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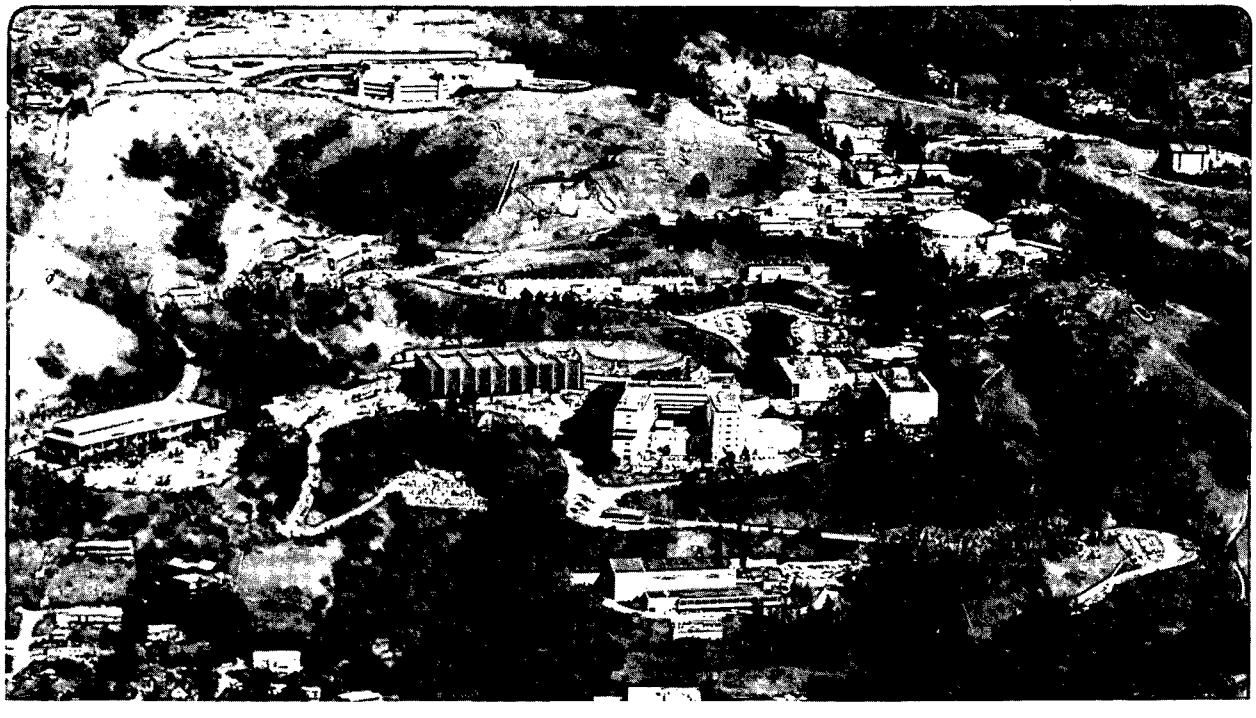
## Engineering & Technical Services Division





## DISCLAIMER

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# ENGINEERING NOTE

| CODE | SERIAL | PAGE |
|---|---|---|
| P40406 | M5663 | 1 of 15 |


| AUTHOR | DEPARTMENT | LOCATION | DATE |
|---|---|---|---|
| Dale Nesbitt D.D.N. | MECHANICAL ENGINEERING | Berkeley | 30 January 1981 |


PROGRAM — PROJECT — JOB

PEP-4

FIELD CAGES (TPC)

TITLE

LARGE RADIUS COURSE FIELD CAGE INSULATION

The purpose of this NOTE is to record pertinent information about the methods used to install the 'Graded' Insulation. This work was done by SHELDAHL, INC., Northfield, Minnesota.

Pages 2 through 12 consist of a copy of SHELDAHL's Specification P00946 which covers the installation of the Insulator. Pages 13 through 15 are a copy of R. Madaras' trip report of 5 June 1980.

Drawing numbers pertaining to this work are:

20C0866 . . . Large Field Cage Insulation Sandwich

20C6256 . . . Ground Plane Assembly, LRCFC

This NOTE does not cover any details of the insulator construction nor electrical testing.

