Can Duct Tape Take the Heat?

by Max Sherman and Iain Walker

Popular culture abounds with uses for duct tape: duct tape calendars, books like 101 Uses for Duct Tape, *and more. But lab experiments have finally proved that duct tape, as it is generally used, should not be used to seal ducts.*

Most duct leakage could be prevented with proper duct sealing. But field examinations often find seals failing over time. To provide lab data about which sealants and tapes last, and which are likely to fail, we are conducting ongoing accelerated testing at Lawrence Berkeley National Laboratory (LBNL).

The major conclusion we can draw so far is that one can use anything but duct tape—if we define duct tape as fabric-backed tape with rubber adhesive—to seal ducts. Under challenging (but realistic) conditions, duct tapes fail. Other kinds of tape and other sealant methods have good longevity when installed properly (see "So Many Sealants, So Many Failures"). The tests have also shown that tapes do not have to be strong to have good longevity, and that none of the various ratings, including those from Underwriters' Laboratories (UL), addresses sealant longevity in realistic conditions.

Durability Is the Key

Today, taping with duct tape is the most common method of sealing ducts. Field crews dislike mastics because they tend to be messy. Foil tapes are used on ductboard, but duct tape is most popular on the most common duct materials—flex duct and metal. Each sealant

has its advantages and disadvantages, but with reasonably careful application, any of them can seal well—initially.

Longevity is another story. Today, houses are said to be designed to last 30 years. Flex duct systems are often rated for a 15-year life. Duct seals ought to last at least as long. But it appears that the physical properties of some of the sealants may cause seals to fail within just a few years.

While some sealants are UL rated, no UL rating addresses longevity (see "Standards for Sealants"). If people choosing duct sealants had relative ratings of longevity, they could make a more informed decision.

IAIN WALKER

Lawrence Berkeley National Lab has now tested over a dozen types of duct tape. There are several qualities—Economy, Utility, General Purpose, Contractors, Industrial, Professional, Premium and even Nuclear. However, accelerated testing shows that fabric-backed tape with rubber adhesive, on its own, tends to fall off, as shown here.

So Many Sealants, So Many Failures

Duct tape is cloth backed and has a rubber-based adhesive. It comes in wide variety of grades with different tensile strengths. The classic duct tape is gray, but it is available in many colors.

Packing tape has a thin, typically clear, polyester backing and an acrylic adhesive. Its tensile strength is usually low unless it is reinforced with fiber. Packing tape is often used on factory-assembled duct systems. There are many kinds of tape that might be called packing tape, but we use the term to mean only those tapes which are intended for use on ducts. Most carton sealing and strapping tapes are not intended for use on ducts.

Foil tape has foil backing and an acrylic or rubber adhesive. Foil tapes are often used on rigid duct systems such as ductboard.

Butyl tape has foil backing also, but it uses a thick (15- to 50-mil) butyl adhesive to allow it to conform to more irregular shapes.

Mastic is a gooey adhesive that is applied wet. It fills gaps and dries to a soft solid. Mastics may or may not contain reinforcing fibers, and they may be used with reinforcing mesh tape.

Aerosol sealant is a sticky vinyl polymer that is applied to the leaks internally. It is pumped through the duct system, where it spans leaks and dries (see "Not Your Daddy's Duct Sealing Method," Jan/Feb '98, p. 44).

All of the products we have tested were intended for use on ducts, and none had a rated temperature below 200°F.

Three Test Rigs

We developed three test procedures—baking, cycling, and aging—to stress standard duct joints and their sealants in different environmental conditions. The baking test uses just a simple oven. The cycling apparatus was funded over three years ago by the U.S. Environmental Protection Agency to measure the longevity of aerosol duct sealant under accelerated conditions. The aging apparatus was built last year with funding from the California Institute for Energy Efficiency. In these testing rigs, we periodically measure duct leakage. We declare that a sealant has failed when it leaks more than 10% of the air that the joint leaked before being sealed. These tests measure the sealant's endurance in the face of exacting environments, but they do not address installation issues.

