Task 4.6: OXICIDE (on shore pilot trials)

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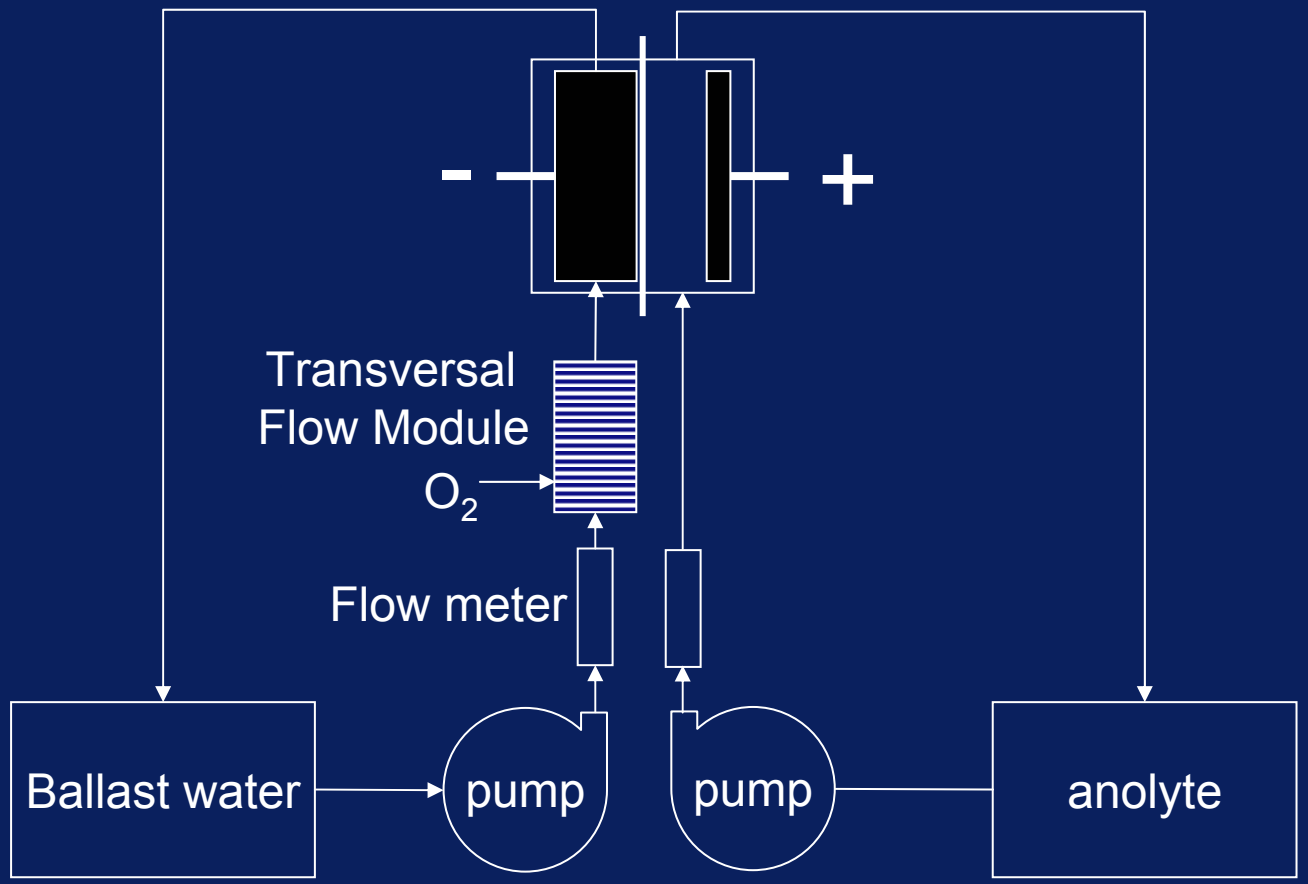
OXICIDE reactor: the principle

Cathode: $O_2 + 2H^+ + 2e^- \longrightarrow H_2O_2$

Anode: $2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$



Planning and progress

		Month								
	Action	March	April	May	June	July	Aug.	Sept	Oct.	Status
1.1	design cell	< March								done
1.2	prod. first cell									done
1.3	lab test cell									done
2.1	design pilot									done
2.2	prod. pilot									done
2.3	lab test pilot									canceled
3	pilot test on location									started
4	evaluation of results									started

