Case Study: Motor Rotor Cracks

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Background Information
Amortisseur Winding Function

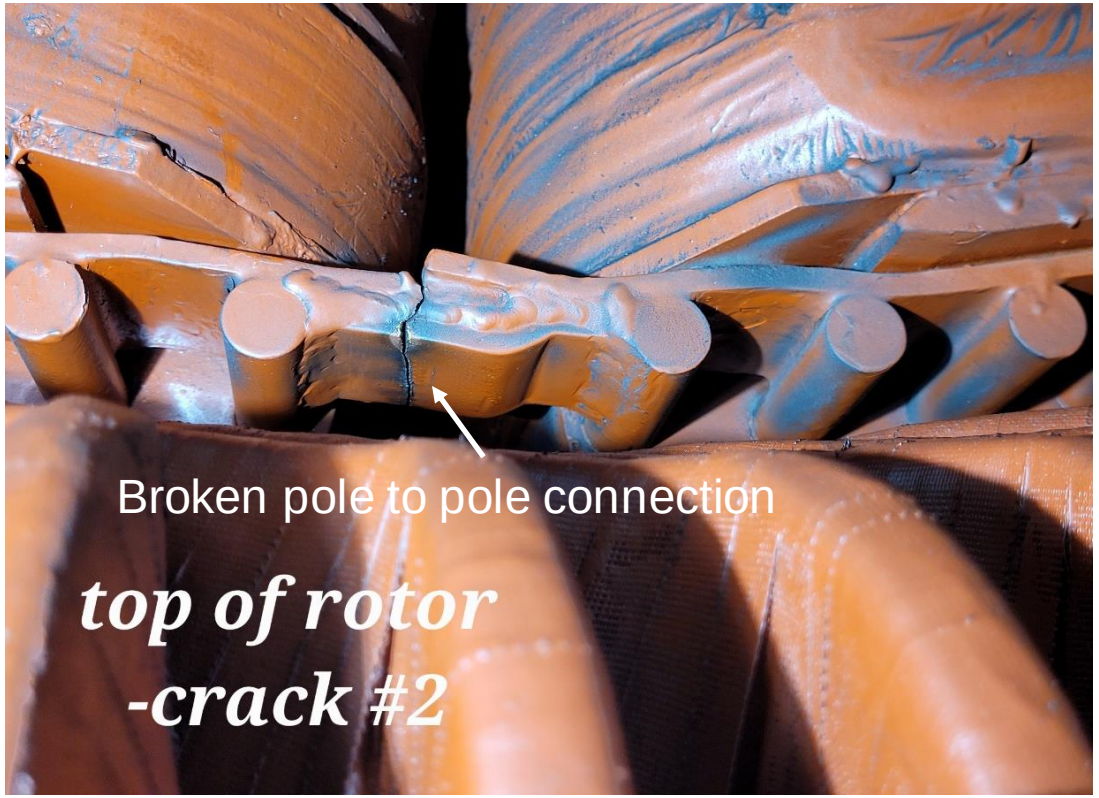
- Used to accelerate motor during start-up
- Dampen any speed fluctuations or oscillations that may occur due to sudden load changes
- Makes a synchronous motor self-starting like a squirrel-cage induction motor

LHQ U10 Rotor
2250 HP Electric Motor

Damage Identification

July of 2022, 5 Year Motor PM visual inspection performed

- Six broken rotor pole to pole amortisseur winding connections identified by plant electrician
- CAP Maintenance Organization immediately notified of findings

