



Ensuring Quality in Hydro-Generator Rewinds

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BUILDING STRONG®





Quality Rewinds

- Quality - Long and Trouble-free Service Life
- They don't happen by accident, they require
 - ▶ Clear contractual and technical requirements
 - ▶ Proven winding and insulation systems
 - ▶ Good design and manufacturing
 - ▶ Proper packaging and storage
 - ▶ Careful installation
 - ▶ Operation and Maintenance matters too





Contractual and Technical Requirements

- Put requirements in the contract
 - ▶ Approval of subcontractors and manufacturing locations
 - ▶ Include specific design features if desired
 - ▶ Require a Design Review meeting – face-to-face
 - ▶ Material, procedure and drawing submittals
 - ▶ Inspection and Test Plans (ITP)
 - Manufacturing inspections and tests
 - In-process and final installation tests
 - ▶ Identify Hold Points for customer approval





Standards

- Standards are not standard
 - ▶ IEEE/ANSI vs. IEC or others
 - Methods and criteria may vary
 - ▶ IEEE “standards” are not always directive
 - Guides (may or should)
 - Recommended Practice (should)
 - Standard (shall)
- Specifically cite what test method and criteria you require, even if it is not a “standard” requirement.





Proposal Evaluation

- Make sure proposals address all requirements
- Lowest Initial Price may not be the same as Best Overall Value
 - ▶ choosing based on bid price alone drives innovation and margin out of design
- Remember that the project staff will have to live with the end product for 30+ years.

“The bitterness of poor quality remains long after the sweetness of low price is forgotten.” – Benjamin Franklin





Design Review Meeting

- All Parties present
 - ▶ Customer/Owner personnel
 - ▶ Manufacturer design engineers
 - ▶ Project managers
- Review technical and contract requirements
- Initial designs, calculations, and drawings
- Manufacturing, testing, and installation procedures
- Identify possible conflicts early!





Submittal Review

- Can be overwhelming, but documentation shows what the supplier will and did do; review it!
- Do the submittals meet the spec, standard, or approved procedures?
 - ▶ Drawings
 - ▶ Work and test methods
 - ▶ Inspection reports
 - ▶ Test reports
 - ▶ Deviations





Manufacturing Inspections

- Confirm process matches submitted and approved procedures
- Witness each of the steps through packaging if possible
- Witness testing of prototype and production coils, if applicable
 - ▶ Physical and electrical tests
 - ▶ Set-up, test values, results
- Ask to see rejects, inquire about disposition
 - ▶ Should be analysis of cause for rejection





Inspection and Test Plan

line #	SI		Characteristics	Inspection Frequency	Document References:
1	SI		<u>Receiving Inspection</u> Chemical Analysis of mill roll steel	each mill run or batch of steel roll	Tempel Steel Quality Assurance Material Certification Certified Material Test Reports from steel mill
2	SI		Lamination ductility	each mill run or batch of material	Incoming in-process verification check
3	SI		Core Loss (Epstein test) Freq: each roll of steel	each mill run or batch of steel roll	Tempel Steel Quality Assurance Material Certification Certified Material Test Reports from steel mill
4	SI	W	<u>1st Article Approval (PPAP)</u> CMM Dimensional Inspection Report – 100% dimensional of all characteristics	1 st off laminations	Tempel Steel CMM report
5		V	CMM Dimensional Inspection Report	1 st and last off laminations	Voith Siemens Hydro CMM Report
6	SI		<u>In-process inspection of critical dimensions:</u> Main laminations-right	1 pc / 2 hrs	Control Plan 3313N Stator Segment – item 01- Right Main Lamination
7	SI		Main laminations-left	1 pc/ 2 hrs	Control Plan 3314N Stator Segment – Item 02- Left Main Lamination
8	SI		Heavy Laminations	1 pc/ 2 hrs	Control Plan 3317N Stator Segment- item 03-Heavy Laminations
9	SI		Cut-back/ Step-back	1 pc/ 2 hr	Control Plan 3318N/19N/20N/21N/22N Cut-back/ Step-back
10	SI		Insulation Resistance Test (Franklin)	every 1000 th lamination	Control Plan -Deburring & C5 Re-Coating
	SI		Insulation Ductility Test	1st Article, every 5000 th lamination	Control Plan -Deburring & C5 Re-Coating
11	SI		Insulation Thickness	every 700 th lamination	Control Plan -Deburring & C5 Re-Coating
	SI		Burr height	every 700 th lamination	Control Plan -Deburring & C5 Re-Coating
	SI		Insulation ductility	First article & every 5000 th lamination	Control Plan - Deburring & C5 Re-coating
12			<u>Vent Plates</u> Perpendicularity, Spot weld pull test, critical dimensions Visual insp.	3 X per shift	Control Plan – Vent Plate Assembly 4431N
13		VI	<u>Final Source Inspection</u> Sample audit of completed laminations, documentation	Audit of final products	Source Inspection Report
14		H	Shipment Release		Shipment Release Document





