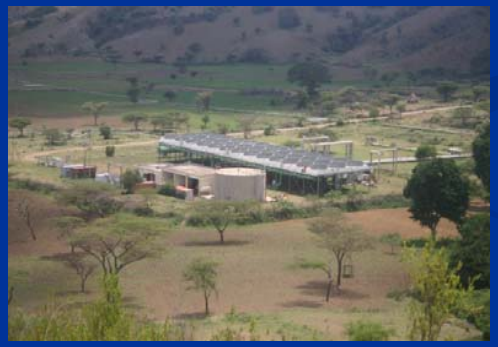
ETHIOPIAN ELECTRIC POWER CORPORATION

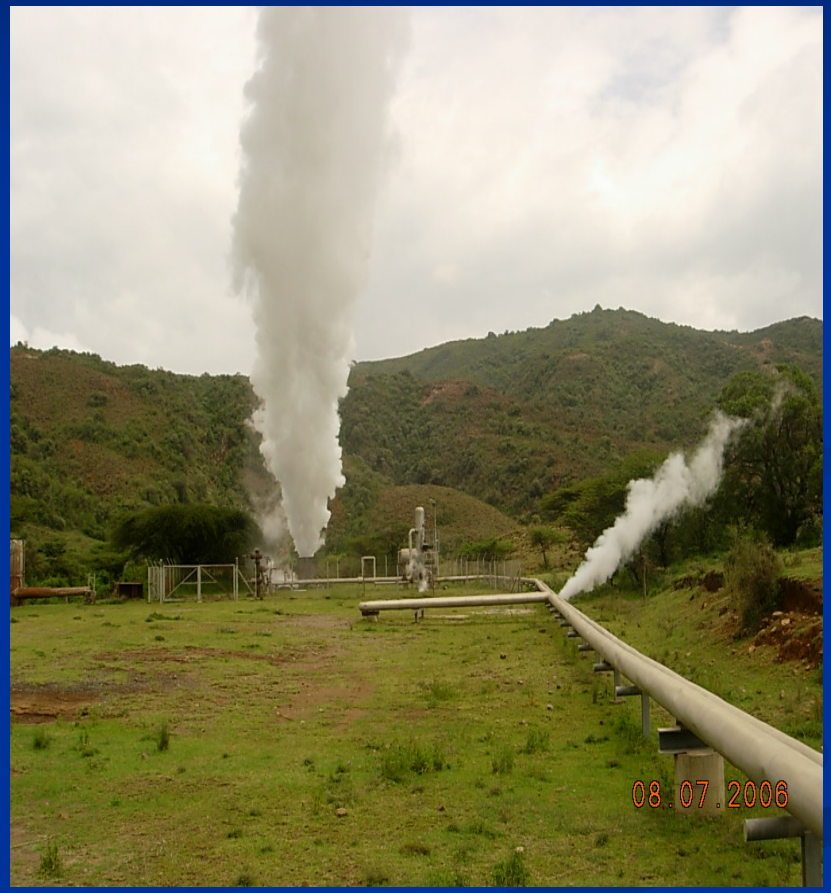
EXPERIENCE GAINED IN REHABILITATION OF THE ALUTO LANGANO GEOTHERMAL PILOT PLANT, ETHIOPIA



