DO_2 MEASUREMENT TECHNOLOGY IN STEAM CYCLE WATER

ELECTROCHEMICAL VERSUS OPTICAL

Greg Thomas

Hach Company

PRESENTATION OVERVIEW

- Dissolved Oxygen Measurement
- Electrochemical technology
- Optical technology
- Results
- Benefits

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DISSOLVED OXYGEN MEASUREMENT

Wet Chemistry

- Winkler titration
- Colorimetric tests
  - Packaged kits

Instrumentation

- Electrochemical sensors
  - Standard for many years
- Optical (luminescent) sensors
  - ppm level
  - ppb level

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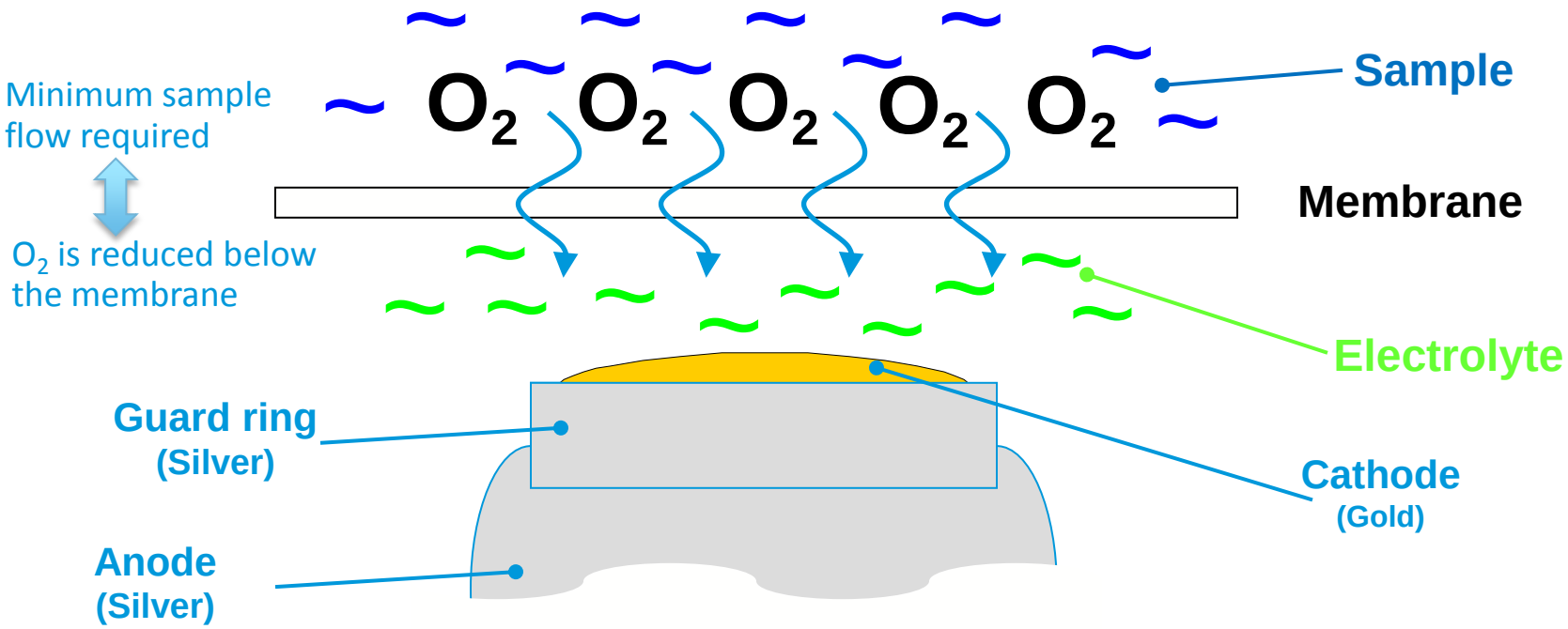
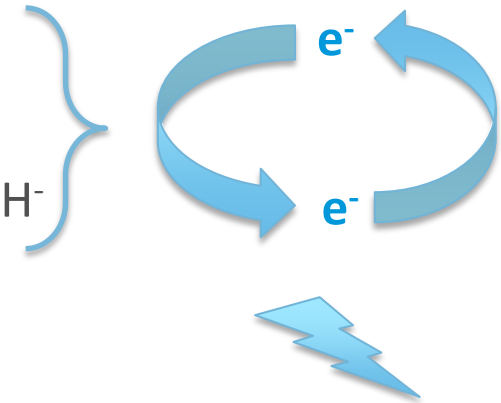
ELECTROCHEMICAL (EC) SENSOR