The baking test is the simplest. We build a metal-to-metal stepped transition finger joint of standard 4-inch sheet metal duct, and support the duct with independent mechanical supports. This is one of the hardest joints to seal. Some standards require a clamp over duct tape at flex-to-collar connections, but there is no way to apply a clamp over the tape or sealant at a stepped transition, such as the duct-to-plenum joint. We apply sealant to the joint, following the sealant manufacturer's instructions, if applicable. We then place the duct section in an oven set to the temperature of a hot attic or heating system supply air, in the range of 140°F–180°F. Temperatures are kept below 200°F because some of the tapes are rated to that temperature. Duct leakage is measured before baking and at various intervals during baking. When testing the leakage, we also look at the sealant and note obvious failures. The sections are baked as long as 4 months.

In the cycling test, we add temperature and pressure changes. We blow hot and ambient air through the duct at pressures between ambient air pressure and 200 Pascals (Pa) to simulate HVAC cycling. This test has its limitations. Cycles take a long time—20 minutes—due to the need to warm up and cool down the duct. And the cycling apparatus cannot subject the test sample to the cold temperatures that might be expected in the winter or even in air conditioning supply ducts.

Only the aerosol sealant has been put through the cycling test. A few aerosol-sealed leaks were sealed over two years ago and have cycled between hot and ambient air every 20 minutes ever since. There has been no significant change in duct tightness.

The aging test was designed to overcome the limitations of the cycling apparatus, and may be a useful proto-

Standards for Sealants

Underwriters' Laboratories (UL) publishes several standards that relate to duct tape, the most important of which is UL 181.It deals with ducts in general, with UL 181A covering field-assembled duct-board. and the three-year-old UL 181B covering flex duct systems. East standard includes test procedures for sealants. Duct tapes and packing tapes that pass UL 181B are labeled "UL 181B-FX." Mastics can pass 181A or B, and are labeled "UL 181A-M" or "UL 181B-M." Foil tapes are designated with a P.

Most tapes that are labeled 181B-FX are duct tapes. Other 181B products are just coming onto the market

UL 181A and 181B appear to do a good job of testing for safety, tensile strength, and initial adhesion. However, they may not do a good job of rating how well sealants seal typical duct leaks or how well they stay sealed under normal conditions.

We found that there is no correlation between sealant longevity and UL listing. Among duct tapes, those that were UL 181B–rated did perform better. Most of the duct tape samples failed within a week in the aging test, but two UL-rated samples and one that was not UL-rated held out for over a month. However, even the UL-rated duct tapes performed much worse than any other sealant.

This lack of correlation should not be surprising. Many of the components of the UL testing address strength and fire safety issues, and neither of these figure in our testing. In fact, some sealants with good longevity, like butyl tape, may have difficulty passing UL 181B. Many tapes, including all the duct tapes we have tested, are UL 723–listed for fire safety.

Unrealistic Test

Although UL tests primarily for safety, one might assume that the tests would also determine which tapes fulfill their primary task of sealing leaks. However, UL tests are limited by some unrealistic conditions:

- In 181B, duct tapes have a clamp on the joint.
- In the shear adhesion test, the tape has no load for 60 days at 150°F (66°C), and is then tested at 73°F (23°C) for 24 hours. Even then, the tape may come away from the duct by ⅛ inch. At that rate, it can come off in as little as two days and still pass.
- The high temperature test cooks the tape for 60 days at 212°F (100°C), but the tape is evaluated by visual inspection only, without testing adhesion.
- The mastic freeze-thaw test is done with the mastic still in its container, unless the container says to prevent freezing.
- The surfaces to which the tape or mastic are applied are all clean (our rig shares this limitation).
- There is no cycling of temperature or pressure to adhesion tests in 181B. 181A has pressure cycling at fixed temperatures of 165°F (74°C), 90°F (32°C), and 0°F (–18°C), but no temperature cycling.

Who Uses Clamps?

One of the biggest differences between the UL test and our longevity test is that for fabric duct tape testing, UL requires a clamp on the joint. To encourage clamping in practice, UL requires that for a duct system to be UL-approved, it has to have clamps on the joint, and manufacturers of UL-listed flex duct must include the need for clamps in their instructions. We have observed that taped joints of flex duct lining may sometimes be held in place by strapping, but we have never seen clamping on the duct-to-plenum type of joint that we tested. Furthermore, when we purchased the fabric tapes, we did not receive instructions or guidelines to do such clamping. Thus, our joints were tested under different conditions than those in UL tests, but our conditions better represent actual construction.

Undoubtedly, clamping would have improved the performance of the UL 181B-FX tapes. It would also have improved the performance of the unrated tapes. However, other sealants can perform acceptably without clamping, and the difficulty and time-intensiveness of clamping makes it unlikely to become prevalent.

