



Experience, solutions and development of operating geothermal ESP-systems in the southern Germany molasse reservoir.



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Agenda

High-Efficiency Geothermal Production Pumps Forum II

- What's about ESP?
- Requirements of ESP-systems
- What kind of problems do we see at ESP-systems?
- What does it look like ? (scary show)?
- Improvements from the suppliers?
- Issues of development?
- Prospects!
- Discussion between users, investors, suppliers

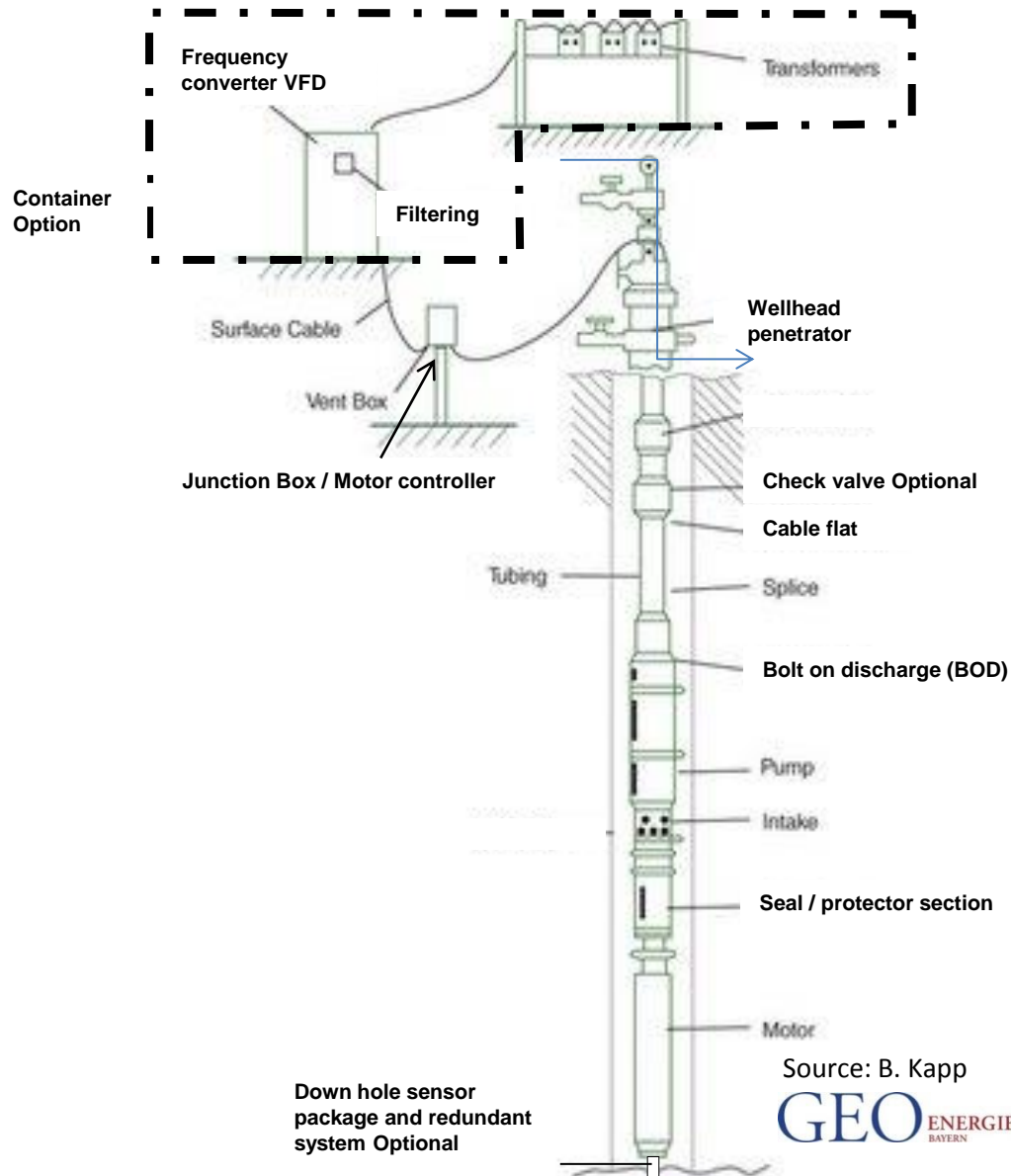
Who is Schaden-support?

Company:

Harden Schaden-support GmbH

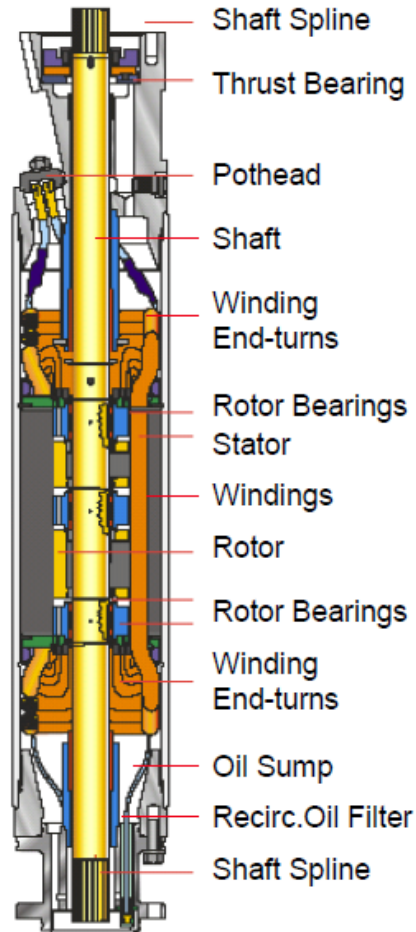
- Company that provides the renewable energy industry with a wide-range of services
 - Surveying, testing, evaluation of technical systems, loss adjusting
- Main field activities
 - Surveyor services, testing, evaluation according to machinery (MB) and loss of profit, mainly for renewables.
 - Macroscopic & Microscopic evaluation of damaged parts (electronic devices and mechanical parts) at our office
- Main tasks:
 - Machinery claims regarding construction machines, reapers, co-generation and heating plants, biogas plants, geothermal plants and conventional fired power plants
 - Photovoltaic (PV) power plants
 - Education, evaluation and interpretation of common engineering insurance conditions.
- Founded 01.04.2011 app. 350 - 400 claims p.a.
- 5 surveyors (2+ 3 x 1/2)
- Hamburg HRB 117901

Single „Electric Submersible Pump“ (ESP-System)

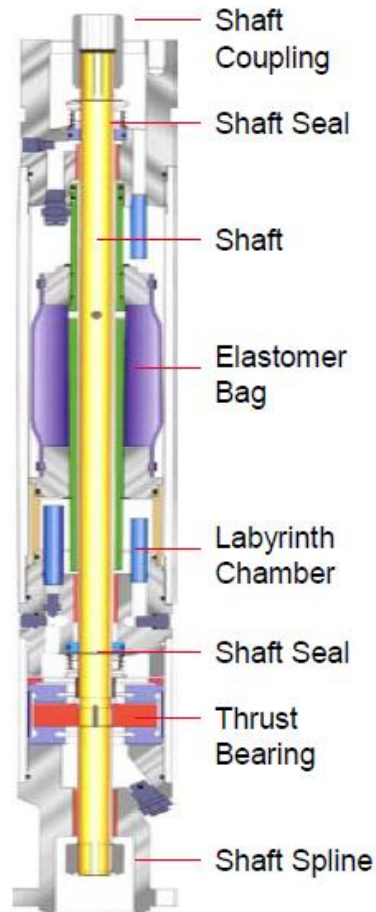


Main components of ESP => down hole equipment!

