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What's Up With Duct Tape?

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Introduction

It's been a couple of years since we last wrote about duct tape in the pages of *Home Energy* and it is time to revisit this ever-popular issue. When last we left duct sealant durability issues, the Energy Performance of Buildings Group at Lawrence Berkeley National Laboratory (LBNL) had done an accelerated longevity test; we found that most everything worked except standard, cloth-backed rubber adhesive duct tape. In response, the State of California had limited the use of such tapes in new construction and manufacturers were considering developing new products.

Several things have changed in the world of duct tape over the last couple of years. LBNL has completed another round of durability testing. There is a new version of Underwriters Laboratories (UL) 181B that now includes testing of the strapping that holds duct connections together. And there is a new American Society for Testing and Materials (ASTM) E2342-03 standard for testing the longevity of duct sealants.

Recent Research

Rather than the collar-to-plenum connection we tested previously (Sherman and Walker 1998), tape manufacturers—primarily TYCO and Shurtape—and UL wanted the latest LBNL tests to use standard core-to-collar joints of flexible duct to sheet metal collars. Their reason for changing the test joint was that the UL 181B (UL 2003) listing is only valid for this application, and the focus of the study was to evaluate UL listed products. Furthermore, the joint was to have no mechanical stress on it because the Uniform Mechanical Code (ICBO 1994), sealant manufacturers' instructions, and industry guidelines from the Air Diffusion Council (2003) require separate mechanical support for ducts.

The core-to-collar duct connection consisted of a six-inch diameter round collar inside a flex duct core (an example is shown in Figure 1). Each sample had two collar-to-flex connections: one at each end of a short (about 12 inches) piece of flex duct core. One of the collars was open ended for connection to a plenum that supplied hot air. The other collar had an end cap that was internally sealed with mastic.

Four different UL 181B-listed duct tape products were tested: two conventional duct tapes; an Oriented Polypropylene (OPP), acrylic adhesive tape; and a foil-backed, butyl adhesive tape. A range of samples was assembled. The test samples had different numbers of wraps and/or used multiple pieces of tape for a total of 18 different combinations. A nylon strap was used to mechanically hold the connection together for 10 of the 18 samples and the other eight samples had no strapping. For the UL listing to be valid for these tapes they must be held in place using straps.

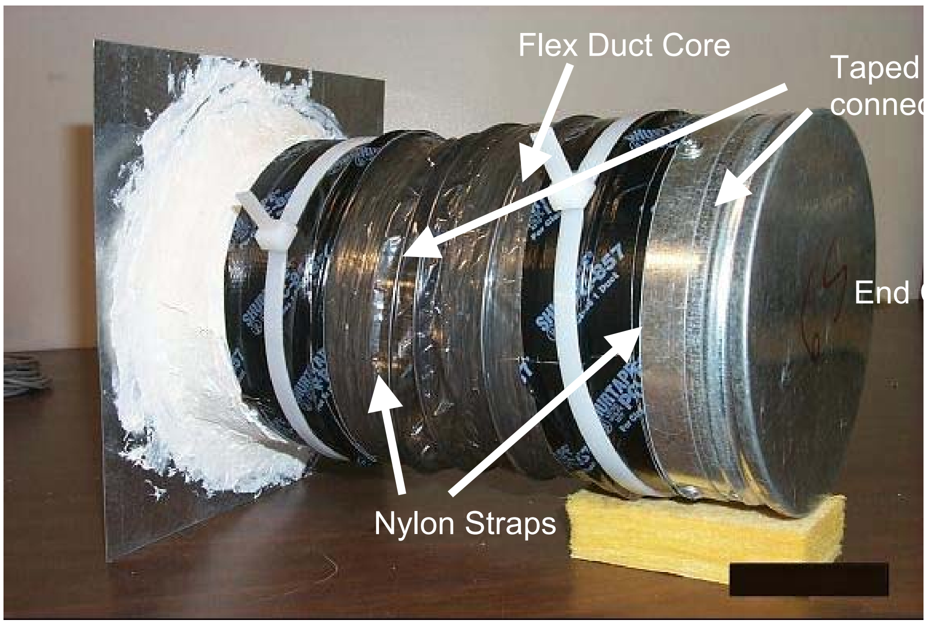

Figure 1. Example of a core-to-collar test sample showing the two taped connections and the mechanical straps.

