

A guide to 3M™ Professional Grade Electrical Tapes: 75+ years of quality and performance.

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Background

Since its first masking tape in 1925, the Scotch® Brand trademark has meant reliable tapes for painting, industrial, electrical and home use. In 1946, 3M invented the first vinyl electrical tape – Scotch® Brand No. 33 Electrical Tape – for insulating electrical connections. Continuous research and development ensure that 3M tapes are made with cutting-edge technology and materials. This paper evaluates some of our premium tapes used in the electrical market, discussing properties, advantages and applications. This paper also covers some installation tips and techniques.

Test reports for most of the tapes discussed in this paper are listed in the reference section on the last page. Please request the reports to get the most up-to-date test data on each of these tapes. Every tape has a quality control (QC) process set up to statistically test critical properties of that tape. This “fingerprint” testing helps ensure that the tapes will perform as expected.

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Scotch® Rubber Splicing Tape 23 and Scotch® Linerless Rubber Splicing Tape 130C

These rubber splicing tapes are ideal for making secure, weather-resistant connections. They have excellent physical and electrical properties and are compatible with common, solid dielectric cable insulation.



Properties, Advantages and Applications

Both tapes are 0.76 mm (30 mil) thick, ultraviolet (UV) resistant and come in different widths for optimal versatility. They are used as primary insulation for splices and terminations through 69 kV, insulation for motor connections, re-jacketing and environmental sealing of medium-voltage splices and other applications. In many of these uses, Scotch® Tape 23 and Scotch® Tape 130C are combined with other tapes to finish the job.

They are applied on terminations to make a geometric ramp and combined with Scotch® Electrical Semi-Conducting Tape 13 to extend the cable insulation shield up the ramp, followed by a silicone tape over the top for track resistance. For medium-voltage splices, rubber tapes are the primary insulation with Scotch® Electrical Tape 13, metallic tape and/or braids to extend the cable metallic shield in the splice. Next, the rubber tape with vinyl electrical tape applied over it is used for the re-jacketing material over the splice and for the environmental seal.

For motor leads, typically a glass cloth or vinyl tape is applied first with the adhesive away from the connection so that the insulating rubber tape can be cleanly removed if the motor needs to be replaced. Then the insulating rubber tape is applied and followed by vinyl tape as the outer layer for abrasion resistance. These are just some examples of the many uses of Scotch® Tape 23 and Scotch® Tape 130C. Many companies keep these two tapes in inventory for emergency work. The versatile tapes are not size sensitive and the same tapes can be used to splice or terminate very small to very large cables and on any voltage.

Differences Between the Tapes

There are three main differences between the tapes.

- Scotch® Rubber Splicing Tape 23 has a removable propylene liner, whereas Scotch® Linerless Rubber Splicing Tape 130C has a thin adhesive layer that doesn't have to be removed.
- Scotch® Tape 130C has a thermal additive so that it dissipates heat away from connectors better than Scotch® Tape 23. Scotch® Tape 130C was developed after the Institute of Electrical and Electronics Engineers IEEE-404 standard was modified to include a current cycle test with the conductor temperature at emergency overload temperature of 130°C/226°F. Scotch® Tape 23 thermally insulated aluminum connectors enough so they wouldn't pass the current cycle test. Scotch® Tape 130C was developed to pass the test.
- Scotch® Tape 23 is made in Brazil and Scotch® Tape 130C is made in the United States of America.

Standards

Both tapes passed or exceeded the requirements of the standards noted on their individual test reports. See **Reference 1** for the Scotch® Tape 23 report and **Reference 2** for the Scotch® Tape 130C test report. Both tapes are halogen free* and compatible with all extruded cable insulations.

*Halogen Free is defined as having less than 900 ppm bromine, less than 900 ppm chlorine, and less than 1500 ppm total bromine and chlorine; other halogens are excluded from this definition. These are the levels set forth in certain industry standards, such as the International Electrotechnical Commission (IEC) 61249-2-21 standard.

Installation Considerations

The tapes must be stretched when applied so that they will fuse together to become one solid insulation. They should be stretched between 50% and 75% of their original width and applied in half-overlapped layers until the desired thickness is achieved.

Scotch® Tape 23 comes with a removable propylene liner that pops off when the tape is stretched and must be removed for the tape to function properly. Scotch® Tape 130C uses the adhesive on it as the liner. This tape must be stretched to separate the liner so that the rubber can bond to itself and form one solid insulation. For both tapes, it is important to only install the thickness of tape required. Too much tape will not allow the heat generated from the connector to be properly dissipated.



