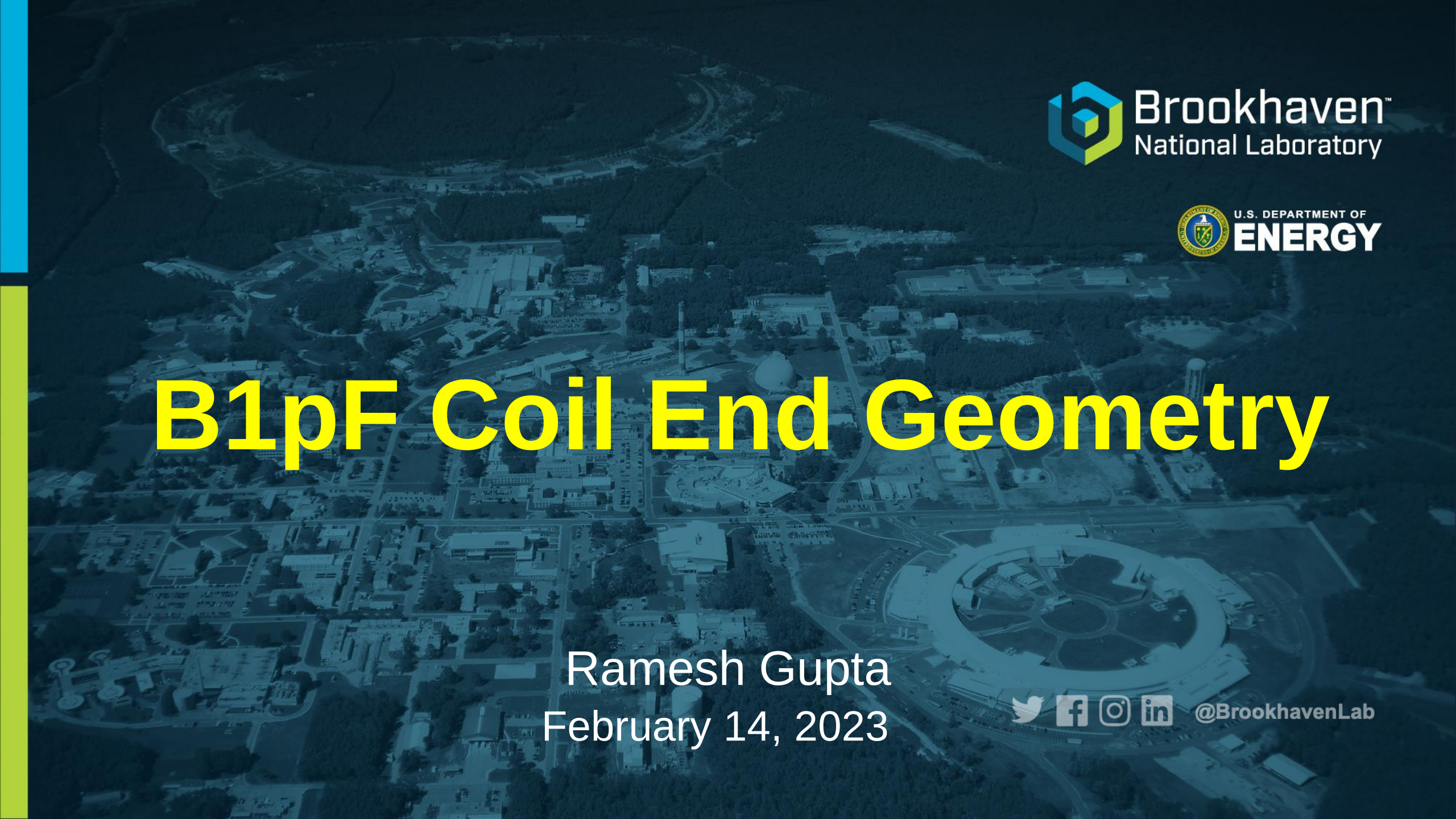


B1pF Coil End Geometry

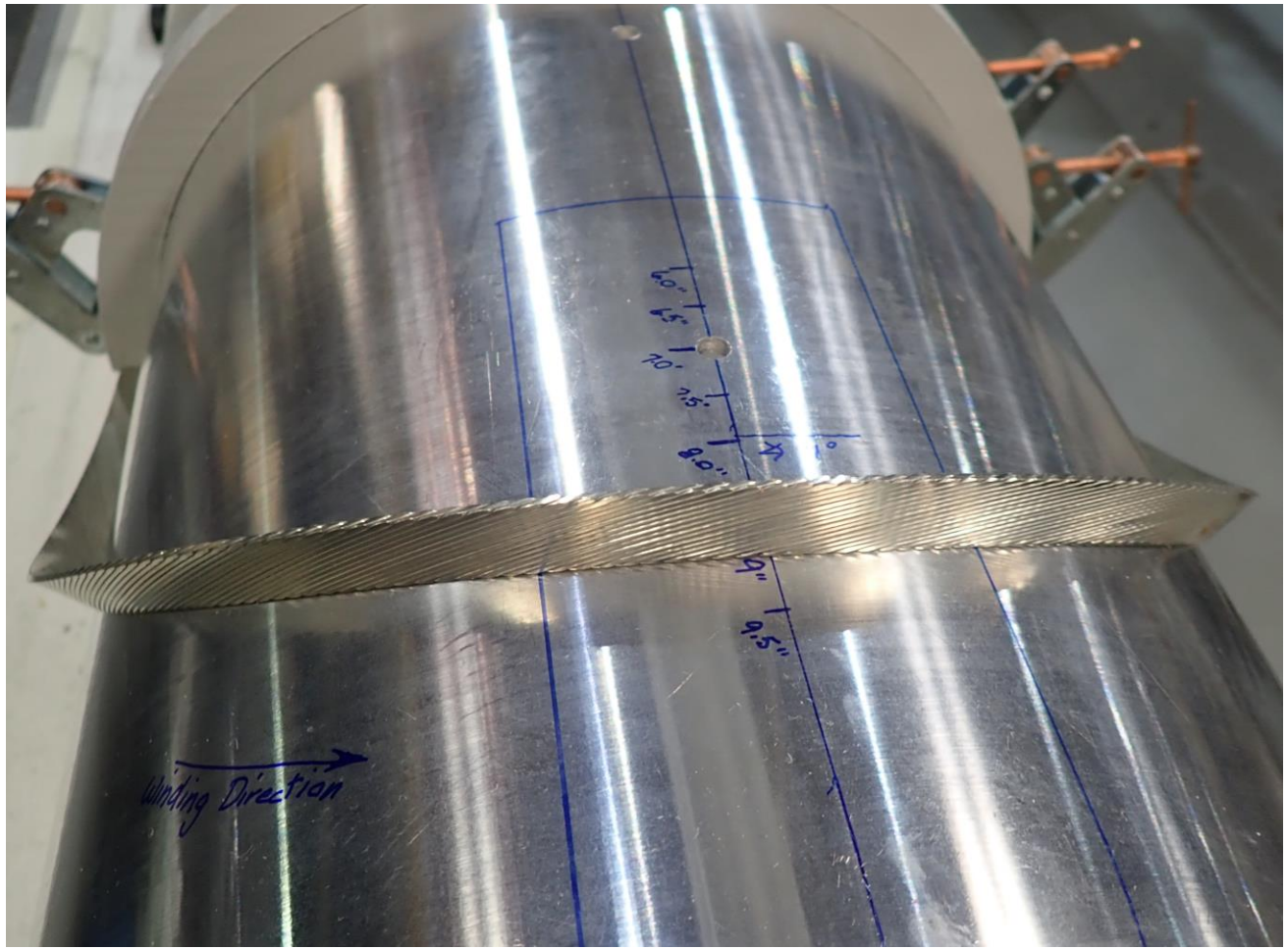
Ramesh Gupta

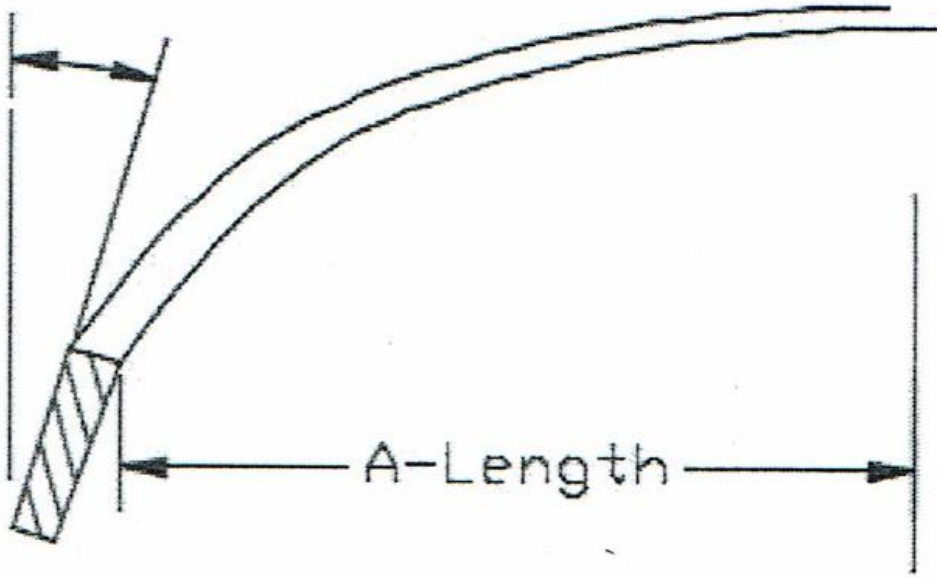
February 14, 2023

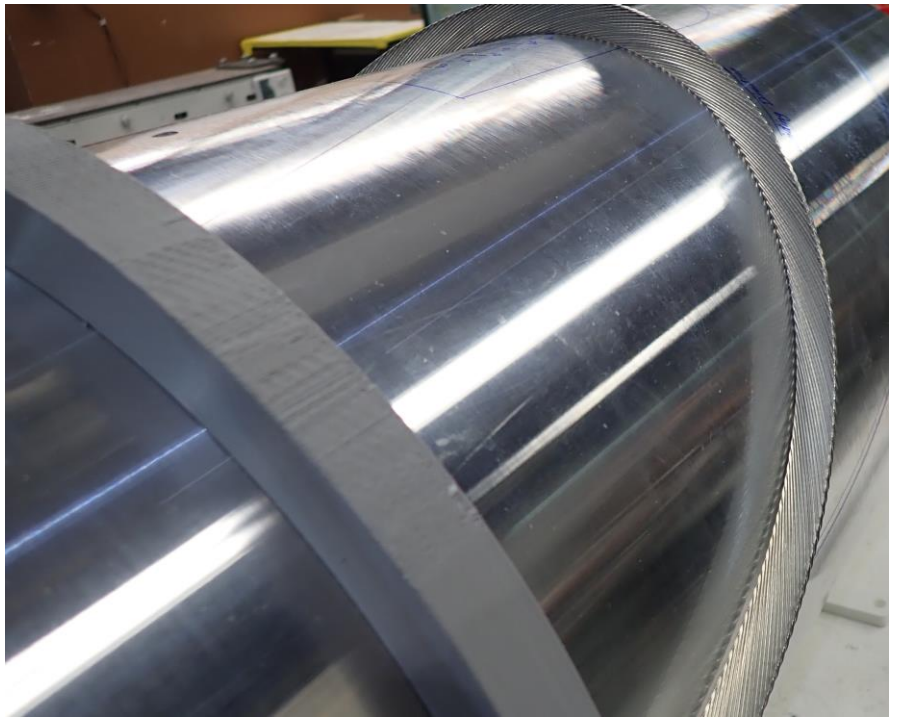
Background

- Coil end geometry is being optimized with ROXIE to obtain both good mechanical design (coil layout) and magnetic design (low integral harmonics, small peak field).
- Recently the coil end geometry was optimized with BEND to minimize strain in the cable in the coil ends and to obtain low tilt angle at the APEX, etc..
- Both ROXIE and BEND try to find the path of the turns individually and collectively in the end blocks to best meet certain design criterion for the parameters specified-length of the ends, ellipticity and the extend of departure from the ideal ellipse, tilt angle at the APEX, strain and path of the cable along the way, etc.
- This is a time-consuming process with unfortunately no clear guidance on the figure of merit on the limits of design variables and constraints on various parameters.
- To get better idea, single turn was wound on 3-d printed mandrel for two geometries optimized with ROXIE (larger tilt angle) and with BEND (smaller tilt angle).
- During the last few days, another approach (discussed earlier) was tried where we find how the turns will lay naturally (minimum strain) when certain parameters are varied systematically to guide ends to a desired direction. Results are encouraging.