UL Still Useful

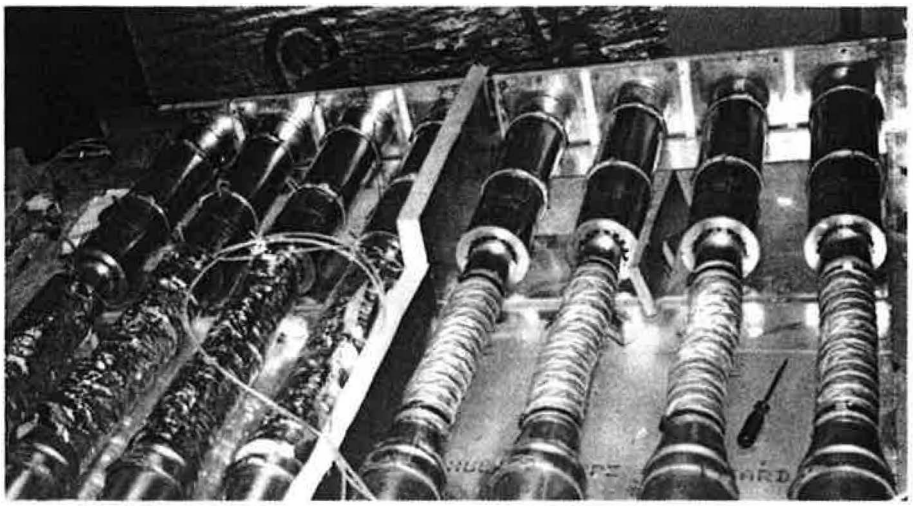
From the sealant longevity perspective, we would not give UL-rated tapes any preference, but other issues may make UL-rated tapes desirable. And local building codes, if they reference the Southern Building Code or the Standard Mechanical Code, require them.

type for conducting standardized tests on duct sealant longevity. The testing rig has a hot-air source and a cold-air source (see Figure 1). Duct sections in the rig have hot air running through them for five minutes, followed by cold air for five minutes. We have tested 19 tapes and sealants in the aging device.

A wide range of products claim to be suitable for duct sealing, but there is often little in the specs or product literature to differentiate them. For example, one major manufacturer lists 16 different duct tapes, available in a range of colors, and 8 foil tapes. Some have product codes printed on the tape, some have codes printed on the hub, and some have no product code on them. All the duct tapes are rated by UL Standard 723, "Test for Surface Burning Characteristics of Building Materials," but only some of the metal foil ones are so rated. Some tapes are labeled as "Code Approved" by BOCA, but one

tape with nearly the same characteristics as the "Code Approved" ones does not indicate that it is "Code Approved."

All the products we tested all sold for use on HVAC ducts. Several companies have recently come out with UL 181B-FX tapes (see definitions in "Standards for Sealants"), which are UL-approved for use on flex duct systems when installed with metal clamps over the tape. Generally, these are not yet listed in product catalogs. While we have not investigated mastics as thoroughly as tapes, there seem to be fewer grades of mastic. Few mastics are currently UL 181B approved, although many are approved by UL 181A. This situation may change in the future.



IAIN WALKER

The accelerated-aging rig simulates realistic conditions by running the air at about 100 Pascals. Each duct sample contains a hard-to-seal joint: finger-jointed sheet-metal duct joining a stepped transition, typical of how ducts join plenums. Different duct sealants have very different longevities under these conditions.

Quick Catastrophic Failure

When we began the aging experiments, we expected it to take weeks to begin to see degradation in performance. We were surprised to find some duct tapes failing in a matter of days. Most failed catastrophically rather than gradually. This made it less necessary for us to use arbitrary numerical criteria in deciding that a sample had failed. Rapid failures have only occured for cloth duct tapes with rubber adhesives.

Of the 19 samples we have aged and 13 samples we have baked, many have failed; eight are still running. The only ducts that have become leaky have been sealed with duct tape (see Table 1). Most of them showed visible signs of failure within about three days of the start of the test. The tests give us no indication of time to failure in the real world. But they do allow us to see which sealants last relatively better than others.

In the baking test, only tapes with rubber-based adhesives have shown degradation. The duct tapes tend to be leakier than the other tapes. Some are approaching failure in the aging test, as well. The other sealants are all leaking less than 2% of the unsealed flow.

