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Manufacturer of Electronic Measuring Instruments

IFF Nitro

SYSTEM INTRODUCTION

Primary Purpose of the System

Original Requirement

A measurement system for determining the level of **dissolved free nitrogen** (N_2) for the purpose of controlling the performance of the **degassing system**

- **Selected Method**
  Accurate measurement of **O_2, CO_2**, and **TDGP**, from which real-time calculation of the water's nitrogen saturation will be performed
- **Conditions**
- The system must require minimal maintenance – service interval **> 3 months**
- Tolerated deviation **< 3%**
- **Assumptions**
  All measured variables **must be accurate** so that the calculated nitrogen value is correct

Challenges for research, development, and business

a big leap is needed

- **No reliable** third-party measurement of dissolved CO_2 exists on the market
- Commercially available TDGP measurement systems are **unsuitable** – gas-selective and too slow
- New technology for measuring CO_2 and TDGP **must be developed**
- The market will **need to be convinced** of both the accuracy of the new sensors and the correctness of the nitrogen level calculation

Measurements must be completely error-free. Even a small deviation would create a significant problem in subsequent calculations.

So the journey has begun

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Absolute Accuracy in O_2 Measurement

GRYF XB4-S sensor, automatic compensation of temperature, salinity, and **atmospheric pressure**

- Atmospheric pressure is often overlooked in measurements, but:

Example – Trondheim
Typical maximum and minimum pressures throughout the year range from 970 hPa to 1045 hPa.
Consider water at 10°C and 35 ppt salinity:

- 100% saturation at **970 hPa: 7.7 mg/L**
- 100% saturation at **1045 hPa: 8.3 mg/L**

Measurement error without pressure compensation: **up to 9.3%**

*GRYF XB90 unit with an integrated atmospheric **pressure** sensor for **real-time compensation***

IFF Nitro provides automatic pressure compensation for all measured gases

Accurate Measurement of TDGP

Total Dissolved Gas Pressure

- The measurement principle is based on measuring pressure with a sensor separated from the water by a solid membrane.
- Most commercially available systems use a microporous polypropylene membrane, which is slow and gas-selective:

Gas	Silicone (Barrer)	Teflon (Barrer)	Microporous Polypropylene (Barrer)
O_2	600 – 800	0.02 – 0.04	1 – 3
CO_2	3000 – 4000	0.1 – 0.2	5 – 10
N_2	200 – 400	0.01 – 0.02	0.5 – 1
Water vapor (H_2O)	15,000 – 30,000	1 – 10	1 – 3

- In conventional systems, the use of silicone is not possible.
- **In IFF Nitro, it is possible** thanks to a unique membrane system and a measuring chamber with a triple reference architecture.

*1 Barrer means that through a material with a surface area of 1 cm² and thickness of 1 cm, **10^{-10} cm³** of gas passes per second (under standard conditions and with a 1.3 hPa pressure difference between both sides).*

Accurate CO_2 Measurement

A completely new concept for aquaculture, but not for GRYF

- The project to develop an **immersion sensor** at GRYF was **concluded** in 2022 after three years, with the conclusion that there is no suitable membrane worldwide for this type of application.

- Because IFF Nitro sensors operate at an “immersion” of about 5 cm, it was possible to use a highly permeable membrane in combination with a **ppm sensor**, which GRYF commonly supplies for medical and military applications.

- The result is **precise and repeatable** measurement with an accuracy level previously unseen in aquaculture.

GRYF MGM-23
*system for measuring CO, **CO_2**, and O_2, supplied to **NATO field hospitals**.*

NATO OTAN
NCAGE CODE: 3952G

When simply meeting the requirements isn’t enough

34 years of experience in sensor development in a single, perfect system

The sensor circuit is **duplicated**: while one is measuring, the other is regenerating and is calibrated against a **third set of reference sensors** that never come into contact with water.