The test samples were exposed to heated air at 200 °F and were pressurized to 0.35 inches of water (85 Pa). The exact value of this pressure is not significant, we just wanted a pressure that was within a reasonable range for residential duct systems. The surface temperatures of each sample, the air temperature, and the pressure across the leaks were continuously monitored using a data acquisition system that also controlled the temperature in the apparatus. Figure 2 shows samples mounted on the test apparatus.

Periodic air leakage tests and visual inspection were used to document changes in sealant performance over a two-year period. The air leakage measurements were conducted on a monthly or weekly basis by removing the samples from the test apparatus. A separate leakage-testing device pressurized the samples to 0.1 inches of water (25 Pa) and measured the airflow rate required to maintain a 0.1 inches of water (25 Pa) pressure difference. The failure criterion for air leakage was set at 10% of the unsealed sample leakage because this was a leakage level after which samples tended to fail rapidly in the previous testing. A key difference between this experiment and the earlier LBNL work was that in the more recent testing there was no quantitative baseline of unsealed joint air leakage from which to objectively determine acceptable air leakage. A joint that had mechanical support including straps had relatively low leakage to begin with, so that the durability of duct tape could not be objectively measured. Nevertheless, some interesting conclusions can be drawn from the test results.

Figure 2. Samples mounted in the test apparatus.

The leakage results over the two years of testing showed no systematic increases in leakage and none of the catastrophic failures seen in our previous studies. Most of the samples showed small changes in leakage (either increases or decreases) of 0.2 CFM or less. The exception was one of the foil tape samples, which showed an increase of 0.4 CFM after the first month of testing. However, this sample then stabilized at this leakage level and did not show any significant further leakage increases. Several of the samples showed leakage reductions and visual observations indicated that this is probably due to the flowing of the adhesive at high temperatures, such that it seals more of the small cracks and leaks as it flows (see Figure 3).

Figure 3. These samples show oozing of the adhesive at the tape edges.

In order to systematically record the visual deterioration of the samples, monthly pictures of all 18 specimens were taken (see Figures 4 and 5). Typical minor deteriorations observed were discoloration, wrinkling, and oozing. The major deteriorations observed were shrinking, peeling, delamination, and cracking. Like the visual inspections of the UL 181B test, these evaluations are subjective, but they do serve to give a relative rating for each tape. Observations showed that the OPP tape had the most deterioration, while foil-butyl tape showed the least deterioration. Although the OPP tape appeared to be almost disintegrated, it still maintained a good air seal. This is because the tape is not being asked to be a mechanical connection, only to seal the gap between the collar and the flex duct.