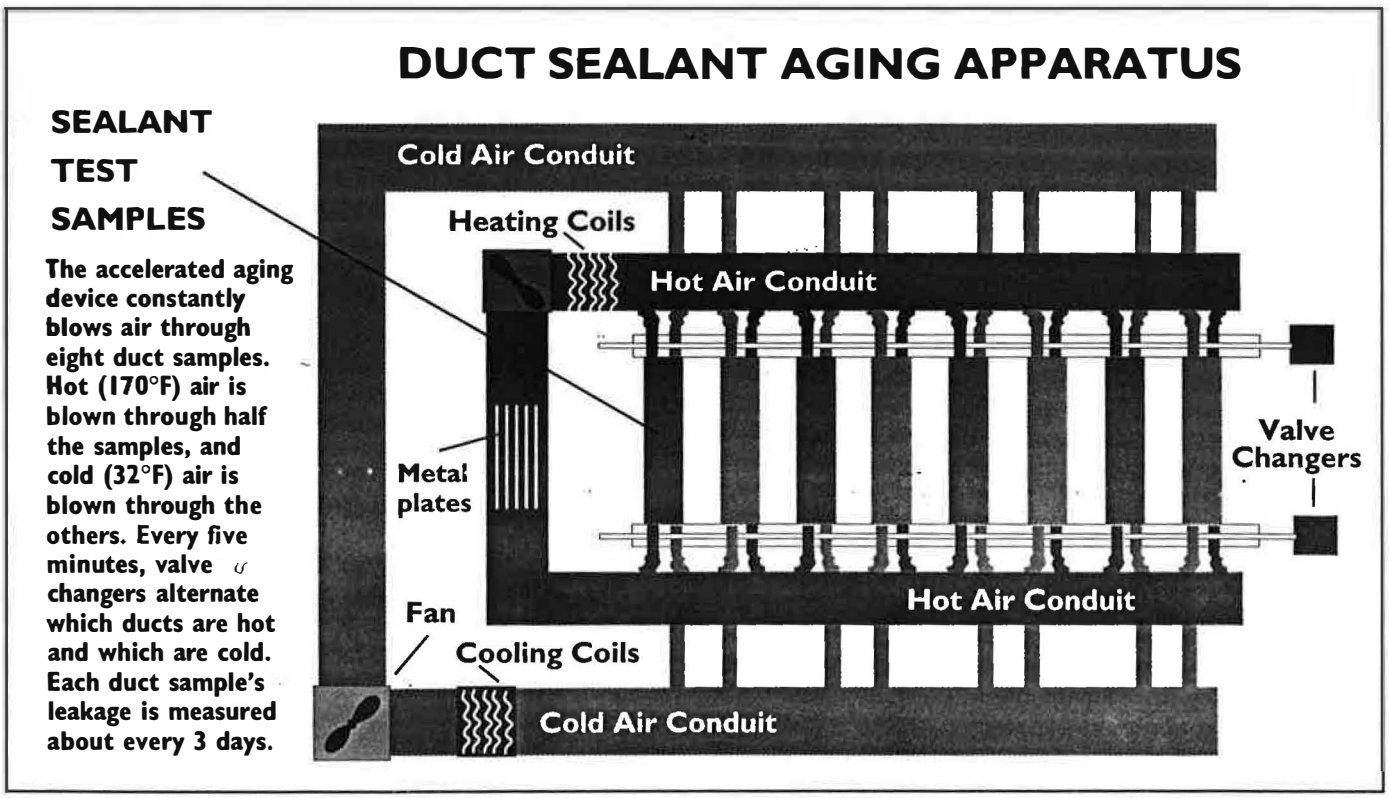


Figure 1. Schematic not to scale. Dark grey areas are filled with hot air, light grey areas are filled with cold air.

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This clear tape, which the authors refer to as packing tape, has proved to have more longevity than duct tape. However, it is not very strong.

After the test samples had spent three days in the test rigs, we measured their joint leakage. The duct tapes had 10%–20% of the unsealed leakage. The premium grade tape had failed completely, falling off the test section. Such complete failure was due to delamination—separation of the cloth backing from the adhesive. The other failed tapes had just started to delaminate. We believe that at elevated temperatures, the rubber-based adhesives in duct tapes change their properties and tend to separate either from the cloth backing or from the surface. We tried a second sample of the premium grade tape; it lasted about seven days before complete failure. The metal-backed tapes with acrylic adhesive, the aerosol, and the mastic showed no visible or measurable signs of degradation after two weeks of testing.