Free Winding of the Midplane Turn (strain naturally minimized)



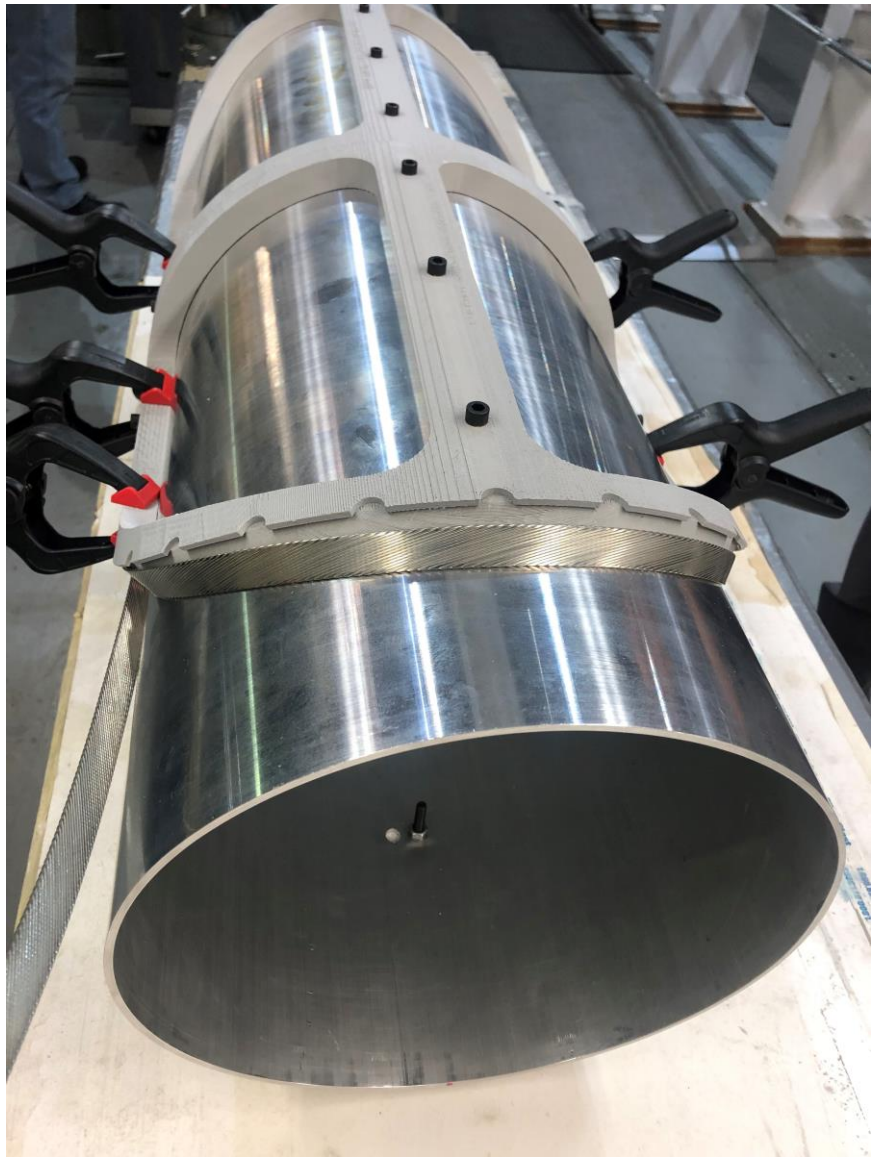


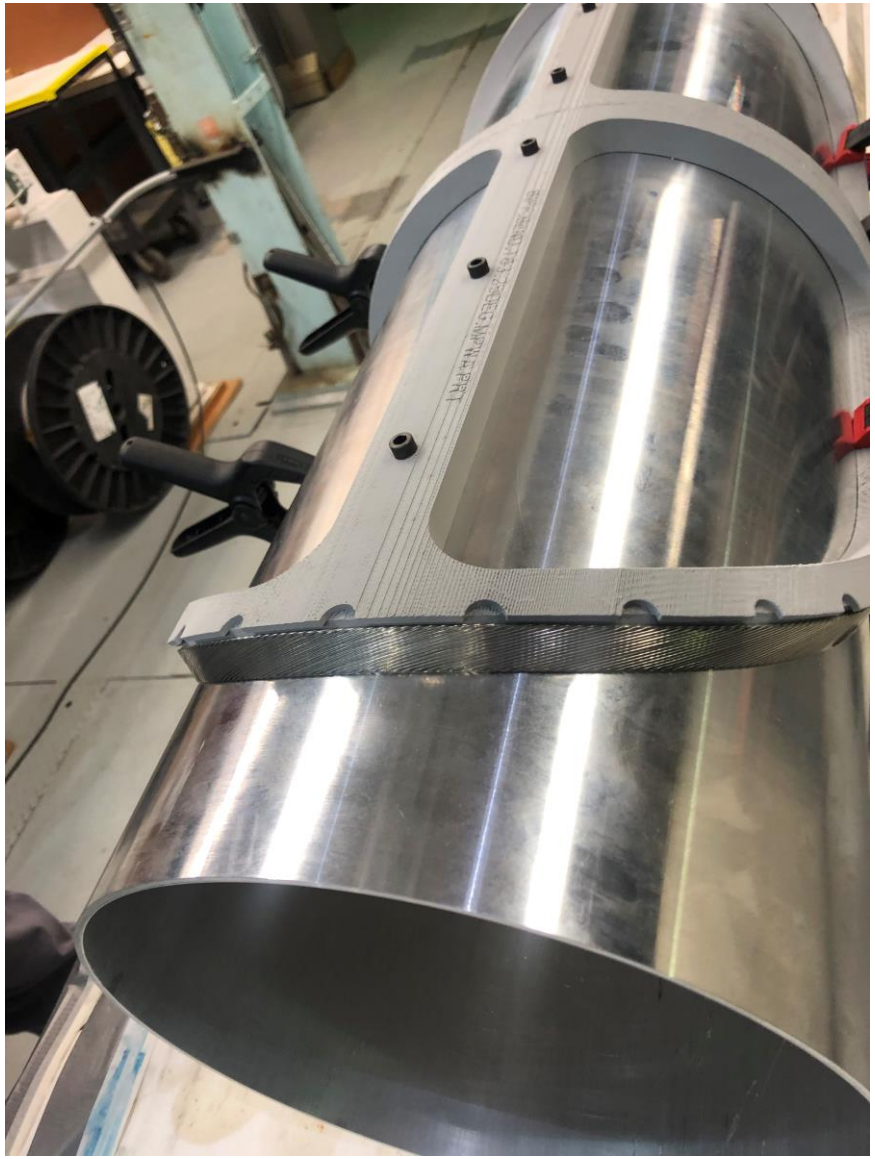


Winding of the Midplane Turn on Mandrel

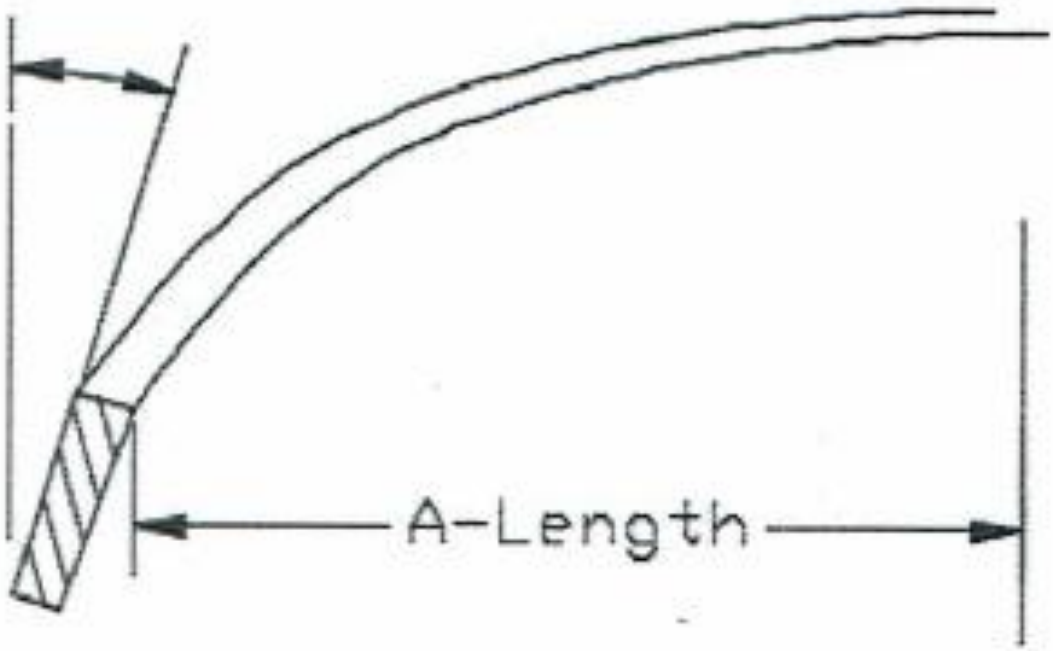
(optimized with ROXIE and BEND)

Tilt angles:
~25° and
~47° (?)





Systematic Study of the Natural Layout of the Midplane Turn



- In all cases, natural layout gives tilt angles much smaller than those used in ROXIE and smaller than in BEND.
- There is almost no change till 7.5". May be acceptable even beyond that.
- Cable stays on the tube (in some cases a gentle push is required)

B1pF Coil End **Cable fit/form checks**

Clamp cable to part straight section - extending free from back end of printed spacer.

Set end turn length to "A" dimension.

Measure turn angle from vertical at apex of turn and an point 1/2 way to apex.