Test Reports – read them!

Dissipation Factor Test Results											
Serial #	1.6kV	3.2kV	4.8kV	6.4kV	8.0kV	9.6kV	11.2kV	12.8kV	14.4kV	16.0kV	25kV
112B1025	0.580	0.587	0.580	0.570	0.562	0.562	0.582	0.608	0.650	0.715	1.190
112B1027	0.595	0.644	0.660	0.666	0.670	0.693	0.694	0.704	0.718	0.742	0.997
112B1029	0.502	0.513	0.512	0.501	0.494	0.491	0.487	0.487	0.493	0.540	0.687
112B1031	0.565	0.568	0.562	0.553	0.545	0.546	0.570	0.590	0.666	0.719	0.982
112B1033	0.511	0.514	0.512	0.503	0.500	0.504	0.507	0.529	0.559	0.604	0.855
112B1035	0.598	0.663	0.699	0.700	0.717	0.719	0.729	0.746	0.790	0.888	1.650
112B1037	0.532	0.538	0.536	0.522	0.514	0.515	0.521	0.528	0.556	0.600	0.890
112B1039	0.569	0.578	0.571	0.568	0.565	0.574	0.595	0.601	0.652	0.716	1.030
112B1041	0.623	0.643	0.641	0.635	0.646	0.653	0.685	0.706	0.733	0.902	1.190
112B1043	0.629	0.661	0.673	0.676	0.700	0.699	0.695	0.701	0.734	0.751	1.050
112B1045	0.555	0.563	0.556	0.552	0.546	0.545	0.568	0.573	0.603	0.702	0.971
112B1047	0.538	0.547	0.544	0.533	0.531	0.529	0.545	0.556	0.583	0.631	0.897
112B1049	0.587	0.630	0.637	0.647	0.660	0.660	0.669	0.686	0.723	0.828	1.720
112B1051	0.565	0.574	0.567	0.558	0.553	0.553	0.556	0.620	0.653	0.741	1.030
112B1053	0.557	0.570	0.568	0.563	0.554	0.564	0.570	0.578	0.610	0.684	0.875
112B1055	0.518	0.521	0.518	0.515	0.510	0.520	0.521	0.544	0.655	0.732	0.985
112B1057	0.600	0.630	0.629	0.622	0.615	0.612	0.610	0.614	0.691	0.689	1.040
112B1059	0.552	0.564	0.563	0.557	0.551	0.545	0.552	0.583	0.614	0.698	1.100
112B1061	0.563	0.565	0.559	0.552	0.550	0.552	0.558	0.575	0.595	0.648	1.030
112B1063	0.562	0.565	0.554	0.535	0.529	0.525	3.990	0.546	0.574	0.609	0.940
112B1065	0.504	0.508	0.503	0.496	0.495	0.511	0.516	0.522	0.548	0.571	0.887
112B1067	0.520	0.525	0.518	0.511	0.511	0.516	0.532	0.547	0.569	0.720	1.000
112B1069	0.610	0.665	0.676	0.704	0.735	0.743	0.773	0.810	0.845	0.931	1.130
112B1071	0.511	0.523	0.520	0.515	0.509	0.508	0.510	0.518	0.541	0.546	0.975
112B1073	0.529	0.553	0.556	0.549	0.543	0.545	0.549	0.569	0.603	0.640	0.978

