The objectives of the assessment have been:

- Carry out any necessary inspections and tests to verify that the runners meet the Contract specification and O&M requirements.

- Correspondence from SEB to TGDCM about an acceptable equipment condition (runner):
  - 2013-08-19-22 Murum-CSR-001-Completion site visit report item 3.2 punch-items runner 3, 3 &1
  - 2013-09-02 Our references PLS7/61/6/IRY/229
  - 2013-10-03 Our references PLS7/61/6/AG/246
  - 2013-09-02 Our references PLS7/61/6/IRY/229
  - 2014-01-02 Our references PLS7/61/6/RN/257 (Unit 1, 2 & 3 runner rectification work at Murum site)
Volume 3, Chapter 5.19 describes shop tests.

D. Tests on Turbine Runner

1. Turbine runner blades shall be checked for surface roughness especially on the water flow side. Liquid penetrant inspection or magnetic particle inspection shall be performed on all surfaces of the blades. Acceptance standards shall be that there shall be no linear indications, and there shall be no rounded indications greater than 1.5 mm. diameter, and no more than 10 rounded indications in a 40 cm\(^2\) area. In no case shall linearly oriented indications have a center-to-center distance less than 5 mm.

2. Furthermore, ultrasonic or radiographic inspection of all doubtful places indicated by one of the above methods and of all highly stressed areas parts shall be made.
Runner 1

- Example, inlet side, Ø5 mm and Ø3 mm indication:
Example, outlet side:

- Pressure side of the blade
- Poor welding
- No grinding carried out
Runner 1

- Example, outlet side, Blade no. 1-7 Linear indication 8 mm:
Runner 2

- Example, inlet side, waviness:
Runner 2

Example, outlet side. Pores and cracks on the pressure side:

- Poor welding

- No grinding carried out
Runner 2

- Example, outlet side, Ø8 mm indication
Runner 2

- Example, outlet side, Ø8 mm indication (close picture)
• Example, the runner cone has only been welded from outside, welding from inside remains to be carried out
Runner 3

- Runner 3 has only been inspected from the outlet side

- Rough surface on the outlet

- 8 mm linear indication
Runner 3

- Runner blade on the pressure side at the outlet, large pits
Some conclusions

• The runners do not meet the contract specifications.
• Spot check shows that all three runners have cracks and pores with sizes that are not allowed according to the contract.
• The quality of welding and grinding on the outlet is poor.
• The turbine runners are not suitable for installation and operation.
• The runners need to be checked thoroughly and repaired.
• We have only few indications of material defects on the cast parts, ring crown and buckets.
Possible consequences of defects

- The defects are located in high stress areas on the runner outlet:
- Defects could likely be the starting point for fatigue cracks
  - Fatigue cracks are growing rapidly in a Francis turbine because of the high frequency of the pressure amplitude (120 hz)
  - 432 000 load-changes every hour of operation.
- Fatigue cracks may cause small or catastrophic break downs
  - Of the runner itself;
  - Involving other adjacent parts of the turbine;
  - Breakdown of the entire aggregate; and
  - in worst case flooding of the power-house or cause fire,….
- Pores, uneven surfaces and rough grinding could likely initiate and enforce cavitation
The sequences could be:

1. Punch marking the outlet of the runner with permanent blade numbering 17, 1, 2.
2. Grinding to correct hydraulic and mechanical shape, especially on the outlet towards the ring and crown.
3. Welding on areas where there is not enough material for a proper geometry. Local heat treatment.
4. Clean the runner 100% from the transparent painting.
5. 100% DPI NDT on all runner water passages.
6. Mark all the unacceptable indications.
7. Repair all marked indications with welding and grinding.
8. DPI on all repairs.
9. Return to point 6 until acceptable.