Electrochemical reaction generated after O_2 passes through the membrane

EC SENSOR SIGNAL

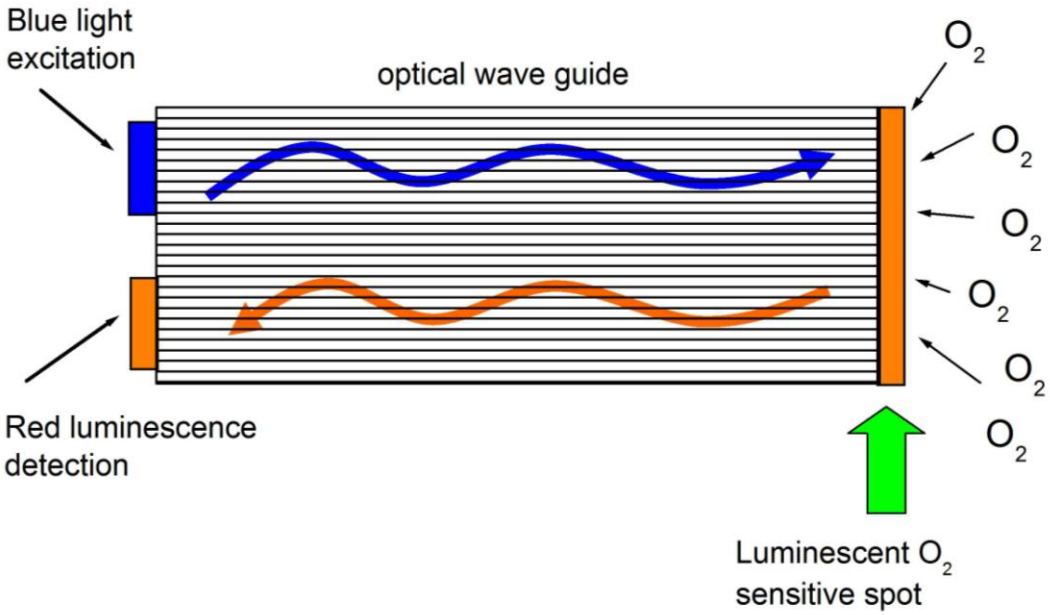
- Reduction: $2\ H_2O + O_2 + 4\ e^- \rightarrow 4\ OH^-$
- Oxidation: $4\ Ag \rightarrow 4\ Ag^+ + 4\ e^-$
- Overall: $2\ H_2O + 4\ Ag + O_2 \rightarrow 4\ Ag^+ + 4\ OH^-$

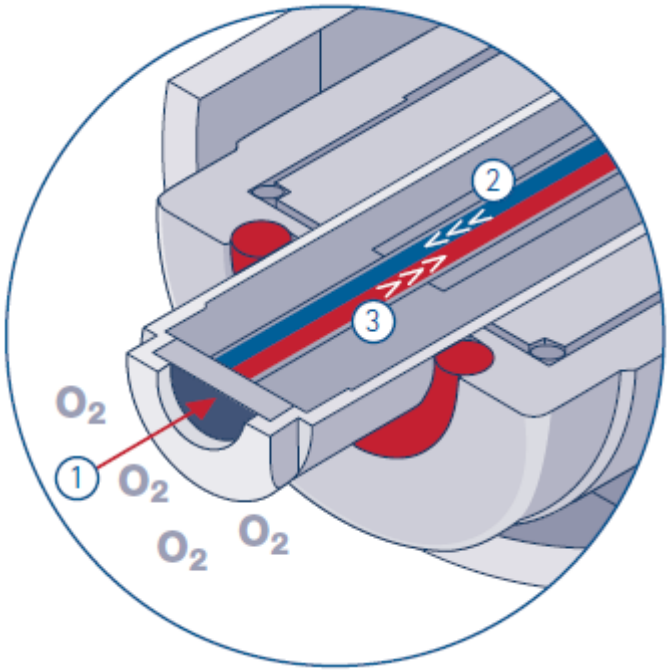


- $i = (\phi_{temp})\ P_{gas}$
  - partial pressure ⇔ concentration
  - Henry's Law ($cO_2 \ \alpha \ pO_2$)

BASIC OPTICAL PRINCIPLE

- A wave of blue light is emitted
- The active luminescent compound is excited
- The active compound emits red light
- The red light is detected





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SIGNAL - PHASE SHIFT TO DO_2

