



Fabrication of NuMI 1MW Horn 1 Stripline

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TSD Topical Meeting

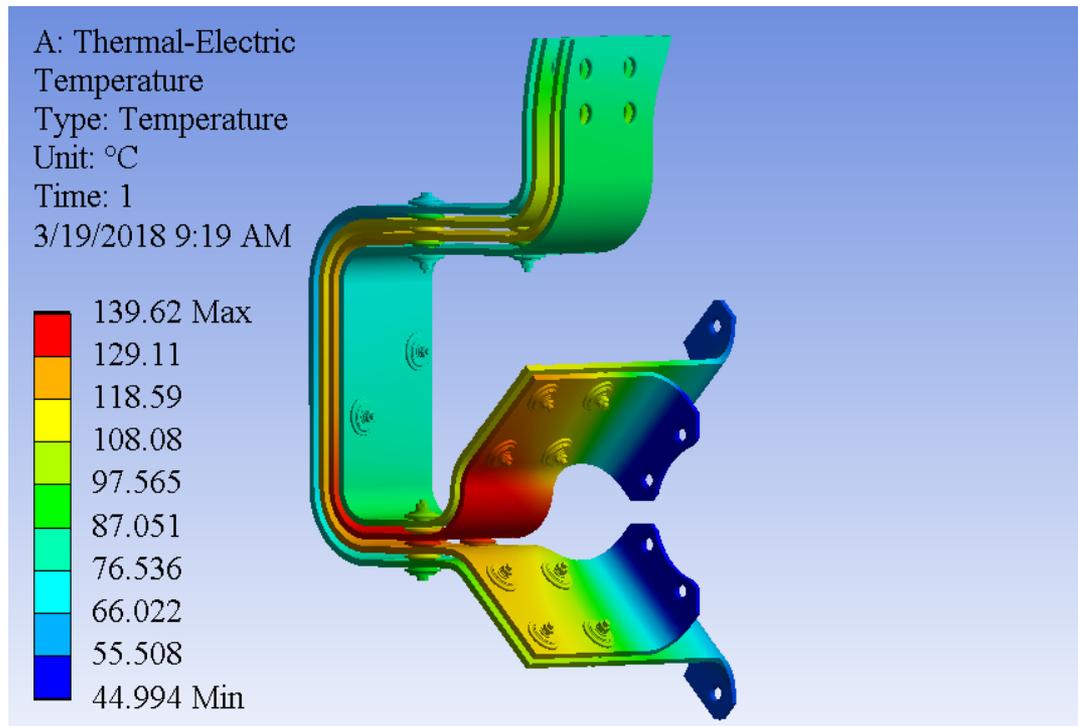
11/20/2019

Outline

- 1MW Stripline Motivation & Requirements
- Alloy Use
- Fabrication Steps (~18 months)
 - Raw Material (4 months if new)
 - Bent Blanks (3 months)
 - Machined Blanks (4 months)
 - Weldments (3 months)
 - Drilled Assembly (1 month)
 - Machined Connections (1 month)
 - Silver Plating (1 month)
 - Final Assembly & Horn Mating (1 month)
- Status
 - Current Status
 - Future Plans

1MW Stripline Motivation & Requirements

- Existing 700kW stripline & air diverter system is not a viable solution at 1MW.
- Max stripline temperature desired to be less than 100C at any point.
- Must maintain 100,000,000 pulse lifetime requirement. Temperature & resultant material creep makes pulse life determination impossible.