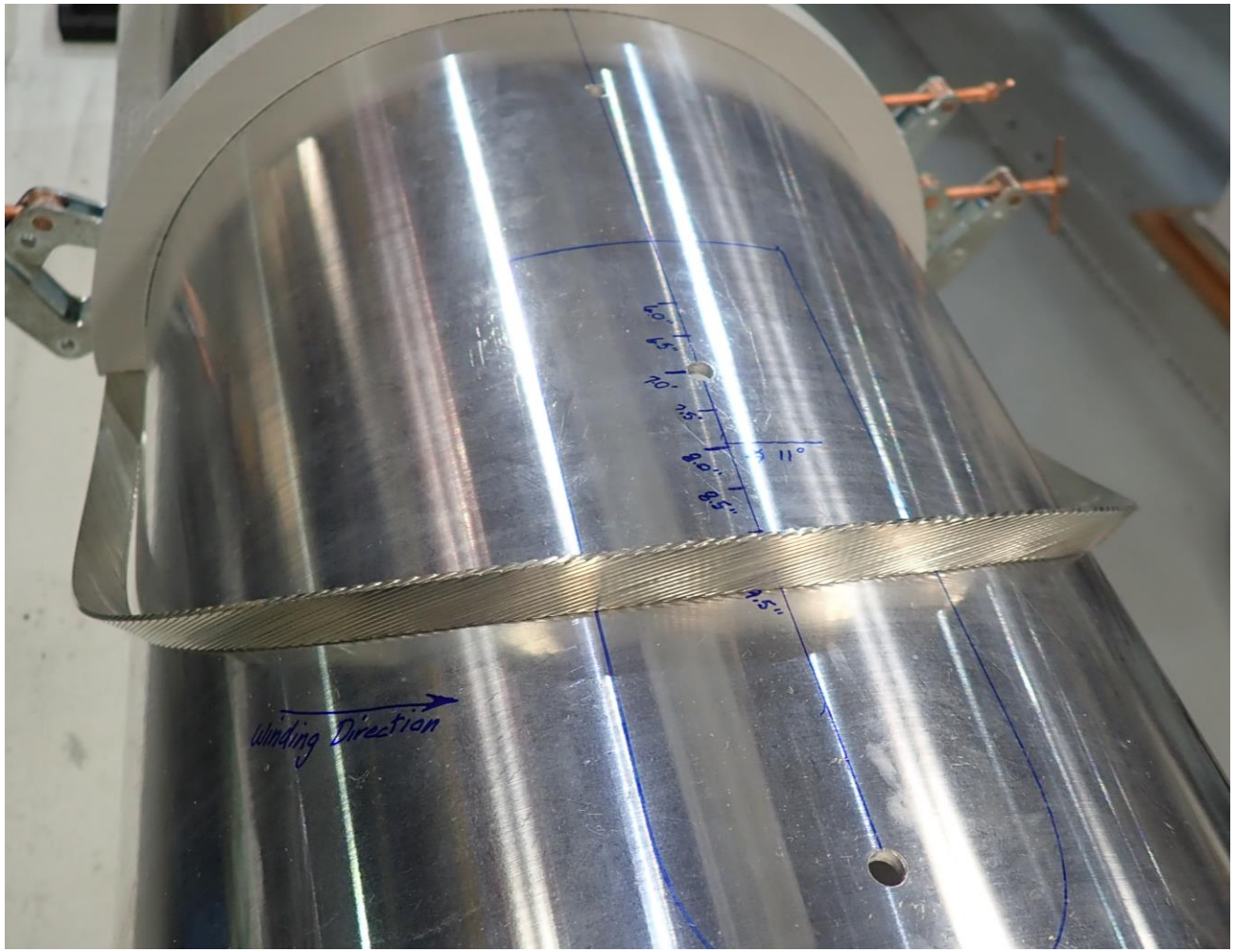
Note any gaps between cable and mandrel.

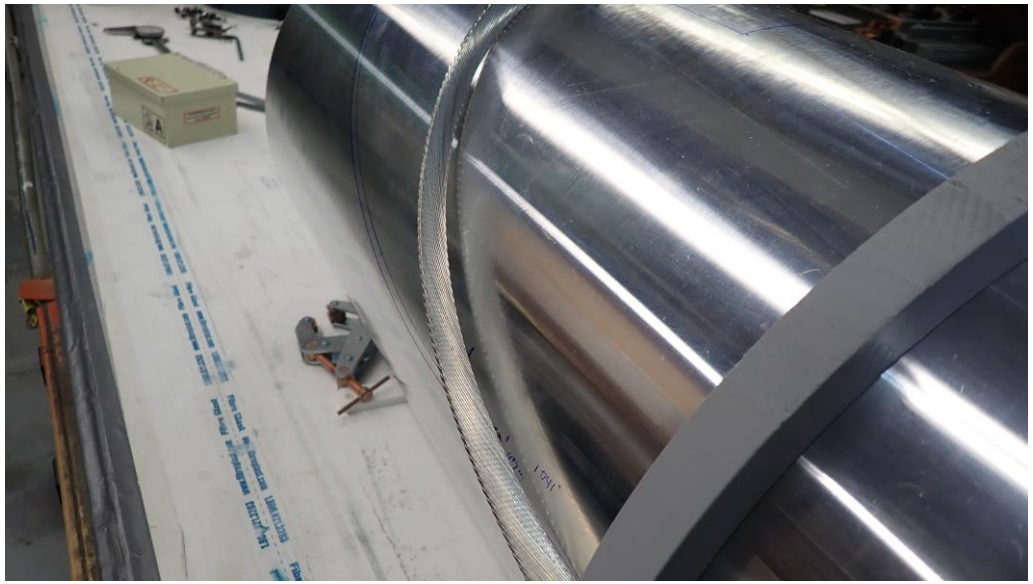
Photograph cable in each position.

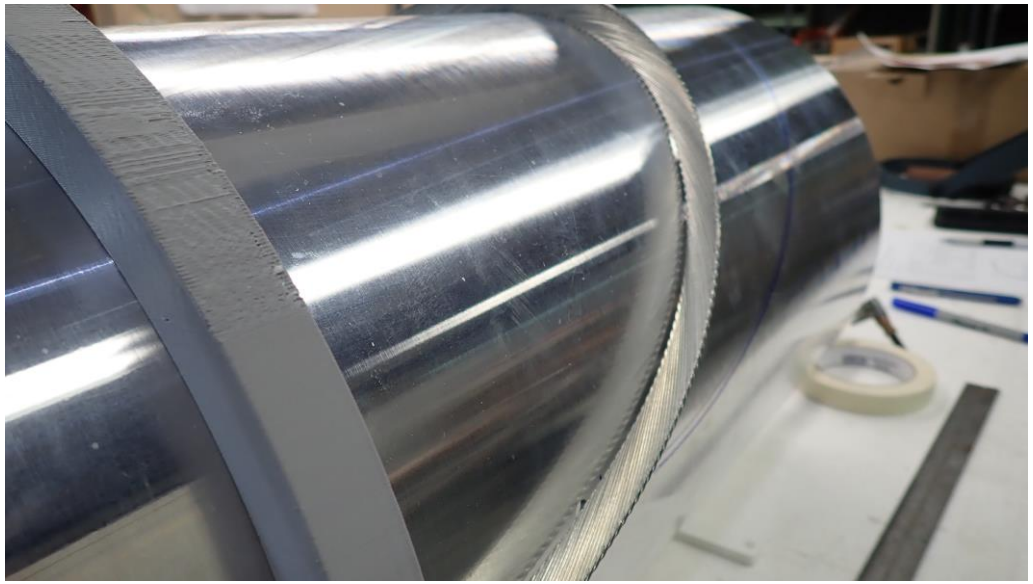
Reference: ROXIE/BEND ~9.25"

"A" Length	Angle apex	Angle 1/2 way	Notes
9.5	7°		.052" / .077"
9.0	8°		Enter ApexGap: .021", Exit ApexGap .062"
8.5	9°		Enter Apex gap: .008", Exit gap .062"
8.0	9°		" " " .006" " " .047"
7.5	8.7°		" " " .008" .047"
7.0	10.5°		.015" .047"
6.5	12.3°		Enter Apex .015" Exit Apex .041"
6.0	12.3°		

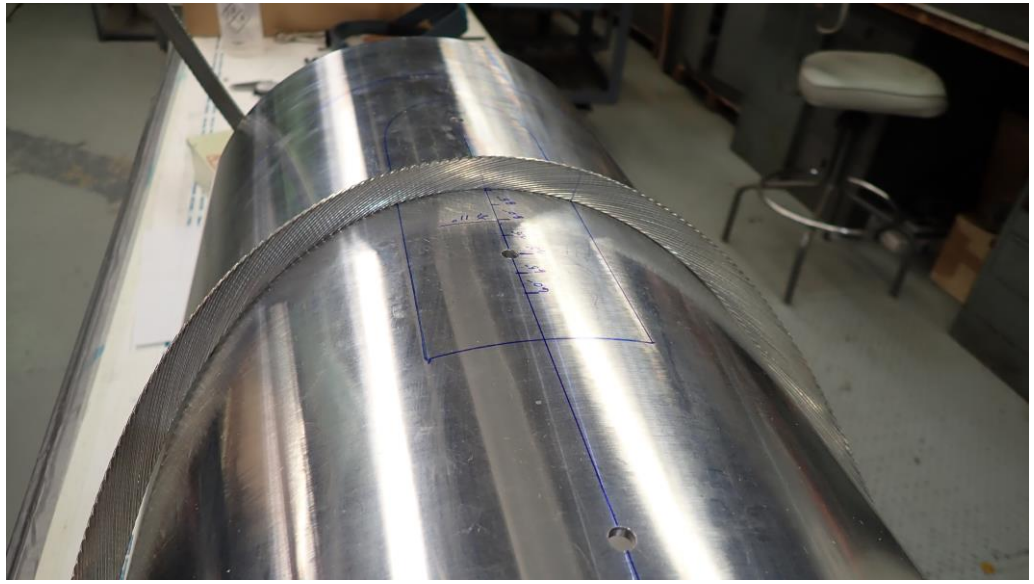
Photos for A-length = 9.5”