Generation-2 reactor design (first scale-up):

- **Improved oxygen feed to seawater using Cel gard module**
  ⟶ higher oxygen concentrations

- **New electrochemical cell design**
  - New dimension electrode (150 x 200 mm^2 graphite felt)
  - Higher flow rates for catholyte and anolyte (200-500 l/h)

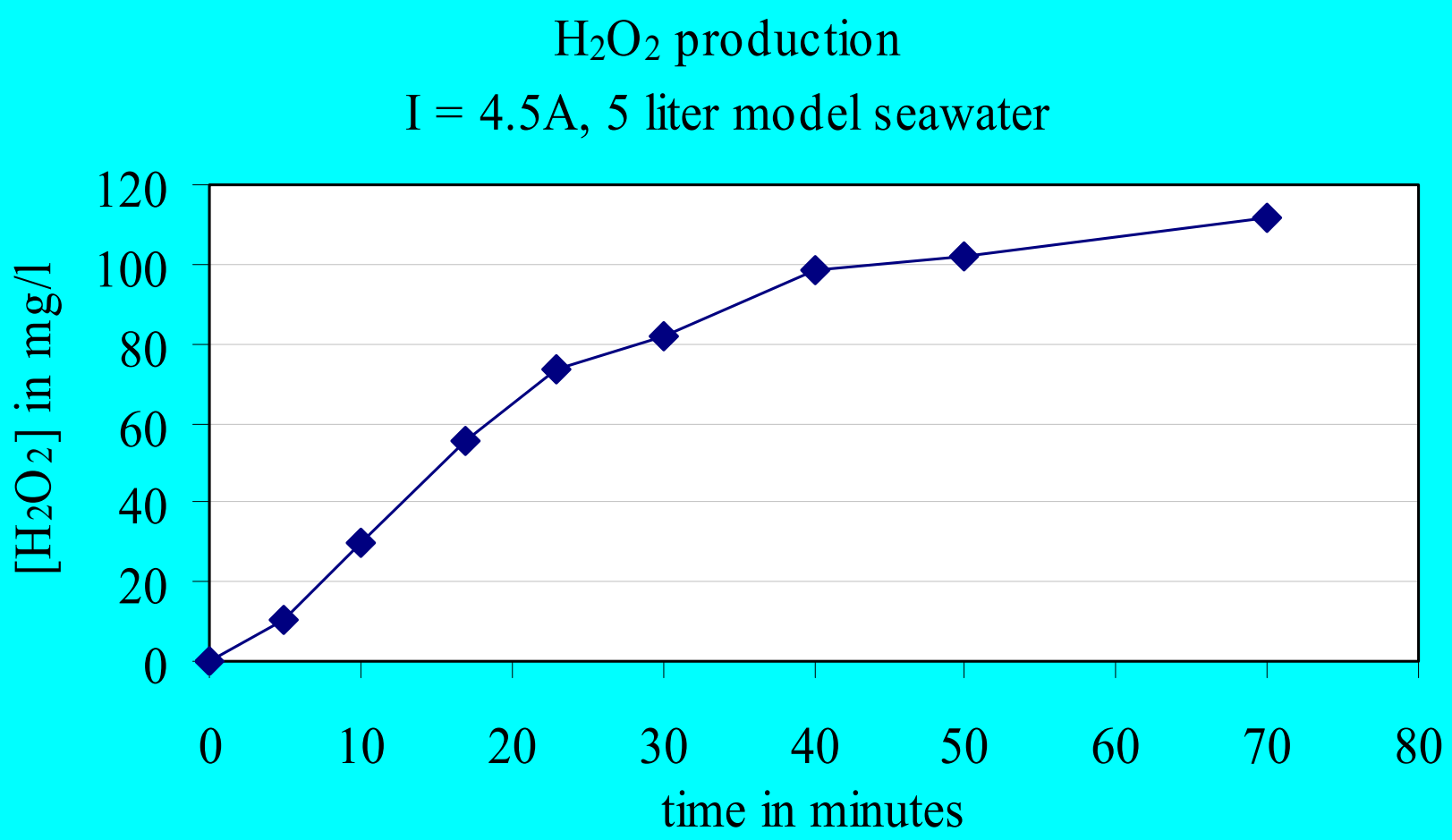
- **Cell made by: Van den Heuvel Watertechnologie**