> 0.15			> 0.30			> 0.40			Tip-Up (<0.9)		
3.2-1.6	4.8-3.2	6.4-4.8	8.0-6.4	9.6-8.0	11.2-9.6	12.8-11.2	14.4-12.8	16.0-14.4	8.0-1.6		
0.007	-0.007	-0.010	-0.008	0.000	0.020	0.026	0.042	0.065	-0.018		
0.049	0.016	0.006	0.004	0.023	0.001	0.010	0.014	0.024	0.075		
0.011	-0.001	-0.011	-0.007	-0.003	-0.004	0.000	0.006	0.047	-0.008		
0.003	-0.006	-0.009	-0.008	0.001	0.024	0.020	0.076	0.053	-0.020		
0.003	-0.002	-0.009	-0.003	0.004	0.003	0.022	0.030	0.045	-0.011		
0.065	0.036	0.001	0.017	0.002	0.010	0.017	0.044	0.098	0.119		
0.006	-0.002	-0.014	-0.008	0.001	0.006	0.007	0.028	0.044	-0.018		
0.009	-0.007	-0.003	-0.003	0.009	0.021	0.006	0.051	0.064	-0.004		
0.020	-0.002	-0.006	0.011	0.007	0.032	0.021	0.027	0.169	0.023		
0.032	0.012	0.003	0.024	-0.001	-0.004	0.006	0.033	0.017	0.071		
0.008	-0.007	-0.004	-0.006	-0.001	0.023	0.005	0.030	0.099	-0.009		
0.009	-0.003	-0.011	-0.002	-0.002	0.016	0.011	0.027	0.048	-0.007		
0.043	0.007	0.010	0.013	0.000	0.009	0.017	0.037	0.105	0.073		
0.009	-0.007	-0.009	-0.005	0.000	0.003	0.064	0.033	0.088	-0.012		
0.013	-0.002	-0.005	-0.009	0.010	0.006	0.008	0.032	0.074	-0.003		
0.003	-0.003	-0.003	-0.005	0.010	0.001	0.023	0.111	0.077	-0.008		
0.030	-0.001	-0.007	-0.007	-0.003	-0.002	0.004	0.077	-0.002	0.015		
0.012	-0.001	-0.006	-0.006	-0.006	0.007	0.031	0.031	0.084	-0.001		
0.002	-0.006	-0.007	-0.002	0.002	0.006	0.017	0.020	0.053	-0.013		
0.003	-0.011	-0.019	-0.006	-0.004	3.465	-3.444	0.028	0.035	-0.033		
0.004	-0.005	-0.007	-0.001	0.016	0.005	0.006	0.026	0.023	-0.009		
0.005	-0.007	-0.007	0.000	0.005	0.016	0.015	0.022	0.151	-0.009		
0.055	0.011	0.028	0.031	0.008	0.030	0.037	0.035	0.086	0.125		
0.012	-0.003	-0.005	-0.006	-0.001	0.002	0.008	0.023	0.005	-0.002		
0.024	0.003	-0.007	-0.006	0.002	0.004	0.020	0.034	0.037	0.014		





Installation Inspections

- Confirm process matches submitted and approved procedures
- Confirm winding (and core) installation matches approved drawings
- Witness testing during installation
 - ▶ Inspection and Test Plan being followed
 - ▶ Right tests performed at the right times





When Things Go Sideways...

