Chapter 5

Coil Winding
Layer, Foil, and Toroidal

Table of Contents

Introduction

Reliability is accomplished through control of design, materials, techniques, and processes. There are many applications where reliability is supreme. Programs that demand this type of reliability are spacecraft, aircraft, missile guidance, and internal medicine. A failure in any one of these programs cannot be tolerated.

Fabrication

The fabrication of a Hi-Rel magnetic component, such as a transformer and/or inductor, must be controlled from ordering of the parts through final inspection. The documentation to fabricate any magnetic component must be exact in every detail. Not one detail should be left to memory or standard operating procedure.

Construction

Transformers and inductors should be constructed according to the latest, signed engineering drawings. A complete up-to-date bill of materials should accompany, or be a part of, the engineering drawings.

Materials

Only materials specified by the engineering drawing should be used in the construction of transformers and inductors. Traceability of all materials is required, including shelf-life certification for materials with limited, life expectancy.

Documentation Requirements

Documentation shall contain all information necessary to fabricate and inspect flight-rated electronic equipment: physical, electrical, environmental, and process criteria.

Drawing Standards

All drawings shall conform to JPL, STD-00001 and ANSI Y14.5 for reproducibility.

Assembly Drawing

The assembly drawing provides eight major types of information:

A. A detailed drawing will show the package outline, terminals or lead location, mounting, and marking. See Figure 5-1.

B. The schematic diagram will show the sequence for all windings. The winding nearest the core would be W1. The next winding would be W2 and continues until the last winding. The schematic diagram will also show wire gauge, number of turns, and start and finish of each winding. See Figure 5-2.

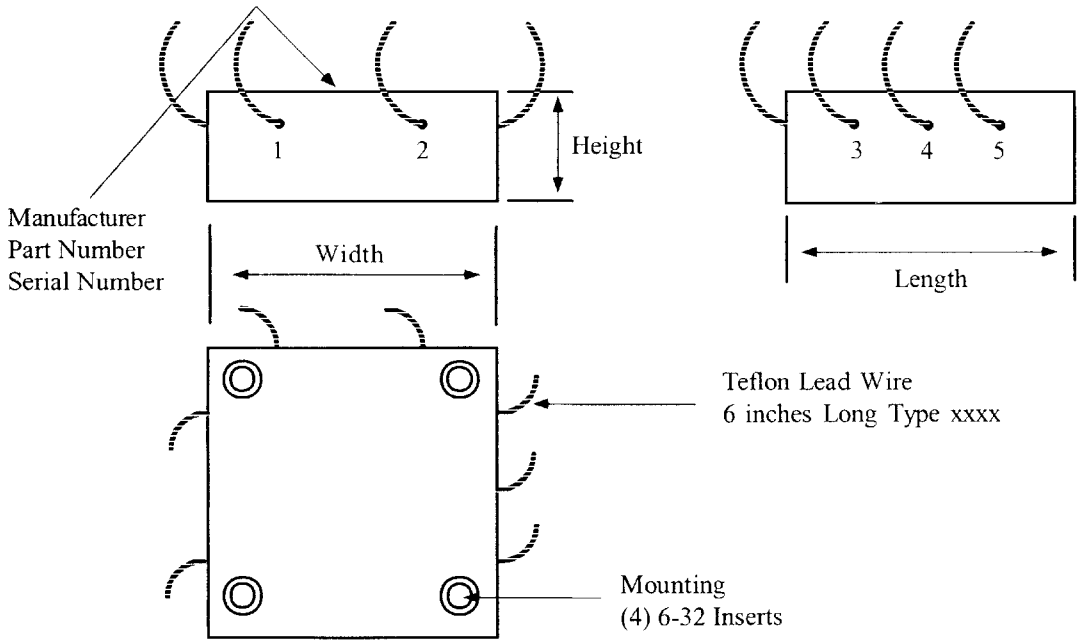

Figure 5-1. Typical Transformer Package Outline.

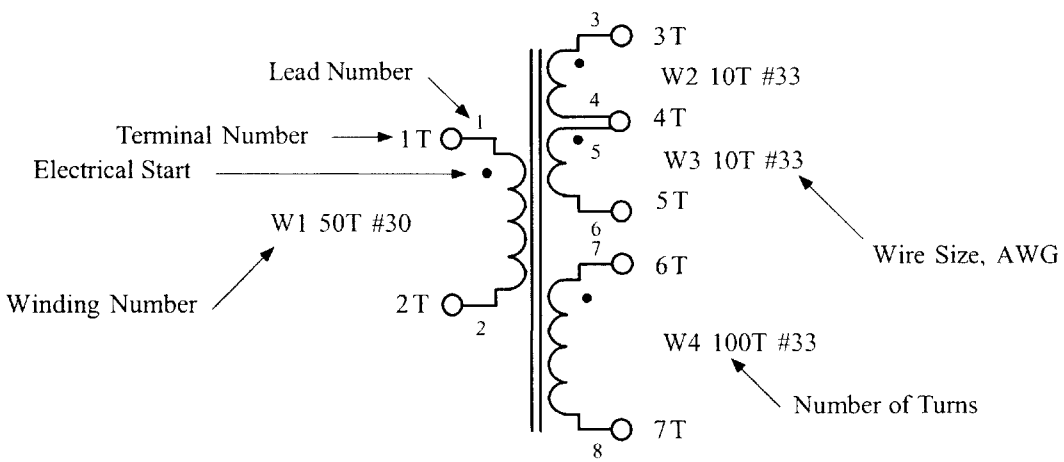

Figure 5-2. Typical Transformer Schematic Diagram.

C. The Winding Information is shown step-by-step:

Toroids

A winding location, a winding type, which is continuous or progressive, a multifilar winding, insulation, wrapper, and lead wire breakout is shown in Figures 5-3 and 5-4.

Bobbins and Layer Windings

A winding type that is, either layered or random, a multifilar winding, insulation, wrapper, and lead wire breakout is shown in Figure 5-5.

D. Winding instructions are required in the step-by-step approach from start to finish. These instructions would include: wrapping the core, placement of the winding on the toroid, the use of fiberglass sleeving over the start and finish lead, the number of turns, if it is layer wound, the turns per layer, the wire gauge, (AWG), including single strand or multifilar, and the required insulation. Each winding will be labeled for start and finish. See Table 5-1.

E. A complete electrical specification, is required which will include: dc resistance, winding inductance, turns ratio, magnetizing current, and the resonant frequency, and a schematic diagram of the test circuit and test equipment used.

F. A detailed drawing is required, showing the internal construction details, such as terminations, splices, lead dressing, bonding and potting. See Figure 5-6.

G. Assembly notes are required in a step-by-step process from start to finish. After the transformer is wound and tested, then, place it in the cup, bond it, terminate the leads, and make it ready for in-process testing. The last steps would be details on impregnating, embedment, and the final test and inspection. See Table 5-2.

H. The Parts' List will include: item number, quantity required, part number, Mil or industrial specification, nomenclature or description, material specification, and material suppliers. See Table 5-3.

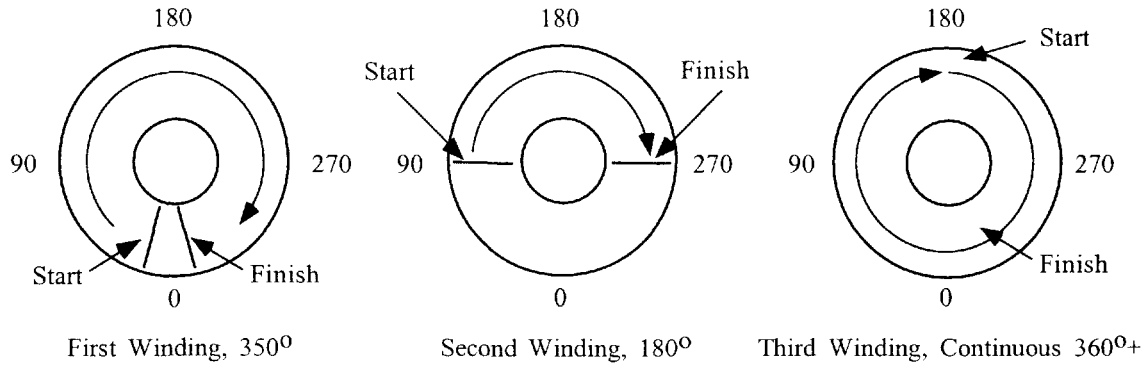

Figure 5-3. Toroidal transformer winding locations.

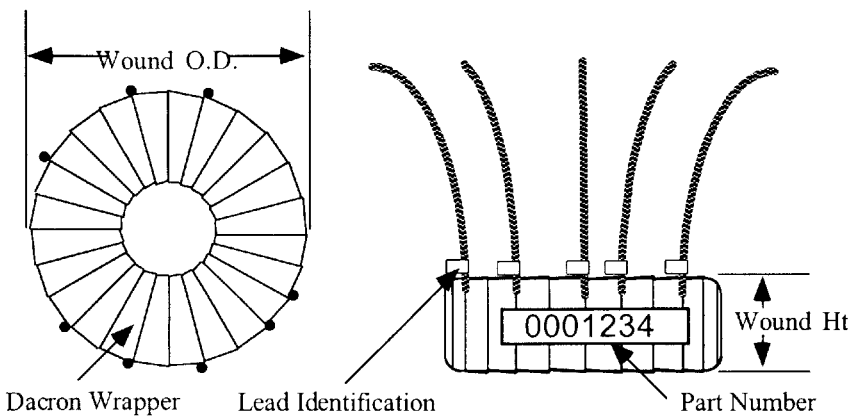

Figure 5-4. Finished toroidal transformer.

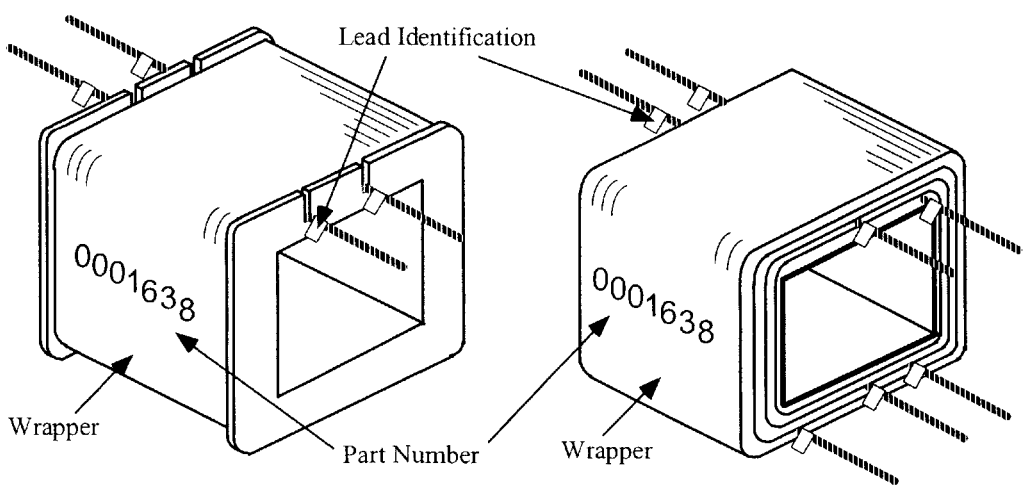

Figure 5-5. Layer and bobbin wounding coil assemblies.

Table 5-1. Example of Step-by-Step Winding Instructions.

Step-by-Step Winding Instructions		
Step No.	Description	References
1	Wrap the toroidal core, Item 1, with mylar tape, Item 2. Overlap is required, Secure the end with, Item 3. See References.	Table 5-3 Figure 5-70
2	There are 4 windings, 2 single and 1 bifilar winding. The start and finish of each winding are distributed around the core, as shown in Figure 5-3.	Figure 5-2 Figure 5-3
3	(W1) Wind the core, Item 1, with 50 turns of #30 AWG magnet wire, Item 4. Place the winding, as shown in Figure 5-3. Progressively wind, 350°, and label Start 1 and Finish 2. Fiberglass sleeving, Item 7, will be used to cover the Start and Finish leads.	Figure 5-2 Figure 5-3 Table 5-3
4	Perform the required electrical test.	Assembly Drawing
5	(W2, W3) Wind bifilar the core, Item 1, with 10 turns of #33 AWG magnet wire, Item 5. Place the winding, as shown in Figure 5-2 and Figure 5-3. Wind progressively, 180°, and label Strand 1 as Start 3 and Finish 4. Label Strand 2 as Start 5 and Finish 6. Fiberglass sleeving, Item 7, will be used to cover the start and finish leads.	Table 5-3 Figure 5-2 Figure 5-3
6	Perform the required electrical test.	Assembly Drawing
7	(W4) Wind the core, Item 1, with 100 turns of #33 AWG magnet wire, Item 5. Place the winding as shown in Figure 5-3. Wind continuously 360°+ and label as Start 6 and Finish 7. Fiberglass sleeving, Item 7, will be used to cover the start and finish leads.	Figure 5-2 Figure 5-3 Table 5-3
8	Perform the required electrical test.	Assembly Drawing
9	Peripheral wrap, with mylar tape, Item 3.	Table 5-3
10	Dress the magnet wire leads to appropriate lead breakout locations. See Figure 5-4.	Figure 5-4
11	Wind the Dacron insulating tape, Item 6, 360°, progressively around the core, and secure the end with item 3.	Figure 5-4
12	Coil is ready for final assembly.	Figure 5-6

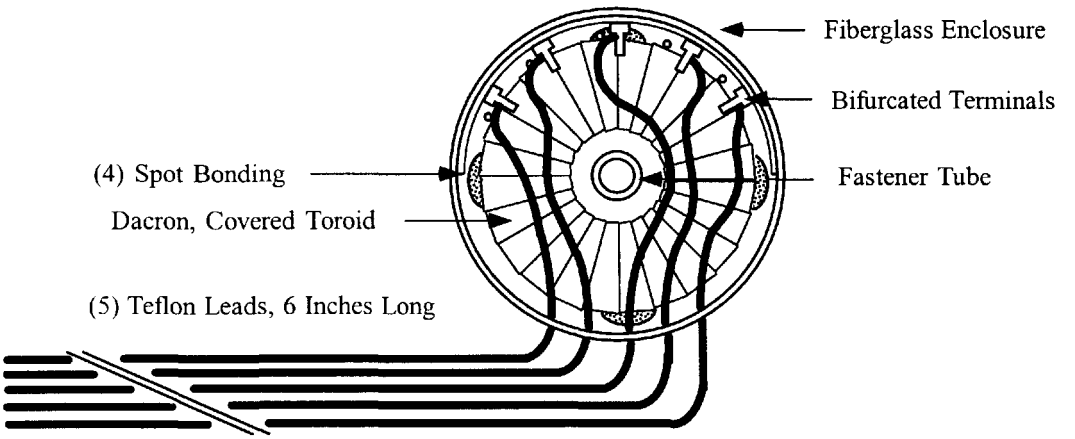

Figure 5-6. Transformer Top View of Assembly showing the Internal Construction.

Table 5-2. Example of a Step-by-Step Assembly Procedure.

Step-by-Step Assembly		
Step No.	Description	Remarks
1	Check potting Cup, Part Number.	
2	Check potting cup (QA) approval.	
3	Check finished winding, magnet component, test data.	
4	Spot bond, terminal board in potting cup, using Stycast 1095.	Mix-Sample
5	Spot bond, magnetic component in position, using Stycast 1095.	
6	Inspection (QA).	
7	Cure Stycast 1095.	
8	Dress the leads of the magnetic component, as shown in the assembly drawing.	
9	Attach leads from the magnetic component to the terminals.	
10	Install and attach the external, teflon leads to the terminals.	
11	Solder all connections.	
12	Inspection (QA).	
13	Do final test before potting.	
14	Preheat magnet assembly for 3 hours at 70°C. (Bake out the moisture.)	
15	Fill the magnetic assembly with vacuum-degassed, impregnating material. When the magnetic assembly is completely covered with impregnating material, then, vacuum the complete assembly.	Mix-Sample
16	After vacuuming the impregnation, pour out the remaining impregnating material.	
17	Fill the magnetic assembly with vacuum-degassed embedment material. When the magnetic assembly is completely covered with the embedment material, then, vacuum the complete assembly.	Mix-Sample
18	Cure the embedment for 16 to 20 hours, at 94°C.	
19	Perform a final electrical test and visual inspection.	
20	Place in Bonded Stores	

Table 5-3. Typical Parts List.

Parts' List						Page 1
L1 Drawing Number 0001234						
Item No.	Qty Reqd	Part Number	Specification	Nomenclature or Description	Material Specification	Material Supplier
1	1	55059-A2		Molypermalloy Powder Core	Powder	Magnetics
2	AR		Mil-I-G31	Tape Mylar Film Non-Adhesive 1 mil	Mylar	Dupont
3	AR	No.1298		Tape Mylar Film Adhesive 3 mil		3M
4	AR	#30 AWG	ST12281-30	Magnet Wire Solderable 155°C	MW-80-C	MWS
5	AR	#33 AWG	ST12281-33	Magnet Wire Solderable 155°C	MW-80-C	MWS
6	AR	7500		Tape Dacron (3/8 inch, 5 mil)		Fralock
7	AR	No. 24	S1600	Flexible Fiberglass Sleeving	Fiberglass	Varflex
8	AR	280		Epoxy Impregnant	Epoxy	Scotchcast
9	AR	281		Epoxy Embedment	Filled-Epoxy	Scotchcast
10	AR		QQ-S-571	Solder, Type SN63	SN63, Type R	Kester
11	AR		Mil-W-22759	Stranded Wire, 26 AWG, Teflon	Clear	
12	1	1234		Fiberglass Cup	G10	Dorco

Winding Facilities and Work Stations

The winding work areas and workbenches should be maintained in a clean, well-ventilated, orderly manner, and have lighting which is adequate for the necessary detail of the required operations. The work area must be cleaned with alcohol dampened Kimwipes, each day, prior to starting a job. There should be no smoking, eating, or drinking permitted within three meters (ten foot) radius.

Prior to handling parts and/or materials, the operator should thoroughly clean his or her hands. The use of any hand lotion is forbidden. Anyone working with or handling parts and/or materials must wear clean gloves and/or finger cots. Gloves must be changed when they show signs of contamination, and finger cots must be replaced, when they are torn or contaminated.

Recommended Work Stations, Tools, and Materials

The following tools are required for lead attachment, soldering, anchoring, and cutting insulating tape.

1. Needle nose pliers (non-serrated)
2. Tweezers, (fine point)
3. Cutters, (full flush cut)
4. Scissors
5. Orange stick
6. Wire scrapers
7. Gloves
8. 3-5X magnification with light.
9. Dial or vernier calipers
10. Ruler
11. Soldering iron (temperature controlled)
12. Alcohol burner

The following materials are required as an aid in the lead attachment, soldering, anchoring, and cleaning. Only those materials that are, "Program Approved," should be allowed in the work area. All materials in the work area are required to have traceability data.

1. Solder, type S/N 60 or 63
2. Alcohol, Isopropyl grade A
3. Liquid flux conforming to Mil-F-14256
4. Sandpaper (emery), 220, 280, 320 grit
5. Kimwipes
6. Cotton swabs
7. Acid brushes (cleaning)

Removing the Enamel

Magnet Wire Stripping, (See Chapter 6)

The enamel on magnet wire can be stripped in many ways: 1. Solder pot can be used for tinning when special solderable insulations are used. 2. Abrasive, fiberglass wheels are used to perform the stripping. 3. The removal of enamel insulation can be done with flame by charring the enamel, then, using an emery paper to clean. 4. Chemicals are used for stripping enamel wire. They are very toxic and cumbersome to use and are not recommended for use in space, unless tightly controlled. See Figure 5-7.

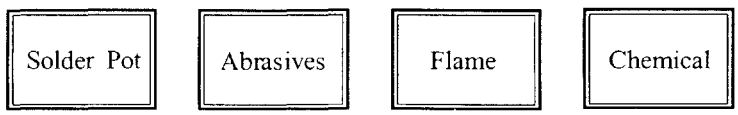

Figure 5-7. Methods Used to Remove Enamel from Magnet Wire.

Chemical Wire Stripping

To strip insulation from magnet wire by the use of chemicals, a step-by-step procedure must be submitted and approved, before starting. Stripping insulation, with the use of chemicals, will only be approved if there is not another way.