For re-jacketing, a wider tape can be used to build up faster, but when utilized as a primary insulation on a medium-voltage splice, choose a narrower width tape to help ensure there are no air voids in the insulation.

One good way to finish wrapping the tape is to use the palm of your hand and push down and out on the end of the stretched tape. This provides a very thin end, so there is no big step to fill. It forces the end down into the existing tape so that it will stay in place. Rubber tapes are similar to cold shrink, in which they exert inward pressure on the cable insulation when they are stretched in application and will expand and contract with the cable insulation as it goes through load cycles. When installed correctly, tape splices are very reliable and many have been in service for over 50 years.



Standard Requirement Comparison

The following **Table 1** compares tape test reported values of our rubber electrical tapes to the standard requirements. See **Reference 1** for Scotch® Rubber Splicing Tape 23 and **Reference 2** for the Scotch® Linerless Rubber Splicing Tape 130C report.

Table 1: Rubber Tape Property Comparison

Property	Elongation (%)	Dielectric Strength (kV/mm)
Standard Requirement	ASTM D4388 Type III 700 Min	ASTM D4388 Type III 24 Min
Scotch® Rubber Splicing Tape 23	1876	36.4
Scotch® Linerless Rubber Splicing Tape 130C	969	30.4

As seen in **Table 1**, Scotch® Tape 23 and Scotch® Tape 130C exceed the standard requirements for elongation and dielectric strength when tested. Dielectric strength is important to ensure adequate electrical insulation is applied to a connection.

The most important consideration when choosing a tape to withstand the voltage is the combination of other properties in addition to dielectric strength, such as elongation and conformability. Elongation and conformability impact the tape's ability to exert inward pressure and eliminate air voids that would cause partial discharges, which lead to splice failure in medium- and high-voltage splices.

Scotch® Professional Grade Vinyl Electrical Tapes:

Scotch® Super 33+™ Vinyl Electrical Tape, Scotch® Vinyl Electrical Tape Super 88 and Scotch® Vinyl Electrical Tape 35

Elastic PVC vinyl tapes are a requirement for installers. Since inventing vinyl electrical tape in 1946 with the introduction of Scotch® Brand No. 33 Electrical Tape, 3M has continuously improved our tape to help optimize the design for demanding field conditions. In 1985, 3M introduced Scotch® Super 33+™ Professional Grade Vinyl Electrical Tape, upgrading the tape's handling characteristics and holding power without jeopardizing its adhesion properties. It can stretch easily at temperatures down to -18°C/0.4°F and is rated for continuous operation up to 105°C/221°F. After more than 75 years of electrical tape development, Scotch® Super 33+™ Vinyl Electrical Tape continues to be an ideal tape for installers. As the power utilities landscape evolves, Scotch® Professional Grade Vinyl Electrical Tapes help provide exceptional insulation solutions for linemen around the world.



Properties, Advantages and Applications

What makes a good vinyl electrical tape? A good vinyl tape has excellent elasticity and adhesion so it installs at both low and high temperatures. Scotch® Professional Grade Vinyl Electrical Tapes excel in all those areas.

Scotch® Super 33+™ Tape, Scotch® Tape Super 88 and Scotch® Tape 35 can be used as primary insulation for splices up to 1,000 volts. If the splice will be submerged in water, then mastic tape (which provides the best seal) or rubber tape should be used first and then vinyl tape as the outer layer. Vinyl tape has many applications, including as an outer layer where sunlight, flame, and cold resistance are required. Vinyl tape can be used for cable jacket repair, as primary replacement or when over-wrapping mastic, rubber or rubber mastic tapes for mechanical protection. Additionally, vinyl tape can be used to wrap around bundles of wires, as a marker tape and for many other creative applications.

Differences Between the Tapes

All three tapes meet or exceed the standard requirements as shown in their respective test reports, see **References 3 and 4** for Scotch® Vinyl Electrical Tape Super 88 reports and **Reference 5** for the Scotch® Super 33+™ Vinyl Electrical Tape report.

While all these tapes have professional grade elastic vinyl (PVC) backing with a non-corrosive rubber, pressure-sensitive adhesive, there are a few differences between the three tapes.

- Scotch® Super 33+™ Tape and Scotch® Vinyl Electrical Tape 35 have nominal thicknesses of 0.178 mm (7 mil).
- For heavier duty applications, Scotch® Tape Super 88 has a nominal thickness of 0.216 mm (8.5 mil).
- Scotch® Super 33+™ Tape and Scotch® Tape Super 88 are both black in color, but Scotch® Tape 35 comes in 10 different colors.

