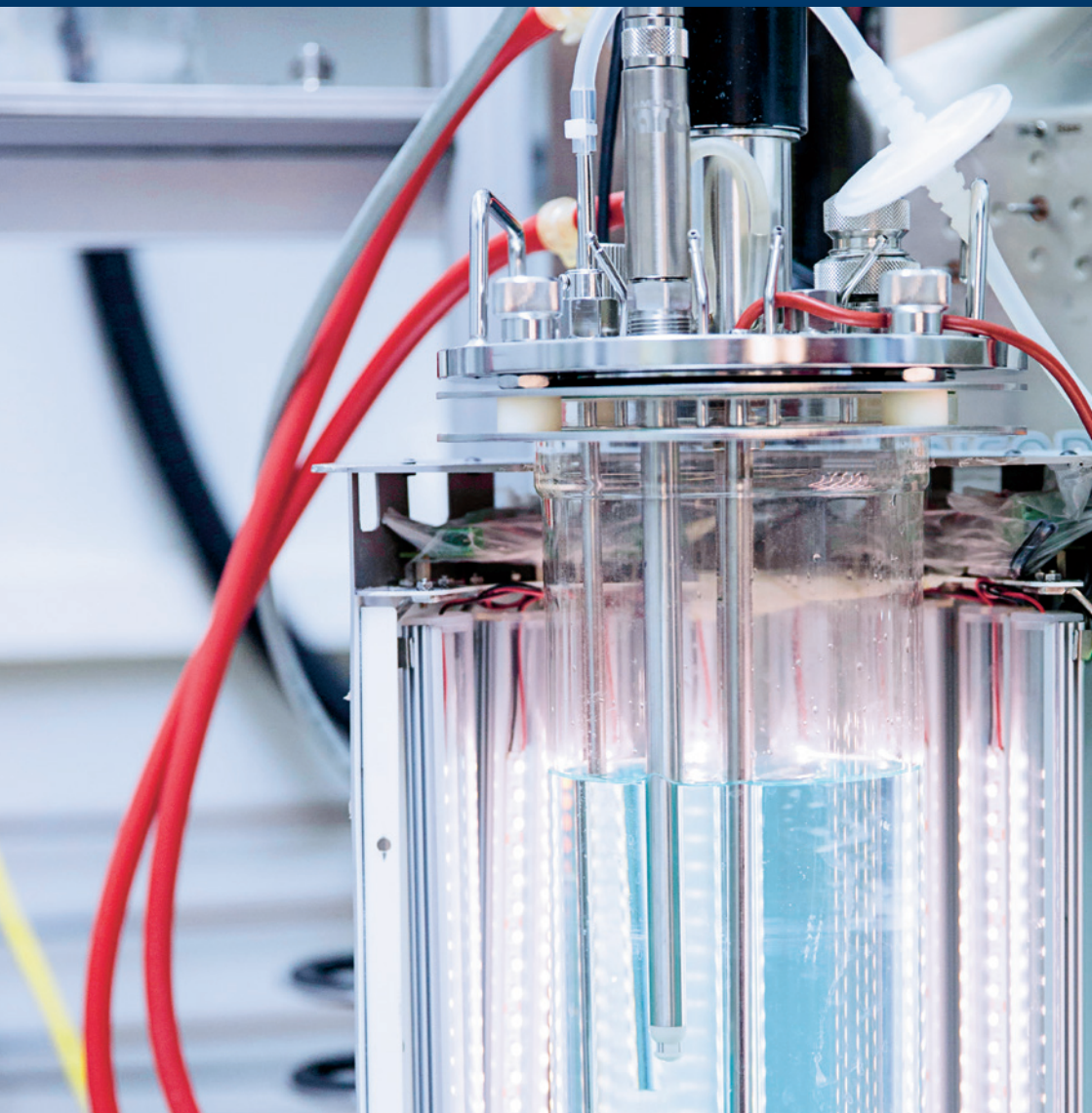
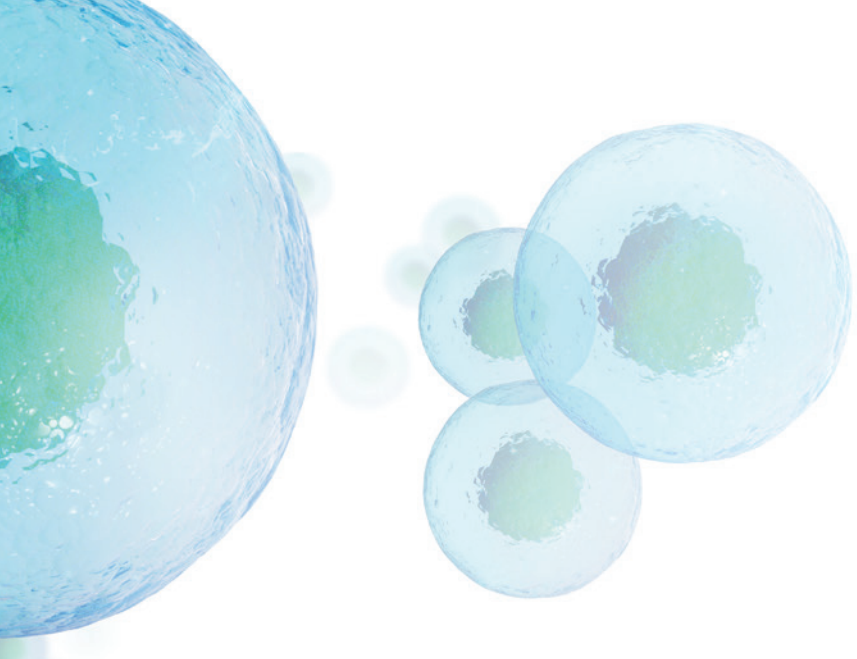
HAMILTON

Incyte Arc Sensor

Operating Instructions





Hamilton Warranty

Please refer to the General Terms of Sales (GTS).

Important note

Contents of this operating instruction can be modified without previous announcement. Technical modifications reserved. Greatest possible care was used on the correctness of the information in this operating instruction. If errors should be discovered nevertheless, Hamilton Bonaduz AG is pleased to be informed about it. Regardless of this, Hamilton Bonaduz AG cannot assume liability for any errors in this operating instruction or for their consequences.

Table of Contents

TABLE OF CONTENTS

1 Preface

Welcome to the World of Hamilton Arc System.

Congratulations on your purchase of an Incyte Arc sensor with integrated transmitter. It works in combination with Hamilton`s computer and mobile software solution ArcAir. The sensor is designed for monitoring permittivity. It enables the online monitoring of viable cell density during biotechnological processes. You can monitor cells in real-time, obtain actionable data, and automate process adjustment.

A standard measuring loop consists of an Arc sensor, which is connected via VP8 cable to the process control system (PCS), Supervisory Control and Data Acquisition (SCADA) or computer with ArcAir (standalone application). The ArcAir application allows to communicate the main measurement values (permittivity, conductivity and temperature) in parallel when an Arc Wi Bluetooth adapter is connected.

To learn about proper care and maintenance, please take the time to read this manual, including the warranty information.

Hamilton would like to thank you for your purchase of Incyte Arc.

2 General Information

2.1 Intended Use

Incyte Arc is designed to measure permittivity in a liquid medium. These measurements may be used for the control of bioprocesses within the defined specifications (see specifications sheets www.hamiltoncompany.com). The permittivity measurement may be correlated to the viable cell density. In addition to permittivity Incyte Arc also measures conductivity and temperature. These measurements should not be used for the control of bioprocesses.

NOTE: Incyte Arc has no Ex approval.

2.2 About this Operating Instruction

These Operating Instructions will help users to operate Incyte Arc correctly and safely. To achieve that goal, this document describes the different components and functions. The Operating

Instructions describe both the hardware and software of Incyte Arc in depth enabling the user to operate the system. After introducing the various parts, it is shown step by step how to operate the system. After reading the Operating Instructions, users should be capable of installing and operating the Cell Density Monitoring System. Following information are highlighted within this document:

⚠ ATTENTION! Essential information for avoiding personal injury or damage to the equipment.

NOTE: Important instructions or interesting information.

3 Liability

The liability of Hamilton Bonaduz AG is detailed in the document «General Terms and Conditions of Sale and Delivery (GTS)», chapter 12.

Hamilton expressly shall not be liable for direct or indirect losses arising out of the utilization of the sensors. It must in particular be ensured in this conjunction that malfunctions can occur on account of the inherently limited useful life of sensors contingent upon their relevant applications. The user is responsible for the calibration, maintenance and punctual replacement of the sensors. In the case of critical sensor applications, Hamilton recommends using redundant measurement points in order to avoid consequential damages. The user shall be responsible for taking suitable precautions in the event of a sensor failure.

4 Safety Precautions and Hazards

⚠ ATTENTION! Read the following safety instructions carefully before installing and operating Incyte Arc.

4.1 General Precautions

For safe and correct use of Incyte Arc, it is essential that both operating and service personnel follow generally accepted safety procedures as well as the safety instructions given in this document, the operating instruction of Incyte Arc. The specifications given regards temperature, pressure etc. may under no circumstances be exceeded. Inappropriate use or misuse can be dangerous. Cleaning, assembly and maintenance should be performed by personnel trained in such work. Before removing the sensor from the measuring setup, always make sure that no process medium can be accidentally spilled. The vessel should be pressureless and cold. When removing and cleaning the sensor, it is recommended to wear safety goggles and protective gloves. If the sensor cannot be repaired by the operator, it has to be sent back to Hamilton for inspection. Necessary precautions should be taken when transporting the sensors. For repair or shipment the sensor should be sent back in the original reusable packaging box. Every sensor sent back for repair must be decontaminated. If the conditions described in these operating instructions are not adhered to or if there is any inappropriate interference with the equipment, all of our manufacturers' warranties become obsolete.

4.2 Operation of Incyte Arc

Incyte Arc must be used for the intended applications, and in optimum safety and operational conditions. The sensor must be qualified for the application. Make sure that the process connections and O-rings are not damaged when screwing a sensor into the process. O-rings are consumable parts which must be exchanged regularly (at least once per year). Even when all required safety measures have been complied with, potential risks still exist with respect to leaks or mechanical damage. Wherever there are seals or screws, gases or liquids may leak out undetected. Do not put stress on the system by vibration, bending or torsion. The sensor can be connected to PCS, SCADA or computer during cleaning in place (CIP) and sterilization in place (SIP). Stand clear of sensor during CIP and SIP procedures as it may become very hot.

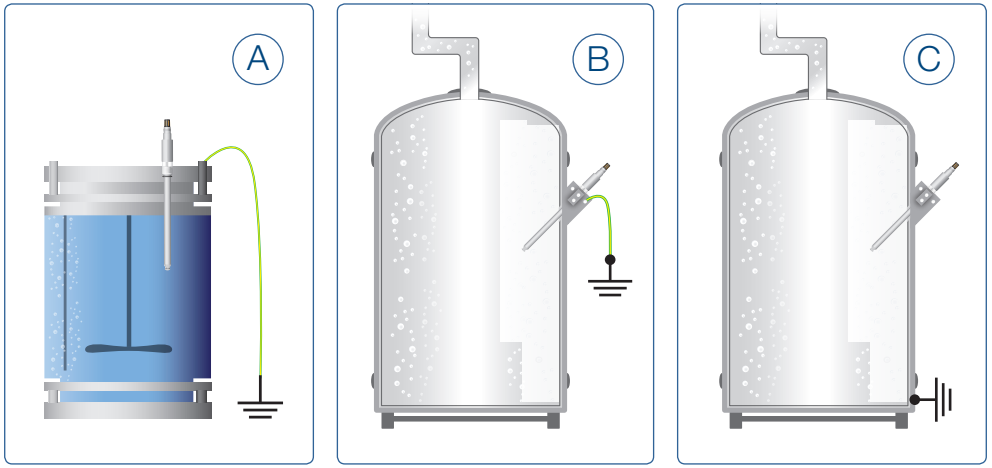
4.3 Electrical Safety Precautions

Only use the cables provided by Hamilton. Do not connect the sensor to a power source of any voltage beyond the range stated in the specifications (see www.hamiltoncompany.com). Failure to do so may lead to malfunction or damage of the system or impair user safety.

⚠ ATTENTION! If the power supply (24 V +/- 10%) is switched off or disconnected, the reading on the process control system is wrong.

SAFETY PRECAUTIONS AND HAZARDS

In areas having significant electronic noise, Incyte Arc sensors may require grounding. Locations having electronic noise may cause interference to your permittivity readings. Grounding the sensor should alleviate the interference. If the headplate of a benchtop bioreactor is not grounded, connect an earth ground wire to it. For large metallic bioreactors it is not necessary to ground the Incyte Arc sensor if the bioreactor is already grounded. For large bioreactors without a ground (e.g. glass lined reactors) connect a ground wire to the fitting the sensor is mounted to.



Incyte Arc grounding: Connect the headplat to the ground. The sensor will be grounded via its stainless steel PG 13.5 thread (A). If the tank is grounded, the stainless steel thread connect the sensor to the ground (B). In case the tank is not grounded, connect the fitting to the ground The sensor wil be grounded via its stainless steel PG 13.5 thread.

4.4 Chemical, Radioactive or Biological Hazard Precautions

Selection of the appropriate biological safety level and implementation of the required biosafety measures for working with Incyte Arc is the sole responsibility of the user. If working with hazardous liquids observe and carry out the maintenance procedures, paying attention to cleaning and decontamination. If Incyte Arc becomes contaminated with biohazardous, radioactive or chemical material, it should be cleaned. Failure to observe and carry out the maintenance procedures may impair the reliability and correction functioning of the system.

Avoid damaging the power cord. Do not bend it excessively, step on it, or place heavy objects on it. A damaged cord can easily become a shock or fire hazard. Never use a power cord after it has become damaged.

PRODUCT DESCRIPTION

5 Product Description

5.1 Why Measuring Cell Density?

Continuous monitoring of bioprocesses is required for both process control and optimization. The control of the environmental conditions including pH or dissolved oxygen is well established but does not provide information on the cell physiology. Parameters relating to cell physiology are usually monitored off-line after periodic sampling of the culture. This method is time-consuming and provides only discrete information on the bioprocess. Incyte Arc sensors offer an alternative for continuous monitoring of viable cell density in real time.

The Incyte Arc sensor enables real-time, and online measurement of permittivity, which correlates with the viable cell density. The measurement is not influenced by changes in the media, or by the presence of microcarriers, dead cells, and cellular debris. The Incyte sensor has been especially designed for monitoring the culture of mammalian and insect cells. Online monitoring of permittivity with Incyte enables the early detection of process deviations, may reduce sampling effort and supports timely process adjustment.

5.2 The Theory of Permittivity Measurement

5.2.1 The Dual-Frequency Measurement Mode

In an alternating electrical field viable cells behave like small capacitors, but not dead cells or cellular debris (figure 1A). The charge of these small capacitors is measured by the Incyte sensor and reported as permittivity in pF/cm.

The permittivity of viable cells is measured at a frequency specific to the cell type (measurement frequency): usually 1 MHz for mammalian cells (figure 1B). It is continuously and automatically corrected for the background permittivity measured at high frequency (background frequency) This is the standard Dual-Frequency Measurement Mode. The permittivity measured by Incyte Arc can be correlated to the viable cell density, especially during the exponential growth phase.

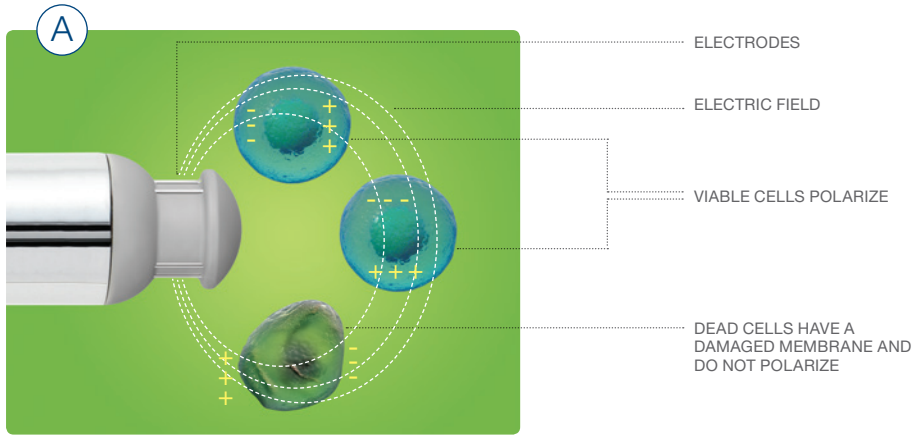


Figure 1A: Incyte measurement principle. Viable but not dead cells exhibit a permittivity signal

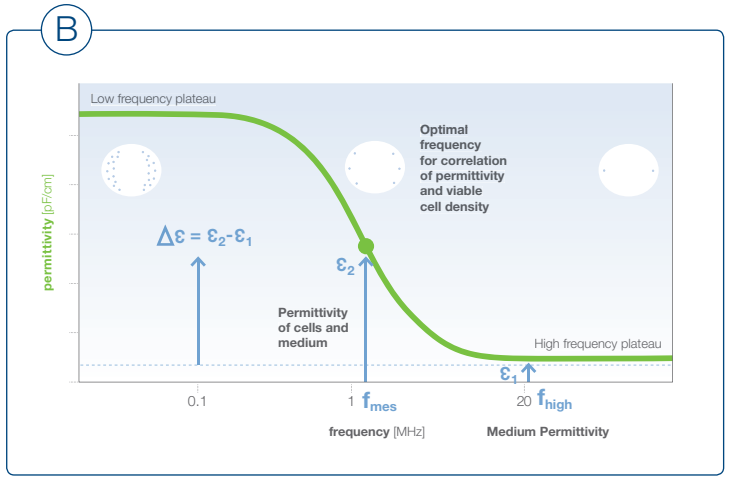


Figure 1B: In the dual measurement mode the permittivity of viable cells is measured at a frequency specific to the cell type (measurement frequency) and corrected by the background permittivity measured at high frequency (background frequency)

5.2.2 Advanced Correlation and the Frequency Scan Mode

NOTE: Please contact you local representative for further details.

PRODUCT DESCRIPTION

5.2.2.1 Theory of Data Modeling for Advanced Off-line/ On-line-Correlation

Incyte Arc provides a measure of the viable cell density. This is influenced by different parameters like size, internal conductivity of the cells and membrane permeability. Therefore the correlation between a highly viable culture at process start may differ to a correlation with a stressed and dying culture (at the end of plateau and death phase). To obtain a good off-line/on-line correlation on reproducible processes on the overall culture the data of Incyte Scan (please see chapter 5.2.2.2 for details) can be processed by the ArcAir Data Modeling Software, where a multivariate model is created. The model can be applied on the sensor and calculated in real-time to enable the correlation.

To set a correlation model, at least 5 batches including offline data of the same process (including relevant/possible variations) are required to build and validate in the ArcAir Data Modeling Software. The use of the Software is described in Chapter 15.2.

5.2.2.2 Theory of the Scan and Cole-Cole Fitting

The polarization behavior of cells varies strongly at different frequencies, as shown in figure 1B. Cells fully polarize at low frequency whereas they hardly polarize at high frequency. This behavior can be described by the mechanistic Cole-Cole equation. The Incyte Scan measures the permittivity signal at 17 different frequencies between 0.3 and 10 MHz (figure 2).

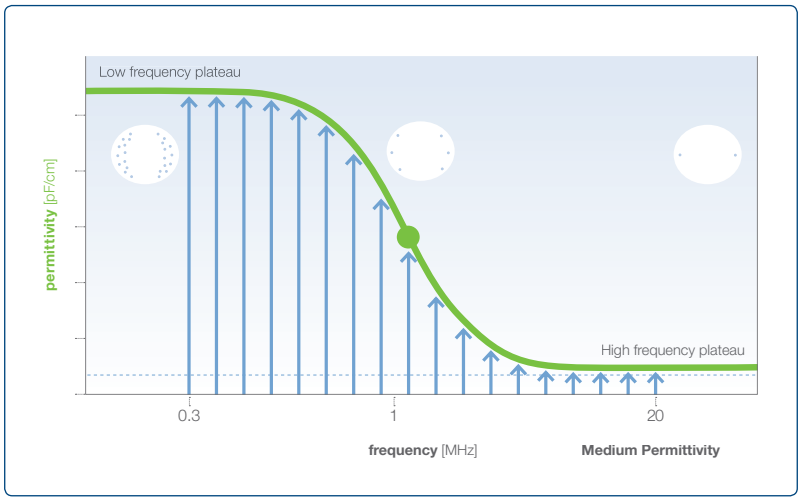


Figure 2: The ideal frequency spectrum of mammalian cells, called beta-dispersion

The analysis of the Incyte Scan may provide additional information on the cell physiology. During the Incyte Scan the most relevant parameters of the Cole-Cole equation – Δε, f_c, and α – are automatically fitted and displayed in ArcAir. The characteristic frequency, f_c, may offer an indication of the average cell diameter. A decrease of f_c, may show that the cell diameter increases during the culture. On the contrary, a shift of fc towards the higher frequency range may indicate that the cell size reduces. The height of the fitted low frequency plateau, Δε, can correlate with the viable cell density. It increases as the cells grow. The slope (α) of the beta-dispersion at the characteristic frequency f_c may provide an indication of the distribution of the cell diameter. A steep slope, i.e. a large α may correlate to a homogenous culture. The scan parameters are provided with a confidence rating, called fitting quality («Cole fit R2»), as not all cultivations may support a good calculation of these parameters. The indicator shows a value between 100 and 0 %, whereas 100% relates to an ideal fit and 0% refers to none fitting data. In addition the Model Error («Cole fit RMSE») is provided in the culture file and Modbus output for further offline data analysis. Whereas a model error as close as possible to 0 indicates a very good fit, the higher it counts to infinite, the worse is the fit.

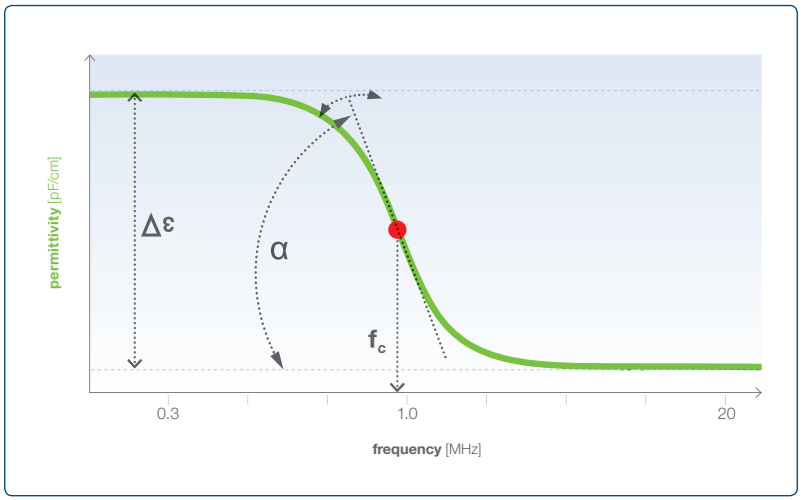


Figure 3: Data Interpretation of the beta-dispersion, gained from an Incyte Scan

NOTE: At Incyte Arc Cole-Cole Fit is optimized to run on the sensor and may lead to different values of alpha, f_c and Δε compared to Incyte preamp-version.

6 Hardware Description

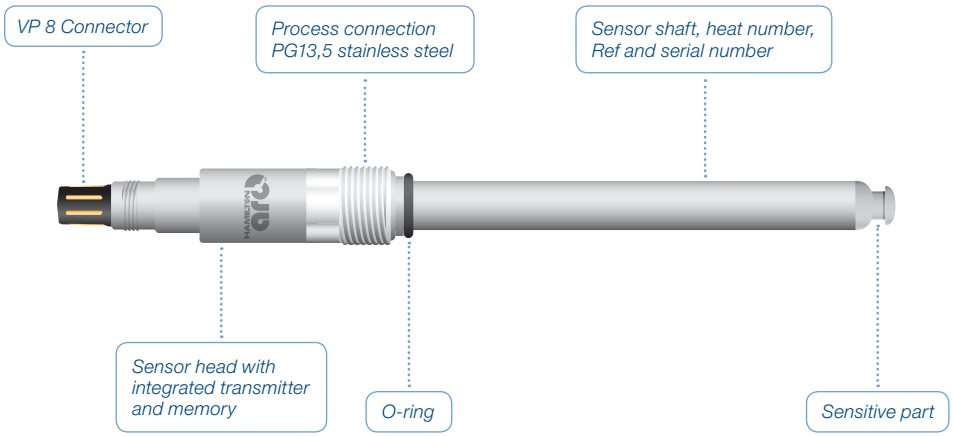


Figure 4: Incyte Arc Sensor

The sensor is available in two versions:

Sensor	Description
Incyte Arc	Dual frequency measurement: Recording on the sensor: Running of an Arc Data Model
Incyte Arc Expert	Dual frequency measurement: Recording on the sensor: Running of an Arc Data Model: Export of Incyte Scan data

Incyte Arc Expert provides the full functionality including the fitting of Cole-Cole and export of the scan data to ArcAir. This is required to build an ArcAir Data Model. Incyte Arc Basic enables dual frequency measurement and the possibility to run an ArcAir Data Model. The Expert version is an ideal sensor for research and development purposes, whereas Incyte Arc fits perfectly to production environment.

Incyte Arc provides the possibility to record 3 weeks of data in the head, with a recording interval of 12 minutes of dual frequency measurement and scan.

7 Outline of Incyte ArcAir System

With the Arc Sensor family Hamilton supplies intelligent sensors for process measurement. With their integrated transmitter, Incyte Arc sensors enable direct communication to the process control system using digital Modbus communication, and optionally via 4-20mA interface, using the Arc Wi Adapter 2G BT (REF 243470). Bluetooth wireless communication with the Arc Wireless Adapter may be used for configuration, and saves time without compromising the quality of the wired connection. It enables wireless communication with smartphones, tablets or computer. With the integrated micro transmitter Incyte Arc sensors provide more reliable measurement directly to the process control system, or ArcAir. The integrated transmitter located in the sensor head stores all relevant sensor data, including calibration and diagnostic information and culture data, simplifying calibration, maintenance and data handling.

Key benefits include:

- No separate transmitter needed
- Simple maintenance
- Easy to install
- Direct digital Modbus or analog communication via Arc Wi 2G Adapter
- Full online wireless option via Bluetooth 4.0 for easy configuration
- Recording functionality (in ArcAir, or the sensor) with data export
- Advanced measurement correlation and multivariate data modeling by using the ArcAir Data Modeling Software
- Reporting and central data management of users and validation reports for verification, configuration and communication within the GMP guidelines, including FDA CFR21 Part 11 and Eudralex Volume 4 Annex 11.

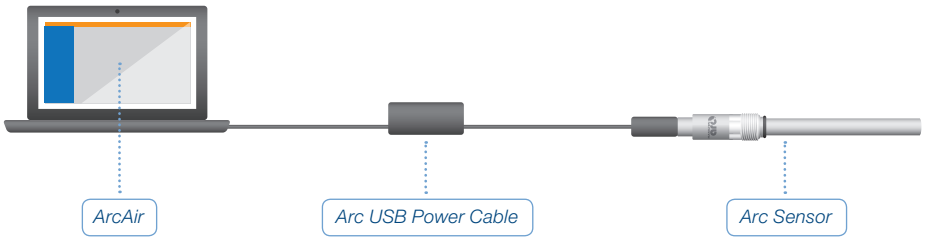
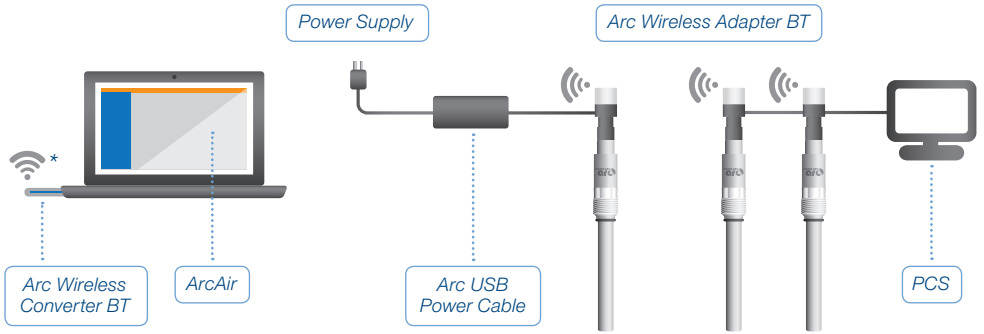


Figure 5: Arc System wired connection to ArcAir application



*Figrue 6: Arc System wireless connection to ArcAir application (*for sensor configuration only)*

For performing an ArcAir Data Model the data- and workflow is described in Chapter 13.