- All projects have issues, some are larger than others
- All problems are opportunities to
 - ▶ Improve communication
 - ▶ Develop innovative solutions
 - ▶ Improve future specifications
- Identify issues, resolve immediate problem, prevent future occurrence



Prototype Coil Dissections



- Voids in insulation
- Replacement bars manufactured
- Revised locations of slices to be checked for voids in specifications

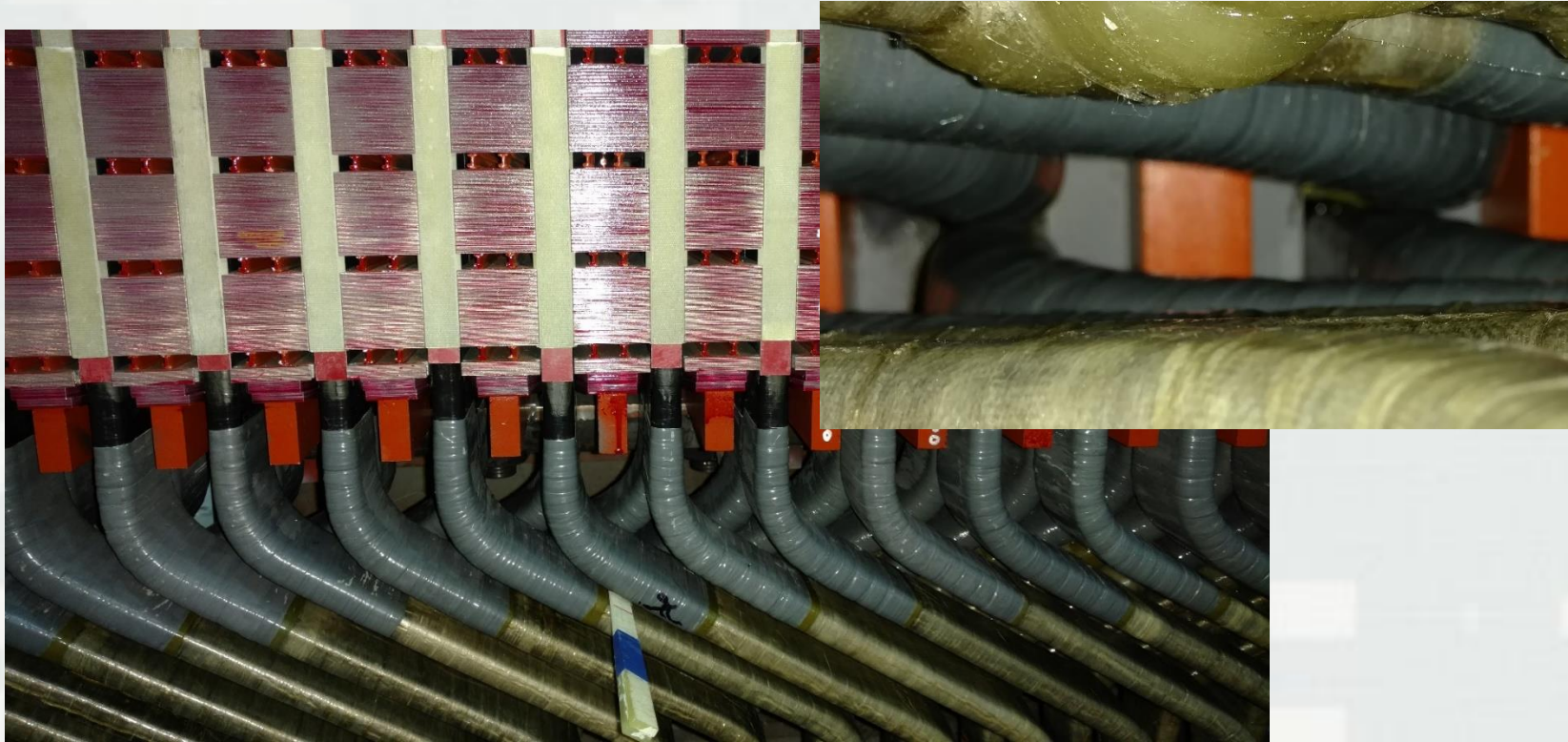
Bar End Arm Shape Control



- End-arm shape not well controlled
- Led to voids, and interference with adjacent bars
- Changed fitment test requirements in “dummy” core section in future specifications