Installation Considerations

When installing vinyl tape, it is important to stretch it between 50% and 75% of its original width so that it will conform and apply inward pressure to provide a seal. It is also recommended to overlap the tape by 50% when applying. However, it is also important to not stretch the last wrap, which will ensure that the tape doesn't flag. When using the vinyl tape as an outer layer over rubber tape, it should cover all the rubber so that the UV- and cold-resistant and flame-retardant qualities of the vinyl can be utilized.



The information contained in this paper is intended for occupational use by persons with the knowledge and technical skills to use such information. It is supplemental only and is not intended to replace the detailed information found in written 3M product instruction and installation manuals.



Standard Requirement Comparison

Table 2 compares some properties of Scotch® Super 33+™ Vinyl Electrical Tape and Scotch® Vinyl Electrical Tape Super 88 to the standard requirements. The data for Scotch® Super 33+™ Tape and Scotch® Tape Super 88 come from the test reports referenced at the end of this paper. See **References 3 and 4** for Scotch® Tape Super 88 reports and **Reference 5** for the Scotch® Super 33+™ Tape report.

Table 2: Vinyl Tape Property Comparison

Property	Elongation (%)	Elongation at -18°C/0°F (%)	Adhesion to Steel oz/in (N/cm)	Adhesion to Backing oz/in (N/cm)	Adhesion to Steel at -18°C/0°F oz/in (N/cm)	Adhesion to Backing at -18°C/0°F oz/in (N/cm)
Standard/Requirement	UL 510 100% Min	ASTM D1000 125% Min	UL 510 16 (2.7) Min	UL 510 16 (2.7) Min	ASTM D1000 30 (3.3) Min	ASTM D1000 30 (3.3) Min
Scotch® Super 33+™ Vinyl Electrical Tape (7 mils)	305	180	25.5 (2.8)	24.5 (2.7)	90.8 (9.9)	79.5 (8.7)
Scotch® Vinyl Electrical Tape Super 88 (8.5 mils)	326	216	27.1 (3.0)	26.6 (2.9)	100.5 (11.0)	86.8 (9.5)

These 3M™ Vinyl Electrical Tapes have high elongation and adhesion in all weather conditions. Having one tape that works well in demanding weather conditions and temperatures is critical to the linemen using the tape.

All three tapes are flame retardant. They pass deformation requirements and storage requirements of Underwriters Laboratories UL 510. The three tapes featured exceed all standard requirements listed in **Table 2**.

Scotch® Rubber Mastic Tape 2228

Properties, Advantages and Applications

Scotch® Rubber Mastic Tape 2228 is a versatile tape with impressive electrical insulating abilities that should be a requirement for all installers. This is a nominal 1.65 mm (65 mil) thick, premium grade, highly conformable, self-fusing rubber electrical insulating and sealing tape. It has Scotch® Linerless Rubber Splicing Tape 130C as its backing with temperature stable mastic adhesive laminated onto it. The mastic is electrically insulating and provides an excellent moisture seal. It is compatible with and bonds well to cable insulation and jacket materials. Excellent for moisture sealing, it is weather resistant and good for both indoor and outdoor applications. The tape is a UL Recognized Component for applications up to 130°C/266°F.



There are many uses for this tape such as the primary insulation for splices or cables rated to 1,000 volts. It is also an excellent moisture seal for cable and wire connections, service drops, ground wire and ground rod connections. It can be used to build up the diameter of power cables to ensure a good jacket seal. The tape is versatile enough to insulate bus bar connections, including irregular-shaped bus bar bolted connections, and to insulate and provide vibration protection for motor connections.

Installation Considerations

The thickness of this tape helps build up diameters faster when used for sealing jackets of power cables. When installing, the tape should be stretched to about 75% of its original width. When installed as the primary insulation for cables, it should be applied in half-lapped layers until the desired thickness is achieved. When installing to build up the diameter of the cable jacket for a cold shrink jacket tube, the layers should be applied directly on top of each other.

To finish wrapping rubber tape, one good way to end is to use the palm of your hand and push down and out on the end of the stretched tape. This provides a very thin end, so there is no big step to fill, and pushes it down into the existing tape so that it will stay in place.

