

nTMM Magnets Assembly Protocol and Budget

General

- Second Magnet Vessel ready at UT, going through leak test. Can Chris take it to UKY on July 17?
- All mu metal for 2 magnets is at UKY
- 18 AWG wires for 8-layers **ONE** magnet are at UKY. For **second** magnet wires to be purchased.
- The magnets assembly at UKY will incl. 8-wire layers coil and 2-layers mu-metal with 8 black clamps.
- Four mu-metal disks OD = 226.0 mm with square holes and slits for wires
to be manufactured at UKY (ORNL drawings)
- Four 1-mm Al wire-supporting disks OD = 226.0 mm with round holes and slits for wires
to be manufactured at UKY (ORNL drawings)
- After transportation from UKY to UTK magnets will be filled with CO₂ and tested for transport-survival incl. leaks and resistance. Magnet(s) will be painted at UTK by Z360 black paint.
- After UTK test magnet(s) will be transported to ORNL for the test in vacuum chamber.

Possible assembly scheme of 8-layer magnet

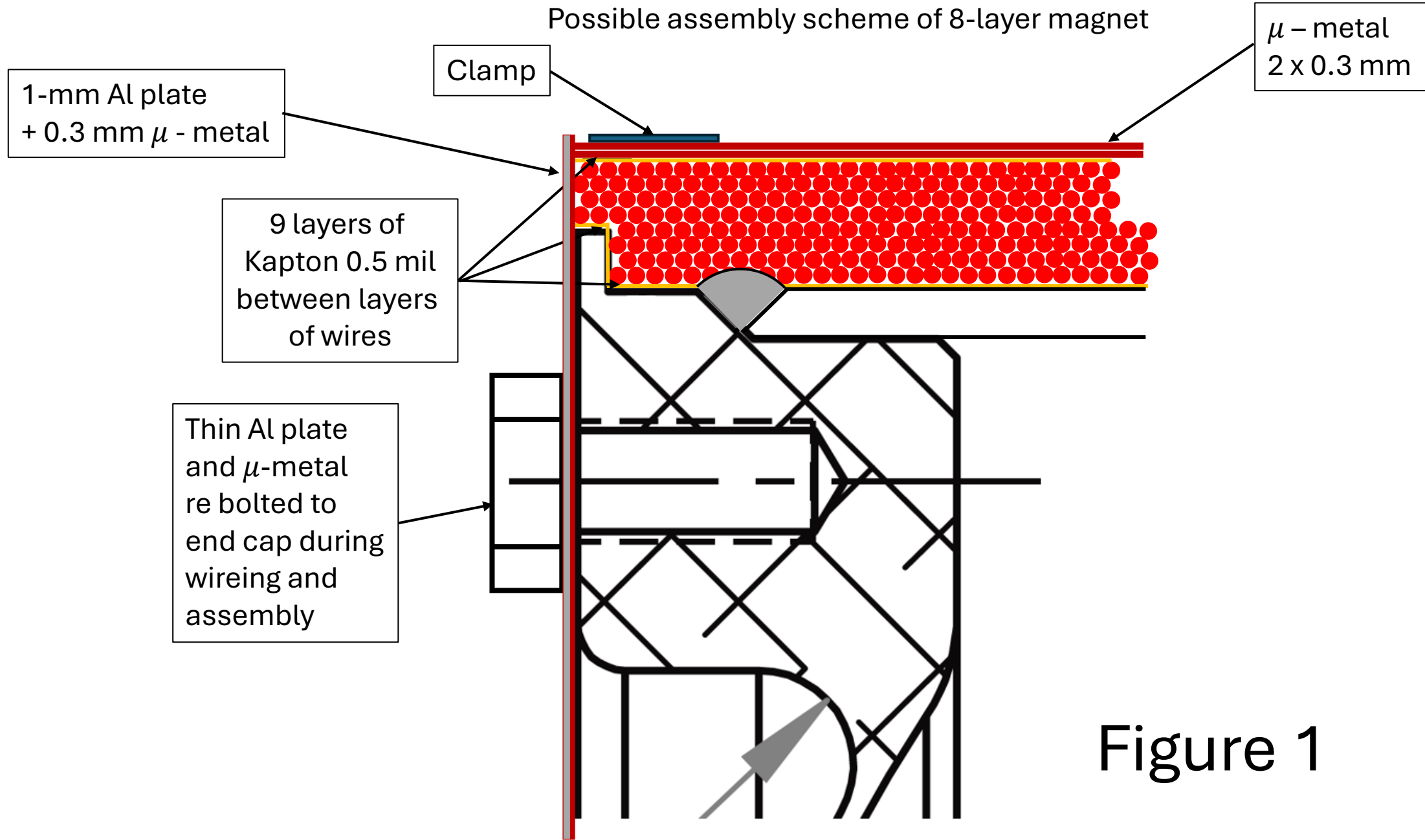
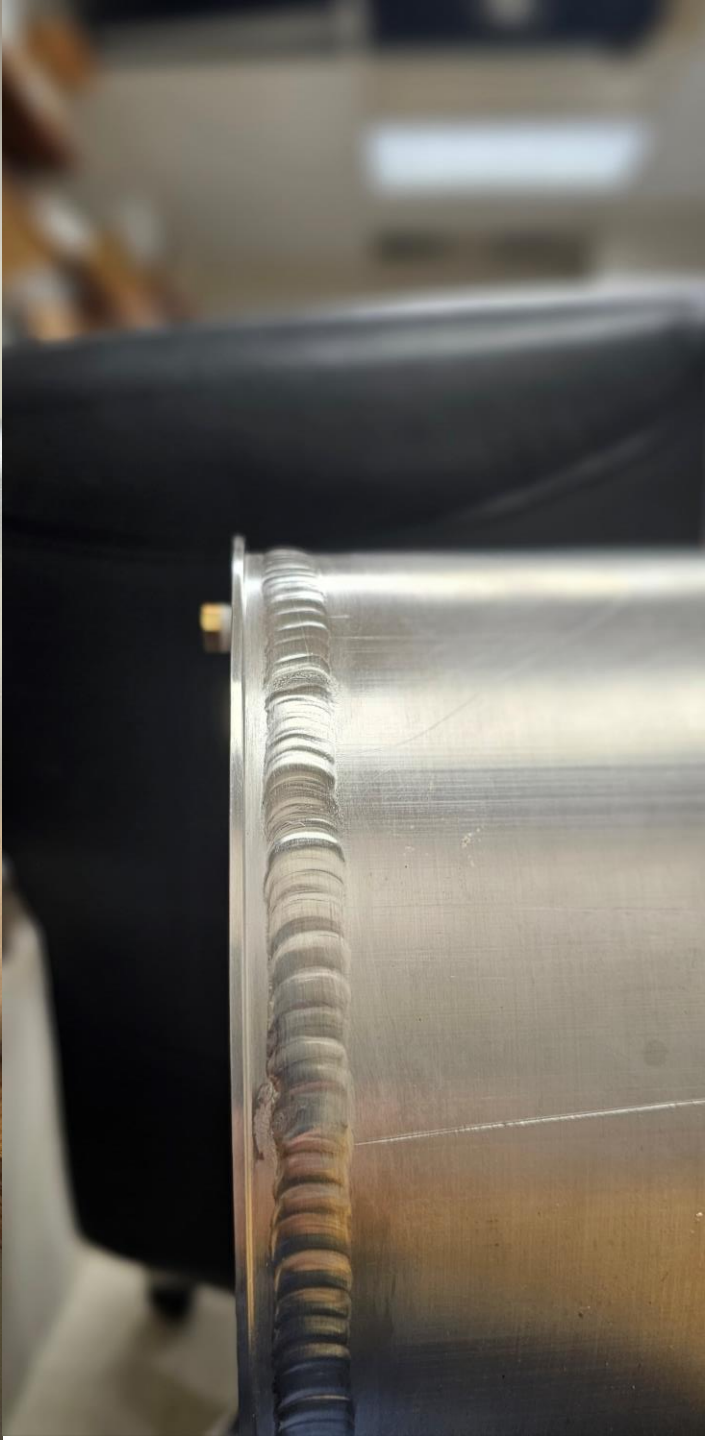
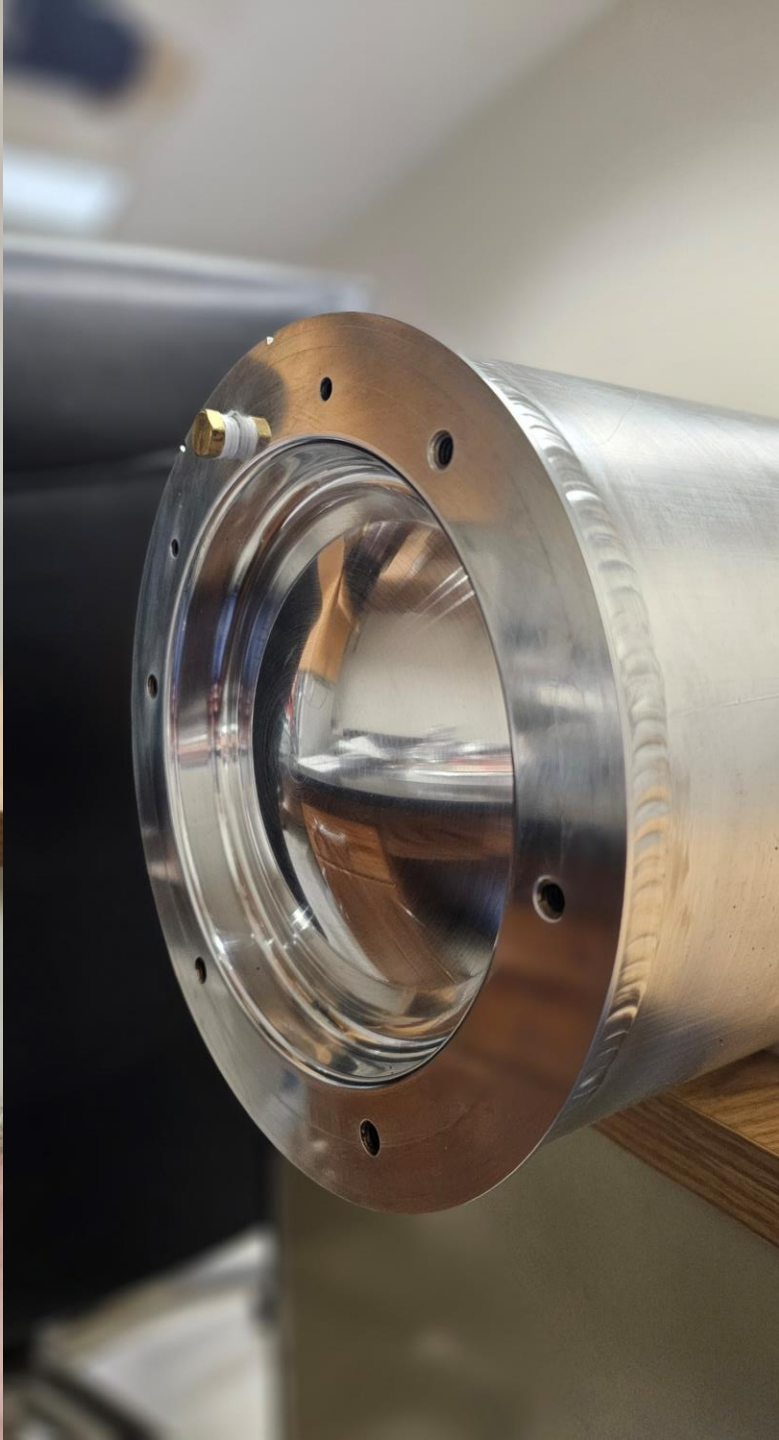
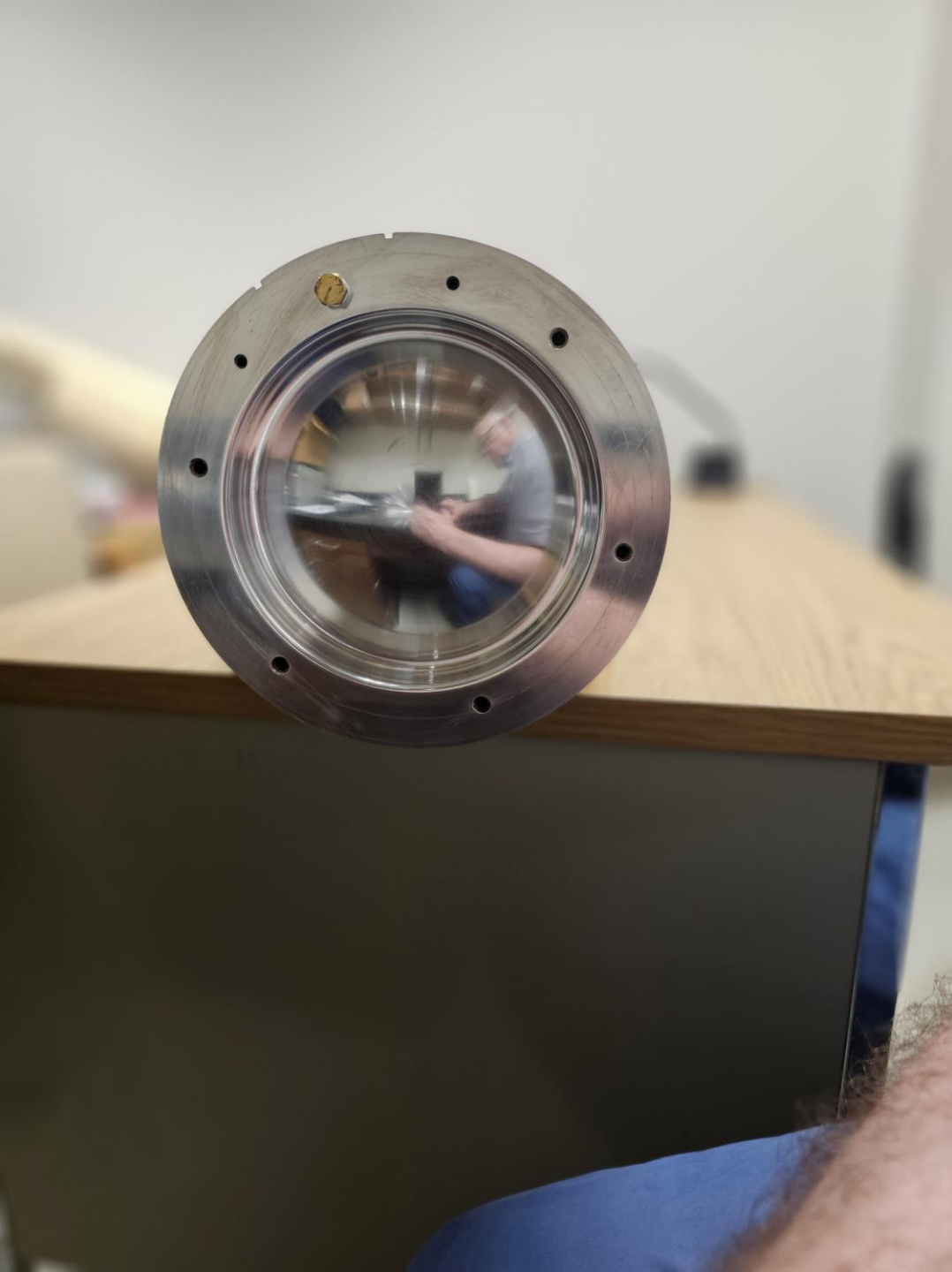