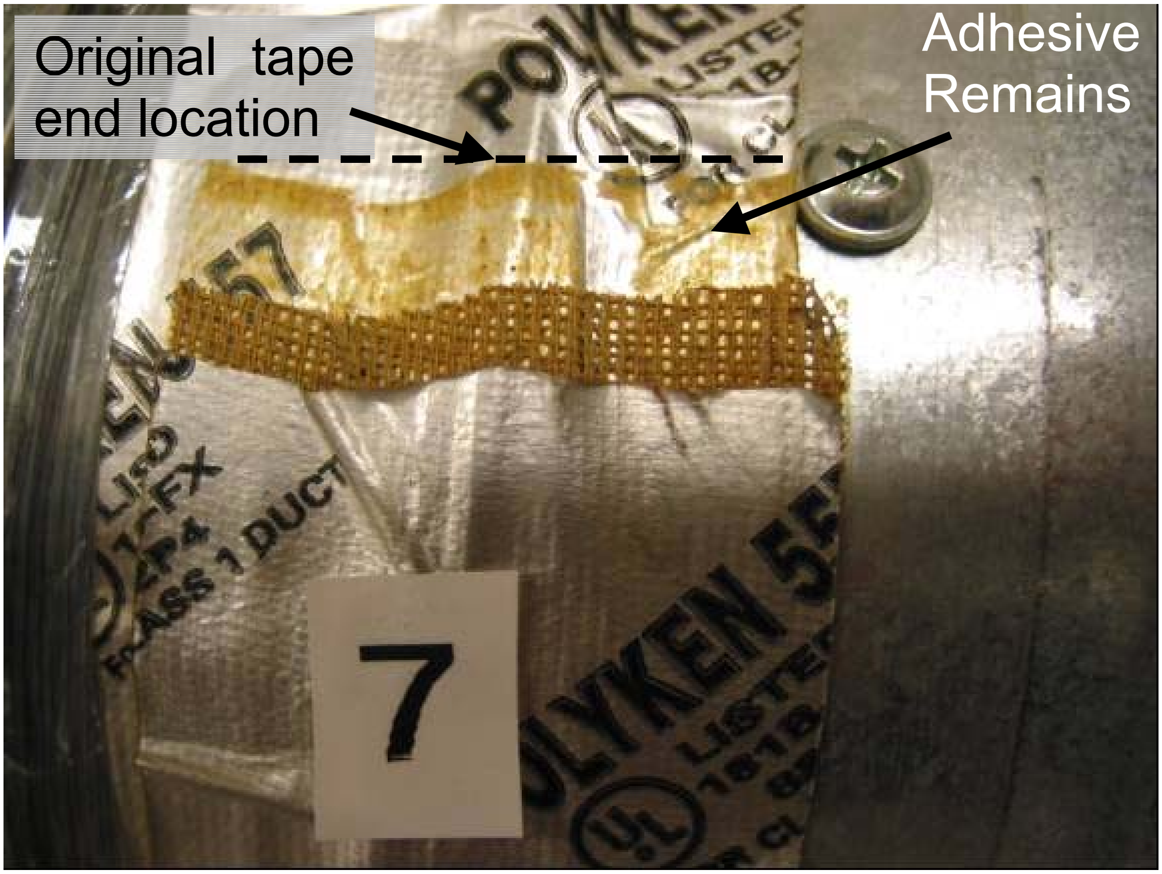

Figure 4. Cloth backed tape sample showing considerable shrinkage and delamination.

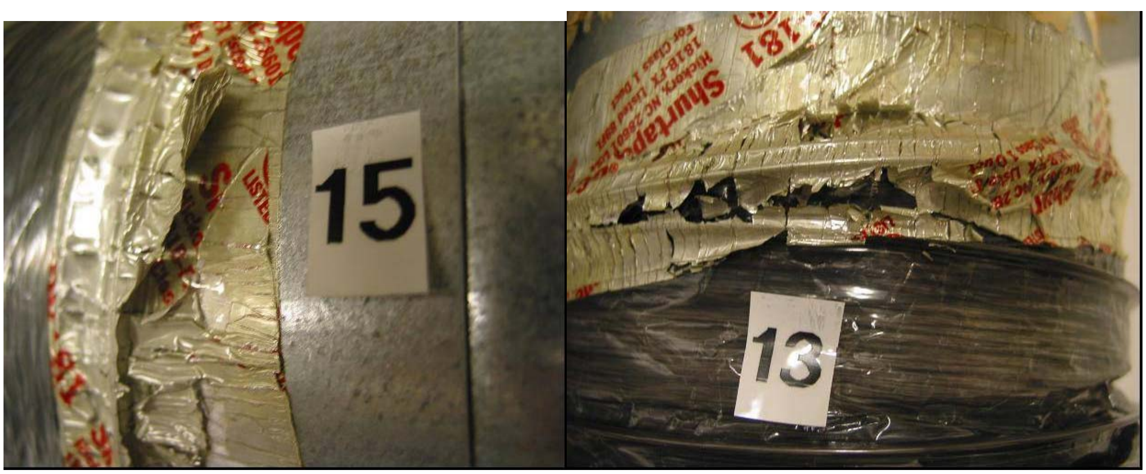

Figure 5. The OPP tape showed considerable visual degradation, even though it still provided a good air seal.

Strap Failure

One unexpected result of the testing was the failure of the nylon straps (see Figure 6). Discoloration of the nylon strapping was observed within one month of the start of testing and the first strap broke after four months. Two different nylon strap materials were used and both showed the same brittle failure. The straps usually failed at the point where the strap passes through the ratchet of the zip-tie mechanism – where the mechanical stresses are greatest.

Figure 6. Failed plastic strapping after four months of aging.