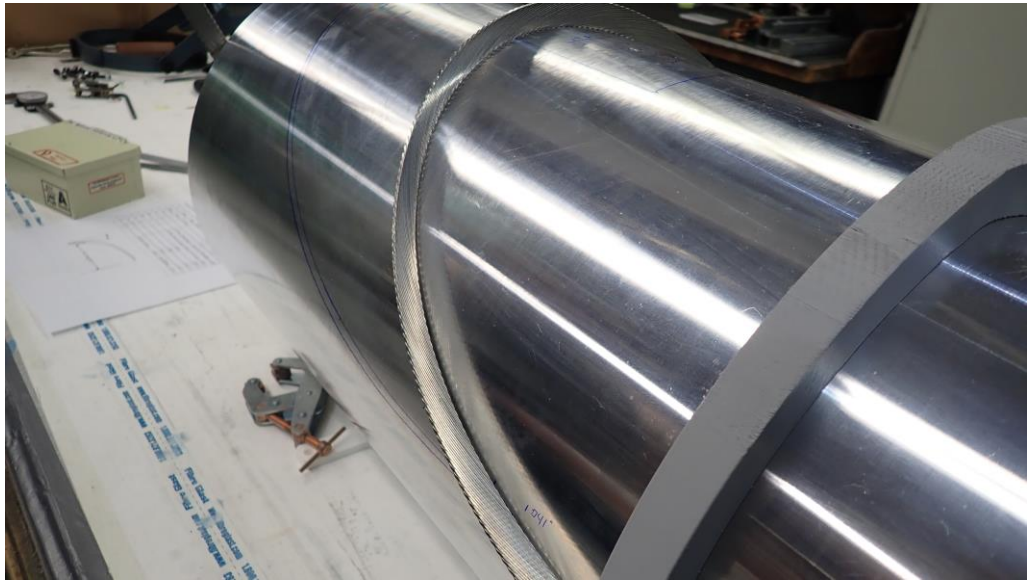


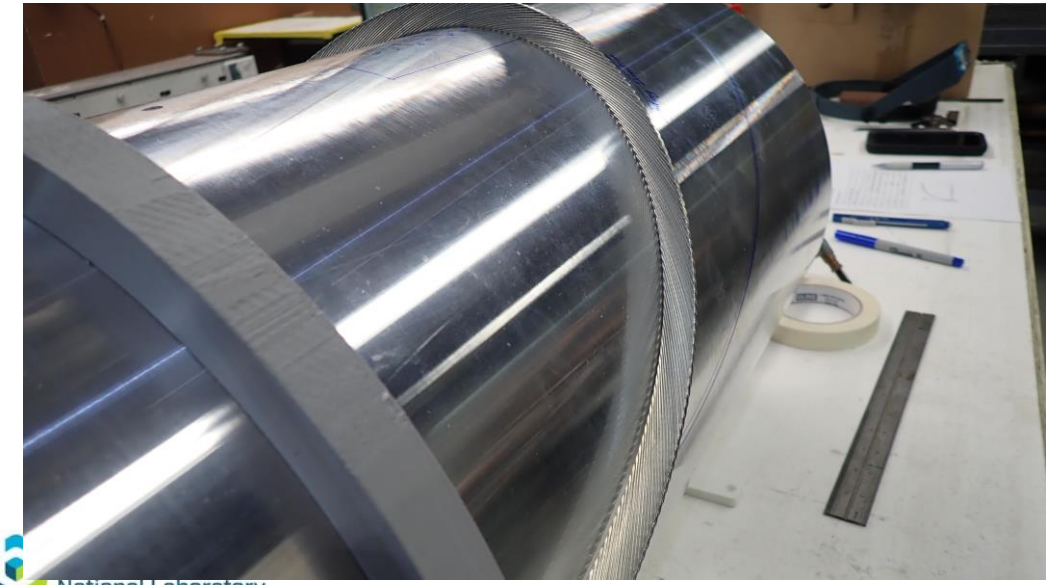


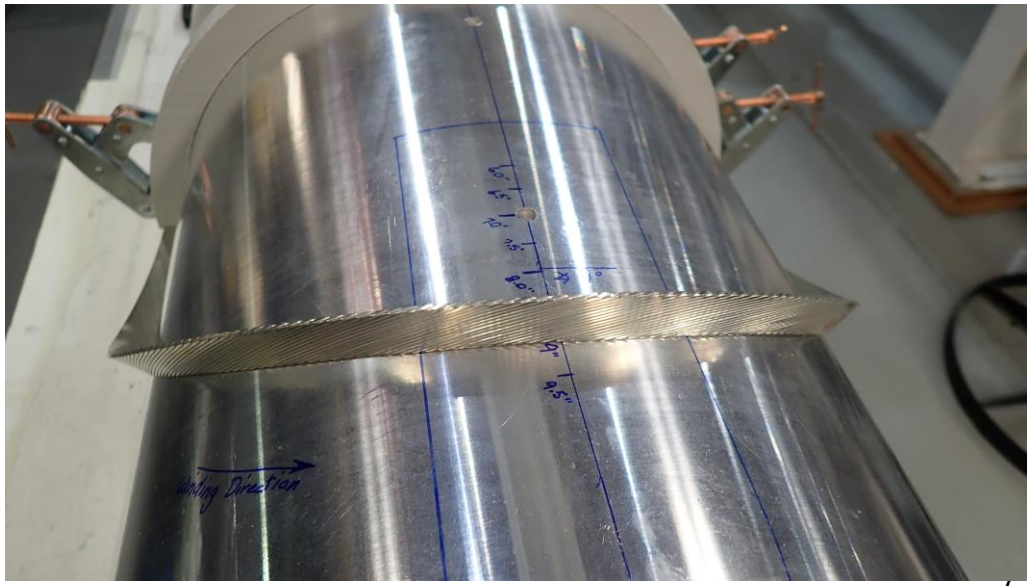


Photos for A-length = 9”

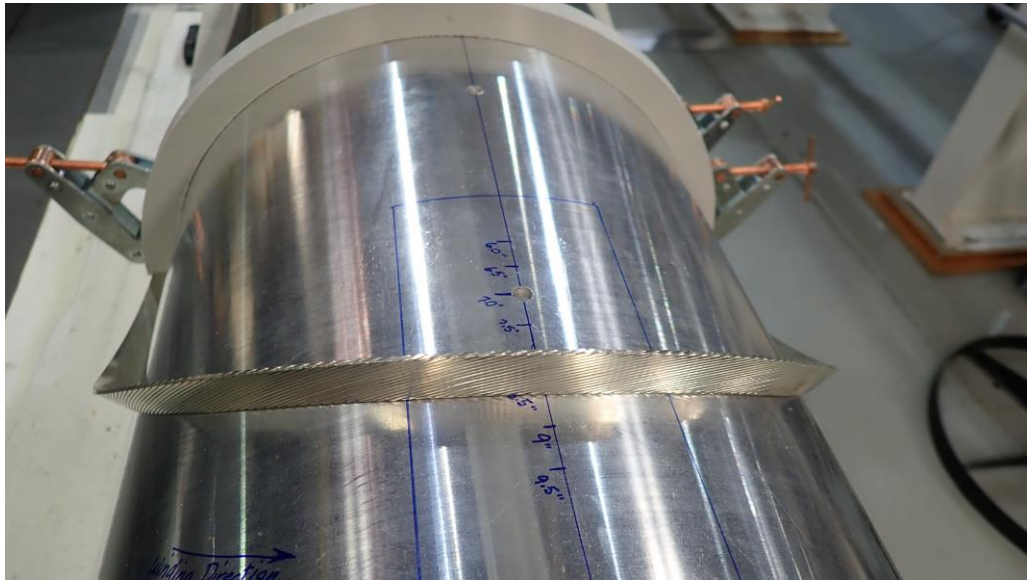


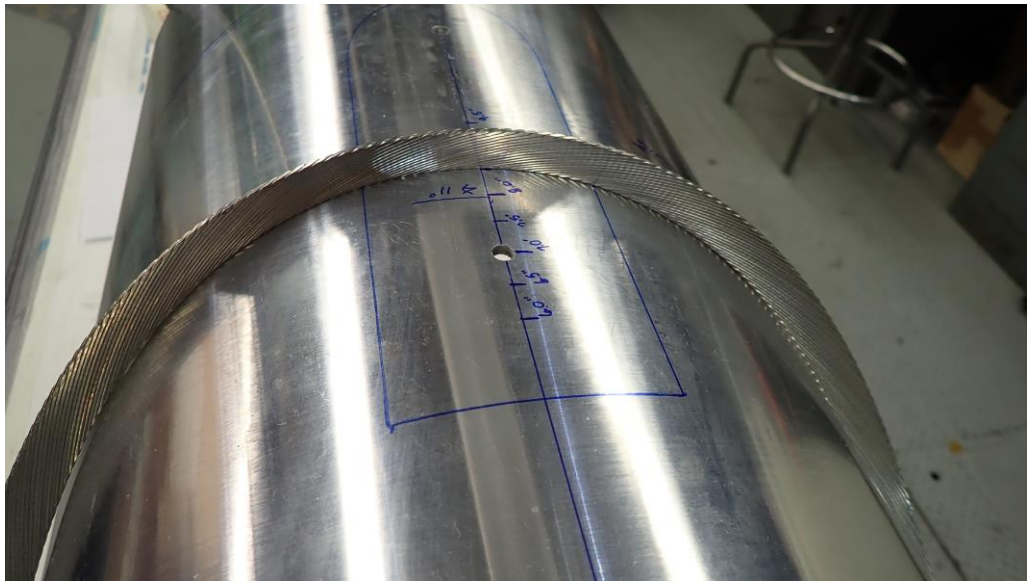


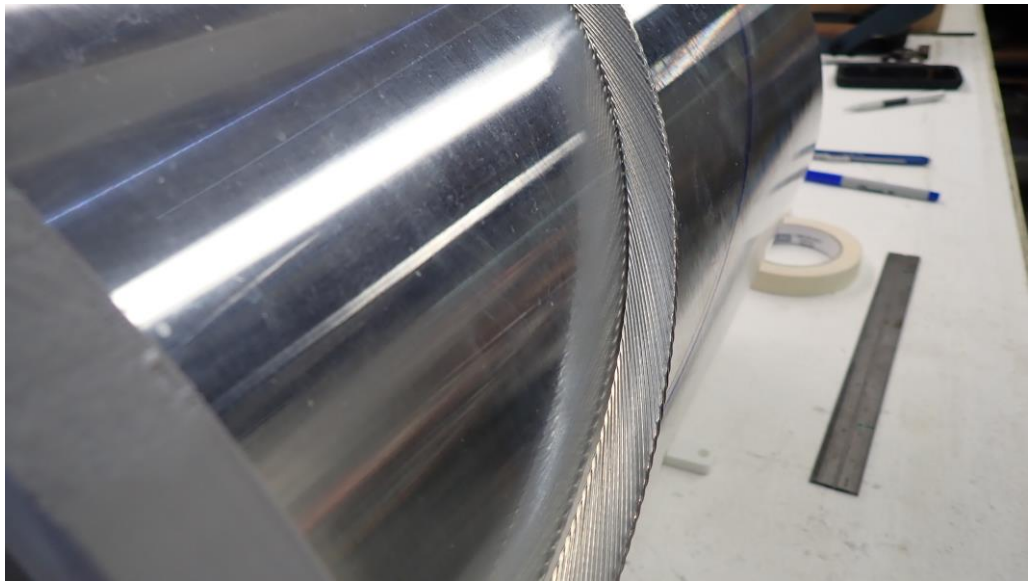




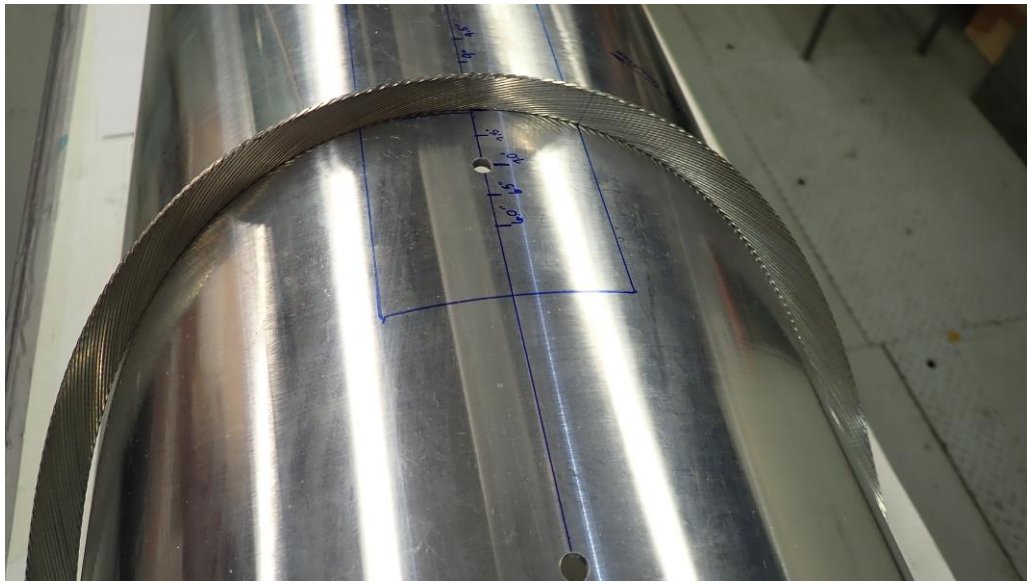
Photos for A-length = 8.5”