Coil Winding Equipment

Coil winding equipment used for the fabrication of magnetic items should have inspection records for both layer type and toroidal type winding machines. Winding equipment controls, settings, and set-up records should be permanently documented for that machine. Records should be available to the operator prior to placing the winding on a core, tube or bobbin. The coil winding machines shall have a complete, see-through, dust cover.

Layer and Bobbin Winders

Layer and bobbin winders should have, at least, a pre-set counter and a wire dereeler, capable of tension adjustment. A simple tube and bobbin winder is shown in Figure 5-8.

Toroidal Winders

The shuttle rings and slider on the toroidal winding machine must be inspected prior to winding. This inspection will look for nicks, burrs and rough spots. After each winding the toroid will be inspected in place for nick and scrapes. Toroidal winders will have a pre-set counter. A simple toroidal winder is shown in Figure 5-9.

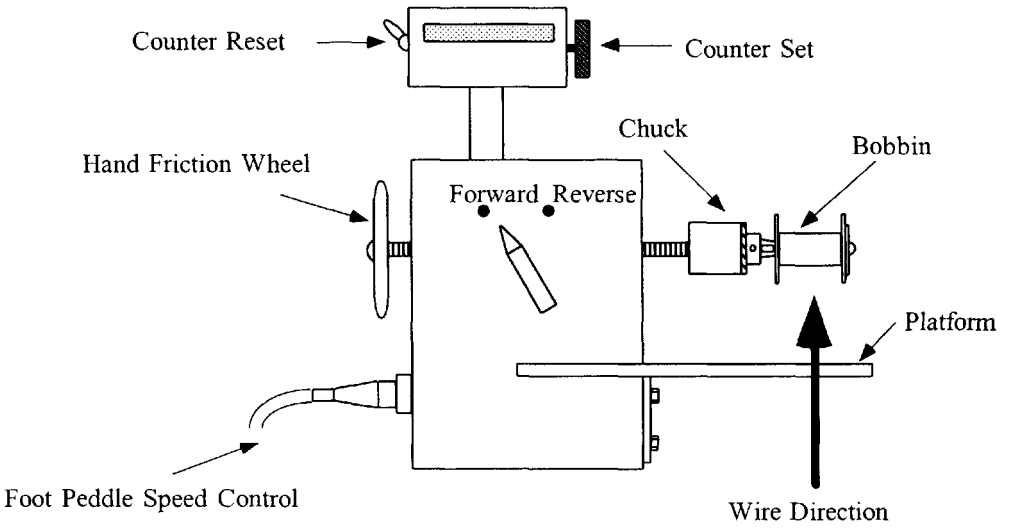

Figure 5-8. Simple Tube and Bobbin, Manually Operated Winder.

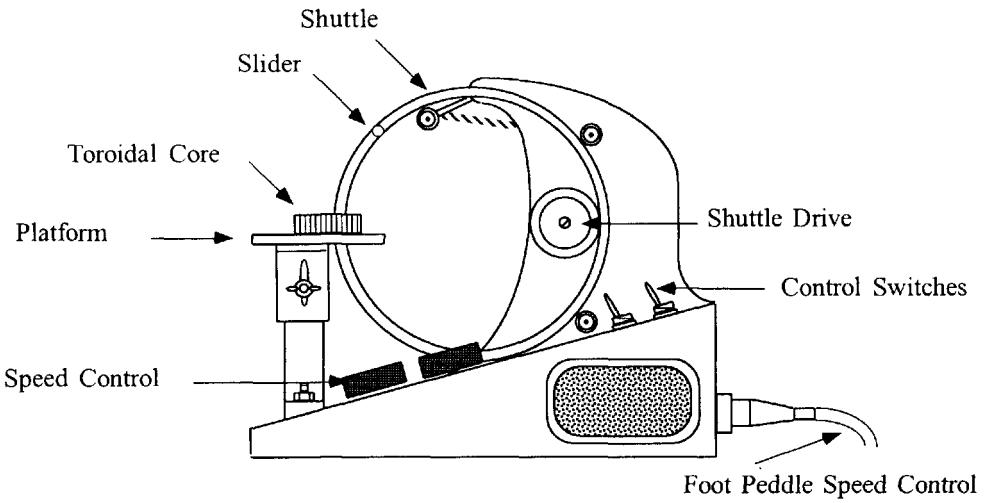

Figure 5-9. Simple Toroidal, Manually Operated Winder.

Winding Tension Device

Magnet wire is supplied on spools and reels. The spool size will depend on the wire size and the quantity ordered. As the winding machine is using the wire, the reels are subjected to starts, stops and speed changes. This non-linear action puts stress on the magnet wire. This excessive tension on magnet wire, during the winding process, will result in damage to the insulation, and increased resistance to the finished coil, due to stretching the wire.

The winding tension device is normally a compensating, mechanical arm with an adjustable spring, which maintains proper tension on the wire, independent of its linear velocity through a system of pulleys, lever arms, and breaks. Winding tension devices must be adjusted and calibrated to the proper wire gauge.

There are basically two types of tension devices. Each tension device has advantages over the other in their application. The tension device, shown in Figure 5-10, allows the wire to be extracted from the spool at almost any speed. The wire supply spool sits on a platform and remains stationary inside a shielded cone.

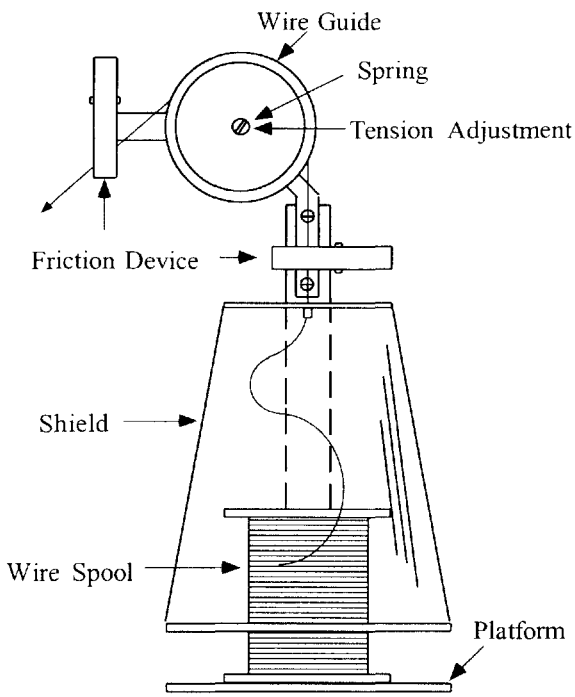

Figure 5-10. Twist Type De-Spooler and Tension Device.

The wire is wound completely around the wire guide whose resistance to turning is controlled by the tension of the spring on the wire guide. This pressure can be varied by means of an adjustable screw. It should be noted, in this type of de-spooling, there should be one twist to the wire for each turn of wire that is removed from the spool. This is because the spool is stationary.

There is an, "Anti-Kink Disk," accessory, shown in Figure 5-11, that is used along with the twist type, tension devices. When the anti-kink disk is placed on top of the spool of wire, as shown, it will prevent the wire from dropping off the spool, and becoming entangled. This entanglement could lead to kinking and breaking of the fine wire. This anti-kink disk is available for a wide range of wire sizes and spool sizes.

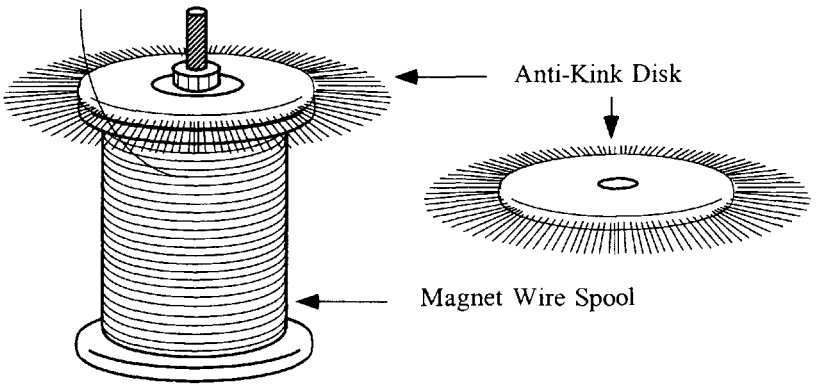

Figure 5-11. Anti-Kink Disk.

The demand type of tension device is shown in Figure 5-12. The demand type is dependent on winding speed and spool weight. The wire spool turns during the winding process. The wire runs over the free-turning wire guide, which is mounted at the end of the lever arm to obtain mechanical advantage over the spring-loaded friction device. The lever arm causes a delay action in releasing the spool, thus providing a constant amount of tension. When the winding demand goes to zero, the spool will stop automatically.

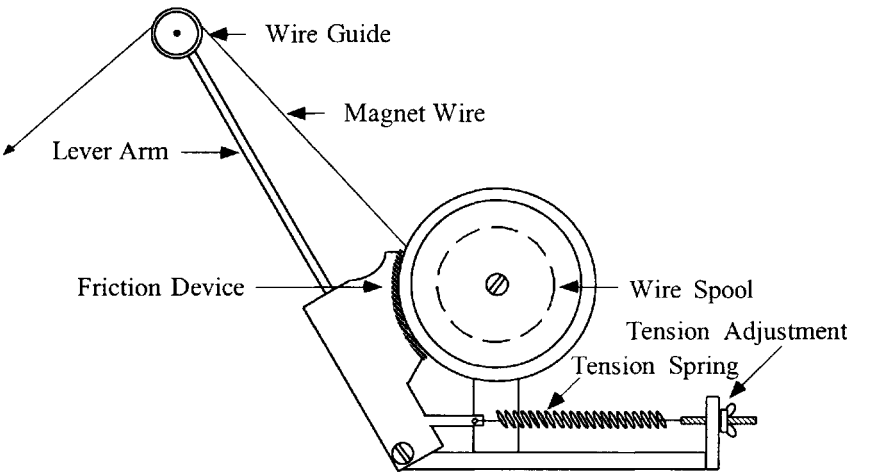

Figure 5-12. Demand Type, Tension Device.

It is always advisable to check the calibration of the tension device before its use. The biggest problem that is encountered is stretching, and distorting, which results in producing the wrong resistance. The nominal and maximum tension range for magnet wire, both copper and aluminum, is shown in Table 5-4. The material properties for copper and aluminum magnet wire are shown in Table 5-5.

Table 5-4

Machine Winding Tension Table				
	Copper		Aluminum	
AWG Size	Nominal Tension	Maximum Tension	Nominal Tension	Maximum Tension
12	61.5 lb	103 lb	20.5 lb	30.8 lb
13	48.9	81.4	16.3	24.4
14	38.7	64.5	12.9	19.4
15	30.7	51.2	10.2	15.4
16	24.3	40.5	8.1	12.2
17	19.3	32.2	6.4	9.7
18	15.3	25.5	5.1	7.7
19	12.1	20.2	4.0	6.1
20	9.7	16.1	3.2	4.8
21	7.7	12.8	2.6	3.8
22	6.0	10.1	2.0	3.0
23	4.8	8.0	1.6	2.4
24	3.8	6.3	1.3	1.9
25	3.0	5.0	1.0	1.5
26	2.4	4.0	360 gm	1.2
27	1.9	3.2	290	430 gm
28	1.5	2.5	230	340
29	1.2 lb	2.0	180	270
30	430 gm	1.6	140	210
31	340	1.3		
32	270	1.0		
33	220	360 gm		
34	170	280		
35	130	220		
36	110	180		
37	84	140		
38	68	110		
39	51	87		
40	40	69		
41	32	56		
42	25	45		
43	20	35		
44	17	29		

Table 5-5

Magnet Wire Material Properties						
Material	Symbol	Density grams/cm^3	Resistivity μΩ/cm	Weight Factor	Resistance Factor	Temperature Coefficient
Copper	Cu	8.89	1.72	1	1	0.00393
Aluminum	Al	2.703	2.83	0.3	1.64	0.0041

There is a relatively simple way to check the wire tension, by using a calibrated spring scale, as shown in Figure 5-13. When the tension device is setup with the correct spool of wire, and the wire has been laced through all the rollers and guides, then pull the wire tight via one end of the scale until the wire spool starts to turn or rotate. Then use the tension adjustment screw to adjust for the proper force. Next, take a reading on the spring scale. That will be the force, either in pounds or grams. Also, there are wire tension devices available with built-in scales for calibration.

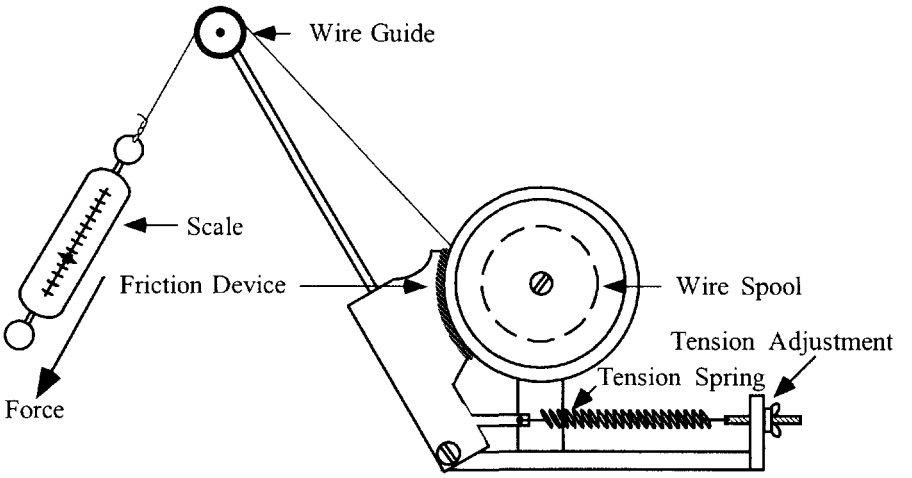

Figure 5-13. Simple, Wire Tension Test.

Crossed Wires

Winding shall be even and smooth. In the insulated, interleaved layer-wound coils, no uninsulated turn shall cross over other turns. In toroidal and cylindrical, or random wound bobbin coils wound in segments, there shall be no uninsulated crossover of any one turn to the adjacent winding segment. All situations, where the voltage stress exceeds the ability of the magnet wire insulation to withstand it, shall be avoided.

Wire Breaks

There shall be no wire breaks for any winding within the coil. The winding operation can be considered complete, only when the coil has been made with an unbroken winding. Should the magnet wire break during winding operation, the magnet wire may be unwound and rewound. In no case may a broken coil wire be repaired. If magnet wire opens after assembly, the entire device shall be rejected. Those devices, that are as multi-series, connected windings, are not to be identified as wire breaks within the definition of the paragraph.

Traveler

A lot traveler, specifying each operation in the sequence, shall be provided with each lot. The initialing or stamping of the individual traveler, by the operator or inspector, prior to moving to the next work station shall be required for each operation in the manufacturing process. A sample traveler card is shown in Figure 5-14a and 5-14b.

In-process Inspection

All critical, in-process operations, used in the manufacturing of these devices, shall be inspected by an adequately, trained inspector. If circumstances preclude inspections, after the process is complete, the inspection shall occur during the process. These inspection stations shall be defined in the manufacturing process.

Traveler-Transformers, Inductors and Coil Assemblies (Front)

Assembly No. _____ Program _____
Drawing No. & Rev._____ Machine _____
Serial No._____ Specification No. _____

Material Core	Part Number	IR/PAT	Type	Tech	Date	QA	Date
Bobbin/Tube							
Wire Hook Up							
Tape Adhesive							
Tape Cloth Poly							
Shielding							
Banding Strap							
Seal Strap							
Air Gap Material Mylar							
Housing							
Terminal Board							
Sleeving							

Figure 5-14a. A Sample Front Page of a Traveler Card.

Traveler-Transformers, Inductors and Coil Assemblies (Back)

Winding Number	Wire AWG	Turns	IR/PAT	*Test	Tech.	Date	QA	Date
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
Inspection Prior to Solding								
Solder Wires and Inspect								
Electrical Test								
Encapsulation								
Marking _____	Serial No. _____							
Assembly No.	Part No. _____							
*Test to Perform	A. Magnetizing Current			B. Turns Ratio		C. See Winding Specification		

Figure 5-14b. A Sample Back Page of a Traveler Card.

Recommended Winding Procedure

for

Layer Wound Coils

Note 1:

Minimize The Use of Mylar Tape

There are two good reasons why the use of Mylar tapes of any kind should be kept to a minimum. First, since Mylar is not porous, impregnation must go around. If the tape is wound too tightly, there may be an air trap within the transformer. Secondly epoxies do not bond well to Mylar. An incipient, fracture plane is produced in the impregnation.

Note 2:

Woven Glass Sleeving

It has been found that the use of woven glass sleeving over the magnet wire improves the reliability. This sleeving is not merely slipped on after the unit is wound. It is actually placed over the lead as soon as the lead is brought out. The sleeving serves several purposes: it helps take the stress off the lead, it prevents sharp bending, and it prevents abrasions of the insulation. See Figure 5-16.

Note 3:

Parallel Winding

A parallel winding is a winding of two or more wires wound simultaneously and adjacent with each turn, consisting of the specified number of wires. The parallel wires are joined at the ends to form a single conductor winding.

Note 4:

Bifilar and Multifilar Winding

A bifilar or a multifilar winding is a winding of two or more wires, as in a parallel winding, except the wires are not connected. The wires could be left unconnected resulting in two separate windings, or connected in a series, and parallel, to form a single multifilar, center-tapped winding.

Tube Layer Windings

Start Leads Anchor Tapes

Anchor tapes for start leads are shown on tube type windings. See Figure 5-15.

Start Leads with Woven Glass Sleeving

Starting leads are shown using woven glass sleeving. See Figure 5-16.

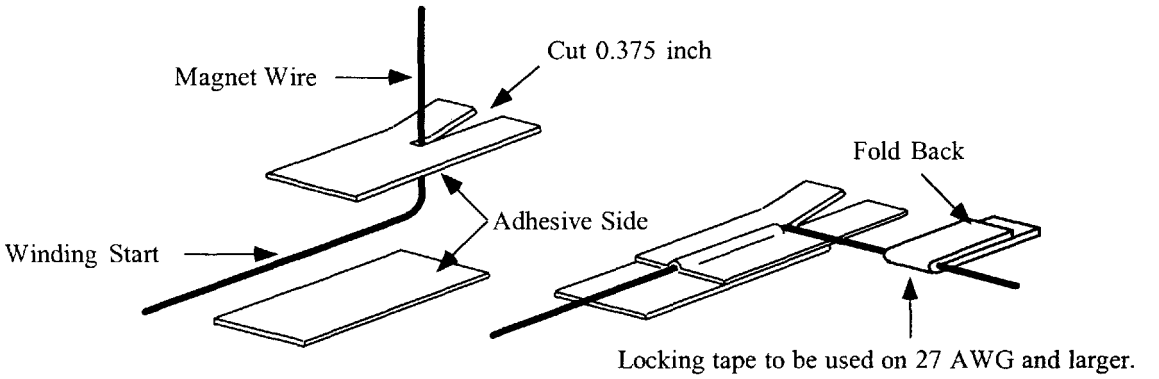

Figure 5-15. Layer Winding Start Lead Using Tape.

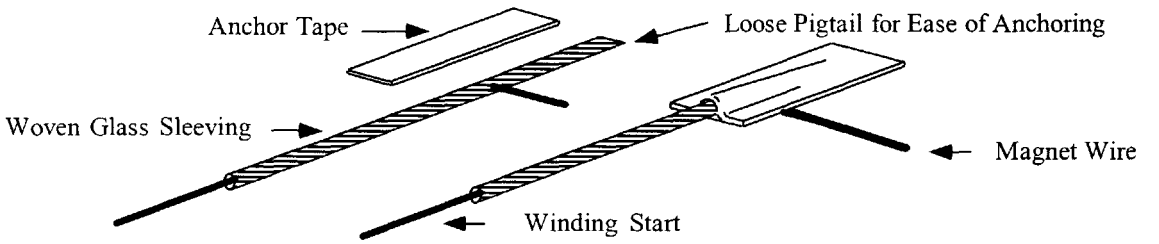

Figure 5-16. Layer Winding Start Lead Using Woven Glass Sleeving.

Start Lead Using Tape

Applying the start lead, using tape, is shown in Figure 5-17, 5-18, and 5-19.