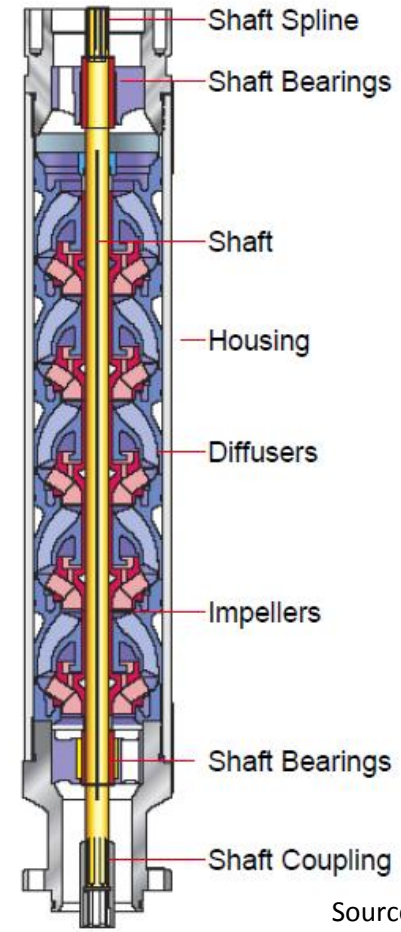
Motor section



Protector / Seal section
Oil-Pressure-Balancing



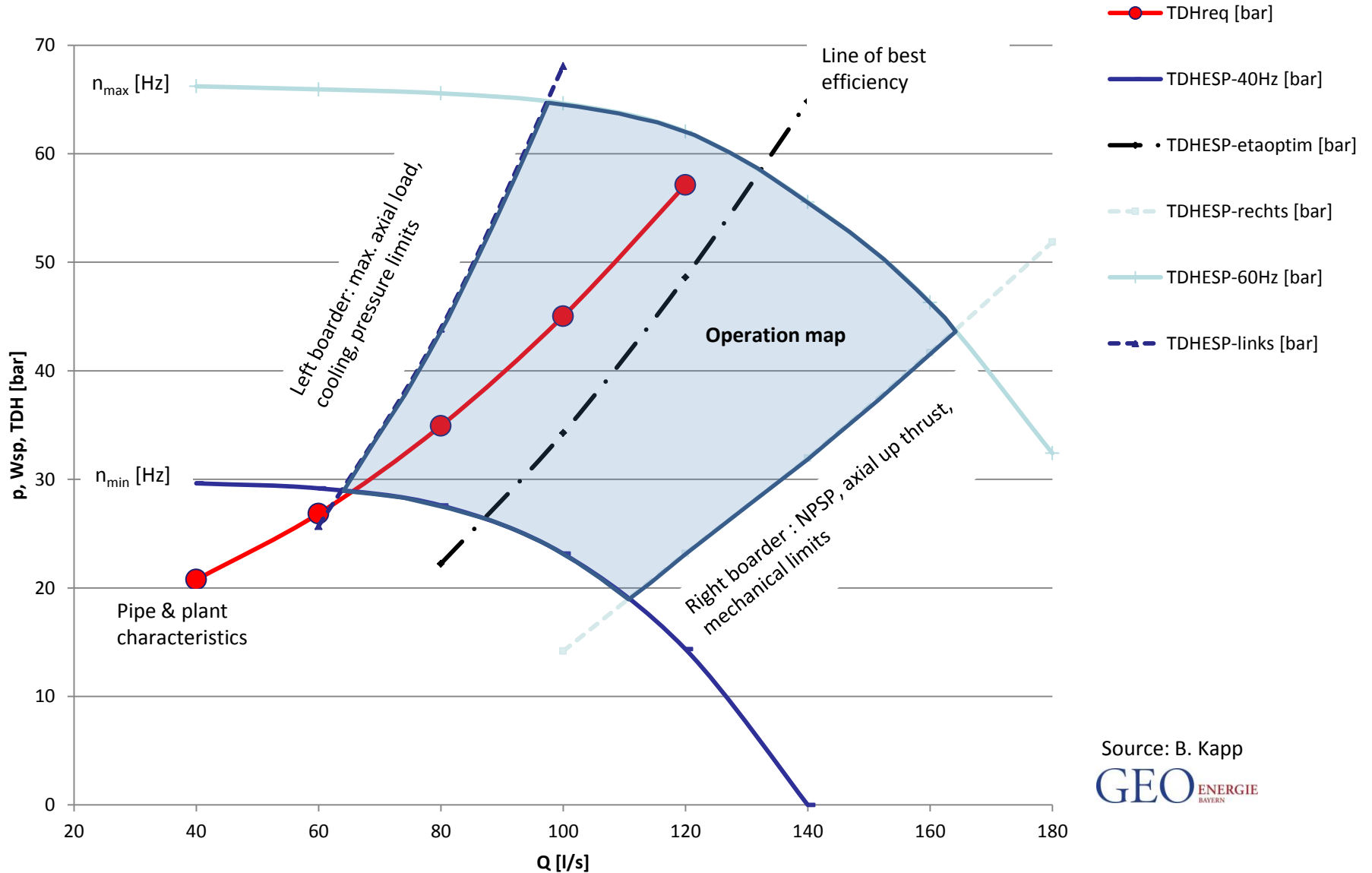
Pump section



Source: B. Kapp

GEO ENERGIE
BAYERN

Q - TDH diagram ESP und plant characteristics (stationary)



Source: B. Kapp
GEO ENERGIE
 BAYERN

Requirements of ESP-systems?

— High Performance!

- High Temperatures (up to 145 °C / 293 °F)
- High flow rates (app. 150 l/s / 540 m³/h / 82.000 bbl/d)
- Deep wells (up to 4.000 m / 13.500 f)
- Intake position (deep) (850 – 1.000m / 2.800- 3.300 f)
- Big pumps (11" / OD 308mm)
- Small casings (13 5/8" / ID 320 mm)
- Long motor tandem sets (up to 8,8" / OD 224mm)
- Start & stop operation (20-30 p.a.)

— Proper reliability

- Long running cycles (min. 24 up to 36 months)
- Short exchange cycles (app. week)
- Low costs (exchange or refurbished parts)
- Back up systems (delivery < 2 days, reinstall < 1 week)
- Exact and fast down hole measurements

— Water conditions

- Variable water consumption of the power plant (no constant load)
- Different NPSH acc. to static & operating water level
- Water is the lubricant for the pump bearings
- Old saturated water.
- Calciumcarbonat, H₂S, minerals etc.

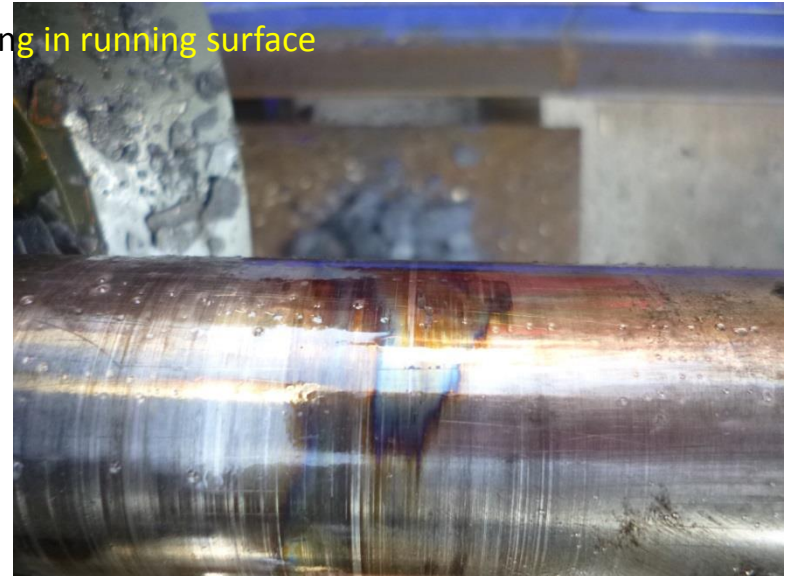
What kind of problems do we see?

— Electrical

- Cables (flat / round) protector, clamps, splices, penetrator
- Converter – variable frequency drive (VFD)-, junction box-, harmonics
- Sensor (down hole sensor), slow data flow (baud), floating Y-point, shorts
- Short circuits in motor, windings, connectors, pot heads,

— Mechanical

- Missing clamps
- Foreign objects damages (from erection, boring)
- Bearings, missing, abrasion, cracking, overload
- Lack of lubrication in pump bearings scaling in running surface
- Lack of lube oil in seals/ protectors
- Thrust bearing failures
- Broken shafts



What kind of problems do we see?