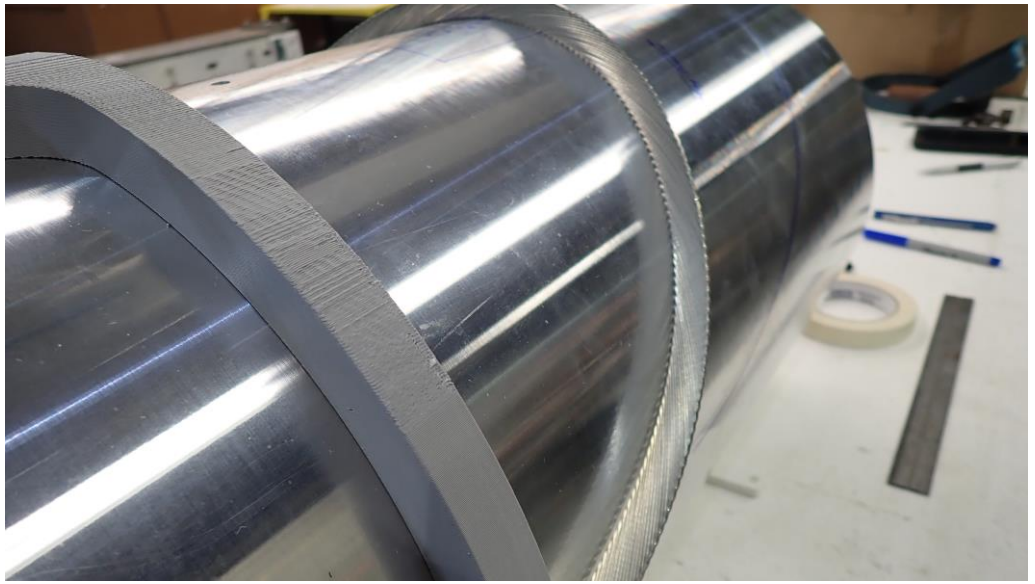


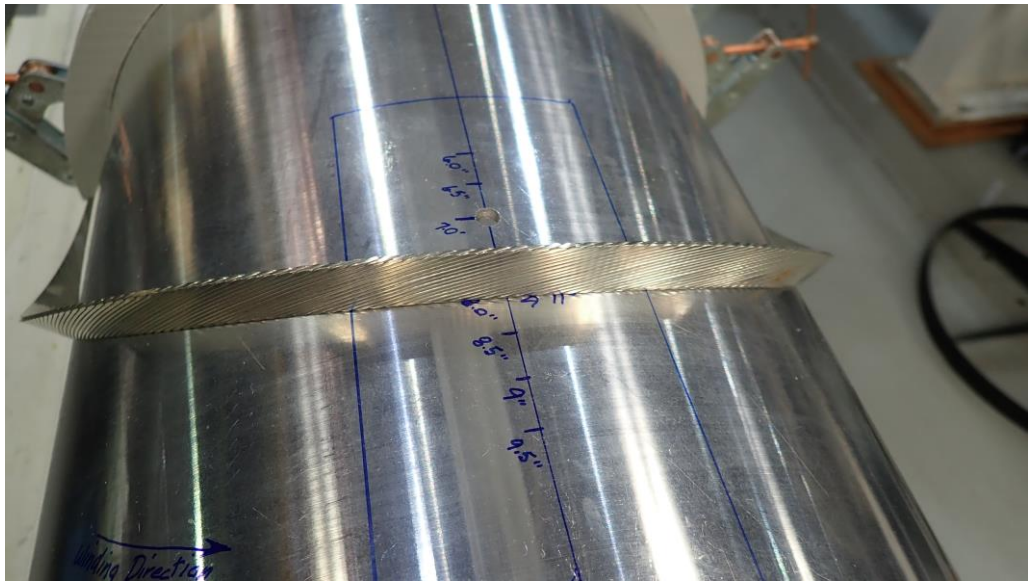




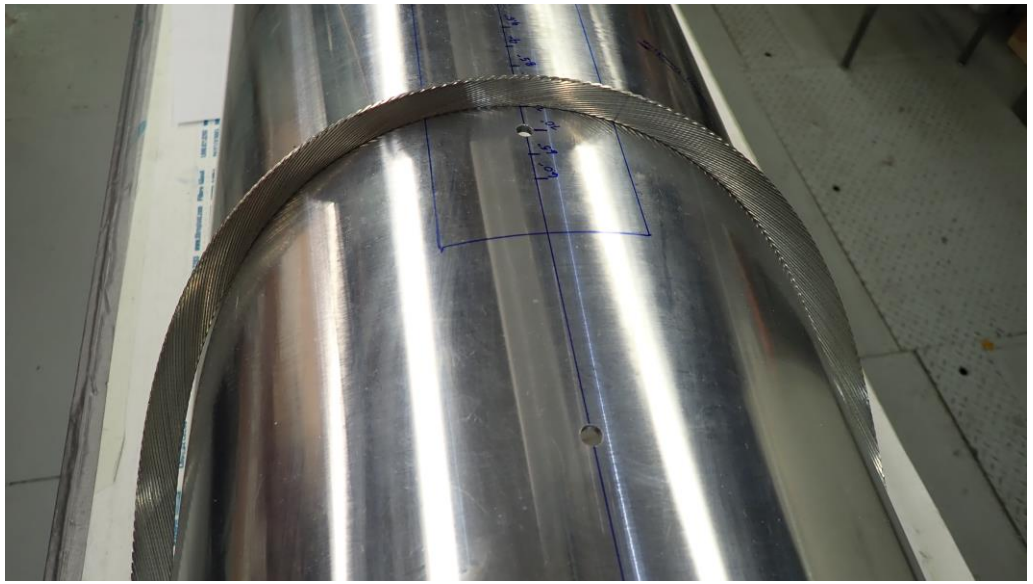
Photos for A-length = 8”