REVISIONS

| LTR | SHT | DESCRIPTION | ECO | DATE | ENG APPR | DOC APPR |
|---|---|---|---|---|---|---|
| - | ALL | PRODUCTION RELEASE | | 7/3/80 | ELH | K. Conkon |





| SHT | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| REV | - | - | - | - | - | - | - | - | - | - |
| SHT | | | | | | | | | | |
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| SIGNATURE | DATE |
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| PREP ELHaack | 6-17-80 |
| CHKD [illegible] | 6-19-80 |
| APPR [illegible] | 6-19-80 |
| APPR ELHaack | 6-19-80 |

Sheldahl
Northfield, Minnesota 55057
SPECIFICATION

TITLE
Graded Insulation Installation on Large Radius Mandrel

| CLASSIFICATION | CODE IDENT | SPECIFICATION NO. | SHT 1 OF 10 |
|---|---|---|---|
| | 53824 | P000946 | REV — |

FORM 3003 (1) T. Olson 6/18/80

## 1.0 Purpose

This specification identifies the procedures for preparing the mandrel, winding the laminate onto the mandrel and finishing the outer surface of the wound insulator. These procedures are based on a customer-furnished specificiation which was modified by mutual consent during the manufacturing process to accomodate unforeseen changes. This specification, therefore, represents the "as-built" configuration of the furnished part. The desired finished dimensions are as follows:

- OD of large-radius course field cage = 77.93" (1979.4 mm)
- circumference of field cage = 244.82" = 20.40'
- thickness of graded insulation = 12.3 mm
- OD of graded insulation = 2004 mm = 78.90"
- circumference of graded insulation = 247.86" = 20.66'
- approximate number of turns = 58
- approximate length of laminate = 1190'

## 2.0 Machinery and Equipment

### 2.1 Winder/laminator

A special laminator was fabricated to perform the operation as shown in Fig. 1. Its purpose is to provide web handling capability, heat and pressure to bond the laminate to the mandrel and a uniform winding speed.

### 2.2 Cut-off Tool

This device is used to trim the starting edge of the laminate to a $15^{\circ}$ bevel to minimize the potential for an air gap under the first wrap. (Fig. 2)

### 2.3 Hand held Pyrometer - $200^{\circ}$F to $400^{\circ}$F range

### 2.4 Soldering Pencils - 40 watt

### 2.5 Steel scale, 8 ft., graduated in 0.01"

2.6 Scissors, misc. paint brushes and rollers, rags, razor blades and other hand tools as required

2.7 Spray paint cartridge and paint bottle

3.0 Material Requirements

3.1 Laminate G155500 approx. 1500 ft. min.

3.2 Adhesive, A258, 2 gal. @ 20% solids

3.3 Methylene Chloride, C-1, approx. 5 gal.

3.4 Butyl Acetate, 1 gal.

3.5 Silver Paint, SC-13

3.6 Silver Paint, CC-2

3.7 2 mil Kapton x 1.0 oz. copper laminate in the following sizes and quantities: (per LBL Dwg 20 C1514)

1 ea. -1, 22-7/8" x 80", with holes
9 ea. -2, 22-7/8" x 80", plain
1 ea. -3, 18-1/2" x 80", plain

3.8 2 mil Kapton in the following size and quantities:

88 ea., 1" x 1"
4 ea., 2" x 2"

3.9 1 oz.copper strips, approx 1/4" wd. x 6" long

3.10 Electronic Solder

3.11 2 mil Teflon, 48" wd., approx. 500 ft.

3.12 1/2 mil Teflon, 48" wd., approx 1500 ft.

4.0 Procedure

4.1 Mandrel Preparation

4.1.1 Wipe the entire mandrel surface with lint free rags dampened with Butyl Acetate, discarding rags as they become soiled. Repeat wiping using clean rags.

4.1.2 Mask surface of mandrel outside of $\pm$ 39.5" ($^{+1/8}_{-0}$) from center with Teflon tape to prevent laminate from bonding there.

4.1.3 Measure where the center ring is on the mandrel with respect to the ends, so that later the finished insulator can be cut to the proper length to $\pm$ 1 mm (see step 4.6.6).

4.1.4 Mask center ring on mandrel with 2 mm wide orange tape. (Center the tape on the ring).

4.1.5 Coat entire mandrel with 4 coats of A258 adhesive at 6 to 9% solids for a total thickness of 2 mils (max.). Dry with heat lamps on and mandrel rotating at a setting 1 ft/min (50% setting) for one hour between coats. Allow an additional 24 hrs. of drying at room temperature prior to winding, with heat lamps on and mandrel rotating during normal business hours.

4.1.6 Remove mask on center ring, and mask on both sides of the center ring using orange tape. (2 mm. wd. gap).

4.1.7 Shake silver paint (SC-13) thoroughly, and paint 2 coats of silver paint on the center ring. Dry thoroughly. Remove mask.

4.1.8 Determine azimuthal fiducial marks for step 4.6.4.

4.1.9 Wrap ~2" wide Teflon sheet around the surface of the mandrel, over the central region, centered over silver stripe.