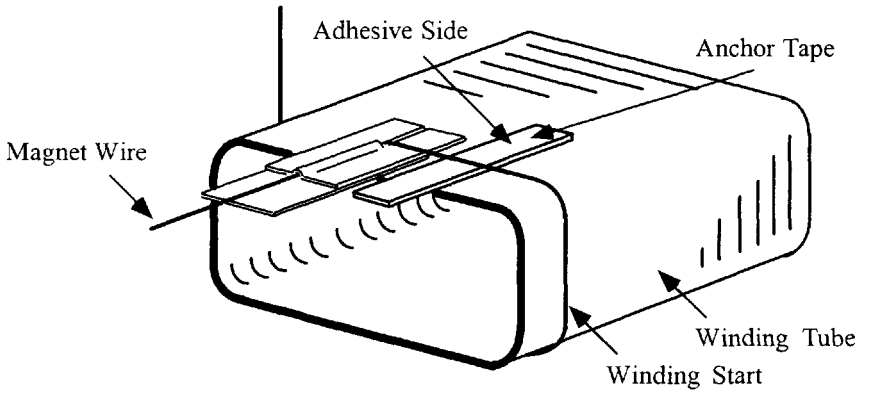

Figure 5-17. Step 1, for the Start Lead, Using Tape.

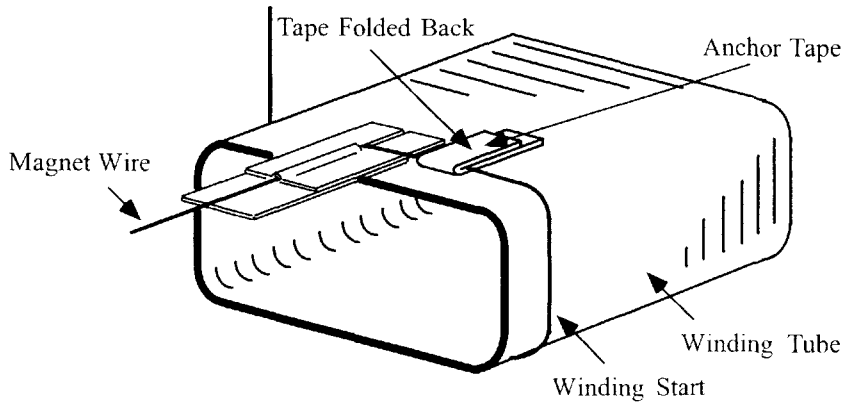

Figure 5-18. Step 2, for the Start Lead, for Folding the Anchor Tape.

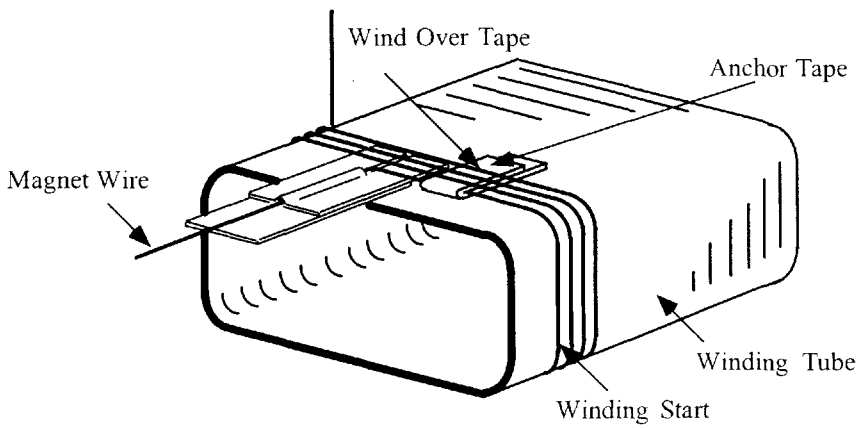

Figure 5-19. Step 3, for the Start for Lead, Locking the Anchor Tape.

Start Lead for Using Woven Glass Sleeving

Applying the start lead, using woven glass sleeving, is shown in Figure 5-20, 5-21, and 5-22.

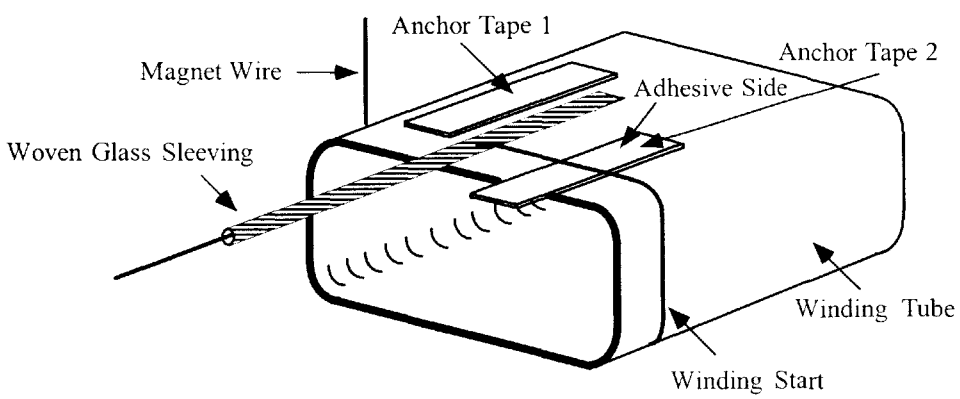

Figure 5-20. Step 1, for the Start Lead, Using Woven Glass Sleeving.

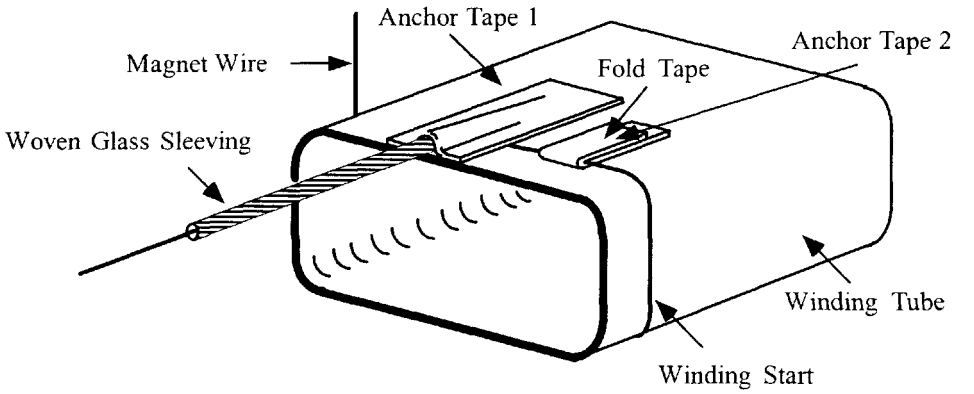

Figure 5-21. Step 2, for the Start Lead, for Folding the Anchor Tape.

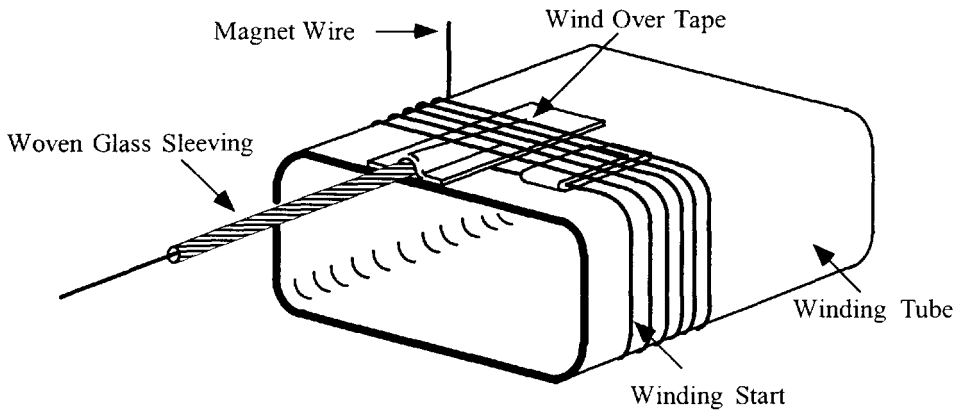

Figure 5-22. Step 3, for the Start Lead, for Locking the Anchor Tape.

Interlayer Insulation

Interlayer Insulation shall be held in place with an approved tape and meet the requirements of the assembly drawing, as shown in Figure 5-23 for tape, and Figure 5-24 for woven glass sleeving.

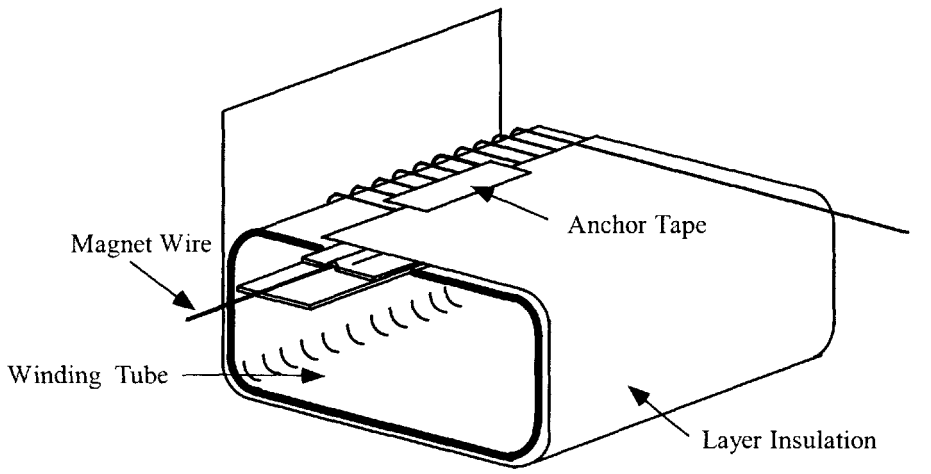

Figure 5-23. Step 1, Applying the Interlayer Insulation and Taping.

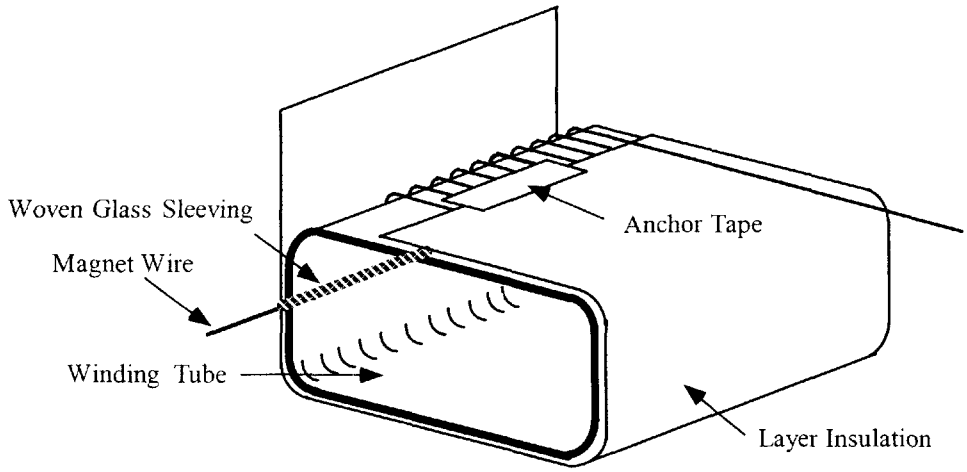

Figure 5-24. Step 2, Applying the Interlayer Insulation and Taping.

Tap Leads Using Tape

Tap leads in a tube windings shall be insulated from the windings, using an approved tape. Tape over and under the tap lead, as shown in Figures 5-25, 5-26, and 5-27.

Tap Leads Using Woven Glass Sleeving

Tap leads in a tube windings shall be insulated from the windings using an approved tape. Tape over and under the sleeving, as shown in Figures 5-28, 5-29, and 5-30.

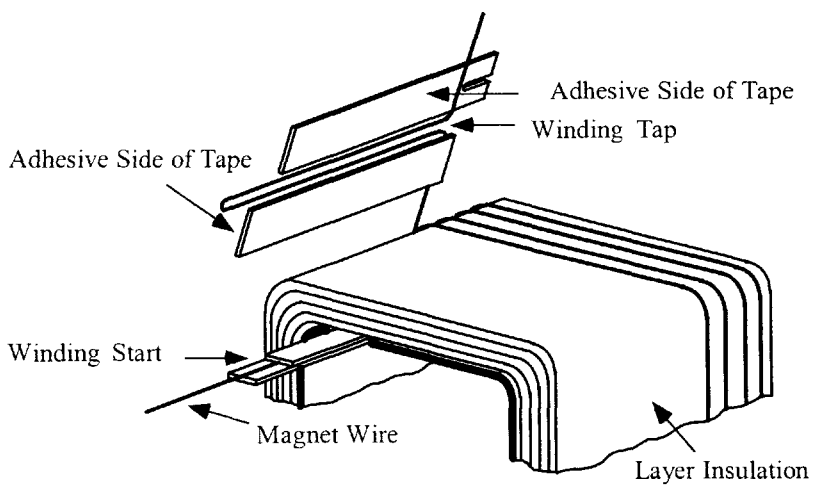

Figure 5-25. Tap Lead Using Tape: Step 1, Showing the Exploded View.

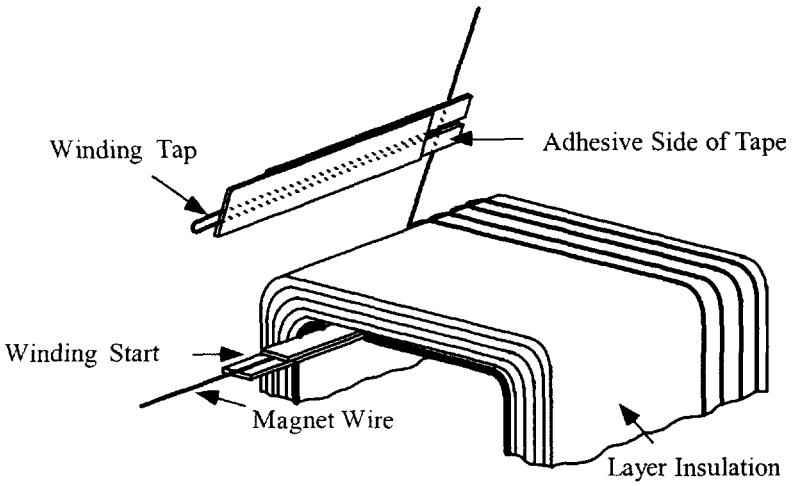

Figure 5-26. Tap Lead Using Tape: Step 2, Showing the Compressed View.

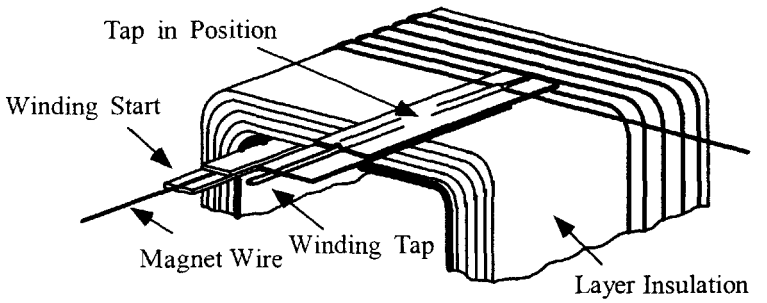

Figure 5-27. Tap Lead Using Tape: Step 3, Showing the Tap Lead in Place.

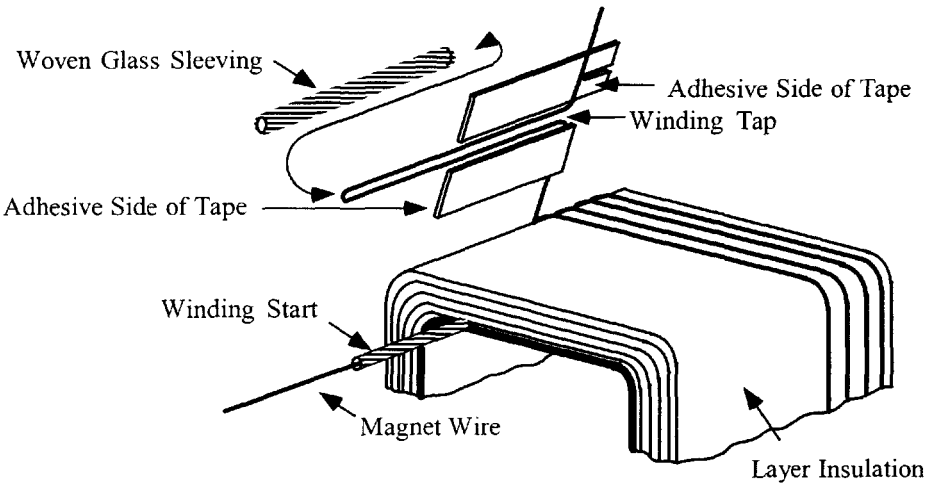

Figure 5-28. Tap Lead: Step 1, Showing the Exploded View, Using Sleeving.

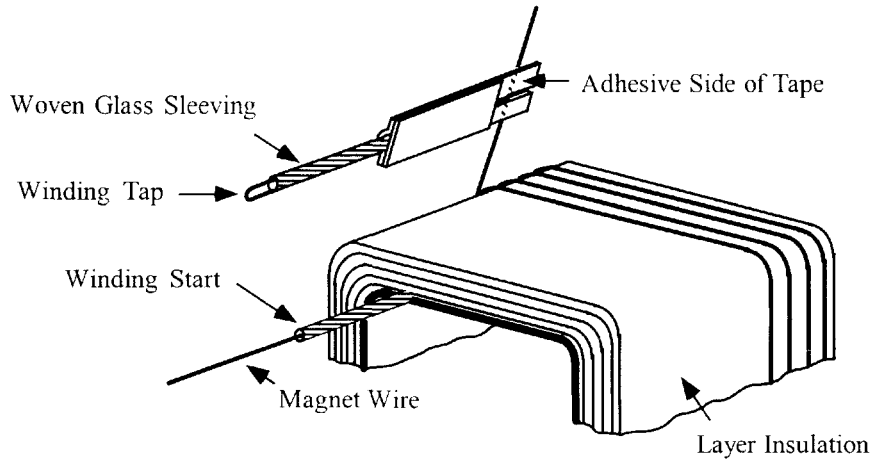

Figure 5-29. Tap Lead: Step 2, Showing the Compressed View, Using Sleeving.

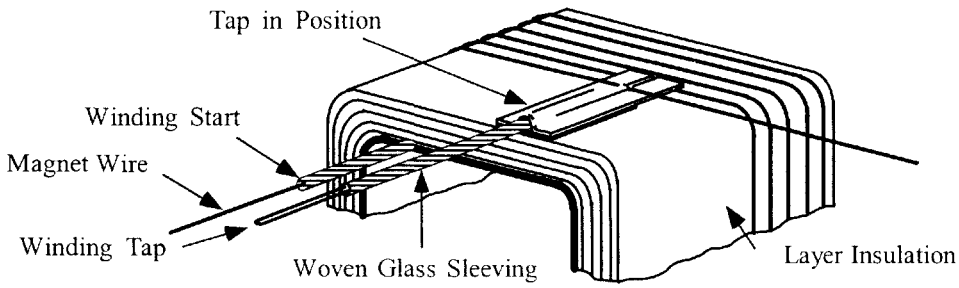

Figure 5-30. Tap Lead: Step 3, Showing the Tap Lead in Place, Using Sleeving.

Crossover Tap Leads Using Tape

Tap leads in layer windings shall be insulated from the windings, using an approved tape. Tape over and under the tap lead, as shown in Figure 5-31.

Crossover Tap Leads Using Woven Glass Sleeving

Tap leads in tube windings shall be insulated from the windings, using an approved tape. Tape over and under the sleeving, as shown in Figure 5-32.

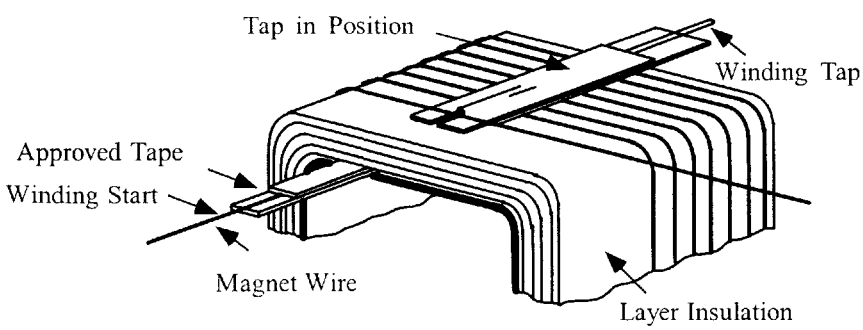

Figure 5-31. Tap Lead Crossing Over a Winding.