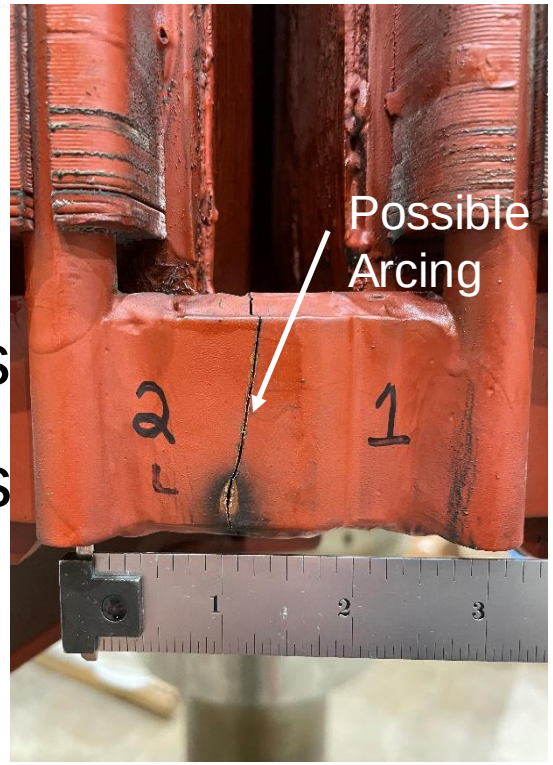


LHQ U10 Motor

Damage Identification

August 2022, rotor removed from unit for further inspection.

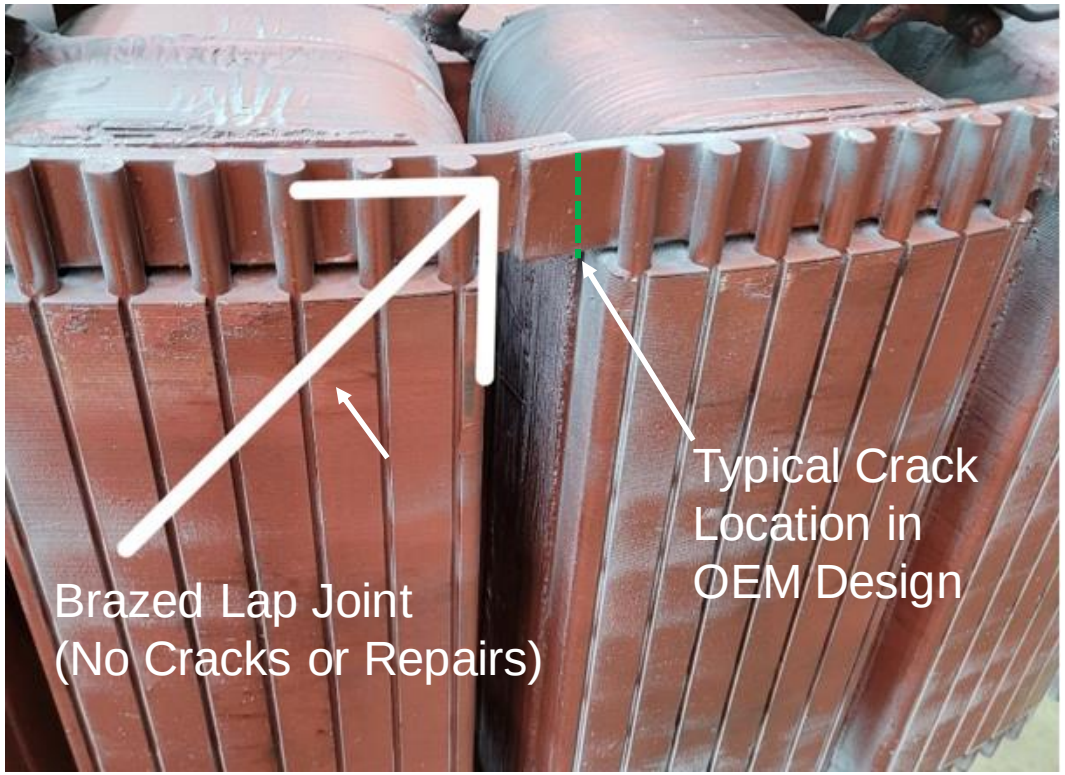
- Confirmed six connections with arcing at some locations
- Three additional connections with hairline cracks
  - Lengths vary from ~ 3/16” to 7/8”



Damage History

Bouse Hills (BSH) and Little Harquahala (LHQ) small unit motors have a history of cracks with the original design.

