

# Optical Dissolved Oxygen Sensors

DO Sensors for Production Environments



# The Rise of Optical DO

## CONTINUOUS INNOVATION GUIDED BY USERS

The introduction of the VisiFerm made it possible for biopharma process engineers to reap the established low maintenance benefits of optical sensing technology for the first time. Now, precise control of this critical process parameter still requires high frequency recalibration to achieve the commonly established verification tolerance and avoid costly deviations in GMP/FDA environments. The next generation VisiFerm incorporates breakthroughs in sensor and cap design to drastically reduce calibration frequency.



2019



### Reduced Calibration

VisiFerm mA reduces the need for frequent calibration



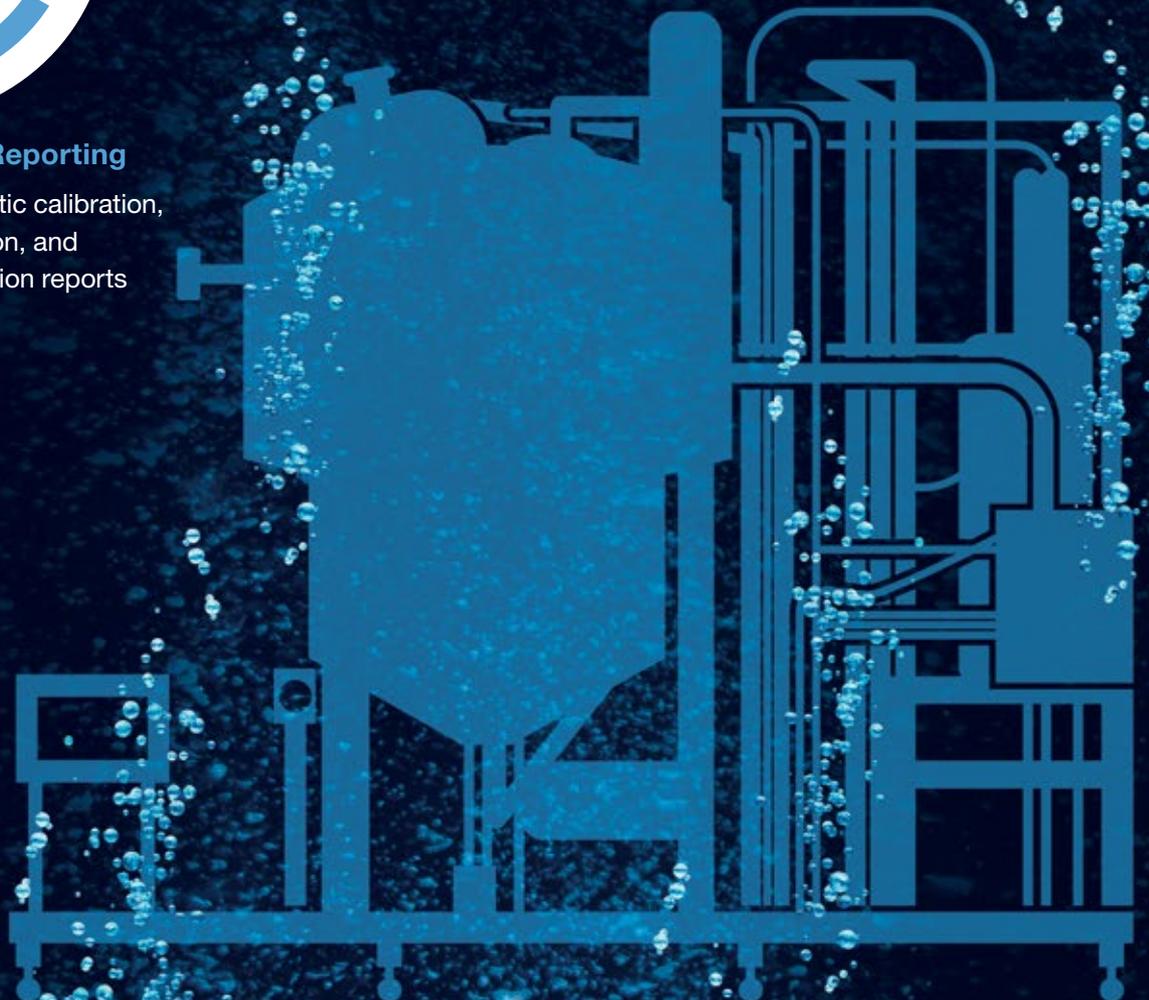
### Single-Use

Reusable sensing technology adopted for single use applications



### GMP Reporting

Automatic calibration, validation, and verification reports



# Analyzing the Impact

## FINDING HIDDEN CONTRIBUTORS TO MEASUREMENT ERROR

Hamilton extensively investigated the effects of the bioprocess on measurement accuracy. Analysis of sensor aging, chemical attack, and physical damage yielded the necessary understanding for development of a next generation VisiFerm which reduces the need for frequent calibration.