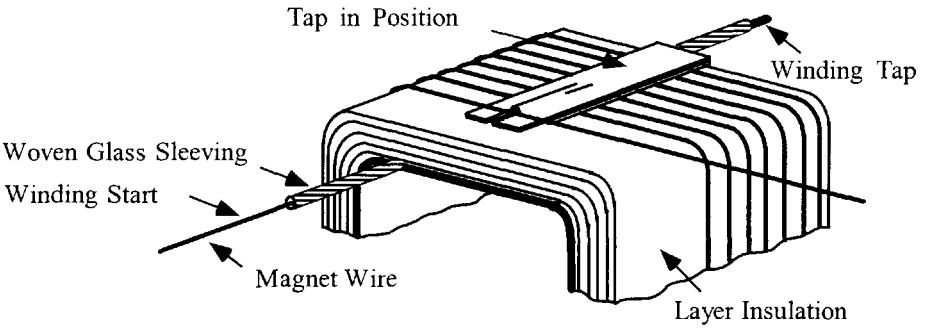

Figure 5-32. Tap Lead Crossing Over a Winding, Using Sleeving.

Parallel and Bifilar Windings

The start of a parallel winding shall be treated as a single magnet wire. The start of a bifilar winding shall be treated as a separate magnet wire. Parallel wires can be brought out together. Bifilar wires have to be brought out separately. Multifilar windings can be brought out with a combination of both. Parallel and bifilar windings shall be wound during fabrication, as shown in Figures 5-33, 5-34, 5-35, and 5-36.

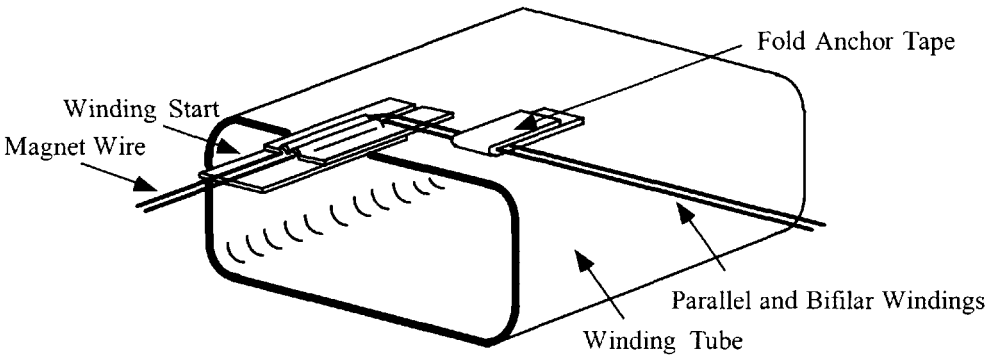

Figure 5-33. Start Lead Positioning for Parallel and Bifilar Windings, Using Tape.

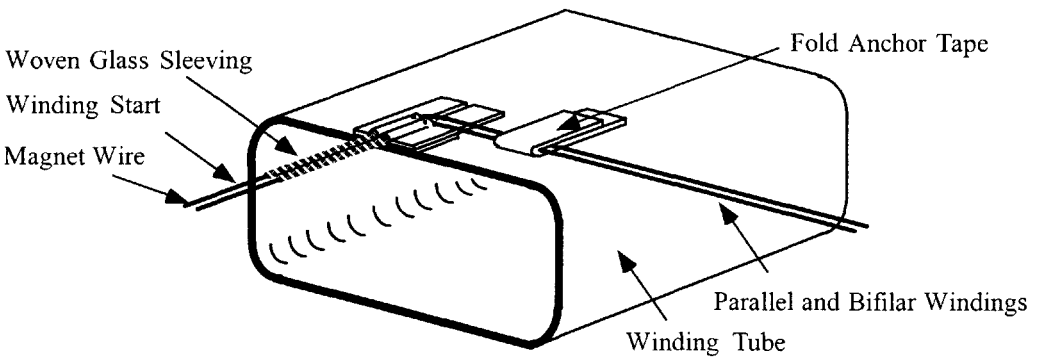

Figure 5-34. Start Lead Positioning for Parallel and Bifilar Windings, Using Sleeving.

Crossovers

There will be no crossovers in bifilar or multifilar windings, as shown in Figures 5-35 and 5-36.

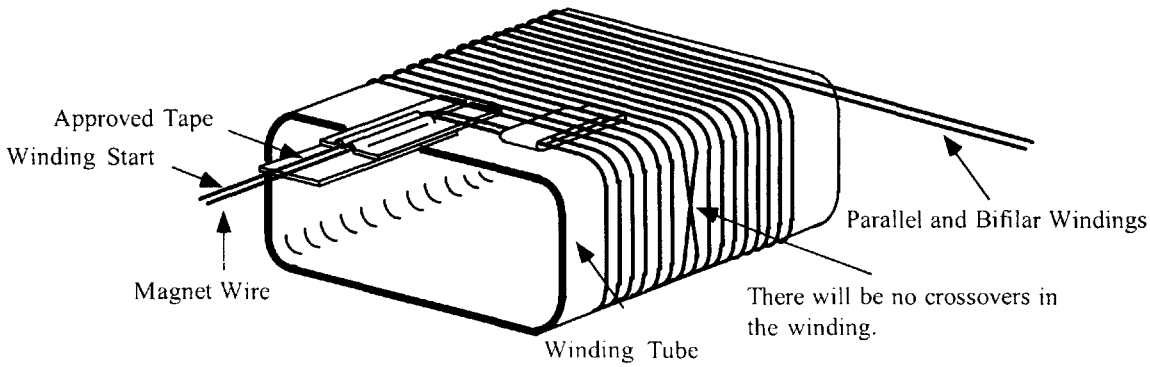

Figure 5-35. Parallel and Bifilar Windings Shall Not Have Crossovers, Using Tape.

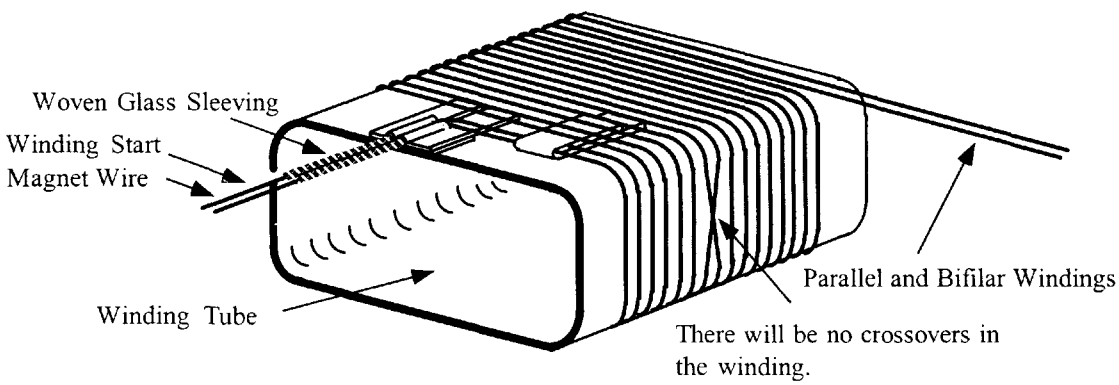

Figure 5-36. Parallel and Bifilar Windings Shall Not Have Crossovers, Using Sleeving.

Wrapper Insulation

The wrapper insulation will be the same width as the interlayer insulation, as shown in Figure 5-37. The anchor tape will secure the wrapper.

Completed Coil

Figure 5-37 shows a view of a finished layer, wound coil ready for the next assembly procedure. Note A: Any of the leads closer than 0.09 inches, or 0.23 cm to the inside of the coil, shall be insulated by tape, or if approved, by woven glass sleeving.

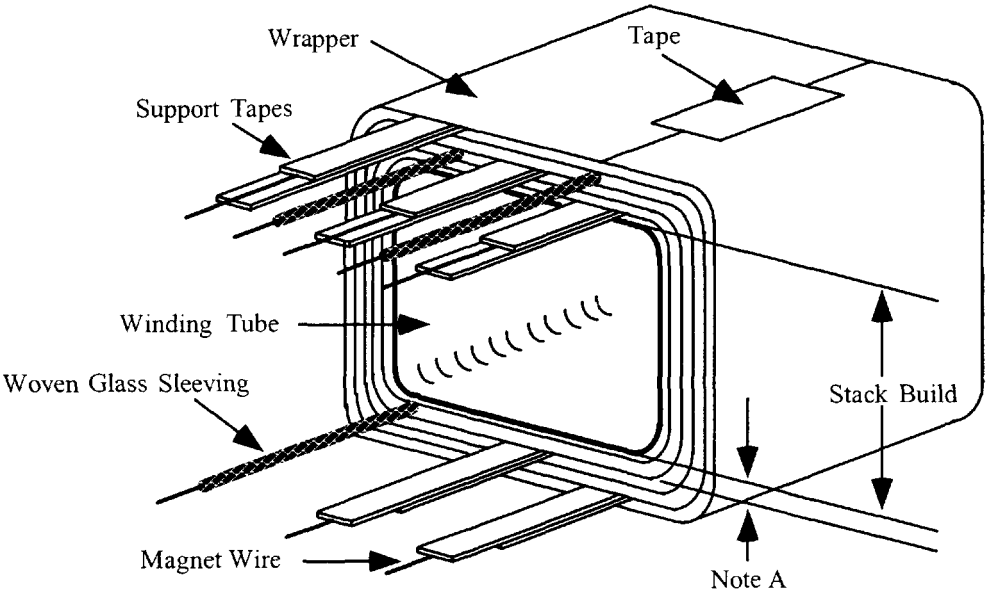

Figure 5-37. Completed Layer, Wound Coil Assembly.

Recommended Winding Procedure

for

Bobbin Wound Coils

Note 1:

Minimize The Use of Mylar Tape

There are two good reasons why the use of Mylar tapes of any kind should be kept to a minimum. First, since Mylar is not porous, impregnation must go around it, and if the tape is wound too tightly, there may be an air trap within the transformer. Secondly, if epoxies do not bond well to Mylar, an incipient fracture plane is produced in the impregnation.

Note 2:

Woven Glass Sleeving

It has been found that the use of woven glass sleeving over the magnet wire improves the reliability. This sleeving is not merely slipped on after the unit is wound. It is actually placed over the lead as soon as the lead is brought out. The sleeving serves several purposes: it helps take the stress off the lead, it prevents sharp bending, and it prevents abrasions of the insulation. See Figure 5-16.

Note 3:

Parallel Winding

A parallel winding is a winding of two or more wires wound simultaneously and adjacent with each turn consisting of the specified number of wires. The parallel wires are joined at the ends to form a single conductor winding.

Note 4:

Bifilar and Multifilar Winding

A bifilar or a multifilar winding is a winding of two or more wires, as in a parallel winding, except the wires are not connected. The wires could be left unconnected resulting in two separate windings or connected in a series and parallel to form single multifilar, center-tapped winding.

Single and Multilayer Bobbin Winding

Single and multilayer bobbin windings shall be fabricated, as follows:

Start Lead Non-Slot Bobbins (Step 1 of 2)

The start lead should be attached using the support tape, as shown in Figure 5-38.

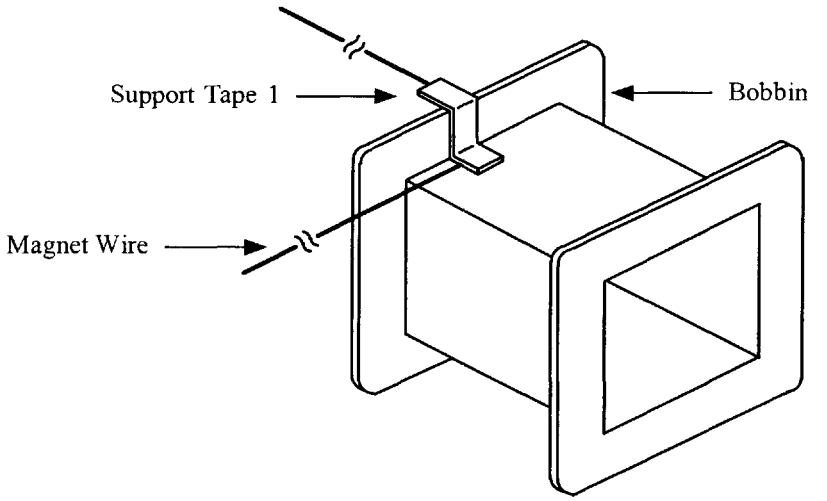

Figure 5-38. Secure Start Lead on a Non-Slot Bobbin.

Start Lead Non-Slot Bobbins (Step 2 of 2)

Place the anchor tape over the support tape and continue winding as shown in Figure 5-39.

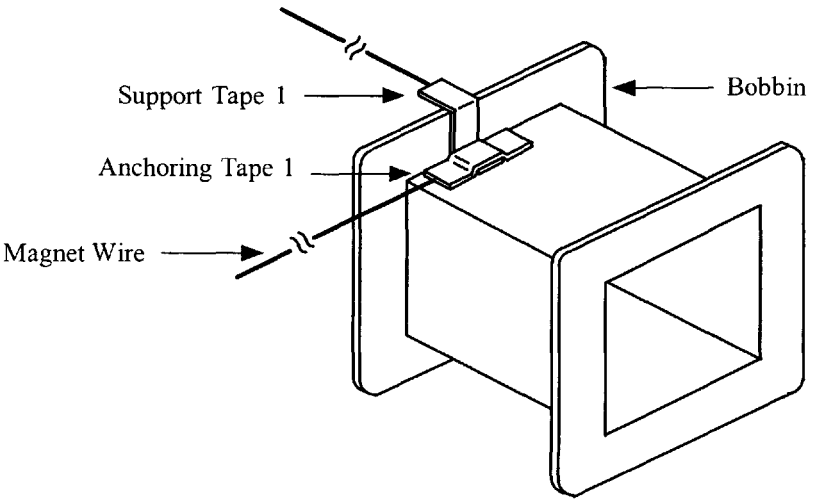

Figure 5-39. Start Lead on a Non-Slot Bobbin.

Interlayer Insulation (Step 1 of 2)

Bobbin interlayer insulation shall be held in place with an approved tape, and meet the requirements of the assembly drawing, as shown in Figure 5-40.

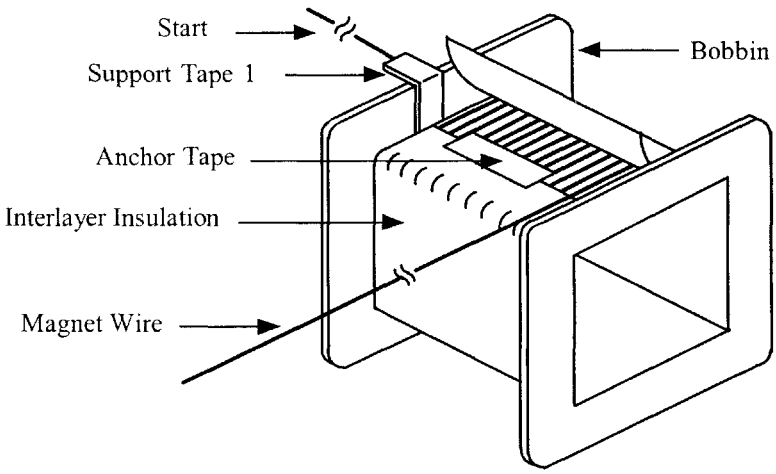

Figure 5-40. Applying the Interlayer, Insulation and Taping.

Interlayer Insulation (Step 2 of 2)

The interlayer insulation should be wrapped around the winding and overlap the interlayer insulation start. The anchor tape can be removed after the interlayer insulation has been secured with the winding, as shown in Figure 5-41.

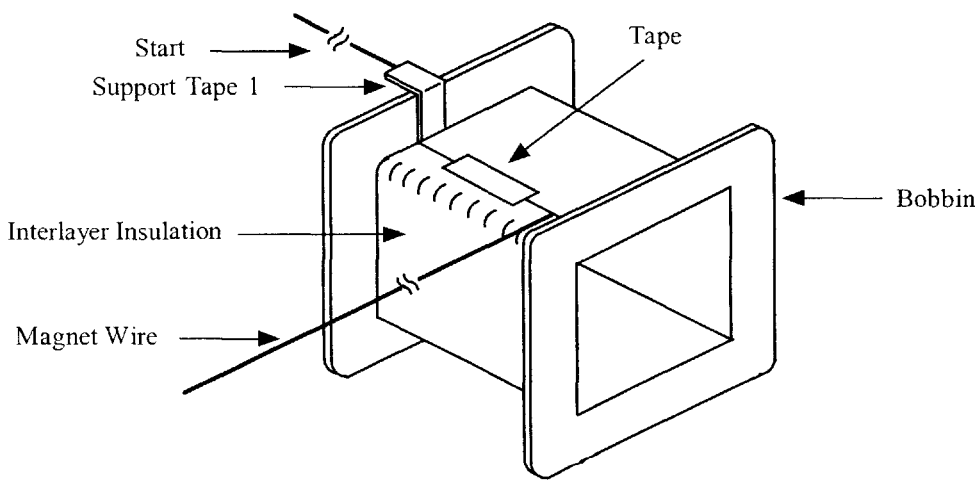

Figure 5-41. Securing the Interlayer Insulation.

Winding Tap (Step 1 of 2)

The winding tap is placed on the bobbin, as shown in Figure 5-42.

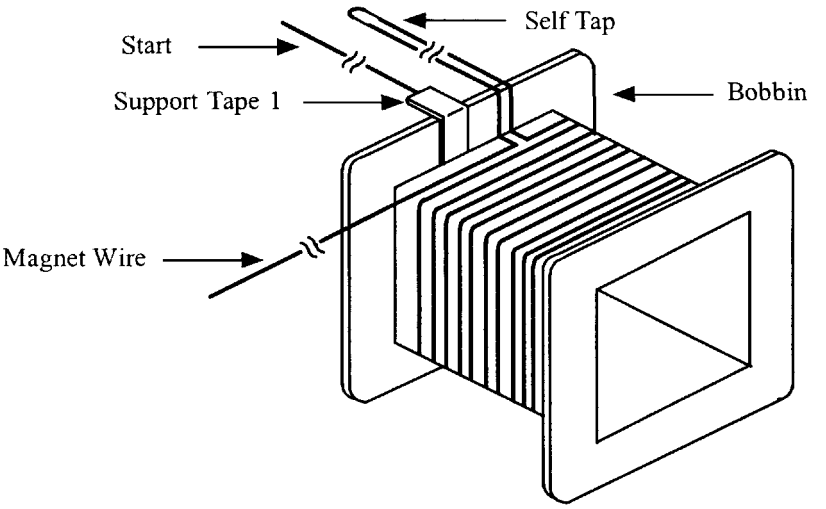

Figure 5-42. Positioning Winding Tap.

Winding Tap (Step 2 of 2)

The support and anchor tape is placed on the self tap lead, as shown in Figure 5-43.

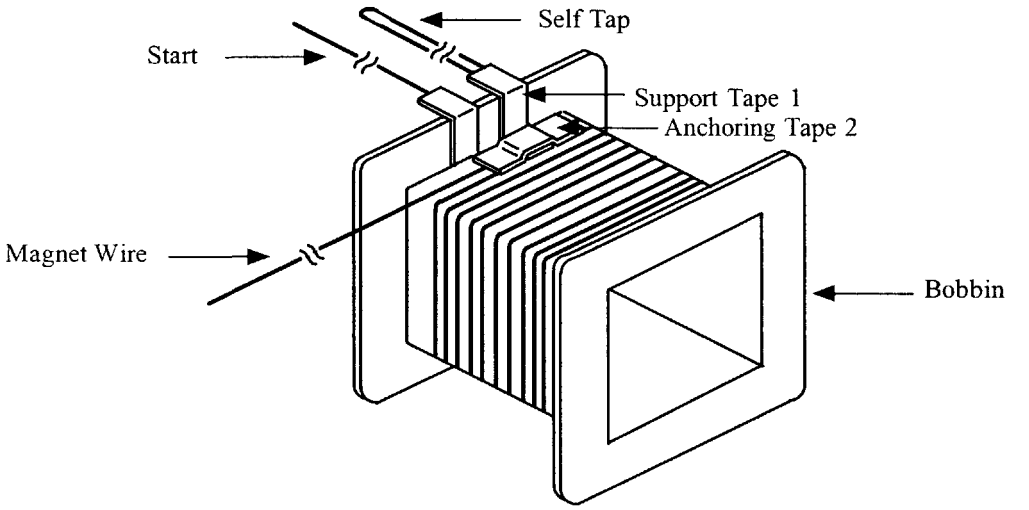

Figure 5-43. Winding Tap with Anchor Tape.