Protection against biofouling

- The water entering the system is **biologically deactivated** using UV.
- During regeneration, the sensor chambers are dried with **preheated air** mixed with ozone (UV-generated).

During both development and testing of the IFF Nitro system, strict adherence to standards normally reserved for military projects is required

October 2024: Pilot Installation

Production prototype of the IFF Nitro system

- Installation took place at the **MOWI** Hellur salmon farm in the **Faroe Islands**.
- Implementation time: **2 days**, including visualization setup in the control center.
- Measured parameters: **TDGP, O_2, CO_2, N_2, pH, and ORP.**




Trial Operation

and Accuracy Evaluation

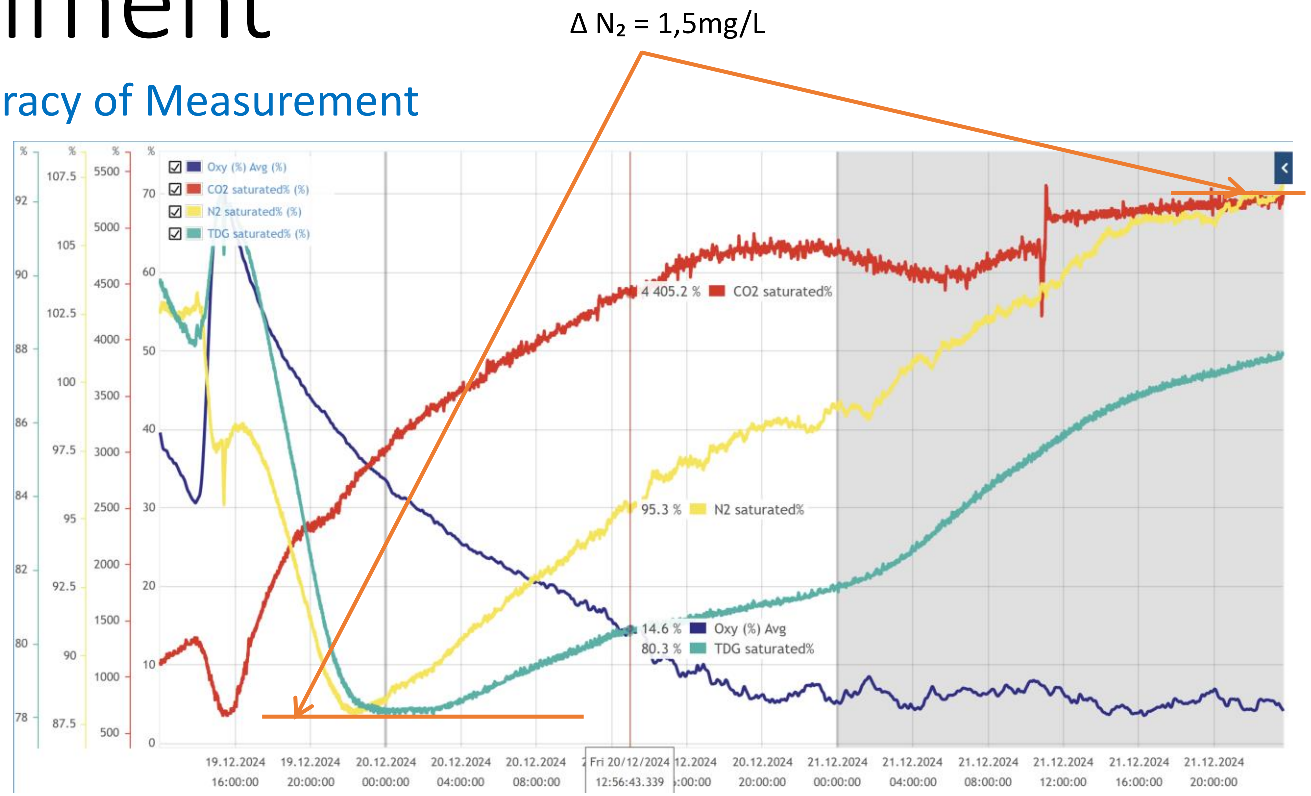
- The system was configured to continuously send data to the cloud.
- O_2, TDGP, pH, and ORP measurements could be validated with third-party reference systems.
- CO_2 and N_2 measurements could not be independently verified.
- **An experiment was designed to verify all measurements at once…**