4.2 Web Alignment and Set-up. (Web diagram of Fig. 1)

4.2.1 Position laminate on unwind so that the guide stripe is lined up with the edge guide and the center stripe is centered on the central ring of the mandrel.

4.2.2 Bring the web up between the nip roll and onto mandrel for approximately 7 ft., and let the Tuftane block on the adhesive on the mandrel surface.

4.2.3 Set all brakes to proper settings. Turn mandrel for one revolution with nip roll OPEN to even tensions and check tracking of the edge guide. If tension or alignment are not correct, repeat this step.

4.2.4 Cut off 2" wd. Teflon sheet and turn mandrel until the Teflon edge passes by where the nip roll would close.

4.2.5 Set up unwind for 48" Teflon and thread under herring bone, through the nip roll and secure end on mandrel.

4.2.6 Check edge guide alignment and machine parameters:

Standby conditions

| | |
|---|---|
| Nip roll pressure | 120 psi |
| Nip roll temperature settings | 340°F (center and ends) |
| Supply roll brake | 120 psi + auxiliary brake |
| Idler roll brake (herringbone) | Minimum to spread web |
| Winding speed | 1.5 ft/min |
| Main Temperature control settings | Emittance 0.72 |
| | Reset 50% |

| | |
|---|---|
| | Manual adj. 0%<br>Set Point 35%<br>Switch S2, Auto. Internal<br>Prop. Band 20% |
| Hand held pyrometer reading at center bottom of nip roll | $340^{\circ}F \pm 10^{\circ}F$ |
| Six heat lamps | on |

4.3 Laminate attachment to mandrel

4.3.1 Close nip roll and start drive for mandrel

CAUTION: The mandrel must always be in the stopped position when the nip roll is opened or closed, i.e., when closing (starting) the nip is closed first, then the mandrel drive is turned on. When opening (stopping) the mandrel drive is turned off, then the nip roll is opened. These steps are done in a visually controlled succession to avoid damage to the laminator.

4.3.2 Turn main heater control down to $285^{\circ}F$ after 1-1/2 turns of nip roll. From this time on, the hand held pyrometer at center bottom of nip roll shall read $330^{\circ}F \pm 10^{\circ}F$. This, and all other machine parameters will be read and recorded at 15 minute intervals initially. After all temperatures have stabilized, these readings and recordings will be done at 1/2 hour intervals.

4.3.3 After ~1/2 turn of mandrel, stop the drive and open the nip roll. Cut the leader part of the laminate off, per Fig. 3, with a bevel angle of $\sim 15^{\circ}$ and then bond down the edge with a hand iron. Apply 2 coats of A258 adhesive to the edge (not by the silver paint, though). Dry thoroughly with moderate heat from heat gun after each coat.

4.3.4 Reset machine settings per 4.2.6 and allow to stabilize.

4.4 Winding Procedure

4.4.1 Before closing nip roll, reverse the drive on the mandrel and rotate approx. 4 to 6 inches on the circumference. This allows the nip roll to close on a surface where material has previously been laminated and avoids any tendency for trapping blisters in the adhesive. Turn mandrel drive back to winding direction.

4.4.2 Close nip roll and restart drive for mandrel. Repeat step 4.3.2 at the prescribed time.

4.4.3 After 2 or 3 wraps have been wound on the mandrel, engage the edge cutters on each side of the machine to trim off the laminate edges where excessive adhesive and polyurethane would otherwise cause a build-up on the mandrel. Approximately 1/2 in. can be trimmed from each edge depending on the width of the laminate.

4.4.4 Remove polyethylene and Teflon release film and discard as they become accessible on the back side of the mandrel either manually or using a portable rewind.

4.4.5 If there is any need for stopping during the winding procedure, the machine parameters will be returned to standby conditions during the shutdown period. At restart, the procedures of Para. 4.4.1 and 4.4.2 will be followed.

4.4.6 Continue until insulator thickness is 12.3 mm (approximately 58 turns), then stop the drive and open the nip roll. NOTE: Stop the winding so that the silver paint at the end of the laminate (see following steps) does not bridge the 1/2" gap in the copper-Kapton laminate (see step 4.6.2), and is greater than 4 ft. from the azimuthal fiducial mark. Return machine settings to standby conditions (step 4.2.6) and turn heat lamps off.

4.5 Finishing the outer end of the laminate

4.5.1 Mask and spray silver paint (CC-2) on the web and cylinder (along the full width in both cases) as shown in Figure 4a, so that they will overlap as shown in Figure 4b, after step 4.5.6 is completed.

4.5.2 Remove masking

4.5.3 Starting at point AA on the surface of the cylinder (see Fig. 4b), cover the cylinder with Teflon sheet so that the nip roll doesn't bond the material past that point (AA).