Figure 1



Assembly features:

- In a magnet the number of layers of wires is 8, or 4 double layers. In double layer two end-leads are on the same side allowing twisted pair connection.
- 0.5 mil layer of Kapton should be used between the Aluminum vessel and the first layer of wires, between every two layer of wires, and between last layer of wires and mu-metal. Contact of wires with grounded metal surface should be avoided.
- Every double layer of wires have two connection end-leads for versatility of connection. End wire connector should be used like e.g. [WAGO 221-2401](#) or more simple from TEMU [LINK](#)
- With wire resistance is $20.943 \Omega/\text{km}$ and length per double layer of 1.879 km the resistance of double layer should be $\sim 39.35 \Omega$ (depends on wire spacing). If double layers are serially connected (total $R=157.4 \Omega$) with correct polarity and are consuming current 0.36 A, the total expected voltage will be 56.8 V and power 20.4 W per magnet. That is for maximal magnetic field of 30 Gauss. Magnetic field is regulated by current, so the Constant Current (CC) power supply with computer controls will be required.
- Copper wire OD = 1.062 mm, however, wire-spacing in the coil is larger than the diameter. Assumed spacing (from prototype) is 1.19 mm. This is an important parameter that should be the same for all wire layers and in both magnets. It is the same thing as the number of wire loops in the layer. The latter number is determined by the total available spacing $68.43_{-0.06}^{+0.00}$ inches. In wire winding the advance per one rotation should be a stable constant in the range 1.10 – 1.15 mm.

Mu-metal cutting. Total purchased length 76 ft (38 ft per magnet)

Mu-metal is 0.012" = 0.305 mm thick with width of 12.0"

Per magnet required length ~ 36.6 ft:

1. First layer: 30" long (with ~ 2" overlap) x 7 pc (~ 2.5" overlap) = 210" = 17.5 ft
2. Second layer: 3 pc x 68.43" (~2.7" overlap) = 205.29" = 17.1075 ft
3. Endcaps mu-metal: 2 x OD=226 mm (drawing ORNL with slits for power wire exits)
cut from 2 x 1' x 1' pieces
4. In First and Second mu-metal layers there should be a synchronized notch 1" x 0.1"
for the return of the degaussing wires
5. UKY assembles 2 layers of mu-metals with mu-metal bending, clamps and degaussing layer
(see below). At UTK the outer layer of mu-metal (3 pc) will be un-installed; the overlapping contact
metal area will be masked with tape, and these three long pieces of mu-metal will be painted with
Z360 paint.

Question: should also magnet endcaps be painted with Z306? How about supporting structure in contact?

Isaiah will suggest the answer

Samples painted with Z360

12 inch



Protocol of Magnet(s) assembly/winding at UKY

1. Magnets are supported at the ends for axial rotation by the end-gadgets (designed at UKY) bolted to the vessel end-caps. Before mounting the gadgets 1 mm thick Al disk and 0.3 mm mu-metal disk are attached to the vessel flanges (see Fig.1). These Al and mu-metal disks will be drawn at ORNL and manufactured at UKY. The mu-metal sheets will be laser cut. Sharp corners will be rounded. Side of the mu-metal on the disk as well as 2 x 4 mm ridge of the Al vessel flange that will be in contact with copper wire should be covered by one-side adhesive Kapton tape with thickness 0.0025" or less. The slit in Al and mu-metal disks (for wires exiting) should be covered with adhesive Kapton tape.
2. Magnet mounted on the UKY lathe.
3. All surfaces are carefully cleaned with iso-propyl alcohol 99%
4. Layer of 0.0005" non-adhesive Kapton 25" wide will cover the cylindrical surface. To provide the full surface coverage ~ 3" Kapton stripe should be added on the side fixed by adhesive Kapton tape ¼" wide. The whole sheet size should be $68.43_{-0.06}^{+0.00}$ inch x 28 inch. When Kapton layer installed it should be temporary fixed by the adhesive Kapton tape.
5. First layer of wires is winded. Number of winds should be counted and be the same in all layers for both magnets.
6. On the top of the first layer of wires a layer of Kapton film 0.0005" x 28" x 68.43" (see above) is installed
7. Second layer of wires is winded. Ends of 1-st and 2-nd layers are exiting through the slit in Al and mu-metal. Tails about 5"-long should be left outside with connectors mounted and labeled.