– Operational

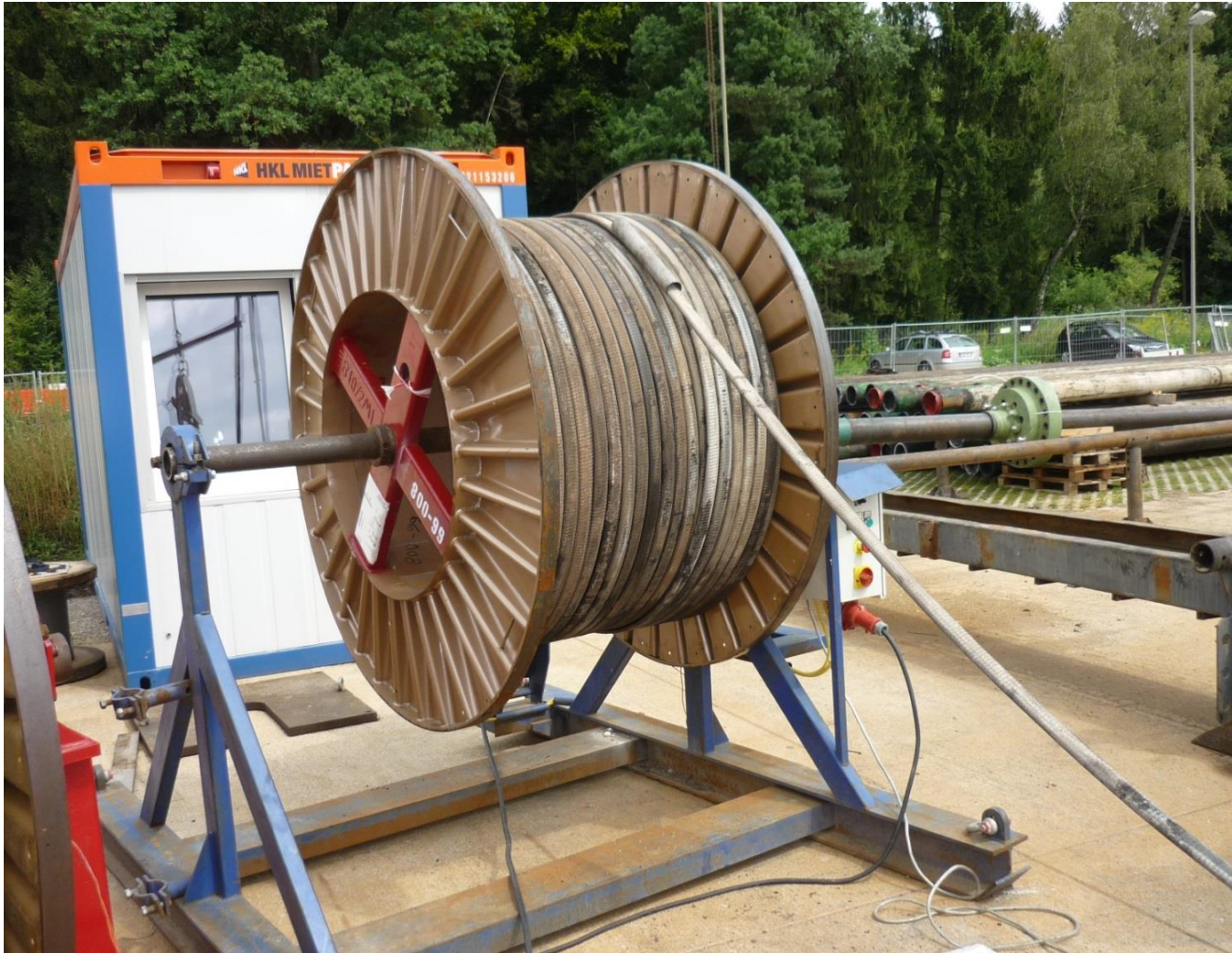
- Lot of starts and stops during commissioning!
- Changes in the surface application (pressure, flow)
- Changes in the water conditions

– Systematical

- High temperatures => high flows => high performance
- Cooling condition at the motor surfaces
- Water is the lubricant of rotation parts in the pump
- Degasing of oil acc. to high oil temp. (180 -200 °C)
- water and electric in low distance
- Different interests of investments between Oil & Gas Industry and Geothermal Industry
 - 1.000 bbl/d pure Oil (fluid 10-20% oil /rest water) x 50 \$/bbl => 50.000 \$/d
 - Geothermal power plants with 5 MW x 24 h x 0,2€/kWh => 24.000 €/d