UV sanitation was turned off, allowing biologically active water into the system. Based on the dynamics of dissolved nitrogen, the approximate **ammonia** content is to be calculated

„ Christmas Experiment“

Confirming the Accuracy of Measurement

- 19.12.2024: The measurement loop was sealed with biologically active water inside (including residual ammonia).
- After 60 hours, the O_2 level dropped to zero, while the N_2 content increased by 1.5 mg/L and then stabilized.
- Using stoichiometric equations, the original ammonia content was calculated (the change in N_2 concentration could only result from biological activity – conversion of ammonia).
- Calculated ammonia value: **1.94 mg/L** NH_4^+**.**
- <u>The difference between the calculated and measured ammonia value was **6%**.</u>



Customer confirmation

The monitored system was at peak production, and the fish were moved the following day. The biofilter was operating at its limits, and an independently measured ammonia value was **1.83 mg/L** NH_4^+.

$$\underbrace{2\,NH_4^+}_{2\times18\,g=36\,g} \longrightarrow \underbrace{N_2}_{28\,g}$$

$$\frac{36\,g\,NH_4^+}{28\,g\,N_2} \approx 1{,}29\,mg\,NH_4^+ \text{ na } 1\,mg\,N_2.$$

$$1{,}5\,mg\,N_2/L \times 1{,}29\,\frac{mg\,NH_4^+}{mg\,N_2} = 1{,}935\,mg\,NH_4^+/L \approx \underline{1{,}94\,mg}\,NH_4^+/L.$$

Evaluation of the Experiment

What Can Be Further Improved?

- The ammonia experiment was repeated under laboratory conditions. It was found that the 6% deviation was caused by disregarding the presence of ammonia in the calculation of N_2 from TDGP, O_2, and CO_2.
- If ammonia had been correctly accounted for, the calculated nitrogen value would have been lower—thus the subsequent calculation of ammonia concentration would have shown a difference of less than 1% from the measured value.

- **It can therefore be stated:**
  - The measurement of **TDGP, CO_2, and O_2 exceeded expectations** and fully met the requirements.
  - The calculated **N_2 value is within tolerance**. However, to achieve complete accuracy, ammonia content should be included in the calculation, as elevated ammonia can skew the results.
  - The experiment demonstrated that the applied sensor regeneration/sanitation methods reduce the impact of **biofouling to an unnoticeable level**.

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Conclusion of the Trial Operation

System Released for Commercial Use

- IFF Nitro provides an unprecedented level of accuracy in measuring TDGP, O_2, and CO_2, which enables it to deliver a highly accurate value of dissolved nitrogen.
- Any potential deviation in the event of elevated ammonia concentrations is insignificant in the context of the intended application. However, the commercial system already allows for compensating this factor through an input from an external sensor.

- **IFF Nitro System Capabilities**
  - Smooth control of degassing system performance → **reduction in electrical power consumption**
  - Meaningful dosing of oxygen → **reduction in energy use relative to results achieved**
  - Control of water recirculation level in an RAS system → **optimization of environmental impact**

Acknowledgements

LEIF MOHR – Andrias Joensen
Inspiration for the development of the IFF Nitro system, R&D consultation, implementation support

MOWI – Michael Mikkelsen
Implementation support, collaboration in evaluating the pilot operation

CzechTrade Agency (Chile branch) – Dipl. Ing. Jiří Jílek
Whose Chilean team helped us with market analysis and confirmed interest in the product from Chilean partners

GRYF – Dipl. Ing. Marek Míša and team
Project manager, system architect

Salmon
Whose farming continually presents us with new and ongoing challenges