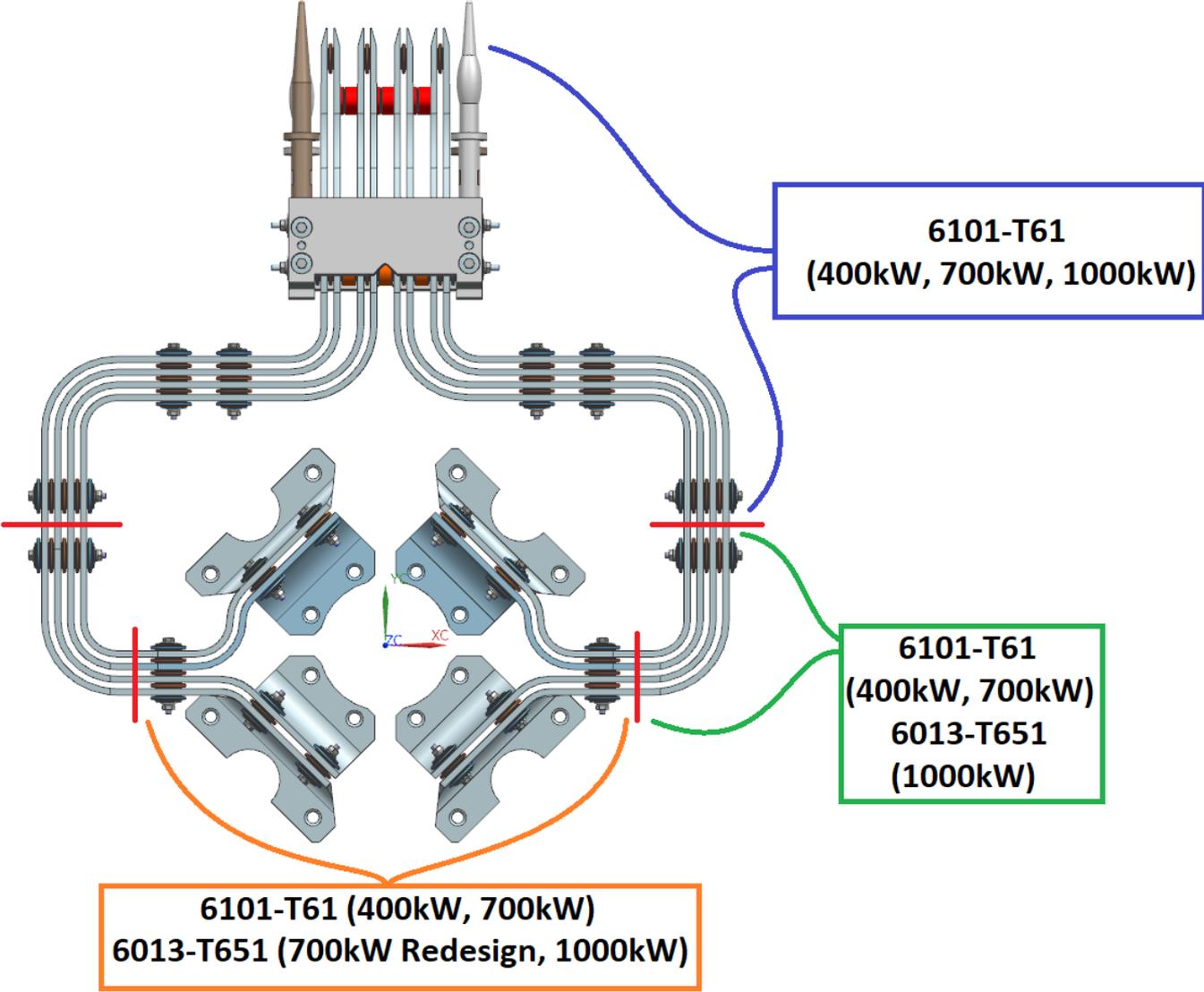


Analysis Credit: Zhijing Tang

New Stripline

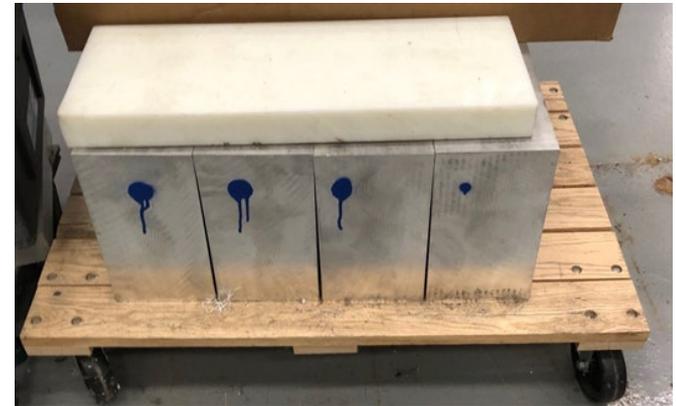
- Must mate to existing NOvA Horn conductor flange geometry.
- Improve material selection where possible (6013 aluminum).
- Improve air cooling to stripline structure.

