# UL 181A/B Listed Adhesive Tapes for HVAC Applications

David Krupa

Berry Global, 2320 Bowling Green Road, Franklin, KY 42134, davidkrupa@berryglobal.com

**Abstract**: Pressure sensitive adhesive tapes play an important role in the Heating, Ventilating and Air Conditioning (HVAC) industry as closure systems for air ducts. To ensure that heating and cooling systems operate safely and effectively over their design life, building codes such as IMC (International Mechanical Code), IRC (International Residential Code), IECC (International Energy Conservation Code), UMC (Uniform Mechanical Code), NFPA 90A (National Fire Protection Association), and NFPA 90B mandate that pressure sensitive tapes meet strict performance criteria. The building codes generally do not set the requirements directly but call out various performance standards like Underwriters Laboratories (UL) 181A Standard for Safety, Closure Systems For Use With Rigid Air Duct and UL 181B Standard For Safety, Closure Systems for Use With Flexible Air Ducts and Air Connectors. A brief overview of the testing requirements for UL 181A and UL 181B will be presented. Duct sealing applications for pressure sensitive tapes in the HVAC industry will be shown, with discussion of the tapes used for the various types of air ducts. In addition to tapes used for duct sealing, building codes permit use of "General Use Tapes" for less demanding applications, such as seaming insulation. These tapes are tested by UL for flammability via test method UL 723 Standard for Safety, Test for Surface Burning Characteristics of Building Materials. These tapes are considered "Classified" via UL 723, and earn a rating for flame spread and smoke developed. The push for higher energy efficiency in residential and commercial heating and cooling, as evidenced by LEED Certification and the Green Building movement, benefits from high performing adhesive tapes with long service life.

## Need for Standardized Testing

Many of the advances to building codes and standards result from the investigation of tragic fires. One such fire took place November 1942 at the Cocoanut Grove nightclub in Boston, Massachusetts. The popular nightclub was packed by over 1000 patrons, far beyond the legal occupancy of 490. A small fire started at 10:15 pm in the basement bar and accelerated very quickly. Within 5 minutes the fire had spread to the first floor where most of the patrons were dining and dancing. The flammability of interior decorations, ceiling tiles and wall coverings was a main cause for the rapid flame acceleration. Incredibly, these same materials had passed a routine fire inspection only a week earlier! In the now darkened building, panicked victims were unable to exit, due to the sheer numbers pressing to the few functioning exits. Some exits had been locked. Many patrons tried to exit where they had entered, through a single revolving door, which quickly became blocked. The fire burned so quickly and intensely that most fatalities occurred within the first 15 minutes, and removing the injured and dead became the firefighter's main focus. This fire is still known as the deadliest nightclub fire in US history, with 492 fatalities. It brought to light many faults in design and practice of fire safety. Perhaps most important, it proved that methods for evaluating the flammability of materials at the time were inadequate. It led to improvements on many fronts including building design and classification, fire enforcement policies, fire exit design, emergency lighting, and changes to medical treatment for burns and smoke inhalation.

The Steiner Tunnel Furnace was developed in 1943 by Albert Steiner, an engineer with the Underwriter's Laboratories, in part as response to the Coconut Grove Nightclub fire. It soon became the preferred method of test for comparing the burning characteristics of building materials. UL published the first edition of UL 723 "Test for Surface Burning Characteristics of Building Materials" in August 1950. It was adopted by ASTM as a tentative standard that same year. In 1961 it was formally adopted by ASTM as ASTM E-84. The testing of surface burning characteristics is a key requirement in UL181, UL181A and UL181B.