4.5.4 Attach (with a dab of adhesive) 3 narrow strips of aluminum foil to the web where it was painted with the silver paint, at positions 1/4, 1/2, 3/4 of the width. The center piece of aluminum foil should extend up past the silver paint and onto the central stripe of the laminate. These strips will insure that the ground connection of the laminate is brought out from under the edge.

4.5.5 Close nip roll and start drive for mandrel. Leave machine settings at standby conditions if length to be laminated is less than 5 ft. After point AA of the cylinder passes by the nip roll, stop the drive and open the nip roll.

4.5.6 Cut web away from cylinder, and then carefully trim the end of the web at the edge of the bond (i.e., at point AA). Be careful not to cut the 3 pieces of aluminum foil. Laminate down the edge with hand iron. Apply silver paint (SC-13) on top of the three aluminum strips.

4.5.7 Cover the whole cylinder with 2 mil Teflon sheet.

4.5.8 Close the nip roll and start the drive for the mandrel. Adjust per Para 4.3.2 and continue for about 10 turns. Then turn the heaters off and continue to turn the cylinder with the nip roll against it until the temperature of the nip roll drops to about 125°F. Remove 2 mil Teflon cover.

4.5.9 Measure and record OD of laminate at a minimum of 5 equally spaced places across mandrel.

4.6 Installation of outside covering

4.6.1 Prepare Kapton-copper laminate sheets:

at LBL: 2 mil Kapton with 1 oz. (1.2 mil) copper

a) Prepare sheets according to print 20C1514-1,2,3:
1 of 20C1514-1: 22-7/8 x 80" with holes (for future soldering of "copper nails")
9 of 20C1514-2: 22-7/8 x 80" without holes
1 of 20C1514-3: 18-1/2 x 80" without holes

b) 88 of: 1" x 1" squares of Kapton (no copper)

at Sheldahl:

After cleaning thoroughly with cloth rags dampened with $MCL_2$, coat the copper side of all eleven sheets, except one of the -2 sheets with one mil (2 coats, 10% solids) of A258 adhesive. Dry thoroughly. The last -2 sheet will be masked for one inch to overlay the silver paint on the mandrel, wherever it occurs. The remaining surface of the copper will be cleaned and coated with 1 mil (2 coats, 10% solids) of A258. The masking will be removed and the exposed 2-inch copper will be painted with ~1 mil of SC-13 silver paint after the adjacent adhesive coating has been masked. Clean and coat both sides of each 1" x 1" square with 1 mil (2 coats, 10% solids) of A258 adhesive. Dry well.

4.6.2 With the winding machine, laminate the Kapton-copper pieces lengthwise on the graded insulation (i.e., with the 80" direction parallel to the axis of the cylinder), with the 1" x 1" Kapton squares under the tinned spots of the copper as shown in print 20C6256.

4.6.3 These sheets are installed one at a time, covered with 2 mil Teflon and laminated. Laminating will be from the center of each sheet outward to both edges. Machine parameters will be standby conditions.

4.6.4 Using A258 adhesive, attach 3-4 thin copper strips to the silver paint area of the mandrel, after removing the silver paint in a small area. Then cover the end of the copper with silver paint. Cut slits in the Kapton-copper piece of laminate with the silver paint so that the copper strips will pass through the laminate when it is bonded onto the cylinder. Solder the copper strips to the copper-Kapton laminate where the Kapton has been removed for this purpose. Cover each of these copper strips with a 2 x 2 inch square of Kapton x A258 and pass through the nip roll.

NOTE: The azimuthal orientation of the sheets is determined by the placement of the special Kapton-copper sheet with the holes. The placement of this special sheet is shown on print 20C6256, (the sheet is placed so that the azimuthal distance from the first set of holes on the sheet to the "azimuthal fiducial" is 5.40" clockwise on the gold end. The "azimuthal fiducial" is the line between the 2 pins in the 58th groove from the gold end). The 11 sheets will be butted together as shown in print 20C6256, except that at one place along the circumference there will be a gap of 1/2" between the Kapton-copper pieces. This gap should be roughly on the opposite side of the cylinder from the special piece of Kapton-copper sheet with the holes.

4.6.5 The tinned copper spots on the sheets will be connected together by soldering a small wire from one sheet to another, as shown in print 20C6256. A minimum amount of heat will be used.

4.6.6 Trim the graded insulation and copper-Kapton to 997 $\pm$ mm (39.25 $\pm$ 0.04 inches), from the center of the central ring, on each end, using the cutter set-up shown in Fig. 1.