- **Laboratory tests aimed at (higher) performance of cell**

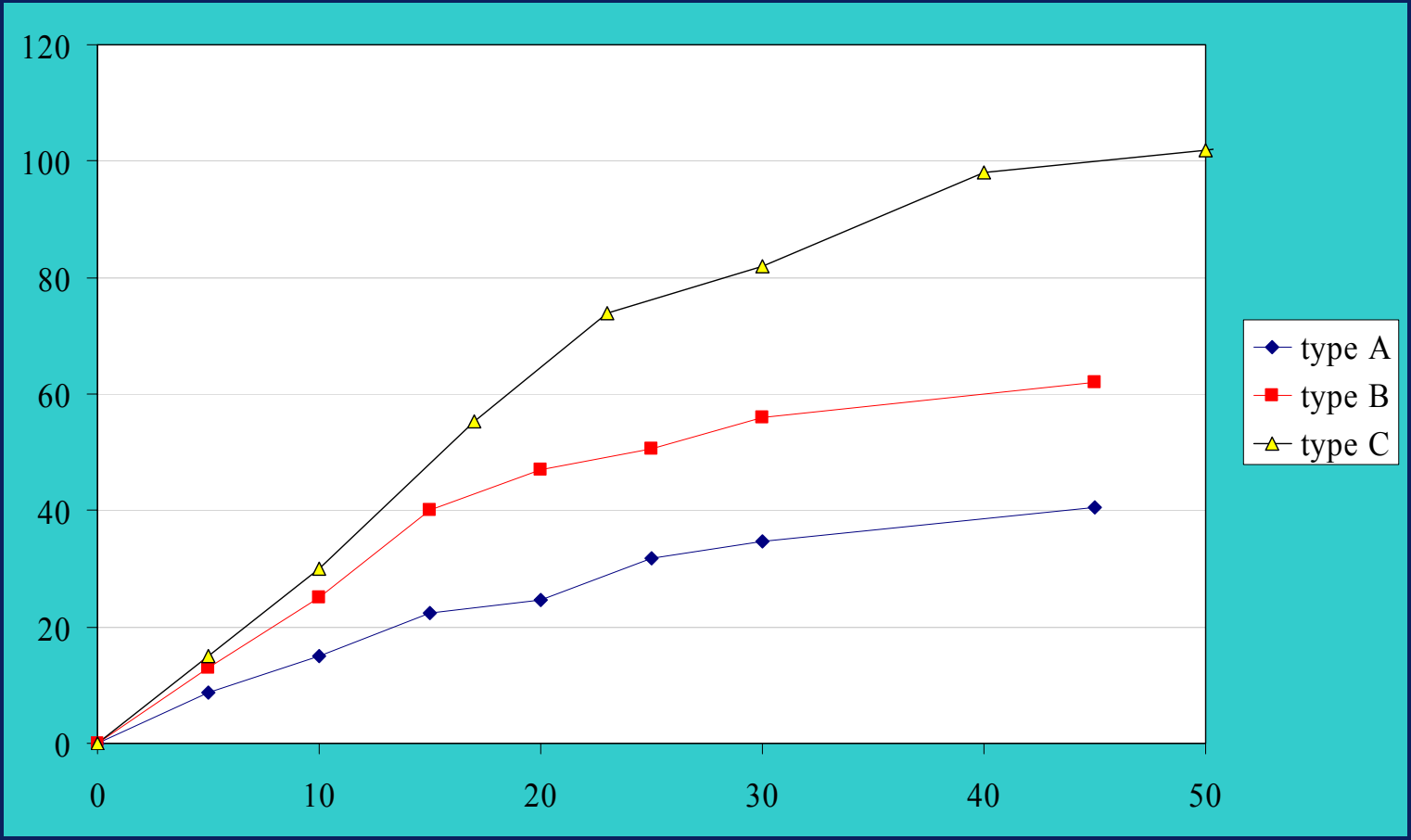
⇒ **Higher H_2O_2 production rate (g/h per m^2)**

Generation-2 electrochemical cell:

Generation-2 electrochemical cell: laboratory tests



Generation-2 electrochemical cell: laboratory tests with 3 felts



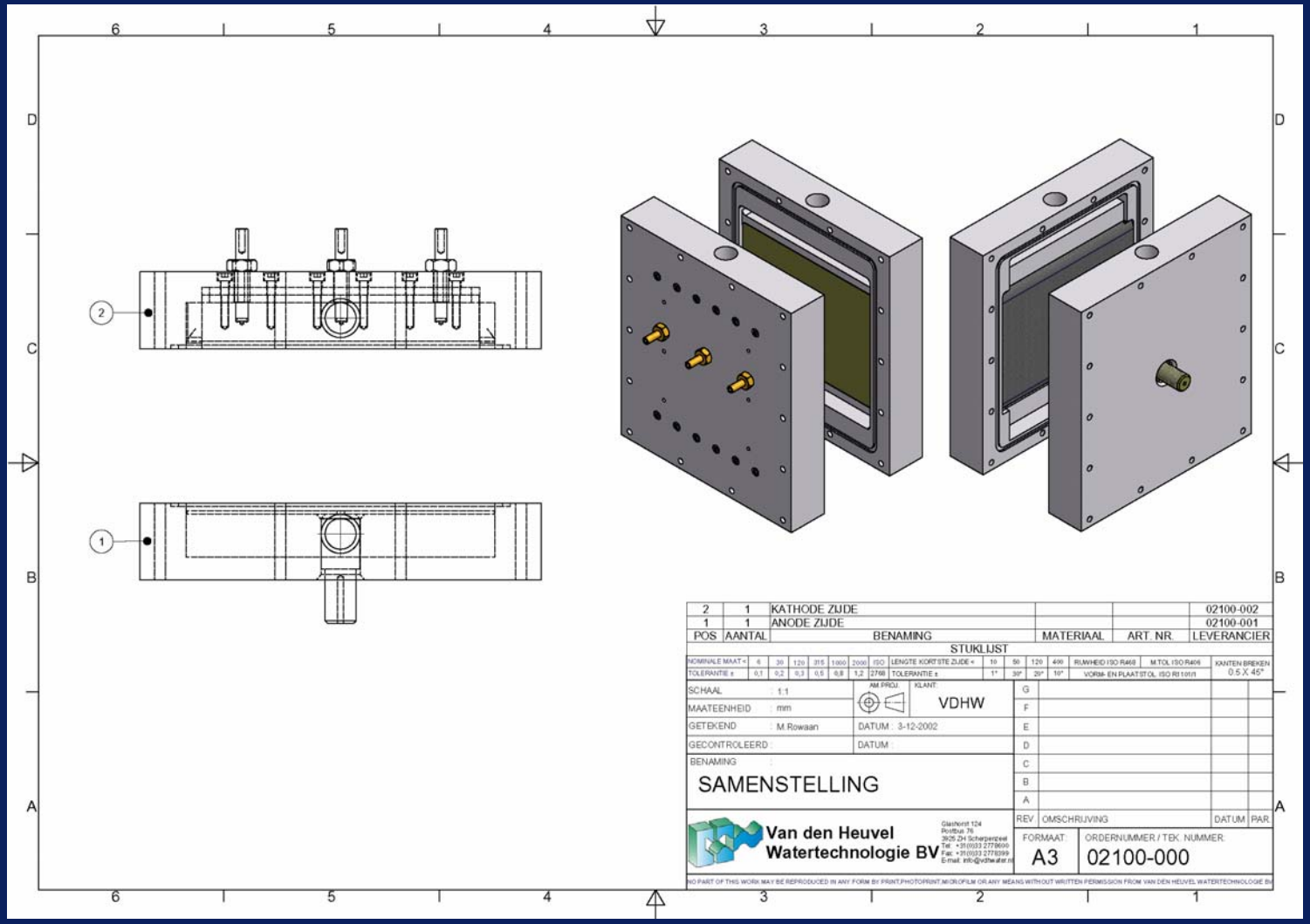
Generation-2 electrochemical cell: results laboratory tests