Winding Tap with Over-Wind (Step 1 of 3)

The winding tap is positioned on the bobbin, as shown in Figure 5-44.

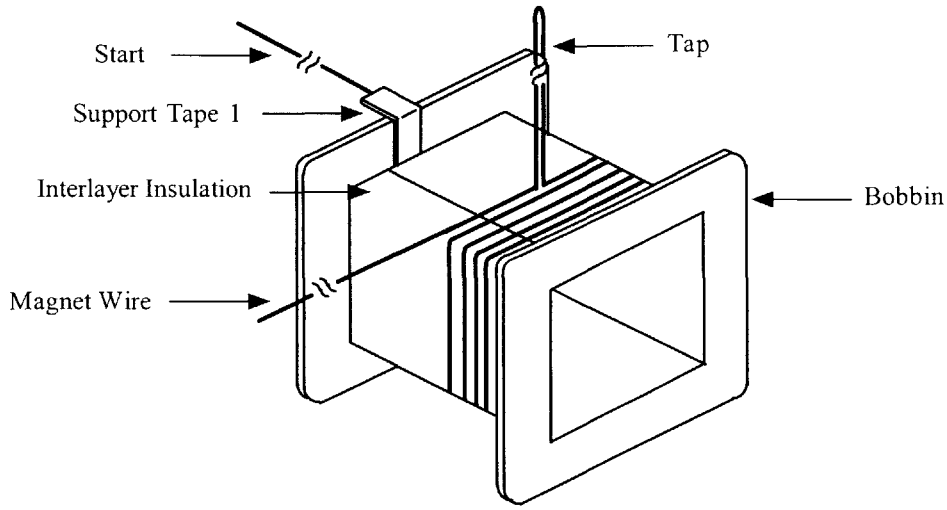

Figure 5-44. Positioning the Over-Wind Tap.

Winding Tap with Over-Wind (Step 2 of 3)

The winding tap is insulated and supported with tape 2, as shown in Figure 5-45.

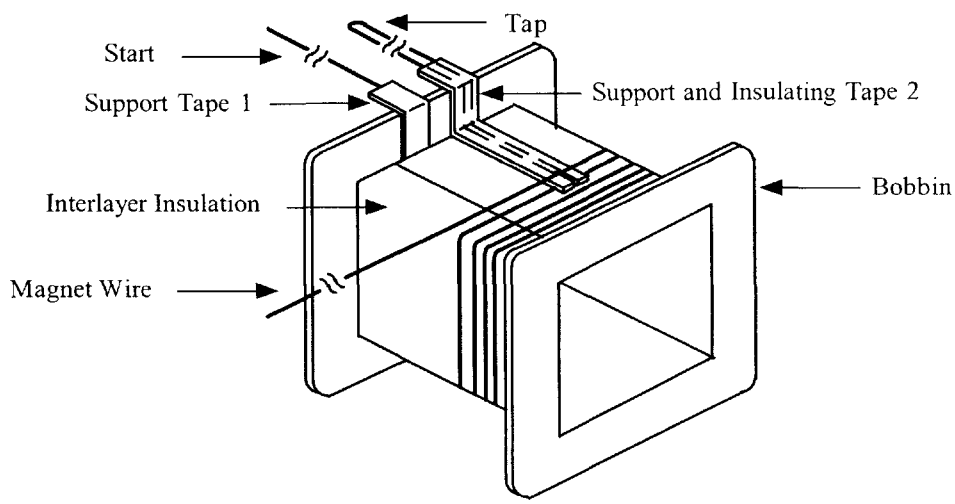

Figure 5-45. Over-Wind Tap with Insulating Tape.

Winding Tap with Over-Wind (Step 3 of 3)

The winding tap is placed on the bobbin, as shown in Figure 5-46.

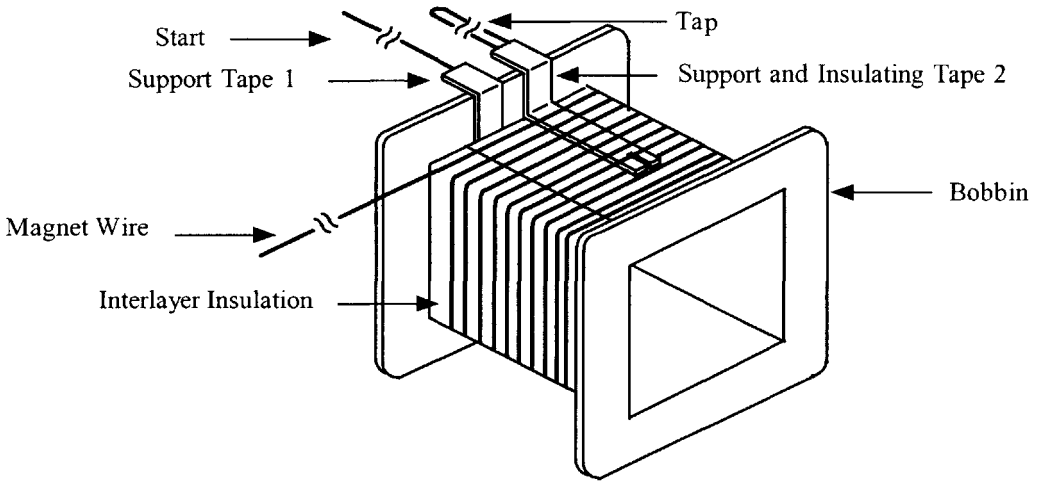

Figure 5-46. Over-Winding Tap Insulation.

Winding Tap with Opposite End Exiting (Step 1 of 3)

The winding tap is positioned on the bobbin, as shown in Figure 5-47.

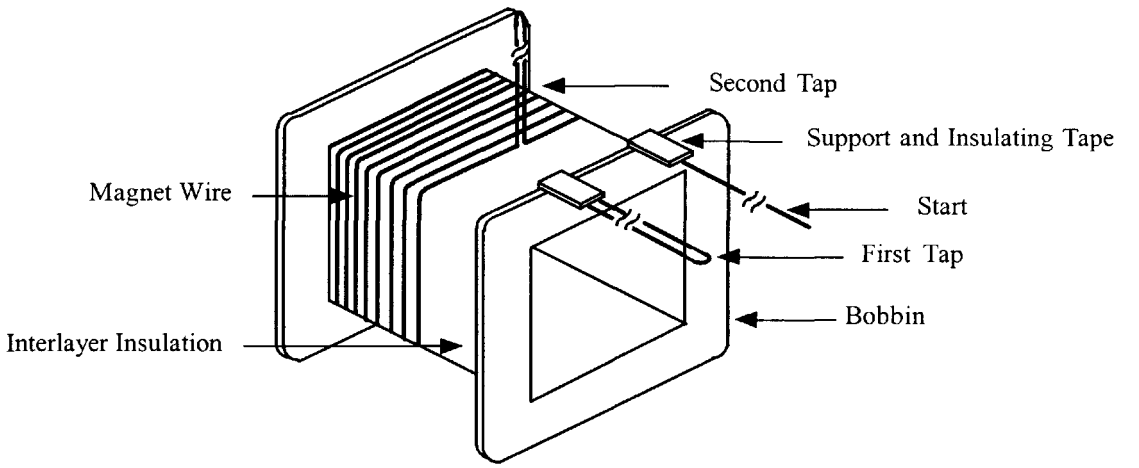

Figure 5-47. Positioning the Opposite End Tap.

Winding Tap with Opposite End Exiting (Step 2 of 3)

The winding tap with applied support tape, is shown in Figure 5-48.

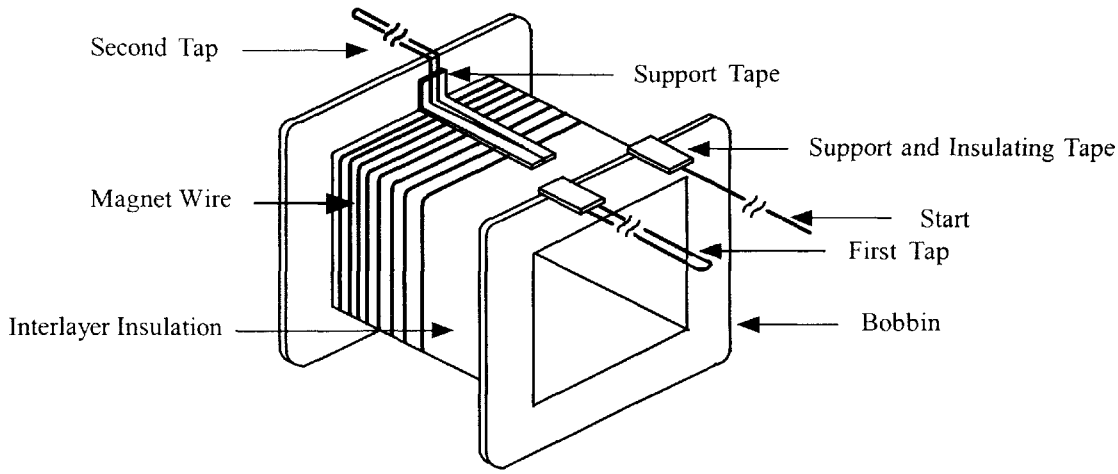

Figure 5-48. Insulating Winding Tap.

Winding Tap with Opposite End Exiting (Step 3 of 3)

Insulating the winding tap and then continuing the winding is shown in Figure 5-49.

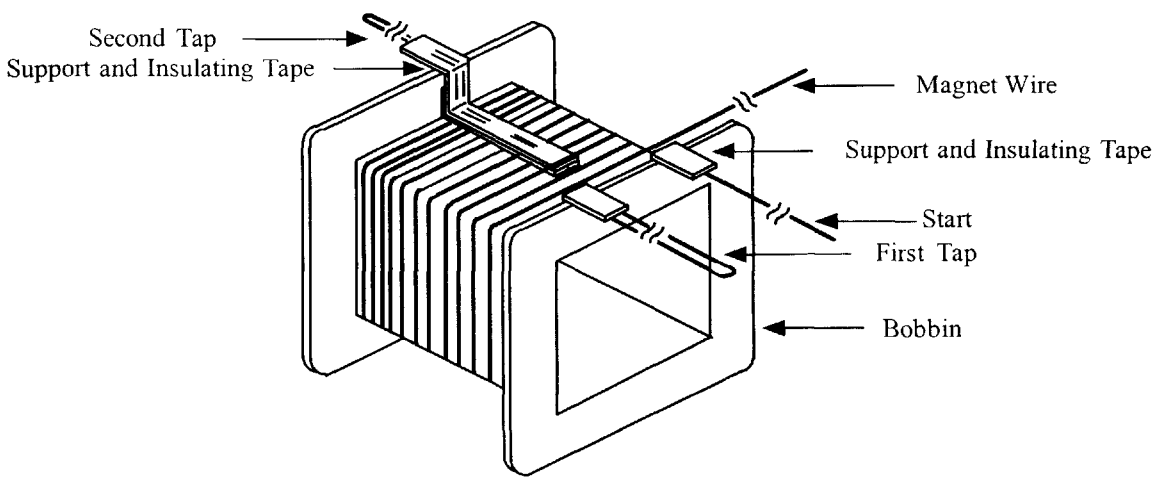

Figure 5-49. Tap Winding Continues After Insulating Tape.

Finish Lead (Step 1 of 2)

Position the finish lead, then, use the support and insulating tape, as shown in Figure 5-50.

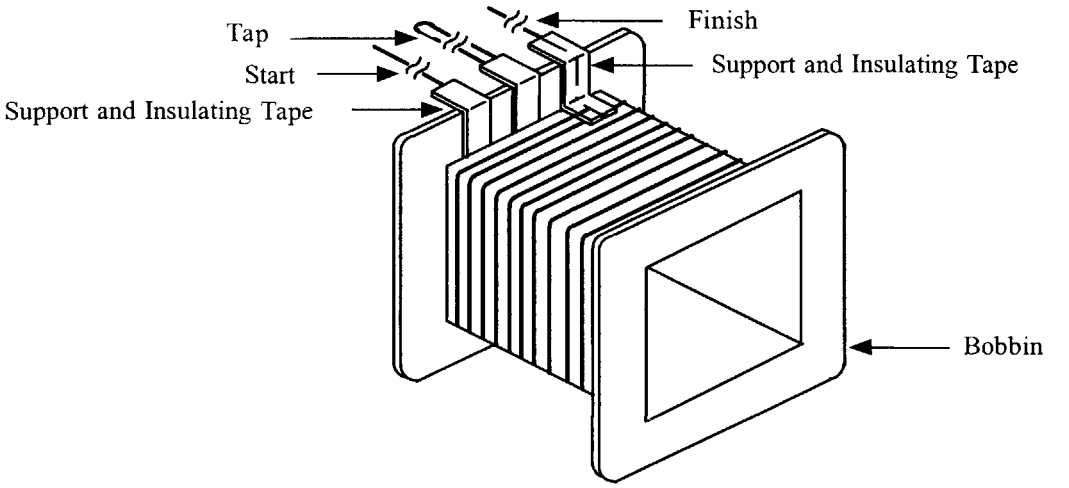

Figure 5-50. Positioning the Finish Lead.

Finish Lead Exiting Opposite End (Step 2 of 2)

Apply the support tape and insulating tape, as shown in Figure 5-51.

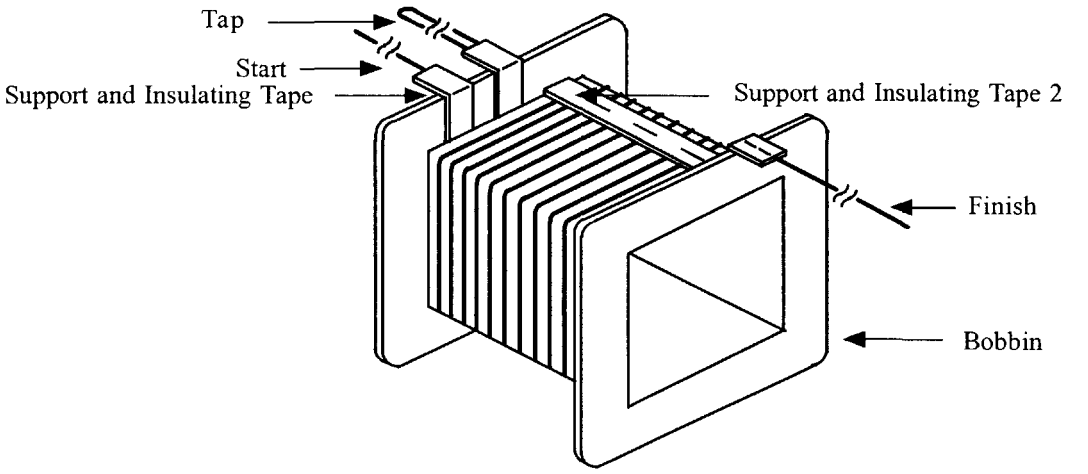

Figure 5-51. Exiting the Finish Lead at Opposite End.

Crossovers

There will be no crossovers in the windings, as shown in Figure 5-52.

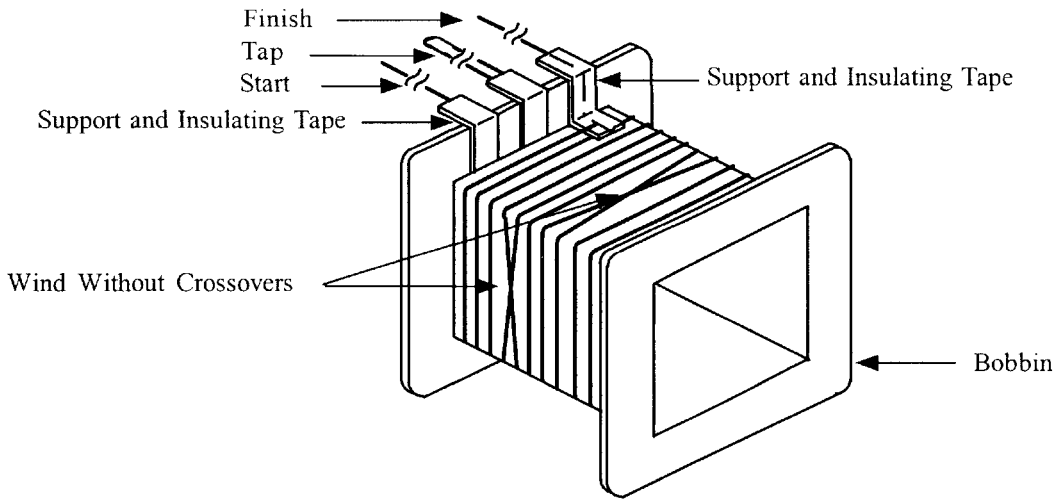

Figure 5-52. Layer Windings Shall Not Have Crossovers.

Slotted Bobbins

Bobbins, with slots in the end plates, shall have the lead wires sleeved with woven glass sleeving, as shown in Figure 5-53.

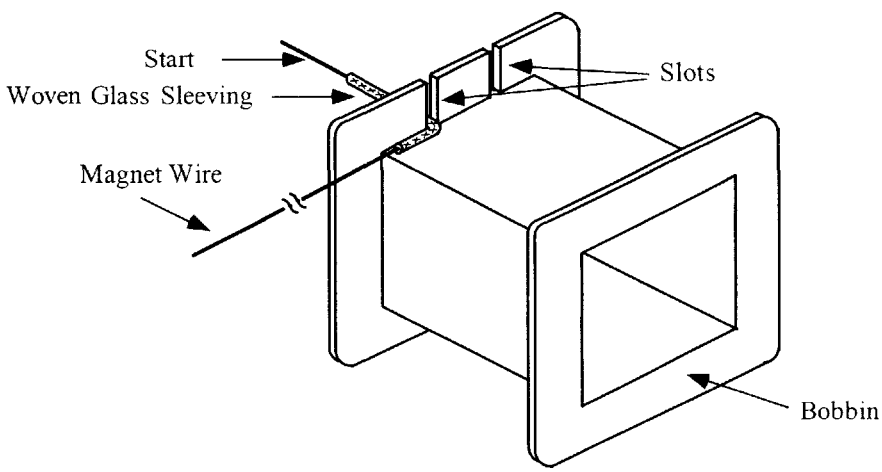

Figure 5-53. Start Lead on a Slotted Bobbin, Using Woven Glass Sleeving.

Slotted Bobbins (Step 1 of 6)

Bobbins, with slots in the end plates, shall have the start lead wires sleeved with woven glass sleeving, as shown in Figure 5-54.

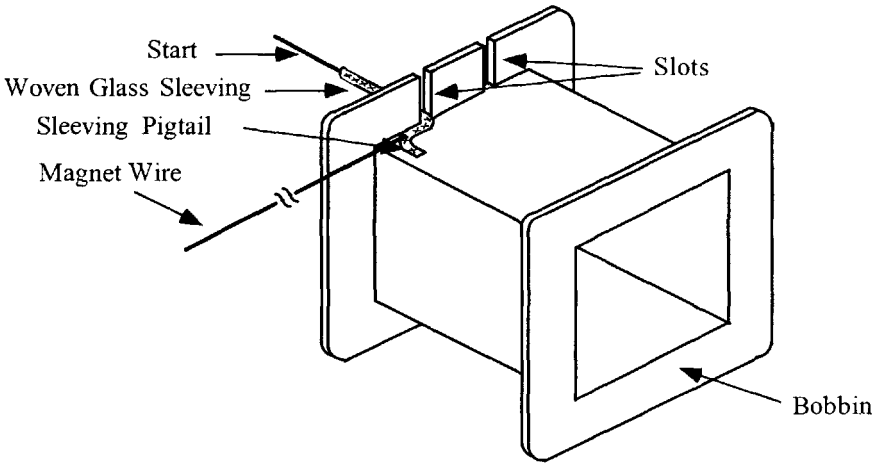

Figure 5-54. Slotted Bobbin with Sleeved Start Lead.

Finish Lead (Step 2 of 6)

Position the finish lead at the slot, as shown in Figure 5-55.