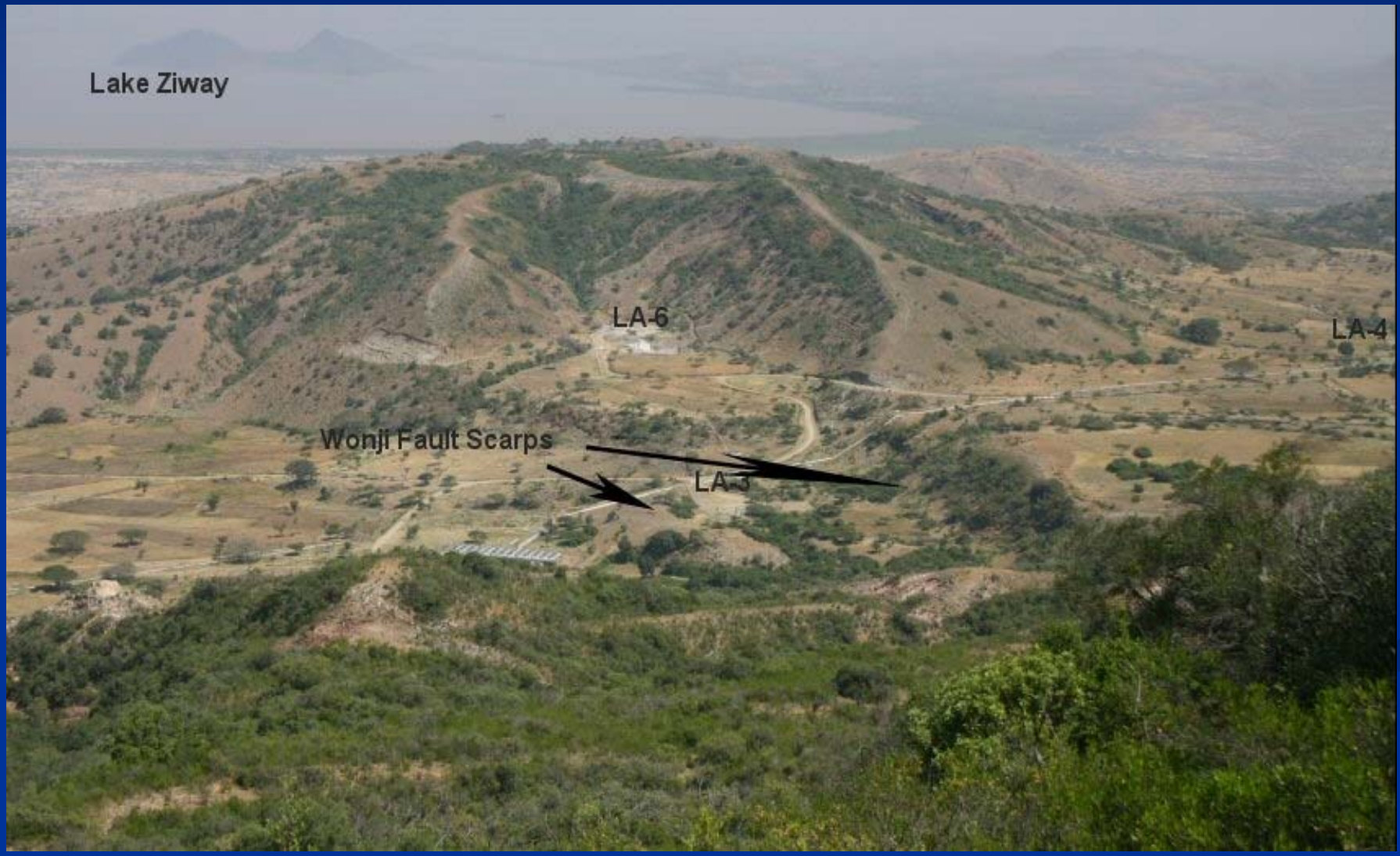
ARGeoc-2
Entebbe, Uganda
November, 2008

Background

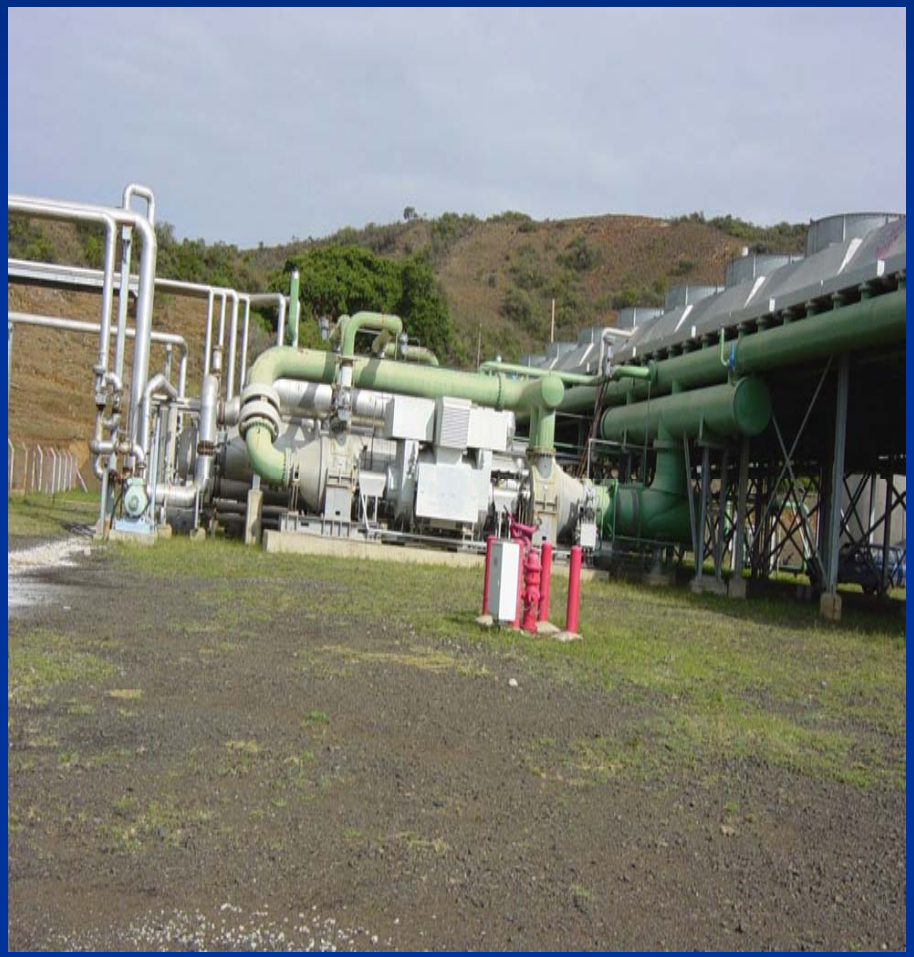
- Drilling Project was financed by the Government of Ethiopia, European Community and UNDP
  - Eight wells drilled within the period of 1981-86
  - Six wells drilled in the Aluto volcanic complex out of which five wells are productive