- increased flow rate
- higher oxygen concentration
- best graphite felt

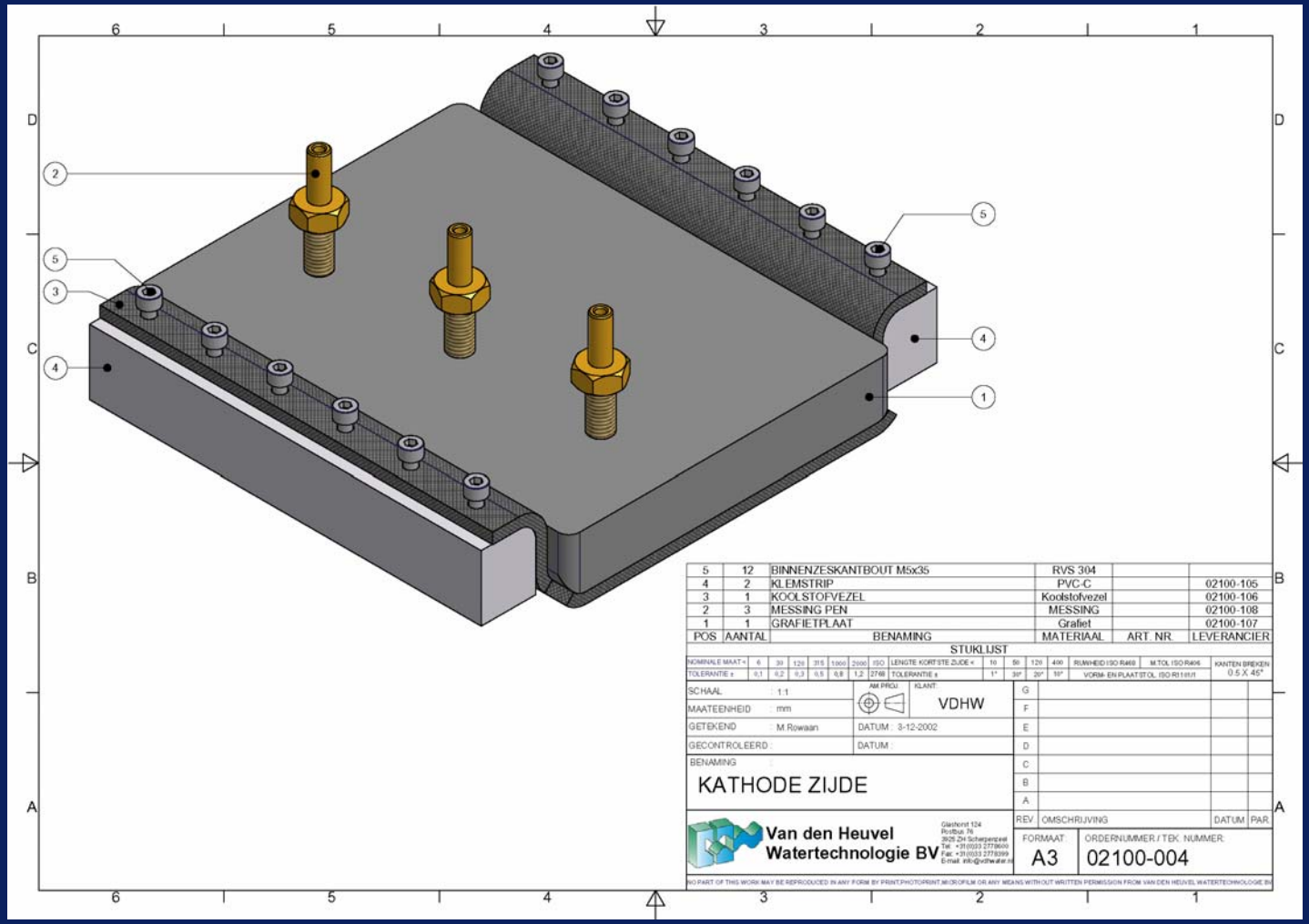
	generation-1		generation-2
H_2O_2 production rate	14 g/m^{2}h	⟶	56 g/m^{2}h

Further improvement in Generation-3 reactor:
i.e. improved current connection to the graphite felt

