# RCA-2025-007 Unit 2 draft tube cone cracks and runner cavitation

Level 2 root cause analysis

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| **Document** | RCA-2025-007 |
| **Revision** | Final |
| **Date** | 2025-12-19 |
| **Applies to** | CCD-U2-TUR-DT, CCD-U2-TUR-RUN, CH-FR-1987-0043 |
| **Owner** | Lead: Priya Nandakumar. Team: Tom Halvorsen, Ray Okafor, Dale Whitaker, Karen Doyle (System Ops), Lars Bergström (Cromley Hydraulics) |
| **Approved** | Elena Marsh, 2026-01-08 |
| **Status** | Actions open (A4, A5) |

## 1 Problem statement

At the annual inspection on 20 October 2025, three cracks were found at stiffener welds of the Unit 2 draft tube cone, and cavitation erosion on the runner band. None was present at the 2024 inspection.

## 2 Impact

Repair outage 216 h after the inspection (WO-2025-0821, WO-2025-0834); approx. 7,400 MWh lost generation; repair cost approx. USD 185k. Risk avoided: a growing cone crack can lead to a draft tube liner failure and a long outage.

## 3 How it was detected

Visual inspection and NDT at the annual inspection. No vibration or pulsation monitoring existed on the units in 2025. Operators had noted "rough running" and noise on Unit 2 several times in July and August 2025 (shift log), without follow-up.

## 4 Timeline

| Date / time | Event | Source |
|---|---|---|
| 26 May 2025 | MOC-2025-012 raised by System Ops: bypass the rough-zone table so units can hold 15–35 MW for a regulation reserve contract | MOC register |
| 30 May 2025 | MOC approved by the plant manager; reliability review not requested | MOC register |
| 2 Jun 2025 | Bypass enabled by I&C | WO history |
| Jun–Sep 2025 | Units regularly held at part load. Unit 2 was the preferred regulating unit (lowest start count). Estimated time in the rough zone from plant controller logs: **Unit 2 approx. 640 h**, Unit 1 approx. 210 h, Unit 3 approx. 180 h | Plant controller logs |
| Jul–Aug 2025 | Shift log notes "U2 rough running / noisy" on 5 occasions | Shift log |
| 30 Sep 2025 | MOC expiry date passed; bypass not removed | MOC register |
| 20 Oct 2025 | Annual inspection: cone cracks 80, 140, 210 mm at stiffener weld toes; runner band cavitation over 0.4 $m^2$, max. depth 4 mm | WO-2025-0821 |
| 25 Oct–3 Nov 2025 | Weld repair (NDT ok) and runner band repair with CH field service | WO-2025-0834 |
| 8 Dec 2025 | Bypass removed, rough-zone table restored | WO history |

## 5 Evidence collected

Parts: crack replicas and photos, cavitation depth map. Position: crack locations in the cone zone where the vortex rope pressure pulsation acts. People: shift supervisors, System Ops, I&C. Paper: plant controller setpoint logs (used to estimate hours in the zone), MOC records, shift log, 2014 overhaul weld records, CH assessment by Lars

Bergström. Paradigms: "the units have always run at part load sometimes, it's fine".

## 6 Hypotheses and verification

| # | Hypothesis | Evidence | Result |
|---|---|---|---|
| H1 | Fatigue from draft-tube vortex rope pulsation (part-load operation) | 640 h in the rough zone for Unit 2 vs. CH guidance of 50 h/year; crack location; CH assessment | **Verified** |
| H2 | Poor weld toe profile from the 2014 overhaul | Weld toe angle steep at the cracked stiffeners | Verified as **contributing** |
| H3 | Cavitation from low tailwater | Tailwater normal all summer | Ruled out |
| H4 | Cavitation from high load / high head | Unit 2 rarely above 90 % gate in the period | Ruled out |
| H5 | Cavitation from part-load operation | Erosion pattern at the band typical for part-load inter-blade vortices; coincides with H1 | **Verified** |

## 7 Root causes

| Type | Root cause | Evidence |
|---|---|---|
| Physical | Fatigue cracking of the cone stiffener welds and runner band cavitation from sustained operation in the vortex-rope zone (contributing: steep weld toes) | Inspection, hours estimate, CH assessment |
| Human | Bypass enabled and left in place beyond its expiry; Unit 2 used as the preferred regulating unit; "rough running" reports not escalated | MOC register, shift log |
| Latent | MOC process allowed a rough-zone bypass without reliability review against the OEM limit (CH-DOC-OM-0101 section 3) | MOC-2025-012 |
| Latent | Commercial value of the regulation reserve was weighed without the equipment cost; no agreed band outside the rough zone | Interview System Ops |
| Latent | No tracking of rough-zone hours and no vibration or pulsation monitoring | Design, KPIs |

## 8 Actions

| # | Action | Root | Owner | Due | Status |
|---|---|---|---|---|---|
| A1 | Remove the bypass, restore the rough-zone table | Physical, Human | Dale Whitaker | 2025-12-15 | Closed 2025-12-08 |
| A2 | OP-03 rev C: reliability engineer sign-off mandatory for any rough-zone bypass; limit on hours; not on units with open findings (MOC-2025-019) | Latent 1 | Priya Nandakumar | 2026-01-31 | Closed 2026-01-15 |
| A3 | Weld repair with improved toe profile; runner band repair | Physical | Tom Halvorsen | 2025-11-15 | Closed 2025-11-03 |
| A4 | Implement a rough-zone hours KPI per unit (monthly review) using CH monitoring PLC data | Latent 3 | Dale Whitaker / Priya Nandakumar | 2026-12-31 | **Open** |
| A5 | Commercial: renegotiate the regulation reserve band so it can be delivered outside the rough zone | Latent 2 | Karen Doyle | 2026-06-30 | **Open, overdue** |
| A6 | Inspect Unit 2 draft tube cone at the 2026 annual inspection | Physical | Tom Halvorsen | 2026-10-31 | Closed 2026-10-22, no new cracks |

## 9 Effectiveness check

Rough-zone hours per unit below 50 h per year (CH guidance), reviewed monthly from 2027 once A4 is in place. No new cone cracks at the 2026 and 2027 inspections.

## 10 Lessons and FMECA / PM updates

FMECA FM-07 added (vortex rope). Lesson: part-load operation is an operating decision with a maintenance cost; the signature (pulsation near 0.28 × runner frequency, high TGB vibration, MW swings) can now be seen in the CH monitoring data.