There is an application technique to remember when using this tape for bus bar connections and motor lead connections: it is not recommended to apply with mastic directly on the bolted connections because it will bond and be difficult to remove if access to the bolted connection is required. If applying directly to the bolted connections, it is best to apply with the mastic out, but it is also better to cover the bolted connections with vinyl electrical tape with adhesive side out, glass cloth tape with adhesive side out or some other tape. By applying these tapes first with the adhesive side out, the insulation can be cut off and the connections will be clean. This tape can also be used as a jacket repair tape. For this application and many other applications where mechanical protection or increased UV-resistance are required, the tape is over-wrapped with two half-lapped layers of vinyl.

Scotch® Electrical Semi-Conducting Tape 13

Properties, Advantages and Applications

Scotch® Electrical Tape 13 is a conformable semi-conductive, high-voltage rubber splicing tape. Semi-conductive means that the tape conducts voltage, but not current. This tape has a low, stable conductivity over a wide temperature range and is rated for use up to 130°C/266°F. It is easily stretched to conform to shapes, retains its low conductivity when stretched and it is compatible with most extruded cable insulations, semi-conductive layers and jackets. It can be used in indoor or outdoor applications. The tape is resistant to cracking from UV light, solvents or moisture. It also meets the requirements of the American Society for Testing and Materials ASTM D 4388 Type IV.



This tape is used in many applications, such as creating the Faraday cage over connectors on tape splices or for the 3M™ Cold Shrink QS200E Splice. It can also be used to extend the cable insulation shield across tape splices, create the semi-conductive ramp for a geometric tape stress cone, repair damaged cable insulation shield, round out bolts on bolted connections and more. This tape works well for any application where a semi-conducting material is required.

Installation Considerations

When applying Scotch® Electrical Tape 13, it should be stretched to a minimum of 75% of its original width. Stretching lowers the conductivity of the tape and provides inward sealing pressure to allow the tape to conform better. It should be applied in half-lapped layers with a minimum of two layers for most applications.

When covering a connector, it is recommended to start taping in the middle of the connector, apply the tape in half-lapped layers in one direction, then tape to the other end and back to the middle, where the tape can be ended by using the heel of your hand to push down and out. This provides a thin end of the tape and pushes it into the existing tape. This method minimizes the step that would be created at the end of the tape which helps minimize electrical stress.

When using as an electrode over a connector, only leave one thickness of tape at each end when applying the two layers. A large step at the end of the electrode creates a high stress point and is difficult to fill in with insulating tape without getting an air void.

This tape should only be used with extruded cables because the low-viscosity oil in oil-filled cables will cause the tape to expand and lose its conductivity, as the carbon molecules separate by the expansion.

Scotch® Electrical Tape 13 has proven to be very reliable when correctly installed and has been in service in some tape splices for over 50 years.

Scotch® Fire-Retardant Electric Arc Proofing Tape 77

Properties, Advantages and Applications

This fire-retardant, electrical arc proofing tape comes in white or black and is 0.76 mm (30 mil) thick. Scotch® Tape 77 comes in either a 39.6 mm (1.5") wide or a 76.2 mm (3") wide roll. Both rolls are 609.6 cm (20') long. The tape passes the following tests: Consolidated Edison Specification EO-5343 "Arc and Fire Resistant Materials Used for Cable Wraps", UL 94 "Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances", and ASTM D2863-19 "Standard Test Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics (Oxygen Index)", as noted in the test report **Reference 6** on the last page.

The tape helps protect electrical power cables from heat and flame from nearby faulted power cables. This halogen-containing elastomeric tape is formulated to generate a thick, insulating charred build-up when exposed to high temperatures. The insulating charred build-up helps protect wrapped cables and cable accessories from the fault arc-generated heat and flames of cable failures within approximately 50.8 cm (20") until limiting devices can interrupt the faulted circuit.

Because tapes within the Scotch® Tape 77 Series are elastomeric and unsupported, they are very conformable. Installers can provide virtually wrinkle-free coverage of cables and irregularly-shaped cable accessories easily and rapidly. This exceptional conformability provides better product control while wrapping and yields more uniform coverage. Also, the tape's thin cross section helps reduce the overall weight compared to other methods while providing arc protection.

Scotch® Tape 77 allows for easy installation and removal for inspection because there is no adhesive on the tape. The tape is self extinguishing and will not support combustion. It allows heat to be dissipated from the cable and accessories so the system doesn't have to be derated. The tape is resistant to water, salt water, sewage, acids and UV light. The white gray color of Scotch® Tape 77 White makes it easy to see where it has been charred so that it can be replaced to help protect the system underneath.