### Aging

Photobleaching of the luminophore and aging of the electronics lessen measurement accuracy over time.



### Temperature

Elevated temperature during SIP/CIP damages the luminophore and accelerates chemical impact.



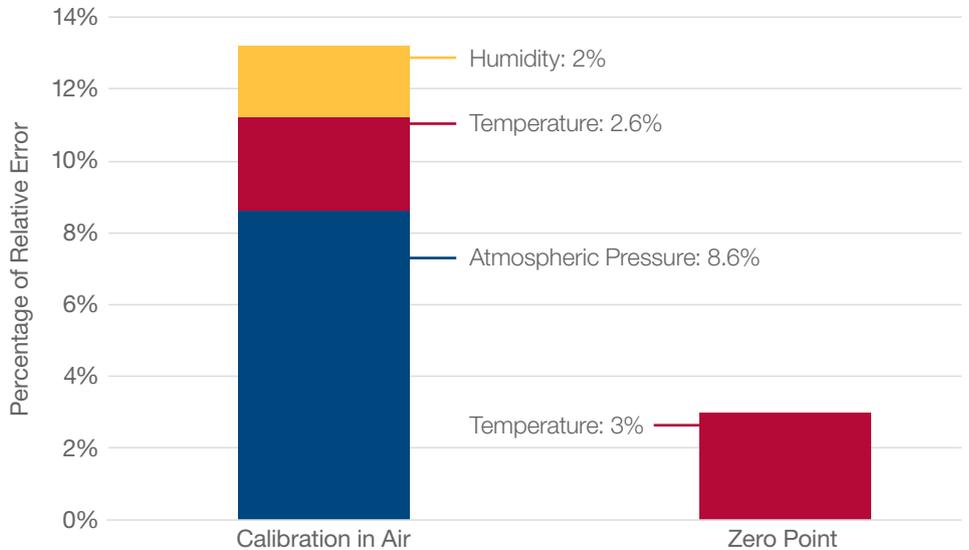
### Calibration

Failure to compensate for humidity, temperature, and pressure can result in large measurement error.



# Calibration is Critical

Up to 13.2% verification error can be introduced by changes in temperature, relative humidity, and atmospheric pressure from the time of calibration to the time of verification. Accounting for these environmental factors reduces the frequency of unnecessary deviation reports.



## Temperature

Heat transfer is less efficient in air than in liquid, so care should be taken in sensor handling to ensure the sensor is at equilibrium before calibration and verification.

## Humidity

Humidity is always 100% in dissolved oxygen measurement but can vary widely when calibrating in air, causing inaccuracies.

## Pressure

Verification errors can result from uncontrolled calibration environments, which can change by as much as 80 mbar from the time of calibration to the time of verification.

