates the movement of a new sealant without the benefit of any aging or weathering and thereby provides data only for an unaged sealant.

5.2.1.3 The user of a sealant should realize that most manufacturers' data sheets report laboratory testing data conducted in an idealized, as-cured state and not in a weathered condition that represents how the sealant will actually appear and perform on a building. Additionally, the performance and other properties reported on many data sheets does not include movement during the curing process.

5.2.1.4 Almost all building sealant applications have movement-during-cure. These natural movements during cure almost always decrease the performance capability of a sealant. Therefore, data sheet performance properties, if correct, generally overstate the expected environmental and cyclic movement performance of a sealant. With this in mind, a sealant joint design should always be performed with mitigating design factors included in the design to account for movement-during-cure (See 12.5).

5.3 Adhesion—Obtaining and then maintaining long-term adhesion of a sealant is the primary variable in a successful installation. A sealant manufacturer will determine what is necessary to achieve adequate adhesion to a particular substrate, and if a primer or surface conditioner is necessary, by using laboratory test methods. In some applications, glass, metal or other substrates may have coatings, surface treatments or difficult-to-remove contaminants requiring special cleaning techniques or primers. Due to this surface variability, the substrates should be sampled and tested by the sealant manufacturer from actual production runs of the materials. Specification C 920 requires a sealant to be rated as Use M, A, G, or O. When listed by a sealant manufacturer it indicates that, in general, the sealant has been found to adhere to and is suitable for use with that substrate type. This is not necessarily a guarantee of adhesion. Samples of the actual substrate should always be tested for adhesion before use, since materials and finishes can be variable or products can change with time and formulation from that as previously tested. Consideration should also be given to identifying a sealant which, without the use of primers if possible, will provide adequate adhesion.

5.3.1 Adhesion Testing— Adhesion of a sealant to a substrate surface or another material or component is determined using laboratory Test Methods C 794 and C 719. Adhesion testing by a sealant manufacturer typically will be performed after one day or 7 days of water immersion. For many applications this is not an adequate test exposure to predict long term sealant joint performance. It is the user's responsibility to evaluate the water immersion condition of an adhesion test conducted by the sealant manufacturer and determine if it is applicable to a particular use. If not, the user should obtain appropriate data consistent with the intended application. In general, for most materials, sealant manufacturers have extensive previous adhesion testing experience and can usually indicate if their sealant will or will not adhere to a generic material's surface. Therefore, pre-qualification testing, prior to specifying, is usually not necessary unless the manufacturer does not have relevant data for a particular material or if the adhesion to a generic substrate varies significantly. Careful review of a sealant manufacturer's data sheet is important, since some

only report extension or simple cyclic movement performance not including all the Test Method C 719 parameters and conditions. To monitor for any subsequent surface changes, consideration should be given to evaluating substrate adhesion on the installed substrates at the project site prior to beginning the installation of the sealant and periodically during the installation. Appendix X1 describes project site adhesion testing methods.

5.4 Compatibility—A sealant must be compatible with the materials and surfaces with which it will be in contact. Occasionally, materials that are in close proximity, but not in contact with the sealant, can have an effect on the installed sealant. Incompatibility can cause, as a minimum, a discoloration of the sealant or, at its extreme, sealant deterioration or adhesion loss. Compatibility must never be assumed but always established by a formal program of testing by the sealant manufacturer, since there are no “always compatible” combinations of a sealant with other materials. A sealant should be tested for compatibility with other sealants which it may contact and with materials and finishes it contacts or is in close proximity. Materials and finishes, with time and exposure to the ultraviolet component of sunlight, can exude or release plasticizers or other materials into a sealant, which can cause a sealant to change color or lose adhesion. Also, these accessories can have surface residues or contaminants from manufacturing that can migrate into the sealant. A change of sealant color is evidence of a potentially detrimental chemical reaction, and although adhesion may not be initially lost, the color change could be predictive of a future loss of adhesion. Other sealant characteristics that could also be affected by incompatibility include the ability of a sealant to cure fully, its ultimate strength development, and its aesthetic qualities.

5.4.1 Compatibility Testing—Materials or components that are nearby or touch the sealant should be tested for compatibility using Test Method C 1087. This test is performed in the laboratory with prepared samples of substrate finishes, gaskets, and various accessory materials, among others. Any color change of the sealant after testing, is sufficient evidence to cause additional evaluation for use of the candidate material or finish. This test is usually performed to prequalify a material or component for use. In general, for most materials, sealant manufacturers have extensive previous compatibility testing experience and can usually indicate if their sealant is compatible with a particular material. Therefore, pre-qualification testing, prior to specifying, is usually not necessary unless the manufacturer does not have relevant data for a particular material. An important aspect concerning compatibility is that often a sealant or joint accessory is substituted at the last minute as an “or equal” product. Products are not equal in compatibility unless they are equally tested for compatibility. Therefore, if a sealant or an accessory material is substituted, the new combination should also be tested for compatibility.

5.5 Staining—There are many causes and manifestations of staining that can occur on or within a building’s materials and systems. Some staining mechanisms are related to a sealant while others are not. For example, chemical staining caused by corrosion of ferrous or other metals, chalking of organic finishes and certain forms of efflorescence are not caused by a sealant. Also, natural staining of a building’s surfaces can be a result of normal environmental effects such as rain and snow melt rundown, accumulation of atmospheric pollutants, and other naturally occurring effects. These types of stains usually manifest themselves as rundown on a building’s surfaces. Some sealants can contribute to staining by blooming, fluid migration and resultant rundown of various sealant components on a building’s surfaces. Some inadvertent staining may be caused by applicator error wherein sealant is misapplied on surfaces not intended to receive sealant. The resultant staining, whether or not caused by the sealant, can manifest itself as a surface stain on both nonporous and porous materials or as a penetrated stain within porous materials.