## Building and Other Codes

Compliance to the UL181A and UL181B Standards is mandated by building codes, which are updated on a three year cycle. States are at liberty to enforce the codes state-wide or delegate enforcement to agencies or local governments. Progressive jurisdictions are more likely to adopt the most recent edition of the code since builders are already earning LEED (Leadership in Energy and Environmental Design) certifications and high performing buildings are prevalent within their area. It is not unusual to see editions of the codes that are 3 or 6 years old being enforced across the United States. For HVAC applications, building inspectors enforce the codes by checking for duct materials and tapes that are labeled for compliance to the relevant UL Standard. Also, compliance to the Standard provides the contractor assurance that the ductwork will perform as designed. The UL Standards which apply to air duct and tapes are as follows:

UL 181: Standard for Safety, Factory-Made Air Ducts and Air Connectors
UL 181A: Standard for Safety, Closure Systems for Use With Rigid Air Ducts
UL 181B: Standard for Safety, Closure Systems for Use With Flexible Air Ducts and Air Connectors
UL 723: Standard for Safety, Test for Surface Burning Characteristics of Building Materials

These standards are cited in the following building codes:

International Code Council:

- International Mechanical Code (IMC)
- International Residential Code (IRC)
- International Energy Conservation Code (IECC)

International Association of Plumbing and Mechanical Officials:

- Uniform Mechanical Code (UMC)

National Fire Protection Association:

- Standards for the Installation of Air Conditioning and Ventilation Systems, (NFPA No. 90A)
- Standards for the Installation of Warm Air Heating and Air-Conditioning Systems (NFPA No. 90B)

## Types of Ducts

For UL 181A, the target duct material is rigid fiberglass duct board, Type 475. Rigid fiberglass duct board Type 475 is a thick composite material made up of resin-bonded fiberglass covered by a foil/scrim/kraft paper (FSK) facing. (See Figure 1) This material finds use in residential and commercial air duct fabrication. In forming the ductwork, the duct board is precisely cut and bent to make square or rectangular cross-sections, then stapled, with the foil side facing out. It is available in 4’ x 8’ sheets and thicknesses of 1, 1.5 and 2 inches. In use, UL 181A listed foil tape is applied to the foil surface on the overlap seam to affect an airtight seal, and to provide structural integrity. This type of air duct is classified under UL 181 as Class 1.

Class 1 air duct is defined in UL181 as having a Flame Spread Index (FSI) of < 25 and a Smoke Developed Index (SDI) of < 50. This refers to the flame spread test result compared to inorganic reinforced cement board (“0” FSI, “0” SDI) and Red Oak board (“100” FSI, “100” SDI). Flame Spread values are calculated from time/distance curves for the sample compared to a red oak calibration standard. The Index value is defined as the average of three such measurements rounded to the nearest 5. Smoke Developed values are calculated in a similar way using photometer light absorption/time curves for the sample vs. a red oak calibration standard.