400kW / 700kW / 1000kW Design Alloy Use



Raw Material

- Purchase bus bar as 12" wide X 3/8" thick profile, 35' lengths. (4 months)
- Flags come from 6013-T651 plate (**RED**). Now supplied by machining vendor. Extra material should be kept.
- **Obsolete flags** for the first 700kW design came from 6101-T61 extrusion (**BLUE**). Difficult to get, likely not offered without large mill order. Do not use, but keep in event some odd future electrical part needed.



Bent Blank Fabrication



- Cut lengths are supplied to vendor (must have 6" extra per side, 1' longer than estimated blank length).
- Flat bar blanks are bent while still at full 12" width.
- Hard bends to make.
 - 2 different bend radii.
 - Tight tolerances.
- After successful bend, machine out profile, leaving tabs and upper offset.
- 8 different blanks are needed. (4LH, 4RH).

Machined Blanks



- Some blanks must be machined. For 1MW, all flags (8) + all elbows (8).
- 6101-T61 is easy to bend and has a minimum recommended bend radius of $4.5(t)$. This means a $.375''$ thick plate can have inner radius, $R = 1.6875''$. Historical minimum is $1.75''$
- 6013-T651 is harder, and has a minimum recommended bend radius of $9(t)$ ($R = 3.375''$) Many stripline bends are already tighter than this, so cannot just buy material and bend.
- Purchase billet aluminum and machine to finished dimension.
- All flags have been machined since first 700kW design.
- Hidden benefit of being very accurate. Tolerance stack-up does not factor in.

Weldments

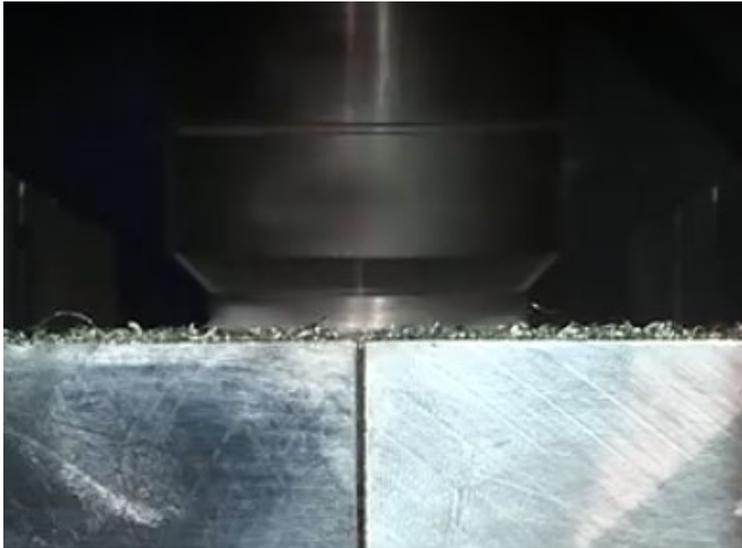
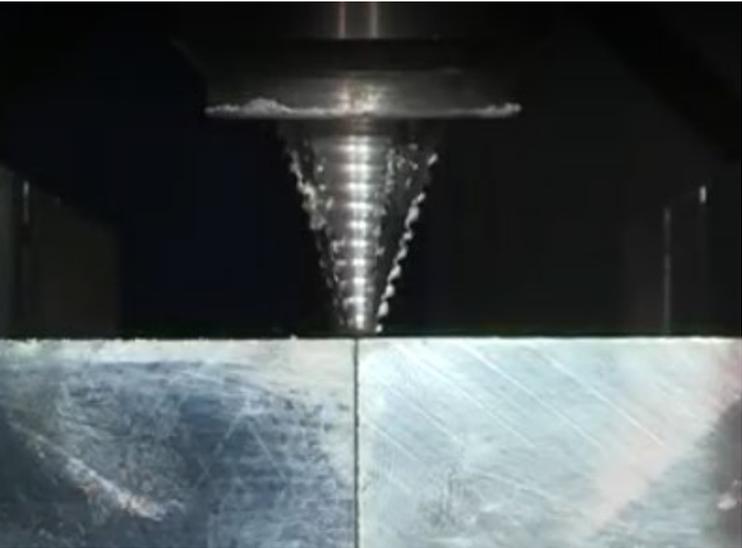
- Bent blanks + machined flags must be fixtured to achieve weld tolerances required for nesting assembly.
- Most horn aluminum welding is a very tightly controlled & monitored TIG process.
- One variable that is difficult to narrow down: weld shrinkage. Depends on:
 - Welder
 - Amperage
 - Technique
 - So many miniscule variables...
- Friction Stir Welding was pursued due to:
 - Excellent dimensional stability.
 - Consistency in application.
 - No amperage variation, purely mechanical.
 - Higher weld strength compared to TIG.