# Compensating for Calibration Errors with ArcAir

## Calibration Wizard

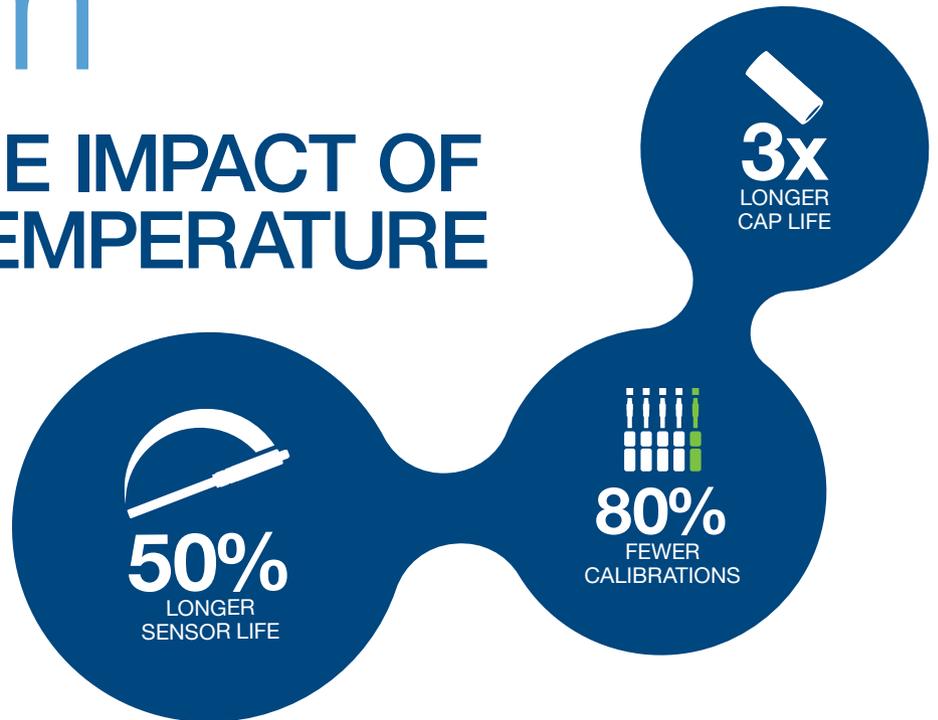
The built-in calibration wizard in ArcAir accepts inputs for relative humidity and atmospheric pressure to provide a perfect calibration every time.



# Next-Generation VisiFerm

## REDUCING THE IMPACT OF AGING AND TEMPERATURE

Every application is unique, so standard compensation algorithms for the temperature effect of SIP and the aging effect of photobleaching have limited utility. Hamilton's vision to fully overcome the influence of SIP/CIP and photobleaching required innovation in both sensor and cap design. This development effort resulted in the new VisiFerm mA.