5.6 Substrate Staining—A sealant, depending on formulation and the quality of its components, can cause staining of adjacent substrate surfaces. Staining by a sealant is usually due to fluid migration or rundown (7-11). Both porous and non-porous substrates are susceptible to this staining mechanism. Fluid from a sealant can migrate into the pores of a porous substrate and then migrate to its exposed surface adjacent to the sealant. The fluid can then discolor the substrate surface or become an attractant for environmental pollution or dirt pick-up. This staining has been colloquially referred to as “clouding” due to its visual appearance. Fluid can also migrate through the exposed surface of the sealant and then run down onto adjacent porous or non-porous surfaces and become an attractant for environmental pollution or dirt pick-up. Staining of porous substrates has proven to be difficult if not impossible to completely remove. Removal has usually been most successfully achieved using an appropriate poultice; however, complete and lasting removal of the stain is rarely achieved. Staining of non-porous surfaces can also be difficult to remove. Depending on the material, the type of fluid, and the type of environmental pollution or dirt pick-up, the staining may be easily removed or can not be removed resulting in a permanent stain to the surface. Development of cleaning materials and methods must be a collaborative effort of the sealant manufacturer and the stained material manufacturer.

5.5.1

5.6.1 Stain Testing—Laboratory testing for potential staining of a porous substrate by a sealant can be performed using either Test Method D 2203, C 510, or C 1248. These test methods are typically used prior to sealant installation to test a specific substrate material with a particular sealant. It should be realized that the tests are meant to be predictive based on accelerated laboratory procedures that attempt to duplicate the natural environment. They are not always successful in duplicating the natural environment and in identifying a potential staining combination of sealant and substrate. Environmental testing for staining can also be performed using a mock-up of the particular sealant and substrate exposed to the same conditions as the end use. This procedure is usually lengthy, sometimes taking years before a judgement can be made as to staining potential. The sealant manufacturer should be consulted for advice since they have a history of their products and staining potential with particular substrate materials. Test data from a method such as C 1248 should be evaluated along with the sealant manufacturer’s recommendation and exposure data from older installations.

5.6

5.7 Sealant Color Change—A sealant, in use, can change color. A joint designer should be aware that developing a special color for a particular application might be inappropriate and additionally become a “throw away” cost. The surface color of some sealants can change in as little as a few years depending on local environmental conditions. Color change can be caused by blooming, ultraviolet and visible radiation absorption, chalking, pollutants in the atmosphere, dirt pick-up, cleaning solutions, and adjacent materials, among others (7-9). Blooming is the movement of components in a sealant to its surface where they attract dirt and atmospheric contaminants to the surface of the sealant, changing its apparent color. Ultraviolet and visible radiation absorption from the sun can permanently alter a sealant, depending on the type and quality of pigment and stabilizer ingredients. Colors that seem to be most affected by ultraviolet and visible radiation absorption are generally those created using organic coloring agents. Better color stability is achieved using inorganic colorants. The degree of color change due to this effect is variable depending on the exposure of the sealant (e.g. northerly versus southerly facing) and the environment (southern versus northern latitudes in the same hemisphere). The formation of chalk (a powder) on a sealant surface due to chalking can impart an apparent color change to the sealant’s surface by hiding the color of the sealant. Most powders tend to be whitish in color, although a color other than white can develop. Organic polymer based sealants, as they weather, can be self-cleaning as rain-water can wash away the surface chalk. A sealant can discolor due to the accumulation of atmospheric contaminants or dirt pick-up as the period of environmental exposure increases. Color change caused by blooming, chalking, and the accumulation of atmospheric contaminants or dirt pick-up, can usually be cleaned from the surface of the sealant using cleaning solutions and procedures recommended by the sealant manufacturer. Building facades are normally cleaned on a periodic basis. Cleaning solutions used for other facade materials may have a deleterious affect on the color and other properties of a sealant and should be verified as having no affect by a mock-up test program prior to application. Occasionally, a substrate material that a sealant is adhered to, or another material that it is in incidental contact with, can cause a color change in the sealant through migration of substrate or material components into the body of the sealant.

5.7.1 Color Change Testing—Test Method C 1087 can be used to determine if sealant contact with a material will cause the sealant to discolor or lose adhesion. Test Method C 510 can also be used; however, its value is limited due to the relatively short time period for the test. Further, it would primarily be useful for porous substrates that may be discolored by components of the sealant that migrate into it. Test Method C 792 can be used to assess the chalking potential of a sealant; however, this test also has a relatively short time period for the test. It should be realized that the tests are meant to be predictive based on accelerated laboratory procedures that attempt to duplicate the natural environment. They are not always successful in duplicating the natural environment and in identifying a potential color change combination of sealant and substrate. Accelerated laboratory tests that use a full spectrum of radiation, such as a xenon lamp, are most useful in predicting color change. Environmental testing for color change can also be performed using a mock-up of the particular sealant and substrate exposed to the same conditions as the end use. This procedure is usually lengthy, sometimes taking years before a judgement can be made as to a color change potential. The sealant manufacturer should be consulted for advice since they have a history of their products and color change potential with particular substrate and incidental contact materials. The specifier or user can also confirm performance by observing older installations.