NOTE: Wireless communication is not intended to be used for process control.

7.1 ArcAir Application

The ArcAir application offers efficient and safe communication for monitoring, validating, management and recording of users and sensors.

Combining the reliability of Incyte Arc sensors with the power, convenience and portability of mobile devices, users benefit from configuration in the laboratory, along with product calibrations (mark and clear zero) in the process environment, as well as sensor verification after the process.

The additional reporting functionality offers management of validation reports for verification, configuration, communication and user profiles within the GMP regulatory requirements for all Arc sensors. ArcAir offers an overview of all the Arc sensors in your environment, through computer, tablet and your mobile phone, whereas the mobile version does only support the most important workflows, not data recording and display.

The chart area within ArcAir is especially designed for the use of Incyte Arc sensors, where recording, data display and product calibration are performed.

8 ArcAir Application Overview

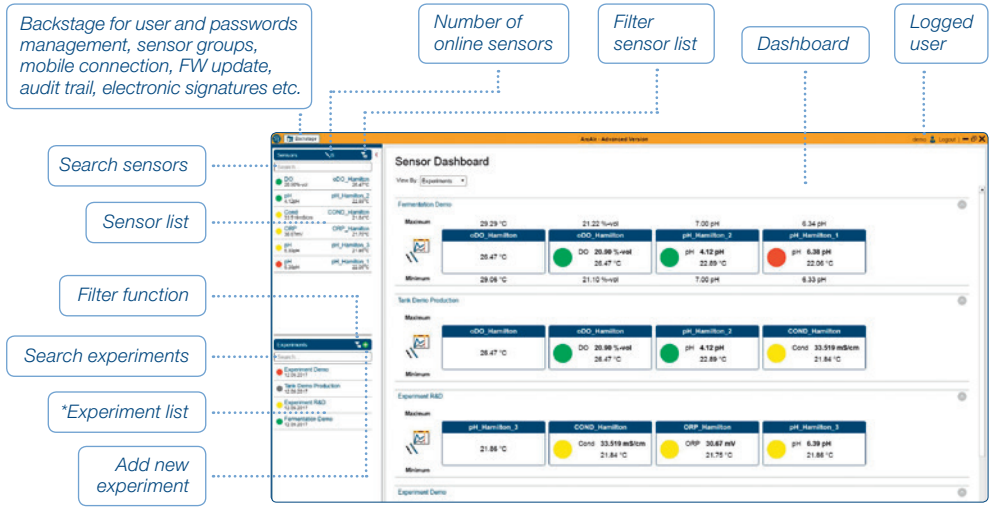


Figure 7: ArcAir Software application on computer

*(*Experiments sections not available for Incyte Arc; all relevant configurations ard done in the Chart)*

Figure 8: The ArcAir application on mobile

9 Installation

9.1 Unpacking Arc Sensors and Accessories

1) Unpack carefully the Incyte Arc sensor. Enclosed you will find the Arc sensor, the Declaration of Quality, this Operating Instructions as well as the material certificates.
2) Inspect the sensor for shipping damages or missing parts.

Figure 9: Incyte Arc sensor delivery package

9.2 Configuring the Incyte Arc Sensor with ArcAir

Arc sensors require application specific configuration. Following parts are required to configure Arc sensors:

- User Interface: Arc View Mobile or ArcAir (recommended) Computer Software
- Wireless: Arc Wi Sensor Adapter BT (Ref 243470) (Wireless option, and 4- 20 mA Output, each Arc sensor requires an Arc Wi Adapter BT)
- Power: External Power supply with Arc USB Power Cable (Ref 243490-01 or -02)

Calibration is not required for Incyte Arc sensors.

In the following table you find the different ArcAir licenses.

INSTALLATION

License	Read	Calibrate	Configure	Documentation	Users Management	Audit Trail & Electronic Signature
Free	✓	–	–	–	–	–
Basic	✓	✓	✓	–	–	–
Advanced	✓	✓	✓	✓	✓	✓

NOTE: ArcAir Basic supports the complete sensor functionality. In addition ArcAir Advanced supports sensor verification and is therefore highly recommended.

9.3 Installing ArcAir Basic on the Computer

1) Download the Zip file «ArcAir» from the Hamilton webpage www.hamiltoncompany.com (Search for ArcAir).
2) Unpack the ZIP-File.
3) Install «ArcAir» by double clicking «ArcAir.exe» and follow the instructions on the screen.
4) Plug in the Wireless Converter once the installation of ArcAir is completed.

The following system requirements must be met when installing and using the ArcAir Software.

Operating system	PC / Notebook: Mobiles:	Windows 7 and higher iOS 9 and higher Android 4.1 and higher Windows 10 and higher
Installation right	Administrator	
Free hard disk space	1 GB	
Free space for data	2 GB	
USB port	One Type A USB port	

9.4 Upgrade ArcAir to Advanced Version

To upgrade ArcAir computer version a special Arc Wireless Converter BT (Ref 242333) or Arc View Mobile Advanced (Ref 10071113) is required which transfers the ArcAir Advanced license key.

Upgrade via Arc Wireless Converter BT

1) After installing ArcAir on the Computer connect the Arc Wireless Converter BT with ArcAir Advanced license key.
2) Once your computer has identified the Arc Wireless Converter BT and its advanced license key, a pop up appears with the message «Your ArcAir is upgraded successfully to Advanced».

Upgrade via Arc View Mobile

1) Open ArcAir Advanced on the mobile device.
2) Go to the «Backstage» and select the mobile connection.
3) Click «Scan for mobile device» in the ArcAir computer version.
4) On the mobile device click on the screen icon and select the computer to establish the connection.
5) Once your computer has identified the mobile device, a pop up appears with the message «ArcAir has been upgraded from Basic to Advanced. Please restart the application to enable the new features.»
6) Restart ArcAir.

9.5 Installing ArcAir on non-Hamilton Mobiles

1) Connect your mobile device to an AppStore with your user account.
2) Download the ArcAir from an AppStore by scanning the barcodes below or entering «ArcAir» into the search field.

Download on the App Store

GET IT ON Google Play

amazon appstore

NOTE: In territories, such as China, the Google Play Store is not an option. ArcAir for Android is nonetheless available after downloading on those devices the Amazon Appstore as described at www.amazon.cn/androidapp. ArcAir on Amazon Appstore is available in three separated versions: light, basic and advanced.

9.6 Upgrade ArcAir via In-App Purchase

1) Select the symbol with three points on the right upper corner.
2) Select Buy Basic Version or Buy Advanced Version.
3) Enter your personal AppStore or PlayStore account password.
4) Message pops up «Please restart the application to enable the new version».
5) Restart ArcAir.

9.7 Update ArcAir on Arc View Mobile Basic or Advanced

1) Tap 5 times on the Arc View Mobile sceen.
2) Enter the app blocker administrator password.
3) Select «Exit SureLock» (this will end SureLock and go back to original Android home screen).
4) Click «Exit».
5) Uninstall the old ArcAir Advanced version.
6) In case you own a Arc View Mobile Basic (Ref 10071111), download the .apk file «ArcAir Basic» from Hamilton webpage www.hamiltoncompany.com (search for «Arc Mobile Devices»).In case you own a Arc View Mobile Advanced (Ref 10071113 or Ref 243690 for the versions before ArcAir 3.0), download the .apk file «ArcAir Advanced» from the same webpage (search for «Arc Mobile Devices»).
7) Click on the .apk file to start the installation.
8) Press Install.
9) After installation switch on the app blocker «SureLock» by clicking on the SureLock application.
10) Update completed.

NOTE: On Hamilton pre-configured mobile devices an app blocker application is installed. The App blocker administrator mode gives you access to the Android user interface of the mobile and system functionality. To access the administration mode a password is required for the application (default password 1234). The password must be changed by entering the default password, open App blocker:
> Left menu > SureLock Settings > Change Password

⚠ ATTENTION! It is possible to update Arc View Mobile Basic only with .apk file «ArcAir Basic» and Arc View Mobile Advanced only with .apk file «ArcAir Advanced». It is not possible to install the .apk file «ArcAir Advanced» on a ArcView Mobile Basic device.

NOTE: ArcAir Advanced.apk works on Arc View Mobile only.

NOTE: Please make sure that the app blocker is switched on after updating ArcAir Advanced.

9.8 Connecting an Incyte Arc Sensor to ArcAir

1) Connect one Incyte Arc sensor with the power supply, by using the Arc USB Power Cable on a standard USB port (REF 243470).
2) The ArcAir application recognizes and displays the connected sensor automatically.

⚠ ATTENTION! Version 01 of the USB Power Cable (REF 243470) is required. This version has a connector for the optional power supply.

⚠ ATTENTION! For automatic sensor login a unique and global Operator Level S password for all Arc sensors is required. Please make sure you have set the same Operator Level S Password for all Arc sensors in the ArcAir application under Backstage/Settings/Operator Level S Password.

9.9 Create User Accounts

ArcAir Advanced allows system Administrators to create user accounts and assign them to userroles with pre-defined role rights.

1) Start ArcAir application on computer.
2) Log in as administrator.
3) Click on «Backstage» left upper corner.
4) Select «User Management».
5) Click the «Add» Button for opening the «New User» window.
6) Type in the user details and define a temporary password.
7) Click on tab «Role» and assign the user to one of the user-roles listed. If no role is chosen, the user will automatically get the role «Administrator».
8) Click on «Save all» right lower corner.
9) In compliance with Part 11 and Annex 11, the first time the new user will log-in, he/she will be requested to enter the temporary password and set his/her own personal password.

ArcAir built-in user roles with pre-defined role-rights:

Role Name	Role Rights
Administrator	Sensor Calibration* Database Management Security Settings Language Changes Role Management Sensor Settings Sensor Firmware Update User Management System Process Settings Communication Validation Audit-trail Verification Electronic Report Signing
Calibration Technician	Sensor Calibration* Process Settings Audit-trail Verification Electronic Report Signing
Production Technician	Sensor Settings Process Settings Communication Validation Audit-trail Verification Electronic Report Signing
Quality Manager	Audit-trail Electronic Report Signing

Not for Incyte Arc

⚠ ATTENTION! First user is the administrator and all user rights are assigned as default.

⚠ ATTENTION! User Accounts are created first on computer. In order to apply the changes to the users on your mobile devices, it is needed to transfer the users information as described at chapter 9.13.

NOTE: Initial operation of ArcAir is in the laboratory mode as long as no user account is created. Laboratory mode does not require a login password and enable all features in the installed license version (see Hamilton Arc Operating Instructions, REF 10071115).

9.10 Create Customized User Roles

This function allows administrators to define customized user roles.

1) Start ArcAir application on computer.
2) Log in as administrator.
3) Click on «Backstage» left upper corner.
4) Select «User Roles».
5) Click «Add Role».
6) Enter the new role name.
7) Check the role rights to be assigned to the new role.
8) Click the save button in the right lower corner.

NOTE: The standard roles Administrator, Calibration Technician, Production Technician and Quality Manager cannot be edited or deleted in order to ensure full traceability of the OQ tests.

An administrator has still the possibility to add and edit user roles according to his/her needs. In this case, a user-added role cannot be deleted as long as it is assigned at least to one user.

9.11 Security Settings for Password and Auto Log-out

In compliance with the GMP guidance for computerized system, ArcAir Advanced enables Administrators to set rules for passwords management and users log-out. Such rules include:

- Password length
- Password complexity
- Password expiration
- Users automatic log-out

In order to access the security settings:

1) Start ArcAir on computer.
2) Log in with Administrator user name / password.
3) Click on «Backstage» left upper corner.
4) Select «Settings».
5) Select «Security Settings».
6) Apply the required settings.
7) Click on the button «Save» on the bottom.

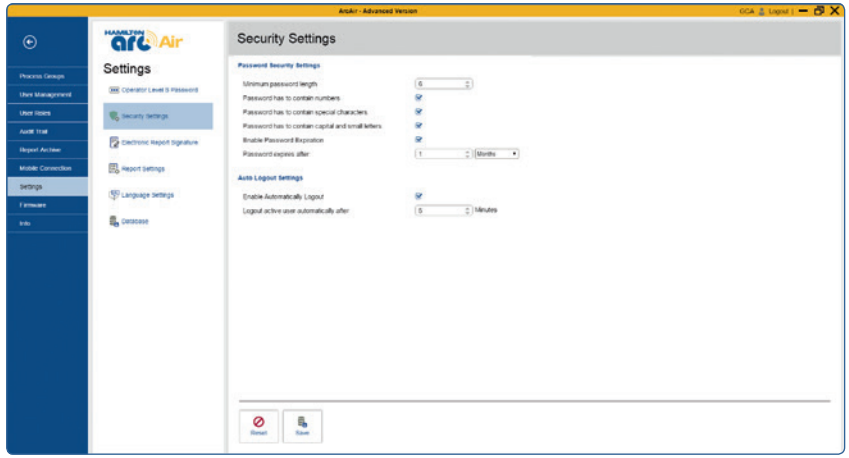


Figure 10: ArcAir Security Settings

9.12 Create Process Groups

This function allows sensors to be organized into Process Groups. A Process Group is used to filter the Sensor Dashboard View or to assign a group of sensors to specific ArcAir users.

1) Start ArcAir application on computer.
2) Log in as administrator.
3) Click on «Backstage» left upper corner.
4) Select «Process Groups».
5) Click the «Add» Button for opening the sensor list.
6) Enter a process group name.
7) Select the sensors for the process group.
8) Click the save button next to the sensor list.

9.13 Assign Process Groups to User Accounts

Users that have been assigned one or more process groups will only be able to see and select sensors that are within the assigned process groups.

In order to assign process groups to users follow the procedure below.

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «User Management».
4) Double click on a user or create a new one (see reference) for opening the user editor.
5) Click the «Process Groups» tab within the user editor.
6) Assign process groups to the user by selecting the assign check boxes.
7) Click «Save all».

INSTALLATION

9.14 Create a Mobile Connection

The mobile Connection will allow your PC to transfer user profiles and to access reports saved on mobile devices.

1) Start ArcAir application on computer.

2) Click on«Backstage» left upper corner.

3) Select «Mobile Connection» and follow the instructions on the screen.

9.15 Create Configuration Profiles

1) Start ArcAir application.
2) Connect to a sensor.
3) Open the settings tab and open the configuration profile drawer.
4) Enter a profile name.
5) Click Create.
6) Message pops up «Configuration Profile was successfully created».

9.16 Import Configuration Profiles to Arc Sensor

1) Start ArcAir application.
2) Connect to a sensor.
3) Open the settings tab and open the configuration profile drawer.
4) Select configuration profile from the dropdown list.
5) Decide if a configuration report is required or not.
6) Click «import».
7) Message pops up «Configuration Profile was successfully imported to sensor».

NOTE: If Modbus device address has been changed the import will lead to a sensor disconnection.

9.17 Create and Edit an Experiment

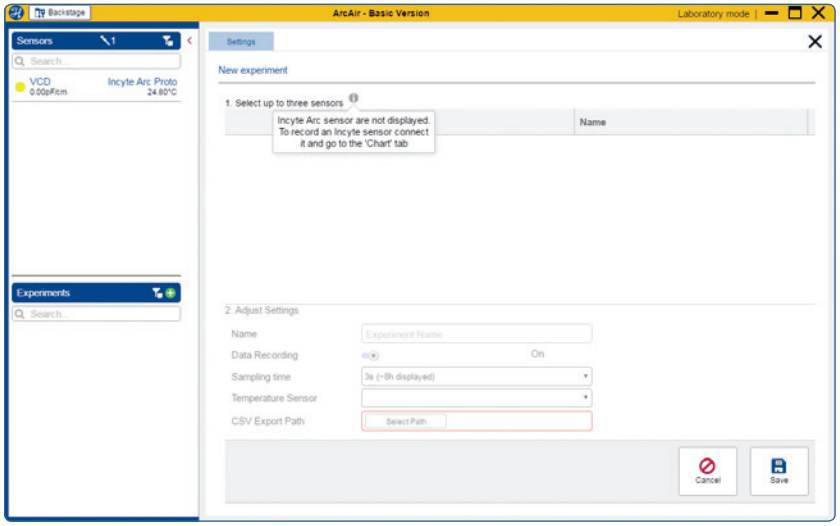


Figure 11: ArcAir Experiment View

⚠ ATTENTION! This feature does not support the use of Incyte Arc sensors.

9.18 Transfer and Print Reports

NOTE: Under the Report Section in the Sensor Information are the reports of the currently connected sensors, whereas the report archive in the backstage contains all available reports.

1) Start ArcAir Advanced on the mobile device.
2) Go to «Backstage» in the computer version and select «Mobile Connection».
3) Press «Fetch Reports».
4) Once all reports are transferred go to «Report Archive».
5) New reports will be displayed on top.
6) Double click or select on one of the reports.
7) A separate window opens showing the selected report.
8) Verify that sensor data in the report are correct.
9) Click «Print».
10) Double sign the reports in the signature fields.

NOTE: All reports downloaded to the ArcAir computer version will be automatically deleted from the mobile device memory.

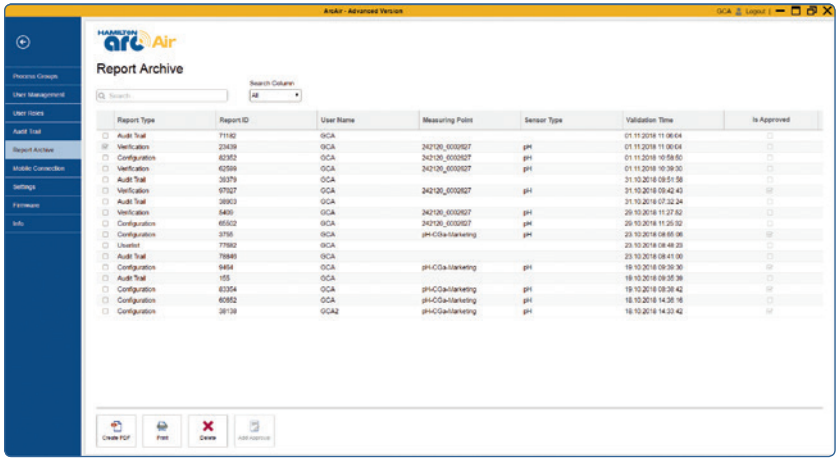


Figure 12: Report Archive View

9.19 ArcAir Settings

9.19.1 Create an Operator S Level Password

Administrators can set an «Operator Level S password» unique for all its Arc Sensors. This is a multiple digits numeric code, which works in background and makes sure that customer's Arc sensors can be accessed only by ArcAir devices a uthorized by the same customer. Please make sure you have added the same Operator Level S Password for all Arc sensors in the

ArcAir application under backstage/Settings/Operator Level S Password. Define and do not share the company «Operator Level S password» to make sure that the access to its Arc sensors is guaranteed only to authorized individuals.

NOTE: Please select one S Level Password for all Arc sensors.

NOTE: All sensors delivered by Hamilton come with the standard password and have to be changed.

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Operator S Level Password».
5) Write the password in the textbox.
6) Press «Save».

9.19.2 Enable Electronic Report Signature

In compliance with GMP guidelines for electronic data management, it is possible to generate and electronically sign reports to document the Arc sensors management operations executed with ArcAir software. Such events include sensors` calibration, validation, and configuration and communication validation.

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Electronic Report Signature».
5) Activate the functionality.
6) Press «Save».

9.19.3 Define Report Settings

ArcAir Advanced enables users to customize the reports, such as include the Company logo and information or change the path folder, where the reports are automatically copied after electronic signature approval (see chapter 9.18.2).

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Report Signature».
5) Enter a Subtitle, Company name and address, as well as notices by writing in the empty textbox. To select a logo, select the correct path.
6) Define the location where reports should be stored, if different from standard setting, which is C:\Hamilton\ArcAir\Reports.
7) Press «Save».

9.19.4 Select the Language Settings

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Language Seetings».
5) Select the language from: English, German, French, Spanish, Italian, Chinese, Hungarian.
6) Press «Save» and re-start.

9.19.5 Manage the Database Settings

Arc system is a closed computerized system. All the GMP relevant electronic records can be accessed only by authorized users. Such users log-in the system tough a unique combination of user-name and password and their actions are tracked in the audit trail. The audit trail, user's accounts and all the others GMP relevant electronic records are saved in ArcAir SQL Lite database.

The database is secured and can be accessed only through ArcAir software. After the software installation it is automatically placed in C:\ProgramData\HAMILTON\ArcAir.

Administrators can manage the database performing operations such as «database backup» or «database change» to older backups (equal to function «database restore»). Administrators can change the path where the database is saved, as well.

9.19.5.1 Define the location to store the database

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Database».
5) Select the path for the active and the backup database.
6) Press «Change Database».

9.19.5.2 Import a backup database

1) Start ArcAir application on computer.
2) Click on «Backstage» left upper corner.
3) Select «Settings».
4) Select «Database».
5) Choose an existing backup database.
6) Create the Backup.
7) Press «Backup Database».

10 Incyte Arc Sensor Operation

10.1 Mount the Sensor in the Bioreactor

1) Select the most appropriate port for mounting the sensor (figure 13). Choose a position where gas bubbles may not interfere with the measurement, for example in ports opposite to the sparger or at a distance to get minimal turbulence. Gas bubbles interfere with the measurement and may cause reading errors. The electrodes of the Incyte sensor have to be kept at least 1 cm away from any solid parts, especially metallic ones. The electric field may be subject to interference and the measurement may be affected.

INCYTE ARC SENSOR OPERATION

2) Remove the yellow protective caps from the Arc sensor shaft and from the VP 8 sensor head.
3) Check the O-ring on the sensor shaft.
4) Verify if the platinum electrodes are not damaged.
5) Insert the sensor in the port. Do not scratch the platinum electrodes while inserting them.
6) Verify the sensor orientation (figure 14).
7) Tighten the connection nut by hand, max. 2 Nm.

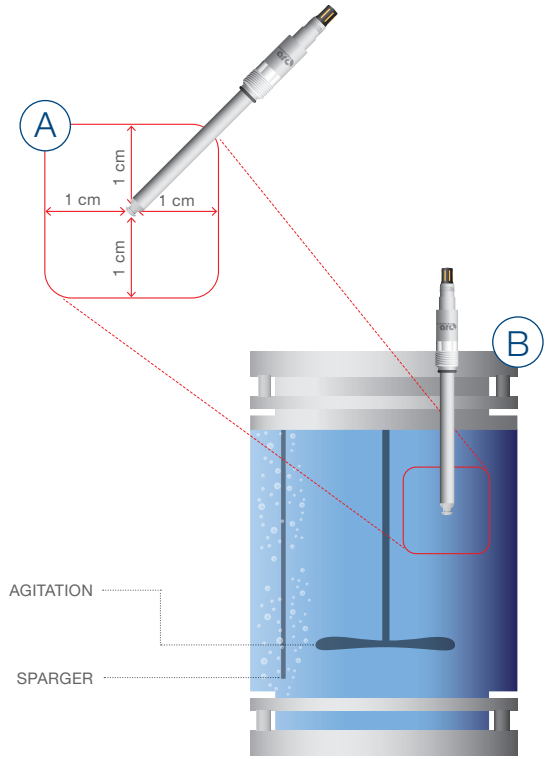


Figure 13: Mounting restrictions, A: Space requirements / B: Reactor mounting restrictions

NOTE: For mounting from a side-port ensure that the notch of the VP8 connector is mounted facing upwards (figure 14).

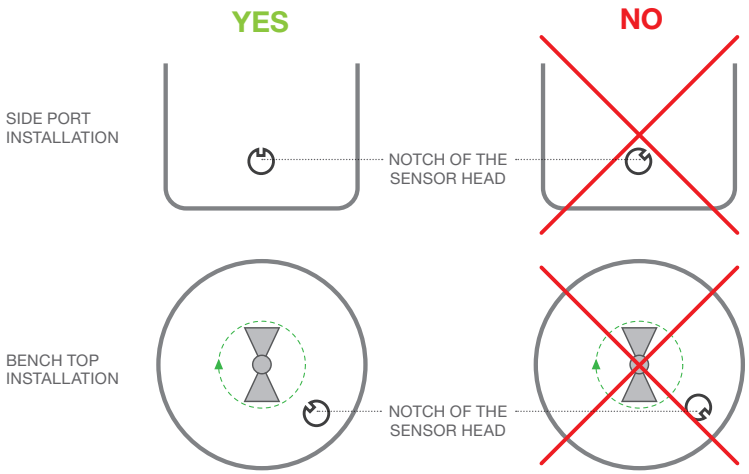


Figure 14: Mounting orientation of the sensor

NOTE: Various housings are available to custom fit your sensor in your installation.

10.2 Connect the sensor to ArcAir

1) Connect the sensor to the computer (see chapter 9.7) or process control system (see chapter 15).
2) Verify the sensor functionality on your computer, mobile device or process control system and create a communication validation report (if connected to the PCS via 4-20 mA).

NOTE: The sensor status (see figure 16) maybe red initially, as the sensor cannot measure correctly in air. Upon insertion in conductivity solution or medium the sensor may stay in yellow warning-state, as no scan fitting, or correlation-calculation can be done without cells/microorganisms.

NOTE: To create Communication Report go to the Communication Validation Tab and follow the instructions on the screen.

INCYTE ARC SENSOR OPERATION

NOTE: Incyte Arc is configured to Baudrate 19'200. In case the Baudrate is changed, the sensor may not be recognised by ArcAir. In this case go to the Back-stage area >> «Settings» >> «Wired connection» and select the Baudrate, Parity and Stopbit according to your settings of ArcAir. Press «Save».

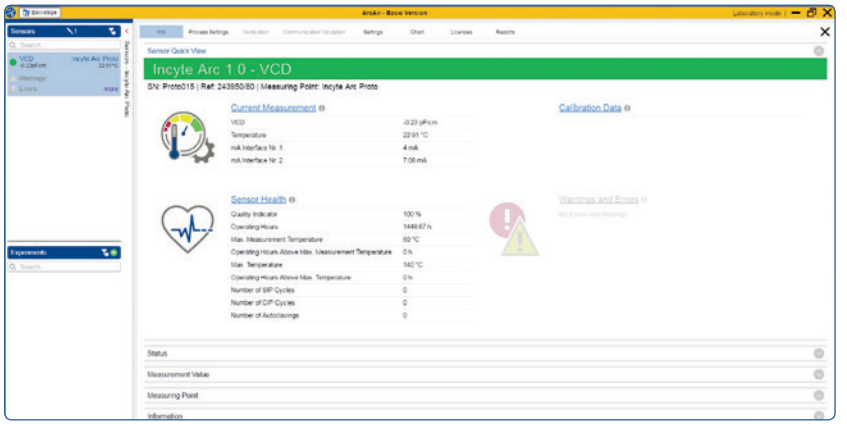


Figure 15: Overview Sensor Info Quick View

10.2.1 Connect up to 4 sensors to ArcAir

NOTE: It is possible to connect up to four Incyte Arc sensors via Arc USB Power cable (REF 243490-01/-02) to one computer, running ArcAir. Each sensor will be shown in the sensor list and can individually be used and recorded. Once the data recording is started, the Chart view for a specific sensor can be closed and data recording is done in the background.

10.3 Configuring the Arc Sensor Parameters

1) Start the ArcAir application.
2) Select the desired sensor.
3) Open the «Measurement Settings» (make sure you have the «Sensor Settings» user right).