Bar End Arm Interference

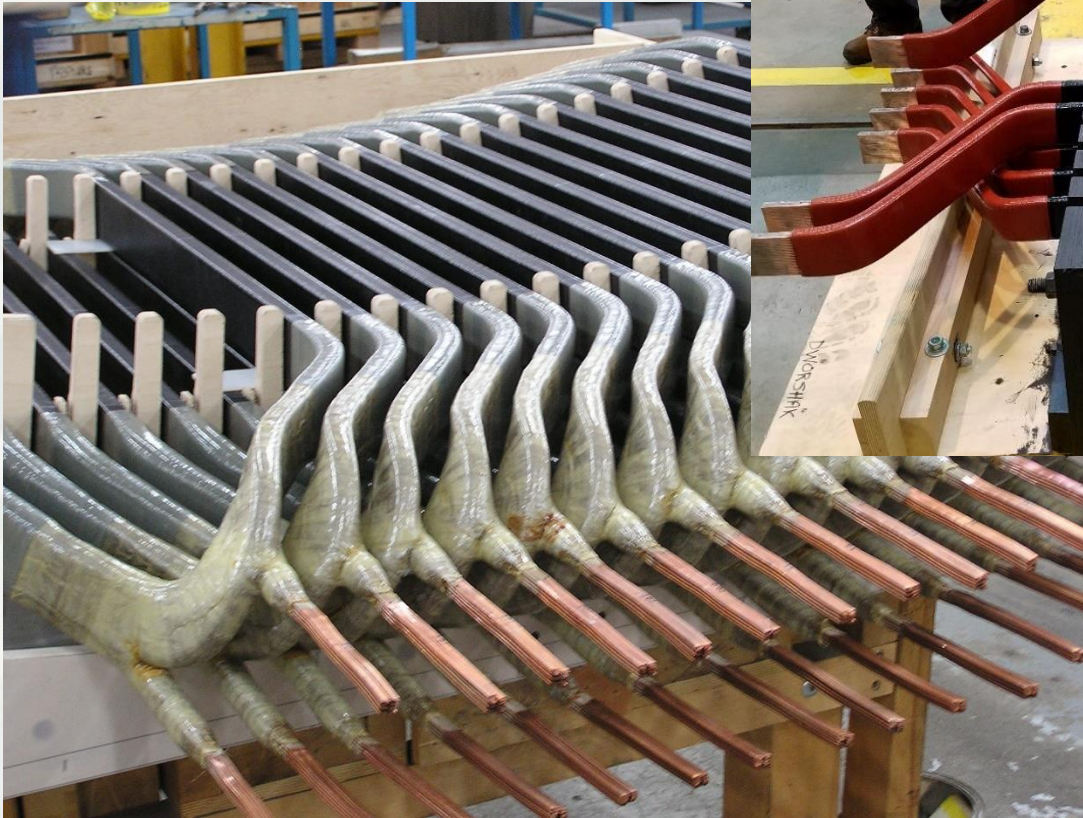


Bars ends touched and top bars could not be seated in a dozen slots; new bars were manufactured.





Coil/bar Fitment Testing



Prototype Coil Dissections



- No visible voids
- Good shape control
- No Problem!