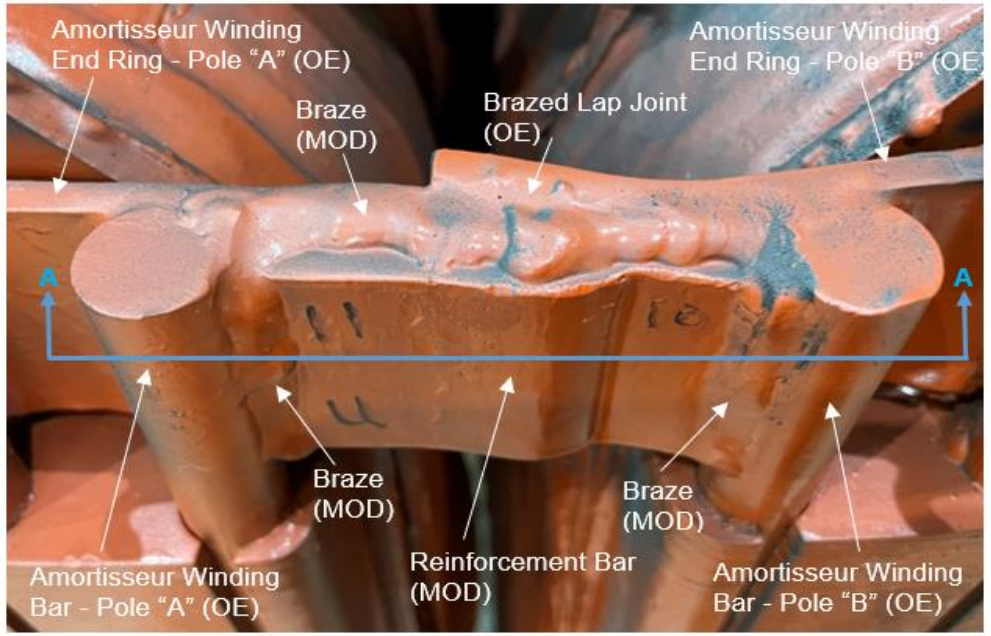
- Mid-1990s, 6 of 8 small units were identified having cracks
- Hassayampa (HSY) small unit motors had no history of cracks