Location of the Steam field



OEC UNIT



Ormat Energy Converter Unit
Medium pressure steam and brine

Pentane absorbs heat from heat exchanger, vaporizes, drives turbine, producing generating electricity

Low pressure pentane flows to air-cooled condensers, liquefies, and is pumped back to heat exchanger

Power Plant

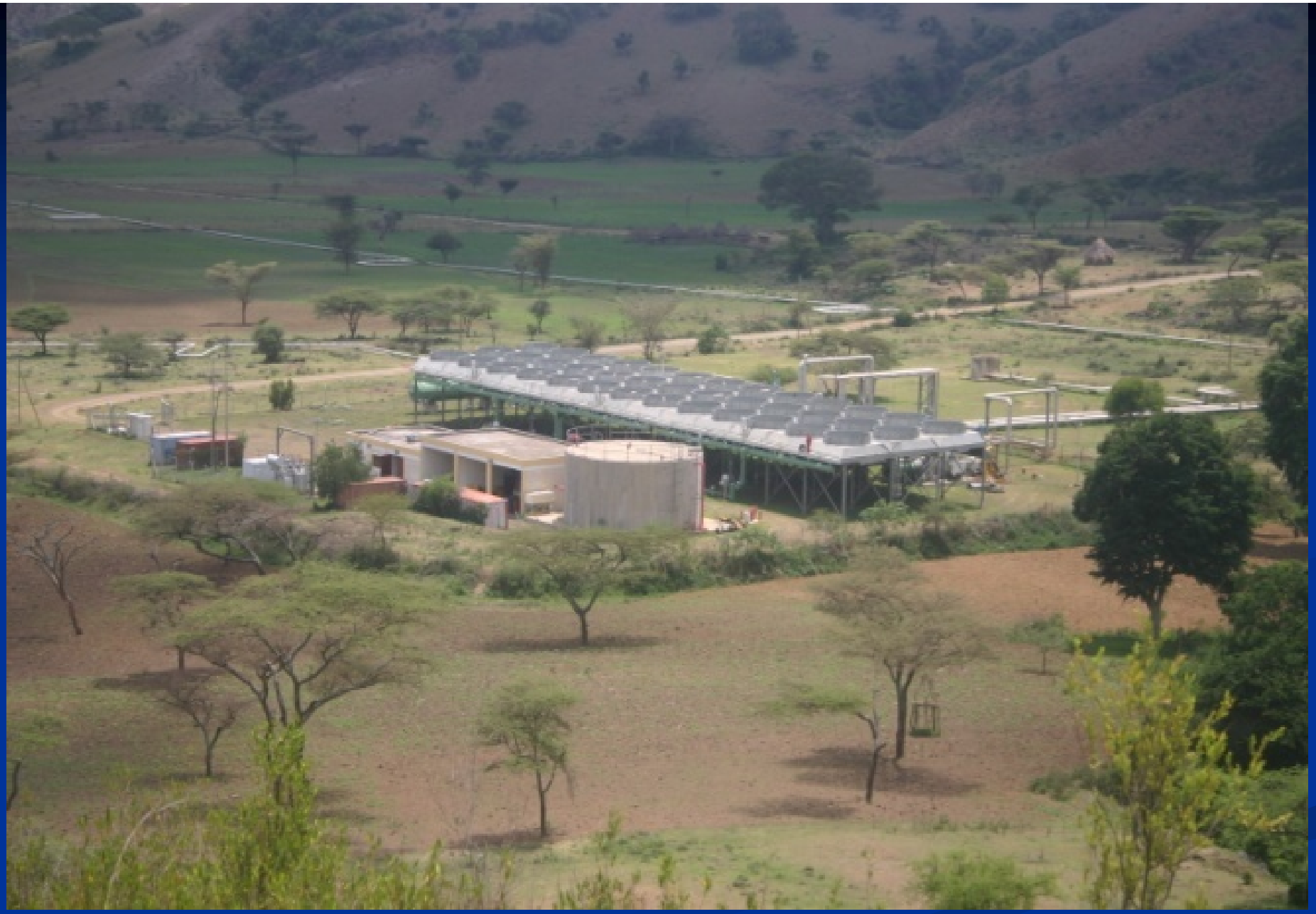
Plant Has Two Units

Geothermal Combined Cycle Unit

Steam enters backpressure turbine producing electricity

Exhausted low pressure steam flows to heat exchanger vaporizing pentane working fluid

Pentane drives organic turbine / generator



The Aluto Geothermal Pilot Power Plant

Problems encountered during the operation of the power plant

After commissioning a number of problems arose that led to shutdown of the power plant.

Some of the identified problems that are related to the steam field and the power plant are:-

- Back flow of the steam from well LA-6 to well LA-3
- Depositions of solids
- Failure of the steam turbine Journal bearing
- Worn-out of the steam turbine shaft from driving end side
- Tube leak of the OEC unit heat exchanger
- Frequent failure of the cooling fan

General discussion on the depositions

Depositions are not uniform so needs to identify their type and locations

- Inside production zone or reservoir
- In production casing or slotted liner
- In surface pipes and equipment
- In turbines and heat exchangers
- In re-injection system

Cont'd
Influence of Solid deposition on power plant operation

- Well output declines (wellhead pressure drops) when solid deposition plugs the flow line inside and outside of the well bore
- Solid deposition reduces the efficiency of the separation of the two-phase fluid separators
- Silica scaling deposits inside inlet turbine nozzles restricts the steam flow which results in loss of turbine power output.
- Condensers can suffer also from sulphure deposition on water distribution plates. This results in the loss of vacuum and power.

Methods of detection of Solid depositions

Using physical measuring

- Go-Devil tool
- Wire basket
- X-Y caliper tool

Type and chemical composition of scales can be analyzed by:

- Microscopy
- X-ray diffraction (XRD)
- X-ray fluorescence (XRF)
- Scanning Election Microscopy (SEM)
- Microprobe

Calcite deposition in well LA-4

- By running a go-devil into the well a blockage found at depth 1080m.
- A white fragments (calcite) found over the go-devil cap
- **Well work over is recommended to clean and bring the well back into normal operation.**