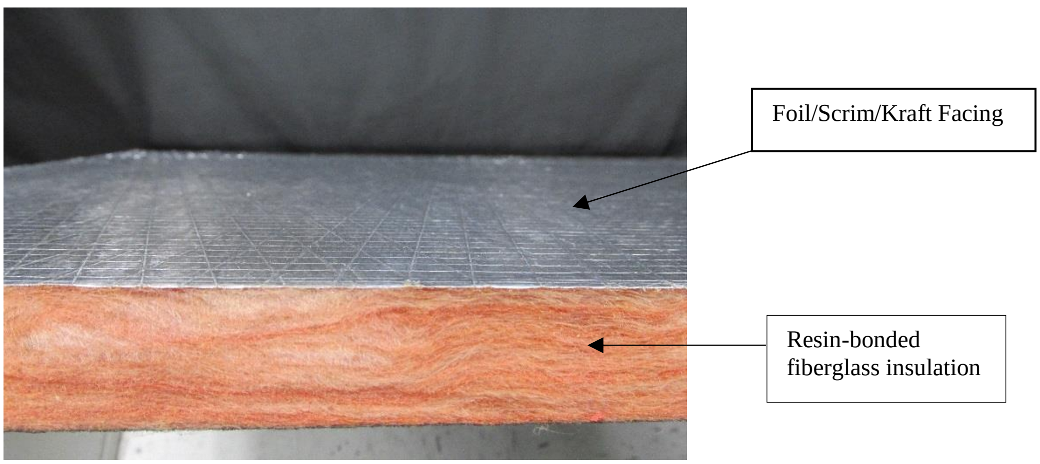


Figure 1: Rigid Fiberglass Ductboard

For UL-181B, the target material is flexible duct. Flexible duct may be metallic or non-metallic, insulated or uninsulated, is usually round in cross-section, and is packaged as a tube in compressed form. In use, it is expanded to maximum length before cutting to fit. It is commonly used in “trunk” and “branch” configuration with rigid fiberglass or sheet metal duct as the “trunk” and the flexible duct as the “branch” with an air register at the end of each branch. Insulated flexible duct is typically used in HVAC applications, providing efficient movement of heated or cooled air. Non-metallic flexible duct has a spiral-wound wire bonded to the film to maintain the round cross-section, ensuring the best airflow through the duct. Various types of flexible duct are available, chosen based on the air pressure and air velocity. It is available in diameters ranging from 2” to 12” in 1” increments, and 14” though 20” in 2” increments. It is also classified via UL 181 as Class 1 using the same criteria of Flame Spread Index (FSI <25) and Smoke Developed Index (SDI <50) as rigid duct (See Figure 2).

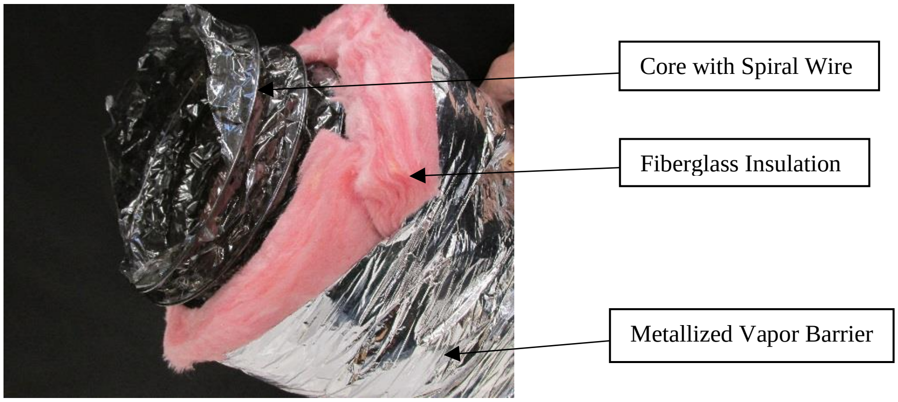


Figure 2: Non-metallic flexible insulated duct

## PSA Tapes Compliant with UL 181A and B

UL 181A/B standards pertain to the materials used in fabricating air handling systems, and the materials used for seam sealing and closure of those systems. The materials covered by UL 181A and UL 181B are pressure sensitive tapes, mastics, and heat activated tapes. This paper will focus on pressure sensitive tapes. Pressure sensitive tapes are an important element in air duct systems as they provide an efficient means of fabricating air duct and sealing seams to prevent leaks in the ductwork. In the case of foil tapes on rigid fiberglass duct, they contribute to the structural integrity of the finished air duct. It is estimated that the market value of tapes used for HVAC applications approaches 100 million dollars per year.

- Foil Tape: UL 181A-P listed tapes are exclusively pressure sensitive adhesive foil tapes with acrylic adhesive and removable release liner.
- Film Tapes: UL 181B-FX listed tapes are self-wound film tapes with acrylic adhesive.
- Tapes with Rubber Based Adhesives: UL 181B-FX listed tapes can also be cloth reinforced or foil tapes with rubber based adhesives and removable release liner.