5.7

5.8 Liquid Immersion— Some sealant applications, for instance a water retention structure or a waste water treatment facility, require a sealant that can tolerate extended periods of continuous immersion in water or other liquids (12, 13). Also, certain building joint applications, such as for plazas and other horizontal surfaces, can subject a sealant to intermittent short or long term immersion in rain water or snow melt. Water immersion of a sealant is often associated with an accelerating influence on loss of adhesion of the sealant to a substrate and degradation of properties including sealant reversion. For other than continuous water immersion situations, it is prudent to design joints that are not exposed to prolonged water immersion. These joints typically are under some stress from movement or other effects that, in combination with immersion, can result in a premature loss of adhesion. An important consideration in immersion situations is the development of a constant dead load due to hydrostatic pressure on the sealant and its adhesion to a substrate. For such applications, an adhesion test should include the effect of hydrostatic pressure on the sealant and its adhesion to a substrate, as well as prolonged water exposure described in 5.7.15.8.1. An appropriate practice for a sealant joint subject to immersion is to design the joint profile as a continuous “bath tub plug.” This is a joint with tapered sides or similar design to cause hydrostatic pressure to assist in forming a compression seal, by pushing a sealant against the substrate.

5.7.1

5.8.1 Liquid Immersion Resistance Testing—Test Method C 1247 can be used to assess adhesion of a submerged sealant to a substrate. Water or other liquids can be used with this method to determine sealant performance. However, this method does not test the added influences of a constant stress from hydrostatic pressure or an induced sealant stress from joint movement. For a particular application, this test may not be an accelerated test depending on the temperature of the test liquid used in the application. The C 1247 test temperature is 50 °C (122 °F) and if that is also the application liquid temperature, then the method may not be an accelerated test. Also, most available immersion test data is based on clean water as the liquid. If a particular application has other than clean water as the liquid, the user should have the test performed with the liquid in which the sealant will be immersed.

5-8

5.9 *Environmental Influences:*

5.8.1

5.9.1 *Low Temperature*— A low substrate temperature during installation generally decreases adhesion since the sealant surface wetting characteristic is reduced. Also, a low ambient air temperature, depending on the sealant formulation and polymer backbone, can reduce the extrudability of a sealant and restrict its ability to flow into joint openings, thereby forming voids in the sealant. Frost, both visible and non-visible, or ice may be present on a cold substrate surface inhibiting adhesion. For these reasons, a sealant is more appropriately applied at an ambient air temperature above 4°C (40°F). If application is necessary when there is visible frost or ice on a substrate surface, the frost or ice must be removed by solvent wiping, evaporation of the solvent, and finally a dry wipe. There is a risk of non-visible frost forming when evaporative cooling of a solvent, used to remove visible frost, causes the substrate temperature to fall below the dew point. A simple test, to determine the presence of non-visible frost on a metal surface is to place a hand on the surface. Heat from ones hand will melt the frost, if it exists, and wet the surface. Also, for adhesion, the manufacturer of the sealant should be consulted regarding the extrudability and surface-wetting characteristics of the sealant as applicable to a particular substrate material. A low temperature can be quite detrimental to a cured sealant's performance. A low temperature can retard cure of the sealant. Some sealants become stiff at a low temperature. If there is joint movement at a low temperature, a failure can result due to the reduced movement capability of the sealant and the increased stress generated at the sealant adhesion surface. If a low temperature will be a factor, then knowledge of sealant performance at low temperature is fundamental as well as knowledge of its brittle point (glass transition temperature). It should be realized that the low temperature used in Test Method C 719 is -26°C (-15°F) and may need to be lowered depending on the particular low temperature application.

5.8.2

5.9.2 *High Temperature*— The sealant applicator should be aware that a sealant that is marginal with respect to hot weather sag resistance may present a problem when working on an application that has a solar exposure. A substrate surface, depending on color and thermal mass, can develop a high surface temperature, which can exceed a sealant's high temperature stability level. Such high temperatures can occur on some dark colored surfaces in the summer. Knowledge of a sealant's sustained high temperature stability and the expected in-use substrate surface temperature is fundamental to developing a durable sealant joint. Many organic sealants will start to deteriorate at 70 to 80 °C (158 to 176 °F). A sealant that meets Specification C 920 is tested by method C 639 for its flow (rheological or sag) properties at a temperature of 50 ±2 °C (122 ±3.6 °F). Depending on a particular sealant and application this may not be adequate. Hot weather may also accelerate sealant cure time, resulting in a shortened working life and tooling time, while tack-free time will be reduced and rain resistance accelerated. This is particularly helpful for a water-based sealant, which is usually more susceptible to rain damage within the first few hours after application. A high substrate temperature can increase bubble formation in a sealant from outgassing of a sealant backing and thus must be avoided (See 9.3).

5.8.3

5.9.3 *Moisture*—Sealant installation, in unprotected exterior locations, cannot be performed during or immediately after a rain and should not be performed when there is a threat or knowledge of imminent rainfall. However, rainfall after application usually has no serious effect on most sealants if the sealant has clearly formed a surface skin. Even a sealant with a skin can be affected if there is forceful impingement of water, prolonged flowing of water, or prolonged immersion of a sealant joint. The sealant manufacturer should be consulted for a specific recommendation when confronted with these or similar situations. The moisture level in a porous substrate can also affect sealant adhesion, especially for joints that occur in horizontal surfaces such as plazas.

6. Substrate

6.1 *General*—Sealants have been developed to seal joints between numerous substrate materials, the more common of which are brick and concrete masonry, concrete, various metals, stone, and glass. Substrates are generally classified as either porous or non-porous. Some substrates are generally more difficult to adhere sealant to than others. Surface characteristics vary considerably, and some substrates may not be suitable for achieving a joint seal unless treated either mechanically or chemically, or both. The substrate must be properly prepared in all cases of use. The substrate must be clean, dry, sound, and free of loose particles, contaminants, foreign matter, water-soluble material and frost and ice.