Continued

8. Next 7 layers of Kapton film and wires are installed in the same way as above. Each double-layer of wires after winding should be tested for the resistance of ~ 39 Ohms. Also, infinite resistance should be observed between every double-layer of wire and the Aluminum vessel and mu-shield.

9. Over the last 8-th layer of wires there is a layer of Kapton to isolate wire from the mu-metal, so, the total number of Kapton layers is 9.

10. On a top of the final layer of Kapton a degaussing coil is laid out between two adhesive tapes 68.23"-long 1"-wide (see picture). Coil consists of 10 wires 18 AWG arranged in a close parallel row on a top of Last Kapton film layer with dimensions $\frac{1}{2}$ " wide x 68.43" long. These individual wires have on each side of the main length (that will be below the mu-shield) an additional ~ 1 -2 m length for the coil Interconnection on the top of mu-shield (see picture). Corresponding notch 1" wide azimuthally and 0.1" along the length is made in both mu-metal layers at the ends of the magnet. These notches are covered by adhesive Kapton tape to prevent mu-metal contact with degaussing wires.



11. Seven (7) pre-bend mu-metal transversal sheets with size 12" x 28" are installed with ~ 2.5 " overlap. They are fixed temporary in place by the adhesive Kapton tape.

12. Three (3) pre-bend mu-metal longitudinal layers with size 68.43" x 12" are installed with ~ 3 " overlap. They are fixed in place with eight black-colored SS clamps located along the length at the ends of the shield and at the joints of transversal layers.

<https://americandurafilm.com/shop/kapton-film/kapton-hn-films/>

Kapton tape roll with length 160 ft

American Durafilm Shop

	Kapton® HN Films - .0005", 25" \$5.88	- 160 +	\$940.80
	Kapton® HN Films - .001", 50" \$4.66	- 160 +	\$745.60

Calculate Shipping Rates
Shipping

- UPS Ground: **\$27.83**
- UPS 2nd Day Air: **\$108.28**
- UPS 3 Day Select: **\$74.66**
- UPS Next Day Air: **\$224.68**

Shipping to
Knoxville, TN 37966

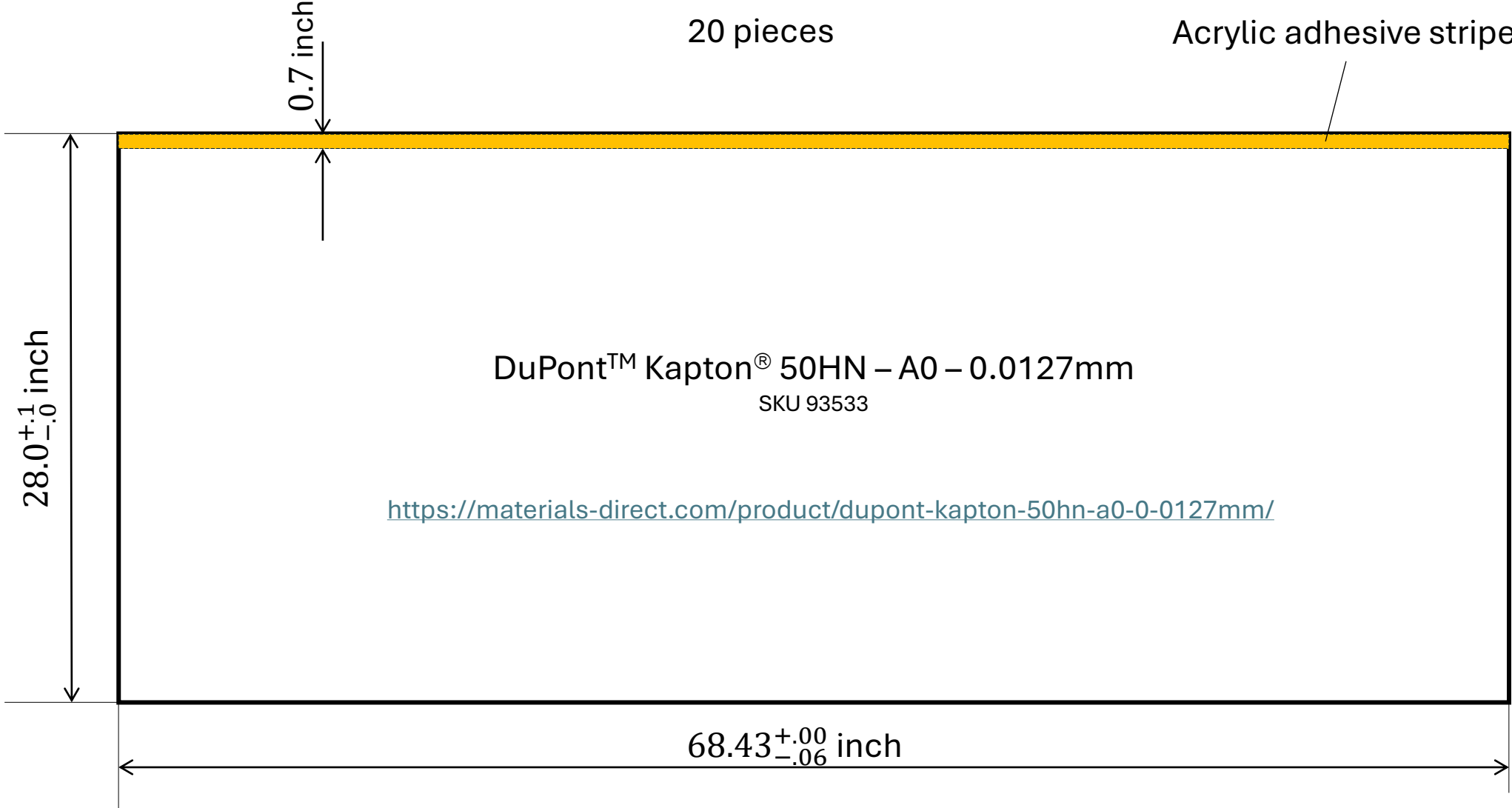
[Change address](#)

Subtotal	\$940.80
Tax	\$0.00
Total	\$968.63

Can be cut in size: 28" x 68.43" with adhesive coat
DuPont™ Kapton® 50HN – A0 – 0.0127mm
Thermally Conductive Substrate Polyimide Film
<https://materials-direct.com/product/dupont-kapton-50hn-a0-0-0127mm/>