Friction Stir Welding



If The Video Fails...



Our Weldments

- Historically completed by Friction Stir Link (FSL) for ~15 years.
- FSL sold to Bayou Manufacturing Services (BMS) in ~2017.
- Flat, linear machines to remain. Robotic capabilities likely ending or unreliable at best. Kicked off vendor search for LBNF.
- NuMI fabrication is fine. BNB???



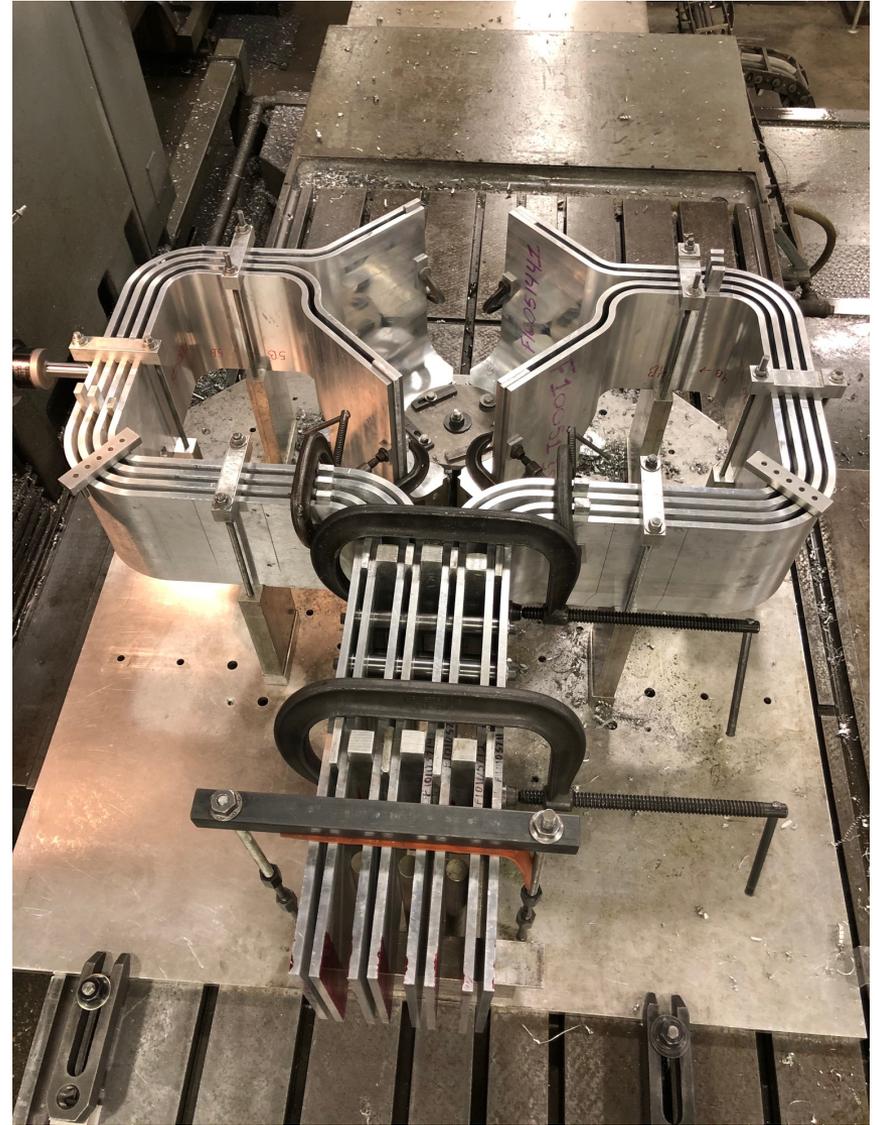
Weldment Testing

- Must qualify new vendors (or when working with new material) to ensure 100K+ & 12 month lead parts aren't scrapped.
- Run weldment test to verify shrinkage ($\sim .030''$ to ???). Depends on vendor.
- Perform root bend test, tensile test, metallographic examination.