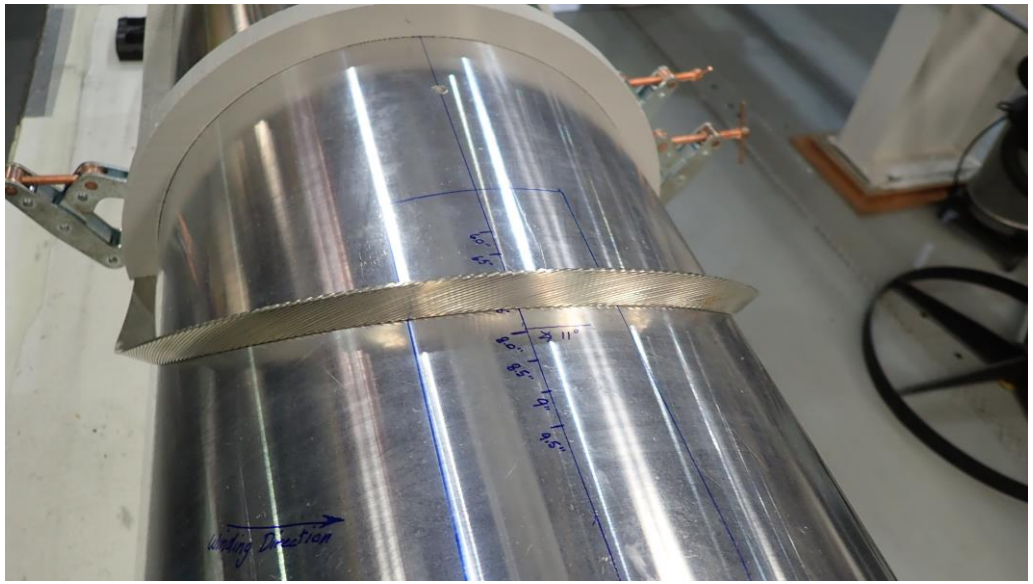


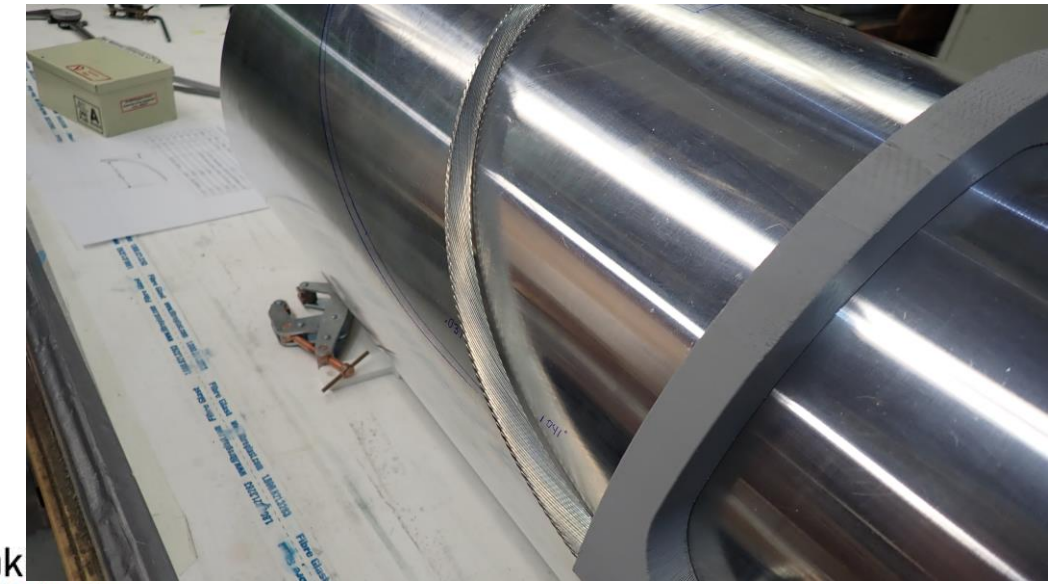


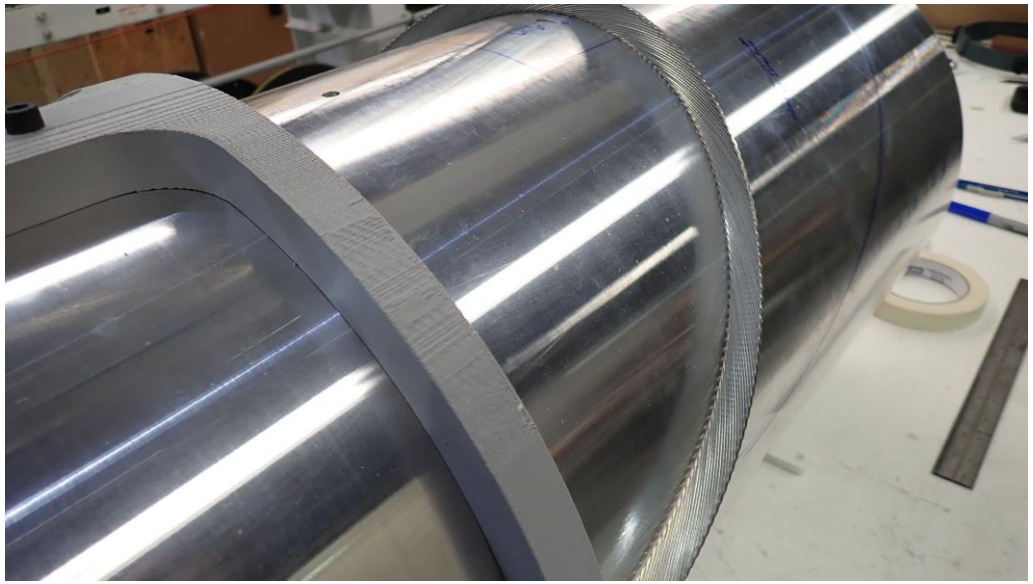


Photos for A-length = 7.5”

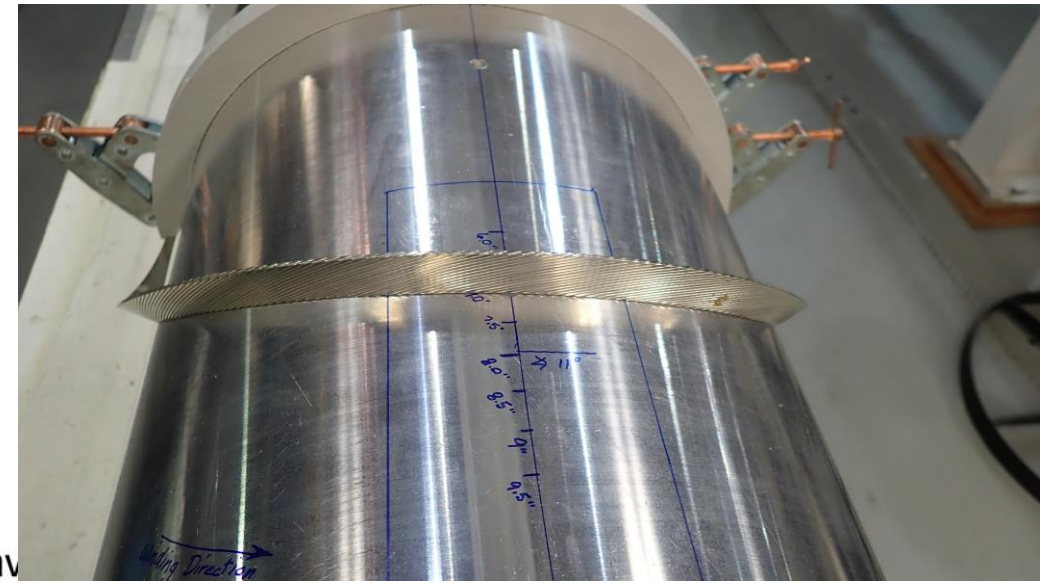


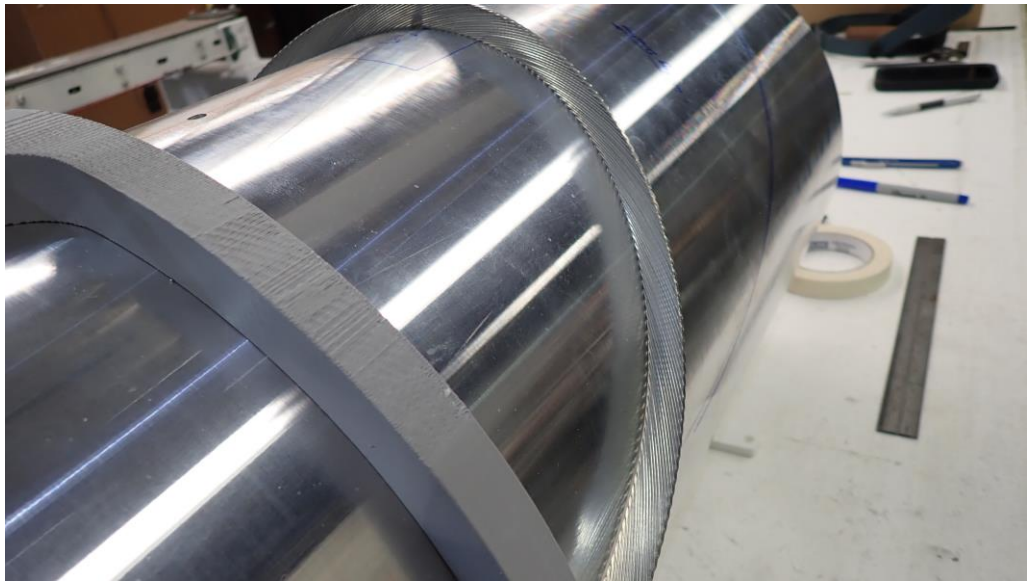




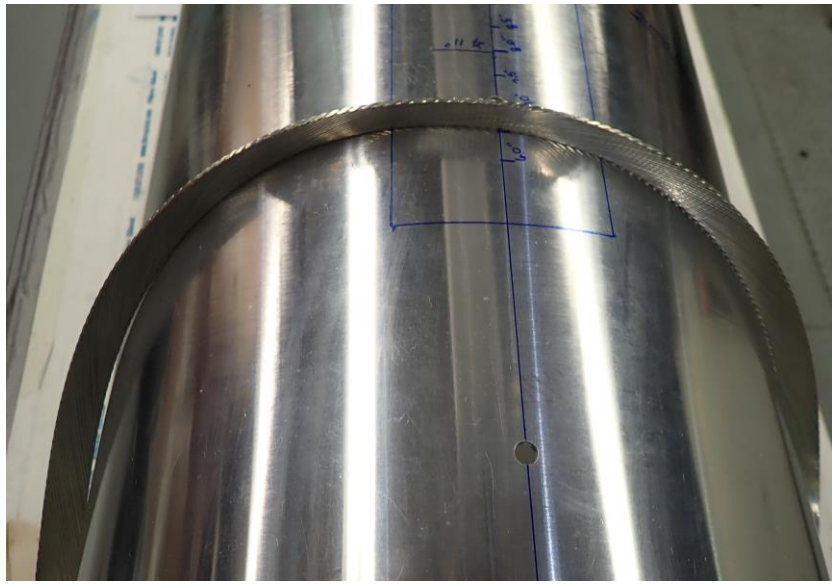


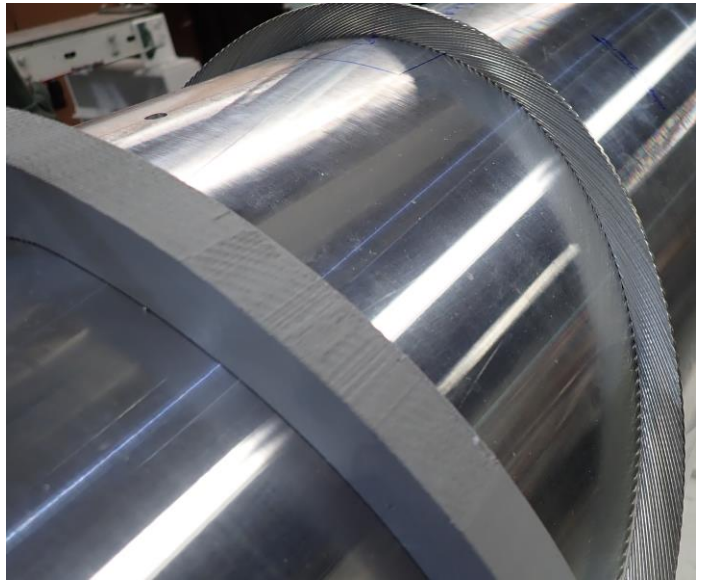
Photos for A-length = 7”