6.2 *Types:*

6.2.1 *Porous*—Materials representative of this type are brick and concrete masonry, concrete, unpainted wood, some building stones, and most cement-based materials. The classification of a material as porous is generally related to its having a pore structure in the body of the material. A water-repellent treatment or coating on a porous substrate may inhibit sealant adhesion. Since these coatings are not always visually apparent, their existence is sometimes unknown until an adhesion failure occurs or testing is performed before installation. These conditions require special consideration and consultation with both the substrate and sealant manufacturers to determine suitable substrate preparation methods and which primer(s), if required, should be used before a sealant is applied. Often, reliability of a selected cleaning and priming method can be predicted only by adhesion testing of a trial application at the project site on project materials. Other problematic conditions are sealant incompatibility with other chemical products on a porous material, such as concrete surface laitance, which provides a weak substrate, and an adhesion-inhibiting form-release agent on a concrete surface. It is therefore essential that these materials be removed from a porous substrate surface. Substrate porosity can also accelerate sealant adhesion loss when the substrate is wetted or immersed. A primer or surface conditioner (See 8) may improve sealant adhesion durability, even if not required for adequate initial adhesion.

6.2.2 *Non-Porous*—Stainless steel, lead-coated copper, and anodized aluminum, factory-applied organic coatings, paints, and glass are examples of materials that are considered non-porous. These materials are non-absorptive. A proprietary treatment or protective coating on a metal surface may inhibit sealant adhesion and should be removed completely. Where a painted or coated metal is the substrate, the adhesion of the paint or coating to the substrate as well as the compatibility and bond of the sealant to the paint or coating is a matter of concern. Also, non-porous materials are often of the type that can't be cut and reshaped at a project site. This becomes a concern when a joint opening, due to workmanship or other considerations, has become smaller than the minimum acceptable width for the joint design. Typically, the joint opening cannot be modified to make a wider joint to permit application of the planned sealant. When this occurs, either a different sealant with greater movement capability should be installed or the joint design should be changed to a fillet or bridge type sealant joint if aesthetically acceptable (See 14.1.4.5 and 14.2).

6.2.3 *EIFS*—An Exterior Insulation and Finish System (EIFS) presents a porous substrate that may be acceptable for sealant adhesion provided certain procedures are followed (14-16). Most manufacturers recommend adhering sealant directly to the base coat and avoiding adhesion to the finish coat which can soften on exposure to moisture and lose adhesion as the sealant extends and exerts a stress on the finish coat. Typically, a sealant that has a low modulus should be used. A low modulus sealant will have a lower stress at the sealant and substrate interface when the joint is in extension. Due to the difficulty that can be encountered in performing remedial work for an EIFS sealant joint, the selected sealant should have very good environmental weathering characteristics so that it will last for the useful lifetime of an EIFS installation. Since an EIFS system is water-based, if it becomes saturated with rainwater or snow melt, the adhesion of a sealant to an EIFS base coat can be lessened. Information on sealant tensile adhesion properties when used with EIFS can be found in Guide C 1382. EIFS can not tolerate grinding or cutting during sealant removal so it is a good candidate for use of a bridge type sealant joint or precured sealant, in a remedial sealant application. This may be helpful since it does not require the removal of all the old or failed sealant but does change the appearance of the joint seal.

7. Cleaner

7.1 *General*—The quality of a cleaning method, cleaning solution, and cleaning cloths, among others, is as important as the quality of a sealant. The surfaces to which a sealant will be applied must be properly cleaned. Any deleterious substances, such as oil, grease, or powdery deposits that may interfere with adhesion, must be removed completely.

7.2 Procedure:

7.2.1 *Porous Substrate*— Grinding, brushing, blowing off with oil-free compressed air, and wiping with cloths are typical procedures that are used to clean a porous substrate. Solvents are not generally used since they tend to dissolve contaminants and then re-deposit them in the pores of the material where they become very difficult to remove. A porous substrate should be free of dust, dirt and any other contaminant that would interfere with sealant adhesion. Concrete-based substrates should have any laitance removed. Laitance is an unsound surface for sealant adhesion. Grinding or brushing should be performed with materials and tools that will not leave deleterious substances (e.g. metal or fibrous particles) detrimental to sealant adhesion.

7.2.2 *Non-Porous Substrate*—Degreasing solvents, such as methyl ethyl ketone (MEK), toluene, xylene, acetone and mineral spirits have been used as cleaners. Many of these solvents are regulated due to their potentially hazardous nature and volatile organic compound (VOC) content. It is necessary to know the environment and safety provisions for a specific application before a particular solvent is selected for evaluation as a cleaner. Some solvents that may be considered appropriate are effective degreasers but can leave a residue film on the cleaned surface, which should be removed. A residue film can be removed using a solution of fifty percent isopropyl alcohol (IPA) and fifty percent water. However, this solution is not an effective degreaser. A two step cleaning method can be used. The first step is a solvent, which is a degreaser followed by the second step, which is a solution of IPA and water to remove any residue film. The sealant applicator should work closely with the sealant manufacturer to develop a suitable cleaning procedure as determined by testing (See 16.4.4). When received at a shop or construction-site, and prior to use, a cleaning agent should have its quality verified. Small quantities of organic and other contaminants, in the shipped cleaning agent, can adversely affect adhesion of the sealant to a cleaned surface. Additionally, containers for storage and use of a cleaning agent must be clean. Cleaning cloths, rags, or paper wipes must also be free of contaminants and be lint free. Some commercially available disposable cloths or wipes contain additives, such as lanolin to improve softness. These additives will contaminate a surface and affect sealant adhesion.