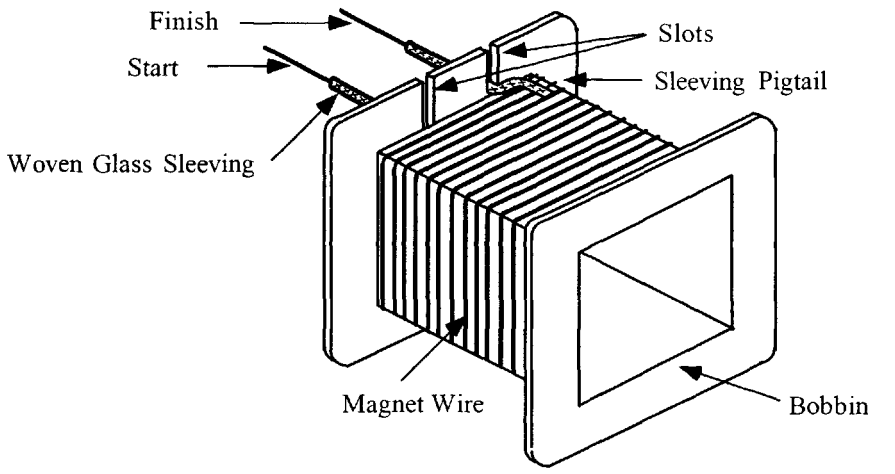

Figure 5-55. Slotted Bobbin with Sleeved Finish Lead.

Finish Lead (Step 3 of 6)

Position the finish lead, then use anchor tape, as shown in Figure 5-56.

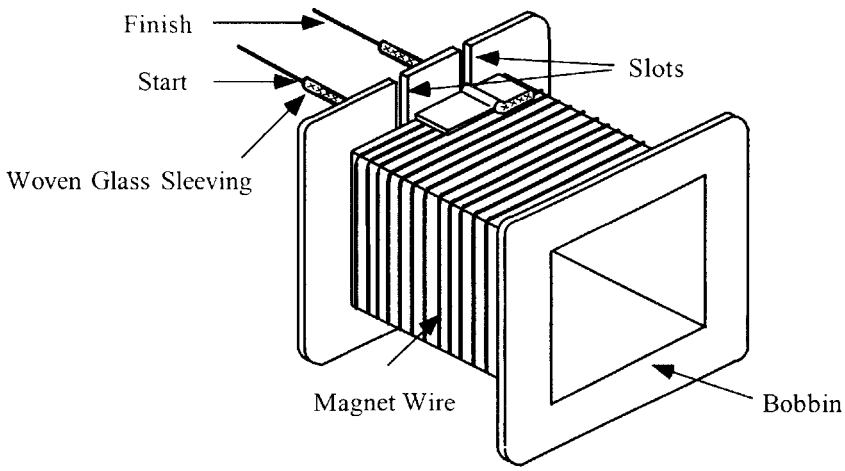

Figure 5-56. Slotted Bobbin, Anchoring the Finish Lead.

Interlayer Insulation (Step 4 of 6)

Bobbin interlayer insulation shall be held in place with an approved tape, and meet the requirements of the assembly drawing, as shown in Figure 5-57.

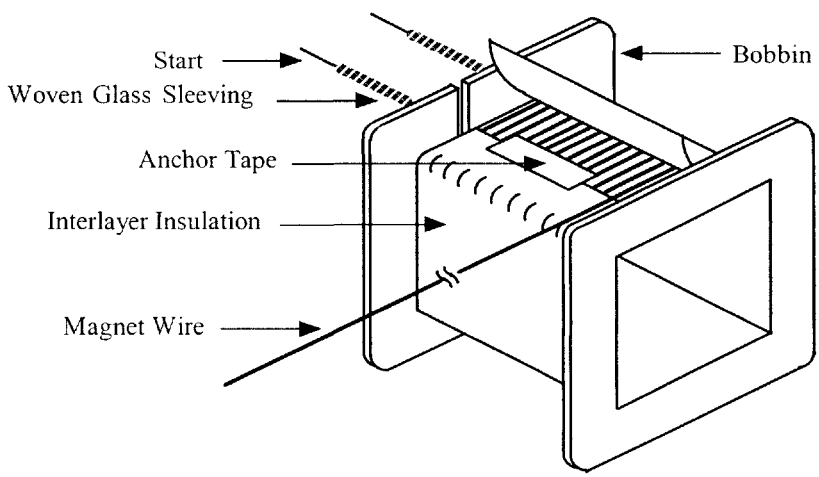

Figure 5-57. Applying the Interlayer Insulation and Taping.

Slotted Bobbins with Tap Leads (Step 5 of 6)

Slotted bobbins, with tap leads using woven glass sleeving, shall be installed, as shown in Figure 5-58.

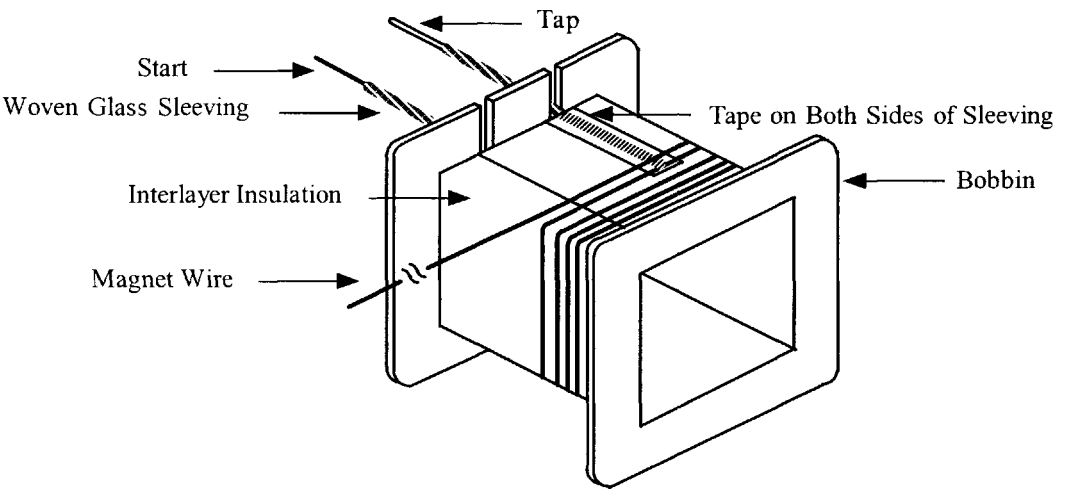

Figure 5-58. Insulating the Tap Lead with Woven Glass sleeving.

Slotted Bobbins with Interim Leads (Step 6 of 6)

Slotted bobbins, with interim leads using woven glass sleeving and shrink tubing, shall be installed, as shown in Figure 5-59.

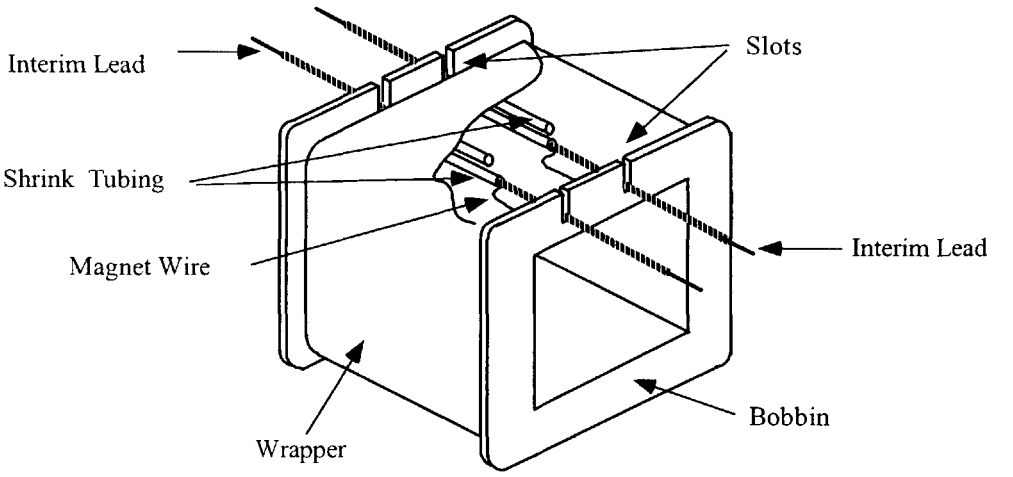

Figure 5-59. Slotted bobbins, with interim leads.

Recommended Winding Procedure

for

Foil Wound Coils

Note 1:

Minimize The Use of Mylar Tape

There are two good reasons why the use of Mylar tapes of any kind should be kept to a minimum. First, since Mylar is not porous, impregnation must go around and if the tape is wound too tightly, there may be an air trap within the transformer. Secondly, epoxies do not bond well to Mylar. An incipient fracture plane is produced in the impregnation.

Note 2:

Woven Glass Sleeving

It has been found that the use of woven glass sleeving over the magnet wire improves the reliability. This sleeving is not merely slipped on after the unit is wound; it is actually placed over the lead as soon as the lead is brought out. The sleeving serves several purposes: it helps take the stress off the lead, it prevents sharp bending, and it prevents abrasions of the insulation. See Figure 5-16.

Note 3:

Parallel Winding

A parallel winding is a winding of two or more wires wound simultaneously and adjacent with each turn consisting of the specified number of wires. The parallel wires are joined at the ends to form a single conductor winding.

Note 4:

Bifilar and Multifilar Winding

A bifilar or a multifilar winding is a winding of two or more wires, as in a parallel winding, except the wires are not connected. The wires could be left unconnected resulting in two separate windings or connected in series and parallel to form single multifilar center-tapped winding.

Foil Material

Foil shall be inspected to be sure there are no slitting burrs, as shown in Figure 5-60.

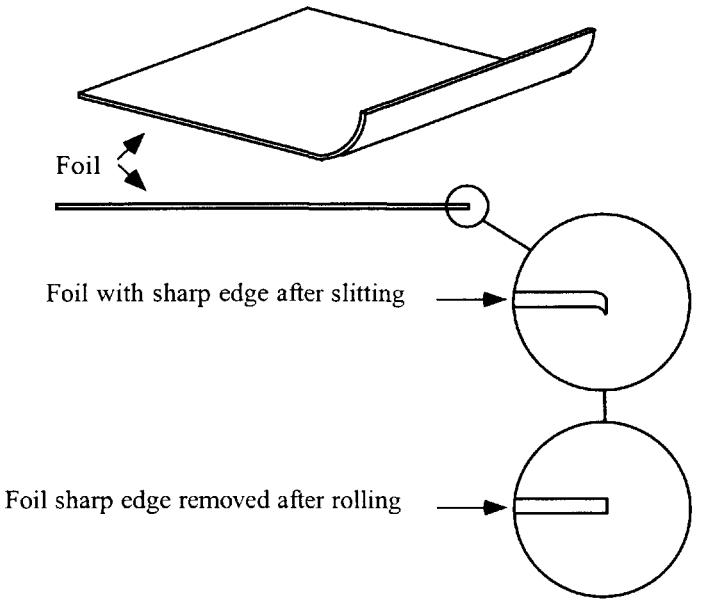

Figure 5-60. Copper Foil with the Burr Removed After Rolling.

Exiting Leads

All exiting leads, starts, taps, and finishes will be sweat-soldered to the foil. The exiting lead or foil will make contact to, at least, 70 to 80% of the copper foil. There will be no solder-wicking at the solder joint, as shown in Figure 5-61.

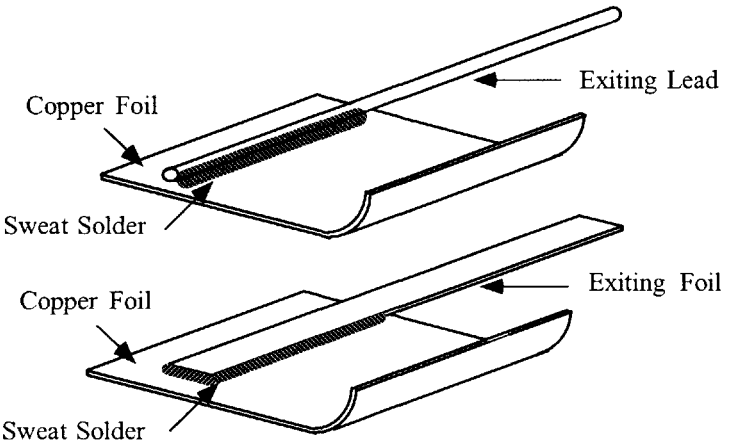

Figure 5-61. Attaching the Lead to the Copper Foil.

Electrostatic Shield (Faraday Shield)

The electrostatic shield (copper foil) must cover the complete winding. There shall be insulation material to cover both sides of the electrostatic shield. There shall be insulating material to overlap the start of the electrostatic shield. The lead that is soldered to the electrostatic shield must be soldered to the center or at an equal distance from each end. The application of the electrostatic shield is shown in Figure 5-62 for the bobbin, and Figure 5-63, for the tube layer, winding type.

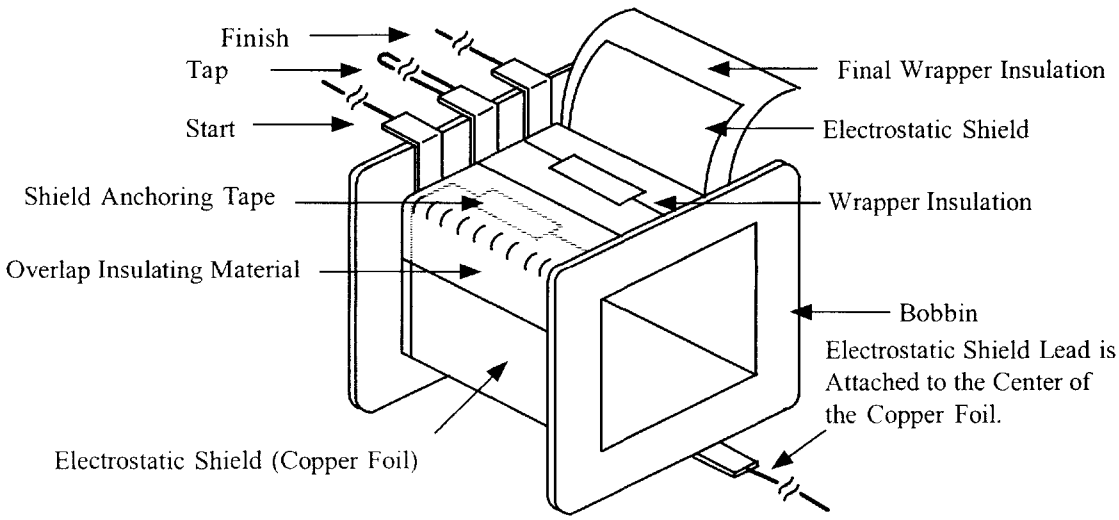

Figure 5-62. Bobbin Winding, with an Electrostatic Shield.

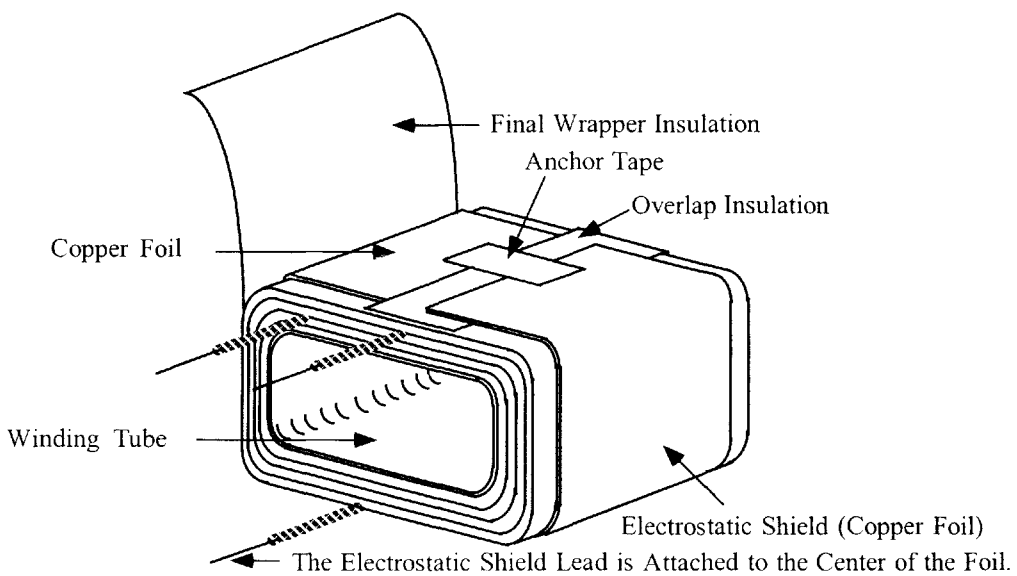

Figure 5-63. Tube Winding, with an Electrostatic Shield.

Foil Wound Coils

Start Lead (Step 1 of 5)

The anchor tape shall overlap the start lead completely, as shown in Figure 5-64.

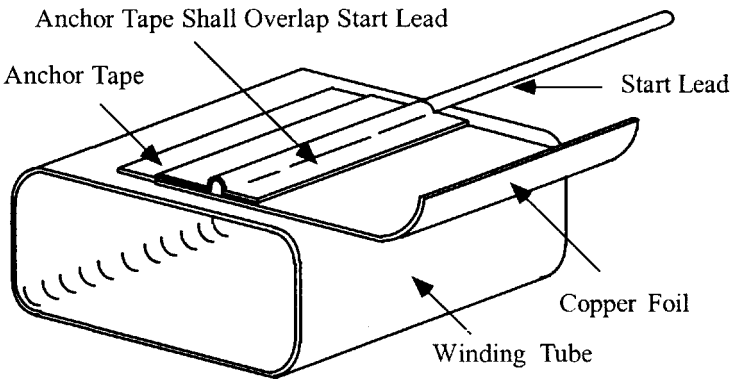

Figure 5-64. Anchor Tape Overlaps the Start Lead.

Interlayer Insulation (Step 2 of 5)

The anchor tape for the insulation shall not overlap the foil, as shown in Figure 5-65. The interlayer insulation shall overlap the edge of the foil, but not extend beyond, the edge of the winding tube. The end view of Figure 5-65 is shown in Figure 5-66.

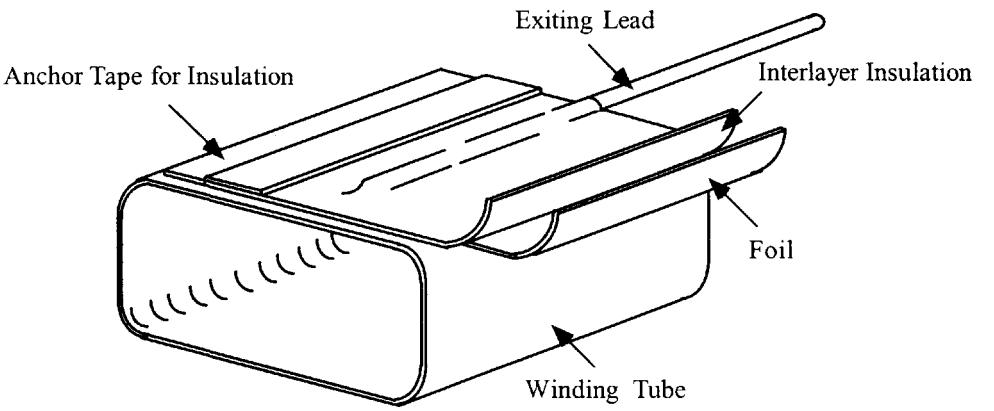

Figure 5-65. Attaching the Lead to the Copper Foil.

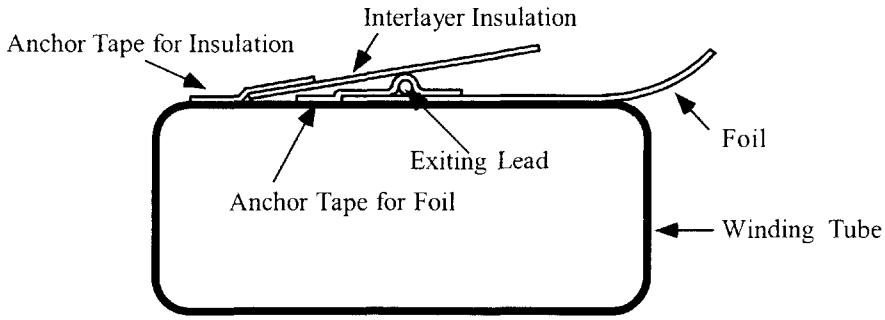

Figure 5-66. End View of Figure 5-65.

Tap Lead (Step 3 of 5)

The anchor tape shall overlap the tap lead completely, as shown in Figure 5-67. Before the application of the anchor tape, the exiting lead will be inspected for solder wicking or sharp points at the surface solder joint.