O_2 partial pressure ⇔ phase shift

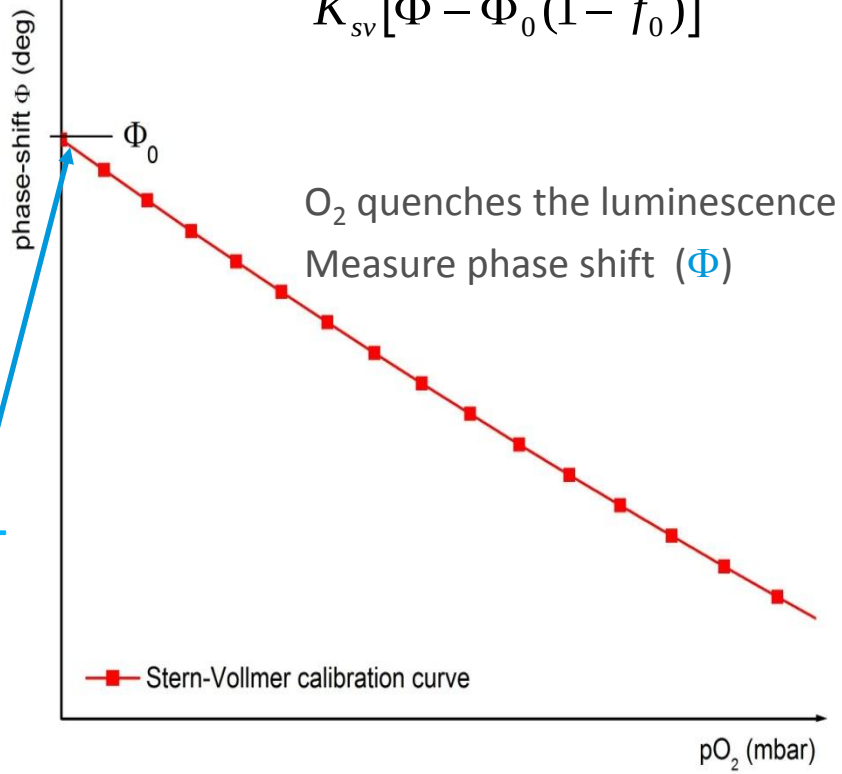
Stern-Volmer equation

$$pO_2 = \frac{(\Phi_0 - \Phi)}{K_{sv}[\Phi - \Phi_0(1 - f_0)]}$$

f_0 = constant

K_{sv} = sensitivity of active spot (known)

Φ_0 = phase in the absence of O_2



SINGLE POINT CALIBRATION

partial pressure ⇔ concentration

Henry's Law ($cO_2 \ \alpha \ pO_2$)

Same with EC measurement

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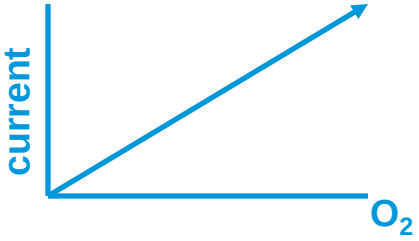
THEORY: EC *VS.* OPTICAL

EC – Electrochemical

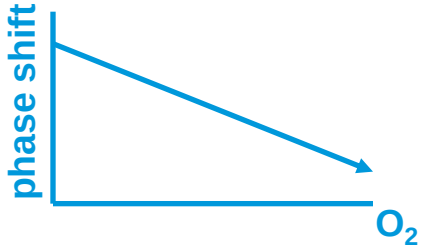


- Smallest signal at zero

Cal in air

- 20% O_2 ⇔ 8 ppm dO_2
- One point cal with fixed zero or zero adjustment to determine slope