- Good welds are consistent, meet NAS 1514 Class 1, and have a weld efficiency of 60% or better. 70-85% is common.

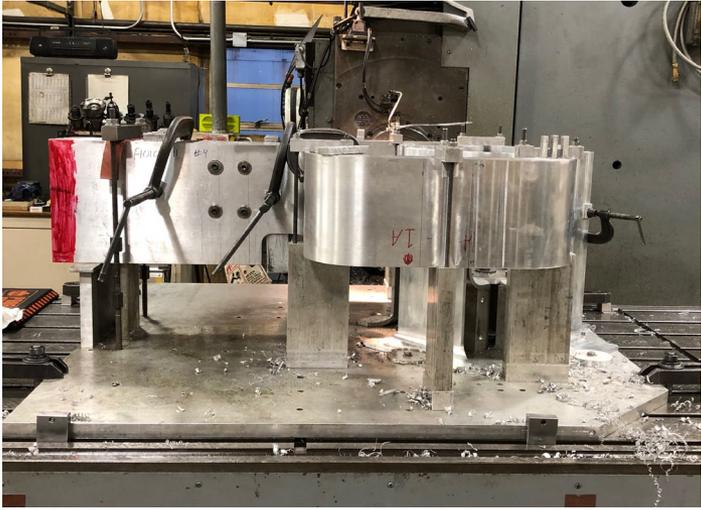


Drilled Assembly

- Achieving a good friction stir weld that meets specification is tough.
- Getting 24 individually bent and machined pieces to allow common bolt groups to fit through is tougher...
- Must machine as an assembly.
- Machining individually will never allow fitment. Tolerance stack up would make that near impossible.
- Historically (and currently) machined in village machine shop. Retain tight QA control.

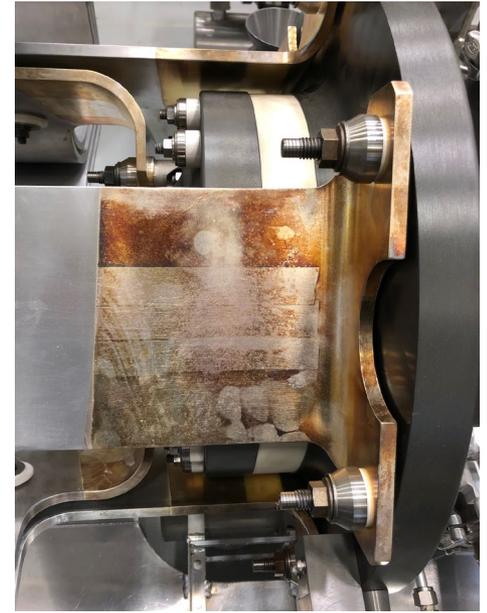


Drilled Assembly Cont...