8. Primer

8.1 *General*—The purpose of a primer is to improve the adhesion of a sealant to a substrate. A primer functions in three ways. First, it changes the chemical characteristics of the substrate surface to render it more suitable for the sealant. Secondly, it stabilizes the substrate surface by filling pores and strengthening weak areas. Lastly, it reduces capillary pressure of moisture through a substrate surface. Some sealants require the use of a primer on all substrates, while some require them on only certain substrates or on none at all. The need for a primer and the adhesion results achieved can vary, not only with the substrate type, but also with the quality of the substrate. No consistent recommendation can be made regarding which substrate surfaces will require priming. Priming is dependent on the sealant manufacturer, sealant type and formulation, substrate, and, in some instances, use and exposure. With some sealants different primers are required for different substrates. This poses a difficult application problem when two different substrates require two different primers on opposite sides of a joint opening. This should be considered when selecting a sealant. Many sealants require a primer for maximum adhesion to concrete and masonry surfaces. To determine if a primer is

required for a specific application, perform adhesion testing as described in 5.3.1.

8.2 *Materials*—A primer or surface conditioner is a specially formulated liquid developed and recommended by the manufacturer of the sealant. A primer, if required, is normally furnished by the sealant manufacturer and is typically formulated for use only with the same manufacturer's sealant. A primer from one sealant manufacturer should never be used with a sealant from another manufacturer unless it has been tested and approved by the manufacturer of the sealant with which it will be used. Some sealant manufacturers have several primers that are used with their different sealants and with different substrates. Selection of a primer for use with a particular sealant and substrate or substrate finish should be the responsibility of the sealant manufacturer based on data obtained from testing performed on submitted substrate finish samples. As for a sealant, a primer must be stored and applied in accordance with the manufacturer's recommendations and used within its stated shelf-life.

8.2.1 *Color*—It is not uncommon for a primer to be clear as well as various shades of pink, red or yellow. The sealant manufacturer should establish an acceptable primer color, and its range. A primer that does not conform should be discarded and replaced. A primer of questionable color or one that is different from the manufacturer's description should never be used.

8.2.2 *Clarity*—Clarity is often confused with color. A clear primer is free of particulate matter or settling and is not cloudy. A primer may be water-white or various colors, such as, pink, red, yellow or some other color, and also clear. The sealant manufacturer should establish the need for and degree of clarity, and the acceptability of solid material in a primer. A primer of questionable clarity or one that is different from the manufacturer's description should never be used.

8.3 *Application:*

8.3.1 *General*—Dipping a cloth or brush in a container of primer may result in inadvertent contamination of the primer. Frequently, an applicator will use a squeeze bottle to pour primer on a cloth or brush (See 16.4.6.1). The length of time a primer must cure before the sealant can be applied should be as recommended by the sealant manufacturer. With some primers, a sealant can be applied almost immediately, while with others a lengthy cure time is required. The latter, when complied with, can cause construction scheduling difficulties for the sealant installer for some applications and should be taken into consideration.

8.3.2 *Porous Substrate*—Often a sealant will require a primer for adequate adhesion to porous substrate surfaces, especially concrete and masonry. A primer is applied to a properly cleaned and prepared porous substrate usually using a brush.

8.3.3 *Non-Porous Substrate*—Depending on the surface, a sealant may require a primer for adequate adhesion to non-porous substrates, especially some metals and organic factory-applied coatings or paint films. A primer on a non-porous surface will generally function by changing the chemical characteristics of the substrate surface to render it more suitable for adhesion of a sealant. A primer is typically applied to a properly cleaned and prepared non-porous substrate using a clean, lint-free, uncolored cloth.

9. Sealant Backing

9.1 *General*—A proper joint design will require the selection and use of sealant backing to ensure anticipated performance and a weather tight joint. Sealant backing should meet the requirements of Specification C 1330. Some non-absorptive sealant backings may act as a secondary barrier in the event of sealant failure (See 9.5.3). It is not expected that the secondary barrier can accomplish this intent completely, or the sealant would not be required. For an application where the degree of water absorbency of a sealant backing is a concern, the backing can be evaluated using Test Method C 1083. Sealant backing and sealant compatibility can be verified by using Test Method C 1087 (See 5.4.1). If the sealant backing is to be used in a joint that will experience movement, then the sealant backing should not cause or contribute to a three-side adhesion condition that would restrict movement of the back of the sealant joint between substrates. Materials that are commonly used for sealant backing include polyurethane, polyethylene, and polyolefin foams. These materials are fabricated or extruded into sealant backing that can have an internal cellular structure that is composed of open-cell material, closed-cell material, or a combination of both. The use of sealant backing to which the sealant will not adhere, or that is so soft as to not restrict sealant movement, may preclude the need for a bond breaker. Some sealant backing may be incompatible with the substrate and sealant and cause stains on either or both. Materials impregnated with oil, bitumen, non-curing polymers, and similar materials should not be used as sealant backing. Some sealant backing may be factory-coated with a suitable material that will provide a barrier to staining. To confirm suitability, the barrier coating should be acceptable to both the sealant and sealant backing manufacturers. When required, a bond breaker may also be capable of performing the function of a barrier against staining of the sealant.

9.2 *Function:*

9.2.1 *Normal*—A sealant backing for a building joint application can have three primary purposes. First, it is used to control the depth and shape of the sealant in the joint opening. Secondly, it assists in attaining full wetting of the substrate when the sealant is tooled. Lastly, depending on type, it allows movement of the backside of the sealant between substrates. A sealant backing should be capable of resisting permanent deformation before and during sealant application. A sealant backing for this application is a flexible closed-cell or open-cell plastic foam, closed-cell or sponge rubber rod or other appropriate shape that is compatible with the sealant. The sealant should be applied immediately after sealant backing placement to prevent water absorption from rain or condensation. Due to the ease of compressibility of open-cell foam sealant backing, this type of sealant backing can be used in varying joint widths provided that adequate compression of the backing is maintained.