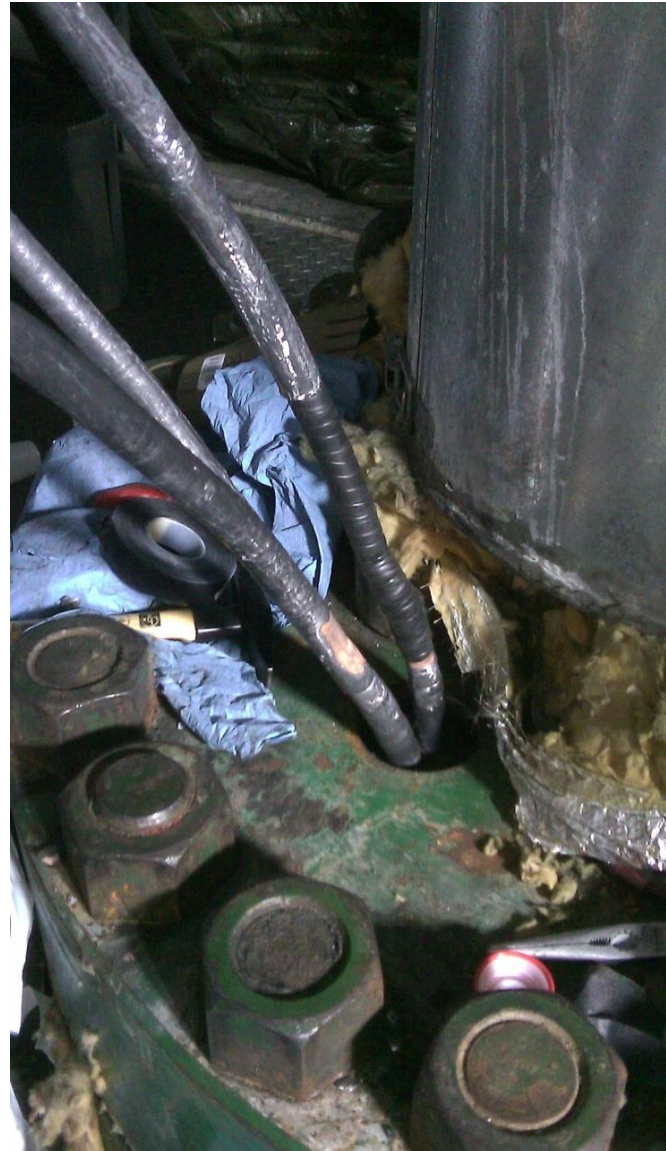
What does it look like ?

High voltage cable for ESP-system



High voltage cable for ESP-systems

Galling at „well head“
(penetrator)



High voltage Cable for ESP-systems



5,62" motor and 11" seal installed in 13 5/8" casing.

High voltage cable for ESP-systems



Foreign object damage the amour
=> Isolation failure /ground short!

Splice at ESP-systems



During run in=> armour of splice is damaged & internal failure in electrics. Short to ground!