## Requirements of UL 181A and UL 181B Standards

The testing required by UL 181A and UL 181B can be described as a combination of physical testing and application testing. Physical testing is conducted on the tapes alone to ensure that the adhesive and backing material will deliver a minimum level of adhesive, cohesive and tensile strength. These tests are recognized as peel adhesion, shear adhesion and tensile testing, with minor adjustments to sample preparation, and reference the ASTM test methods which are routinely performed in the typical physical testing lab. The level of performance is agreed as the minimum required to make air-tight closures on the target duct materials.

Table 1: Summary of UL Standard Testing Requirements

| | UL 181A-P | UL 181B-FX | Method |
|---|---|---|---|
| **Physical Testing** | | | |
| Tensile Strength - Machine Direction | ≥25 lb/inch | ≥17 lb/inch | ASTM D3759 |
| Tensile Strength - Cross-Web Direction | ≥25 lb/inch | ≥8 lb/inch | ASTM D3759 |
| Peel Adhesion at 180° Angle | ≥60 oz/inch | ≥30 oz/inch | ASTM D3330 |
| Peel Adhesion to Tape Backing, 180° | NA | ≥25 oz/inch | ASTM D3330 |
| Static Peel Adhesion at 20°, 2 lb/inch | ≥24 hours | NA | UL 181A |
| Shear Adhesion at 40°F, 5 psi load | ≥6 hours | NA | ASTM D3654 |
| Shear Adhesion at 73°F, 10 psi load | ≥120 hours | NA | ASTM D3654 |
| Shear Adhesion at 150°F , 5 psi load | ≥6 hours | NA | ASTM D3654 |
| Shear Adhesion at 73°F, 2 psi load | NA | ≥24 hours | ASTM D3654 |
| Shear Adhesion at 150°F, 100 gm/sqin load | NA | ≥24 hours | ASTM D3654 |
| Shear Adhesion at 73°F , 60 days at 150°F conditioning | NA | ≥24 hours, 100 gm/sqin | ASTM D3654 |
| Temperature Test at 212°F, 60 days | NA | no visible deterioration | UL 181B |
| Burning Test - Vertical, horizontal and 45° | No glow or flame 60 s after flame removed | NA | UL 181A |
| | | | |
| **Application Testing** | | | |
| Surface Burning Characteristics | <25 FSI, <50 SDI | <25 FSI, <50 SDI | ASTM E84, UL 723 |
| Mold Growth and Humidity (≥ 60 days duration) | No mold spread or tape deterioration | No mold spread or tape deterioration | UL 181A/B |
| Temperature/Pressure Cycling (Air Duct Simulation) | Leakage ≤ 15cfm, no tape damage, displacement or openings > 1/8" | NA | UL 181A |

Application testing is not easily conducted in the typical physical test lab, as it requires specialized equipment. These tests include the Surface Burning Characteristics Test (UL 723 Steiner Tunnel Test, ASTM-E84,) Mold Growth and Humidity Test, and the Temperature/Pressure Cycling Test. A brief description of each of these tests follows.

The Surface Burning Characteristics Test makes use of the Steiner Tunnel, a 25 foot tunnel designed to test materials on a large scale. The test varies slightly between UL 181A and UL 181B standards in that the substrate to which the tape is bonded for UL 181A is rigid fiberglass duct board Type 475 with FSK facing, and for UL 181B is inorganic cement board. The following describes the test as performed for the UL 181A standard. Two strips of tape are applied to the FSK side for the length of three 2' x 8' duct boards, and aligned with the center line of the burner nozzles, 8" apart. Three of these boards are placed end to end in the tunnel with taped side facing down. In this position, the duct boards form the ceiling of the tunnel. A heavy tunnel lid is lowered over the duct boards so that the roof of the tunnel is sealed. Both ends of the tunnel remain open allowing air to be pulled into the tunnel at the burners. The rate of airflow is carefully controlled. At the initiation of the test, two natural gas burners are ignited and the flames come into contact with both strips of tape and the board. The combustion products and heated air are pulled through the tunnel and exhausted to the outside of the building. The operator then carefully observes and records the flame front as the tape ignites. The test is conducted for 10 minutes, and observations are made as to how far down the tunnel the tape burned, whether the tape self-extinguished, and if re-ignition occurred. This is a severe test and normally the tape and board are burned completely through, but only for a short distance downstream of the gas burners. A tape that passes this test with flame spread values <25 will show damage to the first 4 feet downstream of the gas burners, and will self-extinguish with little or no re-ignition over the course of the 10 minute burn cycle. A photometer is simultaneously sensing the smoke generated and relaying this information continuously to data collection. A passing acrylic foil tape will finish the test with flame spread values between 5-15 and smoke developed values between 0–15. An index value for flame spread and smoke generated is calculated based on the results of three passing tests, averaged and rounded to the nearest 5.