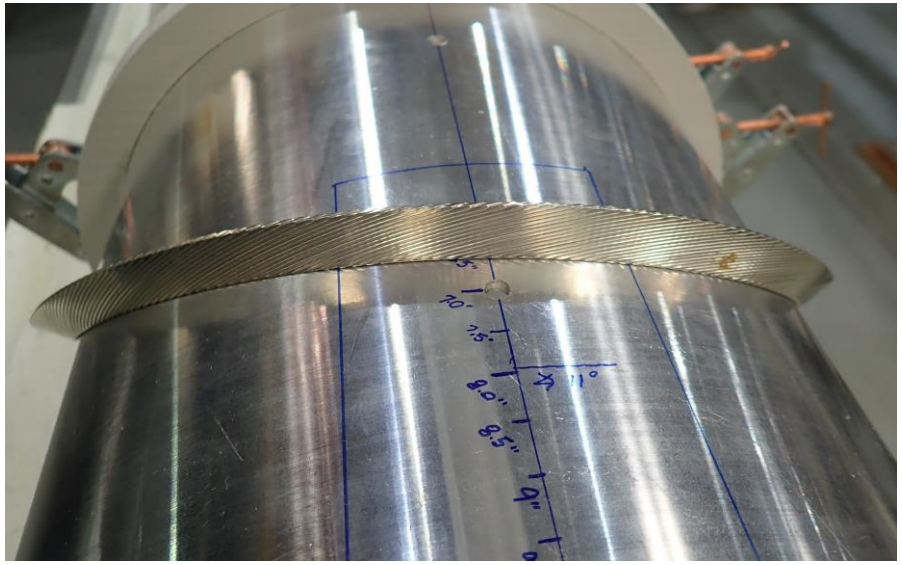


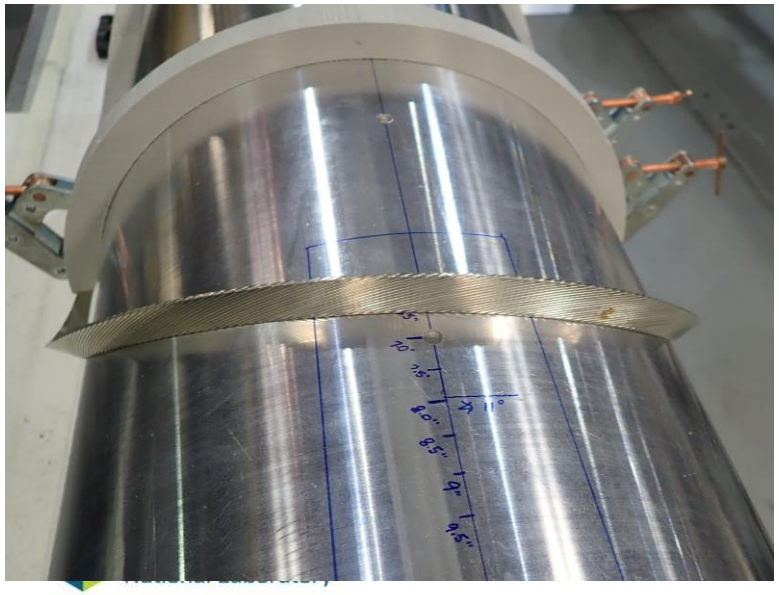


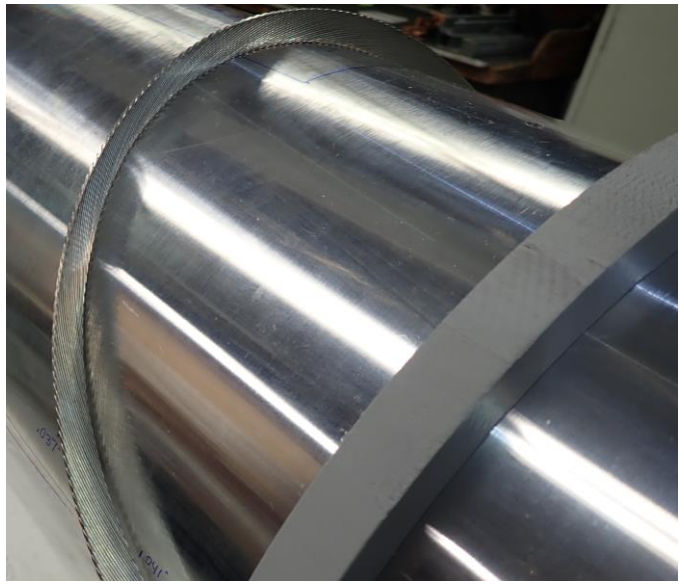
Photos for A-length = 6.5”

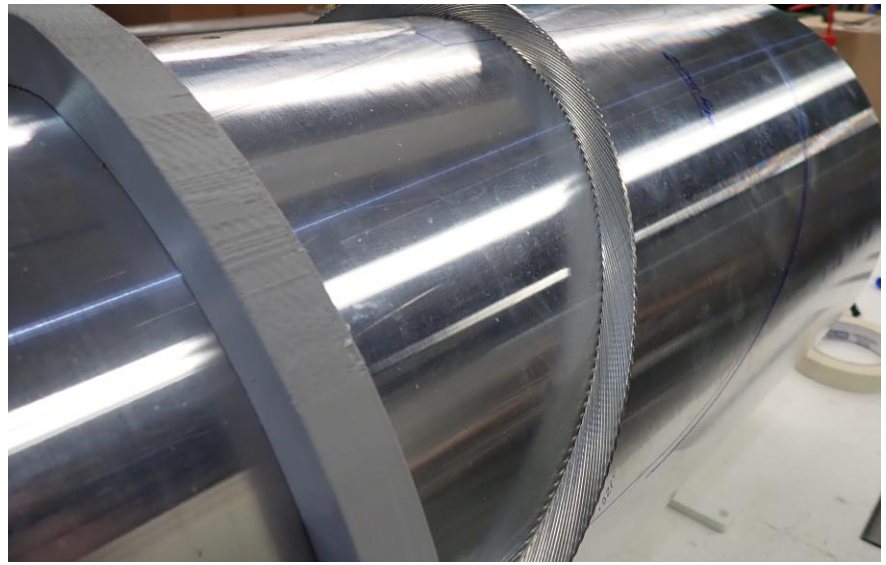




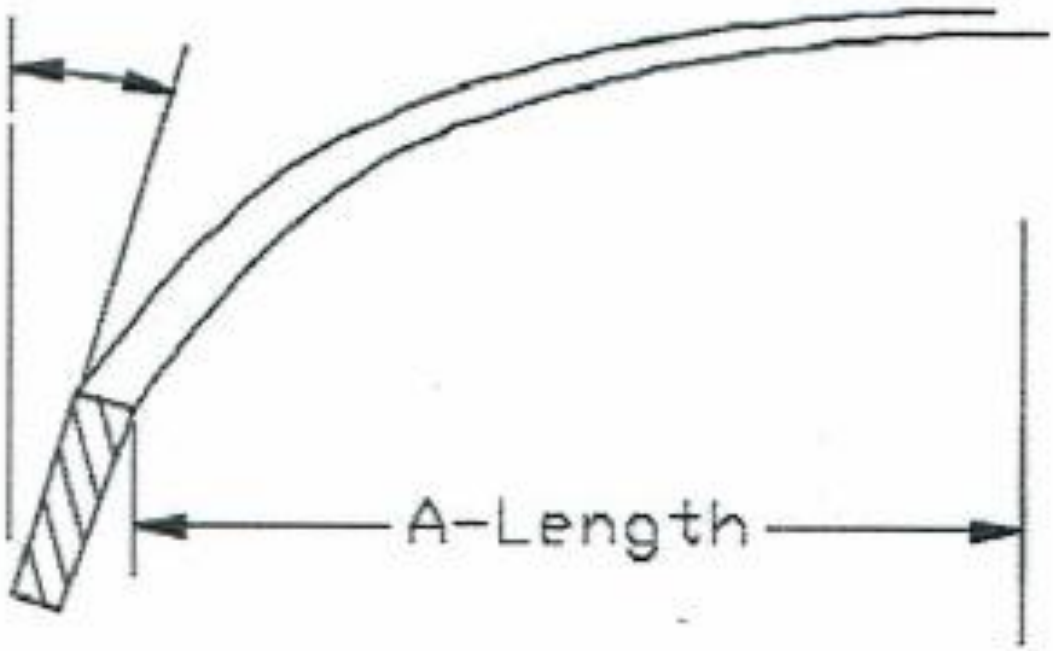








Systematic Study of the Natural Layout of the Midplane Turn



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Measure turn angle from vertical at apex of turn and an point 1/2 way to apex.

Note any gaps between cable and mandrel.

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7.5	8.7°		" " " .008" .047"
7.0	10.5°		.015" .047"
6.5	12.3°		Enter Apex .015" Exit Apex .041"
6.0	12.3°		

Plan for Optimizing the End Geometry

Step #1: We will choose a turn layout which looks mechanically good

- **small tilt angle**
- **cable not lifting from the tube (a gentle push may be ok)**
- **strand not coming out (bird caging)**
- **Looks irregular or anything out of ordinary**

Try to make ends as short length as possible without going off the cliff

Step #2: Try to incorporate this geometry in ROXIE (with limited optimization)

- **We may be able to read the path of the cable on the surface of the tube and the tilt angle at the APEX but how the cable is actually laying out is more tricky**

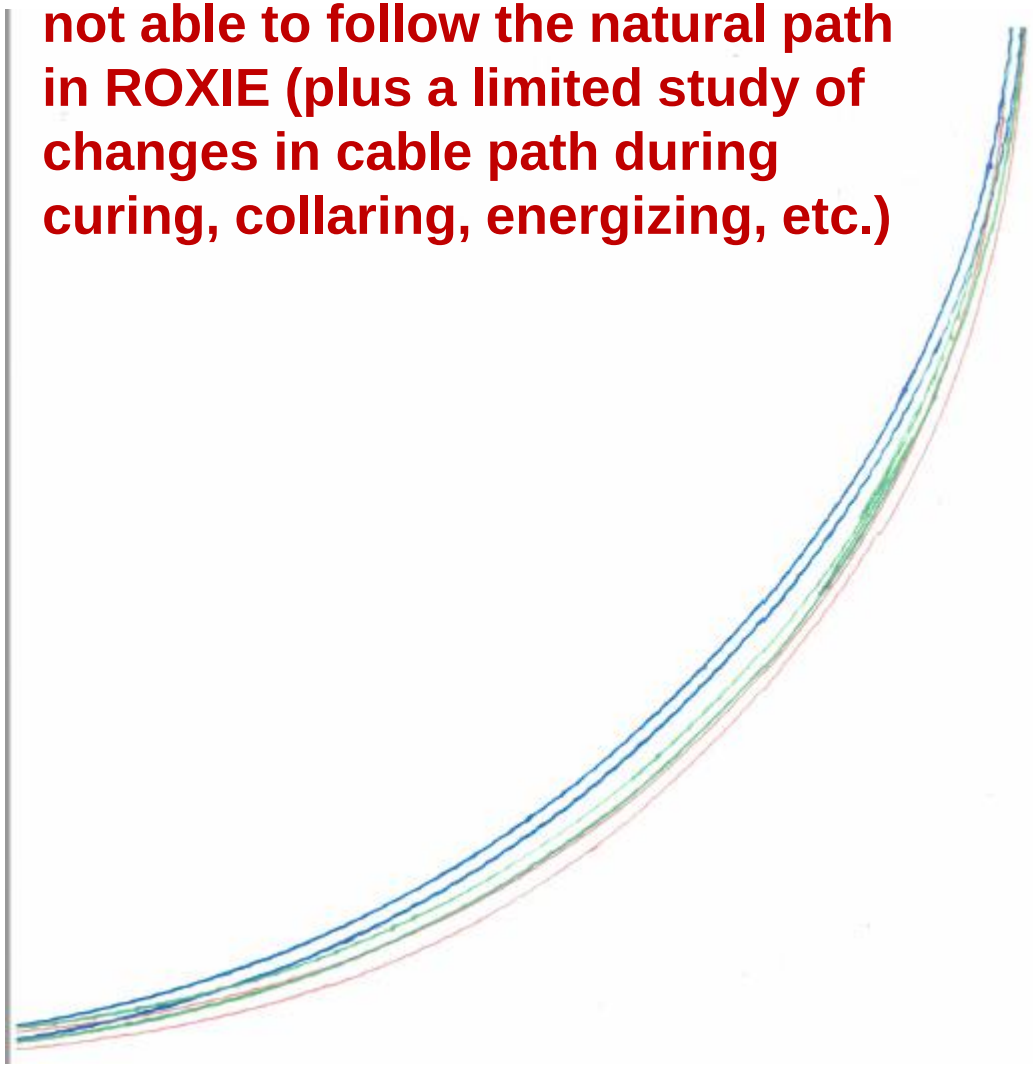
Step #3: 3-d print part and see how the cable lays out