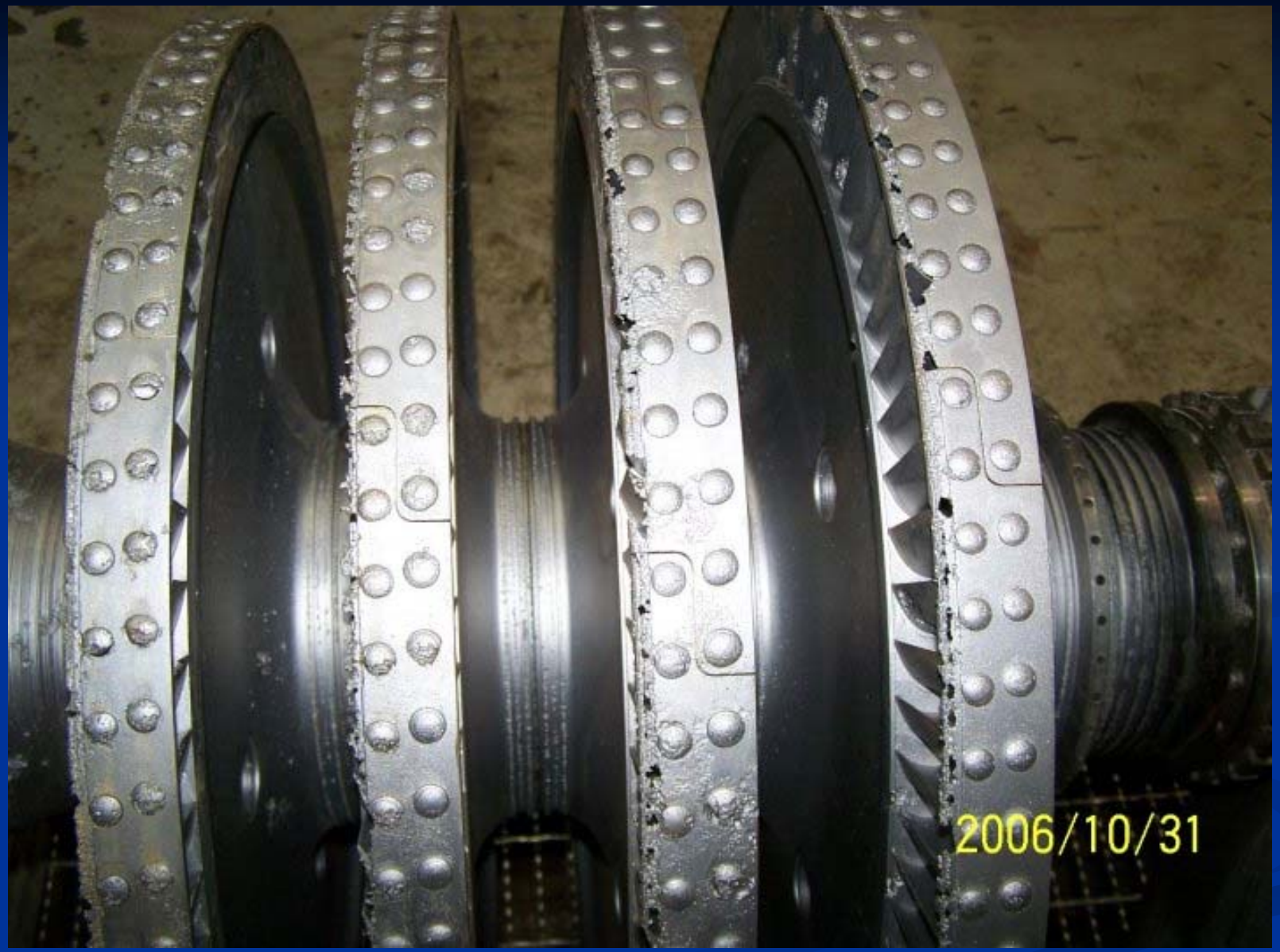
OEC Heat exchanger

- The heat exchanger vaporizer tubes are made up of a 316L stainless steel tube while the pr-eheaters are made of carbon steel tubes (first and second passes)
- The heat exchanger is a counter-flow design with steam on the tube side and organic fluid on the shell-side
- Pitting occurs on the internal diameter of the tube end
- X-ray analysis shows that silica & sulphr depositions with minor traces of K,Na, Cl & Al
- **Brine carryover is suspected to be the cause for the failure**
- **Re-tubing is undergoing and re-commissioning of the OEC unit is planned to be completed at the end of this year**