4) Configure the sensor, regarding the Measuring Point, Temperature Unit, as well as the min. and max customer temperature.

A description of the available settings is given below:

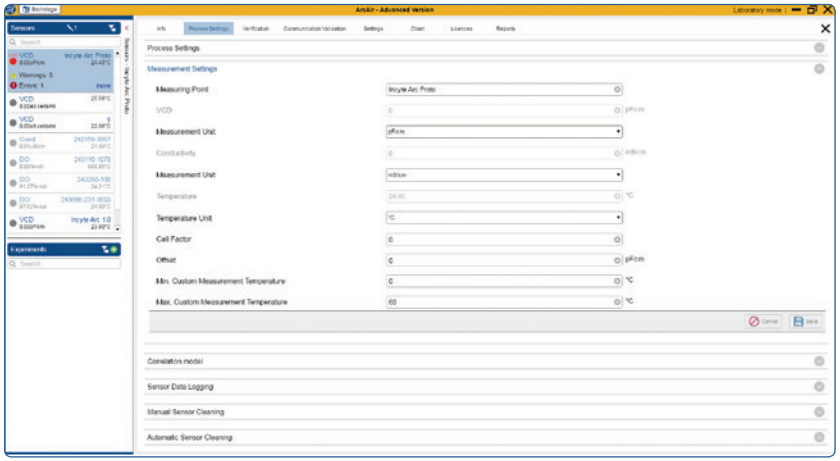


Figure 16: Overview of the Measurement Settings

Setting	Description
Measuring Point	Name of the Measuring Point
VCD	According to the Measurement Unit below
Measurement Unit	pF/cm (Standard) and user defined correlated to the offline measurement
Conductivity	Measurement of the conductivity in mS/cm
Measurement Unit	Set to mS/cm
Temperature	Temperature of the medium
Measurement Unit	°C as Standard , may be adjusted to K or °F
Cell Factor	Value to correlate the offline measurement with the online monitoring
Offset	Product Calibration Offset (in pF/cm), to be marked in medium prior to inoculation
Min. Custom Measurement Temperature	Minimal value, where the electronic switches on
Max. Custom Measurement Temperature	Maximal value, where the electronic switches off

Description ot the Measurement Settings

NOTE: No measurement of permittivity and conductivity is performed at a temperature higher than 60°C medium temperature to protect sensing part and enhance the sensor lifetime.

10.4 Run Culture

10.4.1 Prepare the Sensor and Choose the Cell Type Mode

1) Go to the «Process Settings» (figure 18). Choose the «Cell Type mode», select from the predefined settings:
   - Animal → measurement frequency = 1000kHz, background frequency = 10MHz, moving average (signal integration) = Middle
   - Yeast → measurement frequency = 2000kHz, background frequency = 10MHz, moving average (signal integration) = High
   - Bacteria → measurement frequency = 1000kHz, background frequency = 10MHz, moving average (signal integration) = High
2) Press «Save».

NOTE: Please refer to chapter 10.5.1 to create your own measurement mode, called user 1, 2 or 3.

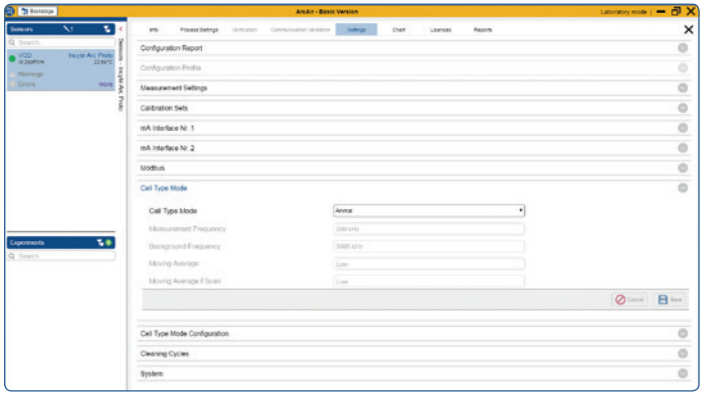


Figure 17: Cell Type Mode Settings

INCYTE ARC SENSOR OPERATION

10.4.2 Set the Cell Factor and define the Measurement Unit

10.4.2.1 Correlation of the Dual Frequency Measurement

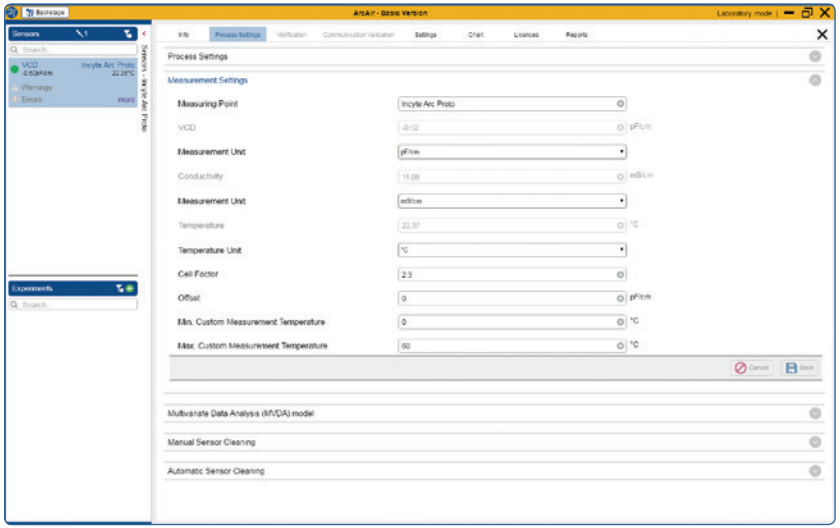


Figure 18: Measurement Settings

The measured permittivity may be correlated to off-line measurements in a simple linear way, by defining a cell factor on the dual frequency measurement (see chapter 19.1).

1) Go to the «Process Settings» and select the «Measurement Settings» (figure 18).
2) Select the correlated Measurement Unit between PCV (packed cell volume), g/l, e6cells/ml or OD. PF/cm is the standard set up, as this refers to the measurement itself.
3) Insert the calculated Cell Factor in the section «Cell Factor».
4) Press «Save», the cell factor is copied to the process and measurement settings in the settings area.

10.4.2.2 Cell Density Correlation on the Scan Data

Using the frequency scan of Incyte Arc it is possible to improve the off-line/on-line correlation for reproducible processes (e.g. production), on the overall process, especially during the plateau and death-phase. The model is created offline in the ArcAir Data Modeling Software (see chapter 19.2). The model can be transferred and run on the sensor to provide a real-time prediction of the viable cell density.

NOTE: To obtain scan data to build the Arc Data Model the Incyte Arc Expert sensor version is required. The Model can run on the Expert and Incyte Arc sensor.

NOTE: The model is identified by a checksum and creation date and time to ensure data integrity between model building and import to ArcAir. This information cannot be changed.

1) Go to the «Settings» and select the «Correlation Model».
2) Go to the «Import model» and select the correlation file (.incal).
3) Press «Import».

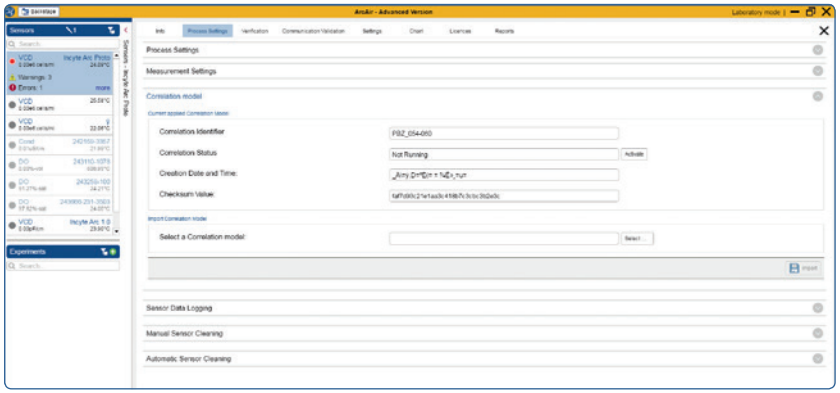


Figure 19: Arc Data Model Import

1) Go to the «Current applied model».
2) Check that the model identifier is the same like in the selected model.
3) Press «Save».

INCYTE ARC SENSOR OPERATION

10.4.3 Start Recording Measurements in a Culture File

The main tasks to start recording the data and to configure sensor parameter are placed in the Chart Menu (figure 20). The Menu is separated in 5 parts. On the upper part is the dual-frequency Measurement Chart (measurement over time) and the optional correlation factor to the offline method above, at the right side buttons to start recording, perform a product calibration and inoculate are placed. If available and activated the Scan Chart (permittivity over frequency) is placed below, indicating the beta-dispersion calculations (including a fitting indicator) at the right part.

NOTE: In case ArcAir Application stops for any reason, the recorded data can be exported, using the «export last» button.

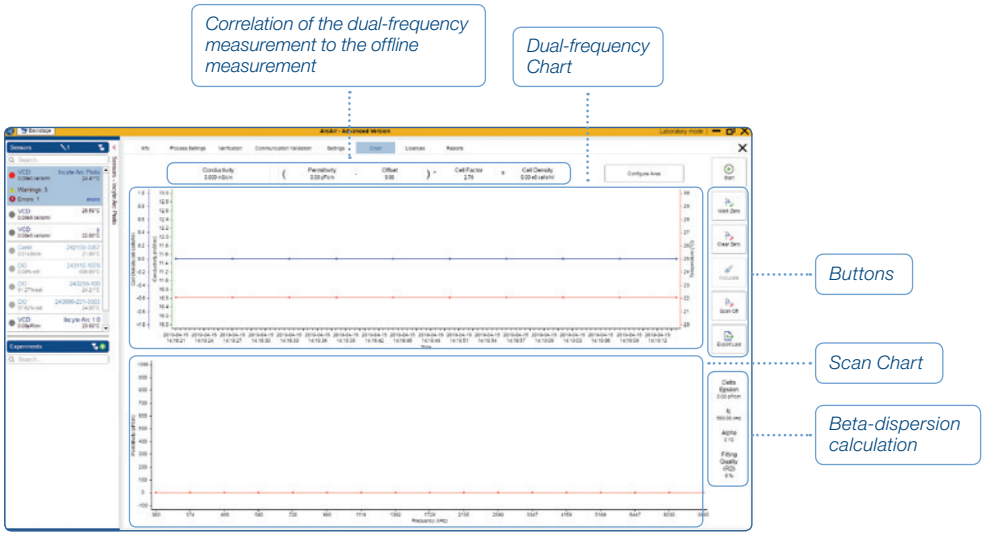


Figure 20: Chart Menu for Incyte Arc

1) Go to the «Chart Menu» (figure 20).
2) Press «Start» (the Button will now switch to «Stop»).
3) A pop up will open. Define the File name, sampling time (the time from between recorded measurements), select the place to store the file and add an optional comment.
4) Press «Start».
5) A comment «Start recording» is now added to the chart.

10.4.4 Start the Incyte Scan

NOTE: The Expert Sensor is required to use the Incyte Scan option.

1) Go to the «Chart Menu» and press «Scan On» on the Button (figure 20). The Button will now switch to «Scan Off».
2) The curve of the Frequency Scan is displayed in the Chart, below the dual frequency measurement, as well as $\Delta\varepsilon$, f_c and α and a fitting indicator are calculated and shown on the right side.

NOTE: The fitting indicator in ArcAir describes how good the scan data can be fitted to the Cole-Cole equation. An indicator between 90 and 100 % describes a good fitting, between 70 and 90 % refers to an average fit, whereas everything below 70 % is considered not to be reliable.
In the Culture File the corresponding values are recorded between 0 and 1.

10.4.5 Perform a Product Calibration and Set the Inoculation Time

⚠ **ATTENTION! If using an ArcAir Data Modeling, the event «inoculation» starts the calculation of the Model in the sensor and is highly important to be marked.**

NOTE: Even though the Dual Frequency Measurement Mode reduces the influence of medium and medium changes on the measurement, it is usual to do a product calibration, i.e. a zero-adjustment before inoculation. The product calibration is done by pressing the mark zero button.

Figure 21: Inoculation Information

1) Equilibrate the Incyte Arc Sensor in culture medium, for at least 30 minutes prior to product calibration and inoculation.
2) Verify on the «Chart Menu» that the cell density measurement is stable.
3) Go to the «Chart Menu» and press «Mark Zero» to perform a product calibration (figure 20) on the dual measurement and frequency scan (if activated).
4) The event is marked in the chart.
5) The cell density measurement is now compensated for an offset shown in the measurement values above the dual-frequency graph.
6) To assign the inoculation time, go to the «Chart Menu» and press «Inoculate» (figure 21). A new time scale (culture time) and comment is added to the culture file to track the real culture time.
7) The successful inoculation is displayed in a Pop-Up Menu (figure 21).

NOTE: After inoculation it is not possible to set an offset, or change the scansettings.

INCYTE ARC SENSOR OPERATION

10.4.6 Add a Comment to the Culture File

During recording, a comment can be added at any time to the Culture File. This functionality may be used to track offline samplings.

1) Go to the «Chart Menu» left-press with the mouse on the measurement point, where the comment should be added.
2) Enter comment in the text-box and click «Save».

10.4.7 Customize the Chart

1) Go to the «Chart Menu» and select «Configure axes» at the upper right corner.
2) Select the axis to be adjusted in the upper area:
   a) Temperature
   b) Cell Density
   c) Conductivity
3) After Selection go to the lower section and define minimum and maximum value.
4) Press «Save».

NOTE: Only the y-axis of the dual frequency chart can be adjusted.

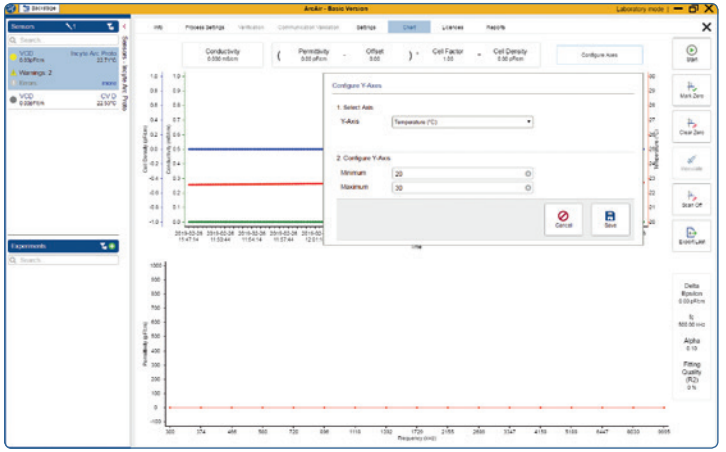


Figure 22: Definition of the Dual Frequency Chart

INCYTE ARC SENSOR OPERATION

10.4.8 Stop Recording the Culture File

1) Go to the «Chart Menu» and press «Stop», the button will change to «Start» and a pop up message for the successful export will be indicated.

10.4.9 Recording Culture Files on the Sensor

Incyte Arc has the capability to store a 3 weeks run (recording every 12 minutes, incl scan) in the sensor head. Depending on the recording settings the run is overwritten with every new run. Once the storage is full a warning will be provided and no more recording done, until the memory is freed up.

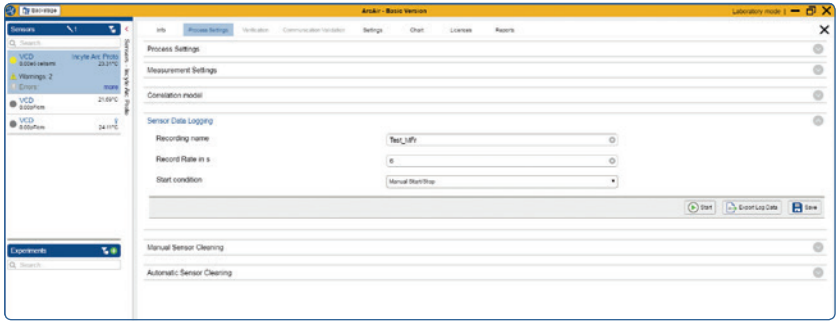


Figure 23: Sensor Data Recording Setting

10.4.9.1 Configure Recording

1) Go to the «Process Settings».
2) Go to «Sensor Data Logging».
3) Insert at name for the file.
4) Define a date for recording data in seconds.
5) Define the start condition for recording:
   a) Manual start/Stop → done in ArcAir Computer Software, or via mobile version.
   b) Start recording with Inoculation, will start the recording once the culture is inoculated (inoculation is pressed in ArcAir Computer Software, or via mobile version).
   c) Start Recording with next power up → upon powering up the sensor, recording automatically starts once and has to be configured again for the next power up.
6) Press «Save».
7) The configuration is confirmed with a pop up message.

NOTE: Sensor data logging is indicated in the Sensor List by the indication "LOG".

NOTE: Incyte Arc does not need to be connected to ArcAir to perform Sensor Data Recording.

10.4.9.2 Export the Recorded Data

NOTE: Export only possible cable-bound to ArcAir application.

1) Connect the sensor to ArcAir (if not connected) with cable.
2) Go to the «Process Settings».
3) Go to «Sensor Data Logging».
4) Press «Stop».
5) Press «Export Log Data» and wait until the data is downloaded from the sensor (may take upto 12 minutes, if memory is full (figure 23)).
6) Select date and time for the log file.
7) Press «Confirm». The file is stored per default at: C:/Hamilton/ArcAir/Incyte Log Data/

10.4.9.3 Increase the Sterilization Cycle Counter

After every sterilization process the sterilization counter increases. For CIP and SIP this is done automaticall (see chapter 14.4) for autoclaving this has to be done manually (see chapter 14.4.1).

10.5 Define Additional Incyte Arc Settings

10.5.1 Define the Custom Measurement Mode

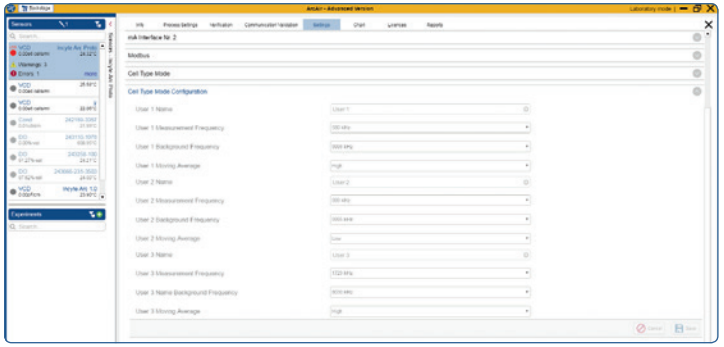


Figure 24: Cell Type Mode Configuration

NOTE: If Cole-Cole fittings are used for data anlysis a high moving average time is strongly recommended.

1) Go to the «Settings Menu» (figure 18). Select the «Cell Type Mode Configuration»:
2) Select User 1,2 or 3.
3) If needed, define a dedicated name
   - Choose the measurement frequency from the drop down list
   - Press «Save»
   - Choose the background frequency from the drop down list
   - Press «Save»
   - Choose a moving average, between low, middle and high

   The moving average is a mean value over a defined amount of measurements:
   Low: 32 measurements (refers to dual 32 sec scan 96 sec)
   Middle: 64 measurements (refers to dual 64 sec, scan 192 sec)
   High: 128 measurements (refers to dual 128 sec, scan 384 sec)
3) Press «Save».

INCYTE ARC SENSOR OPERATION

10.5.2 Use Sensor Cleaning

The Sensor Cleaning is deactivated per default. It is only required if cell adhesion at the sensor electrodes is noticed. The Cleaning function may reduce the attachment of cells and may be required in few processes, i.e. in long-term cell culture or fermentation of filamentous fungi. Use the cleaning mode with caution and only if adhesion of cells at the platinum electrodes is noticed or suspected. Start with SHORT cleaning time and a long Auto-Cleaning Period, at least 12 h. Increase cleaning time / decrease the Auto-Cleaning Period only if no improvement is observed.

10.5.2.1 Manual Sensor Cleaning

NOTE: Manual cleaning can be performed at a specific time in the culture as described here, or as cleaning procedure in saturated sodium sulfite solution to maintain a clean electrode prior to a cultivation (see chapter 12.2.2).

1) Go to the «Process Settings».
2) Select «Manual Sensor Cleaning» (figure 19).
3) Choose between short (10 seconds) and long (100 seconds) cleaning.
4) Press «Start».

NOTE: No measurement is available during cleaning.

10.5.2.2 Automatic Sensor Cleaning

1) Go to the «Process Settings».
2) Select «Automatic Sensor Cleaning» (figure 19).
3) Enable automatic sensor cleaning.
4) Choose between short (10 seconds) and long (100 seconds) cleaning.
5) Define the repetition rate (the time where a cleaning is done) in hours. The shortest rate is 1 cleaning per hour.
6) Press «Save».

NOTE: Measurements are unavailable during the cleaning cycle.

11 Functionalities of ArcAir for Mobiles

NOTE: Sensor configuration on the mobile requires the Arc Wi 2G BT adapter (REF 243470). The configuration is essential, if the sensor is integrated, e.g. by 4-20 mA and actions like «mark zero» or «inoculate» have to be performed.

Following functionalities are implemented in the advanced ArcAir Mobile version:

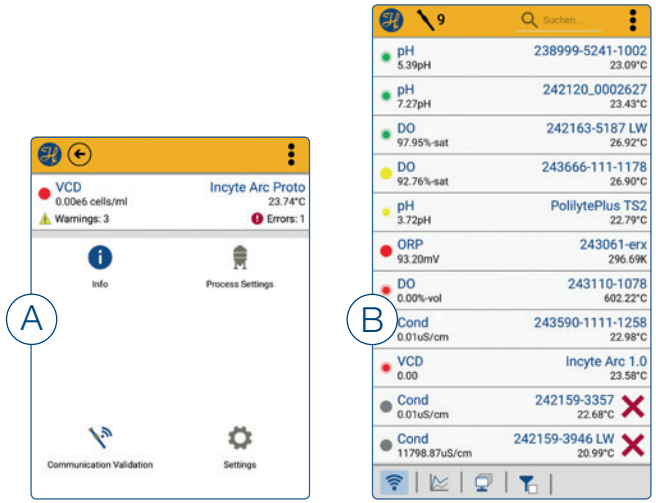


Figure 25: Sensor Quick View (B) and Status (A)

- Checking the sensor information
- Adjusting the Process Settings
- Validate the Communication
- Manage the Sensor Settings

FUNCTIONALITIES OF ARCAIR
FOR MOBILES

11.1 Check the Sensor Information

1) Select the sensor from the sensor list.
2) Select «Info».
3) In the sensor Quick View (figure 25), the status, measurement value, measurement point, information and User space are accessible.

11.2 Adjusting the Process Settings

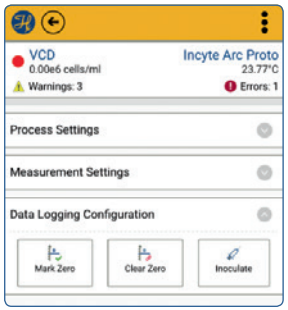


Figure 26: Sensor Settings

In the Sensor Settings (figure 26), the process settings and measurement settings can be adjusted.

11.2.1 Select the Cell Type Mode

1) Select the sensor from the sensor list.
2) Select «Measurement Settings» (figure 26).
3) Go to the cell type mode drawer and select the cell type .
4) Press «Save».

11.2.1.1 Define a Custom Cell Type Mode

Please see chapter 10.5.1.

11.2.2 Perform a Product Calibration on Mobile

1) Select the sensor from the sensor list.
2) Select «Process Settings» (figure 26).
3) Go to «Data Logging Configuration».
4) Press «Mark Zero», or «Clear Zero», to perform a new or delete the last product calibration.

11.2.3 Set the Inoculation Time on Mobile

⚠ ATTENTION! If using an ArcAir Data Model, the event «Inoculation» starts the calculation of the model on the sensor and is therefore highly important to be marked.

1) Select the sensor from the sensor list.
2) Select «Process Settings» (figure 26).
3) Go to «Data Logging Configuration».
4) Press «Inoculate».

11.3 Validate the Communication

1) Select the sensor from the sensor list.
2) Select «Communication Validation».
3) Select to Validate, or Adjust the mA Setting, or the Modbus Communication and follow the instructions on the screen.

11.4 Manage the Sensor Settings

See chapter 10.4.1.

12 Incyte Arc Sensor Maintenance

12.1 Daily Maintenance

Periodic maintenance routines need to be run in order to ensure safe and reliable operation and measurement of Arc sensors and accessories.

⚠ ATTENTION! Avoid any contact of the equipment with corrosive media.

1) Connect the Incyte Arc sensors by using the Arc USB Power Cable on a standard USB port (see chapter 9.7).
2) Control the status in the Sensor Quick View or sensor list (figure 27).
3) Please refer to the troubleshooting section (see chapter 16.1) to interpret the status.
4) Control the quality of the sensor under Info «Quick View» (figure 25).

The sensor is performing correctly.
No errors or warnings have been registered.

At least a warning has been registered.
Verify the sensor warnings in Sensor Status.

At least an error has been registered.
Verify the sensor errors in Sensor Status.

Offline

Figure 27: Description of the traffic lights on the ArcAir.

NOTE: Quality Indicator – The quality indicator provides infotmation about the measurement performance rated between 100 and 30 %. At every verification the integrity of the sensor is checked at the relevant frequencies and aligned to the upper and lower acceptance limit. If the quality indicator stays below 30% after cleaning please contact Hamilton Technical Support.

12.2 Maintenance after every bioprocess

12.2.1 Sensor Verification

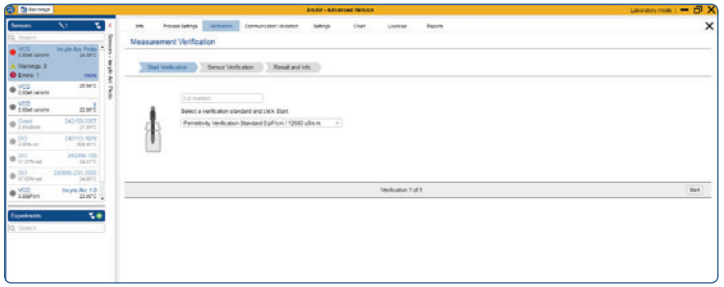


Figure 28: Sensor Verification

NOTE: The Hamilton 12880 µS/cm Conductivity Standard (REF 238988) is needed to perform the Sensor Verification.

NOTE: To run a Sensor verification ArcAir Advanced is required.

NOTE: During the verification procedure the dual frequency measurement as well as the scan are analyzed to check the purity and consistency of the electronics. The verification may influence the sensor quality indicator.

1) Start ArcAir and connect the Incyte Arc sensors with the power supply, e.g. by using the Arc USB Power Cable on a standard USB port (see chapter 9.7) and equilibrate for at least 30 minutes prior to starting the Sensor Verification procedure.
2) Go to the «Verification» (figure 28).
3) Optionally add the Lot number of the buffer.
4) The verification Standard is pre-defined and refers to the Hamilton Conductivity standard (REF 238988).

INCYTE ARC SENSOR MAINTENANCE

5) Insert the sensor in the standard ensure a proper mounting in a stand (figure 14), pour the standard in a beaker to ensure enough space around the sensor tip. Try to avoid air bubbles around the tip.
6) Press «Start», the sensor will now equilibrate for 120 sec. (figure 29).
7) In case impurities are detected on the electrodes a cleaning will be recommended and the sensor quality indicator will decrease (see chapter 12.2.2).
8) Perform a cleaning and run the verification again.
9) The successful verification is shown, in case the verification was not successful press done and try again once (figure 30).
10) Press «Save Report».