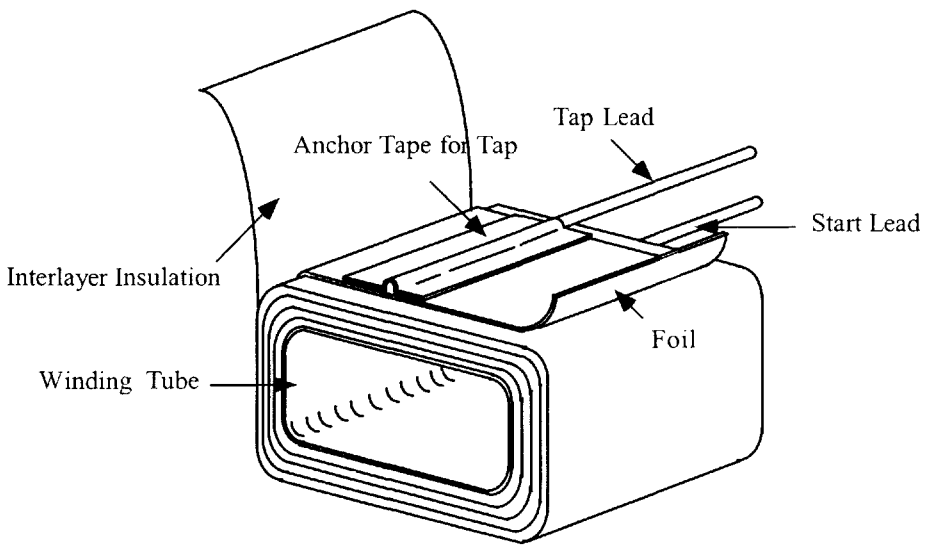

Figure 5-67. The Anchor Tape Overlaps the Tap Lead.

Finish Lead (Step 4 of 5)

The anchor tape shall overlap the finish lead completely, as shown in Figure 5-68. Before the application of the anchor tape, the exiting lead will be inspected for solder wicking or sharp points at the surface solder joint.

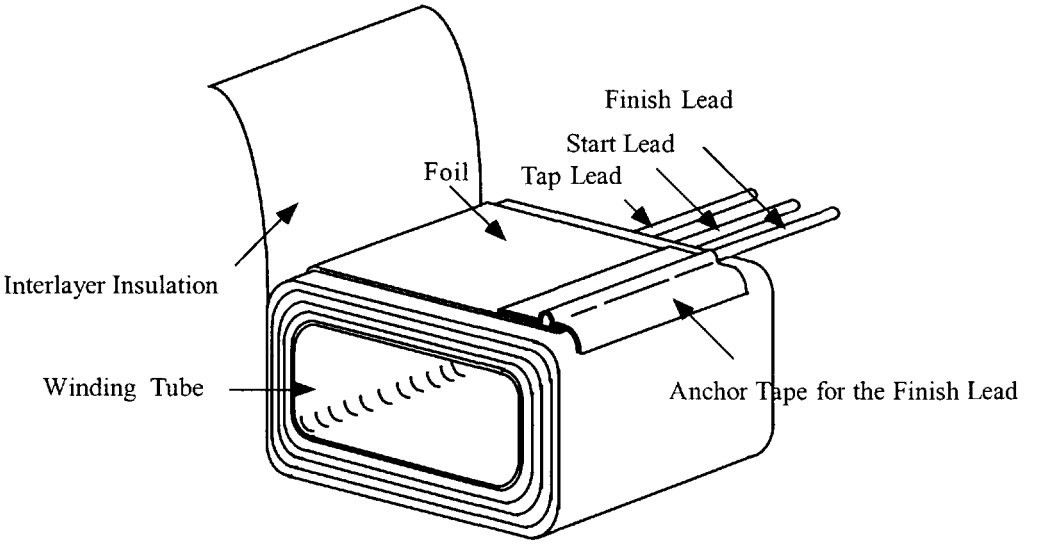

Figure 5-68. The Anchor Tape Overlaps the Finish Lead.

Wrapper Insulation (Step 5 of 5)

The wrapper insulation will be the same width as the interlayer insulation, as shown in Figure 5-69. The anchor tape will secure the wrapper.

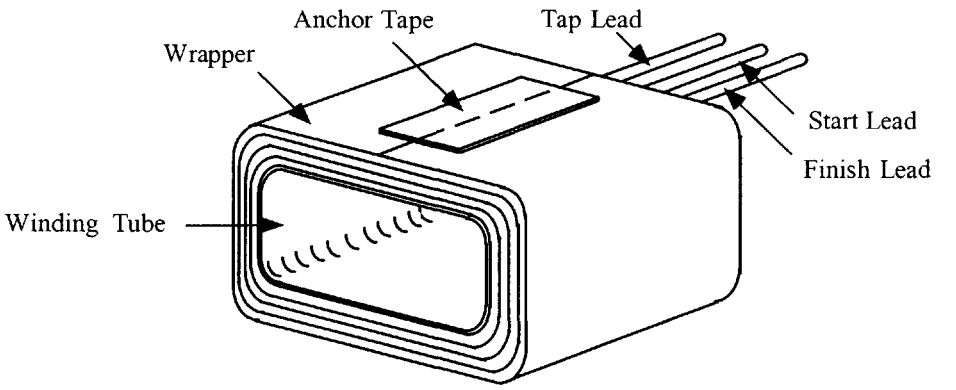

Figure 5-69. Finished Foil Winding with a Wrapper.

Recommended Winding Procedure

for

Toroidal Wound Coils

Note 1:

Minimize The Use of Mylar Tape

There are two good reasons why the use of Mylar tapes of any kind should be kept to a minimum. First, since Mylar is not porous, impregnation must go around and if the tape is wound too tightly, there may be an air trap within the transformer. Secondly, epoxies do not bond well to Mylar; an incipient fracture plane is produced in the impregnation.

Note 2:

Woven Glass Sleeving

It has been found that the use of woven glass sleeving over the magnet wire improves the reliability. This sleeving is not merely slipped on after the unit is wound; it is actually placed over the lead as soon as the lead is brought out. The sleeving serves several purposes: it helps take the stress off the lead, it prevents sharp bending, and it prevents abrasions of the insulation. See Figure 5-16.

Note 3:

Parallel Winding

A parallel winding is a winding of two or more wires wound simultaneously and adjacent with each turn consisting of the specified number of wires. The parallel wires are joined at the ends to form a single conductor winding.

Note 4:

Bifilar and Multifilar Winding

A bifilar or a multifilar winding is a winding of two or more wires, as in a parallel winding, except the wires are not connected. The wires could be left unconnected resulting in two separate windings or connected in a series and parallel to form single multifilar center-tapped winding.

Single and Multiple Toroidal Windings

Single and multiple windings shall be fabricated as follows:

1. All toroidal leads will be anchored on the periphery of the wound core.
2. Splices and solder joints shall be prohibited within the winding.
3. A magnetic device, wound with 33 AWG or smaller wire sizes, shall be joined with an intermediate lead, per Table 5-6.
4. All solder joints will conform to the solder connection, as shown in Figure 5-80. There will be a minimum of three turns of insulated magnet wire, wrapped tightly, for stress relief. There will be a minimum of two turns of magnet wire, visibly soldered.
5. Splicing is acceptable, only, when the number of turns specified, requires more wire than the shuttle can hold.

Strain Relief Loop

A Strain Relief Loop shall be provided for all spliced lead breakouts.

Bend Radii

The wire, Bend Radii, shall be greater than five times the wire diameter, except for one-time bends around terminals and wire splices.

Winding Tension

The Winding Tension, used in the winding, shall be the minimum required to pull the wire into position.

Wire Lay

The Wire Lay shall be smooth and uniform, unless, otherwise required, by the detailed winding instructions.

Splicing

Splicing shall not be made because of a broken wire. If a winding has a broken wire, then, the entire winding shall be replaced. The only winding splice that can be made is if the toroidal winding shuttle does not hold enough wire for the required number of turns.

Toroid Core Taping

All toroids, including tape cores, powder cores, and ferrites, shall have the core wrapped with Mylar polyester, prior to winding. The tape shall be either adhesive-coated, or if uncoated, the ends shall be secured with adhesive coated tape. See Figure 5-70.

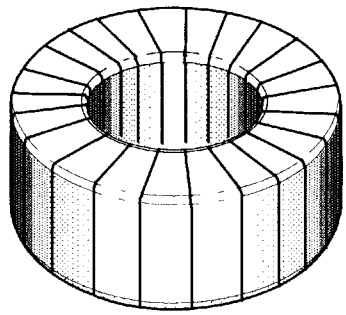

Figure 5-70. Mylar-Wrapped, Toroidal Core.

Hand Shuttle

A hand shuttle is normally used to put on windings of very few turns. The shuttle, shown in Figure 5-71, is a typical handheld shuttle, that is normally patterned and fabricated to the size of the toroidal core and the wire size.

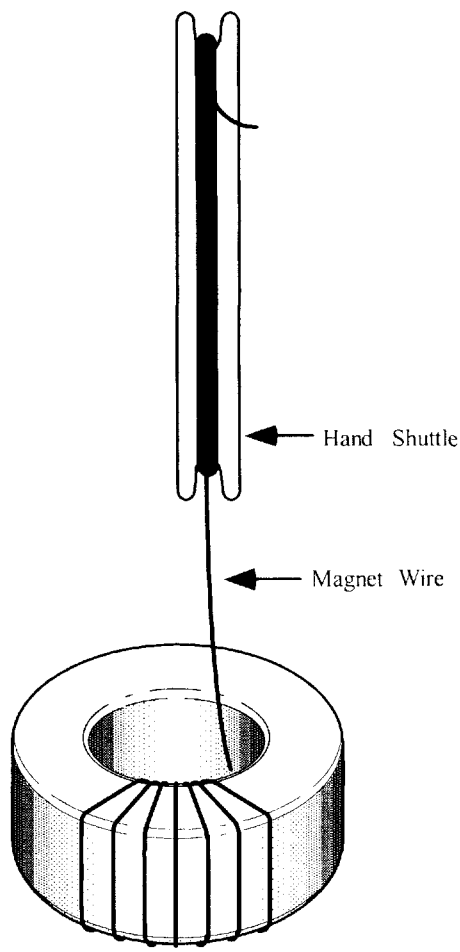

Figure 5-71. Typical Hand Shuttle for Winding Small Number of Turns.

Marlinespike Tool

A marlinespike is a tool used to expand the window of a wound toroidal transformer or inductor, as shown in Figure 5-72. Care must be taken when using this tool, as to not exert too much pressure that could break or distort the windings.

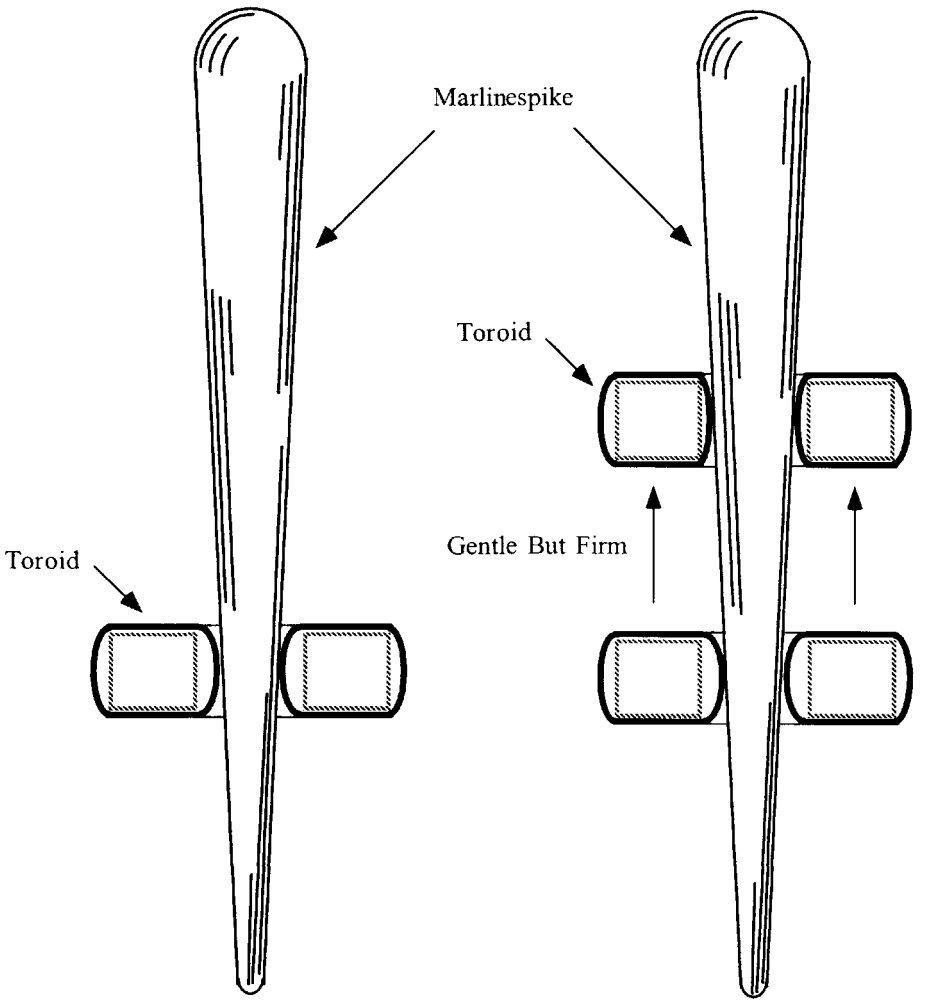

Figure 5-72. Expanding Tool, Similar to a Marlinespike to Open the Window on Toroids.

Intermediate Wire Leads

Magnetic devices, wound with AWG 33 or smaller wire sizes, shall be joined with an intermediate lead per Table 5-6.

Table 5-6. Intermediate Lead Wire Size.

Intermediate Lead	
Magnet Wire Size AWG	Intermediate Wire Size
#32 and larger	None
#33 to #40	#26
#41 and smaller	#32

Woven Glass Sleeving

Place unimpregnated, woven glass sleeving over all leads from AWG 24 to AWG 33, coming from the magnetic devices, as shown in Figure 5-73.

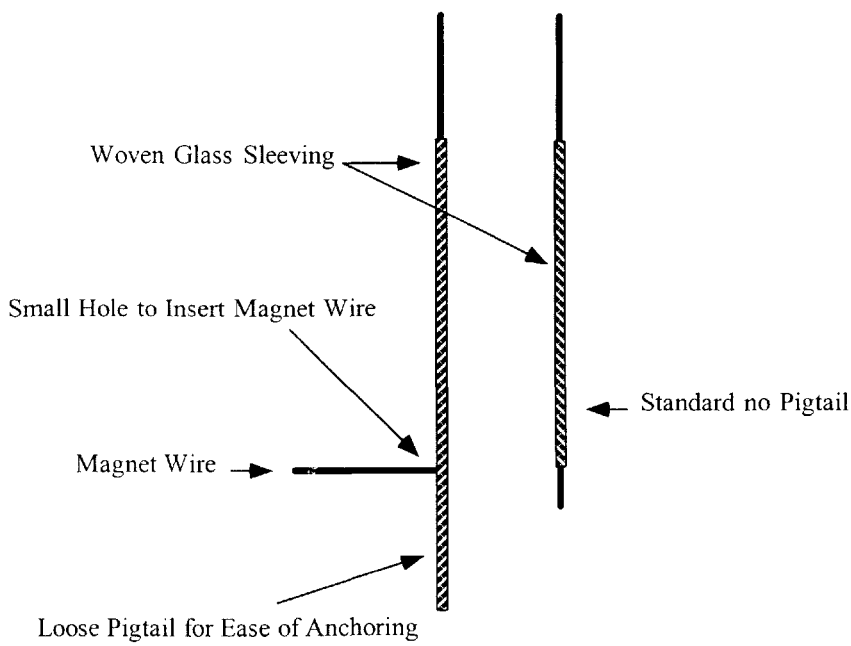

Figure 5-73. Magnet Wire Lead with Woven Glass Sleeving.

Toroid Self Lead

Toroid Self-Start Lead

The Toroid Self-Start Lead on a toroidal core shall be fabricated, as shown in Figure 5-74.

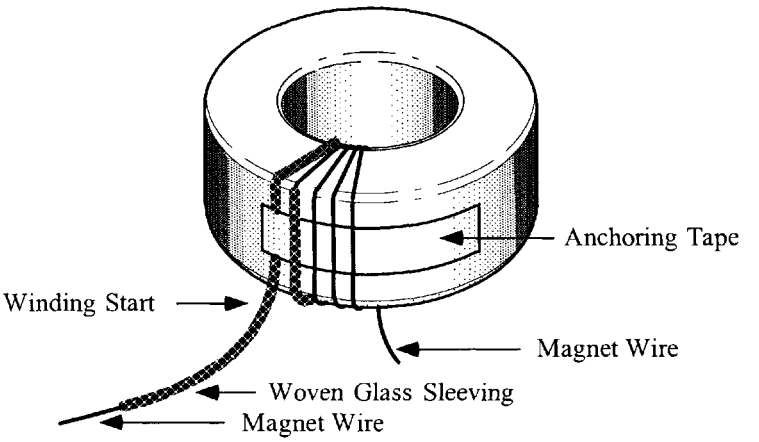

Figure 5-74. Toroid, Self-Start Lead with Woven Glass Sleeving.

Toroid Self-Finish Lead

The Toroid Self-Finish Lead shall be fabricated, as shown in Figure 5-75.

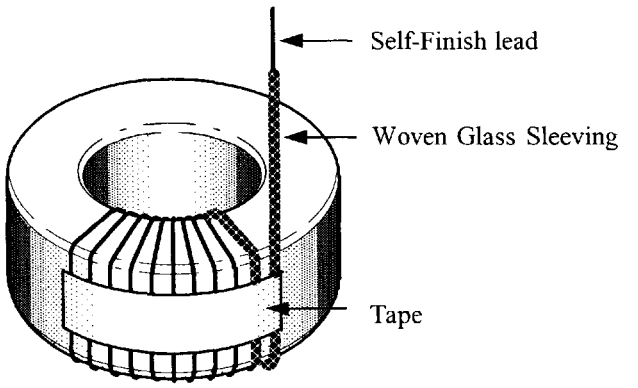

Figure 5-75. Toroid, Self-Finished Lead with Woven Glass Sleeving.

Toroid Self-Tapping Lead (Step 1 of 3)

The Toroid Self-Tapping Lead shall be fabricated with a loop, as shown in Figure 5-76.

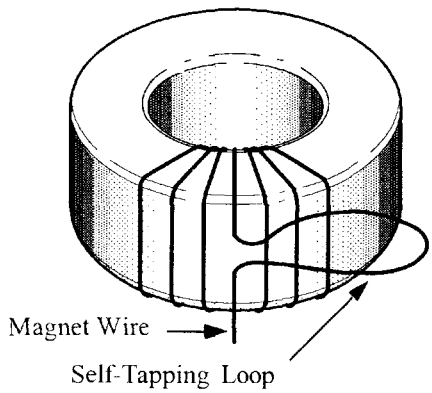

Figure 5-76. Breakout Loop for Self-Tapping Lead.

Toroid Self-Tapping Lead (Step 2 of 3)

The Toroid Self-Tapping Lead is anchored with tape, as shown in Figure 5-77.

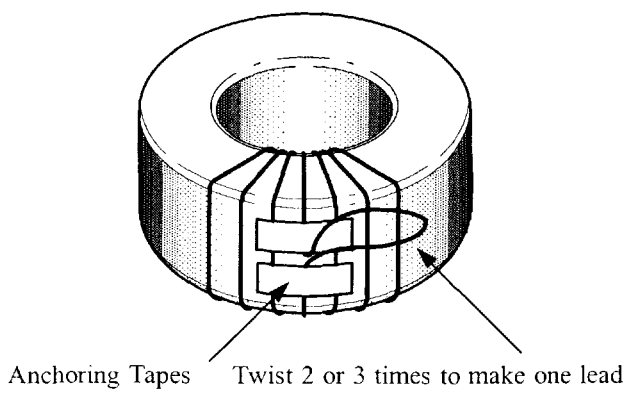

Figure 5-77. Anchor Tape the Breakout Loop for Self-Tapping Lead.

Toroid Self-Tapping Lead (Step 3 of 3)

The Toroid Self-Tapping Lead shall be fabricated, as shown in Figure 5-78.