Installation Considerations

For installation, it is recommended to slightly stretch the tape so that it conforms and creates a smooth installation. Since the tape has no adhesive, it is also recommended to lock down the first and last wrap with two layers of 3M™ Glass Cloth Electrical Tape 69. When applying a new roll of tape, it is recommended to overwrap 152.4 mm (6") of the existing roll of the protected cable system.

One half-lap wrap provides adequate protection for most installations. However, if conditions warrant, additional wraps can be applied without requiring a reduction in conductor loads.



Scotch® Self-Fusing Silicone Rubber Electrical Tape 70 and Scotch® Self-Fusing Silicone Rubber Electrical Tape 70 HDT

Properties, Advantages and Applications

Scotch® Tape 70 and Scotch® Tape 70 HDT (High Density Tape) are high temperature silicone rubber electrical tapes with easy-tear liners. Scotch® Tape 70 is 0.3 mm (0.012") thick and the Scotch® Tape 70 HDT is tapered to help make installation easier, so it is 0.20 mm (0.008") thick on the edges and increases to 0.51 mm (0.020") thick at the center of the tape. Both tapes are very conformable and can be applied at both high and low temperatures.

The tapes have excellent arc- track- and ozone-resistance and have a National Electrical Manufacturer Association (NEMA) Class H temperature rating (180°C/356°F). The tapes have a high dielectric strength of 600 V/mil and excellent fusion so that multiple layers become one continuous piece of rubber.

The tapes have many applications and can be used as the primary insulation for low-voltage (up to 1,000 volts) high-temperature cables, such as cables with silicone insulation. When hand taped geometric medium-voltage terminations are made with rubber tapes, this silicone tape should be the outer track resistant layer. Where cable insulation is exposed on terminations, these silicone tapes should be used to cover the cable insulation to help protect against tracking by leakage current. An example of this type of application would be an existing taped geometric termination, which is too long to meet the standards, with a newer high dielectric stress control termination installed on a new cable next to it. To help avoid failures, the semicons of both cables should be on the same plane, which means there is a lot of cable exposed above the high dielectric termination. This cable insulation must be covered with Scotch® Tape 70 to help protect it from tracking. Scotch® Tape 70 can also be used as the outer layer on any outdoor splices, such as for spacer cables, to provide UV and tracking protection.

Installation Considerations

The silicone tapes should be applied typically in half-lapped layers with moderate tension (10% – 100% stretch) until the desired thickness is achieved. For terminations, the tape can be applied in multiple layers on the lug barrel if needed to build up the diameter. Do not stretch the last one or two wraps of the tape and remember to press it into the tape underneath so that it will fuse together and not unwrap.



The tapes' light gray color has an interesting history. When 3M™ Cold Shrink QT-II Terminations and Scotch® Tape 70 were developed, Lyndon B. Johnson was president of the United States of America and his wife Lady Bird Johnson required that the terminations and silicone tape be a light gray color so they wouldn't be as visible against the sky background.

Scotch® Cable Jacket Repair Tape 2234

Properties, Advantages and Applications

Scotch® Tape 2234 is a very tough tape that provides a cost-effective and efficient means of repairing damaged jackets of power cables. The outer layer of the tape is composed of vulcanized Chlorosulfonated Polyethylene (CSM) rubber to provide outstanding chemical and environmental resistance. The inner layer is composed of flame-retardant mastic and acts as a moisture barrier and seal which provides excellent adhesion to a variety of jacket materials.

The tape is flame retardant and has excellent abrasion resistance. It is resistant to heat, oil, UV light and ozone. The mastic bonds and provides an excellent environmental seal. The tape maintains its flexibility to -30°C/-22°F and is rated up to 105°C/221°F.



Installation Considerations

During installation, the tape should be slightly stretched and installed in half-lapped layers. The last wrap should be installed with no stretch and both the beginning and ending wraps should be wrapped with vinyl tape, either Scotch® Super 33+™ Vinyl Electrical Tape or Scotch® Vinyl Electrical Tape Super 88.



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Summary

For over 75 years, Scotch® Electrical Tape has been the pro's choice for trusted quality and performance that stands the test of time. As applications and requirements continue to evolve, 3M constantly strives to improve its tape offerings. If you have unusual tape applications, please ask your representative what 3M tape solutions can help you solve your problem.

Please ask your 3M sales representative for the test reports that are listed in the references on the last page. They show the actual values of the tape characteristics, which are generally higher than the values listed on a data sheet.

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6. RPT-816876_1 – EMD External Test Report – 3M Scotch® Fire-Retardant Electric Arc Proofing Tape 77



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