Photo of the vaporizer with man plug's in

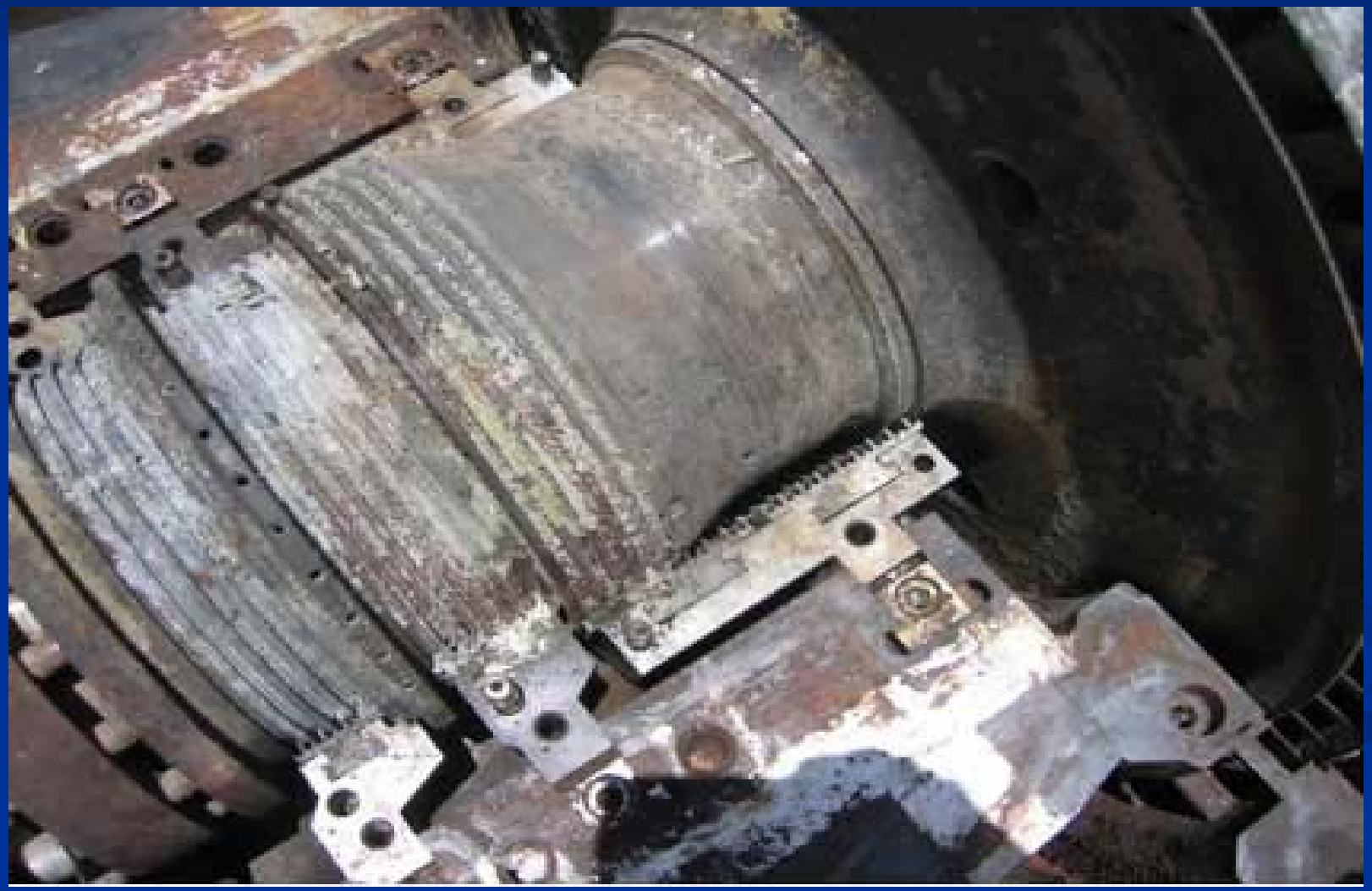
Re-commissioning of the GCCU unit

- During the initial operation, when well LA-6 was operated in parallel with LA-3, the flow of LA-3 sharply decreased at a considerable rate. LA-3 was unable to flow sufficient steam at higher system pressure to maintain the stable flow to the unit
- Thus de-staging of the steam turbine was done as part of the rehabilitation to enable the operation of the GCCU at a lower pressure
- **Matching of the stable production pressure of the wells to the turbine inlet pressure is achieved**



Corroded shroud bands

Worn-out labyrinth seal



Experience gained during the rehabilitation of the plant

- Operating and data interpretation using the digital Kuster (K-10) tool for the down hole pressure and temperature logging
- Knowledge acquired in the steam field resource management, wellhead equipment and steam gathering system .
- Knowledge acquired in refurbishment of the Cooling towers fans
- Knowledge gained in rehabilitation of the power plants automation system such as operation of the PLC and SCADA system
- Power plant operation and maintenance management system

Conclusion

- The plant has been successfully refurbished and put back into normal operation 3MW as of June 2007
- Further rehabilitation is currently underway to bring the plant to full capacity 7.3 MW.
- Experience gained at Aluto will ultimately be used to develop and harness the huge geothermal energy reserve exists in the Ethiopian rift system such as in Tendaho and others prospects

The way forward

- In a view of further exploration and development the geothermal resource of the Country strategically, the first priority is given to the ALuto geothermal field (75MWe) for the next.
- Donors/investors conference will be held in Addis Ababa, Ethiopia organized by the Ministry of Mines and Energy.

THANK YOU!