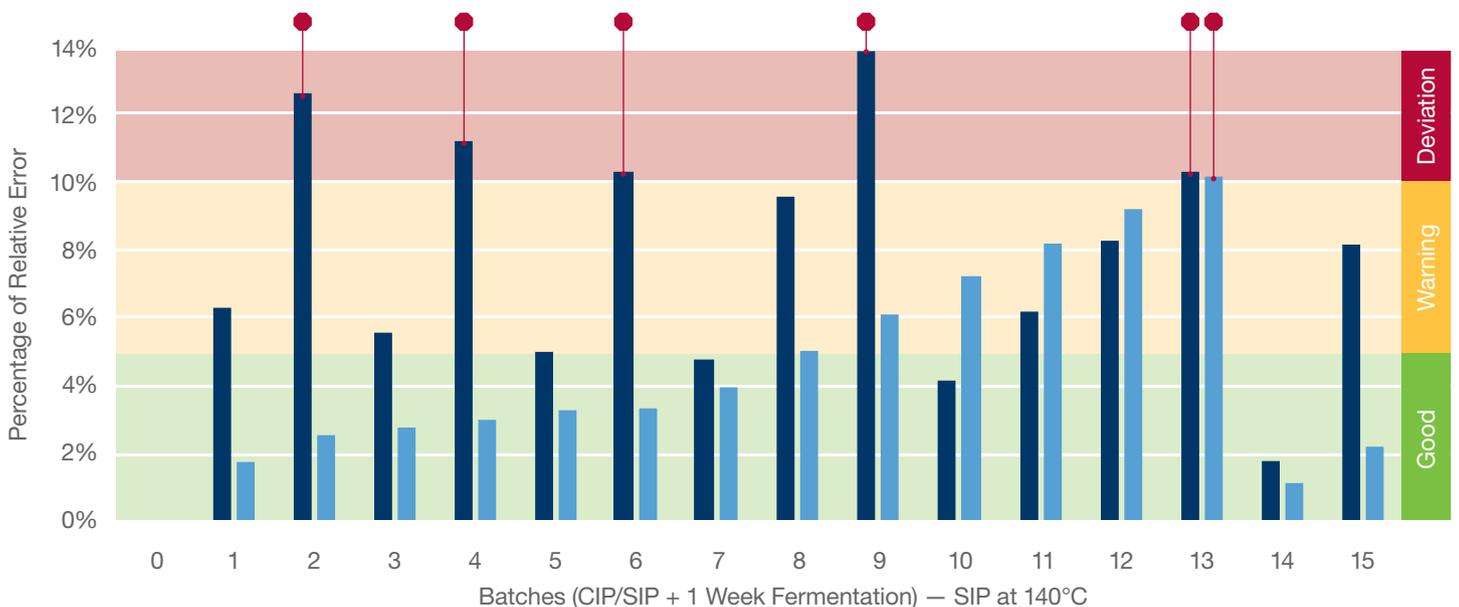


## Realization of the Vision

The need for calibration is determined by a post-run verification. A relative verification error of 5% triggers calibration, while an error of 10% requires a deviation report. To avoid deviations, current DO sensors require calibration after almost every run.

**The VisiFerm mA extends the time between calibrations and significantly reduces the chance of deviation.**

■ H0/H2 Cap (Current Technology) ■ H3/H4 Cap (New Technology) ● Calibration Required



# MAKING A BETTER SENSOR

Hamilton improved upon both sensor and cap design to create the most robust VisiFerm yet. Upgrading both key pieces allowed the VisiFerm mA to have less frequent calibration, less measurement drift, and longer lifetime than previous optical DO sensors.

## Cap Stability

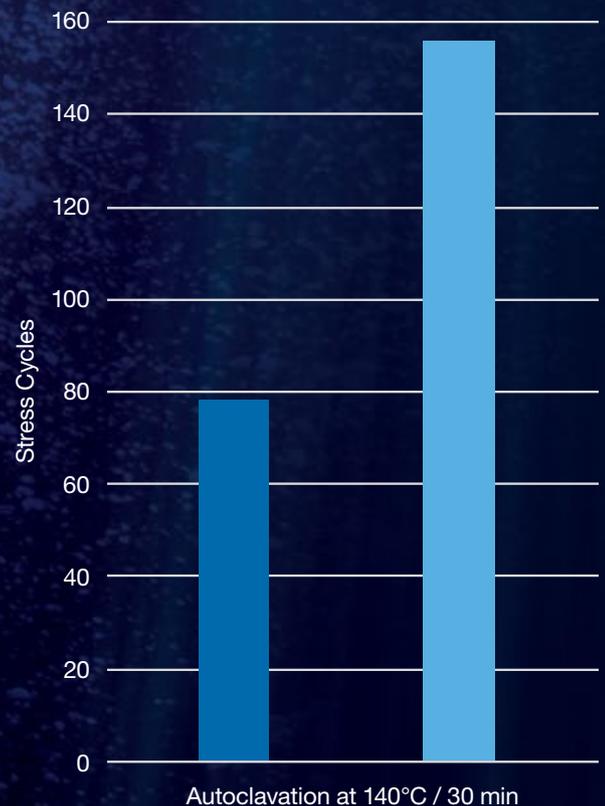
New VisiFerm mA caps have improved formulation and construction:

- Strengthened luminophore matrix for better temperature stability
- Enhanced luminophore chemistry for resistance to photobleaching
- Stronger mechanical stability for higher process resilience

## Sensor Robustness

The newest VisiFerm sensor has the ability to withstand more temperature cycles than ever.

- Tougher electronic components for higher temperature stability
- LED intensity adjustment to reduce the impact of aging
- Increased memory for storage of enhanced diagnostic data
- M12 connector resistant to temperature and mechanical stress



■ Current Optical Sensors  
■ Hamilton VisiFerm mA

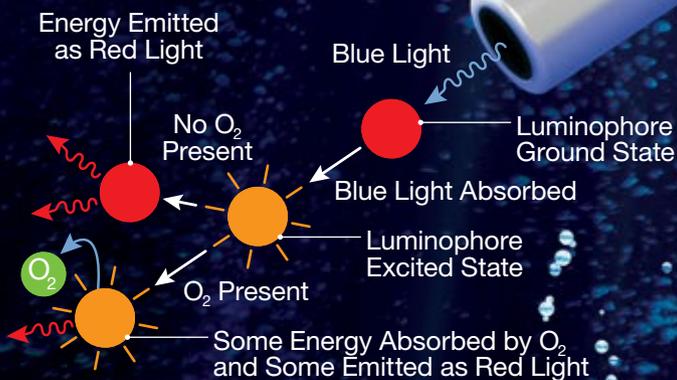
# Production 2-Wire VisiFerm mA

Take advantage of the VisiFerm mA's benefits with no changes to existing infrastructure. The sensor has all relevant certifications for GMP production environments and connects to existing 4-20 mA (2-wire) installations.