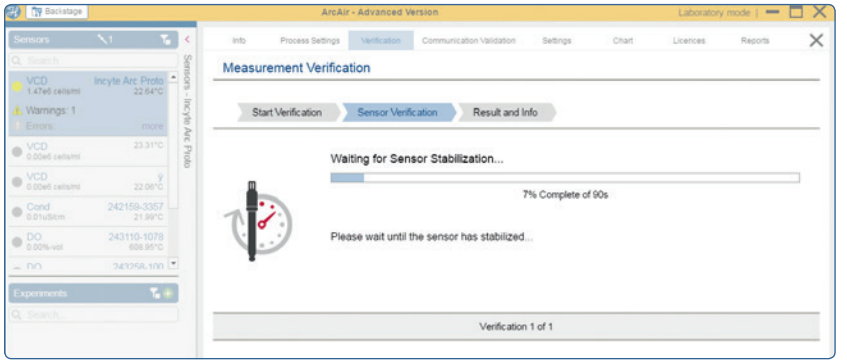


Figure 29: Sensor Stabilization

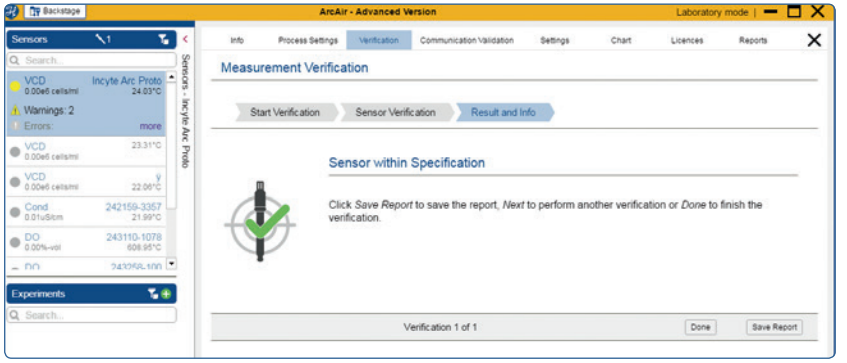


Figure 30: Succesfull Sensor Verification

12.2.2 Manual Cleaning

1) After decontamination, immerse the PEEK sensor tip in saturated Sodium Sulfite (Na2SO3) solution.
2) Go to the «Process Settings».
3) Select «Manual Sensor Cleaning».
4) Select «Long cleaning».
5) Press «Start».
6) Connect the Incyte Arc sensor with the power supply, e.g. by using the Arc USB Power Cable on a standard USB port.
7) Remove the Sensor from the solution and rinse the residual sodium sulfite with deionized water.
8) Perform the «Sensor Verification» (see chapter 12.2.1).

12.3 Yearly Maintenance

NOTE: No preventive maintenance like calibration required.

12.3.1 Software Update

1) Please check our Homepage www.hamiltoncompany.com/process-analytics/accessories/communication-and-controllers/arc-software-and-accessories/arcair-software for new updates if available: save the file on an USB or the required PC.
2) Please perform an installation (see chapter 9.3).

12.4 Transfer Licenses

The sensor comes equiped with the licenses ordered and is ready-to-use.
In case the sensor lifetime is at the end the license can be transferred to one new sensor.

12.4.1 Identify the Sensor ID

1) Go to «Info Settings» and select «Information».
2) Check the sensor ID (figure 31).

INCYTE ARC SENSOR MAINTENANCE

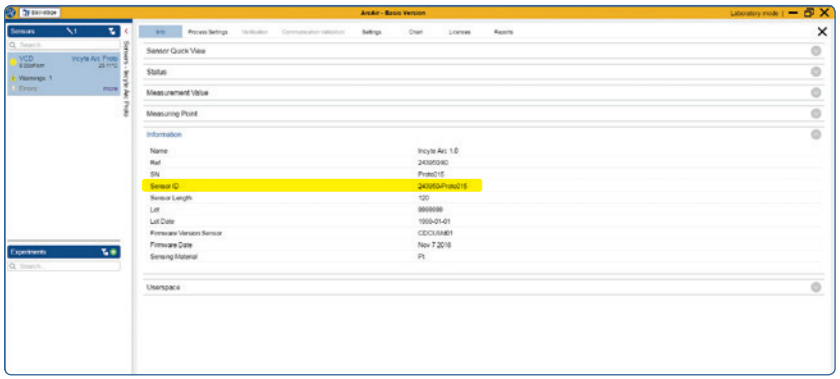


Figure 31: Identify the sensor ID

12.4.2 Create a Transfer License

NOTE: Once the transfer license is created, the corresponding license is deleted from the sensor.

⚠ ATTENTION! Prior to creating a transfer license connect the target sensor for the license to ArcAir so that the Sensor ID is saved by ArcAir.

1) Connect the new sensor and select it in the sensor list.
2) Got to the «Licenses Menu» (figure 32).
3) Select «Create Transfer License».
4) Select the sensor for transfer the license to at the target sensor.
5) Select the licenses to transfer.
6) Define the path to save the transfer license file.
7) Click «Create Transfer License».
8) Import the license on the new sensor (see chapter 12.4.3).

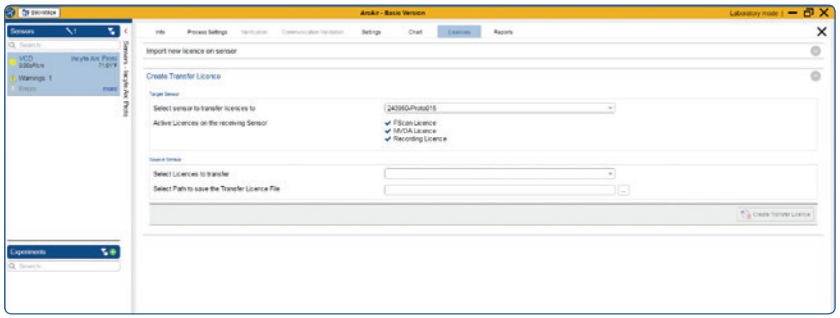


Figure 32: Transfer License creation

12.4.3 Import a new License

1) Go to the «License Settings» and select «Import a new license».
2) Select the corresponding license file «.ini» and press import (figure 33).

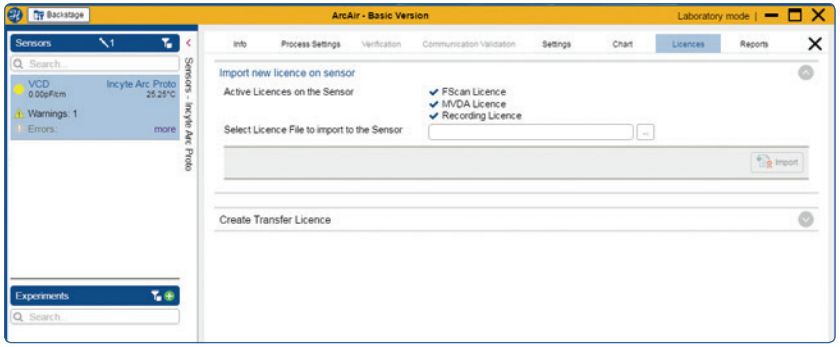


Figure 33: License Import

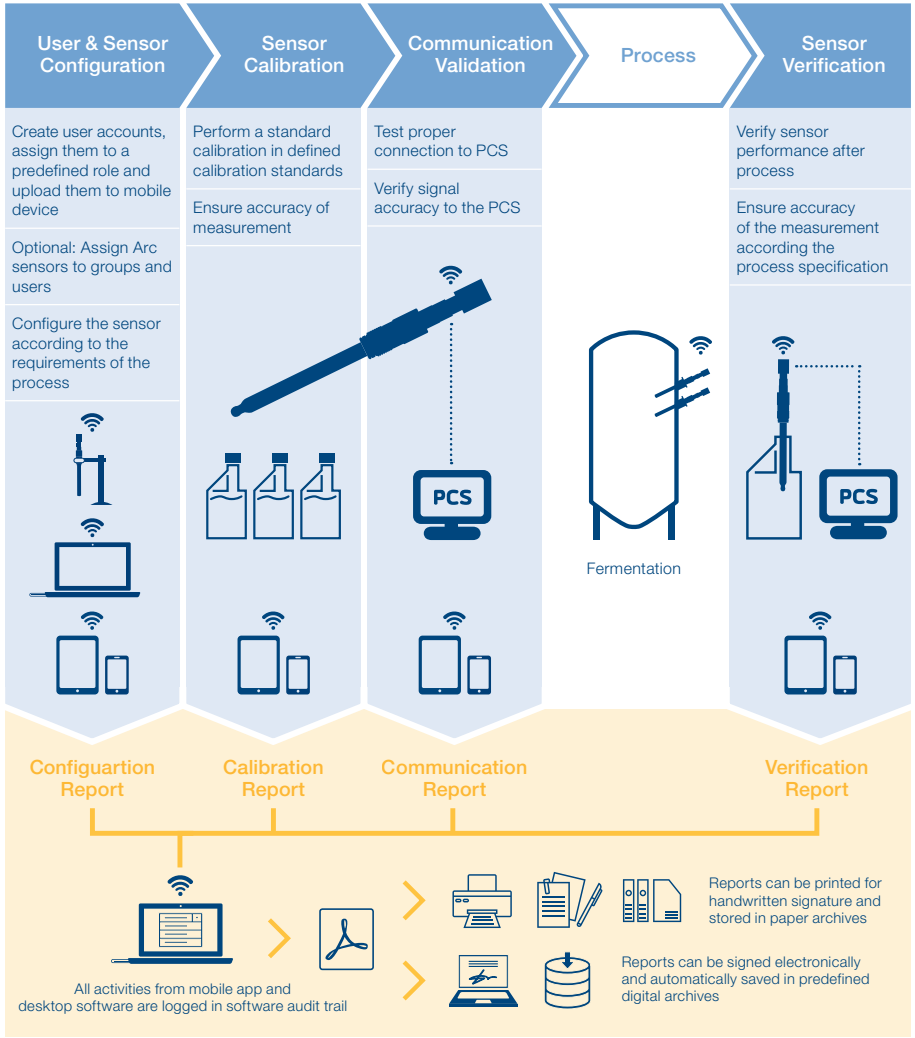
12.4.4 Perform a FW Update on Arc Sensors, Wireless Converter and Wi Adapter

1) Go to «Backstage».
2) Select the «Firmware».
3) Select Arc Sensors, Wireless Converters, Wi Adapter.
4) Follow the written procedure.

13 GMP for Incyte Arc

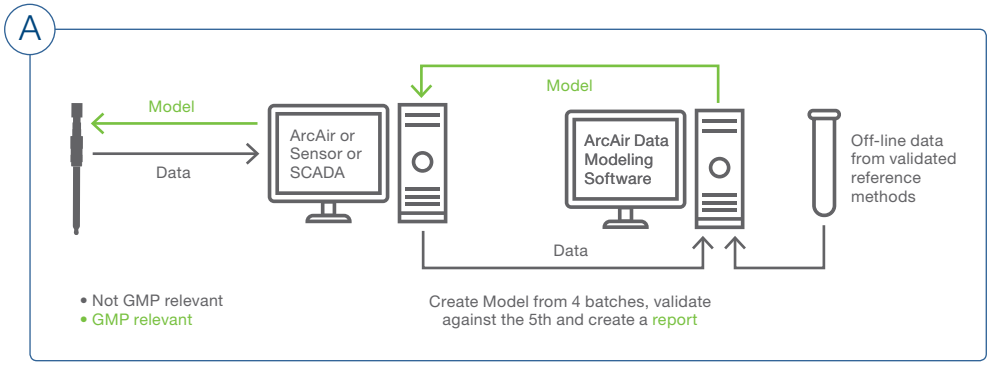
Below the validation process of Arc sensors in GMP environments or laboratory:

Laboratory and Production



Office

For performing an ArcAir Data Model the workflow is summarized in Figure 34 and described in detail in chapter 19. The Data is recorded on the sensor or in ArcAir/SCADA, exported to the Arc Data Modeling Software, where the model is created using Incyte Arc on-line data and the off-line data of the reference method. The model is the transferred from ArcAir Data Modeling to ArcAir and imported to the sensor.



The correlation between on-line and off-line data at the process end is not «per se» GMP relevant. The use of correlation models developed with ArcAir Data Modeling to perform on-line measurement of cell density during the process is GMP relevant. The correlation at process end is performed in the ArcAir Data Modelling Software. It is the user's decision to transfer a specific model onto a sensor for routine measurement, after its validation. This transfer is performed only via ArcAir. Therefore Arc Air records the GMP relevant actions as indicated in figure 34 electronically.

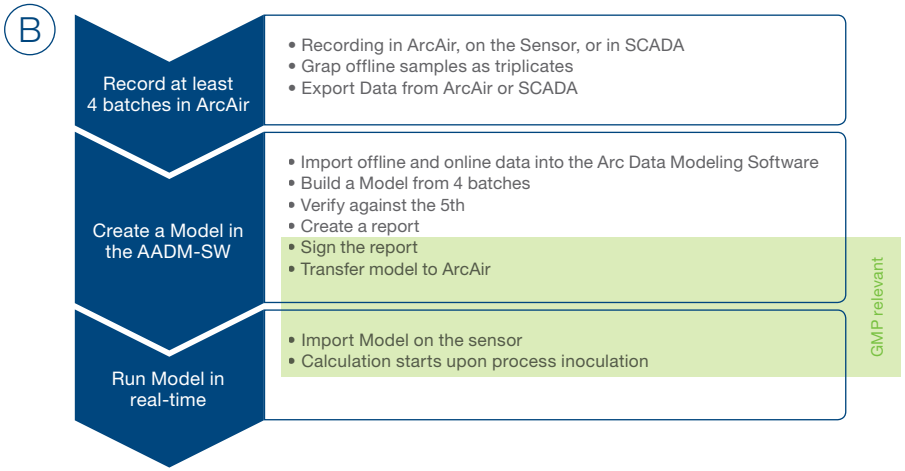


Figure 34: ArcAir Data Modeling Overview (A) and Procedure (B)

13.1 CFR 21 Part 11 and Eudralex Annex 11 Compliance

Arc sensors with ArcAir Advanced constitute a computerized system ready for compliance with FDA CFR 21 Part 11 and Eudralex Volume 4 Annex 11 guidance. This is valid for all the GMP relevant entries and actions performed by Arc system users as described in this manual.

13.1.1 Audit Trail

In compliance with CFR 21 Part 11 and similar EU Annex 11 recommendations, ArcAir enables the use of a secure, computer-generated, time-stamped audit trail to independently record the date and time of users entries and actions that create, modify or delete electronic records. The Audit Trail is automatically generated and can be viewed by every user, independently from the user's roles described in chapter 9.5.

In order to view the ArcAir audit trail:

1) Start ArcAir on computer.
2) Log in with user name / password.
3) Click on «Backstage» left upper corner.
4) Select «Audit Trail».

⚠ ATTENTION! In order to enable complete traceability of all GMP relevant actions, no user is enabled to edit the ArcAir audit trail.

In ArcAir the GMP relevant operator entries and actions are defined as «Events». As per example in the Fig. 7, each event is tracked by:

- Timestamp
- Event Name
- User Name
- Measuring Point
- Information (event details)
- Source (desktop or mobile)
- Comments (e.g. unsuccessful validation)

GMP FOR INCYTE ARC

The complete list of the events recorded in the ArcAir Audit-trail are:

GMP event's group	Event logged in Audit trail
User Roles Management	Adding a role Editing a role Deleting a role Create a user Edit a user Inactivate a user Assign role to a user
Process Groups Management	Create a process Edit a process Delete a process
System Management	Change of language Synchronization mobile-desktop Backup of database
Electronic Signature	Electronic signature
Sensor management	Communication validation Product Calibration (Mark and Clear Zero) Calibration (done by Hamilton Technician) Verification Product calibration Sensor settings changes Firmware update Importing a configuration profile Changes to «Process Settings» Changes to «Communication validation» Changes to «Information» Single-use sensors calibration data saving
Sensor Setting Changes	Inoculate Manual Cleaning Automatic Cleaning Activated - «Duration: short (10 seconds)» or «Duration: long (100 seconds)» - Repetition rate: {hours} hours Automatic Cleaning Deactivated Scan Turned On and Off Model Transfer Model Activated Model Deactivated Licence Import Licence Transfer Incyte Data Logging Started and Stopped Data Logging on the Sensor (start and stop)

Specific information logged into the audit trail can be searched compiling the «Search» field identified by the magnifier lens and choosing the appropriate «Search Column» drop-down menu.

⚠ ATTENTION! In compliance with CFR 21 Part 11/ Eudralex Volume 4 Annex 11, it is responsibility of the end-user to validate all Arc sensors, desktop computers and mobile devices intended to be used in GMP environments. System validation and maintenance should be compliant to standard computerized system lifecycle steps comprising: Design Qualification, Installation Qualification, Operation Qualification and Performance Qualification. At the same time, it is also the sole responsibility of the end-user to operate Arc sensors only with validated computer, mobile devices and/or any other computerized system intended to be used for Arc sensors management. If other software tools are used (e.g PCS, HDM), the user is responsible to validate and document the changes according to their own internal procedures.

13.1.2 Transfer Audit Trail Entries

User's entries and actions performed with mobile devices are logged in the Audit Trail as soon as a synchronization between mobile and desktop is performed.

1) Start ArcAir advanced on the mobile device.
2) Go to «Backstage» in the computer version and select «Mobile Connection».
3) Follow the instruction on screen to connect the computer and the mobile device.
4) Click on «Fetch Audit Trail» on bottom left corner.
5) Verify Audit Trail entries as described in 13.1.1.

⚠ ATTENTION! It is strongly recommended to regularly synchronize the audit trail entries from all validated devices in order to ensure full traceability of GMP events. The audit trail records every time a synchronization is performed, in order to support full traceability of the regular execution of this action.

13.1.3 ArcAir Database

Arc system is a closed computerized system. All the GMP relevant electronic records mentioned in chapter 13.1.1 can be accessed only by authorized users. Such users log-in the system tough a unique combination of user-name and password as described in chapter 9.9 and their actions are tracked in the audit trail as explained in chapter 13.1.1. The audit trail, user's accounts and all the others GMP relevant electronic records are saved in ArcAir SQL Lite database.

The database is secured and can be accessed only through ArcAir software. After the software installation it is automatically placed in C:\ProgramData\HAMILTON\ArcAir. Administrators can manage the database performing operations such as «database backup» or «database change» to older backups (equal to function «database restore»). Administrators can change the path where the database is saved, as well.

In order to access the database management:

1) Start ArcAir on computer.
2) Log in with Administrator user name / password.
3) Click on «Backstage» left upper corner.
4) Select «Settings».
5) Select «Database».
6) Perform the required operations.

13.1.4 ArcAir Data Modeling Software

When using the ArcAir Data Modeling Software the GMP relevant parts are tracked in ArcAir, please refer to figure 34 for details. The GMP relevant parts are indicated in green and have to be approved and released by at least one specific user.

The relevant data is recorded or exported via ArcAir and has to be imported into ArcAir Data Modeling Software. Here the Model is built and validated. After validation the model is defined by creation date and time as well as s checksum. This checksum works by hash and salt identification and ensures that the data was not changed between model-export from ArcAir Data Modeling onto the sensor via ArcAir.

14 ArcAir Settings Section

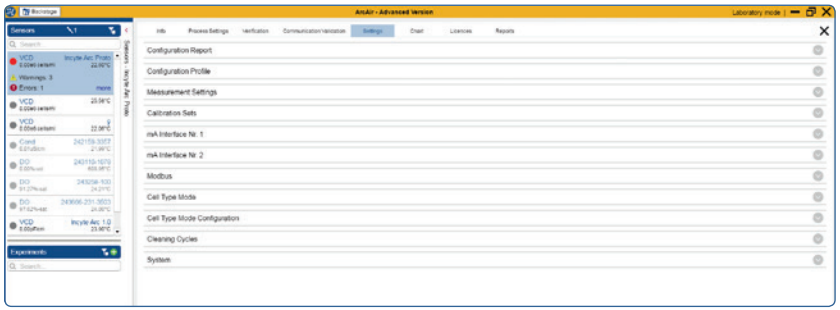


Figure 35: Sensor Settings Overview

The Setting Section in ArcAir comprises all required sets to configure a sensor.

Besides the Measurement Settings, Cell Type Mode and Cell Type Mode configuration, which are described in chapter 10, it is possible to arrange the 4–20 and Modbus communication.

Additionally the configuration report and profile can be exported (see chapter 9) and the sensor reset to factory settings.

It is also possible to define the Cleaning cycles conditions.

14.1 Definition of the Modbus Communication in ArcAir

1) Go to the «Measurement Settings» (figure 35).
2) Open «Modbus»
3) Adjust, Device Address, Baudrate, Parity and Stopbits according to the needs (see chapter 15.2).
4) Press «Save».

NOTE: Following values are the standard:
Device Address: 1; Baudrate: 19200, Parity: None, Stopbit:2

14.2 Definition of the 4-20 mA Output in ArcAir

NOTE: Please see chapter 15.1 for the details of the 4–20 mA connection of the sensor.

NOTE: The Arc View 2 G Adapter BT (REF 243470) is required to get a 4–20 mA signal.

1) Go to the «Measurement Settings» (figure 35).
2) Open the «mA Interface Nr 1».
3) Select between 4 to 20 mA linear (standard), fixed, or off mode.
4) Define the assigned measurement channel, you can choose between the viable cell density (which is the raw permittivity signal, of no product calibration, or cell factor is defined), the conductivity or temperature.
5) Define the value at 4 and 20 mA.
6) Select the warning mode between off (standard) and continuous warnings.
7) Select the error mode between off and continuous errors (standard).
8) Define the mA error Value.
9) Define the temperature out of range value.
10) Press «Save».
11) Repeat steps 2 to 10 for the «mA Interface Nr 2».

14.3 Reset the Sensor

1) Go to the «Measurement Settings» (figure 35).
2) Open «System».
3) Activate «Restore of Factory Settings» and press «Save».

14.4 Define the Sterilization Cycle Conditions

To automatically count the SIP and CIP cycles the conditions can be defined. SIP and CIP definitions are set as standard, but can be customized. The standard settings are for SIP a temperature between 120 and 140 °C for a duration of 20 minutes and CIP between 80 and 100 °C over 20minutes.

1) Go to the «Measurement Settings» (figure 35).
2) Open «Cleaning Cycles».
3) Define the minimal and maximal temperature, as well as duration of the SIP and/or CIP cycle.
4) Press save.

14.4.1 Increase the number of Autoclavings

As it is not possible to increase the autoclavation cycles automatically, the cycles can be monitored manually.

1) Go to the «Measurement Settings» (figure 35).
2) Open «Cleaning Cycles».
3) Increments the number of autoclavings, once they are done and press save.

15 Connection to the Process Control System

The mechanical design of the Incyte Arc sensor is compatible with all Hamilton process housings, including FlexiFit, Retractex, RetractoFit and Hygienic Sockets. Before installing the armatures, you should test that the seal is tight and the parts are all in working order. Ensure that there is no damage to the sensor or the armature. Check whether all O-rings are in place in the appropriate grooves and are free of damage. To avoid any mechanical damage to O-rings on assembly, they should be slightly greased.

Please note that O-rings are wetted parts and greasy compounds must comply to your FDA application needs.

15.1 VP 8 or M12 Pin Designation

Always use Hamilton VP8 or M12 sensor cables for safe connections, which are available in different lengths (3m REF 355320 / 5m REF 355221).

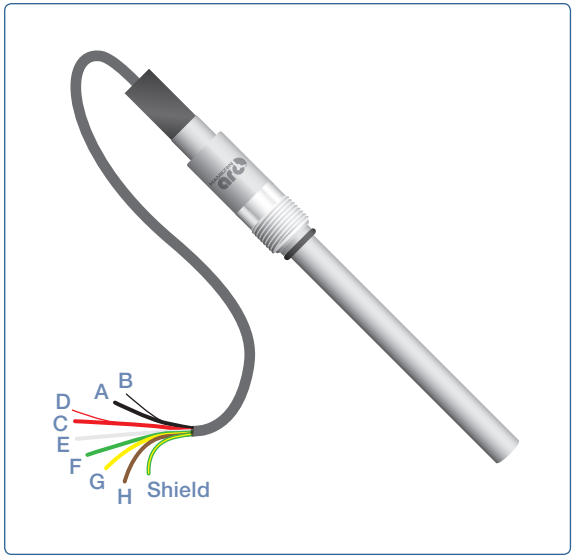


Figure 36: Arc sensor with VP8 double coaxial open end cable

VP Pin	Function	Color Double Coaxial Cable	Color Data Cable
A	4–20 mA interface (mA interface 2) > only if Arc Wi 2 G Adapter is connected	Coaxial core black transparent	Yellow
B	4–20 mA interface (mA interface 1) > only if Arc Wi 2 G Adapter is connected	Coaxial shield black	Green
C	Power supply: +24 V ± 10 %	Coaxial core red transparent	Red
D	Ground	Coaxial shield red	Blue
E	Temperature sensor	White	Brown
F	Temperature sensor	Green	White
G	RS485 A	Yellow	Gray
H	RS485 B	Brown	Pink
Shaft	Sensor shaft connected to earth	Green/Yellow	Green/Yellow

CONNECTION TO THE PROCESS CONTROL SYSTEM

M12 (A coded) Pin Designation with Respect to Hamilton M12 Sensor Cable Conductor Colors:

M12 Pin	Function	Color	Description
1	+4-20 mA # 1	White	4-20 mA two-wire interface, functions as a current sink and needs to be powered. It regulates the input current according to the sensor measurements and galvanically isolated from the power supply.
2	-4-20 mA # 1	Brown	
3	+4-20 mA # 2	Green	
4	-4-20 mA # 2	Yellow	
5	RS485 (A)	Gray	Modbus RTU RS485
6	RS485 (B)	Pink	Modbus RTU RS485
7	GND	Blue	Ground
8	+ 24 VDC	Red	Power supply: +24 V ± 10 % (Power supply can be external; not from PCS)
Housing	Shield	Green/Yellow	Connected to the housing including the VP8 female connector.

15.2 Connect via 4-20 mA

NOTE: Arc Wi 2G Adapter (REF 243470) is required to output an analog 4-20 mA signal from the digital Modbus communication.

15.2.1 Electrical Connection for Analog 4-20 mA Connection

The 4–20 mA interface enables indirect connection of the Incyte Arc sensor to a data recorder, indicator, control unit or PCS with analog I/O. Incyte Arc requires the Arc Wi Adapter 2G (REF 243470). In combination with the Arc Wi Adapter the sensor works as a current sink sensor and is passive. Connect the sensor according to the pin designations (see chapter 15.1). The 4–20 mA interface of the combination between Arc Wi Adapter and Arc sensor is pre-configured with default values for the 4–20 mA range, and measurement unit. Configure the 4–20 mA interface according to your requirements for proper measurement (see chapter 14.2).

CONNECTION TO THE PROCESS CONTROL SYSTEM

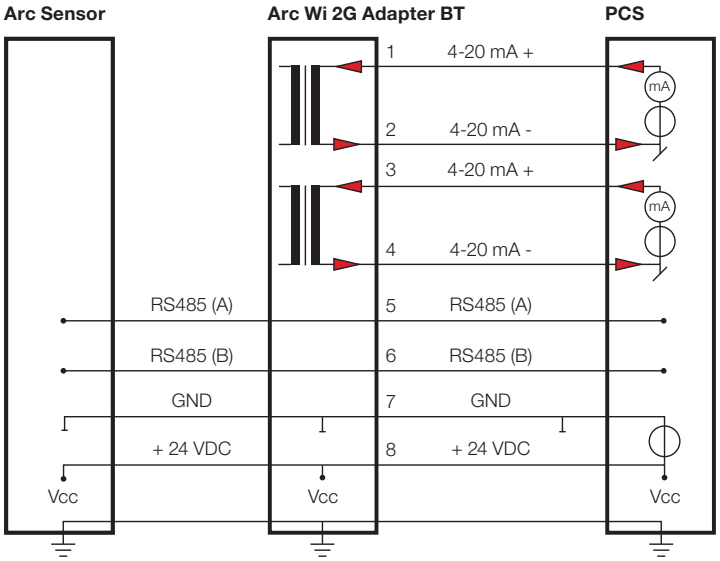


Figure 37: Typical connection to PCS using the Arc Wi 2G Adapter BT. This is the safest form of wiring an Arc sensor. The Arc Wi 2G Adapter BT provides internal galvanic isolators for enhanced analog signal quality. Connection to the PCS is simplified. Connection to the process control system is simplified.