9.2.2 *Temporary Joint Seal*—Sealant backing can serve as a temporary joint seal for weather protection or as a secondary barrier behind the prime sealant barrier, or both. As a temporary seal, an elastomeric gasket with low compression set, such as closed-cell foam or rubber, should be selected for building joint applications (walls). A sealant backing for this application may be compatible

elastomeric tubing or rod of such materials as neoprene, butyl, or EPDM. These may be applied immediately as a temporary seal until the sealant is applied, after which they serve to a limited degree as a secondary water barrier. As with closed-cell sealant backing, these materials should be non-absorbent to water and gas and not blow or emit gas upon mild heating or rupturing, since this can cause bubbling of the sealant. In addition, this sealant backing should have the ability to remain resilient at temperatures as low as -26°C (-15°F) and have low compression set.

9.3 Material:

9.3.1 *Open Cell Foam*— An open-cell, sponge-type material such as urethane foam can be used. This material may be satisfactory for an application, provided its water absorption characteristics are recognized. It should not be used where water absorption by the sealant backing may be detrimental to sealant performance, such as for a horizontal joint or where condensation or infiltration of water can occur behind the backing in a vertical joint. An open-cell sealant backing is normally made from a polyurethane material, which is fabricated into various size cylindrical, rectangular, or other shapes that do not have a surface skin. By not having a surface skin the risk of outgassing is avoided. Due to its open cell structure this sealant backing has a low density and is easily compressible into place. However, the open cell structure can wick and retain water that may infiltrate behind the sealant joint or through other system deficiencies. The use of an open cell sealant backing should be carefully evaluated so that the possibility of a water-saturated sealant backing in direct contact with a sealant is precluded, or where condensation or infiltration can occur behind the sealant backing in a vertical joint, particularly before the sealant cures. Open cell sealant backing that is uncompressed should have a width approximately 40 to 50 percent greater than the joint width. This will ensure adequate compression when in place, so that it will not fall out of the joint before sealant application or be displaced deeper into the joint opening when the sealant is tooled against it. An open cell sealant backing material will allow a sealant that cures by exposure to atmospheric moisture or air to cure from the interior or unexposed sealant face as well as its exposed face, thereby accelerating sealant cure. For some applications, where movement during cure is expected, an open cell sealant backing material can be beneficial to accelerating sealant cure and minimizing sealant exposure to movement-during cure.

9.3.2 *Closed Cell Foam*— A closed-cell foam sealant backing is non-absorbent to liquid water and gas and should not emit gas upon mild heating as this can cause bubbling of the sealant. Generally, this sealant backing material is used where the joint opening width is constant with little variation. A closed cell sealant backing is usually made from a polyethylene material, but also from neoprene, butyl or EPDM and combinations thereof. It is extruded usually into various size cylindrical or sheet shapes that have a surface skin. Due to its closed cell structure this sealant backing has a low density and is less easily compressible into place than an open cell sealant backing. However, the closed cell structure tends to not wick and retain water that may infiltrate behind the sealant joint or through other system deficiencies. However, if proper workmanship is not employed during installation, the surface skin of the backing can be punctured and the backing can out-gas into an uncured sealant producing voids and other defects in the cured sealant. This condition can result in water infiltration and compromise the ability of the sealant to accommodate movement. Test Method C 1253 can test sealant backing for out-gassing potential; however, it tests the outgassing potential of a purposely punctured sealant backing. A condition that this method will not identify is a closed cell sealant backing that has a thin skin that following installation subsequently ruptures due to environmental conditions. Caution should be exercised when installing this sealant backing to avoid puncturing it or causing excessive compression. Closed cell sealant backing that is uncompressed should have a width approximately 25 to 33 percent greater than the joint width. This will ensure adequate compression when in place, so that it will not fall out of the joint before sealant application or be displaced deeper into the joint opening when the sealant is tooled against it.

9.3.3 *Bicellular Foam*— This sealant backing is normally made from a polyolefin or polyethylene material which is extruded typically into various size cylindrical shapes that have a surface skin. It has an open cell structure with a surface skin. Due to its surface skin, it has the water absorption characteristics primarily of a closed cell sealant backing; however, the cut ends can wick and retain water. Due to its combination of open and closed cell core, if the surface skin is punctured this backing will not out-gas into an uncured sealant. However, the skin can wrinkle or fold over when installing the sealant backing into a joint opening if it is over sized for the opening or installed by pressing inward on one side of the sealant backing. Folding over of the bicellular sealant backing will result in a sealant profile that may not be conducive for optimum movement performance. It is useful for textured or rough substrate surfaces like some exposed aggregate precast concrete, where skin puncturing is likely.

9.3.4 *Others*—Some joint applications may require use of an elastomeric material, such as butyl, EPDM, neoprene, or other polymers fabricated into an appropriate shape. These materials can be formulated as a closed-cell, sponge or dense rubber gasket. The gasket may then function as sealant backing. The performance properties of these other materials are usually matched to a specific application. For example, in pedestrian walkways, the sealant backing may have to be a high-density material to assist in resisting the impact of a high heel shoe on the sealant surface. Use of these materials is dependent upon appropriate compatibility testing of a particular gasket with the proposed sealant (See 5.4.1). Additionally, a bond breaker tape may be required to separate the gasket from the sealant and prevent three-side adhesion from developing.

9.4 Shape and Form:

9.4.1 *Round*—This shape is the most commonly used for butt type sealant joints. It creates a concave inboard face on the sealant. The various types of sealant backing materials are produced in several diameters for application in a variety of joint opening widths.