5.0 Quality Assurance Provisions

A Quality Control Inspector will monitor all machine settings and manual operations to insure compliance with this specification. The inspector will be responsible for recording all information collected during the winding operation.

6.0 Packaging for Shipment

The finished mandrel/laminate surface will be wrapped with a minimum of 4 wraps of "bubble Poly". The finished mandrel will then be removed from the machine and installed in the customer-furnished shipping container. Shipment will be specified by the customer.

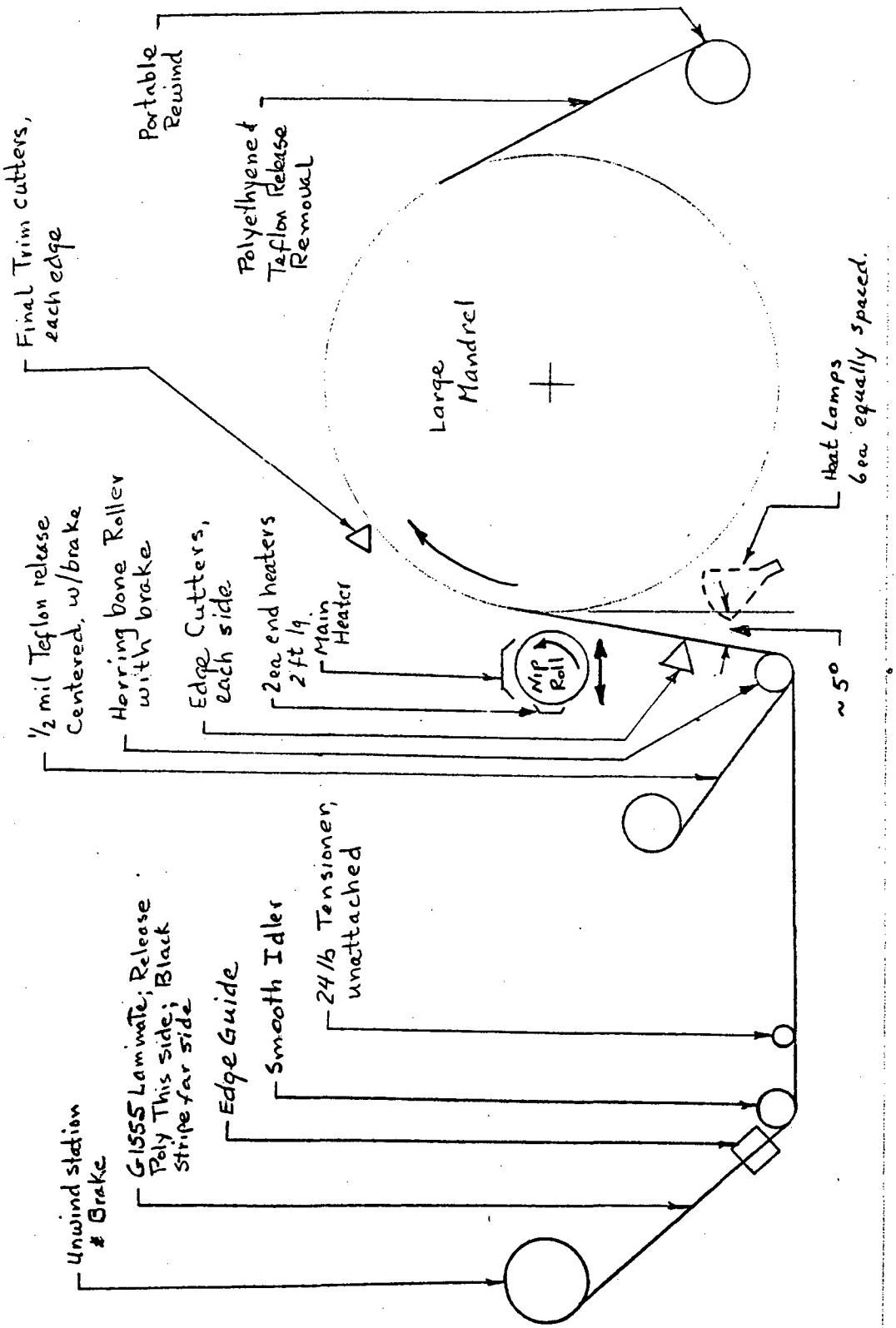


Fig. 1. Insulation Winding Machine

| Sheldahl Northfield, Minnesota 55057 | CLASSIFICATION: | CODE IDENT 53824 | SPECIFICATION NO. P000946 | SHT 9 REV 1 |
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FORM 3003 (2)