Quote should be requested, requires a .dxf drawing

Cutting Kapton film



Black Stainless Steel Adjustable Clamps



ISPINNER 2pcs 10 Inch Stainless Steel Adjustable
241-267mm Size Range Worm Gear Hose Clamp,
Fuel Line Clamp for Plumbing, Automotive and
Mechanical Application (Black)

[Amazon link](#)

\$10⁹⁹ (\$5.50 / Count)

We need 8 of these
for each magnet



<https://www.accuglassproducts.com/components/kapton-tape-adhesive>



110794 and 110793 /
1/4 and 1 Inch Kapton® Tape, with Acrylic and Silicone Adhesive, respectively

Kapton® Tape

Kapton® Tape provides a clean, flexible electrical insulation with low outgassing characteristics. It has a dielectric strength of 7500 volts and a tensile strength of 30 lbs/inch-width. It is suitable for use in ultrahigh vacuum applications. Available with acrylic or silicone adhesive.

Kapton® Tape — See Above / UHV to 1x10⁻¹⁰ Torr

Qty. (Rolls)	Width	Thickness	Length (Yards)	Model Number	Part Number	Unit Price \$
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Single Sided — Acrylic Adhesive / -30°C to 175°C

1	0.250	0.0025	36	KAP-TP-36-1/4A	110794	37
1	0.375	0.0025	36	KAP-TP-36-3/8A	111205	48
1	0.500	0.0025	36	KAP-TP-36-1/2A	110795	55
1	0.750	0.0025	36	KAP-TP-36-3/4A	111206	78
1	1.000	0.0025	36	KAP-TP-36-1A	110790	100
1	2.000	0.0025	36	KAP-TP-36-2A	111207	193

Single Sided — Silicone Adhesive / -75°C to 260°C, with minimal outgassing above 120°C


1	0.250	0.0035	36	KAP-TP-36-1/4S	110791	48
1	0.375	0.0035	36	KAP-TP-36-3/8S	111200	57
1	0.500	0.0035	36	KAP-TP-36-1/2S	110792	75
1	0.750	0.0035	36	KAP-TP-36-3/4S	111201	108
1	1.000	0.0035	36	KAP-TP-36-1S	110793	140
1	2.000	0.0035	36	KAP-TP-36-2S	111202	278
1	4.000	0.0035	36	KAP-TP-36-4S	111203	550
1	6.000	0.0035	36	KAP-TP-36-6S	111204	795

Double Sided¹ — Silicone Adhesive / -75°C to 260°C, with minimal outgassing above 120°C

1	0.250	0.004	36	KAP-TP-36-1/4SD	112740	54
1	0.500	0.004	36	KAP-TP-36-1/2SD	112741	95
1	0.750	0.004	36	KAP-TP-36-3/4SD	112742	148
1	1.000	0.004	36	KAP-TP-36-1SD	112743	167

1. 1.5 mil silicone adhesive on both sides of 1 mil thick Kapton film

Kapton Adhesive Tape




Kapton® Tape - Acrylic 1/4" Wide **\$51.00**

Part Number: 110794

Kapton® Tape - Acrylic 1/4" Wide, 0.0025 inch thick. 36 yards long.

Quantity:

Add to Cart



Kapton® Tape - Acrylic 1" Wide **\$138.00**

Part Number: 110790

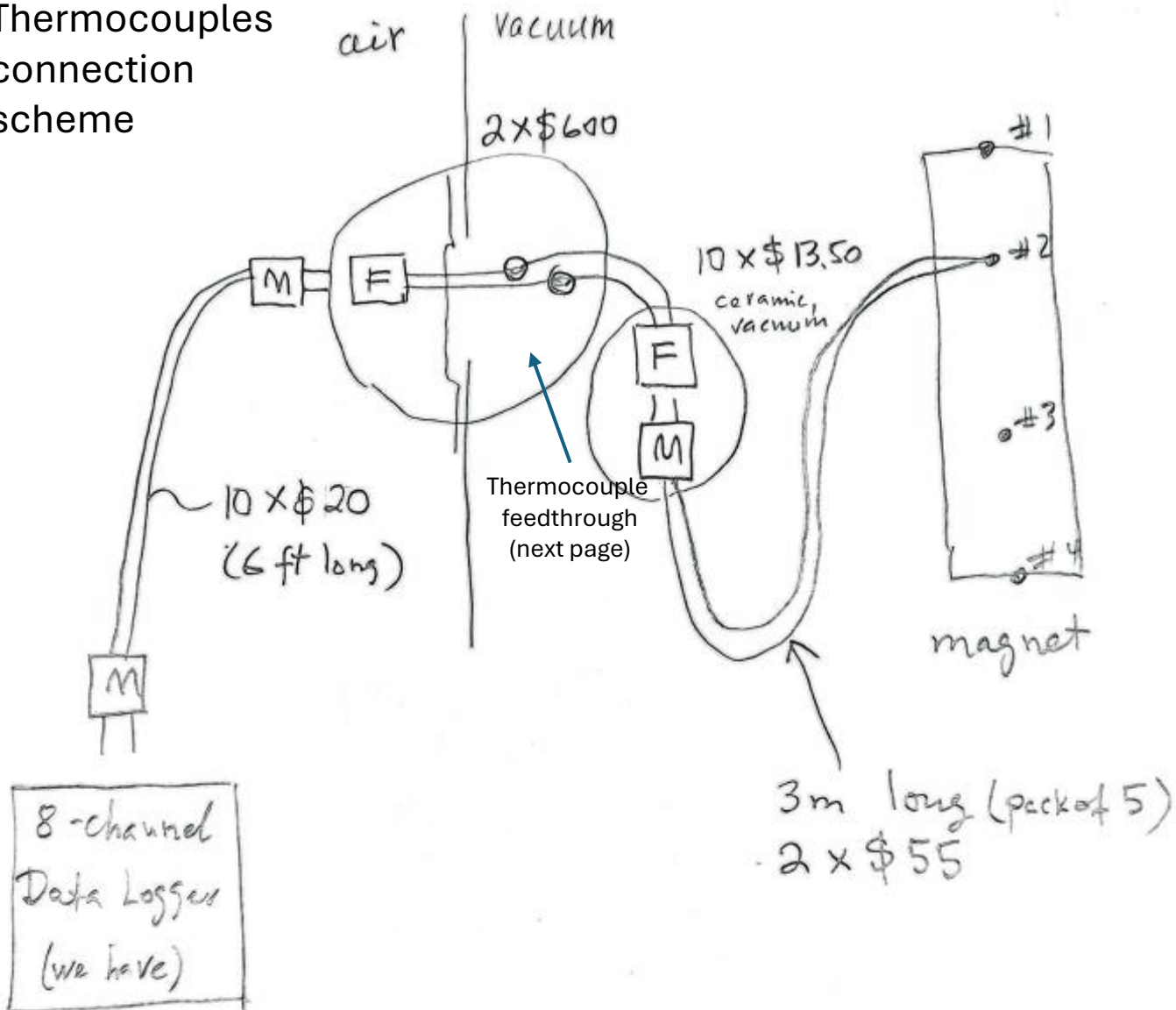
Kapton® tape, 1" wide, 0.0025 inch thick, with acrylic adhesive. 36 yards long....