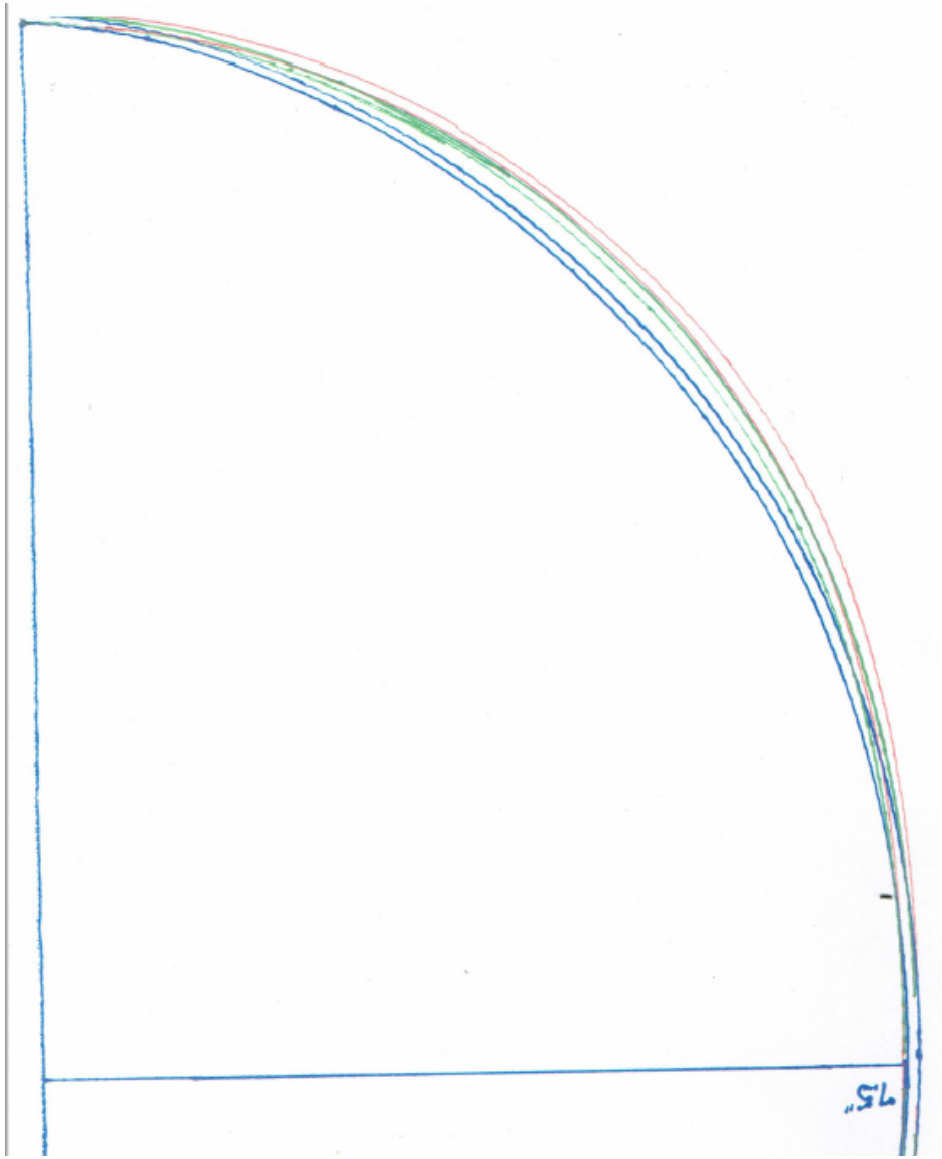
Step #4: Do above for various block (first & last turn for blocks with many turns)

Next step : try to

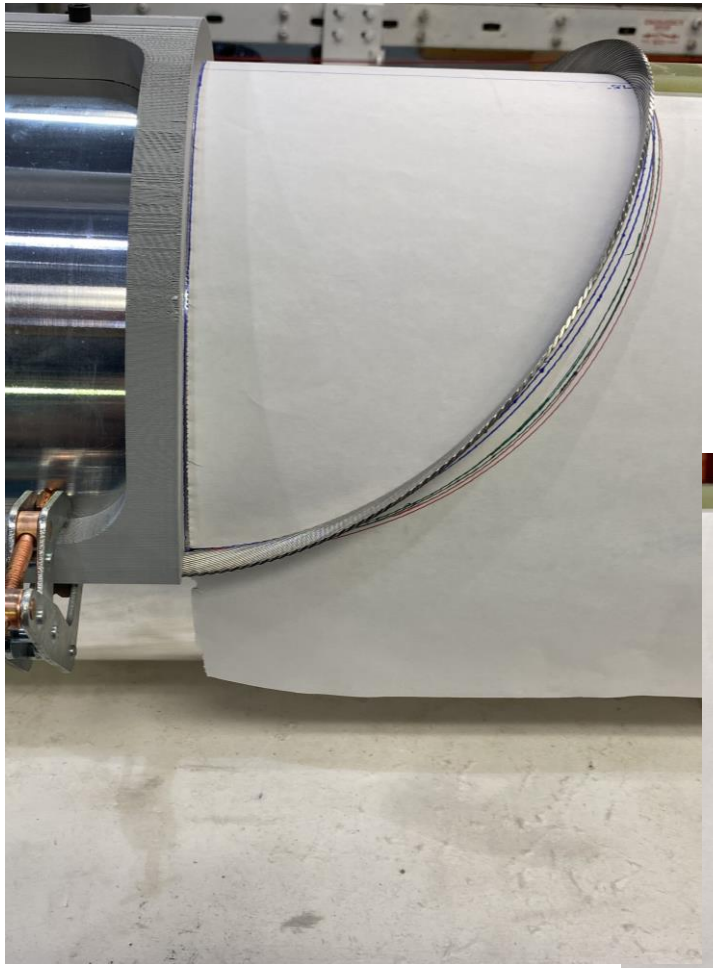
Variations in layout for A-length = 7.5”

Study of what happens if we are not able to follow the natural path in ROXIE (plus a limited study of changes in cable path during curing, collaring, energizing, etc.)





Variations in layout for A-length = 7.5”



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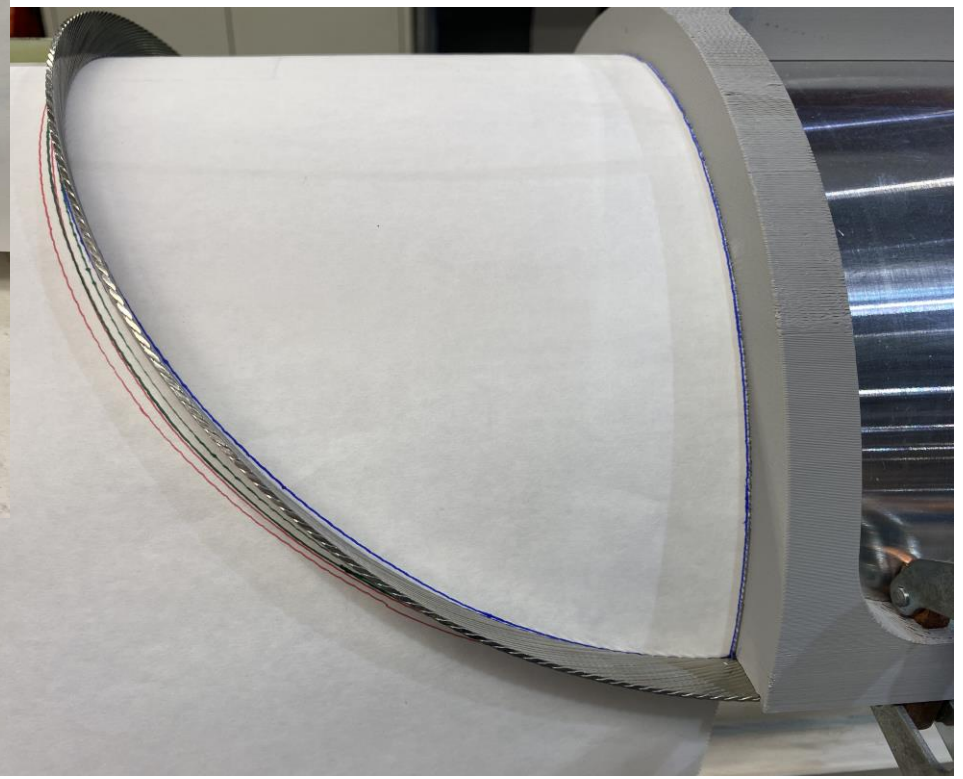

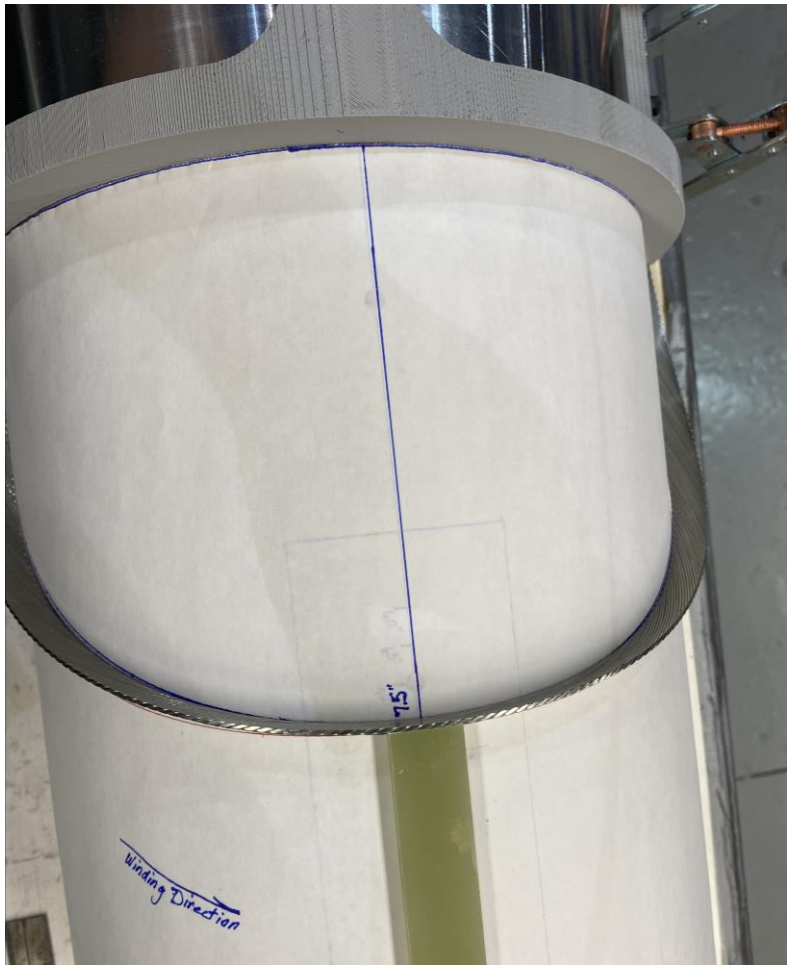

Summary and Next Step

- This has been a very useful exercise
- It gives us a good and definite direction on how to proceed without relying on the abstract parameters
- If a turn is laying out naturally in its complex 3-d end position with small tilt angle, little lifting-up, and without strand getting out registry, etc., then it means that this is a naturally optimized path where cable wants to layout
- This is likely to produce good ends
- Next, we need to transfer this geometry to ROXIE for all turns and then to end parts. We have a reasonable plan to move forward. It may be modified based on suggestions and further experience
- We may need to tweak ROXIE to keep field harmonics and peak fields low