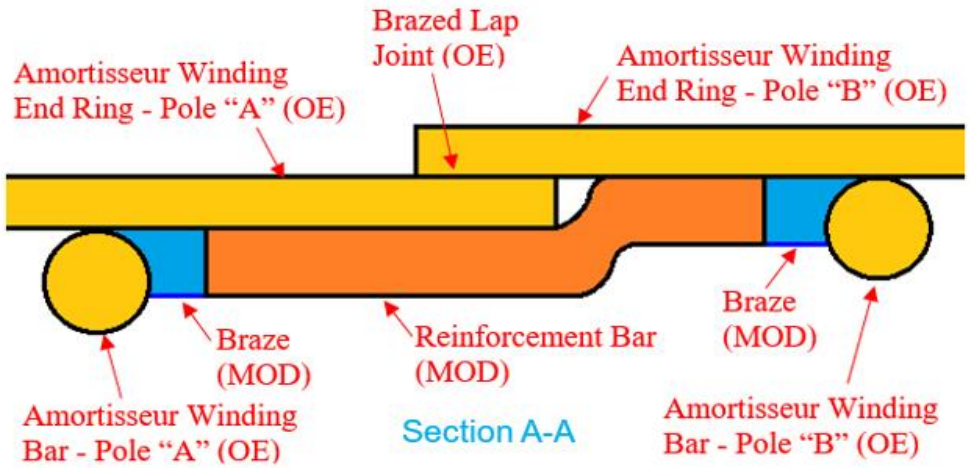


Original Pole to Pole
Amortisseur Connection

Repair History

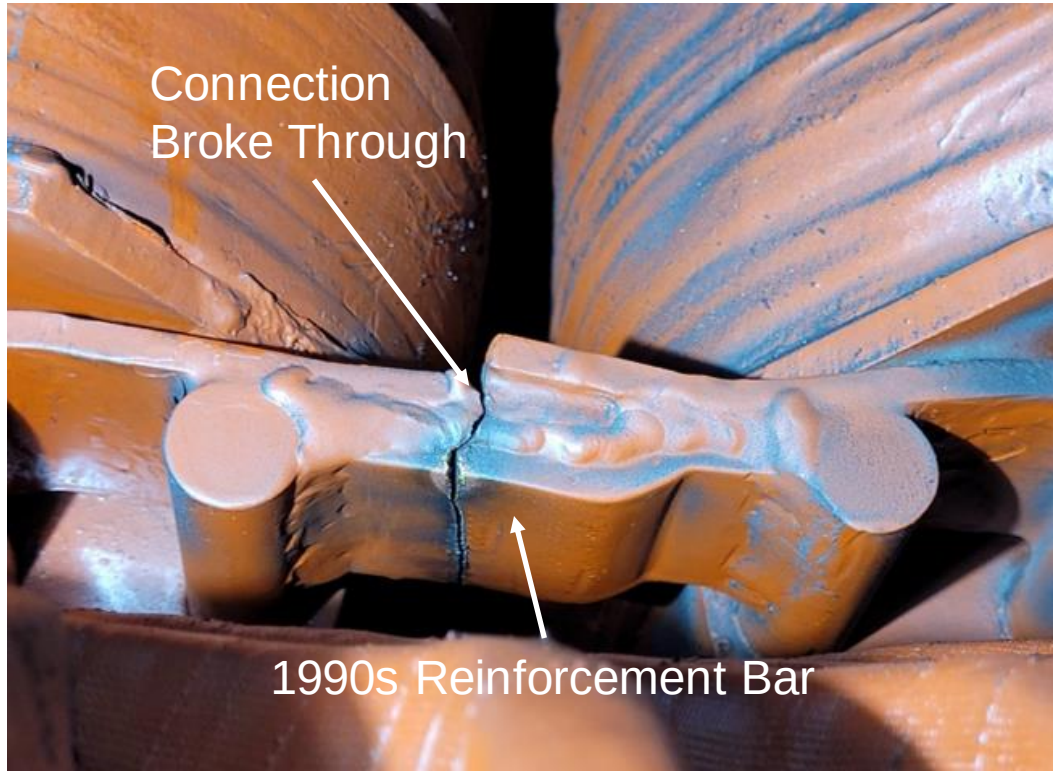
- 1996-2000, all BSH, LHQ, and HSY small units received a design modification.
- Adding reinforcement bar onto lap joint.
  - Brazed in place
- Increased cross section at joint expected to eliminate cracking.





Damage History

- All six broken connections identified on LHQ U10 had the 1990s modifications performed.
- With these results, all small units of BSH, LHQ, and HSY were inspected.
- Cracks were identified on 6 of 12 units



Modified Pole to Pole Amortisseur Connection With Cracks [LHQ U10 – July 21, 2022]