9.4.2 *Rectilinear*— Some sealant applications may require a square or rectangular shape sealant backing. As an example, a

horizontal expansion joint in a masonry wall may require this shape to appropriately accommodate wall flashing and sealant (17). A sealant joint that is wide and shallow will often use this shape. To accommodate installation, a pressure sensitive adhesive and release paper can be applied to one face.

9.4.3 *Triangular*—A fillet type sealant joint is most effective if a triangular shaped sealant backing is used at the root of the joint (18). To accommodate installation, a pressure sensitive adhesive and release paper can be applied to one face. Triangular sealant backing can be fabricated from open cell polyurethane or closed cell polyethylene foam. Some manufacturers provide quarter-round sealant backing in lieu of triangular.

9.5 *Application:*

9.5.1 *Vertically Oriented Surface* —A surface that is sloped from vertical no more than 15 degrees is generally considered as vertical. One that is sloped more than 15 degrees should be considered as a horizontal surface relative to choice and use of sealant backing (See 9.5.2). Open cell, closed cell, and bicellular sealant backing can be used for a joint in a vertical surface. Choice of material, and its cellular structure, is dependent on a particular application. Water absorption characteristics of a sealant backing may be a deciding factor. Water saturated sealant backing has been identified as a cause of sealant adhesion loss and, in some cases deterioration of a sealant, when in prolonged contact with it.

9.5.2 *Horizontal Surface*—Sealant backing for joints in floors, pavements, sidewalks, plazas, patios, and other light traffic areas is generally made from extruded closed cell, high density foam, resin impregnated fiberboard, or elastomeric tubing or rods. The sealant backing material should have at least the following properties. It should remain resilient to temperatures as low as -26°C (-15°F); should exhibit good compression recovery; should not out-gas, caused by heating or rupturing, resulting in the formation of voids in the sealant; and should not absorb water. In addition, it should be capable of providing support for the sealant in traffic areas. A sealant backing can support the sealant in a narrow horizontal joint seal subject to pedestrian or vehicular traffic. For a joint more than 50 mm (2 in) wide, a metal plate with a bond breaker is normally used under the sealant to support it, especially when the sealant is used for vehicular traffic (See Fig. 1). Sealant backing and joint filler should not exude liquids under compression, as this could exert sufficient hydraulic pressure to cause sealant failure by forcing the sealant from the joint opening. Various combinations of sealant backing and joint filler are often used to satisfy the several requirements of a horizontal joint seal. For example, premolded joint filler may be used to form a joint opening in concrete. At sealant installation time, the recess above the joint filler may be wet and contaminated or the joint filler may not be compressed against the substrates, due to shrinkage of concrete or thermal movement of the joint opening, permitting loss of sealant if a self-leveling type is used. The problem may be resolved by allowing a greater recess above the premolded joint filler, or by using a joint filler with a removable strip. The strip is removed, replacing it with an additional sealant backing under compression, across the joint opening width, and to the proper depth, just prior to application of the sealant (See 14.1.5.3 and Fig. 1).

9.5.3 *Temporary Joint Seal*—Sealant backing can function as a temporary joint seal for weather protection when conditions are unsuitable for immediate sealant application. As a temporary joint seal, it is subject to weathering, and normally should be replaced prior to sealant application with a new permanent sealant backing. In some cases, the temporary sealant backing may be suitable for use as a permanent sealant backing. The following conditions, however, would render it unsuitable and necessitate replacement with new material; if it becomes wet; if it becomes dirty or otherwise contaminated; if it takes a compression set and will not remain in place under tooling pressure; if its surface has been damaged or ruptured or punctured during the cleaning operation prior to sealant application. If the intent is to use the temporary sealant backing as a permanent sealant backing, and there is a question as to its suitability, the sealant manufacturer should be consulted for a recommendation.

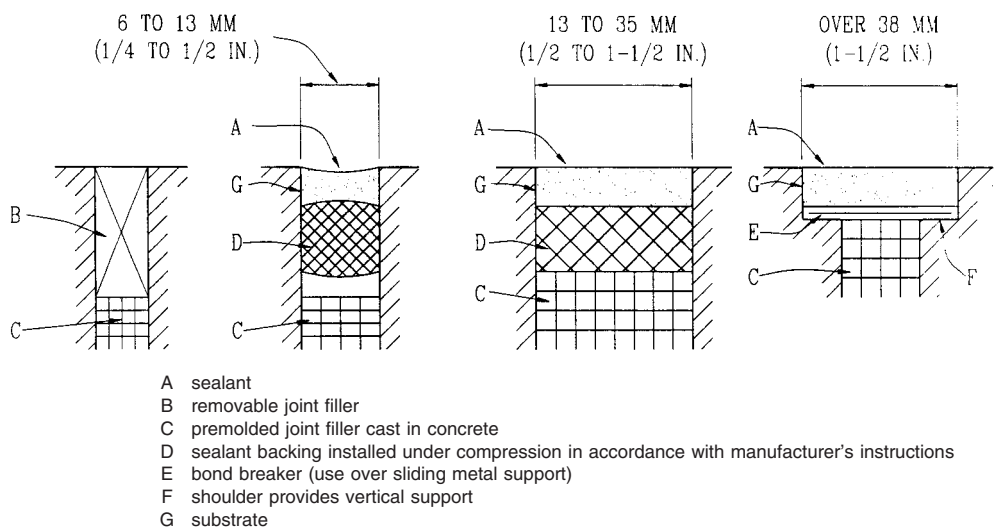


FIG. 1 Use of Sealant Backing and Joint-Fillers in Horizontal Applications

10. Joint Filler

10.1 *General*—Use of a joint filler is frequently encountered in concrete and masonry construction to form, for example, an expansion, control, or isolation joint. Frequently, the joint is deeper than the thickness that results from the sum of the sealant depth and its (usually round) sealant backing. The remaining joint depth is occupied with a permanent joint filler. Materials typically used for the joint filler include closed-cell polyethylene for masonry joints and compressible asphalt impregnated cane fiber for concrete joints subject to traffic. These materials are fabricated into the desired shape, usually rectilinear.