15.3 Connection by Modbus

15.3.1 Electrical Connection for the Digital RS485 Interface

The digital RS485 interface enables communication with Arc sensor for performing measurements and monitoring the sensor status of the Arc sensor and for changing the sensor's configuration parameters.

Arc sensors are always connected to digital controlling devices as a Modbus slave. To function, they require a power supply (VP 8 pins C and D, see above). The section entitled «Configuring the Arc sensor parameters» describes operation in digital mode.

Additional information:

The Modbus RTU communication protocol corresponds to the Modbus-IDA standard (see www.modbus.org). Arc sensors use an open register set developed by Hamilton. Additional information about the register content and structure can be found in this chapter The Modbus physical layer is described in detail with requirements on cabling and line termination in the «Modbus Serial line Protocol and Implementation Guide» www.modbus.org > Technical Resources / Modbus Specifications / Modbus Serial line Protocol and Implementation Guide.

⚠ ATTENTION! Because all sensors are delivered with factory-default settings, each sensor must be configured for its specific application before first use (see the section entitled «Configuring Arc Sensors»).

In an electromagnetically noisy environment, it is advisable to connect the VP cable shield to the earth. This significantly improves noise immunity and signal quality.

Example of circuit arrangement

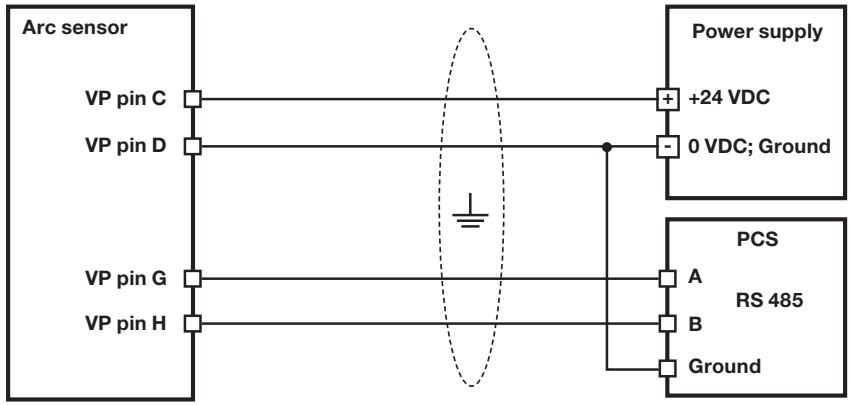


Figure 38: Wiring diagram for the RS485 interface

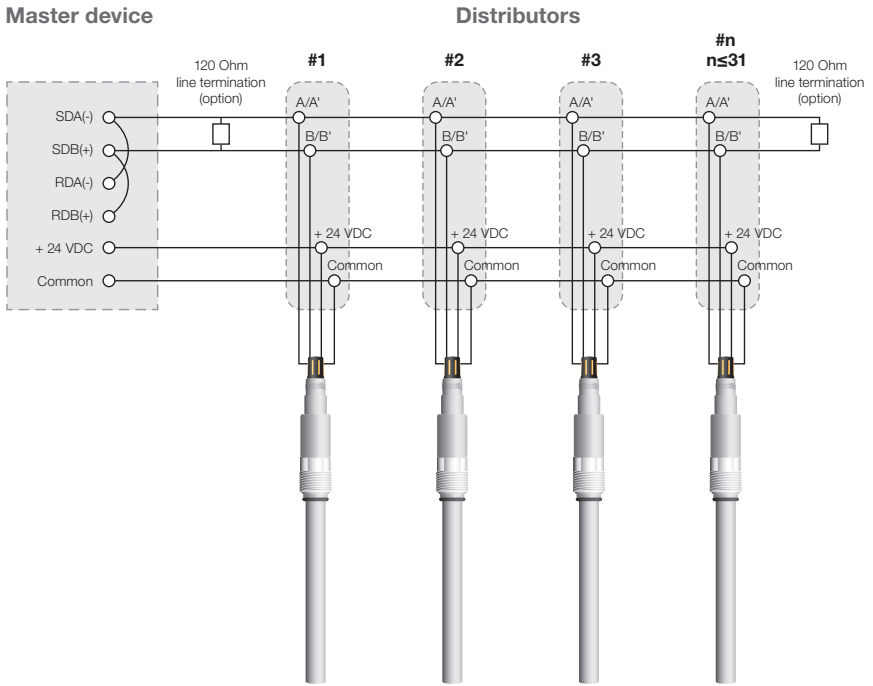


Figure 39: Multi-drop bus wiring for the Modbus two-wire mode. Each sensor functions as a Modbus slave

NOTE: In order to avoid signal reflection on the lines the use of line termination resistors (120 Ohm each) is recommended. The effect of signal reflections becomes more relevant with long cable length and/or high baud rates.

NOTE: In the connection scheme shown above, each sensor must have the unique Modbus device address for proper communication.

The serial Modbus connection between the RS485 port of the master and the corresponding interfaces of the sensors has to be ensured according to the EIA/TIA RS485 standard. Only one sensor can communicate with the master at any time.

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.2 Modbus RTU General Information

Introduction

This document describes in detail the Incyte Arc Sensors Modbus RTU interface. It is addressed to software programmers.

The general information about Modbus command structures and its implementation in the Hamilton Arc Sensor family is described in detail in Chapter 1 of the «VisiFerm DO Modbus RTU Programmer's Manual» (REF 624179). If you need this general information about Modbus programming, then please consult REF 624179.

In the present manual, only the specific command structure for the Incyte Arc Sensors is described. It is valid for the firmware version:

- CDCUM001

Please check the software version by reading register 1032.

This present definition of the command structure is an additional document to the Operating Instructions of the specific Incyte Arc Sensors. Before reading this manual, the operating instructions of the sensors should be read and understood.

15.3.3 Default Modbus Interface Configuration

The Incyte Arc Sensor communicates via a RS485 interface. Because of its higher data throughput compared to other Arc Sensors, the Incyte Arc Sensor is running at 19200 Baud by default.

The default interface configuration is as follows:

Start Bits	1
Data Bits	8
Parity	None
Stop Bits	2
String length	11 Bits
Baud Rate	19200
Device address	1

15.3.4 Modbus RTU Error Messages

Here are listed the Modbus standard error-codes that are implemented in Arc Sensors.

Error-Code Hex	Status-Text
0x00	OK
C0x01	Illegal function
0x02	Illegal data address
0x03	Illegal data value
0x04	Slave device failure

See «Modbus_Application_Protocol_V1.1b» (www.modbus.org) for details.

If a slave device failure exception occurs, try to repeat the command that has thrown the exception. If the exception remains, check the sensor status.

15.3.5 Incyte Arc Sensor Commands in Modbus RTU

15.3.5.1 General

In order to communicate with an Incyte Arc Sensor over Modbus RTU protocol a Modbus master terminal application software is needed. The Modbus RTU is an open standard and a number of free and commercial application toolkits are available.

⚠ ATTENTION! In the present manual the addressing of the Modbus registers starts at 1. But the Modbus master protocol operates with register addresses starting at 0. Usually, the Modbus master software translates the addressing. Thus, the register address of 2090 will be translated by the Modbus master software to 2089 which is sent to the sensor (Modbus slave).

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.6 Operator levels and Passwords

15.3.6.1 Reading / Setting Operator Level

An Incyte Arc Sensor can be operated at three different operator levels. Each operator level allows a defined access to a specific set of commands.

Abbreviation	Description	Code (hex)	Password (decimal)
U	User (lowest level)	0x03	none (any value)
A	Administrator	0x0C	18111978
S	Specialist (highest level)	0x30	16021966

At each power up or processor reset, the operator level falls back to the default level U.

The active operator level can be read and written in register 4288.

Start register	4288
Number of registers	4
Reg1 / Reg2 (uint)	Operator Level Code
Reg3 / Reg4 (uint)	Password
Modbus function code	3, 4, 16
Read access	U/A/S
Write access	U/A/S

⚠ ATTENTION! If the password is wrong, the operator level falls back to User level U. To make sure that operator level switch was successful, read back register 4288.

15.3.6.2 Changing Passwords for Operator Level

The passwords for accessing the operator levels A and S can be modified by S (Specialist) only. U (User) and A (Administrator) have no right to change any password. If they try anyway, an illegal data address exception (0x02) is returned.

The new password will remain stored after power down.complete Measuring Loop.

Start register	4292
Number of registers	4
Reg1 / Reg2 (uint)	Level
Reg3 / Reg4 (uint)	New password
Modbus function code	16
Read access	None
Write access	S

15.3.7 Configuration of the serial RS485 Interface

Factory settings for the RS485 interface:

Start Bits	1
Data Bits	8
Parity	None
Stop Bits	2
Baud Rate	19200

15.3.7.1 Device Address

15.3.7.1.1 Reading and Writing the Device Address

The sensor specific device address can be read and written in register 4096.

Start register	4096
Number of registers	2
Reg1 / Reg2 (uint)	device address
Modbus function code	3, 4, 16
Read access	U/A/S
Write access	S

CONNECTION TO THE PROCESS CONTROL SYSTEM

The device address can be set by S (Specialist) only, default value is 1. If the address limits are not met when setting a new address, the former address stays active.

⚠ ATTENTION! The device address changes immediately, what means that the next Modbus access has to be done using the new address!

15.3.7.1.2 Reading the Device Address Limits

The device address limits can be read in register 4098.

Start register	4098
Number of registers	4
Reg1 / Reg2 (uint)	Min. device address
Reg3 / Reg4 (uint)	Max. device address
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Device address limits for Incyte Arc are:

- Minimal device address: 1
- Maximal device address: 32

15.3.7.1.3 Broadcast

Independent from the selected device address, the Incyte Arc sensor responds to broadcasted Modbus commands (address 0).

15.3.7.2 Baud Rate

Reading and Writing the Baud Rate.

The baud rate can be read and written in register 4102.

Start register	4102
Number of registers	2
Reg1 / Reg2 (uint)	Baud rate code (definition see below)
Modbus function code	3, 4, 16
Read access	U/A/S
Write access	S

The code for the baud rate is defined as follows:

Baud rate	19200	38400	57600	115200
Code	4	5	6	7

Code for the baud rates

The baud rate can be set by S (Specialist), default is 19200.

⚠ ATTENTION! If the baud rate limits are not met when setting a new baud rate, the former baud rate stays active. The baud rate does not change before the next power up!

15.3.7.2.1 Reading the Baud Rate Limits

The baud rate limits can be read in register 4104.

Start register	4104
Number of registers	4
Reg1 / Reg2 (uint)	Min. Baud rate code
Reg3 / Reg4 (uint)	Max. Baud rate code
Modbus function code	3, 4
Read access	U/A/S
Write access	none

CONNECTION TO THE PROCESS CONTROL SYSTEM

The baud rate limits for Incyte Arc are:

- Minimal baud rate code: 4
- Maximal baud rate code: 7

15.3.7.2.2 Parity and Stop Bits

Start register	4108
Number of registers	2
Reg1 / Reg2 (uint)	Interface parameter
Modbus function code	3, 4, 16
Read access	U/A/S
Write access	S

The interface parameter is coded as following:

0xAABBCCDD where

- AA = no meaning (reading: 0x00)
- BB = Parity (0x00: no parity, 0x01: even, 0x02: odd)
- CC = Stop bits (0x00: 1 stop bit, 0x04: 2 stop bits)
- DD = no meaning (reading 0x00)

The interface parameters do not change before the next power up!
When writing to register 4108 set Bytes AA and DD to 0x00.

⚠ ATTENTION! If one of the parameter limits is not met, the old configuration stays active! Parity option (even or odd) is only available with one stop bit (max. string length of 11 bits). The configuration does not change before the next power up! Configuration of the Analog Interfaces.

NOTE: Incyte Arc does not have any analog interfaces itself. They are provided by an Arc Wi 2G adapter. But the registers to configure these interfaces are available on the Incyte Arc sensor. That means, that these registers can be read and written with or without Arc Wi adapter!

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.3 Configuration of the Analog Interface

15.3.7.3.1 Available Analog Interfaces

Equipped with an Arc Wi 2G Adapter, the Incyte Arc Sensor has two individual physical analog interfaces that have identical functionalities, but can be configured independently from each other.

- Analog Output Interface 1 (AO1)
- Analog Output Interface 2 (AO2)

The number of analog interfaces is defined in register 4320.

Start register	4320
Number of registers	2
Reg1 / Reg2 (uint)	Available analog interfaces
Modbus function code	3, 4
Read access	U/A/S
Write access	none

The answer always is «0x03» meaning that there exists an Analog Interface 1 (AO1) and an Analog Interface 2 (AO2).

15.3.7.3.2 Available Analog Interface Modes

With register 4322, the available analog interface modes for AO1 and AO2 are defined

Start register	4322
Number of registers	8
Reg1 / Reg2 (uint)	Available Analog Interface Modes for AO1
Reg3 / Reg4 (uint)	Available Analog Interface Modes for AO2
Reg5 / Reg6	reserved
Reg7 / Reg8	reserved
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 4322 defines the analog interface modes available for AO1 and AO2. The analog interface modes are described in chapter 15.3.7.3.5.2.

Code (Hex)	Analog Interface Mode	Description
0x00	4-20 mA inactive	Analog interface is deactivated
0x01	4-20 mA fixed	Set to a constant output value for current loop testing See 2.4.5.7 Defining a Constant Current Output for Testing
0x02	4-20 mA linear	Linear output of measurement (PMC1 / 2 / 6)

The answer is a bitwise combination (OR) of the available modes defined in chapter 15.3.7.3.5.2.

Reg1/Reg2 and Reg3/Reg4 always return «0x03» meaning that fixed and linear mode are available. Reg5 to Reg8 return 0.

How to select or change the analog interface mode, see 15.3.7.3.4 Selection of an Analog Interface Mode.

15.3.7.3.3 Description of the Analog Interfaces 1 and 2

Register 4352 / 4480 contain the descriptions of AO1 / AO2 as plain text ASCII:

Start register	4352	4480
Number of registers	8	8
Reg1 to Reg8 (16 ASCII characters)	Description of AO1	Description of AO2
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

15.3.7.3.4 Selection of an Analog Interface Mode

The analog interface mode of AO1 / AO2 is selected by programming the analog interface mode in register 4360 / 4488.

Start register	4360	4488
Number of registers	2	2
Reg1 / Reg2 (uint)	Analog interface mode for AO1	Analog interface mode for AO2
Modbus function code	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S
Write access	S	S

For available interface modes see chapter 15.3.7.33.

Only one bit can be set. Using not allowed interface mode codes will leave the selection unchanged.

15.3.7.3.5 Configuration of the 4-20 mA Interface

NOTE: The configuration of AO1 / AO2 is only effective if register 4360 / 4488 (active analog interface mode) is set to the value 0x01 or 0x02.

15.3.7.3.5.1 Reading the Available Primary Measurement Channels to be Mapped to the Analog Output

Start register	4362	4490
Number of registers	2	2
Reg1 / Reg2 (uint)	Available Primary Measurement Channels for AO1	Available Primary Measurement Channels for AO2
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

Code (Hex)	Primary Measurement Channel (PMC)
0x01	PMC1 (VCD)
0x02	PMC2 (Conductivity)
0x20	PMC6 (Temperature)

Code for selection of the primary measurement channel

Reading the available Primary Measurement Channels (PMC) always return the hexadecimal value of «0x23» meaning that PMC1 (VCD), PMC2 (Conductivity) or PMC6 (Temperature) can be mapped to AO1 respectively AO2.

15.3.7.3.5.2 Selecting the Primary Measurement Channel to be Mapped to the Analog Interface

Start register	4364	4492
Number of registers	2	2
Reg1 / Reg2 (uint)	Selected PMC for AO1	Selected PMC for AO2
Modbus function code	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S
Write access	S	S

Write this register to change the mapped measurement channel to AO1 respectively AO2. Make sure that only one bit is set, according to chapter 15.3.7.3.5.1. Writing 0 or an illegal code will leave the selection unchanged. Only one bit can be set!

Reading this register returns the selected PMC for AO1 respectively AO2 according to chapter 15.3.3.5.

- The factory setting for register 4364 is «0x01» mapping PMC1 to AO1
- The factory setting for register 4492 is «0x02» mapping PMC2 to AO2

15.3.7.3.5.3 Reading the Minimal and Maximal Possible Physical Output Current

Register 4366/4494 delivers the limits of the physical output current for AO1/AO2.

Start register	4366	4494
Number of registers	4	4
Reg1 / Reg2 (float)	Min physical output current for AO1 [mA]	Min physical output current for AO2 [mA]
Reg3 / Reg4 (float)	Max physical output current for AO1 [mA]	Max physical output current for AO2 [mA]
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

For Incyte Arc, the limits are fixed to:

- Minimum is 3.5mA
- Maximum is 22 mA

NOTE: Currents above 20 and below 4 mA indicate erroneous measurements or errors.

15.3.7.3.5.4 Reading the Minimal and Maximal Current for Measurement Value Output

Start register	4370	4498
Number of registers	6	6
Reg1 / Reg2 (float)	Min output for measurement value for AO1 [mA]	Min output for measurement value for AO2 [mA]
Reg3 / Reg4 (float)	Max output for measurement values for AO1 [mA]	Max output for measurement values for AO2 [mA]
Reg5 / Reg6 (float)	Mid output for measurement values for AO1 [mA]	Mid output for measurement values for AO2 [mA]
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

These registers deliver the minimal, maximal and middle output current for AO1 respectively AO2 in mA during normal operation. They are fixed to 4, 20 and 12 mA.

15.3.7.3.5.5 Reading the Selected Physical Unit for Analog Interface

Start register	4376	4504
Number of registers	2	2
Reg1 / Reg2 (uint)	Selected physical unit of AO1 (see chapter 2.5.1)	Selected physical unit of AO2 (see chapter 2.5.1)
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

Read the selected unit of the selected PMC of AO1 respectively AO2. The value returned is an unsigned integer that represents the unit according to chapter 15.3.7.4.5.

The physical unit for the PMC is defined in Reg. 2090 or 2410 and applies automatically for 4-20 mA output.

15.3.7.4 Measurement

15.3.7.4.1 Defining the Measurement Values for 4 and 20 mA Output

Start register	4378	4506
Number of registers	6	6
Reg1 / Reg2 (float)	Measurement value at Min Output Current (4 mA) for AO1	Measurement value at Min Output Current (4 mA) for AO2
Reg3 / Reg4 (float)	Measurement value at Max Output Current (20 mA) for AO1	Measurement value at Max Output Current (20 mA) for AO2
Reg5 / Reg6 (float)	Measurement value at Mid Output Current (12 mA) for AO1	Measurement value at Mid Output Current (12 mA) for AO2
Modbus function code	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S
Write access	S	S

These registers define the relation between measurement value and output current in linear mode (see 0). Reg1/Reg2 define the measurement value at 4mA and Reg3/Reg4 define the measurement value at 20mA. Reg5/Reg6 do not affect the 4-20mA output. When writing, write 0 or any random value. When reading, Reg5/Reg6 return half of Min + Max.

The corresponding physical unit can be read in register 4376 / 4504 respectively in the corresponding PMC register (2090 for PMC1, 2154 for PMC2, 2410 for PMC6).

⚠ ATTENTION! When assigning measurement values to 4-20 mA analog output by using register 4378 / 4506, you need to consider the following:

- **The PMC you have mapped to AO1 / AO2 (register 4364 / 4492)**
- **The physical unit currently in use for the selected PMC (register 2090 for PMC1 (VCD), 2154 for PMC2 (Cond) and register 2410 for PMC6 (temperature).**
- **The «Cell factor VCD» (register 3114) when PMC1 is mapped to AO1 / AO2.**
- **The «Offset VCD» (register 3146) when PMC1 is mapped to AO1 / AO2. Offset VCD changes as soon as «Mark Zero VCD» (register 41246) is applied.**
- **Therefore, when the operator redefines any of the above mentioned register, the definitions of the register 4378 / 4506 should be reviewed. If not, the current output at the 4-20 mA interfaces may suddenly be unexpected!**

Example:

- Register 4364 is set to 1 (PMC1 is mapped to AO1)
- Register 2090 is set to 0x20000000 (the unit «pF/cm» is assigned to PMC1)
- Register 4378 is set to 0 and 20 (4 mA = 0pF/cm, 20 mA = 20pF/cm)

The sensor reads currently a value of 5.6pF/cm, the output at the 4-20 mA accordingly is 8.48 mA. The operator now applies «Mark Zero VCD» what sets PMC1 (VCD) to zero. Therefore, the output of AO1 reduces to 4.0 mA.

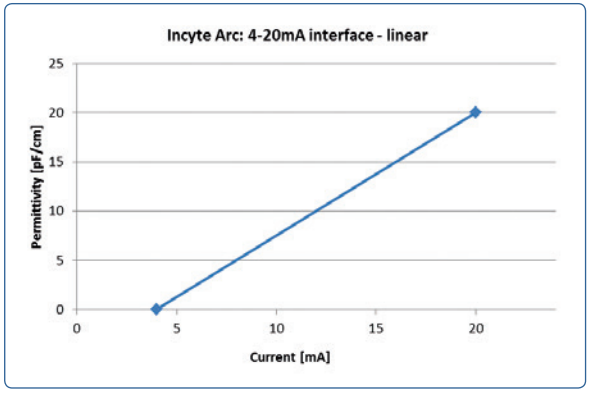


Figure 40: Example of linear 4-20mA output characteristics

15.3.7.4.2 Defining a Constant Current Output for Testing

NOTE: For constant current output, the AO1 / AO2 must be set to analog interface mode 0x01 (see 15.3.7.3.4 Selection of an Analog Interface Mode).

Start register	4384	4512
Number of registers	2	2
Reg1 / Reg2 (float)	Constant current output value for AO1 [mA]	Constant current output value for AO2 [mA]
Modbus function code	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S
Write access	S	S

Values lower than 4mA respectively higher than 20mA will automatically be set within the limits.

15.3.7.4.3 Defining the Error and Warning Output of the 4-20 mA Interface

Errors and warnings can be mapped to the AO1 / AO2.

Start register	4386	4514
Number of registers	8	8
Reg1 / Reg2 (uint)	Code of warnings and errors for AO1	Code of warnings and errors for AO2
Reg3 / Reg4 (uint)	Current in case of «warning» for AO1 [mA]	Current in case of «warning» for AO2 [mA]
Reg5 / Reg6 (uint)	Current in case of «error» for AO1 [mA]	Current in case of «error» for AO2 [mA]
Reg7 / Reg8 (uint)	Current in case of «T exceed» for AO1 [mA]	Current in case of «T exceed» for AO2 [mA]
Modbus function code	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S
Write access	S	S

CONNECTION TO THE PROCESS CONTROL SYSTEM

Bit #	Code (hex)	Behavior of the 4-20 mA interface in case of errors and warnings
0 (LSB)	0x000001	Error continuous output
16	0x010000	Warning continuous output

Code for the 4-20 mA interface in case of errors and warnings.

If the corresponding bits for the errors and warnings are not set (=0x00), the respective options are inactive.

«T exceed» is always active. What means that in case of a measurement temperature limit violation, the output current will be as the specified value.

The default settings are:

- Code 0x01
- current in case of warnings: 3.5 mA
- current in case of errors: 3.5 mA
- current in case of measurement temperature limits violation: 3.5 mA

Command: ErrorWarnings AO1	Modbus address: 4386	Length: 8	Type: 3	Read
Parameter	**Format**	**Value**		
Warning code	Hex	0x010001		
Current in case of warning [mA]	Float	3.5		
Current in case of error [mA]	Float	3.5		
Current in case of temperature exceed [mA]	Float	3.5		

Example: read the settings for AO1 in case of warnings and errors.

Warning code 0x010001 corresponds to the continuous output current in case of warning (0x010000) and continuous output current in case of error (0x01) of 3.5 mA. The output current in case of temperature exceed is 3.5 mA.

For more information about warnings, errors and temperature limits see chapter 15.3.3.35.

15.3.7.4.4 Reading the Internally Calculated Output Current

Reg. 4414 / 4542 provides internal calculated output current of AO1 / AO2. These values are helpful in order to compare against the externally measured electrical current.

Start register	4414	4542
Number of registers	4	4
Reg1 / Reg2 (float)	Set point [mA] AO1	Set point [mA] AO2
Reg3 / Reg4 (float)	Internally measured [mA] AO1	Internally measured [mA] AO2
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

⚠ ATTENTION! Current outputs of Incyte Arc are provided by the Arc Wi 2G Adapter. Therefore, the sensor cannot internally measure any output currents. Reg3/Reg4 always deliver the same value than Reg1/Reg2 even though there is no Arc Wi 2G Adapter connected. This is due to compatibility to other Arc sensors.

NOTE: For more information about the measurement theory and the meaning of the different measurement channels see chapter 5.

15.3.7.4.5 Definition of Measurement Channels and Physical Units

The Arc Modbus register structure allows the definition of 6 individual Primary Measurement Channels (PMC), and 16 individual Secondary Measurement Channels (SMC).

Bit #	Hex code	Description	Definition
0 (LSB)	0x000001	PMC1	VCD
1	0x000002	PMC2	Conductivity
2	0x000004	PMC3	not available
3	0x000008	PMC4	not available
4	0x000010	PMC5	not available
5	0x000020	PMC6	Temperature
6	0x000040	SMC1	alpha
7	0x000080	SMC2	fc
8	0x000100	SMC3	delta Epsilon
9	0x000200	SMC4	Cole fit R2
10	0x000400	SMC5	Cole fit RMSE
11	0x000800	SMC6	Permittivity
12	0x001000	SMC7	not available
		…	
21 (MSB)	0x200000	SMC16	not available

In Register 2048, the available PMC and SMC are defined for a specific Incyte Arc Sensor and a specific operator level.

Start register	2048
Number of registers	2
Reg1 / Reg2 (uint)	Available measurement channels PMC and SMC (bitwise set)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Example:

Command: Avail. PMC and SMC	**Modbus address: 2048**	**Length: 2**	**Type: 3**	**Read**
Parameter	**Format**	**Value**		
Avail. PMC and SMC	Hex	0x0FE3		

CONNECTION TO THE PROCESS CONTROL SYSTEM

In case of operator S/A/U, the value 0x0FE3 is returned. In other words the following PMC's and SMC's are available to S/A/U: PMC1 / PMC2 / PMC6 / SMC1 / SMC2 / SMC3 / SMC4 / SMC5 / SMC6

The Incyte Arc Sensor register structure uses the following physical units used for Primary or Secondary Measurement Channels.

Bit #	Hex code	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
0 (LSB)	0x00000001	none	1920
1	0x00000002	K	1924
2	0x00000004	°C	1928
3	0x00000008	°F	1932
4	0x00000010	PCV	1936
5	0x00000020	-	1940
6	0x00000040	-	1944
7	0x00000080	-	1948
8	0x00000100	g/l	1952
9	0x00000200	uS/cm	1956
10	0x00000400	mS/cm	1960
11	0x00000800	1/cm	1964
12	0x00001000	pH	1968
13	0x00002000	mV/pH	1972
14	0x00004000	kOhm	1976
15	0x00008000	MOhm	1980
16	0x00010000	pA	1984
17	0x00020000	nA	1988
18	0x00040000	uA	1992

CONNECTION TO THE PROCESS CONTROL SYSTEM

Bit #	Hex code	Physical unit	Start register. (8 ASCII characters, length 4 registers, Type 3, read for U/A/S)
19	0x00080000	mA	1996
20	0x00100000	uV	2000
21	0x00200000	mV	2004
22	0x00400000	V	2008
23	0x00800000	-	2012
24	0x01000000	-	2016
25	0x02000000	Ohm	2020
26	0x04000000	%/°C	2024
27	0x08000000	°	2028
28	0x10000000	e6 c/ml	2032
29	0x20000000	pF/cm	2036
30	0x40000000	kHz	2040
31 (MSB)	0x80000000	OD	2044

Command: Unit text	Modbus address: 1952	Length: 4	Type: 3	Read
Parameter	**Format**	**Value**		
Text	8 ASCII characters	g/l		

15.3.7.5 Primary Measurement Channel 1 (VCD)

Definition of PMC1

Start register	2080	2088	2090
Data size (registers)	8	2	2
Function	Description of PMC1	Available physical units of PMC1	Selected physical unit for PMC1
Data type	ASCII chars	uint	uint
Modbus function code	3, 4	3, 4	16
Read access	U/A/S	U/A/S	none
Write access	none	none	S

In register 2080, a plain text ASCII description of PMC1 is given. PMC1 for Incyte Arc is called «VCD».