Although our failure criterion was 10%, we continued to monitor most of the samples until their leakage was more than 50% of the unsealed flow. In most of these, leakage continued to increase rapidly, often ending with a catastrophic failure.

A visual inspection of the baked duct sections revealed that in most of the duct tape samples, the rubber adhesive had changed properties and the tape had delaminated. Some samples appeared to have baked on in such a way as to maintain their seal. However, the adhesive baked on without air pressure from the leaks pushing against the tape; such permanence is unlikely in the field.

In the aging test, we occasionally saw some duct tapes begin to separate from the duct and then get resealed when an overlapping piece of tape failed in such a way as to plug the first leak, leaving a bubble. We have observed this same phenomenon in the field. This behavior may explain why some duct tapes last longer; we did not observe it on any other type of sealant. We consider such failing and resealing to be unacceptable, but we did not fail samples on this basis.

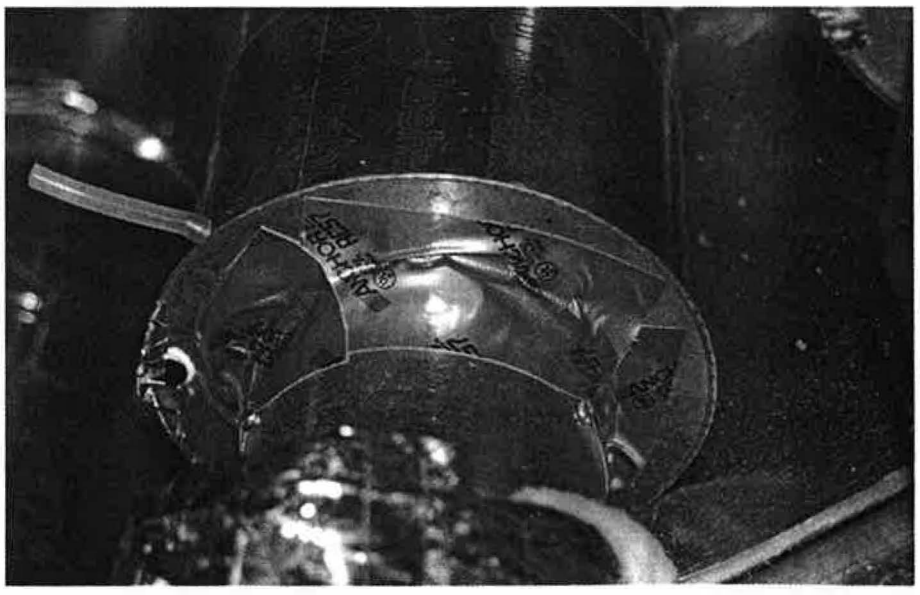
There appears to be little difference in performance among duct tapes, as compared to the difference between duct tape and the other sealants. Different grades of duct tape have different strengths, but the differences do not affect longevity.

Heat Exhaustion

Although our testing cannot differentiate among the mastics and the aerosol sealant, the data show that duct tape is not a good sealant for use in ducts that operate at much above ambient temperature. We believe this is due to the rubber adhesive, but we cannot say so definitively. For the most part, cloth backing and rubber adhesives go hand in hand. The other sealant products have not demonstrated any of the failure modes we have seen in the duct tapes.

There are a few products that use rubber adhesives with a backing that is not made of cloth. We intend to test these products in the future. Although the current crop of duct tapes fails our longevity tests, there is no reason to believe that the adhesive cannot be reformulated to work better at the higher temperatures found in attics or heating systems.

We have found that clear, unreinforced plastic-backed tape—which we call packing tape—holds up well. At



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Duct tape can form a good seal—initially. But under the challenging conditions of the aging rig, it quickly fails.

least one version of this tape has been UL 181B-FX rated and is commercially available. We have tested the UL rated version for over one month and the nonrated version for over three months, and there is no significant leakage.

Foil tape products with 181B-FX ratings are now available. The ore we have tested has held up fine for a month in the aging rig.