Production Coil Dissections - Voids

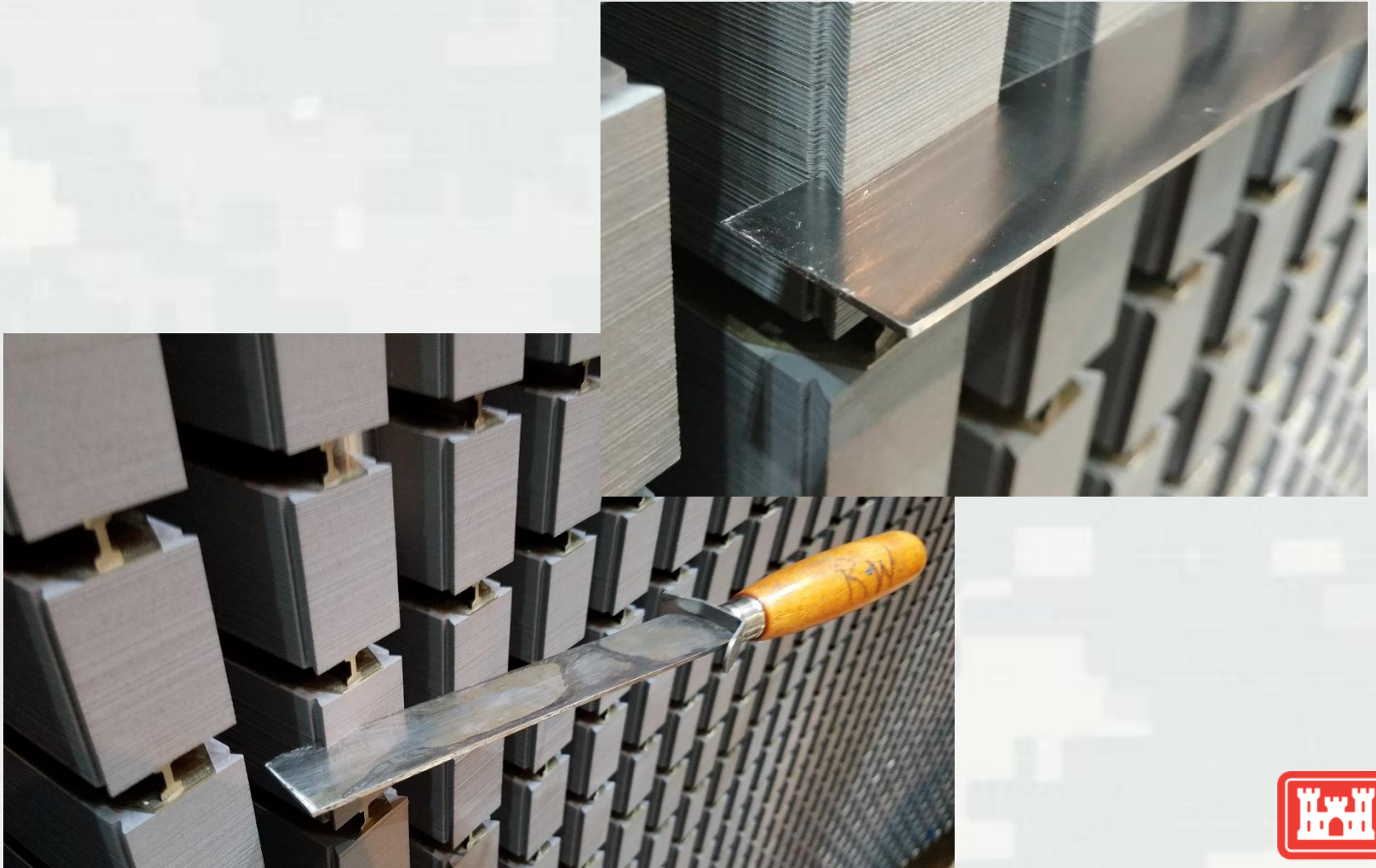


- Prototype coils were ok
- Face-to-face meetings conveyed requirements
- Manufacturing process reviewed
- Replacement coils were manufactured
- Specifications were edited to be more clear