In register 2088, the available physical units for this channel are defined. The available physical units for PMC1: 0xB0000110 => PCV, g/l, e6 c/ml, pF/cm and OD

In register 2090, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2088.

Selecting an invalid unit code will leave the current unit unchanged.

Command: PMC1 set unit	Modbus address: 2090	Length: 2	Type: 16	Write
Parameter	**Format**	**Value**		
Unit	Hex	0x10000000		

15.3.7.5.1 Reading the measurement value of PMC1

Register 2090 is also used to read the measurement values of PMC1.

Start register	2090
Number of registers	10
Reg1 / Reg2 (uint)	Selected physical unit
Reg3 / Reg4 (float)	Measurement value of PMC1 (1)
Reg5 / Reg6 (uint)	Measurement status (2)
Reg7 / Reg8 (float)	Min allowed value (1)
Reg9 / Reg10 (float)	Max allowed value (1)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

(1) Value is always in the physical unit defined in register 2090.

(2) Definition of the status see chapter 15.3.7.12. All bits set to zero means: no problem.

For the definition of the measurement status see chapter 15.3.7.8.

The measurement value is defined as follows: VCD = (Permittivity – Offset VCD) * Cell factor VCD

- VCD = PMC1 (Reg. 2090)
- Permittivity = SMC6 (Reg. 2632)
- Offset VCD = Reg. 3146
- Cell factor VCD = Reg. 3114

⚠ ATTENTION! You cannot selectively read a single register. If you want to read the measurement value, you have to read the entire length of the command (10 registers) and extract the desired information.

NOTE: Changing the physical unit of VCD does not affect the measurement value which is calculated according to the formula above.

15.3.7.6 Primary Measurement Channel 2 (Conductivity)

Definition of PMC2

Start register	2144	2152	2154
Data size (registers)	8	2	2
Function	Description of PMC2	Available physical units of PMC2	Selected physical unit for PMC2
Data type	ASCII chars	uint	uint
Modbus function code	3, 4	3, 4	16
Read access	U/A/S	U/A/S	none
Write access	none	none	S

In register 2144, a plain text ASCII description of PMC2 is given. PMC2 for Incyte Arc is called «Cond».

In register 2152, the available physical units for this channel are defined. The available physical units for PMC2: 0x00000400 => mS/cm

In register 2154, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2152. For PMC2 only 0x400 (mS/cm) is available.

Selecting an invalid unit code will leave the current unit unchanged.

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.6.1 Reading the measurement value of PMC2

Register 2154 is also used to read the measurement values of PMC2.

Start register	2154
Number of registers	10
Reg1 / Reg2 (uint)	Selected physical unit
Reg3 / Reg4 (float)	Measurement value of PMC2 (1)
Reg5 / Reg6 (uint)	Measurement status (2)
Reg7 / Reg8 (float)	Min allowed value (1)
Reg9 / Reg10 (float)	Max allowed value (1)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

(1) Value is always in the physical unit defined in register 2152.

(2) Definition of the status see chapter 15.3.7.12. All bits set to zero means: no problem.

⚠ ATTENTION! You cannot selectively read a single register. If you want to read the measurement value, you have to read the entire length of the command (10 registers) and extract the desired information.

15.3.7.7 Primary Measurement Channel 6 (Temperature)

Definition of PMC6

Start register	2400	2408	2410
Data size (registers)	8	2	2
Function	Description of PMC6	Available physical units of PMC6	Selected physical unit for PMC6
Data type	ASCII chars	uint	uint
Modbus function code	3, 4	3, 4	16
Read access	U/A/S	U/A/S	none
Write access	none	none	S

In register 2400, a plain text ASCII description of PMC6 is given. PMC6 for Incyte Arc is called «T».

In register 2408, the available physical units for this channel are defined. The available physical units for PMC6: 0x0000000E => K, °C and °F

In register 2410, the active physical unit for this channel can be selected, by choosing one of the physical units that are defined in register 2408.

Selecting an invalid unit code will leave the current unit unchanged.

⚠ ATTENTION! Changing the physical unit of PMC6 has also an influence on the output of AO1 / AO2, as the same physical unit is active for the analog outputs. All limits of the 4-20 mA analog output have to be redefined after changing the physical unit!

15.3.7.7.1 Reading the measurement value of PMC6

Register 2410 is also used to read the measurement values of PMC6.

Start register	2410
Number of registers	10
Reg1 / Reg2 (uint)	Selected physical unit
Reg3 / Reg4 (float)	Measurement value of PMC6 (1)
Reg5 / Reg6 (uint)	Measurement status (2)
Reg7 / Reg8 (float)	Min allowed value (1)
Reg9 / Reg10 (float)	Max allowed value (1)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

(1) Value is always in the physical unit defined in register 2410.

(2) For definition of the status see chapter 15.3.7.12. All bits set to zero means: no problem.

CONNECTION TO THE PROCESS CONTROL SYSTEM

Command: PMC6 read	Modbus address: 2410	Length: 10	Type: 3	Read
Parameter	**Format**	**Value**		
Unit	Hex	0x04		
Value	Float	24.35834		
Status	Hex	0x00		
Min limit	Float	-20		
Max limit	Float	140		

Example to read register 2410

Physical unit is set to °C (0x04), PMC6 is 24.35834 °C, Status is 0x00, Min allowed value is -20 °C, Max allowed value is 140 °C.

For definition of the measurement status see chapter 15.3.7.8.

⚠ ATTENTION! You cannot selectively read a single register. If you want to read the measurement value, you have to read the entire length of the command (10 registers) and extract the desired information.

15.3.7.8 Definition of the Measurement Status for PMC1/PMC2/PMC6

This is the definition of the status registers read in registers 2090 (PMC1), 2154 (PMC2) and 2410 (PMC6):

Bit #	Hex code	Description
none	0x00000000	Sensor OK
0 (LSB)	0x00000001	Temperature out of measurement range (see chapter 2.8.1)
1	0x00000002	Temperature out of operating range (see chapter 2.8.1)
2	0x00000004	not used
3	0x00000008	Warning not zero (see chapter 2.8.3)
4	0x00000010	Error not zero (see chapter 2.8.4)
..		
23	0x00800000	Probe cleaning in progress

15.3.7.9 Secondary Measurement Channels 1-6

Incyte Arc Sensors do allow access to six secondary measurement values (SMC). The access to the individual SMC depends on the operator level. The available SMC's are defined in register 2048 according to the selected operator level and the sensor type.

15.3.7.9.1 Description of SMC

The registers defined here give a plain text ASCII description of each available SMC.

Start register	Address
Number of registers	8
Reg1 to Reg8 16 ASCII characters	Description of each SMC
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Full list of starting register addresses for the plain text ASCII description of each SMC:

Description	Address	Plain Text (16 ASCII)	Description
SMC1	2464	alpha	Cole-cole Parameter: alpha
SMC2	2496	fc	Cole-cole Parameter: fc
SMC3	2528	delta Epsilon	Cole-cole Parameter: delta Epsilon
SMC4	2560	Cole fit R2	R2 of the Cole-cole fitting
SMC5	2592	Cole fit RMSE	RMSE of the Cole-cole fitting
SMC6	2624	Permittivity	Permittivity

Example:

Command: SMC 1 text	Modbus address: 2464	Length: 8	Type: 3	Read
Parameter	Text			
Value	alpha			

Example to read the description of SMC1 at address 2464.

15.3.7.9.2 Reading the measurement value of SMC

The registers defined here are used to read the measurement values of each SMC.

Start register	Address
Number of registers	6
Reg1 / Reg2 (uint)	Physical unit
Reg3 / Reg4 (float)	Measurement value of SMC
Reg5 / Reg6 (float)	0
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Full list of register addresses for the measurement values of SMC1 to SMC6:

Description	Address	Text	Unit	Min value	Max value
SMC1	2472	alpha	none	0	1
SMC2	2504	fc	kHz	300	5000
SMC3	2536	delta Epsilon	pF/cm		
SMC4	2568	Cole fit R2	none	0	1
SMC5	2600	Cole fit RMSE	pF/cm		
SMC6	2632	Permittivity	pF/cm		

During the Incyte Scan the most relevant parameters of the Cole-Cole equation (see chapter 5.2.2) (Modbus parameter in brackets) – Δε (delta Epsilon), fc (Fc), and α (alpha) - are automatically fitted.

Reg5/Reg6 has no functionality. It always returns 0. Nevertheless, all 6 registers have to be read!

Example:

Command: SMC1 read	Modbus address: 2472	Length: 6	Type: 3	Read
Parameter	**Format**	**Value**		
Unit	Hex	0x00		
Value	Float	0.95		
Reg5/Reg6.	Float	0		

Example to read register 2472

15.3.7.9.3 Reading Scan Data

15.3.7.9.3.1 Information about Frequency Scan

Register 40988 delivers information about the frequency scan.

Start register	40988
Number of registers	8
Reg1 / Reg2 (uint)	Nbr of frequencies
Reg3 / Reg4 (uint)	Unit frequencies
Reg5 / Reg6 (uint)	Unit permittivity
Reg7 / Reg8 (uint)	Unit conductivity
Modbus function code	3, 4
Read access	U/A/S
Write access	none

- Nbr of frequencies: Amount of frequencies that are used for one scan. This value for Incyte Arc is 17
- Unit frequencies: Unit that is used for the frequencies when reading scan values. See chapter 15.3.7.9.3.
- Unit permittivity: Unit that is used for the permittivity when reading scan values. See chapter 15.3.7.9.3.
- Unit conductivity: Unit that is used for the conductivity when reading scan values. See chapter 15.3.7.9.3.

15.3.7.9.3.2 Scan Data

Start register	Address
Number of registers	6
Reg1 / Reg2 (float)	Frequency
Reg3 / Reg4 (float)	Permittivity
Reg5 / Reg6 (float)	Conductivity
Modbus function code	3, 4
Read access	U/A/S
Write access	none

CONNECTION TO THE PROCESS CONTROL SYSTEM

Address	Description
40998	Scan values at frequency 0
41004	Scan values at frequency 1
41010	Scan values at frequency 2
41016	Scan values at frequency 3
41022	Scan values at frequency 4
41028	Scan values at frequency 5
41034	Scan values at frequency 6
41040	Scan values at frequency 7
41046	Scan values at frequency 8
41052	Scan values at frequency 9
41058	Scan values at frequency 10
41064	Scan values at frequency 11
41070	Scan values at frequency 12
41076	Scan values at frequency 13
41082	Scan values at frequency 14
41088	Scan values at frequency 15
41094	Scan values at frequency 16

With each data set (permittivity, conductivity), the corresponding frequency is given in Reg1/Reg2.

15.3.7.9.3.3 Scan Index

The Incyte Arc sensor updates the scan data every 3 seconds. To make sure, that you do not read the same data twice, there is a scan index which is incremented as soon as new data are available.

Start register	40996
Number of registers	2
Reg1 / Reg2 (uint)	Scan index
Modbus function code	3, 4
Read access	U/A/S
Write access	none

When the sensor is powered up, the scan index is initialized to 0. After reaching 232-1, the value rolls over to 0.

15.3.7.10 Configuration of the Measurement

This chapter describes the configuration of the PMC's and SMC's by means of measurement parameters.

Measure Mode

Register 41200 contains the descriptions of the measure mode as plain text ASCII:

Start register	41200
Number of registers	8
Reg1 to Reg8 16 ASCII characters	Measure mode label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 41200, a plain ASCII text description of Measure mode is given.
It returns «Measure mode».

Register 41208 delivers the available units for the measure mode parameter:

Start register	41208
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Measure mode
Modbus function code	3, 4
Read access	U/A/S
Write access	none

For this parameter the only unit available is «none» (0x00000001).

CONNECTION TO THE PROCESS CONTROL SYSTEM

Register 41210 allows reading or changing the current measure mode:

Start register	41210	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	Measure mode	Measure mode
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Unit always is 0x00000001 meaning that the measure mode parameter has no unit (see chapter 15.3.7.4.5). Writing a different value to Reg1/Reg2 does not have any effect.

Reg3/Reg4 represents the measure mode of the Incyte Arc sensor:

0 = Idle
1 = do not use
2 = Dual frequency measurement (default)
3 = Frequency Scan (only available with Scan license)
4 = Frequency Scan + Dual frequency (only available with Scan license)

When reading the register, it is 8 byte wide with an additional minimal and maximal value. They represent the numerical range for measure mode. Minimal value always is 0. Maximal value depends on the availability of a Scan License. If a license is available, Maximal Value is 4, otherwise 2.

Violating the measure mode limits leads to illegal data exception!

Idle: The sensor switches off the measurement and reduces the power consumption to a minimum of less than 500mW. Communication and configuration via Modbus is still possible.

Dual frequency measurement: The sensor measures Permittivity (SMC6), Conductivity (PMC2) and Temperature (PMC6). Permittivity is measured using the two frequencies (fc and fhigh) defined by the Cell Type Mode. Out of this value VCD (PMC1) is calculated. The correlation is given by the Cell factor (see 2.6.4 Cell Factor VCD). In this mode, the sampling rate is 1S/s.

Frequency Scan: In this mode, the sensor is measuring a Permittivity spectrum at 17 different frequencies. For more information see 2.5.7 Reading Scan Data. Furthermore, Conductivity (PMC2), Temperature (PMC6), as well as alpha (SMC1), fc (SMC2), delta Epsilon (SMC3), R2

(SMC4) and RMSE (SMC5) are available. VCD (PMC1) and Permittivity (SMC6) will be zero. In this mode, the sampling rate is 1 Sample per 3 Seconds.

Frequency Scan + Dual frequency: This is a combination of the two measure modes Frequency scan and Dual frequency measurement. Therefore, all above mentioned measurement channels are available. The sampling rate is 1 Sample per 3 Seconds.

⚠ ATTENTION! ArcAir only uses measure mode 2 and 4. If you connect your sensor to ArcAir while mode 0 or 3 is selected, some values might be missing on the User Interface or in the log file!

NOTE: For more information about the measurement theory see chapter 5.

15.3.7.10.1 Cell Type Mode

The Incyte Arc Sensor offers 6 different Cell Type Modes which define the measurement frequencies and the filtering for the Dual Frequency Measurement Mode. Cell Type Mode 1 to 3 (Animal, Yeast and Bacteria) are fix, whereas Cell Type Mode 4 to 6 are user definable.

The Cell Type Mode parameter (Reg. 41218, 41226 and 41228) defines the active Cell Type Mode.

The different Cell Type Modes themselves are defined by the registers starting at 41648.

15.3.7.10.1.1 Cell Type Mode Parameter

In register 41218, a plain ASCII text description of the Cell Type Mode parameter is given:

Start register	41218
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Cell Type Mode parameter label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41218 returns «Cell Type Mode».

Register 41226 delivers the available units for the Cell Type Mode parameter:

Start register	41226
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Cell Type Mode parameter
Modbus function code	3, 4
Read access	U/A/S
Write access	none

The available units are coded according to chapter 15.3.7.4.5. For this parameter the only unit available is «none» (0x00000001).

Register 41228 allows reading or changing the currently selected Cell Type Mode:

Start register	41228	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	CTM	CTM
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Unit always is 0x00000001 meaning that the Cell Type Mode parameter has no unit (see chapter 15.3.7.4.5). Writing a different value to Reg1/Reg2 does not have any effect.

The Incyte Arc Sensor offers 6 Cell Type Modes represented by an index of 0 to 5. Therefore, Minimal value is 0 and Maximal value is 5. Writing an invalid index to the CTM register will leave the selection unchanged!

CTM index (Reg3/Reg4):

0 = Cell Type Mode 1: Animal
1 = Cell Type Mode 2: Yeast
2 = Cell Type Mode 3: Bacteria
3 = Cell Type Mode 4: User 1

4 = Cell Type Mode 5: User 2

5 = Cell Type Mode 6: User 3

Cell Type Mode 4 to 6 can be defined by the user (see chapter 15.3.7.10.1.2).

15.3.7.10.1.2 Definition of the Cell Type Modes

Start register	41648 + n * 24	41656 + n * 24	41664 + n * 24
Number of registers	8	8	6
Reg1 / Reg2	Label (16 ASCII characters)	Index fmeas (uint)	Moving avg (uint)
Reg3 / Reg4	Label (16 ASCII characters)	Index fhigh (uint)	Moving avg min (uint)
Reg5 / Reg6	Label (16 ASCII characters)	Index min (uint)	Moving avg max (uint)
Reg7 / Reg8	Label (16 ASCII characters)	Index max (uint)	
Modbus function code	3, 4 / 3, 4, 16	3, 4 / 3, 4, 16	3, 4 / 3, 4, 16
Read access	U/A/S	U/A/S	U/A/S
Write access	none / S	none / S	none / S

Definition of the Cell Type Modes (n = 0..5)

The definition of Cell Type Mode 1 starts at 41648. With an offset of 24 bytes the definition of the next Cell Type Mode is following.

Cell Type Modes 1 to 3 are read only, whereas CTM 4 to 6 are writeable as well for operator level S.

In register 41648 + n *24, a plain ASCII text description of the Cell Type Mode is given:

n=0: Cell Type Mode 1: "Animal"

n=1: Cell Type Mode 2: "Yeast"

n=2: Cell Type Mode 3: "Bacteria"

n=3: Cell Type Mode 4: "User 1"

n=4: Cell Type Mode 5: "User 2"

n=5: Cell Type Mode 6: "User 3"

Register 41656 + n *24, define the measure frequencies (fmeas, fhigh) for the Dual Frequency Measurement Mode.

CONNECTION TO THE PROCESS CONTROL SYSTEM

The frequencies are defined by an index:

Index	Frequency [kHz]
0	300.1
1	373.8
2	465.7
3	579.8
4	720.0
5	896.4
6	999.5
7	1117.7
8	1392.3
9	1729.3
10	2002.7
11	2155.3
12	2689.3
13	3347.3
14	4158.0
15	5187.9
16	6446.8
17	8029.9
18	9994.5

Index min is 0, Index max is 18. Writing values out of range will automatically be corrected to within the borders.

NOTE: For more information about the measurement theory and the meaning of the different frequencies see the Incyte Arc Operating Instructions (chapter: The Theory of Permittivity Measurement).

Using moving average (register 41664 + n * 24), the short term signal stability can be improved; on the other hand, the response time of the sensor increases with increasing moving average.

Reg1/Reg2 defines the amount of filter tabs (moving average elements). The filter time delay (response time) is defined by this number and the sampling time of the sensor which is

3 seconds. With a Minimal value of 1 and a Maximal value of 128 filter times between 3 and 384 seconds are possible.

Writing values lower than 1 or higher than 128 will automatically be corrected to the closest valid value!

⚠ ATTENTION! When changing the moving average in the cell type mode tab of ArcAir, not only the moving average of the Dual Frequency Measurement but also the moving average of the Frequency Scan Measurement (see chapter 15.3.7.10.6) is changed. Both parameters are set to the same value.

ArcAir allows the following settings:

- None: Moving average = 1
- Low: Moving average = 32
- Medium: Moving average = 64
- High: Moving average = 128

15.3.7.10.2 Mark Zero VCD

Start register	41236
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Mark Zero VCD label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 41236, a plain ASCII text description of Mark Zero VCD is given. It returns «Mark Zero VCD».

Start register	41244
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Mark Zero
Modbus function code	3, 4
Read access	U/A/S
Write access	none

CONNECTION TO THE PROCESS CONTROL SYSTEM

The available units are coded according to chapter 15.3.7.3.4.5 physical units. For this parameter the only unit available is «none» (0x00000001).

Start register	41246	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	Value	Value
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 41228 allows setting the VCD measurement value to zero (Mark Zero) or to undo this setting (Clear Zero). Zeroing the measurement value means that the current measurement value is saved and will be subtracted from the following measurements as an offset (see 2.6.5 Offset VCD).

Unit always is 0x00000001 meaning that the Cell Type Mode parameter has no unit (see chapter 15.3.7.4.5). Writing a different value to Reg1/Reg2 does not have any effect.

The zeroing functionality is controlled by the Value (Reg3/Reg4).

0 = Clear zero (zeroing not active)
1 = Mark zero (zeroing active)

Only 0 and 1 are valid Values. Therefore Minimal value is 0 and Maximal value is 1.

Mark zero has the effect that the offset VCD (15.3.7.10.4 Offset VCD) is set to the current Permittivity value, what results in a VCD value (PMC1) of zero. Clear zero sets the offset VCD back to zero.

⚠ ATTENTION! Zeroing the VCD value might have an influence on the output of AO1 / AO2 if PMC1 is mapped to one of it. Define the limits of the 4-20 mA current interface such that the zeroing does not lead to an unintentional behavior of the current output.

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.10.3 Cell Factor VCD

Start register	3104
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Cell factor VCD label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 3104, a plain ASCII text description of Cell factor VCD is given. It returns «Cell factor VCD».

Start register	3112
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Cell factor VCD
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 3112 delivers the available units for the Cell factor VCD parameter. It is coded according to chapter 15.3.7.4.5 physical units.

Start register	3114	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (float)	Value	Value
Reg5 / Reg6 (float)		Minimal value
Reg7 / Reg8 (float)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 3114 allows reading or changing the current Cell factor VCD.

Unit always is 0x00000001 meaning that the Cell factor VCD parameter has no unit (see chapter 15.3.7.3.4.5). Writing a different value to Reg1/Reg2 does not have any effect.

The Cell factor VCD Value (Reg3/Reg4) defines the correlation between the measured Permittivity (SMC 6) and the VCD value (PMC1).

VCD = (Permittivity – Offset VCD) * Cell factor VCD

- VCD = PMC1 (Reg. 2090)
- Permittivity = SMC6 (Reg. 2632)
- Offset VCD = Reg. 3146
- Cell factor VCD = Reg. 3114

Minimal value is –inf, Maximal value is +inf.

⚠ ATTENTION! Changing the cell factor might have an influence on the output of AO1 / AO2 if PMC1 is mapped to one of it. All limits of the 4-20 mA current interface have to be redefined after changing the cell factor!

15.3.7.10.4 Offset VCD

Start register	3136
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Offset VCD label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 3136, a plain ASCII text description of Offset VCD is given. It returns «Offset VCD».

Start register	3144
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Offset VCD
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 3144 delivers the available units for the Offset VCD parameter. It is coded according to chapter 15.3.7.4.5. The only available unit for this parameter is «pF/cm» (0x20000000).

Start register	3146	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (float)	Value	Value
Reg5 / Reg6 (float)		Minimal value
Reg7 / Reg8 (float)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 3146 allows reading or changing the current Offset VCD.

Unit always is 0x20000000 meaning that the Cell factor VCD parameter is in «pF/cm» (see chapter 15.3.7.4.5). Writing a different value to Reg1/Reg2 does not have any effect.

The offset value has a direct influence on the VCD value (PMC1). For details see 15.3.7.5.1 Reading the measurement value of PMC1.

Minimal value is –inf, Maximal value is +inf.

⚠ ATTENTION! Executing Mark Zero respectively Clear Zero (15.3.7.10.2 Mark Zero VCD) changes the offset value!

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.10.5 Mark Zero Frequency Scan

Start register	41254
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Mark Zero Scan label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 41254, a plain ASCII text description of Mark Zero Scan is given. It returns «Mark Zero Scan».

Start register	41262
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Mark Zero Scan
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41262 delivers the available units for the Mark Zero Scan parameter.

Start register	41264	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	Value	Value
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 41264 allows setting the Scan measurement values to zero (Mark Zero) or to undo this setting (Clear Zero). Zeroing the measurement values means that all the current measurement

values (at each single frequency) are saved and will be subtracted from the following measurement values as an offset.

Unit always is 0x00000001 meaning that the Mark Zero Scan parameter has no unit. Writing a different value to Reg1/Reg2 does not have any effect.

The zeroing functionality is controlled by the Value (Reg3/Reg4).

0 = Clear zero (zeroing not active)
1 = Mark zero (zeroing active)

Only 0 and 1 are valid values. Therefore minimal value is 0 and maximal value is 1.

Mark zero has the effect that the offset values are set to the current scan values (15.3.7.9.3.2 Scan Data), what results in a spectrum with all Zeros. Clear zero sets the offset values back to zero.

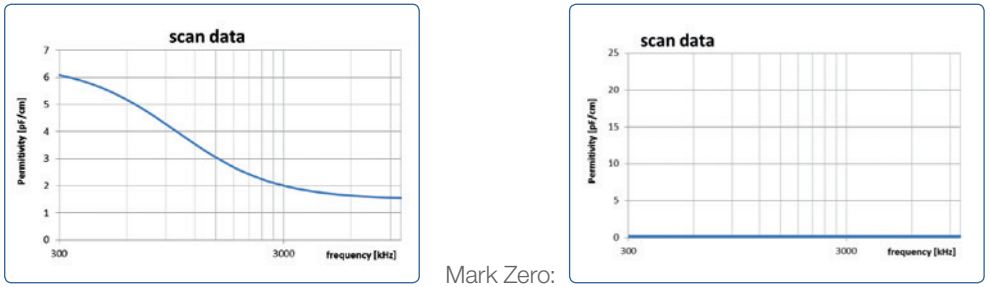


Figure 41: Effect of Mark Zero

Offset Frequency Scan

Start register	41868 + 2*n
Number of registers	2
Reg1 / Reg2 (float)	Permittivity offset at Frequency n
Modbus function code	3, 4, 16
Read access	U/A/S
Write access	S

The registers starting from 41868 deliver the offset values of the frequency scan data. These values are in pF/cm and represent the permittivity at the time when Mark Zero was applied. n is in the range of 0 to 16. The corresponding frequencies can be read through the scan data registers (15.3.7.9.3.2 Scan Data)

CONNECTION TO THE PROCESS CONTROL SYSTEM

NOTE: Use the Mark Zero functionality (Scan) to write the scan offset values.

15.3.7.10.6 Moving Average Frequency Scan

Start register	41272
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Moving average Scan label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 41272, a plain ASCII text description of Moving average Scan is given. It returns «Mov avg Scan».

Start register	41280
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Moving average Scan
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41280 delivers the available units for the Moving average Scan parameter.

Start register	41282	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	Value	Value
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 41282 allows reading or changing the amount of measurement points used for the averaging of the scan data.

Unit always is 0x00000001 meaning that the Moving average Scan parameter has no unit. See Table 12. Writing a different value to Reg1/Reg2 does not have any effect.

Using moving average, the short term signal stability can be improved; on the other hand, the response time of the sensor increases with increasing moving average.

Reg3/Reg4 defines the amount of filter tabs (moving average elements). The filter time delay (response time) is defined by this number and the sampling time of the sensor which is 3 seconds. With a Minimal value of 1 and a Maximal value of 128 filter times between 3 and 384 seconds are possible.

Moving average is applied to every single frequency of the scan data.

Writing values lower than 1 or higher than 128 will automatically be corrected to the closest valid value!

NOTE: When using ArcAir, the moving average of the Frequency Scan Measurement is set to the same value than the moving average of the Dual Frequency Measurement (see 2.6.2.2). This value can be changed in the cell type mode tab of ArcAir.