Quantity:

Add to Cart

System of thermocouples

Thermocouples connection scheme



Question: where thermocouples should be mounted on the magnets to provide a relevant valuable information during experiment? Probably best will be mount them on the end flanges of the vessel.

Tip of thermocouple should be installed on the Kapton tape pad and covered by another Kapton Pad. The tip should not be in contact with metal.

Thermocouple vacuum feedthrough 5 pairs K-type

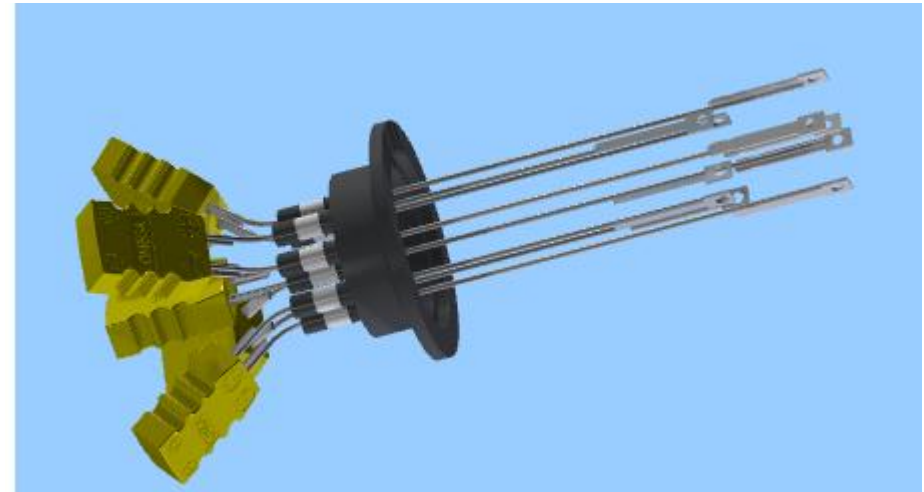
<https://www.lesker.com/feedthroughs/thermocouple-feedthroughs-typek-miniplug-singleend/part/tft5ky00008b>

TFT5KY00008B

THERMOCOUPLE FEEDTHROUGH, SINGLE ENDED, 5 PAIR
TYPE K, MINI PLUG STYLE ATM CONNECTOR, MOUNTED
ON A QF40 FLANGE

Unit Price: \$600.00

Availability: In Stock



Inside the vacuum thermocouple cable interconnected by special vacuum connectors

Ceramic Miniature Thermocouple Connectors for High Temperature

Ultra High Temperature Miniature Connectors, Including Series for High Vacuum Applications

<https://www.omega.com/en-us/temperature-measurement/temperature-connectors-panels-and-block-assemblies/temperature-connectors/shx/p/USHX-K-M>

<https://assets.omega.com/pdf/connectors/thermocouple-and-rtd-connectors/SHX.pdf>

\$13.50 per pc. We need 10

652 In stock

Lead Time (If not in stock): 3 weeks

 **OMEGA**[™]
a DwyerOmega brand



Thermocouple connection from feedthrough to Data Logger

https://www.meter-depot.com/k-type-thermocouple-extension-cable-wire-with-mini-male-to-mini-male-connector/?setCurrencyId=1&sku=K-type-EXT-PVC-Mini-M-Mini-M%202ft&gad_source=1&gclid=EAlaIQobChMIh_TptK6GhwMV_zHUAR1DvQiqEAQYBCABEgLsxD_BwE



MN MEASUREMENT INSTRUMENTS™

K-Type Thermocouple Extension Cable Wire with Mini Male to Mini Male Connector

6 ft \$19.99 We need 10



Existing data logger

Amazon:

5pcs Pack High Accuracy K Type Mini-Connector Thermocouple Temperature Probe Sensor, 3 Meters Long Measure Range -50°C~482°C (-58°F~899°F)

Brand: HUNGTOR

5.0 ★★★★★ 4 ratings | [Search this page](#)



\$54⁹⁹ We need 10 → \$110

Or \$10.15 /mo (6 mo). Select from 1 plan

✓prime Two-Day

FREE Returns ▾

S Best price

Save up to 5% with business pricing. Sign up for a free Amazon Business account

Size: 3 M

1 M
\$44.99

3 M
\$54.99
✓prime

5 M
\$65.99
✓prime

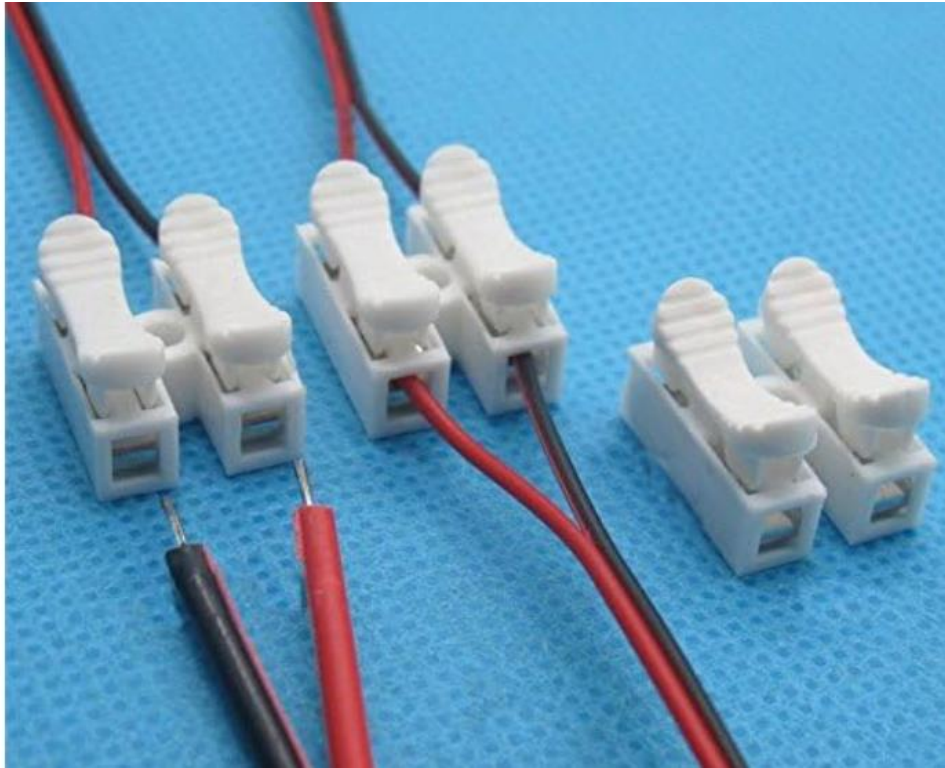
[Amazon Link](#)