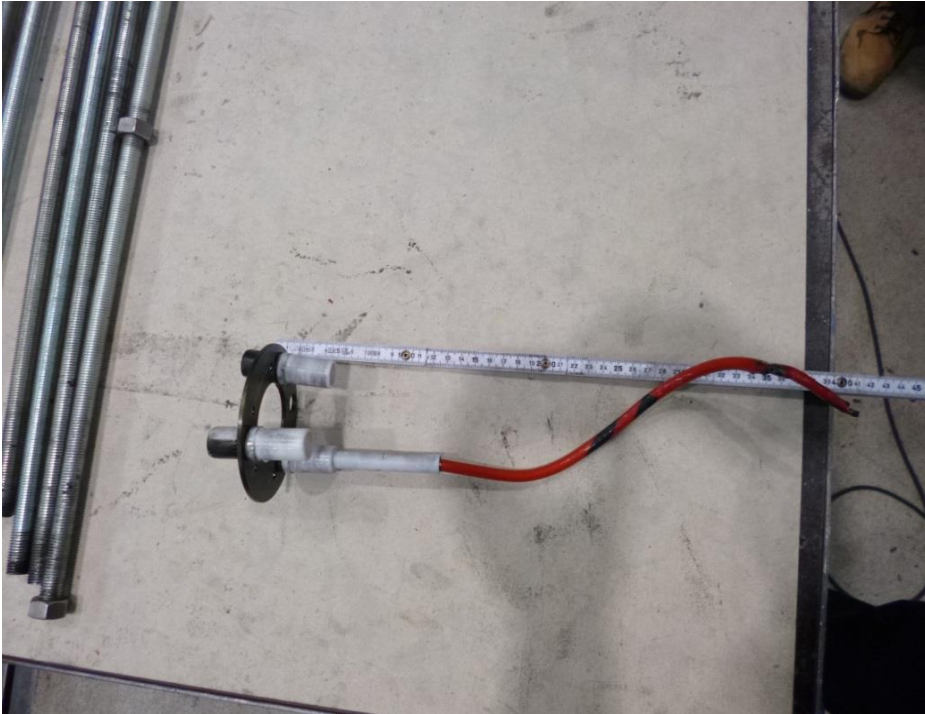
Connector at ESP-systems



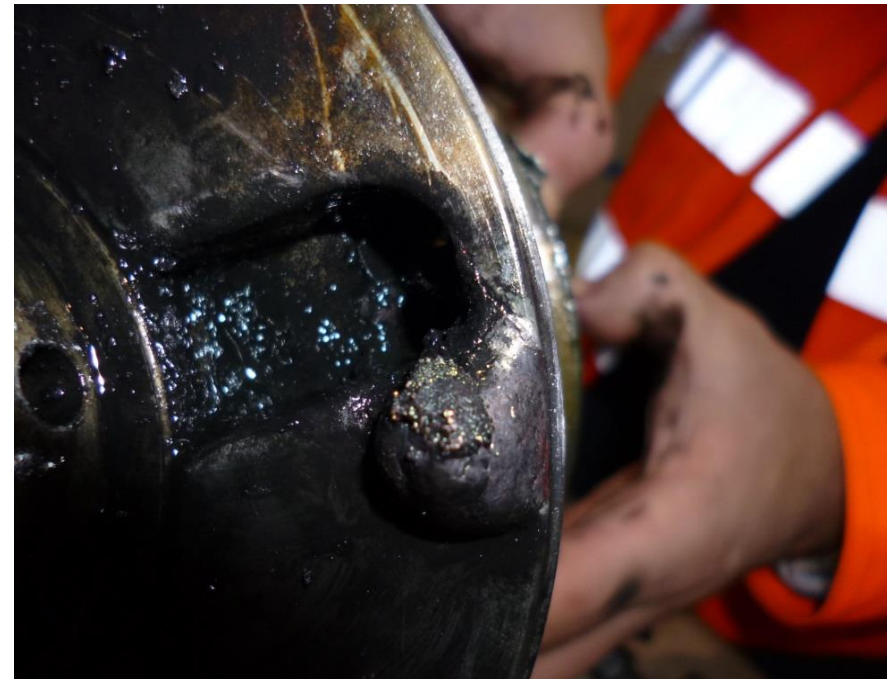
Missing axial fixing at the connector pins!

Rubber swelling. O-rings squared. Thermal influence

Electrical induced failure at ESP motor



During Operation the isolation decrease and the partial discharge increase. Severe contamination of the motor oil.

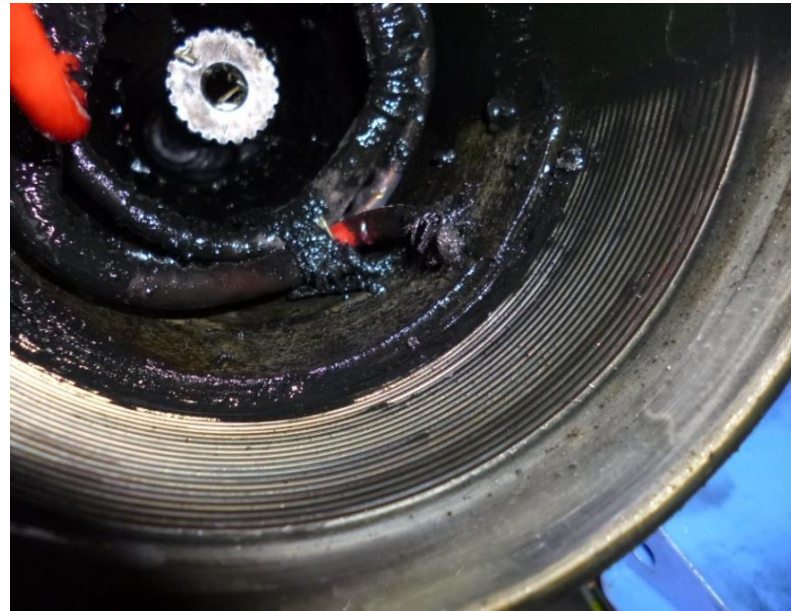


Electrical induced failure at ESP motor



Severe oil contamination with carbon and copper. Short at the end windings.

Due to a unbalanced load 2 phases were overloaded. 1 phase missing. Short at floating-Y-point