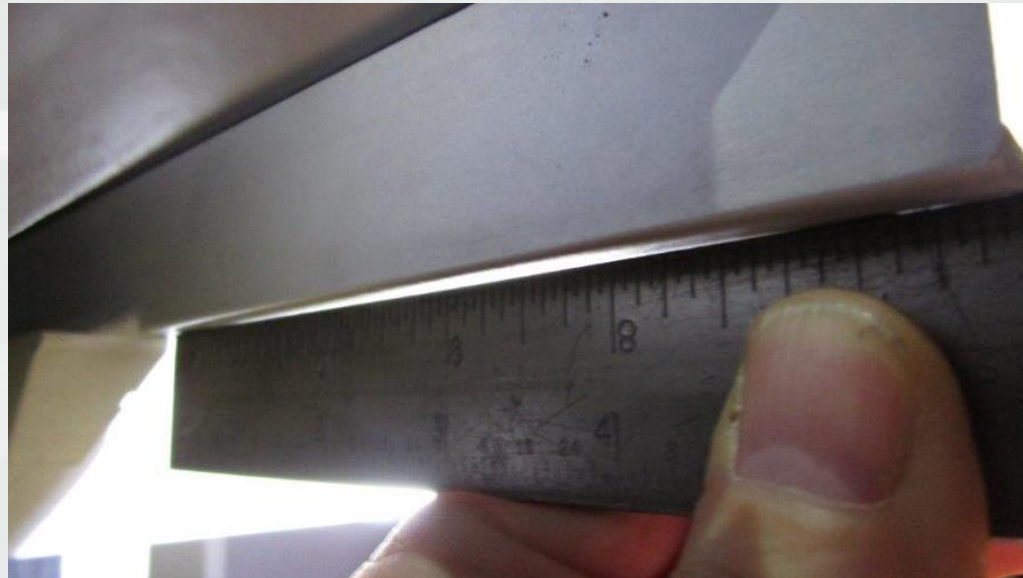


New Core - Loose





New Core - Not Supported Well





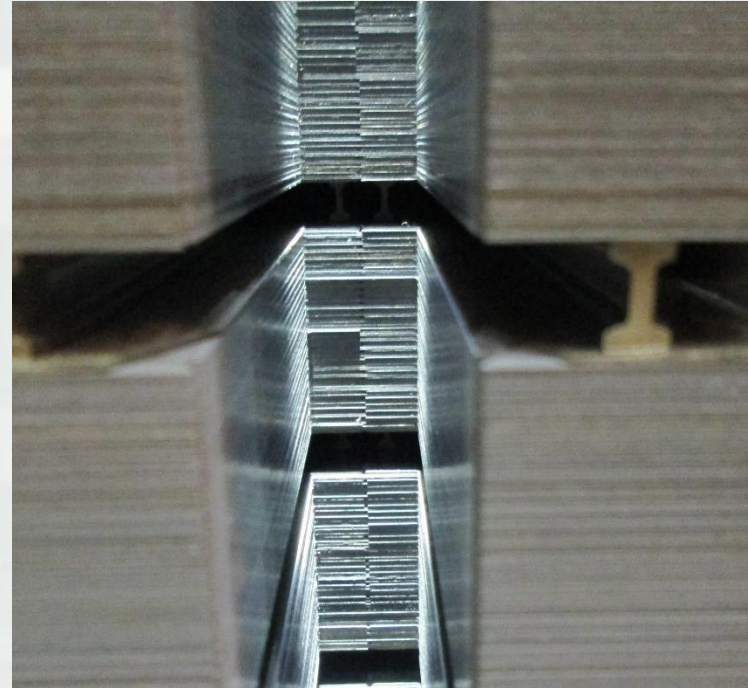
Resolution

- Un-pile laminations
- Use stronger lower finger plates
- Control piling process more closely
 - ▶ In process checks
 - ▶ Judicious use of shims

- Problems at another project with bar/slot dimensions led to decision to enlarge slots before re-piling