- Product Name: K type thermocouple temperature probe sensors.
- Measurement range: 3 Meters Long Measure Range -50°C~482°C (-58°F~899°F).
- Good insulation: The thermocouple is insulated internally with fiberglass cable, allowing the thermocouple to be formed and bent without fear of cracking.
- Universal compatibility: Compatible with Type-K temperature measuring instruments, fast response time.
- High Accuracy, Ease of Use and Plug in & Play

Shown yellow connectors will be removed, cable will be cut in two pieces with the vacuum connectors in between.



Wire quick connectors for magnet power wires in vacuum



Tool-Free Wire Connectors 25 Pieces -
Quick Splice Terminal Blocks - No Crimp
Tool Needed

Brand: Nextronics

4.4 ★★★★★ 641 ratings | Search this page

300+ bought in past month

11 Price Changes

[Amazon link](#)

-10% \$4⁹⁷

This is an example. Many simple kinds exists

Other possible type: [Amazon link](#)

Jialan 2 Pin Connector 18 AWG Automotive
Waterproof Wire Connectors, Plug in Wire
Connectors Ideal for Motorcycle Car Boat
and Other Wire Connection-(5 kit)

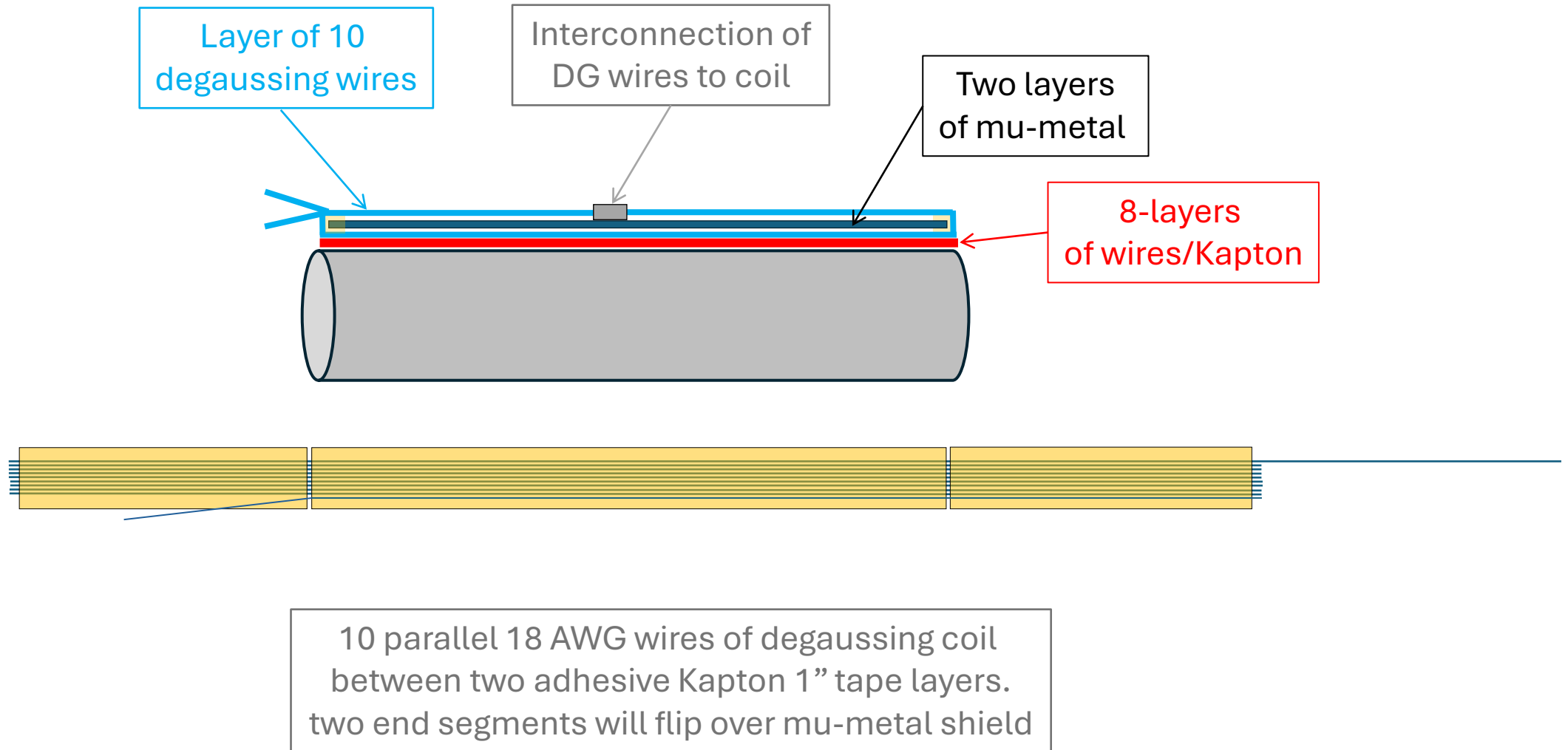
\$9.99



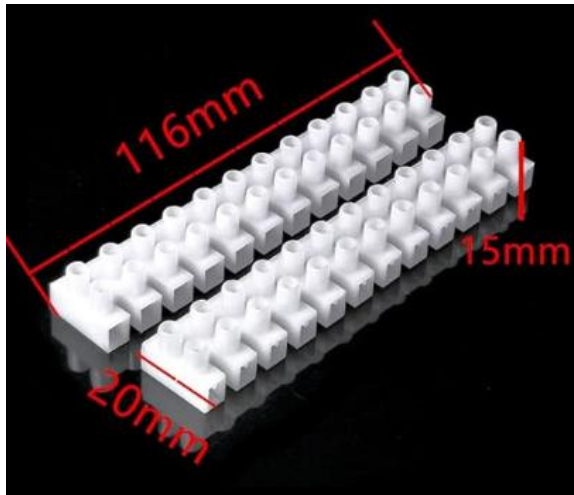
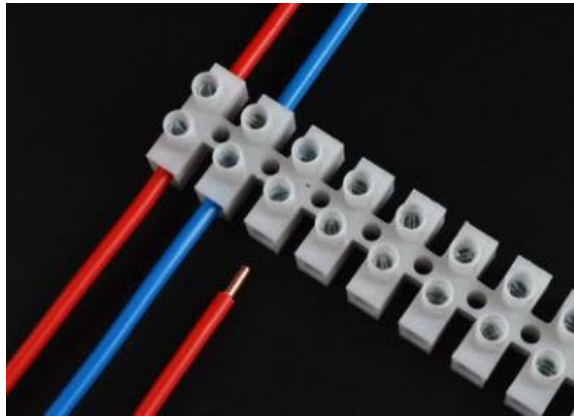
My favorite: WAGO Lever-Nuts Inline Splicing
Connector for Solid and Stranded Conductors,
2-Conductor with Operating Levers, 20-12 AWG,
Transparent Housing, White Cover [60 Pieces]
for \$24 [Amazon link](#)



Degaussing coil installation



Degaussing wires interconnection on the top of mu-metal




6pcs 450V 35A 12P Double Row Covered Barrier Screw Terminal Block Strip

Brand: uxcellyilufa

4.4 ★★★★★ 3 ratings | [Search this page](#)

[Amazon link](#)

 Best Price on Amazon

\$11⁰⁰ (\$1.83 / Item)

Alternative: [Amazon Link](#)

Marine Terminal Block Nickel Plated Brass 11 Gang 0113-10-3640-11 Dinkle 10 to 18 AWG Gauge 35A 600V

[Visit the International Connector Store](#)

4.6 ★★★★★ 65 ratings | [Search this page](#)

 Best Price on Amazon

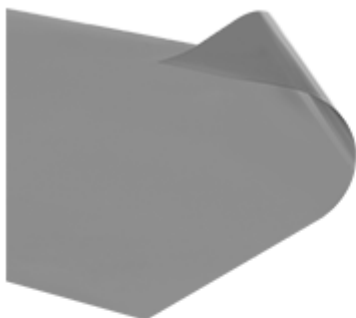
\$17⁹⁹




Purchase list (*-alternatives possible)

	Total
1. Two spools of 18 AWG wires from Remington	\$2,100
2. Kapton roll 0.0005" x 25" x 160 ft link	\$1,000
3. * Kapton acrylic adhesive tape for high vacuum 0.0025" x 1/4"x 36 yr link	\$ 51
4. WAGO 221-2401 connectors 20 pc link	\$ 10
5. Vacuum feedthrough for thermocouples x 2 link	\$1,200
6. Ceramic Miniature Thermocouple Connectors for vacuum x 10 link	\$ 135
7. High accuracy K-type thermocouple sensors 3 m long: 2 sets of 5 link	\$ 110