Optical - Luminescence



- Largest signal at zero

Cal in N_2 gas

- Fixed slope (K_{SV}), hence one point cal at zero O_2

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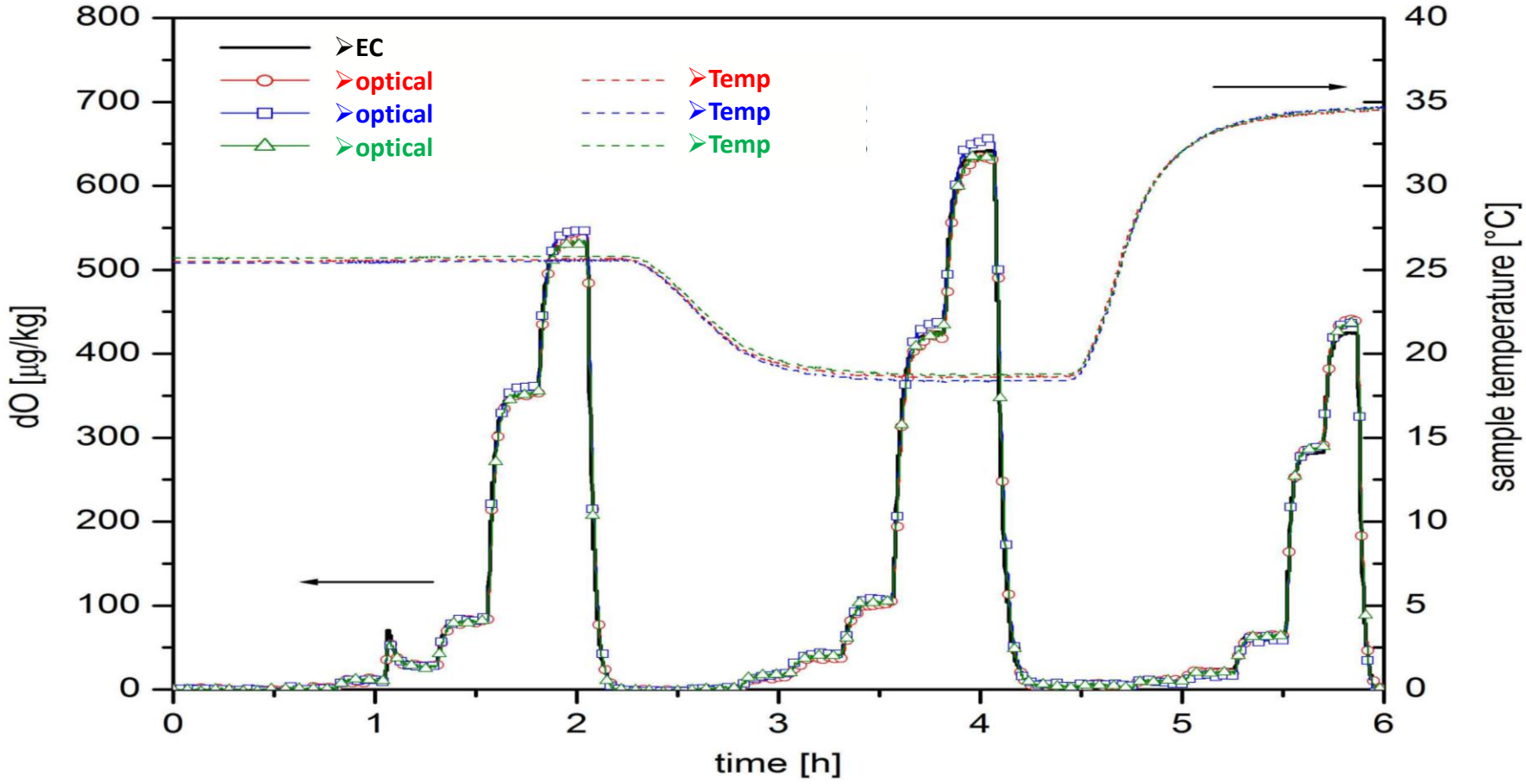
DO_2 RESULTS – IN THE LAB