Electrical induced failure at ESP motor / sensor

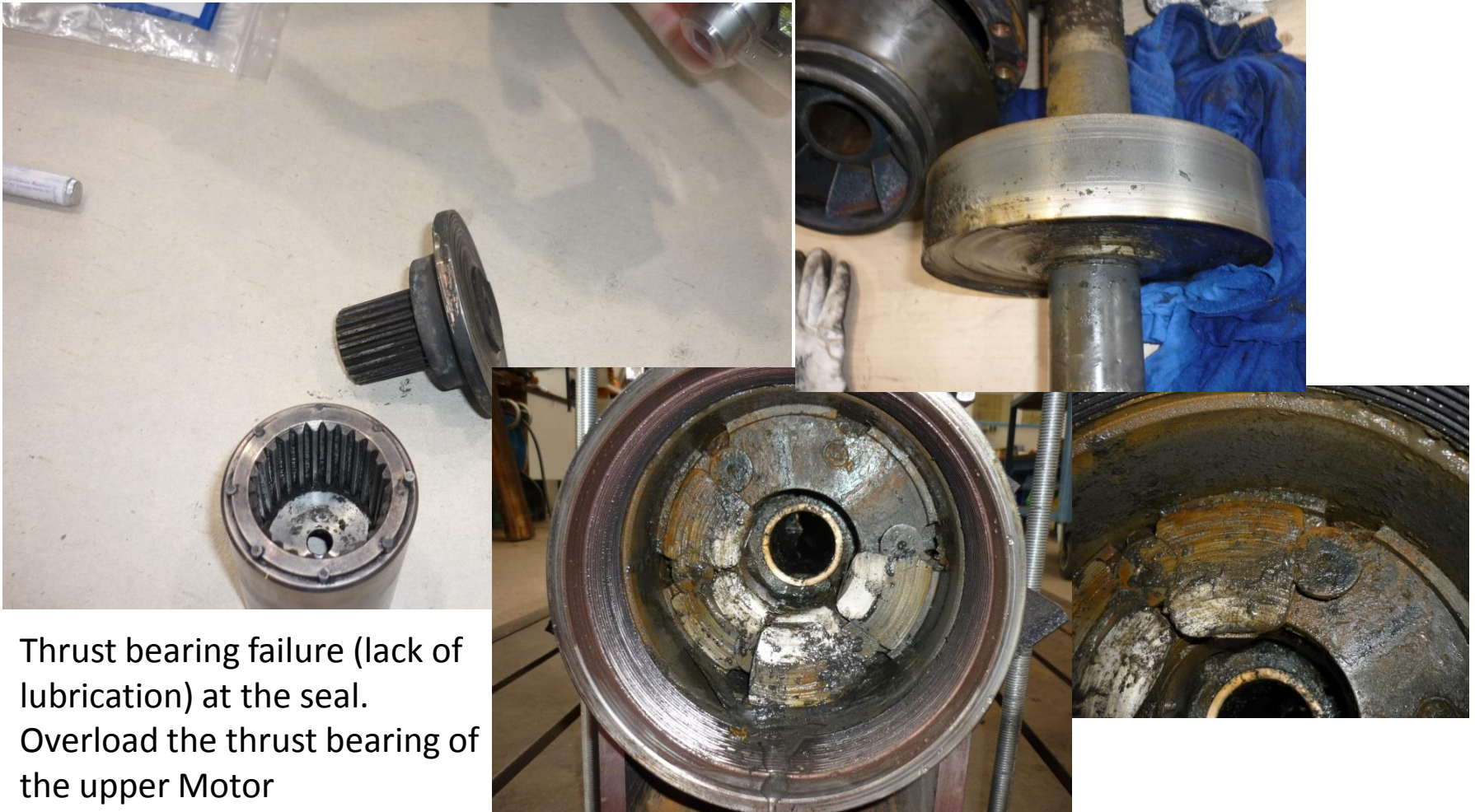


Isolation failure => damaged sensor!

Sediments of carbon and residue of thermal alteration deposits connect the ground an Y point potential. Ground short!



Mechanical induced failure at ESP motor



Thrust bearing failure (lack of lubrication) at the seal.
Overload the thrust bearing of the upper Motor

Protector / Seal issues at ESP-systems



Geothermal water in upper chamber => O.K.

Water in lower chamber in the thrust bearing area => lack of lubricant.



Protector / Seal issues at ESP-systems



Running surface destroyed!

Thrust bearing segments are totally worn out.



Protector / Seal issues at ESP-systems



O-rings in case of thermal influence destroyed. Heavy weight oil $\rho \approx 1,9 \text{ kg/l}$ leaked out.

Flat and squared O-rings. Thermal influence caused a leakage.



Pump issues at ESP-systems



Broken shaft caused by a lack of lubricant (water).

Heavy Scaling on „intake“.
Thermal discoloring in the bearing area.



Lubrication and cooling bores clogged with scale.



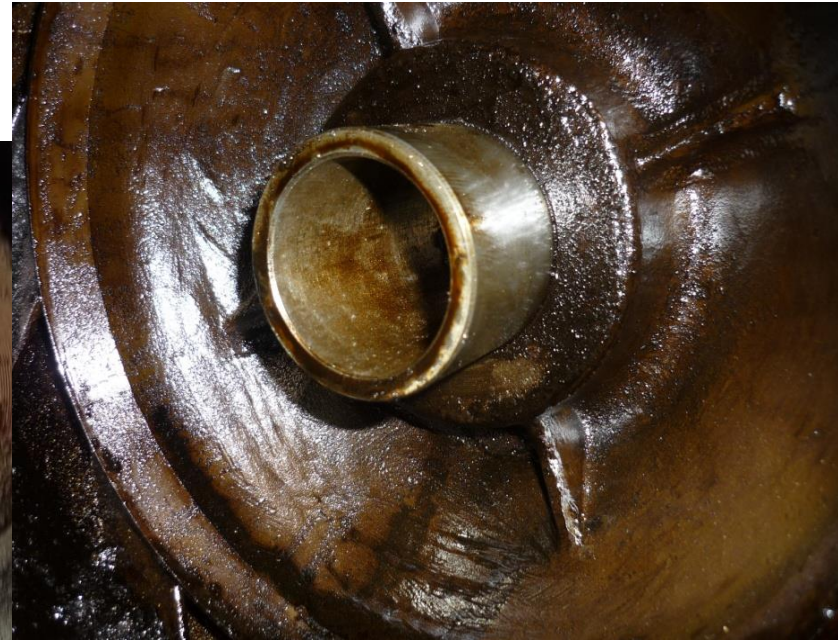
Pump issues at ESP-systems



Missing radial bed
destroyed the WC
bushings.



Bearing lost there axial position.