Re-piled Core



Required special bottom filler to protect bars

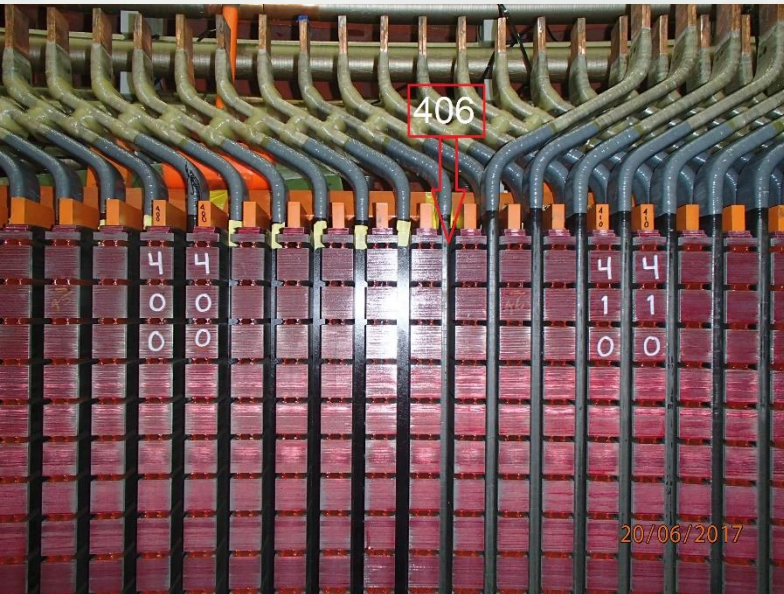




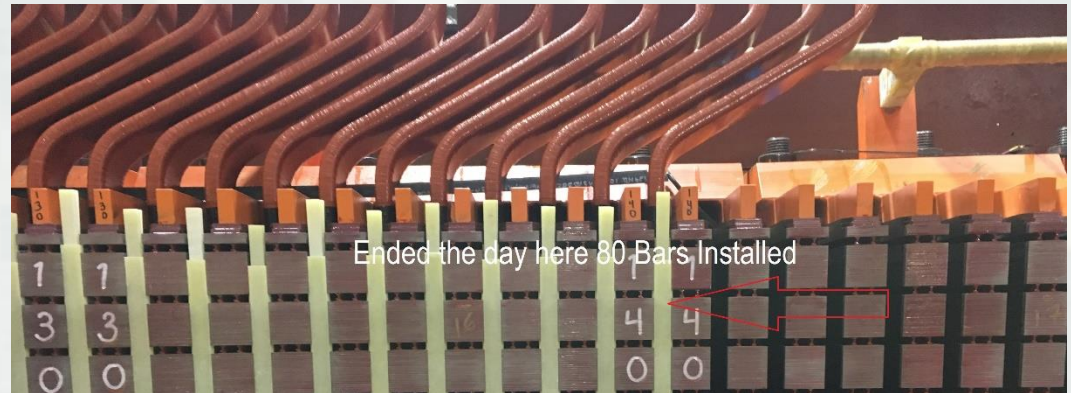
Wrong from the beginning!



Replacement Bars



Original bar installation



Replacement bar installation



Bars Inserted Upside Down

- Different factory stamped serial number on opposite end of bar
- Resolution
 - ▶ Agree on procedures
 - ▶ Remove bars
 - ▶ Touch up surfaces and retest
 - ▶ Install right side up
- Prevent future occurrences
 - ▶ Pay attention to beginning of winding process – see that it matches the drawings!





Coil Failed In-process Testing





Coil Failed In-process Testing

- Damage went un-noticed until hi-pot
- Many coils installed over failed coil
 - ▶ 50-60 coils would be disturbed by lift to replace
- Half coil splices allowed in new winding to minimize schedule delays
 - ▶ Good coils needed to be cut to allow replacement of bad coil
- Closer adherence to ITP to prevent re-occurrences





Cut Coils to Allow Replacement





Spliced New Front Half Coil





Summary

- Work is not done with contract award
- Starts with good specs and contract
- Requires communication with manufacturer
 - ▶ Resolve problems at lowest levels possible
 - ▶ Some give and take between owner and manufacturer
- Document submittals, review, discussions and resolutions
- Catch issues early to allow time to correct