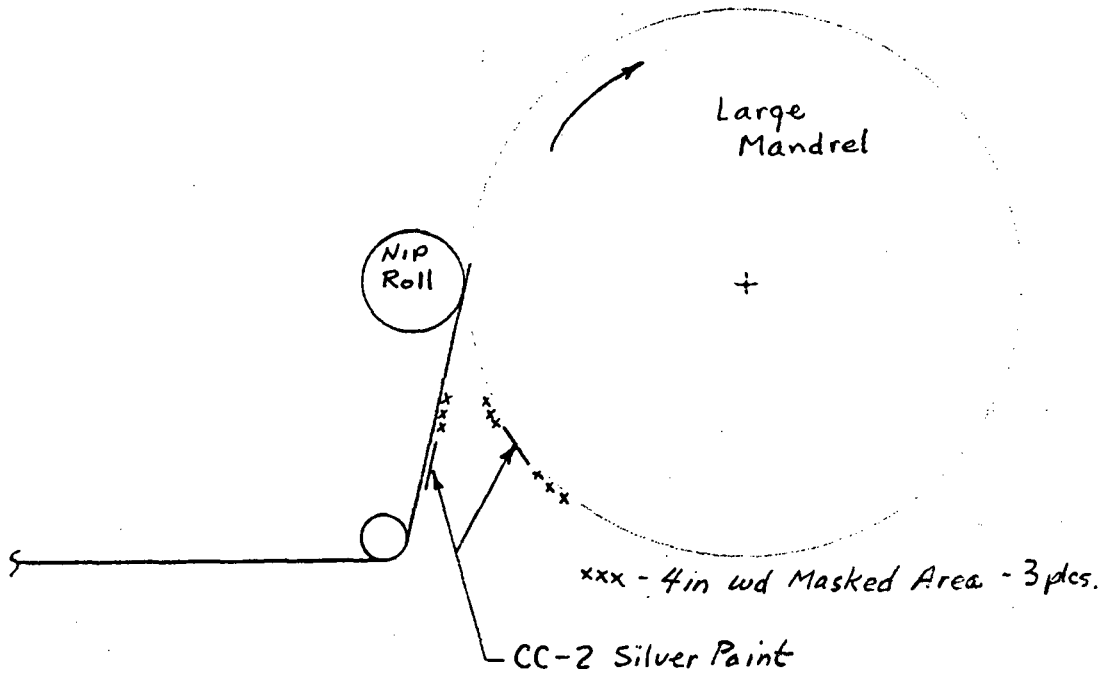


Fig 4a. Laminate End Preparation

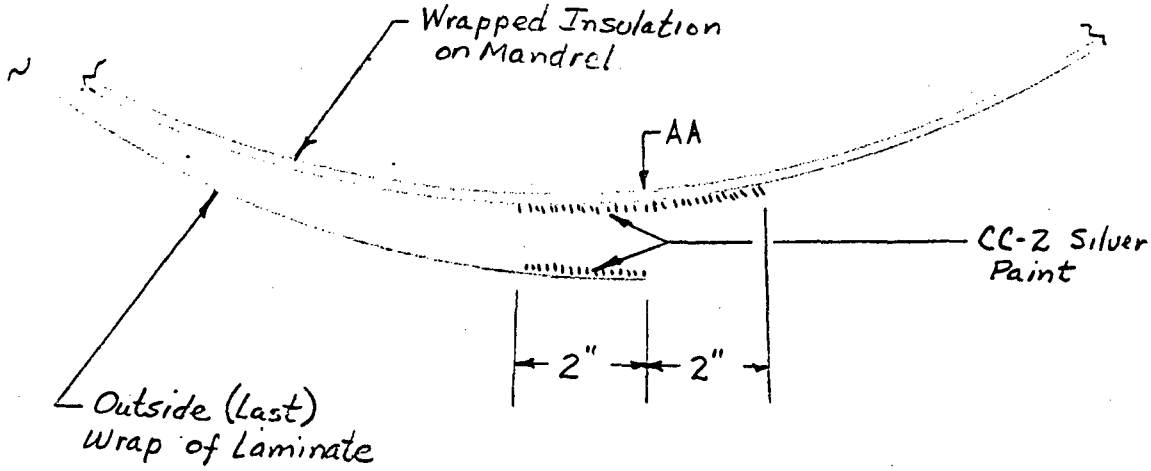


Fig 4b Finished End Detail.