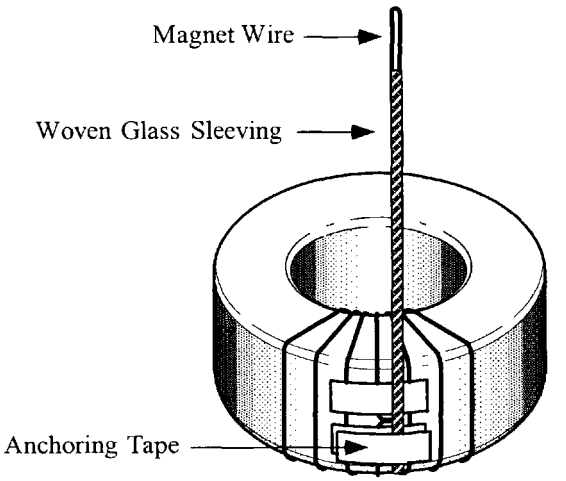

Figure 5-78. Breakout Loop with Woven Glass Sleeving.

Solder Joints

Solder joints are prohibited within the winding. All splicing, including the interim leads, must be placed on the periphery toroid after it is wound, as shown in Figure 5-79.

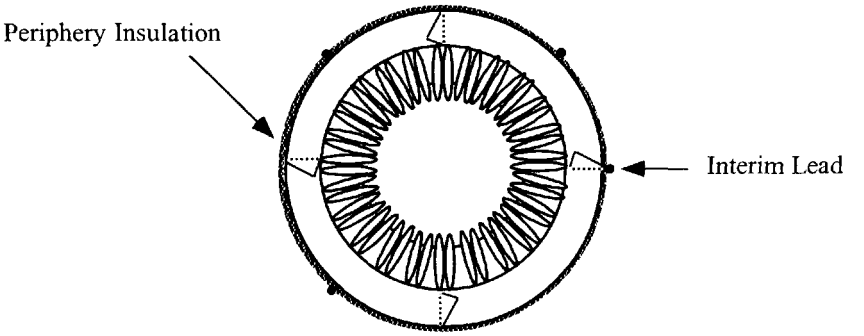

Figure 5-79. Soldering and Finishing the Interim Lead.

External Toroid Leads

External Toroid Leads (vertical)

The External Interim Lead Wire shall be fabricated, as shown in Figures 5-80, 5-81, and 5-82.

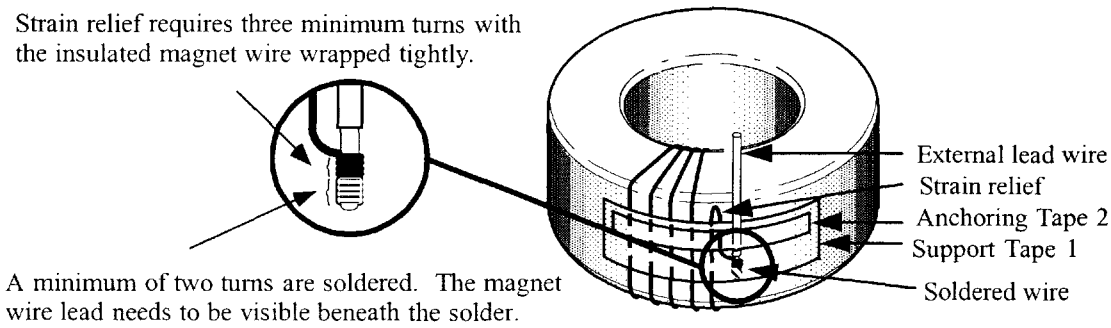

Figure 5-80. Soldering the Interim Lead.

Finished External Toroid Lead (Vertical)

The External Interim Lead Wire shall be finished, as shown in Figure 5-81.

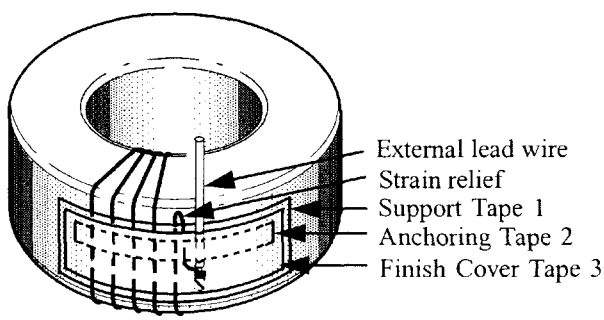

Figure 5-81. Finished, Vertical Interim Lead.

External Toroid Lead (Horizontal)

The External Interim Lead Wire shall be fabricated, as shown in Figure 5-82.

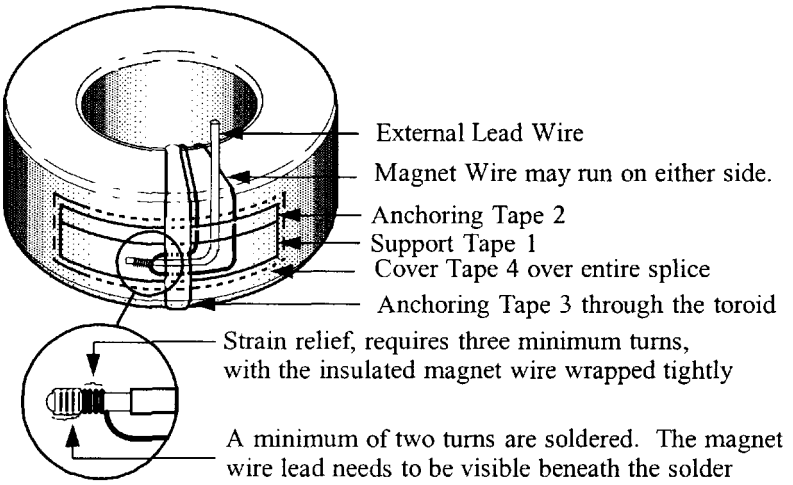

Figure 5-82. Finished, Horizontal Interim Lead.

Winding Requiring Interim Lead (Step 1 of 11)

Secure the Start Lead with Anchor Tape, as shown in Figure 5-83.

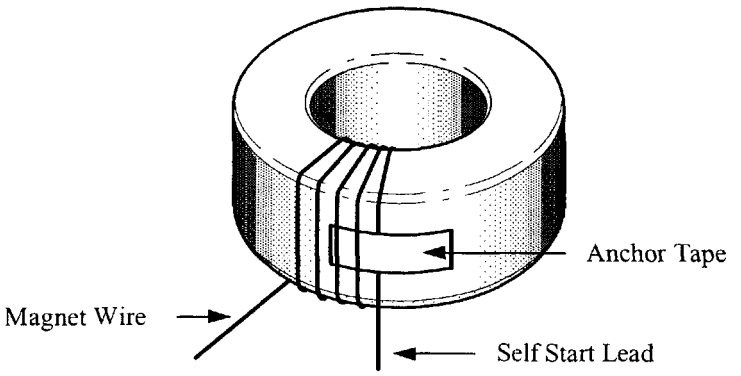

Figure 5-83. Securing the Start Lead with Anchor Tape.

Winding Requiring Interim Lead (Step 2 of 11)

Securing the Finish Lead with Anchor Tape, as shown in Figure 5-84.

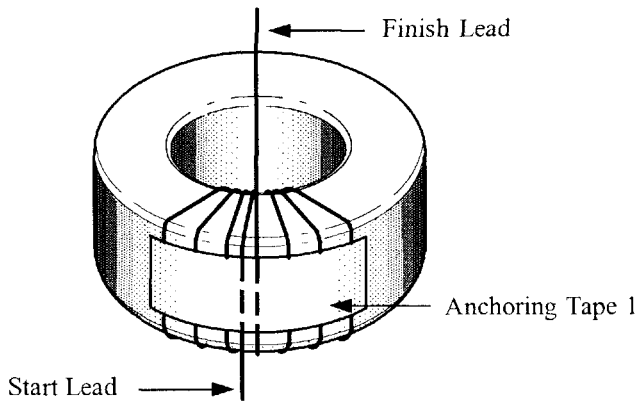

Figure 5-84. Securing the Finish Lead with Anchor Tape.

Winding Requiring Interim Lead (Step 3 of 11)

Positioning the Start and Finish Leads with Anchor Tape 1, as shown in Figure 5-85.

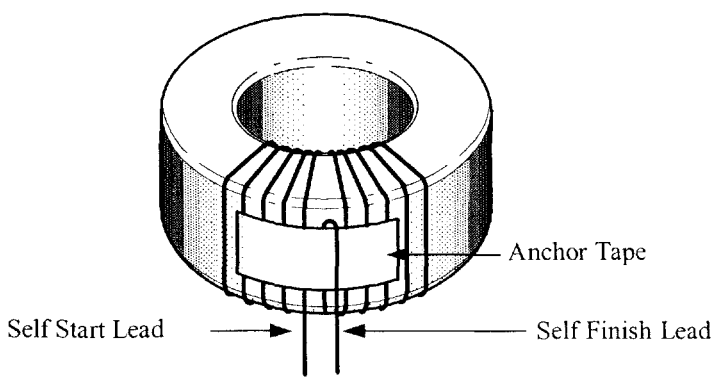

Figure 5-85. Positioning the Start and Finish Leads.

Winding Requiring Interim Lead (Step 4 of 11)

Securing the Finish Lead with Anchor Tape 2, as shown in Figure 5-86.

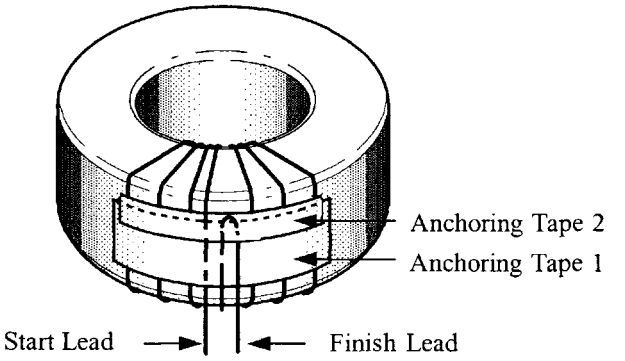

Figure 5-86. Securing the Finish Lead.

Winding Requiring Interim Lead (Step 5 of 11)

Attach Interim Leads No. 1 and No. 2 with Anchor Tape 3 and Solder, as shown in Figure 5-87.

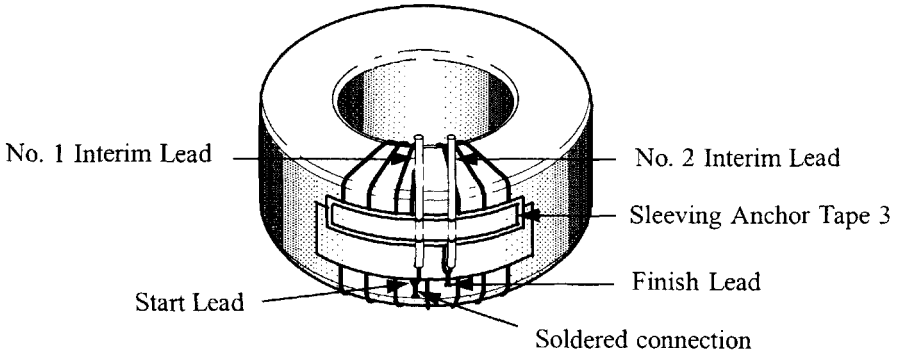

Figure 5-87. Attach Interim Leads.

Winding Requiring Interim Lead (Step 6 of 11)

Insulate the solder connections with the Finish Cover Tape 4, as shown in Figure 5-88.

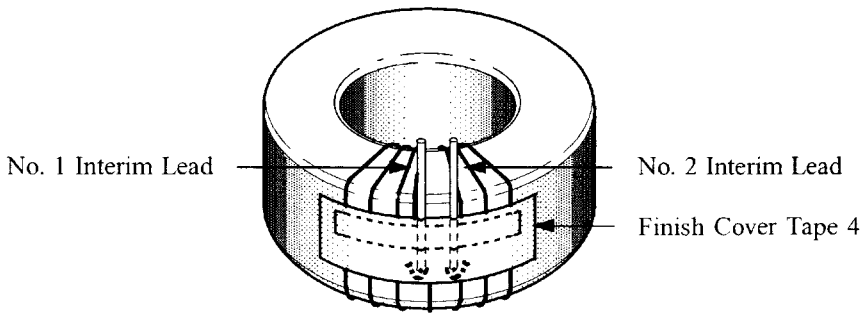

Figure 5-88. Insulate the Solder Connections with Tape.

Winding Requiring Interim Lead (Step 7 of 11)

Breakout the loop for Self-tapping Lead, as shown in Figure 5-89.

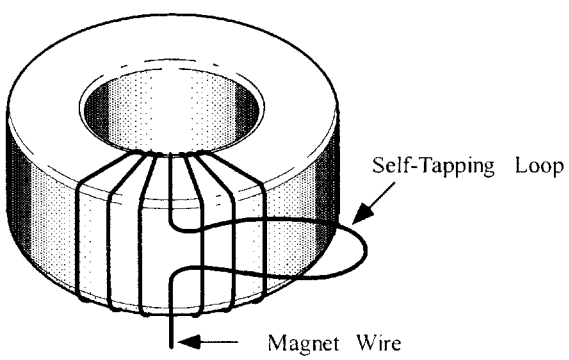

Figure 5-89. Breakout the Loop for Self-Tapping Lead.

Winding Requiring Interim Lead (Step 8 of 11)

Anchor tape the Self-tapping Lead, as shown in Figure 5-90.

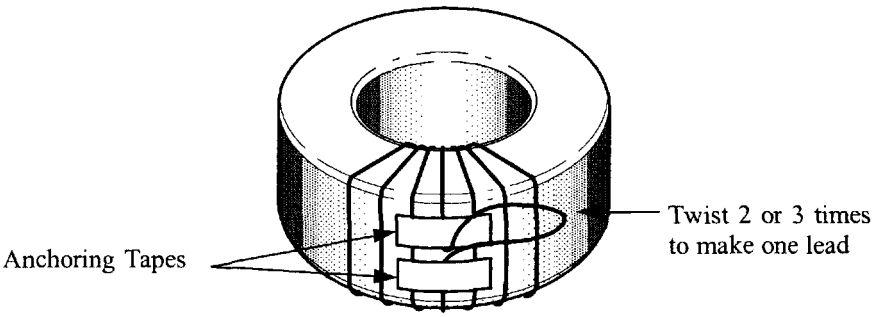

Figure 5-90. Anchor Tape the Self-Tapping Lead.

Winding Requiring Interim Lead (Step 9 of 11)

Securing the Self-tapping lead with Anchor Tape 3, as shown in Figure 5-91.

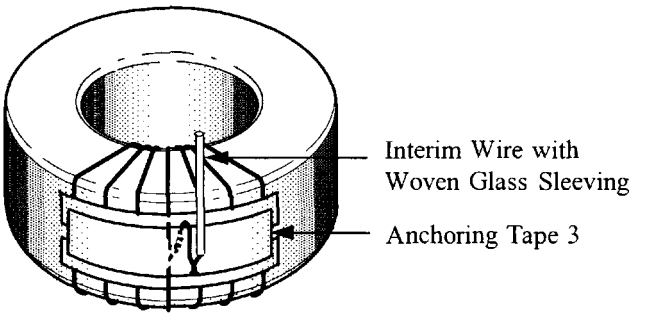

Figure 5-91. Securing the Self-Tapping Lead.

Winding Requiring Interim Lead (Step 10 of 11)

Secure the Interim Lead with Anchor Tape 4 and solder, as shown in Figure 5-92.

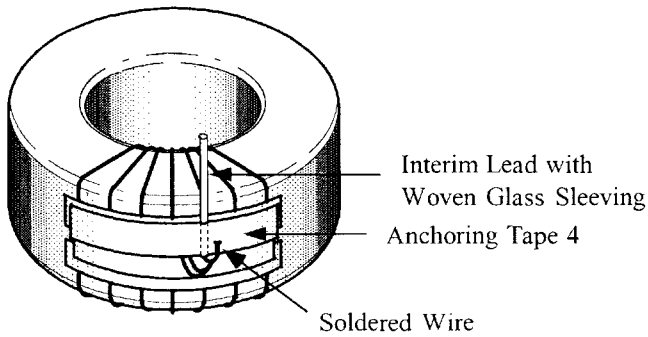

Figure 5-92. Securing the Interim Lead.

Winding Requiring Interim Lead (Step 11 of 11)

Insulate the solder connection with Anchor Tape 5, as shown in Figure 5-93.

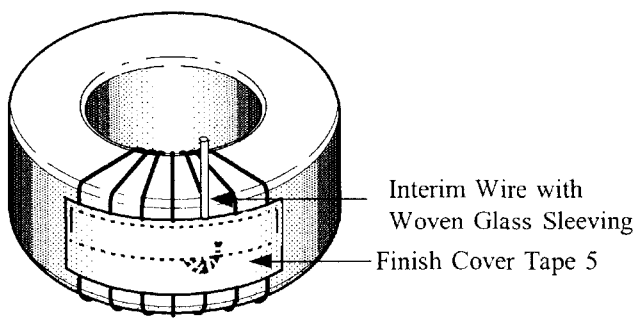

Figure 5-93. Finished Interim Lead, with Insulating Tape.

Progressive or Bank Winding

The winding is placed on the core in sections. A tape barrier is placed around the core for the start. The start of the first section is at the tape barrier, as shown in Figure 5-94. Then, after so many turns, the second section is started. The start of the second section will overlap the first. This continues around the core for about 350°, as shown in Figure 5-95.

An overview is shown of how the winding should look when it is finished. The number of overturns, each section has, is dependent on the design engineer, as shown in Figure 5-95.

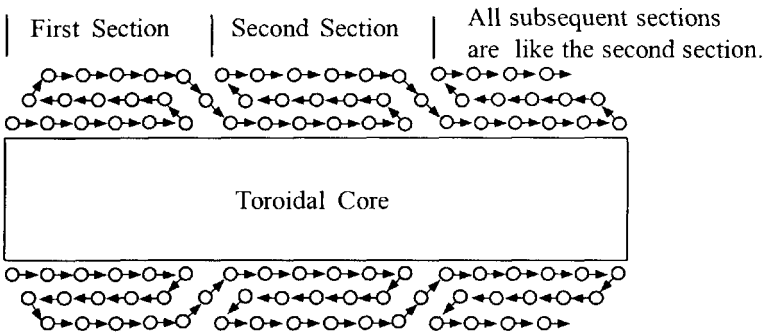

Figure 5-94. A Side View of a Progressive Wound Toroid.

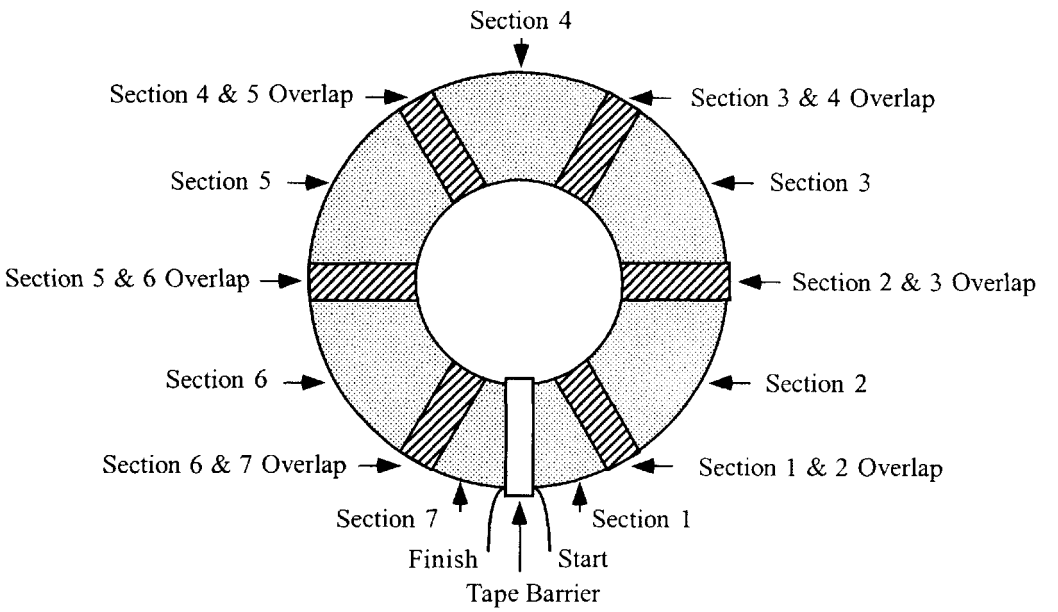

Figure 5-95. A Top View of a Progressive Wound Toroid.