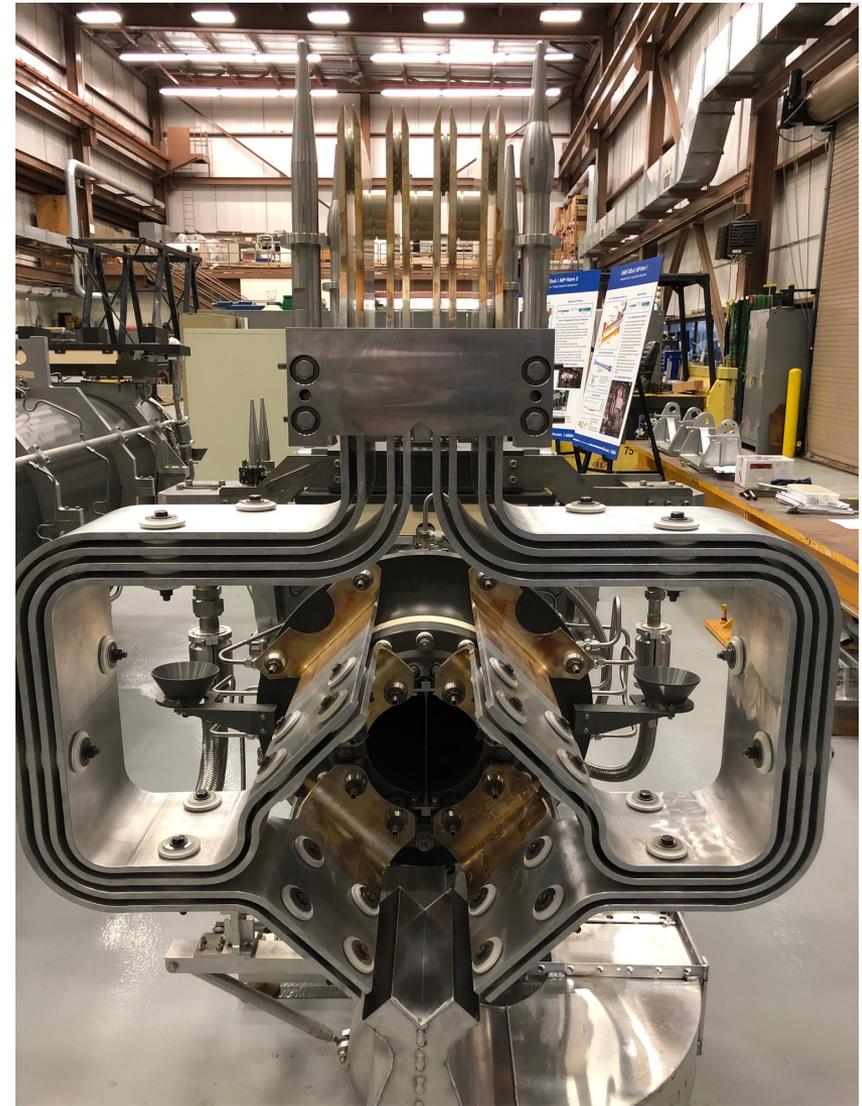
Machined Connections & Silver Plating

- Stripline ends must be machined to obtain good mating surfaces.
 - 32Ra finish or better.
 - Slight undercut (“fly cut”) needed.
 - Stock material cannot be processed and maintain that type of a finish.
- Silver Plating
 - Plating prevents Al oxide film from increasing resistivity.
 - Ag oxide is still conductive.
 - Fills in microscopic voids to increase contact patch.



Final Assembly / Horn Mating

- Loosely assemble with ceramics + hardware.
- Measure stripline dimensions relative to horn mating surfaces and make silver plated spacer washers.
- Loosely bolt to horn mounting flanges.
- Torque stripline fasteners.
- Torque mounting flange fasteners.



Current Status

Activity	1MW Stripline Fabrication Status						
	PH1-05	PH1-06	PH1-07	PH1-08			
Raw Material							Finished
Bent Blanks							Almost Delivered
Machined Blanks				Nov			Just Started
Weldments							To Be Completed
Drilling	Nov						
Connection Machining	Dec						
Silver Plating	Jan						
Assembly	Feb						

- Most vendor supplied work is complete.
- Months listed are fairly firm estimates.
- Remaining work mainly rests on village machine shop.

Future Plans

- Find more vendors to ensure LBNF horn striplines can be made.
- Work with existing vendors to understand capabilities.
- Test / verify / improve weld quality with bidding vendors.