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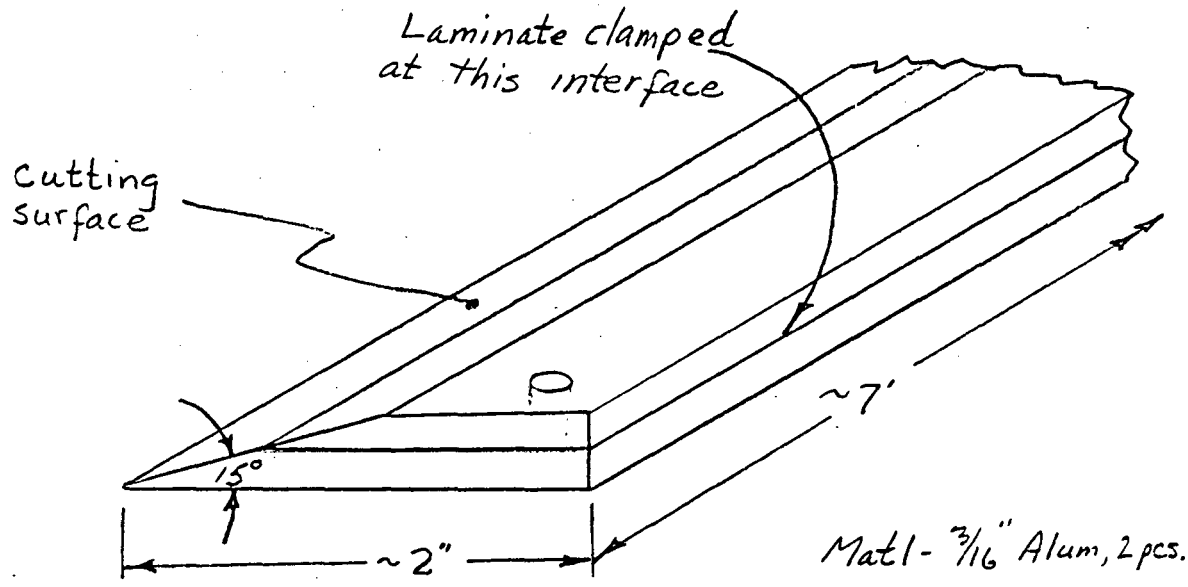


Fig 2 Edge Beveling Tool

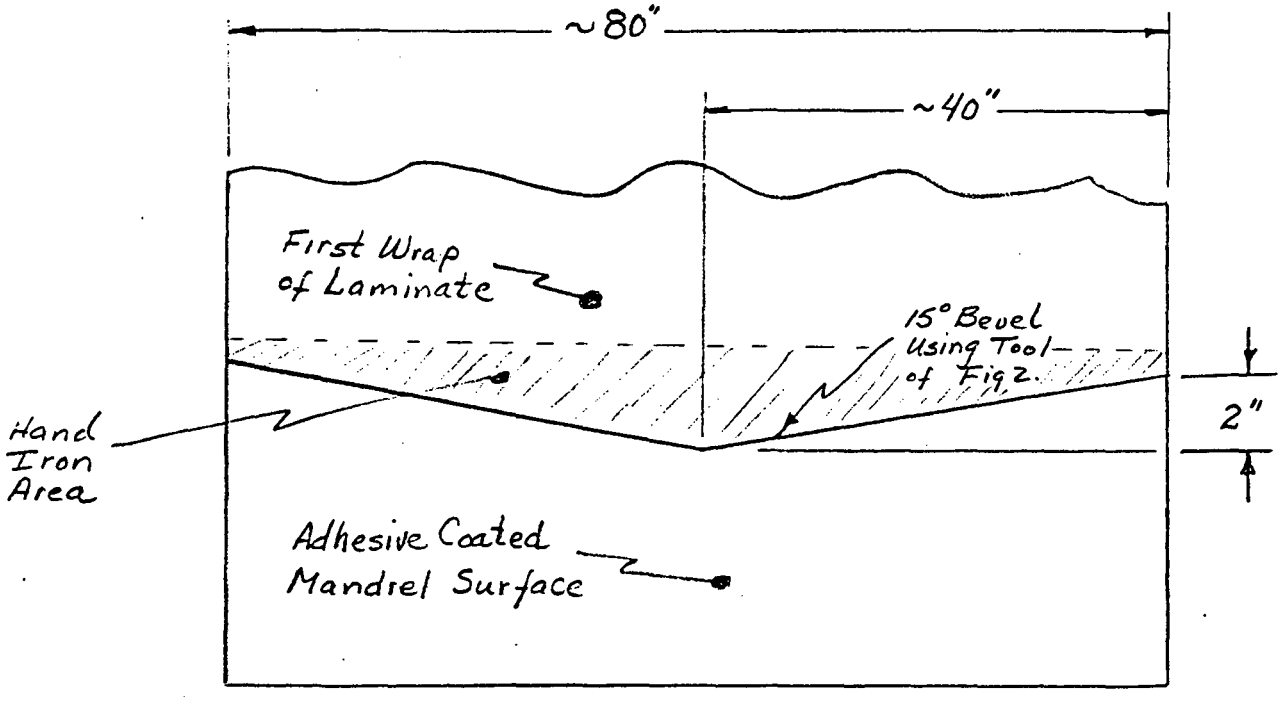


Fig 3. Starting Laminate onto Mandrel

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LAWRENCE BERKELEY LABORATORY
Bldg.: 50B Room: 5239 Ext.: 4410