Design generation-3 electrochemical cell

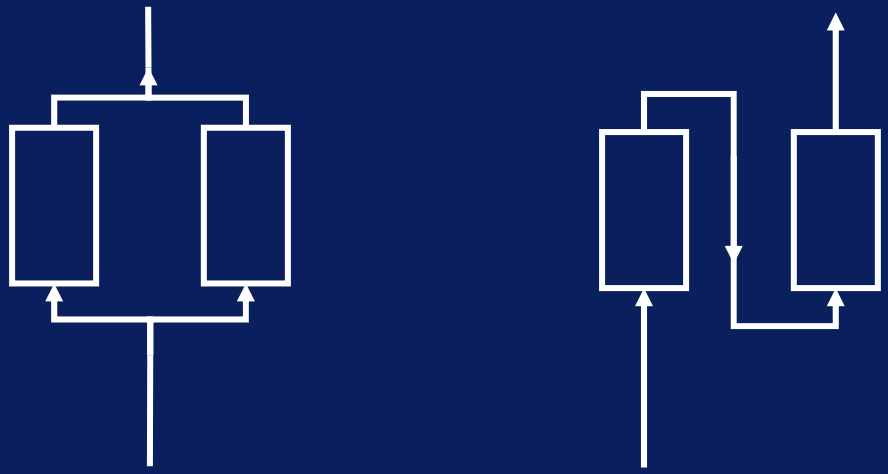


Generation-3 electrochemical cell



Design pilot installation

- Two OXICIDE units (cell guard and electrochemical cell)
- Both parallel (high throughput) and series (high H_2O_2 concentration) circuits possible



- made by: Van den Heuvel Watertechnologie
- in-situ H_2O_2 sensor
- Cl_2 detection
- spill tray with leakage detector

Pilot installation with 2 Oxicide cells

Pilot installation Oxicide

Onshore test location Den Helder (the Netherlands)

Den Helder

Experiments Oxicide pilot onshore

Problems faced:

- Delay in delivery of ballast water pump
- Start-up problems with ballast water pump
- Very low phytoplankton concentrations:
  - Not possible to determine the activity of the plankton

Experiments Oxicide pilot onshore

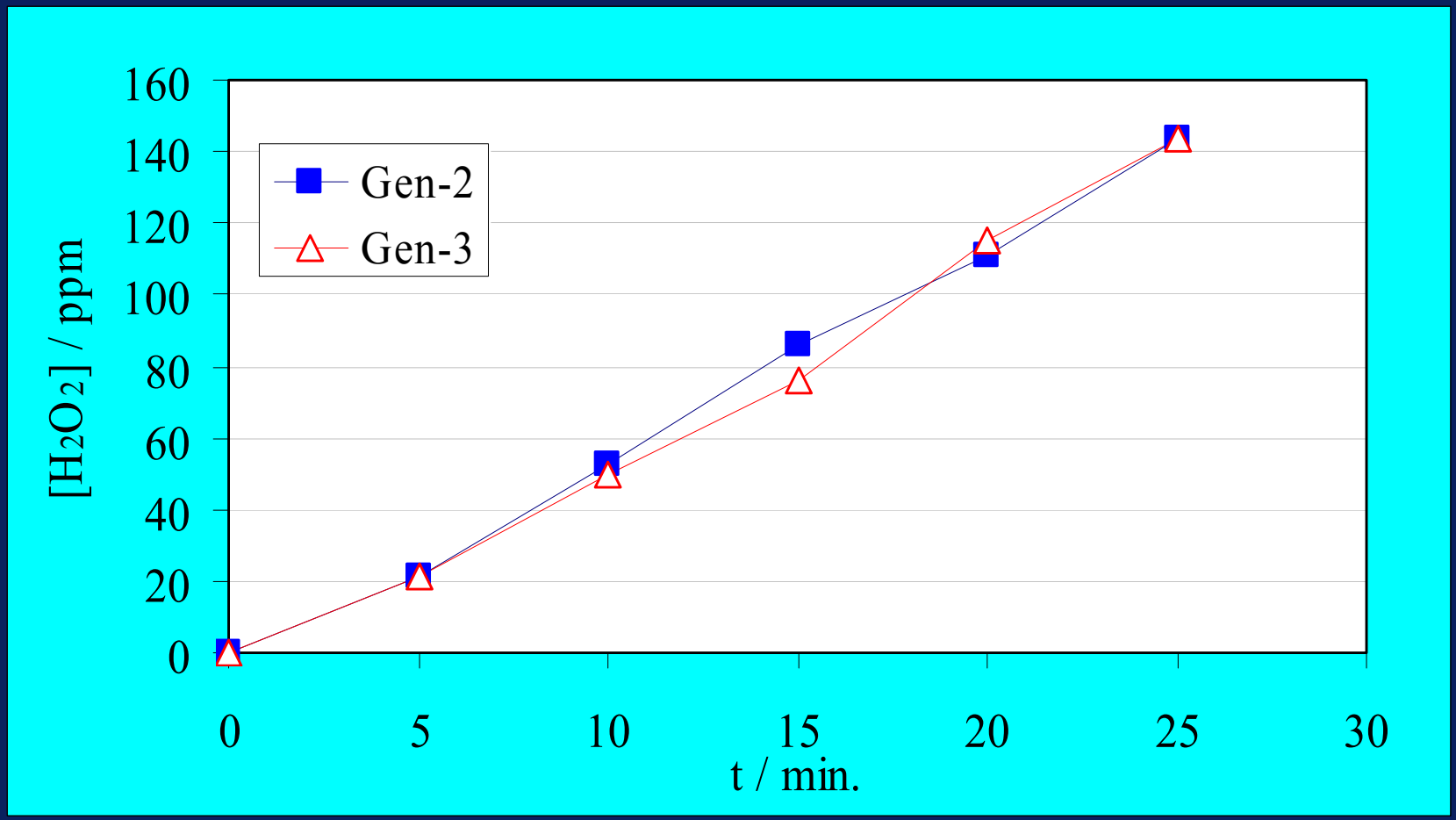
- Series and Parallel tests with two generation-3 reactors
  Low H_2O_2 production rate: 0.7 ppm @ 500 l/h (!)