Two straps were used—one at the cap end and one at the open end. The failure times for each end were recorded separately. The results show no significant pattern for flange or end caps failing first; the two straps on each sample generally failed within a couple of months of each other. Similarly, the failures were independent of the tape they were used with. All but two straps had failed by the end of our testing. The two remaining straps showed the same discoloration as failed straps but had not broken and fallen off. Strap failure is a major problem because mechanical attachment thereafter only is maintained by the duct sealant. If ducts are not well supported, significant mechanical stress can occur to cause the sealant to fail after the strap fails, in extreme cases, the duct connection may separate.

The materials used for the straps were typical of those used in the field, which have an unknown temperature rating. Product literature from strap manufacturers shows that there are other strap materials that have higher temperature ratings, such as Heat Stabilized Nylon 6/6 for continuous exposure above 185 °F and TEFZEL® for even higher temperatures, and these straps may have improved high-temperature durability. As an alternative, the authors recommend metal straps because they will not fail at even higher temperature ranges.

UL181B Revisions for Straps

In 2003, perhaps in response to LBNL's preliminary reports, UL181B was revised to include a new test for fasteners including straps. Products that pass the test are to be marked UL 181B-C. Because LBNL testing started before this new UL strap requirement, the researchers were not able to evaluate the performance of UL listed straps. The tests include tensile strength, smoke spread, heat production, mold growth, tension test (evaluation of the mechanical integrity of the connection), air leakage, and low and high temperature aging.

The most relevant test for longevity is the high temperature test in which the straps are heated to 212°F for 60 days. The straps are tested for tensile strength before and after the 60 days and must retain 75% of their initial strength. The tensile testing itself does not occur at high temperature; instead, the straps are conditioned for 48 hours at 73 °F (23°C) and 50% relative humidity (RH) before tensile testing at some unspecified temperature. In other words, their performance at elevated temperature is not evaluated; instead, the effect of high temperature exposure on material properties is the object of the UL test.

While a good step forward, the new UL test falls short in being a good indicator of strap performance. The problems with the UL test are:

- The straps are not tested in the failure mode that is observed, such as brittle failure in bending. We do not know if the strapping materials show greater or lower tensile strength as they become more brittle; many ductile materials, in fact, show greater tensile strength as they become brittle. In addition, the straps are not subjected to any strain during the UL high temperature baking. In real applications (and in laboratory testing), the straps are under the influence of combined heat and strain. Without additional testing we do not know if this is a factor, but in general we would expect that it is.

- The testing is for 60 days only. In the LBNL study, none of the straps failed in 60 days. Testing for only 60 days appears to be insufficient. Given the relatively arbitrary nature of selecting time limit criteria, we should select an appropriate time limit that allows us to differentiate between acceptable and non-acceptable performance.
- The test wording is somewhat unclear, making unambiguously following the testing procedure extremely difficult.

New ASTM Standard

Because the UL tests do not sufficiently address durability issues, researchers have worked with ASTM to develop a new test method: ASTM E2342-03 "Standard Test Method for Durability Testing of Duct Sealants". This standard tests sealants on a collar-to-plenum connection. This connection is much harder for tapes to seal because of the complex three-dimensional shape that the tape needs to conform to and that mechanically stresses the tape. In the future we hope that the ASTM standard will be used to specify durable duct sealants, rather than relying on the UL listing that does not sufficiently address durability.

Recommendations for Better Duct Sealing

Our recent research suggests that almost any tape can be made to work for a core-to-collar joint when perfectly applied. Given all the better choices available and all the problems that can and do occur in the field, we would not recommend that cloth-backed (natural) rubber-adhesive tapes be used, unless they can pass a suitable E2342 test.

If visual degradation is an important factor, OPP and cloth-backed tapes should be avoided. While tapes that fail usually show visual degradation, the converse is not always true. We speculate, however, that visually degraded tapes are more likely to be susceptible to damage from vibration and other mechanical stresses.

Conventional nylon straps are quite prone to fail at higher temperatures, but no systematic studies have yet been done across product classes. UL has proposed a new standard for straps, but the protocol for the current UL test does not, however, suggest that it would be a good indicator of durability. Products meeting the new UL standard for straps should be independently tested for the failure modes observed in the field and laboratory to determine if that test is a reasonable indicator of durability.

Until a suitable test for strap durability exists, we recommend that only high temperature nylon or metal straps be used—especially in cases where tapes may be sensitive to mechanical stresses.

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