June 5, 1980

TO: Distribution

FROM: Ron Madaras

SUBJECT: Trip Report for Visit to Sheldahl on May 29 - June 4, 1980

Alan Bross also went to Sheldahl on this trip. Larry Brown was at Sheldahl too, having been there for 1-1/2 weeks observing the fabrication of 2,025 feet of graded insulation laminate. The purpose of this trip was to observe the winding and bonding of that laminate around our large-radius coarse field cage to make a large-radius high voltage insulator for the TPC. The fabrication of the large-radius insulator was successful!

At Sheldahl we worked with Gene Haak, Terry Origer, Gus Myran, Dean Lembke, Jeff Solberg and Dave Knudsen.

1) As on past visits, I was again impressed by the dedication and committment that the people at Sheldahl have for our high voltage insulation project. They worked very hard, and very skillfully, to complete the successful fabrication of the large-radius insulator. For example, after working for two weeks on the fabrication and striping of the laminate itself, the Sheldahl people listed above worked the following schedule to wind the large-radius insulator:

   8 am - 10 pm on Saturday
   8 am Sunday to 11 am Monday (non-stop)
   8 am - 7 pm on Tuesday

   They were very responsive to our suggestions, did a very good job, and I am very pleased with their work.

2) The large-radius insulator has 62 layers of laminate.

3) Of the 1,625 feet of striped laminate we started with:

   325 feet was used up in solving problems
   1250 feet was used to fabricate the large-radius insulator
   50 feet was left over

4) About 400 feet of non-striped laminate is left over from the original 2,025 feet of laminate, which can be used for a future small-radius insulator.

5) On the first try at winding the large-radius insulator, we had a problem with large voids appearing whenever the operation was stopped and started.

This was solved by backing up the cylinder a few inches before starting after a stop, with a tensioning bar on the laminate to keep it tight.

6) We also had a problem with voids right at the beginning edge of the laminate on the cylinder, which was solved by adding several coats of adhesive to the edge.

7) We also had the usual problem with wrinkles appearing in the laminate as it was wound around the cylinder. After trying things like adjusting the brake on the herringbone idler roll, shimming the supply roll and re-positioning the supply roll, the wrinkles were finally elimianted by reversing the herringbone idler roll so that the pattern of its grooves pointed "up" to an observer in front of the winding machine (which is opposite from the way it was for the winding of the small-radius insulator). This pattern, with a light to moderate brake, eliminated the wrinkles.

8) On the second try at winding the large-radius insulator, the polyethylene (which prevents the adhesive from sticking and accumulating on the hot nip roll) began sticking to the nip roll. No matter how much the nip roll was cleaned, the polyethylene continued to stick to it at several places near the center. Finally the problem was solved by interleaving 4', 1/2 mil teflon between the polyethylene and the nip roll, on a continuous basis.

9) There was also a problem with keeping the resistive stripe of the laminate aligned on the center ring of the coarse field cage for the first turn. This was not, in fact, accomplished, and the resistive stripe effectively shorts together the central ring and the ring next to it on the north (blue) side. It was decided to continue to wind the insulator and live with this problem.

10) On the eighth turn two wrinkles developed side-by-side, about 8" in from the gold end. They were about 1-1/2 feet long. Since they would have caused severe voids in subsequent layers it was decided to "shave" them off and fill them in with adhesive.

11) After ~ 30 turns were done, the mandrel temperature on the side opposite from the nip roll was 95° F.

12) The outside diameter of the finished large-radius insulator was measured and ranges from 78.87" to 78.90". The specifications say it should be 78.90" or less, so the size is perfectly acceptable.

13) The G-10 coarse field cage moved azimuthally 2.2" with respect to the metal mandrel underneath it.

14) In the food department, honorable mention goes to Angelo's pizzas, as the large-radius insulator probably couldn't have been wound without them. All of us have fond memories (burp!) of the many Angelo's pizzas delivered to Sheldahl night after night.

15) First prize goes to the delicious blueberry pancakes at the Quaterback Club. Not being readily available in California, they were a special treat for me. They almost made getting out of bed enjoyable after working late at Sheldahl the night before.

Ron

Ron Madaras

RM/jrb

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