ArcAir allows the following settings:
- None: Moving average = 1
- Low: Moving average = 32
- Medium: Moving average = 64
- High: Moving average = 128

15.3.7.10.7 Inoculate

Start register	41290
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Inoculation label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

CONNECTION TO THE PROCESS CONTROL SYSTEM

In register 41290, a plain ASCII text description of the Inoculate parameter is given. It returns «Inoculate».

Start register	41298
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units for Inoculate
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41298 delivers the available units for the Inoculate parameter. It is coded according to chapter 15.3.7.4.5.

Start register	41300	
Number of registers	4	8
Reg1 / Reg2 (uint)	Unit	Unit
Reg3 / Reg4 (uint)	Value	Value
Reg5 / Reg6 (uint)		Minimal value
Reg7 / Reg8 (uint)		Maximal value
Modbus function code	16	3, 4
Read access	none	U/A/S
Write access	S	none

Register 41300 allows marking the inoculation.

Unit always is 0x00000001 meaning that the Inoculate parameter has no unit (see chapter 15.3.7.4.5).

Writing a different value to Reg1/Reg2 does not have any effect.

The inoculate functionality is controlled by the Value (Reg3/Reg4).

0 = stop culture
1 = inoculate

Only 0 and 1 are valid Values. Therefore Minimal value is 0 and Maximal value is 1.

The culture time starts counting from zero when writing a 1 (inoculate) to the register 41300. Repeated writing of a 1 does not have any effect. When writing a 0 (stop culture) the culture time stops counting and is set back to zero.

15.3.7.10.8 Culture Time

Start register	41308
Number of registers	8
Reg1 to Reg8 (16 ASCII characters)	Culture time label
Modbus function code	3, 4
Read access	U/A/S
Write access	none

In register 41308, a plain ASCII text description of the Inoculate parameter is given. It returns «Culture time».

Start register	41316
Number of registers	2
Reg1 / Reg2 (bitwise defined)	Available units culture time
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41316 delivers the available units for the Inoculate parameter.

Start register	41318
Number of registers	8
Reg1 / Reg2 (uint)	Unit
Reg3 / Reg4 (uint)	Value
Reg5 / Reg6 (uint)	Minimal value
Reg7 / Reg8 (uint)	Maximal value
Modbus function code	3, 4
Read access	U/A/S
Write access	none

Register 41318 is read only. It delivers the culture time in seconds. The culture time can be controlled by the inoculate command.

CONNECTION TO THE PROCESS CONTROL SYSTEM

⚠ ATTENTION! Although Reg1/Reg2 returns 0x00000001 the unit for the culture time is second.

Minimal value is 0, maximal value is 232 – 1.

15.3.7.11 Sensor Cleaning

This chapter describes the electrochemical cleaning of the electrodes and not CIP or SIP cycles. For CIP and SIP see 15.3.7.15 Definition of SIP and CIP.

The Incyte Arc Sensor offers auto or manual cleaning. The auto cleaning consists of periodic cleaning events. As soon as auto cleaning is activated, the cleaning event takes place periodically with the defined repetition rate. In the manual cleaning mode however, the cleaning event takes place only once as soon as it is started.

15.3.7.11.1 Defining a Cleaning Event

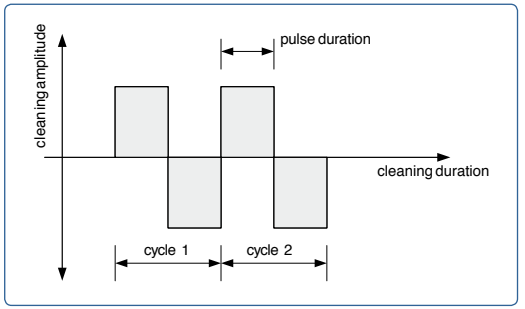


Figure 42: Definition of a cleaning event

Start register	41508
Number of registers	4
Reg1 + Reg2	Nbr of cycles (uint)
Reg3 + Reg4	Pulse duration [s] (uint)
Read access	U/A/S
Write access	S

NOTE: ArcAir defines a short and a long cleaning. These cleanings are defined as follows:
- short: cycles = 1, duration = 5
- long: cycles = 10, duration = 5

15.3.7.11.2 Autocleaning

Start register	41512	41514
Number of registers	2	2
Reg1 + Reg2	Repetition rate [min] (uint)	Activate autocleaning (uint)
Read access	U/A/S	U/A/S
Write access	S	S

Write a 1 to register 41514 to activate the autocleaning. Write a 0 to deactivate it.

15.3.7.11.3 Manual Cleaning

Start register	41516	41516
Number of registers	2	2
Reg1 + Reg2	Start manual cleaning cycle (uint)	Manual cleaning status (uint)
Read access	none	U/A/S
Write access	S	none

Write a 1 to register 41516 to activate the manual cleaning event.

Reading the register 41516 delivers the cleaning status which can be as following:

0: no action
1: manual cleaning running
2: cleaning not started, conductivity too low

CONNECTION TO THE PROCESS CONTROL SYSTEM

NOTE: Cleaning status 2 (conductivity too low) stays active until the register 41516 is written again. Therefore it is possible to write a 0 to the register just to update the cleaning status.

⚠ ATTENTION! A manual cleaning event cannot be deactivated or stopped!

15.3.7.12 Sensor Status

15.3.7.12.1 Temperature Ranges

In registers 4608 and 4612 two different temperature ranges are defined:

- Operation – outside of this range, the sensor should not be operated at all!
- Measurement – in this range the sensor works properly within the specification.

Outside of this range the sensor still allows Modbus communication, but as soon as the specified temperature range (ambient and/or medium) is exceeded, the permittivity and conductivity measurement is switched off. In this case the last value of measurement will be frozen.

Start register	4608	4612
Number of registers	4	4
Reg1 / Reg2 (float)	Operating temperature min	Measurement temperature min
Reg3 / Reg4 (float)	Operating temperature max	Measurement temperature max
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	none	none

The unit of the temperatures is according to the selected unit of PMC6.

If one of this ranges is exceeded the measurement status will be set accordingly (see chapter 15.3.7.8 Definition of the Measurement Status for PMC1 / PMC2 / PMC6).

For Incyte Arc the ranges are as follows:

- Operating temperature: -20 .. +140°C
- Measurement temperature: 0 .. +60°C

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.12.2 Operating Hours, Counters and System Time

Start register	4676	4682	4688	4692	8232
Number of registers	6	6	4	2	2
Reg1 / Reg2	Operating hours [h] (float)	Number of Power ups (uint)	Number of SIP cycles (uint)	No. of autoclavings (uint)	System Time Counter [s] (uint)
Reg3 / Reg4	Operating hours above max measurement temperature [h] (float)	Number of Watchdog resets (uint)	Number of CIP cycles (uint)		
Reg5 / Reg6	Operating hours above max operating temperature [h] (float)	Heartbeat (uint)			
Modbus function code	3, 4	3, 4	3, 4	3, 4, 16	3, 4, 16
Read access	U/A/S	U/A/S	U/A/S	U/A/S	U/A/S
Write access	none	none	none	S	S

In register 4676 are stored:

- total operating hours
- operating hours above max measurement temperature
- the operating hours above max operating temperature

In register 4682 are stored:

- number of power ups
- number of watchdog resets
- Heartbeat: counts repetitively from 0 to 19 in a 3 seconds cycle.

In register 4688 are stored:

- number of sterilizations in place (SIP) (see chapter 15.3.7.15)
- number of cleanings in place (CIP) (see chapter 15.3.7.15)

In register 4692 is stored:

- number of autoclavings

In register 8232 is stored:

the system time counter: When the sensor is powered up, the system time is set to 0. A value between 0 and 232 - 1 can be written into this register. From this value, the sensor increments this value every second.

We recommend to use as base date the so-called UNIX timestamp (www.epochconverter.com) which starts at 1st of January 1970 GMT. Be sure to update this register if needed after every power up of the sensor.

Accuracy of the system time, if not updated by the operator: The deviation of the system time is less than one minute per week.

15.3.7.13 Warnings

A «Warning» is a notification message which still allows further functioning of the system. This message alerts the operator of a possible problem that could lead to uncertain results.

It is reported by the PMC (15.3.7.8 Definition of the Measurement Status for PMC1 / PMC2 / PMC6) if a warning is active or not. Therefore it is not necessary to poll the Warnings register!

15.3.7.13.1 Currently Active Warnings

The currently active warnings are stored in register 4736. For the definition of the warnings see chapter 15.3.7.13.2.

Start register	4736
Number of registers	8
Reg1 / Reg2	Active warning measurement (uint)
Reg3 / Reg4	Active warning calibration (uint)
Reg5 / Reg6	Active warning interface (uint)
Reg7 / Reg8	Active warning hardware (uint)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

15.3.7.13.2 Definition of Warnings

Bit #	Hex code	Description
none	0x00000000	OK
5	0x00000020	Out of calibration range: lower limit
6	0x00000040	Out of calibration range: upper limit
8	0x00000100	SNR too high
12	0x00001000	Measurement off, because of over temperature
13	0x00002000	Measurement off, because of too weak power supply
22	0x00400000	Scan fitting poor input data (R2)
25	0x02000000	T below lower limit
26	0x04000000	T above upper limit
28	0x10000000	Too many sterilization cycles

Definition of warnings «measurement»

Bit #	Hex code	Description
		not available

Definition of warnings «calibration». None is defined.

Bit #	Hex code	Description
		not available

Definition of warnings «interface». None is defined.

Bit #	Hex code	Description
none	0x00000000	OK
0	0x00000001	Sensor supply voltage too low
1	0x00000002	Sensor supply voltage too high
21	0x00200000	Recording memory full

Definition of warnings «hardware»

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.14 Errors

An «Error» message indicates a serious problem of the sensor which does not allow further proper functioning of the sensor. This problem must be solved.

It is reported by the PMC (15.3.7.8 Definition of the Measurement Status for PMC1 / PMC2 / PMC6) if an error is active or not. Therefore it is not necessary to poll the Errors register!

15.3.7.14.1 Currently Active Errors

The currently active errors are stored in register 4800. For the definition of the errors see chapter 15.3.7.13.2.

Start register	4800
Number of registers	8
Reg1 / Reg2	Active error measure-ment (uint)
Reg3 / Reg4	Active error calibration (uint)
Reg5 / Reg6	Active error interface (uint)
Reg7 / Reg8	Active error hardware (uint)
Modbus function code	3, 4
Read access	U/A/S
Write access	none

15.3.7.14.2 Definition of Errors

Bit #	Hex code	Description
none	0x0000000	OK
25	0x2000000	Temperature sensor defective

Definition of errors «measurement»

Bit #	Hex code	Description
		not available

Definition of errors «calibration». None is defined.

CONNECTION TO THE PROCESS CONTROL SYSTEM

Bit #	Hex code	Description
		not available

Definition of errors «interface». None is defined.

Bit #	Hex code	Description
none	0x0000000	OK
2	0x0000004	Temperature reading far below min
3	0x0000008	Temperature reading far below max
22	0x0040000	Internal error (I2C, EEPROM)
24	0x0100000	Internal error (I2C)
25	0x0200000	Internal error (Sync error)
26	0x0400000	Internal error (Stack overflow)

Definition of errors «hardware».

If an internal error occurs, reset the sensor and try again.

15.3.7.15 Definition of SIP and CIP

Incyte Arc Sensors are counting special cleaning events such as sterilizations or cleaning cycles by means of tracking typical temperature profiles.

Register 4988 defines a typical temperature profile for SIP (sterilization in place) and register 4996 for CIP (cleaning in place). For the explanation the following values are given:

- CIP temperature min: 80 °C
- CIP temperature max: 100 °C
- CIP time min: 30 minutes

- SIP temperature min: 120 °C
- SIP temperature max: 130 °C
- SIP time min: 30 minutes

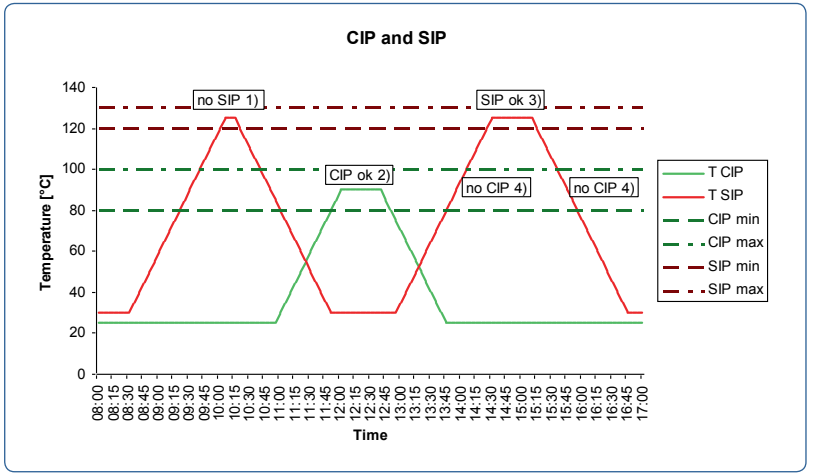


Figure 43: Definition of CIP and SIP cycles

1) no SIP-cycle counted, because time too short <30 minutes.
2) CIP-cycle counted, because time >30 minutes and in CIP temperature range.
3) SIP-cycle counted, because time >30 minutes and in SIP temperature range.
4) no CIP-cycle counted, because of reaching the SIP-min limit.

Start register	4988	4996
Number of registers	8	8
Reg1 / Reg2 (float)	SIP Temperature min	CIP Temperature min
Reg3 / Reg4 (float)	SIP Temperature max	CIP Temperature max
Reg5 / Reg6 (float)	SIP Process time min [min]	CIP Process time min [min]
Reg7 / Reg8	Empty	Empty
Modbus function code	3, 4	3, 4
Read access	U/A/S	U/A/S
Write access	S	S

The unit of the temperatures is according to the selected unit of PMC6.

15.3.7.16 Reading the Sensor's Quality Indicator

In register 4872 the sensor's quality indicator (0-100%) is given.

Start register	4872
Number of registers	2
Reg1 / Reg2 (float)	Quality [%]
Modbus function code	3, 4
Read access	U/A/S
Write access	none

The sensor's quality indicator is influenced by:

- Conductivity
- Warnings
- Errors
- Verification procedure running in Arc Air

15.3.7.17 Sensor Identification and Information

15.3.7.17.1 General Information

General information about the sensor is available as shown in the Table below.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1024	8	FW Date	2017-09-04	3, 4	U/A/S	none
1032	8	FW	CDCUM001	3, 4	U/A/S	none
1040	8	BL Date	2017-09-18	3, 4	U/A/S	none
1048	8	BL	BL5UX001	3, 4	U/A/S	none
1056	8	Userend PN	243892/00	3, 4	U/A/S	none
1064	8	Userend SN	1234	3, 4	U/A/S	none
1072	8	not available	not available	3, 4	U/A/S	none
1080	8	not available	not available	3, 4	U/A/S	none
1088	8	not available	not available	3, 4	U/A/S	none
1096	8	not available	not available	3, 4	U/A/S	none
1104	8	not available	not available	3, 4	U/A/S	none
1112	8	not available	not available	3, 4	U/A/S	none
1120	8	not available	not available	3, 4	U/A/S	none
1128	8	not available	not available	3, 4	U/A/S	none
1136	8	not available	not available	3, 4	U/A/S	none
1144	8	not available	not available	3, 4	U/A/S	none

Due to compatibility reason to other ARC sensors, register 1088 – 1144 are readable. They return ASCII «not available» and have no further meaning.

15.3.7.17.2 Sensor Identification

Definition of registers containing sensor identification:

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1280	8	Sensor Ref	243950/00	3, 4	U/A/S	none
1288	8	Sensor name	Incyte	3, 4	U/A/S	none
1296	8	Sensor Lot	3214567	3, 4	U/A/S	none
1304	8	Sensor Lot date	2010-04-30	3, 4	U/A/S	none
1312	8	Sensor SN	0001001	3, 4	U/A/S	none
1320	8	Manufacturer part 1	Hamilton Bonaduz	3, 4	U/A/S	none
1328	8	Manufacturer part 2	AG Switzerland	3, 4	U/A/S	none
1336	8	Sensor type	Arc CDC Sensor	3, 4	U/A/S	none
1344	8	Power supply	22-26V 1.5W	3, 4	U/A/S	none
1352	8	Pressure range	0 ... 12 bar	3, 4	U/A/S	none
1360	8	Sensor ID	243950-0001001	3, 4	U/A/S	none
1368	8	a-length	120	3, 4	U/A/S	none
1376	8	(space holder)	not available	3, 4	U/A/S	none
1384	8	Electrical connection	VP 8.0	3, 4	U/A/S	none
1392	8	Process connection	PG 13.5	3, 4	U/A/S	none
1400	8	Sensing material	Pt	3, 4	U/A/S	none

CONNECTION TO THE PROCESS CONTROL SYSTEM

15.3.7.17.3 Free User Memory Space

These registers can be used to store any customer specific information in the sensor. There are different registers which can be read by everybody, but only specific operators can write them.

Start register	Number of registers	Reg1 to Reg8 (16 ASCII characters)	Example of content	Modbus function code	Read access	Write access
1536	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1544	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1552	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1560	8	Free user space U/A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	U/A/S
1568	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1576	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1584	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1592	8	Free user space A/S	*FREE_USERSPACE*	3, 4, 16	U/A/S	A/S
1600	8	Measuring point	243950-0001001	3, 4, 16	U/A/S	S
1608	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1616	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1624	8	Free user space S	*FREE_USERSPACE*	3, 4, 16	U/A/S	S
1632	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1640	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1648	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1656	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1664	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1672	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1680	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1688	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1696	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1704	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1712	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1720	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1728	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1736	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1744	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none
1752	8	Free user space others	*FREE_USERSPACE*	3, 4	U/A/S	none

An important register is 1600, as it is the description of the measuring point. This information is used by ArcAir in order to identify individual sensors.

⚠ ATTENTION! The Free User Memory Space is located in a memory which allows in total max 1’000’000 write operations.

15.3.7.18 System Commands

15.3.7.18.1 Restore Factory Settings

Using register 8192 you can recall the sensor manufacturer values (interfaces, calibration data and passwords), except the SIP and CIP data which remain unchanged. By sending the recall value «911», all configuration values will be set to default.

Start register	8192
Number of registers	2
Reg1 / Reg2 (float)	Recall by value 911
Modbus function code	16
Read access	none
Write access	S

16 Troubleshooting

16.1 Sensor Self-Diagnostic

Arc sensors provide a self-diagnostic functionality to detect and identify the most common sensor malfunctions. All interfaces, analog 4–20 mA or digital Modbus, as well as connection to the PC may provide warning and error messages. The analog 4–20 mA interface can be configured according to the NAMUR recommendations to indicate an abnormal event (see chapter 15.1). Use ArcAir for monitoring the sensor status and for troubleshooting. The following types of messages are provided by the self-diagnosis function.

NOTE: Errors must be addressed and corrective action is immediately necessary.

NOTE: Warnings must be acknowledged. Corrective action is depending on the root cause. The warning will be displayed continuously until the corrective action is successfully completed.

NOTE: For additional information about the sensor status and the diagnostics features refer to the sensor's operation instruction manual or the programmer`s manual.

16.2 Warnings and Errors

Indicator State	Warning	Description
Green	OK	Ready to use
Yellow	Viable Cell Density too low	The viable cell density cannot be calculated as the measured permittivity values are too low.
Yellow	Viable Cell Density too high	The viable cell density cannot be calculated as the measured permittivity values are too high.
Yellow	Conductivity too low	The conductivity is below the specified range, so no measurement of the permittivity is possible.
Yellow	Conductivity too high	The conductivity is above the specified range, so no measurement of the permittivity is possible.
Yellow	External interferences detected	The permittivity measurement is disturbed by external electrical interferences. Please check your environment and ground the sensor as described in chapter 4.3.
Yellow	Ambient temperature too high, no measurement is possible	The ambient temperature is too high, no measurement possible. Please ensure temperature conditions below 40 °C.
Yellow	Power too low, no measurement possible	The power is too low to measure. If using the Power Cable (REF), please use the provided power supply and not only the energy from the USB connection.
Yellow	alpha below lower limit	The viable cell density is too low to calculate alpha.
Yellow	alpha above upper limit	The viable cell density is too high to calculate alpha.
Yellow	fc below lower limit	The viable cell density is too low to calculate the characteristic frequency.
Yellow	fc below lower limit	The viable cell density is too high to calculate the characteristic frequency.
Yellow	dEps below lower limit	The viable cell density is too low to calculate delta Epsilon.
Yellow	dEps below lower limit	The viable cell density is too high to calculate delta Epsilon.
Yellow	Parameter fitting cannot be applied, as the input data quality is not good enough	The Cole-Cole parameter fitting cannot be calculated as the measured viable cell density values are too low. This may be the case if the sensor is in medium only, or at process start, as well as low density cultures.
Yellow	Temperature too low, no measurement possible	The temperature is below the specified range, so no measurement of the permittivity is possible. Please ensure at least 4 °C temperature.
Yellow	Temperature too high, no measurement possible	The temperature is above the specified range, so no measurement of the permittivity is possible. The maximal measuring temperature is 60 °C.
Yellow	Supply voltage too low	The power is too low to measure. If using the Power Cable (REF 243470), please use the provided power supply and not only the energy from the USB connection.
Yellow	Supply voltage too high	The power is too high to measure. The electronics are regulated down to not get damaged.

Indicator State	Warning	Description
Yellow	Please replace the sensor, too many sterilization cycles have been performed	The sensor is specified and tested to survive 100 sterilisation cycles. Once the cycles are done, it is highly recommended to replace the sensor.
Yellow	Internal memory failure. Restart the sensor	The electronical board does not provided the expected signal. Please disconnect and re-connect the sensor. If the warning consists, please contact your local representative.
Red	No valid probe factor available	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid calibration available	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid ADC offset	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid analog gain	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid temp. Measurement calibration	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid power monitor calibration	The sensor is not completely calibrated. Please contact your local representative.
Red	No valid rodage	The sensor is not completely calibrated. Please contact your local representative.
Red	Memory full, no further recording possible.	The internal memory of the sensor is full. Please download the data (see chapter 10.4.9.2) and re-connect the sensor.
Red	Temperature measurement not possible, please contact your Hamilton representative	The temperature sensor is defect. Please contact your local representative.
Red	Internal communication error, please contact your Hamilton representative	The electronical board does not provided the expected signal. Please contact your local representative.

16.3 Getting Technical Support

If a problem persists even after you have attempted to correct it, contact Hamilton`s Customer Support: Please refer to the contact information at the back of this operating instruction.

16.4 Return Back for Repair

Before returning an Arc sensor to Hamilton for repair, contact our Customer Service (correct reference) and request a Returned Material Authorization (RMA) number. Do not return an Arc sensor to Hamilton without an RMA number. This number assures proper tracking of your sensor. Arc sensors that are returned without an RMA number will be sent back to the customer without being repaired. Decontaminate the Arc sensor and remove health hazards, such as radiation, hazardous chemicals, infectious agents etc. Provide complete description of any hazardous materials that have been in contact with the sensor.

17 Disposal

The design of Arc sensors optimally considers environmental compatibility. In accordance with the EC guideline 2012/19/EU Hamilton sensors that are worn out or no longer required must be sent to a dedicated collection point for electrical and electronic devices, alternatively, must be sent to Hamilton for disposal. Sensors must not be sent to an unsorted waste disposal point.

有害物質表，請參閱www.hamiltoncompany.com, 章節過程分析，符合性聲明

18 Ordering Information

NOTE: Specifications are available on the homepage.

18.1 Sensors

REF	Name
243950-0211	Incyte Arc 120 – Expert

Description: Sensor (length 120) with the full capability of running Dual Frequency Measurement and Scan (including measurement export), owning the possibly to run Cole-Cole Fitting and off-line/on-line correlation (ArcAir Data Modeling). Full GMP compliance is provided with and ArcAir Advanced.

243950-0212	Incyte Arc 220 – Expert

Description: Sensor (length 220) with the full capability of running Dual Frequency Measurement and Scan (including measurement export), owning the possibly to run Cole-Cole Fitting and off-line/on-line correlation (ArcAir Data Modeling). Full GMP compliance is provided with and ArcAir Advanced.

243950-0213	Incyte Arc 320 – Expert

Description: Sensor (length 320) with the full capability of running Dual Frequency Measurement and Scan (including measurement export), owning the possibly to run Cole-Cole Fitting and off-line/on-line correlation (ArcAir Data Modeling). Full GMP compliance is provided with and ArcAir Advanced.

243950-0214	Incyte Arc 420 – Expert

Description: Sensor (length 420) with the full capability of running Dual Frequency Measurement and Scan (including measurement export), owning the possibly to run Cole-Cole Fitting and off-line/on-line correlation (ArcAir Data Modeling). Full GMP compliance is provided with and ArcAir Advanced.

ORDERING INFORMATION

18.2 Accessories

REF	Name
243470	Arc Wi 2G Adapter BT

Description: Arc Wi Adapter to convert Modbus to 4-20 mA signal and enable Bluetooth communication for sensor configuration.

243490-01	Arc USB Power cable USB /VP 8

Description: Cable to connect the sensor to a computer running ArcAir for data recording and sensor configuration. Supplied with optional power supply, in case the computer does not provide enough energy to power the sensor. USB 2.0 provides enough power.

243490-02	Arc USB Power cable USB /M12 – 8 pole

Description: Cable to connect the sensor with an Arc Wi Adapter to a computer running ArcAir for data logging and sensor configuration. Supplied with optional power supply, in case the computer does not provide enough energy to power the sensor. USB 2.0 provides enough power.

355320	Arc M12 8-Pole Data Cables – 3m

Description: Cable to connect the sensor with an Arc Wi Adapter to 4-20 mA entry of a process control system.

355321	Arc M12 8-Pole Data Cables – 5m

Description: Cable to connect the sensor with an Arc Wi Adapter to 4-20 mA entry of a process control system.

355322	Arc M12 8-Pole Data Cables – 10m

Description: Cable to connect the sensor with an Arc Wi Adapter to 4-20 mA entry of a process control system.

242333	Arc Wireless Converter BT, Advanced

Description: This converter enables the used of ArcAir Advanced Software, once the basic version is installed on a computer.

10071113	Arc View Mobile Advanced (Tablet)

Description: Tablet having the ArcAir Advanced Software already installed.

18.3 Verification Tools

REF	Name
238988	**Conductivity standard 12880 µS/cm, Basic Line**

Description: Referred as Permittivity Verification Standard; 0 pF/cm; 12,88 mS/cm. Required to verify the proper function of the sensor during the sensor verification procedure.

19 SOP to Create Data for off-line/on-line Correlation

1) Configure the sensor (see chapter 10).
2) Prepare the culture.
3) Start recoding (see chapter 10).
4) Perform a product calibration.
5) Take regular samples 2-3 times per day. At least 3 samples are required on the overall process. Take 3 separate samples each time a regular sample is taken. When taking the samples, mark the sampling time in ArcAir by adding the comment ‘samplen’ with ‘n’ being the sample number. We recommend using an impedance based cell counter such as CASY or Coulter Counter for off-line measurement. In addition to measuring the cell counts, an analysis of the average cell diameter is recommended.
6) If only one sample was taken for each regular sample at Step 5, repeat the off-line measurement 3 times. Enter the results from the 3 samples in the provided Excel spreadsheet on the homepage and determine the average of the off-line measurement.
7) Export the culture file (see chapter 10).
8) Repeat the culture five times (Steps 1-7).