Laboratory Results

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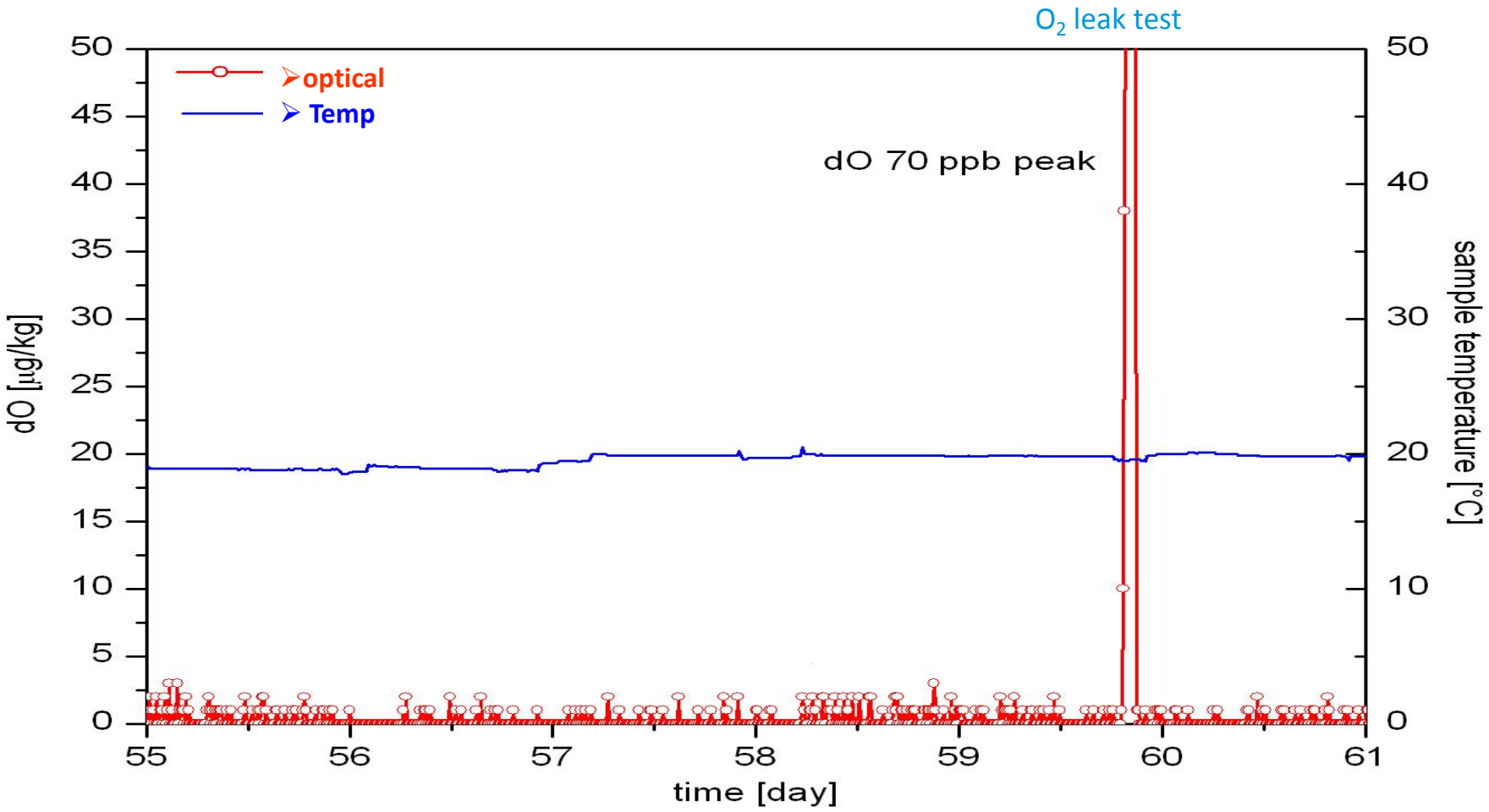
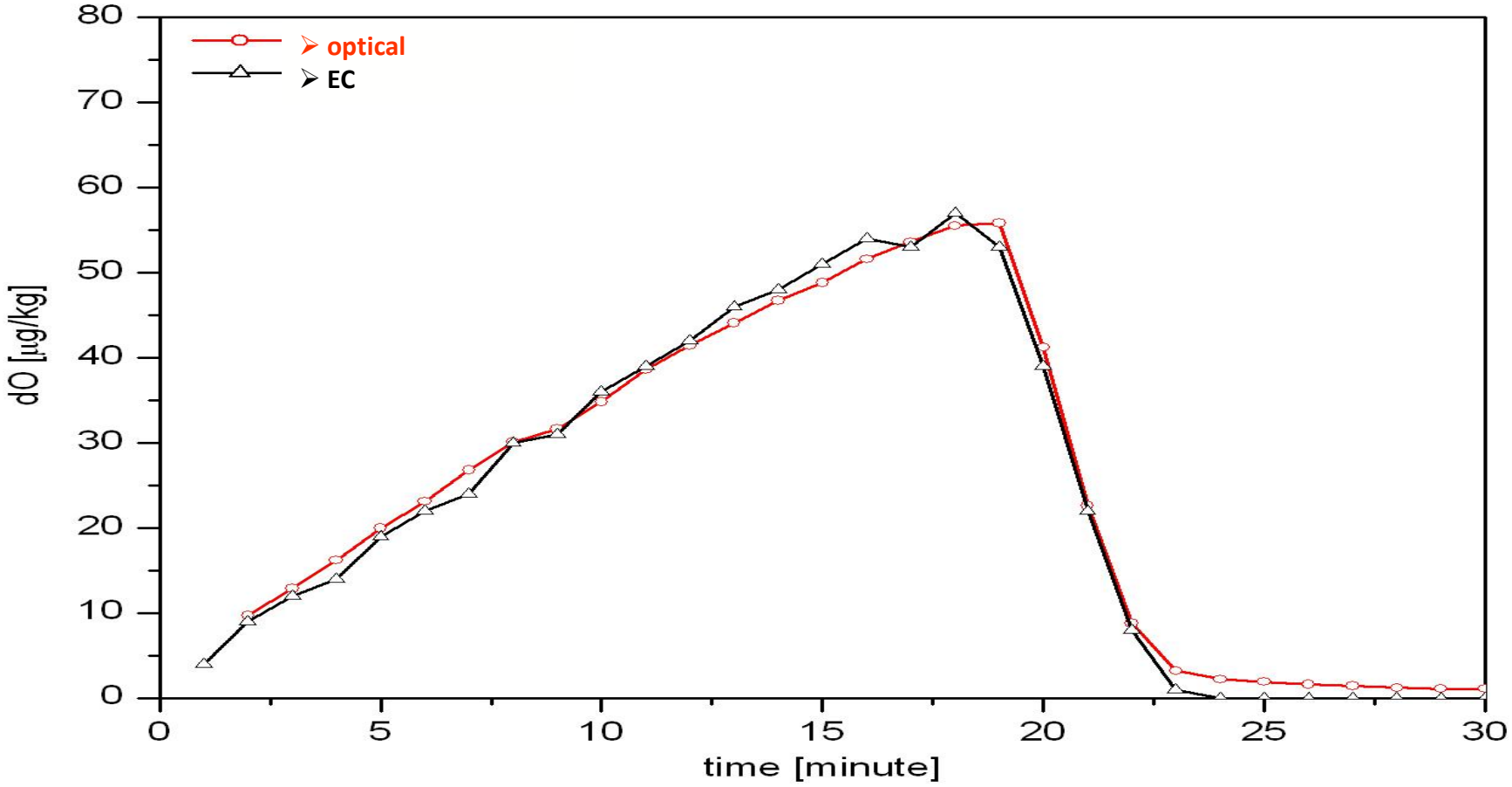
RESULTS – FEEDWATER