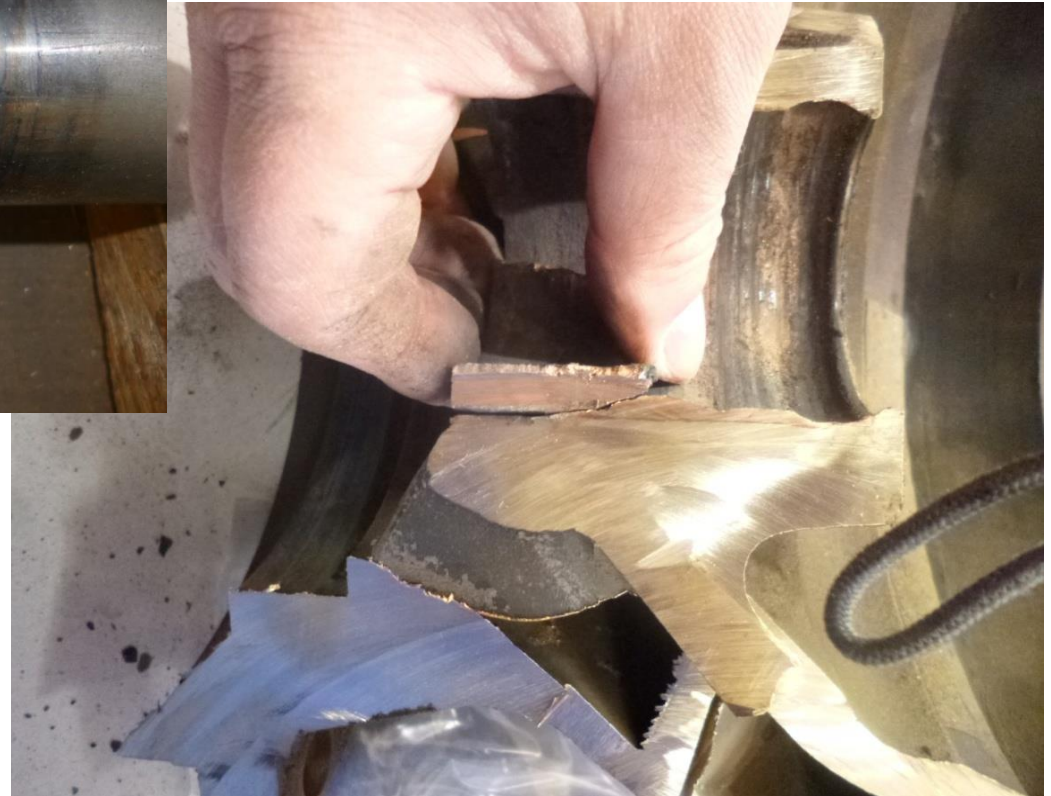


Pump issues at ESP-systems



Bearing material melted with the shaft in the middle of the bearing surface

Bearing material splits axial and angular. Lot of puzzle cracks are visible. Overheating.



Pump issues at ESP-systems



Shaft material brittle in consequence of liquid metal embrittlement from bearing material.

Pump issues at ESP-systems



Melting material on the impeller seal surface.

Axial and radial rubbing of the impeller into the diffuser.



Loss experience at ESP-Systems

- User view
 - Incidents mainly during commissioning or during warranty.
 - Life time between some h up to 9 month.
 - Suppliers improve their products.
 - The estimated life time of the pump reliability is insufficient.
- Suppliers view
 - Geothermal applications are different to Oil & Gas applications.
 - Big pumps in small casings (low clearance in the installed location).
 - Increase smooth operation with less start & stops.
 - The increasing requirements according to temperature and flow, bring a lot of additional problems with the life time and availability of the used ESP systems.
 - More details of the water / nature concerning of changing pressure, flow, speed and decrease of transient pressure should be necessary.

Improvements from the suppliers?

- Change and do safer install procedures (run in)
- Install flat cables!
- Optimize the penetrator and potheads
- Improve the filling and assembling procedures
- Improve the dielectric medium in motors
- Change and improve the oil qualities
- Change and optimize the bearing materials and design
- Seals designed with polymer bags
- Currently no heavy weight oil seals without bags in operation
- Install low and high pass filters after the VFD

Improvements from the user?

- Reduces start and stop issues
- Use back up systems to reduce the outage
 - Stock and delivery solution
 - Complete back up ESP in 2nd hole behind the well
- Reduce the speed and power
- Optimize the surface equipment
 - Filter cycles, redundancies
 - Operating pressures for the surface plant
- Optimize and evaluated process parameters

Issues of development?

- Supply ESP-systems with a life span > 24 month or more than 17.000 OH
- Evaluate the circumstances in the running area of water lubricated bearing and bearing material pairing.
- Develop polymer materials for temperatures > 220 °C (better than Aflas)
- Develop a heavy weight labyrinth protector with an degasing system.
- Implement variable VFD filter systems in range of 40 - 60 Hz.
- Reduce the surface pressure (Hertz) of the thrust bearing.
- Evaluate and permit an water conditioning inhibitor to solve the local scaling procedures in the pump bearing surfaces. (environmental issue!)
- Develop an alternative pump system (e.g. linear pump or impulse pump)
- Develop an alternative drive system (hydraulic water/oil/Leonhard set)
- Evaluate the nature and changings of the used fluid concerning pressure, fluid speed and transient pressure decreasing effects.
- Develop an dynamic fluid model to analyze partial low pressure areas on the fluid contact surfaces (casing, tube & bearing) between fluid and installed materials.
- Fast sensor systems with high sampling and transfer rates (incl. motor, seal data)

Prospects!

**Discussion between users,
investors, suppliers**

Using renewable energy resources in a way with the nature and not against her!

- The available ESP-systems are conditionally and permanently usable for the southern Germany molasse reservoirs.
- The suppliers need to improve their systems. However some developments are necessary.
- Think about back up ESP-systems!
- Think about commercial provisions for maintenance and depreciations concerning the ESP-systems



We would like to provide you
with our expert services!
Thank you for your attention!

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