West Small Unit Inspection Results

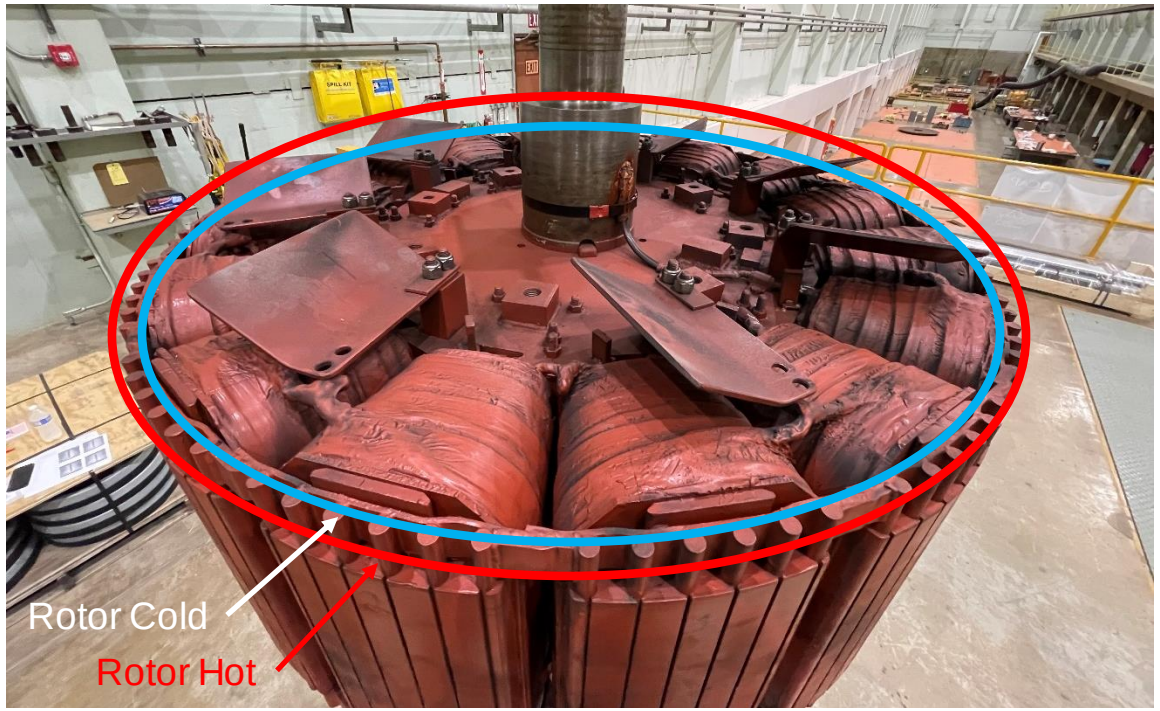
			History			Current	
Unit	Hours	Starts	Design Modified	Year	Cracked Connections	Inspection	Cracked Connections
BSH U02	58205	1885	Yes	1996	2	Aug. 2022	6
BSH U01	47469	1547	Yes	1996	2	Aug. 2022	0
BSH U09	50530	1246	Yes	1996	4	Sep. 2022	0
BSH U10	47423	1589	Yes	1996	0	Sep. 2022	2
LHQ U01	85619	2437	Yes	1996	2	Sep. 2022	6
LHQ U02	83534	1699	Yes	1996	0	Sep. 2022	1
LHQ U09	76782	1584	Yes	1996	8	Aug. 2022	2
LHQ U10	68463	1852	Yes	1996, 2000	1 - 1996, 3 - 2000	Jul. 2022	6
HSY U01	86441	2123	Yes	1997	0	Sep. 2022	0
HSY U02	66893	1695	Yes	1997	0	Sep. 2022	0
HSY U09	78105	1782	Yes	1997	0	Aug. 2022	0
HSY U10	75915	1912	Yes	1997	0	Aug. 2022	0

BSH, LHQ: 16 rotor poles (32 connections)
HSY: 12 rotor poles (24 connections)

$N_{poles} = Freq_{Hz} \times 120$
$Speed_{rpm}$

Suspected Cause

- Insufficient OEM Design
  - Connection not sufficient for operating stresses
    - thermal expansion of rotor during operation (20 *C to 60*C)
    - Inertial forces
- Modifications in 1990s not adequate
  - May have introduced residual stresses (counterproductive)



Functional Impact

Review of unit operating history and test data

- No operational impact to currents, vibrations, and temperatures
- No noticeable change to starting times
- No significant change to motor test results
  - Offline Tests: Doble, PDMA
  - Online Tests: Partial Discharge
- No functional impact observed

Long Term Risks

- Arcing across broken connections
  - Debris thrown out into the stator end turns, possibly resulting in insulation failure.
- Additional broken connections result in single rotor poles no longer part of amortisseur winding electrical circuit
  - Impact to motor starting times and synchronization