Feedwater - AVT

RESULTS EXPANDED EC *VS.* OPTICAL



Cracked fitting to produce O_2 leak

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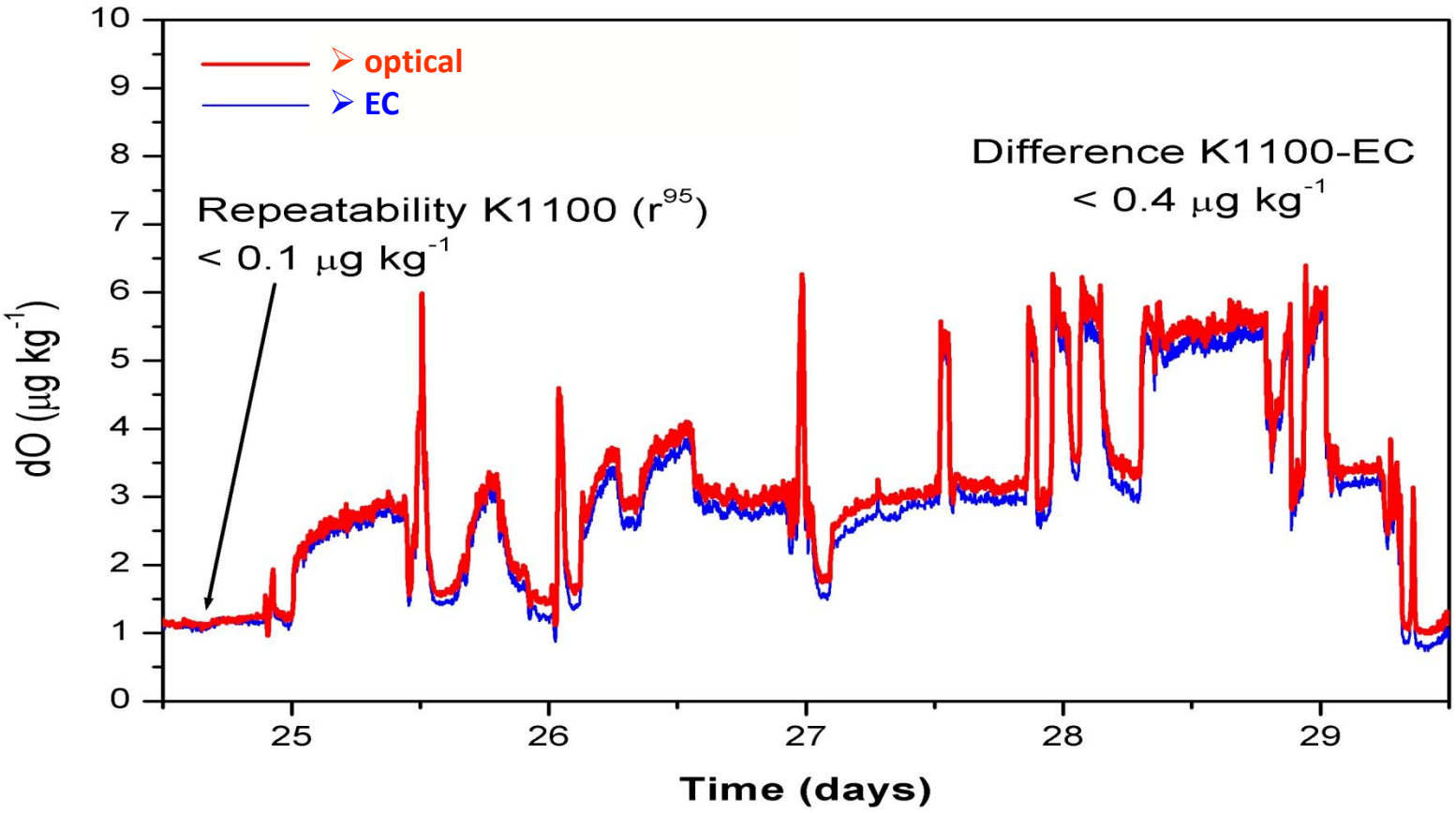
EC *VS.* OPTICAL