Packing tape has a low tensile strength. Because the purpose of a duct sealant is only to reduce leakage, we did not test strength. Some field users dislike using weaker tapes, perhaps because they like to hang ducts with tape, but duct systems are not supposed to be mechanically supported by sealants.

Installation Matters

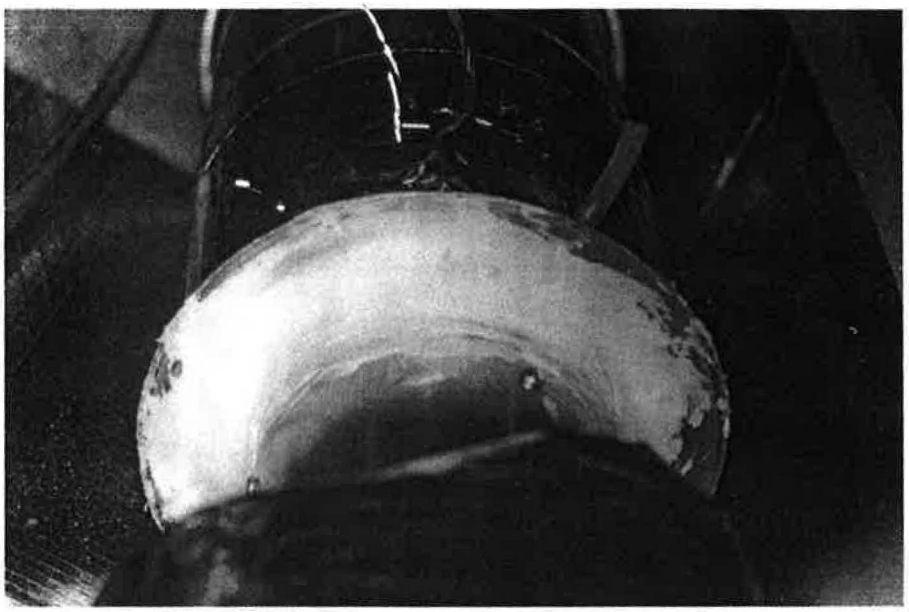
Our testing focused on the properties of the sealants themselves. We made sure we got good initial seals for our test section by following good practice and the manufacturer's instructions. For example, the test section was clean and dry. We applied the sealant with meticulous care, and we checked for a good seal before beginning any of the tests.

In a normal application, such care is not practical. Access to the ducts may be limited, and ducts may be dirty. These problems make it difficult to install tapes. Thus some tape jobs may perform poorly because they were poorly installed, not because of any intrinsic fault in the tape. Field experience shows that mastics and aerosol sealant often seal better than tape in dirty or inaccessible locations.

The best choice of duct sealant will vary by climate, construction type, and local experience. Our recommendation? Consider installation issues, but use anything but duct tape.

For a more detailed description of the testing apparatus itself as well as the testing protocol, refer to the project report, "Leakage Diagnostics, Sealant Longevity, Sizing and Technology Transfer in Residential Thermal Distribution Systems," Lawrence Berkeley National Laboratory Report No. 41118. Tel:(510)486-4022; Web site: www.lbl.gov.

Max Sherman and Iain Walker are staff scientists in the Energy Performance of Buildings Group at Lawrence Berkeley National Laboratory in Berkeley, California.



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Mastic has performed very well in the aging rig, with no noticeable increase in leakage over time.

Table 1. Duct Tape Failures

# of Tests	Sealant Type	Approximate Duration
Aging Test		
8	5 different grades of duct tape	7 days, failed
3	181B-FX–approved duct tape	10 days, failed
1	181B-FX–approved duct tape	3 months
1	15-mil foil-backed butyl tape	3 months
1	Aerosol sealant	3 months
1	181A-M– and 181B-M–approved mastic	3 months
1	181A-P–approved foil tape	3 months
1	181A-P– and 181B-FX–approved foil tape	1 month
1	Packing tape	3 months
1	181B-FX–approved packing tape	1 month
Baking Test		
5	3 different grades of duct tape	34 days, failed
1	181B-FX-approved duct tape	60 days, failed
2	Duct tape	4 months
3	181B-FX-approved duct tape	4 months
1	Packing tape	4 months
1	181A-P–approved foil tape	4 months
1	Aerosol sealant	4 months
Cycling Test		
4	Aerosol sealant under pressure cycling only	2 years
4	Aerosol sealant with heat and pressure cycling	2 years

Grey bars denote failed samples