10.2 *Function*—The joint filler can provide additional support for the sealant and its sealant backing when a joint occurs in a horizontal surface subject to traffic. Additionally, in masonry wall construction, it can be installed as the masonry is constructed to preclude mortar droppings from occupying the joint opening. Mortar droppings in a joint opening are incompressible and will prevent a moving joint from properly closing due to thermal or other movements. The joint filler also needs to be compressible enough to avoid restricting joint movement.

11. Bond Breaker

11.1 *General*—A bond breaker should be used to prevent adhesion of a sealant to any surface or material on which adhesion would be detrimental to the performance of the sealant (See Fig. 2). A bond breaker is normally a self-adhesive, pressure sensitive tape, usually made from a TFE-fluorocarbon or polyethylene material, to which a sealant will generally not adhere. The use of duct tape as a bond breaker material is unacceptable. A material impregnated with oil, bitumen, a non-curing polymer, or similar deleterious material should also not be used as a bond breaker. A bond breaker has very low or no adhesion to a sealant thereby avoiding a three-side adhesion condition. Liquid-applied bond breaker is not recommended due to the difficulty of installing it on the intended surface without contaminating the sealant adhesion surface. A bond breaker should be applied to the bottom of a joint containing a rigid, non-flexible sealant backing material or to a raked mortar joint to preclude the possibility of the sealant adhering to these materials and forming detrimental three-side adhesion where movement will occur. A bond breaker is not required to prevent a sealant from adhering to a soft, flexible, open cell sealant backing material that would not significantly restrict the freedom of movement of a sealant. Typically, they are also used where dimensional constraints preclude the use of a conventional sealant backing. Frequently, in remedial sealant work a bridge type sealant joint is required, wherein a bond breaker tape is used to separate an old sealant from the new and to permit the designed movement capability of the new sealant (19).

11.2 *Compatibility and Adhesion Testing*—When bond breaker tape is required for an application, its compatibility (See 5.4.1) and lack of adhesion with a sealant should be confirmed by testing. Instances have occurred, wherein a newly developed sealant formulation has had detrimental adhesion to a previously acceptable bond breaker material. Sealant manufacturers are continually

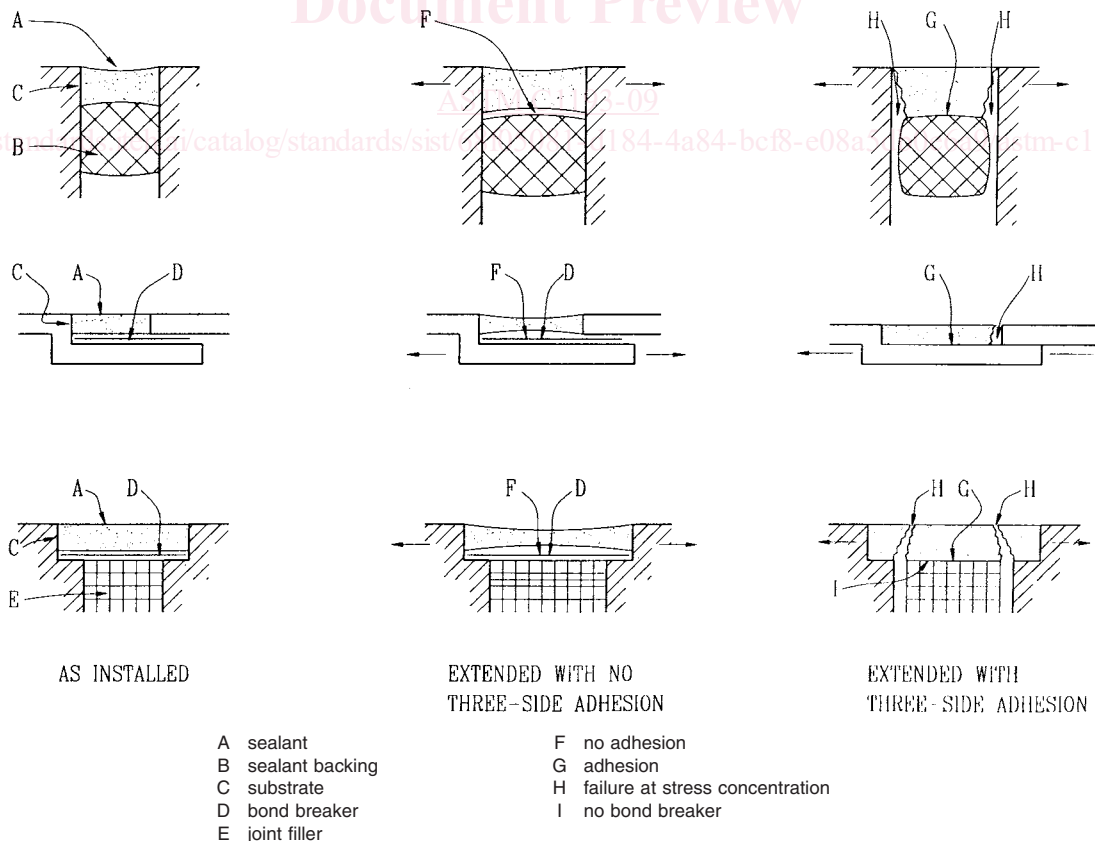


FIG. 2 Sealant Joint Configurations Experiencing Movement and Illustrating Effect of Three-Side Adhesion