- Generation-2 reactor produces according to lab results:
  6.0 ppm @ 250 l/h with only one cell

Possible causes of performance difference:

- Coating titanium DSA electrode
- Membrane (different batches)
- Graphite felt
- Electrical contacts, i.e. between carbon and graphite felt
- (minor) Differences in cell dimensions

Comparison Gen-2 and Gen-3 DSA electrodes (in Gen-2 reactor)



Results economic evaluation Gen-1 and Gen 2-reactor

Case:

- **2000m^3 ballast water**
- **24 hours treatment time**
- **15 g H_2O_2 / m^3**

	Generation 1 (WP 3)	Generation 2 (WP 4)
H_2O_2 production rate (g/m^{2}h)	14	56
Membrane area needed (m^2)	120	30
Equipment weight (kg)	2400	600
Footprint equipment (m^2)	8.75 + 10 = 18.75	4.4 + 6 = 10.4
Investment costs (€)	1,550,000	387,500
Total costs per year (€/y)	234,491	60,257
Costs per m^3 ballast water (€/m^3)	2.34	0.60

Preliminary conclusions task 4.6

- Oxygen feed to the water improved by using Cel gard
- First up-scaling succesfull
- 4 times higher production rate with Gen-2 reactor (i.r.t. Gen-1); further improvements are possible
- Gen-3 reactor has unexplained low peroxide production rate

Further plans Task 4.6

- Systematic experiments to find the origin of the problem with the Gen-3 reactor
- Finishing experiments with the pilot
- Biological efficacy performance check
- Duration experiment

Remarks regarding the onboard installation feasibility

- **Location:** in-side, close to the ballast tanks or pump.
  The location should be well ventilated

- **Heat:** from pumps and power source (small)

- **Vibrational and noise effects:**
  non other than those of the ballast water pumps
  (anolyte pump relatively small)

Technology Implementation Plan (TIP)

Results

1. Biological efficacy of H_2O_2 (type B)

2. In-situ electrochemical hydrogen peroxide production, using the Oxicide reactor (type B)

Market application sectors (result 2):

17 Manufacture of textiles
21 Man. of pulp, paper and paper prod.
24 Man. of chemicals and chemical prod.
35.1 Building and repair of ships and boats
41 Collection, purification and distribution of water
55 Hotels and restaurants
61.1 Sea and coastel water transport
92 Recreation, cultural and sporting activities

Technology Implementation Plan (TIP)
in-situ electrochemical H_2O_2 production

Items (about the results)	Estimated (or future) quantity [b]
Time to application / market	24 months
Number of (public or private) entities potentially involved in the implementation of the result :	2^+
of which : number of SMEs :	2
of which : number of entities in third countries (outside EU) :	0
Targeted user audience: # of reachable people	2000
# of S&T publications (referenced publications only)	1
# of publications addressing general public (e.g. CD-ROMs, WEB sites)	4
# of publications addressing decision takers / public authorities / etc.	3
Visibility for the general public	No