The Mold Growth and Humidity Test is conducted at room temperature and 100% relative humidity to determine the ability of mold and spores to thrive when placed on the adhesive surface. The adhesive side of the tape is inoculated with mold mycelia and spores and placed in a closed vessel saturated with water vapor until maximum growth is observed, or the mold and spores have disintegrated, but not less than 60 days. The tape is observed for deterioration, and for significant mold growth and mold spread beyond the inoculated area.

The Temperature/Pressure Cycling Test simulates the forces placed upon a fabricated rigid fiberglass ductwork and tape under rapid pressure cycling and three temperature conditions ranging from 0°F to 165°F. It is a rather severe test for pressure sensitive tapes used to seal rigid fiberglass duct board. The normal leakage rate is determined for the ductwork at room temperature and 3" water column pressure and must be less than 5 cfm to proceed with pressure and temperature cycling. The duct is placed into a test chamber at 165°F and subjected to 30,000 cycles of pressure fluctuation. Leakage rate is then checked at 3" w.c. After this is completed, the test chamber is set to 90°F and 90% RH and the pressure cycling is repeated for 15,000 cycles. Again, leakage rate is checked. Finally the test chamber is lowered to 0°F and the pressure cycling is repeated for 5000 cycles. Leakage rate is checked and cannot exceed 15 cfm at 3” w.c.

## Conclusion

Building codes that address the flammability of building materials rely on UL Standards for Safety to determine the suitability of these materials. Lessons learned through catastrophic fires such as the Cocoanut Grove nightclub fire have helped to advance the science and practice of fire safety in building design and materials qualification, and serve to remind us of the critical nature of meeting these codes. Pressure sensitive tapes that comply to UL 181A and UL 181B standards provide a safe, convenient and durable closure system for rigid and flexible air duct. Energy conservation and environmental design in the built environment emphasizes the role of efficient HVAC systems.

## References

Flexible Duct Performance and Installation Standard, Fifth Edition, Copyright 2010, Air Diffusion Council

Last Dance at the Cocoanut Grove, Casey C. Grant, PE, NFPA Journal November/December 2007

Report Concerning the Cocoanut Grove Fire, November 28, 1942 by William Arthur Reilly, Fire Commissioner, City of Boston

STANDARD FOR SAFETY; Closure Systems for Use With Rigid Air Ducts, UL181A, Fourth Edition, January 8, 2013

STANDARD FOR SAFETY; Closure Systems for Use With Flexible Air Ducts and Air Connectors, UL181B, Third Edition, January 8, 2013

STANDARD FOR SAFETY; Test for Surface Burning Characteristics of Building Materials, UL 723, Tenth Edition, September 10, 2008

Standard Method for Surface Burning Characteristics of Building Materials ASTM E84-00a published May 2000

Standard Practice for Specimen Preparation and Mounting of Tapes to Assess Surface Burning Characteristics ASTM E2688-10 published February 2010.

Understanding Code Development, Adoption, Appeals by Mary Kate McGowan ASHRAE JOURNAL October 2017