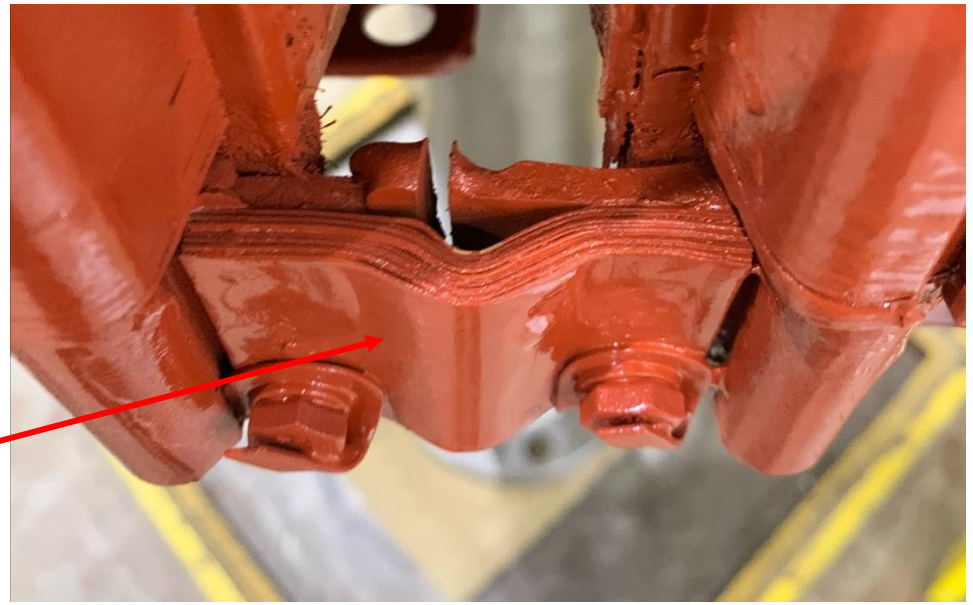
Risk Mitigation Efforts – Near Term

- Prioritize operation of units without cracks.
- If a unit with cracks must be operated, recommend that this unit become a constant runner.
  - Pole to pole connection experience significant current flow and the most force during the start sequence of motor before synchronization.
  - Pole to pole connections experience the most thermal growth/contraction during the starting and stopping of the motors.
  - Reducing the frequency of starting and stopping of damaged units will help mitigate risk of any additional damage.

Risk Mitigation – Long Term

- Design modification performed by supplier specializing in motor repairs

Motor Rotor Cracks



Modify Design with Flexible Pole to Pole Amortisseur Winding Connectors

Estimated Repair Scope & Costs

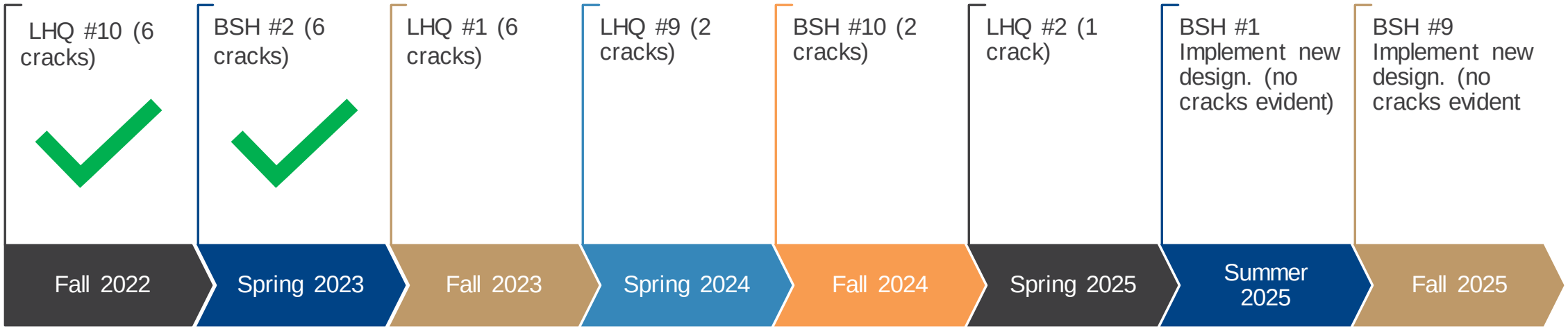
Estimated Repair scope

- Remove rotor (CAP)
- Visual inspect and evaluate connection modifications (Contractor)
- Electrically test rotor – pole drop, insulation resistance (Contractor)
- Steam clean and bake rotor (Contractor)
- Perform insulation resistance test (Contractor)
- Preform connection modification (Contractor)
- Final electrical testing - pole drop, megger (Contractor)
- Reassemble rotor (CAP)

Estimated repair costs

- CAP Labor: ~700 hrs.
- Contractor Repair Services : $56,361
  - Material: $6,136.16
  - Contactor Labor: $50,224.84
  - Repair Time: 6-8 weeks

Repair Plan



15