AVT boiler FW sample

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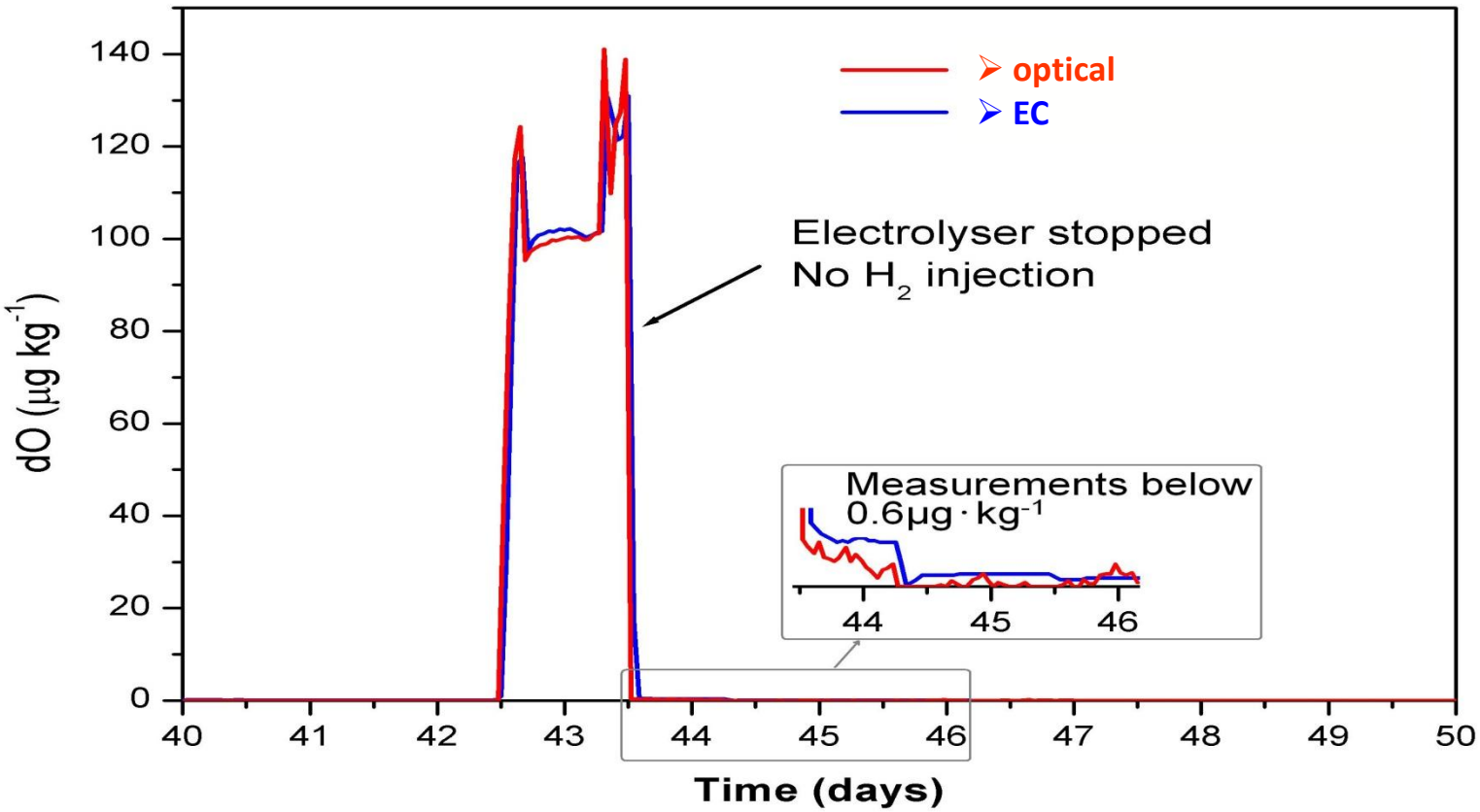
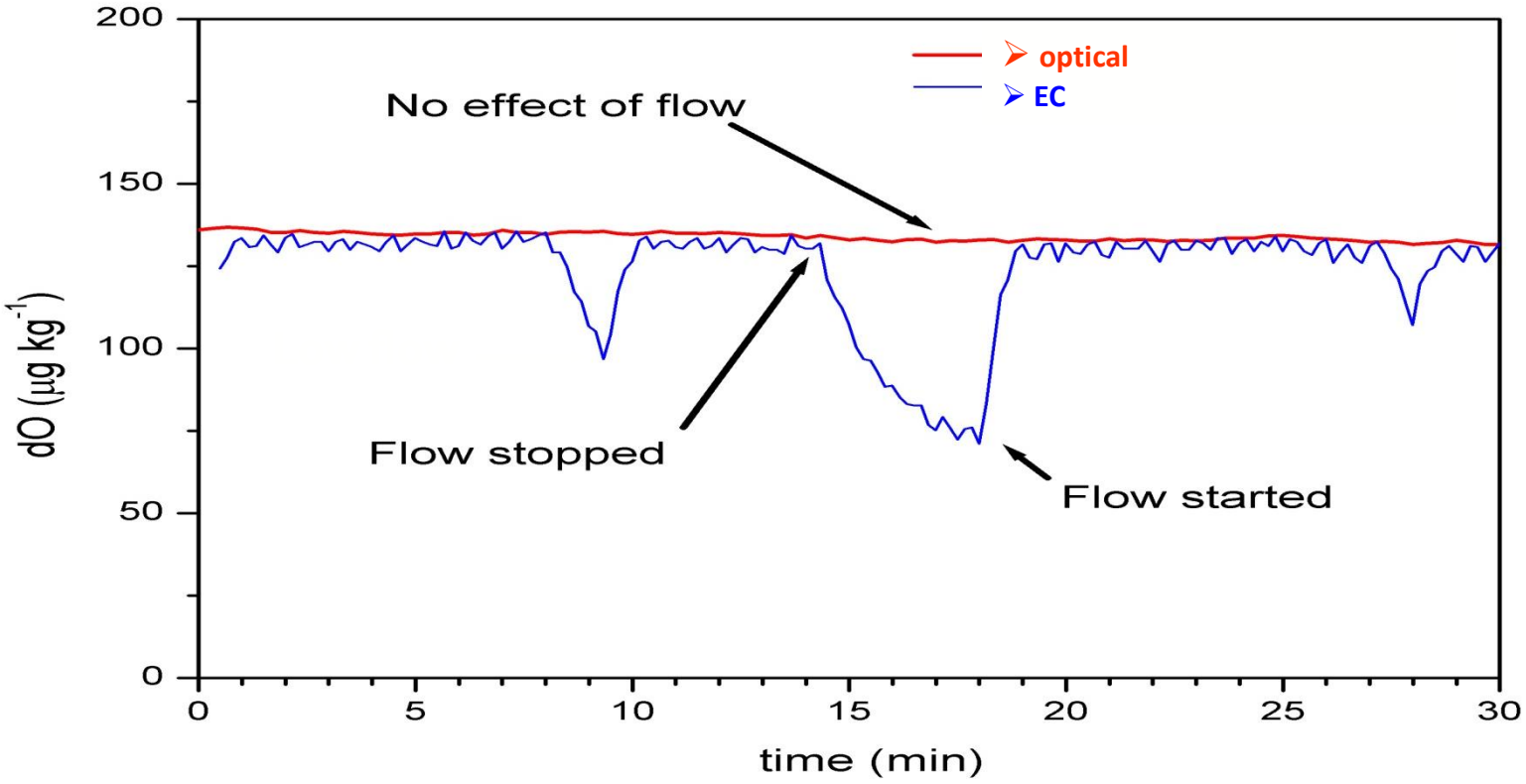
BWR IN HWC



Reactor water sample

FLOW SENSITIVITY



OT FW

SPECIFICATIONS: EC *VS.* OPTICAL

EC

- Accuracy +/- 1 to 0.1 ppb
  - Detection limit 1 ppb to 0.1 ppb
  - Most are 1 ppb
- Consumes O_2
  - Minimum flow required
- ~ 6 month maintenance interval
  - Influenced by O_2 concentration and temperature

OPTICAL

- Accuracy +/- 1 ppb
  - Detection limit 1 ppb
- Does not consume O_2
  - No flow required
- 12 month maintenance interval
  - Not influenced by O_2 concentration or temperature

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BENEFITS OF OPTICAL DO_2 TECHNOLOGY

- Optical performance comparable to EC
- Dry sensor with no membrane, no electrolyte and no chemical cleaning
- Not flow dependence
- Not influenced by the presence of magnetite on the sensor head
- Only 5 minute optical spot replacement and calibration every 12 months

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THANK YOU FOR YOUR ATTENTION

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