8. Male-Male Thermocouple connection cables x 10 link	\$ 200
9. Black ISPINNER 8-10-inch SS Clamps x 20 link	\$ 110
10. Kapton Adhesive Tape for high vacuum 0.0025' x 0.25" x 36 yr - 2 pc + 1" - 1 pc	\$ 102 +138
11. Power wire connectors in vacuum	\$ 20
12. Vacuum Feedthrough for power connection x 2	\$?
13. Z360 paint for 2 magnets 1 qt	\$ 225

Thermally Conductive Kapton® Polyimide Film



Because this film dissipates heat, it is often used for printed circuit boards and power supplies. It's made of Kapton® polyimide, which provides outstanding strength across a broad temperature range.

 For technical drawings and 3-D models, click on a part number.

Plain-Back Film

- Color: Amber
- Temperature Range: -450° to 750° F
- Tensile Strength: 20,000 psi (Excellent)
- Impact Strength: 0.58 ft.-lbs./in. (Poor)
- Hardness: Not Rated
- For Use Outdoors: No
- Specifications Met: UL 94 V-0

Thick.	Thick. Tolerance	12" x 12"		12" x 24"		24" x 24"	
		Part No.	Price	Part No.	Price	Part No.	Price
0.001"	-0.0001" to 0.0001"	2271K912	\$16.46	2271K913	\$32.90	2271K914	\$65.78

Kapton® Polyimide Film, Thermally Conductive,
24" x 24" x 0.001"

Each

ADD TO ORDER

Product Detail



3-D Solidworks

Download

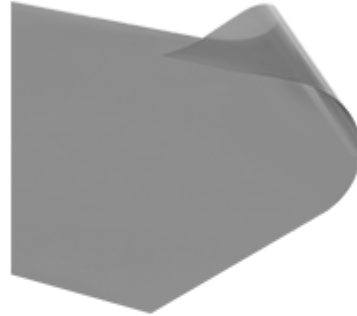
Electrical-Grade Kapton® Polyimide Film

This Kapton® polyimide film maintains outstanding strength and electrical insulating properties across a broad temperature range.

Amber plain-back film is also known as Type HN.

 For technical drawings and 3-D models, click on a part number.

Plain-Back Film—Semi-Clear Amber



- Temperature Range: -450° to 750° F
- Tensile Strength: 33,500 psi (Excellent)
- Impact Strength: 0.58 ft.-lbs./in. (Poor)
- Hardness: Not Rated
- For Use Outdoors: Yes
- Specifications Met:
 .001", .002", and .005" Thick.: ASTM D5213, UL 94 V-0
 .003" Thick.: ASTM D5213

Thick.	Thick. Tolerance	Lengths	Length	
			12" Wd. Each	24" Wd. Per Ft.
0.001"	-0.0001" to 0.0001"	1ft., 2ft., 3ft., 5ft., 10ft.		2271K41 \$24.06

Kapton® Polyimide Film, Electrical-Grade, 24" Wide, 0.0010" Thick

Each

ADD TO ORDER

Length
 1ft.
 2ft.
 3ft.
 5ft.
 10ft.

[Product Detail](#)





3-D Solidworks

Download

0.001"	-0.0001" to 0.0001"	12"	2271K1	\$13.82
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American Durafilm Shop

Kapton thermal conductivity 0.12 W/m-K; max temperature 400°C
Teflon thermal conductivity 0.25-0.30 W/m-K; max temperature 260°C

	Kapton® HN Films - .0005", 25" \$5.88	- 160 +	\$940.80	✕
	Teflon® FEP Films - .0005", 24" \$3.90	- 160 +	\$624.00	✕