## Measuring Principle

Blue light excites a fluorescent dye (luminophore) in the sensor cap. In the absence of oxygen the energy is fluoresced as red light. In the presence of oxygen some energy is transferred to the oxygen molecule and less red light is emitted. The partial pressure of oxygen is reliably given by the phase shift between excitation and emission.



## Sensor Caps



### H3

The perfect cap for most biopharmaceutical applications



### H4

Convex design and PTFE membrane for enhanced chemical resistance

# LED Indicator

- At least one sensor error ●
- Sensor in warning state ●
- Ready to operate, no sensor errors or warnings ●
- Wirelessly communicating ●●●



## M12, 4-20mA, HART™

Optimized power consumption and a 2-wire configuration allow you to connect instantly to existing infrastructure.

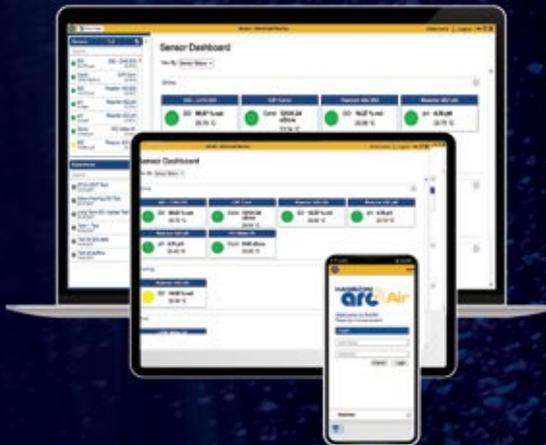


## Bluetooth 5

Utilize the integrated benefits of Bluetooth 5 for a faster, more secure and robust sensor connection.

## Arc

Hamilton's Arc technology streamlines access to all sensor information, including health, measurement, and settings.



Sensor Wire  
Junction Box

Process Cable

# Tools for Predictive Maintenance

Arc technology in the VisiFerm mA pairs with the newest ArcAir software to automatically store all sensor activities, diagnostic data, and health indicators throughout the life of the sensor. Calibration, verification, and maintenance data are readily available to facilitate predictive maintenance planning.



## Automatic History



Audit Trail



Verification Reports



Cap Change Recognition



Calibration Reports



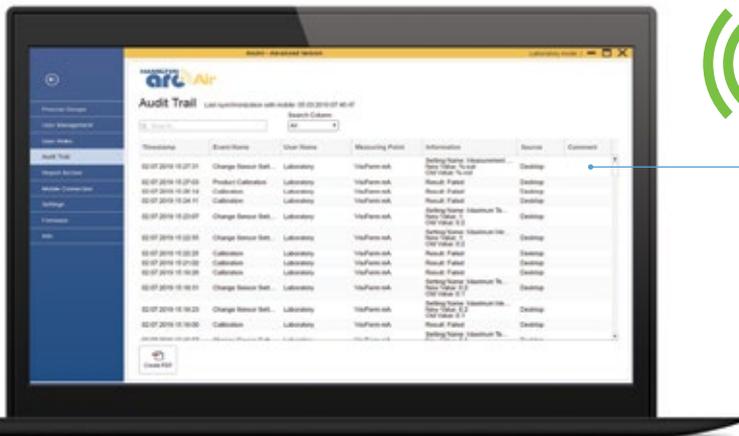
# VisiFerm Quality Indicators

## Sensor

Installation of a new cap triggers automatic evaluation of the sensor electronics and updates the sensor health indicator

## Measurement

Measurement quality is an indicator of the combined health of sensor and cap



## Sensor Audit Log

VisiFerm mA with ArcAir now comes with a built-in audit log to track all changes to the sensor from a simple setting change to automatically recognized cap replacements

## Cap

Luminophore intensity is continuously monitored and used to calculate a cap health metric



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