SOP TO CREATE DATA FOR
OFF-LINE/ON-LINE CORRELATION

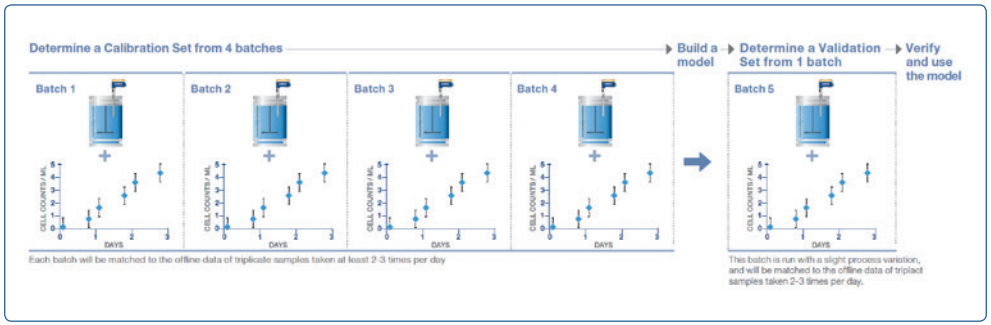


Figure 44: Experimental setup to collect data for Correlation

19.1 SOP to correlate the Dual Frequency Measurement

The system provides the possibility to correlate the permittivity signal of the Incyte with a reference measurement such as Viable Cell Count (cell/ml), OD or Dry Cell Weight (g/l). The correlated value is referred to as the «Viable Cell Density» value and is linked to the permittivity according to the following equation: Cell Density = (Permittivity – Offset) x cell factor. In order to correlate the permittivity signal with the reference measurements, the cell factor during the exponential phase of a culture has to be determined by simultaneously taking your off-line reference measurements and the permittivity readings. The linear relationship is build between the capacitance measurements (x axis) and the reference measurements (y axis): the slope of the linear correlation corresponds to the cell factor. The cell factor is cell line specific.

NOTE: It is recommended to perform the cell factor on at least three batches to get a reasonable fit.

NOTE: Cell density is usually overestimated in the lag and death phases using this method.

1) Plot the online and offline cell density measurements against time for comparison (figure 44).
2) Identify the measurements within the exponential phase (figure 45 A, green square). Plot the offline measurements of the exponential phase against the online measurements and

determine the correlation factor (figure 45 B), using the data of all three batches (figure 45 C). Calculate the slope (= cell factor).

3) To graph the data on the Excel file, perform the following steps:

- Load your data into the Excel spreadsheet
- Create an X-Y Diagram with interpolated lines.
- Use the culture time as x-axis and the permittivity measurement as y-axis. Plot the offline data on the secondary y-axis.
- Define the exponential growth phase.
- Use the Excel function =SLOPE (y value, x value) to calculate the slope of the corresponding data from the growth phase.

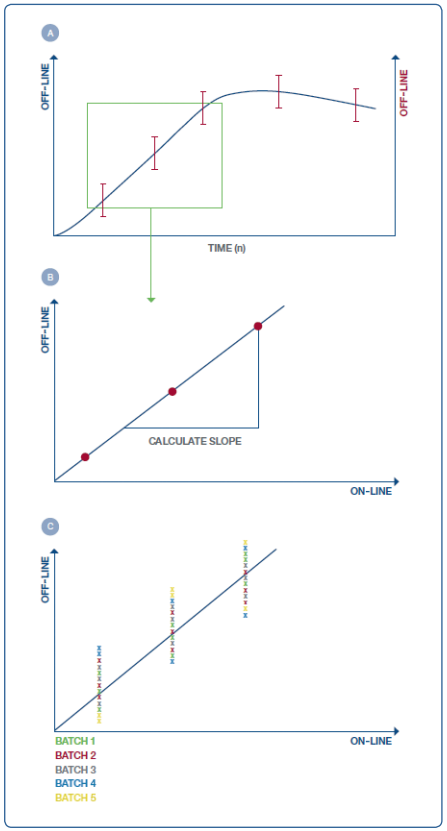


Figure 45: Linear data correlation, for one and three batches

SOP TO CREATE DATA FOR
OFF-LINE/ON-LINE CORRELATION

19.2 SOP to correlate using ArcAir Data Modeling Software

NOTE: At least five batches are required to obtain a reliable model evaluation.

⚠ ATTENTION! Please analyze everytime your complete set of process data, as the Arc Data Model may not perform ideally, in case the process runs significantly different compared to the teaching data.

19.2.1 Installation of the Software

NOTE: The Software is provided with Incyte Arc Expert.

1) Please download the ArcAir Data Modeling Software from: www.hamiltoncompany.com/process-analytics/accessories/communication-and-controllers
2) Unpack the zip file.
3) Execute the installation file.

NOTE: Following minimal system requirements are needed to run the software:

Operating System	Windows 10, 8.1, 8, or 7 For Windows 7, the latest service pack and other updates are required to be installed 64 bit
CPU	Intel Core i5 or comparable AMD processor 2 cores 64 bit
RAM	4 GB
Hard drive	4 GB free space before installation SSD recommended

NOTE: The Software is designed to run on windows only.

19.2.2 Running the Software

NOTE: Please use the provided sheet from the file upload and import area to prepare the offline data for the Software (see figure 46). It is possible to insert data as triplicate. Either TCD (total cell density) or VCD (viable cell density) data may be used as input. Click on the TCD or VCD row to select the suitable value (cells/ml; OD; PCV; g/l) from the pre-defined sets.

⚠ ATTENTION! The batch name of the culture- and off-line data file have to be identical. The name is combining the off-line and on-line data within the Software to one set.

The software is separated into three sections, the database for the input data, where the online and offline data is imported and stored, visualization of the data and models as well as the model area, where the models are stored (figure 47).

	A	B	C	D	E	F	G	H	I
1	Please insert the name of the batch, the absolute timestamps (dd.mm.yyyy HH:MM) and the offline measured TCD/VCD values.								
2									
3	Batch Name:	ExampleBatch							
4	Date Time	TCD (g/l)			VCD (e6 cells/ml)				
5	20.01.2017 12:00	5.40	5.50	5.90	5.80	5.60	5.50		
6	20.01.2017 13:00	6.90	7.15	7.30	7.30	7.10	7.00		
7	20.01.2017 14:30	7.70	7.85	7.80	8.10	7.90	7.70		
8									
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Figure 46: Offline Data Spreadsheet

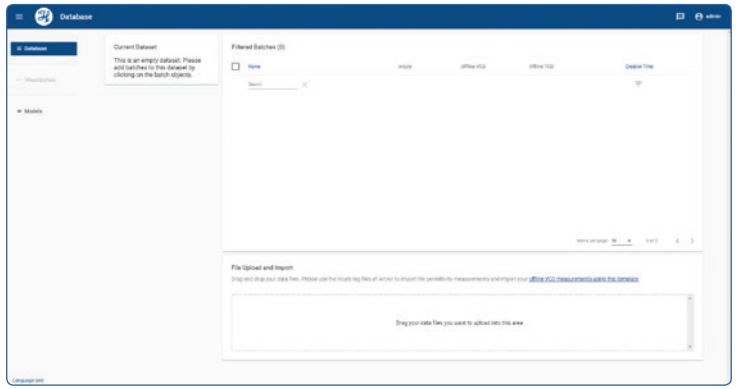


Figure 47: Overview of ArcAir Data Modeling

19.2.2.1 Import Data

NOTE: Please do not change the culture file prior to import. The Software is designed to work with the raw data.

1) Upon start of the Software the database is displayed.
2) Upload the data in the file upload and import section by drag and drop (figure 48), make sure the batch names of the offline and online data are the same, as offline and online data are combined during this procedure.
3) The import is indicated with a green (successful, figure 49) or red (not successful, figure 50) symbol, additionally the completeness of a dataset is shown in the database, an indicator with Incyte and one off-line value (VCD or TCD) has to be shown in table to ensure completeness.

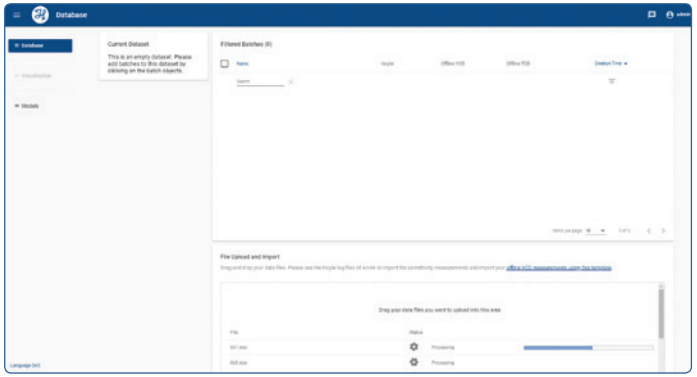


Figure 48: Database View with Data Import running

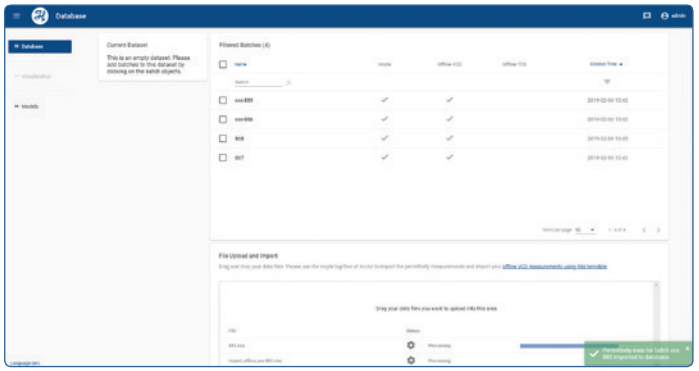


Figure 49: Succesful Data Import

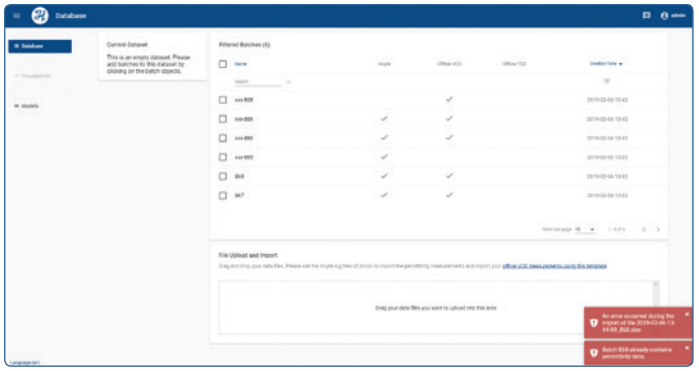


Figure 50: Failed Data Import

SOP TO CREATE DATA FOR
OFF-LINE/ON-LINE CORRELATION

19.2.2.2 Selection of Model Data

1) Select at least 4 batches of the same process to build a correlation model.
2) Add the selection to the current dataset, the selection is shown in the current dataset view.
3) Select visualization to check you data prior to model building, this step is recommended, or build the model directly.

19.2.2.3 Visualization of the Model Data

1) In the standard view it is possible to select one batch for visualization by selecting this in the data matrix. It is possible to select just one or all values of the selected data by activating the row (figure 51).
2) Select the advanced variable to display scan variables of the permittivity, or the Cole-Cole parameter: Delta eEpsilon (DeltaESP), characteristic frequency (f_c) or alpha (figure 52).

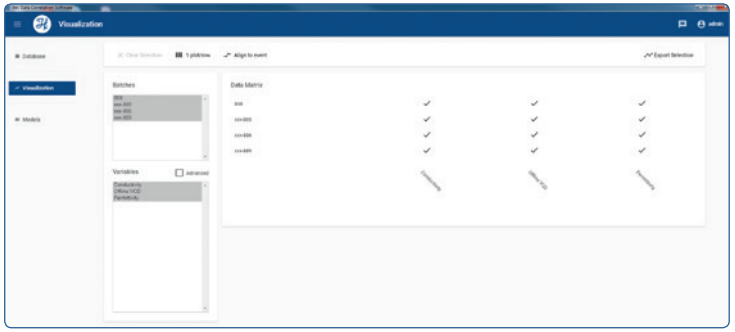


Figure 51: Basic Data Matrix for visualisation

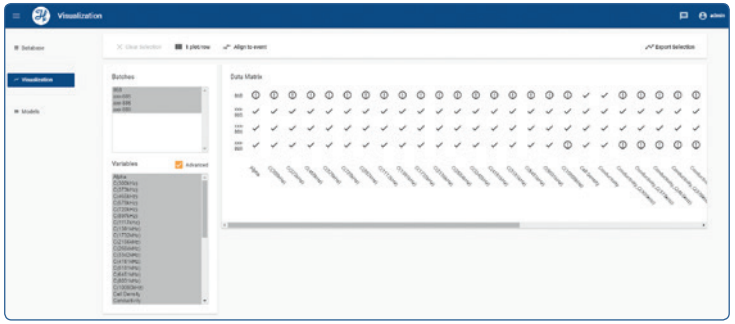


Figure 52: Advanced Data Matrix to display all possible measurements

3) The selected data is graphed in the lower part of the screen (figure 53); each batch is displayed in one graph, which can be in 1 or 2 plots, whereas 1 plot is set as standard. Data can be aligned to an event (all batches are aligned to time zero, which is the time of induction). If required the selected data can be exported as json, excel or csv-file.

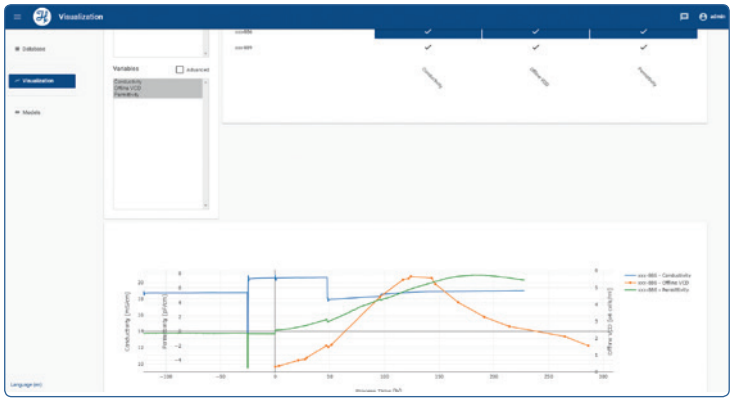


Figure 53: Data visualisation

NOTE: The correct inoculation time has to be marked during data recording to ensure a proper modeling procedure.

4) By scrolling over the graph, following actions are possible.

a. Download plot as a png
b. Zoom (Zoom in the graph)
c. Pan (move the diagram to any direction)
d. Box Select (select an area in shape of a box)
e. Lasso Select (select an area in shape of a ring)
f. Zoom In
g. Zoom Out
h. Autoscale
i. Reset axes
j. Toggle Spike Lines (shows orientation lines on the x and y axis) when swiping with the mouse over the data
k. Show closest data on hover (defines which data point is shown when swiped with the mouse)
l. Compare data on hover (defines which data point is shown when swiped with the mouse)
m. Produced with Plotly (for information only)

5) If the data is analyzed and defined to be consistent go to the model section.

19.2.2.4 Build a Model

1) Make sure that the current dataset contains the selected data, if other batches should be used, edit them and perform a visualisation (see chapter 19.1.2.3).
2) If the dataset is correct and complete click build model.
3) Select the culture performed. Algorithms for animal cell culture, yeast or bacterial fermentation are available (figure 53).
4) Click build and validate model.
5) Enter a specific name for the calibration model (max 16 digits).
6) The successful creation is indicated by a traffic light (figure 54):
   - green: model can be used
   - orange: input data should be improved, it is not recommended to use the mode without improvement
   - red: the input data is not sufficient, the model should not be used
7) For further information see the details, where a residual plot, the measured and predicted R^2 values for the training and validation data are displayed.

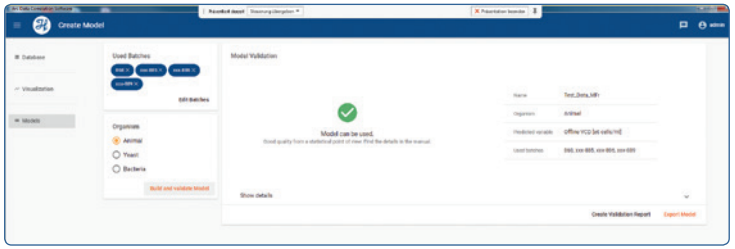


Figure 54: Quality Indicator

SOP TO CREATE DATA FOR
OFF-LINE/ON-LINE CORRELATION

NOTE: A quality indicator is provided on the model and based on following measures: At least 5 batches are required to get an good (green) quality indicator, 4 batches lead to an average (yellow) indication, whereas less than 3 batches do not provide a statistically relevant model and results in a red (not recommend) indicator.
Additionally the R^2 value for the validation is added to ensure the model quality, and defined to the following measures:

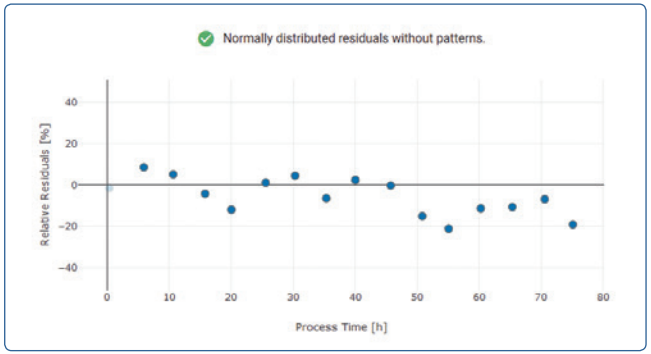
- $R^2 > 0.9$: green
- $R^2 > 0.8$: yellow
- Below 0.8: red

If less than 3 offline samples per batch are used, a warning will be shown.

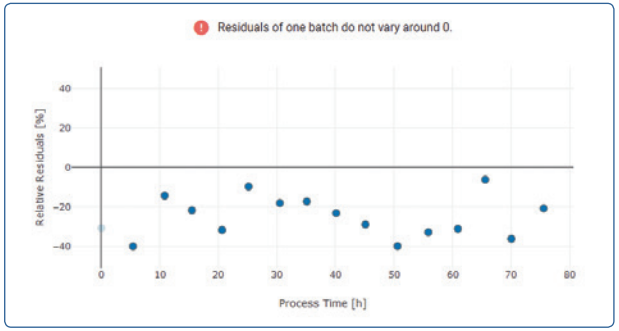
19.2.2.4.1 Interpretation of the Residual Plot

The Residual Plots provide a measure of the data, used for the Data Model.

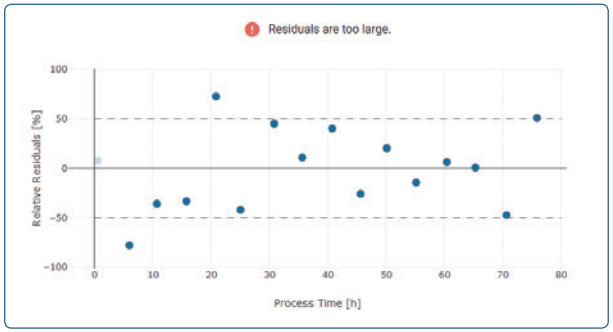
A good model results in an homogenous distribution:



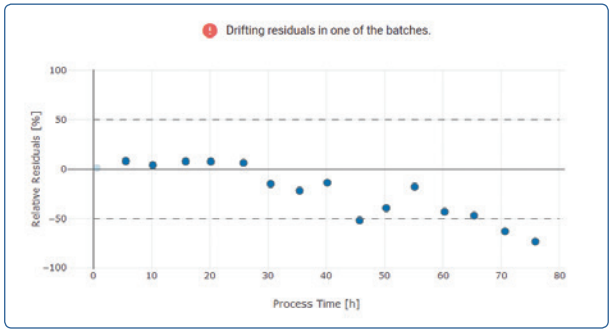
In case on batch does not vary around 0. It is recommended to replace it, with one being closer to zero.



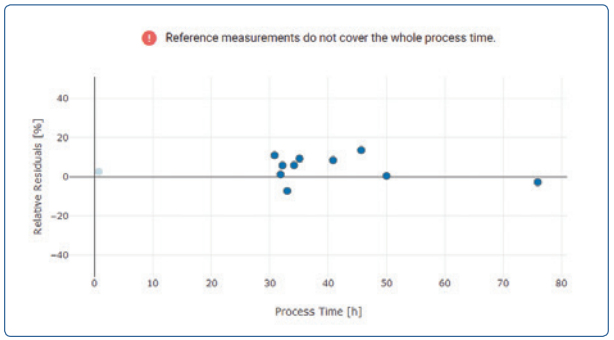
Some processes show a high variability and are not recommended to be used for the modeling process. It is recommended to replace it.



Maybe a process shows a drift of the measurement. In case this behavior is observed, it is recommend to replace the batch with a more stable one.



In case offline data was missed, the data set is not complete. A batch with complete data should be used instead.



NOTE: Interpretation of the graphed data:
As the algorithm is working after the principle «leave one out», one batch is used for validation, whereas the others are used for modeling. At every cycle a different batch is used for validation. Due to this procedure the same number of predictive models as well as input data is shown. Each graph displays the online and offline measurement as well as the model. Based on these graphs it is possible to judge the model quality visual.

NOTE: Interpretation of the R^2 value:
The closer the R^2 to 1, the better is the model. The R^2 of the training data is higher compared to the validation data. The better the R^2 of the trainings set, the more equal is the input data. If the R^2 of the validation data is in the same range as the R^2 of the data, where the model was built on, both data set compare well. But the lower the value the less comparable is the validation data.

19.2.2.5 Apply a Model on New Data

NOTE: The Quality of the application is analysed according to following measures:
- $R^2 > 0.9$: green
- $R^2 > 0.8$: yellow
- Below 0.8: red

SOP TO CREATE DATA FOR
OFF-LINE/ON-LINE CORRELATION

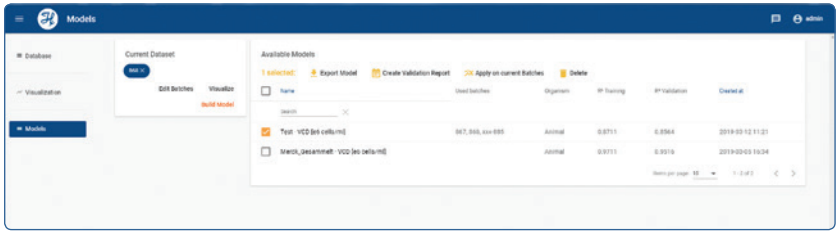


Figure 55: Application of an Arc Data Model to new Batches (item is placed in the upper row)

It is possible to apply an existing model to new data for further validation. To check if the model works properly for new, unknown data.

1) Go to the Database and add the desired data to the current dataset.
2) Go to the Models area and select the model.
3) Apply it on current Batches.
4) The validation quality is indicated by a green, yellow or red symbol.

19.2.2.6 Create a Validation Report

After building, or re-applying the model it is possible to create a validation report

1) Select the model in the model area (figure 55).
2) Create a validation report (item is located in the upper row).
3) Select the path and press save.
4) The report is created a PDF which can be signed by two persons to release the model, it comprises all data and information, additionally it contains a unique identifier, which is called a check-sum to ensure model integrity upon export and transfer of the model.

NOTE: Checksum:
The Checksum functionality ensures that the files are used for the intended purpose – trying to minimize as much as possible the human error. It ensures safety, traceability and usability, being realized using Hash and Salt methodic.

19.2.2.7 Delete a model

1) Select the model in the model area (figure 55).
2) Click in delete (item is located in the upper row).
3) Press «ok».

19.2.2.8 Export a model

1) Select the model in the model area (figure 55).
2) Export the model.
3) Select the path and press save an «incal» file is now created for real-time application on the sensor.

NOTE: The model import on the sensor is described in chapter 10.4.2.2.

20 Hardware compatibility

⚠ ATTENTION! Incyte Arc is not compatible with the Cell Density Monitoring System. It is not possible to connect Incyte Arc Sensors to the Arc View Controller, ComBox or PC Box.

21 Glossary

Alpha

Parameter calculated according to Cole-Cole equation (for details see chapter 5.2.2.2).

Arc Data Model

The same as Model, or Correlation Model, describes the model build using the ArcAir Data Correlation Software. This model can be transferred on the sensor to allow an improved correlation on the complete process.

Arc Data Modeling Software

Software Tool to create and validate models to improve off-line/on-line correlation of reproducible processes, using the (Incyte) Scan.

Batch

Refers to the data recorded during a process, maybe the on-line (culture file) and/or off-line data.

Calibration

The sensor come factory calibrated, where electronics and sensor-shaft are aligned over the specified conductivity, permittivity and frequency range.

Capacitance Measurement

Measurement principle of Incyte Arc, please refer to chapter 5.2 for details.

Characteristic frequency

Parameter calculated according to Cole-Cole equation (for details see chapter 5.2.2.2).

Cole fit R2

Confidence rating of the parameters calculated according to Cole-Cole equation. It is the statistical calculated R^2 error of the fit (for details see chapter 5.2.2.2).

GLOSSARY

Cole fit RMSE

Absolute error of the parameters calculated according to Cole-Cole equation. The error is based on a statistical calculation (for details see chapter 5.2.2.2).

Correlation

Correlation of the dual frequency measurement, or based on Scan data with the offline method. Sometimes referred as cell factor (in the dual frequency measurement) or Model (in the Scan measurement).

Correlation Model

The same as Model, or Arc Data Model, describes the model build using the ArcAir Data Correlation Software. This model can be transferred on the sensor to allow an improved correlation on the complete process.

Culture

Refers to a bioprocess, cell culture or fermentation

Delta epsilon

Parameter calculated according to Cole-Cole equation (for details see chapter 5.2.2.2).

Model

The same as Arc Data Model, or Correlation Model, describes the model build using the ArcAir Data Correlation Software. This model can be transferred on the sensor to allow an improved correlation on the complete process.

Moving average

The moving average is a mean value of a defined amount of measurements over time.

MVDA

Multivariate data analysis. This technique is used to perform off-line/on-line correlation on the Scan data in ArcAir Data Modeling Software.

Off-line

Refers to samples taken from the bioreactor.

On-line

Refers to the Incyte measurement, in real-time, done in-line, in-situ, or at-line.

Permittivity Measurement

Measurement principle of Incyte Arc, please refer to chapter 5.2 for details.

Probe

Different wording for sensor.

Process

Refers to a bioprocess, cell culture or fermentation

Sensor

Different wording for Probe.

(Incyte) Scan

Permittivity measurement over the defined frequency range.

22 FAQ

Can the electric field of Incyte damage/harm the cells?

No. The frequency of the electric field applied by the system is within 300 kHz and 10 MHz. These frequencies do not damage the cells.

What is the effect of cell aggregates, cell clumping on the Incyte measurement?

The proximity of cells can induce a slight decrease in the capacitance signal, up to 3-4%. It is also known that cell aggregates can create some noise on the signal which can be minimized with the system integration function which is based on a moving average calculation.

Can I use the Incyte Sensor with micro-carriers?

Yes, the Sensor is insensitive to micro-carriers. Incyte measures the bio volume of each cell on the microcarrier

How is Incyte measurement influenced if the organisms are not round but cylindrical or long stretched?

The measurement is possible but scan calculations are based on a spherical model. Therfore a correlation on the dual frequency measurement may work, whereas the Scan may not work sufficient.

Are spores detected by Incyte Sensor?

Spores are not detectable because they do not have a plasma membrane, and are too small.

Will oil drops influence the measurement of Incyte?

Oil will most likely create a surface layer on the electrodes and that will affect calibration and probably disturb the signal stability during the run. The effect at higher concentrations is not significant.

What is the effect of changes in conductivity on the Incyte measurement?

Changes in conductivity during a culture do not impact the permittivity measurement. The Sensor is calibrated over the specified conductivity, and frequency range to compensate against conductivity changes.

FAQ

What is the effect of changes in pH on the Incyte measurement?

There is no effect from pH on the measurement. But pH may have an influence on the organism, which may be realized by on-line measurement.

What is the effect of changes in temperature on the Incyte measurement?

There is no effect from temperature on the measurement. But the temperature change may have an influence on the organism, which may be realized by the online measurement.

What is the effect of changes in the osmolality on the Incyte measurement?

There is no effect from temperature on the measurement. But the osmolality change may have an influence on the organism, which may be realized by the online measurement.

Can I use the Incyte Sensor in very high cell concentrations?

Yes, there is no limitation in the higher end of concentrations.

Can I use the Incyte Sensors for offline measurements?

Yes, the Sensor may be used in stirred beaker experiments. For optimal results, it is important mount the sensr correctly (figure 13). The moving average function may be reduced to low for real-time measurements.

What is the effect of solid particles on the Incyte measurement?

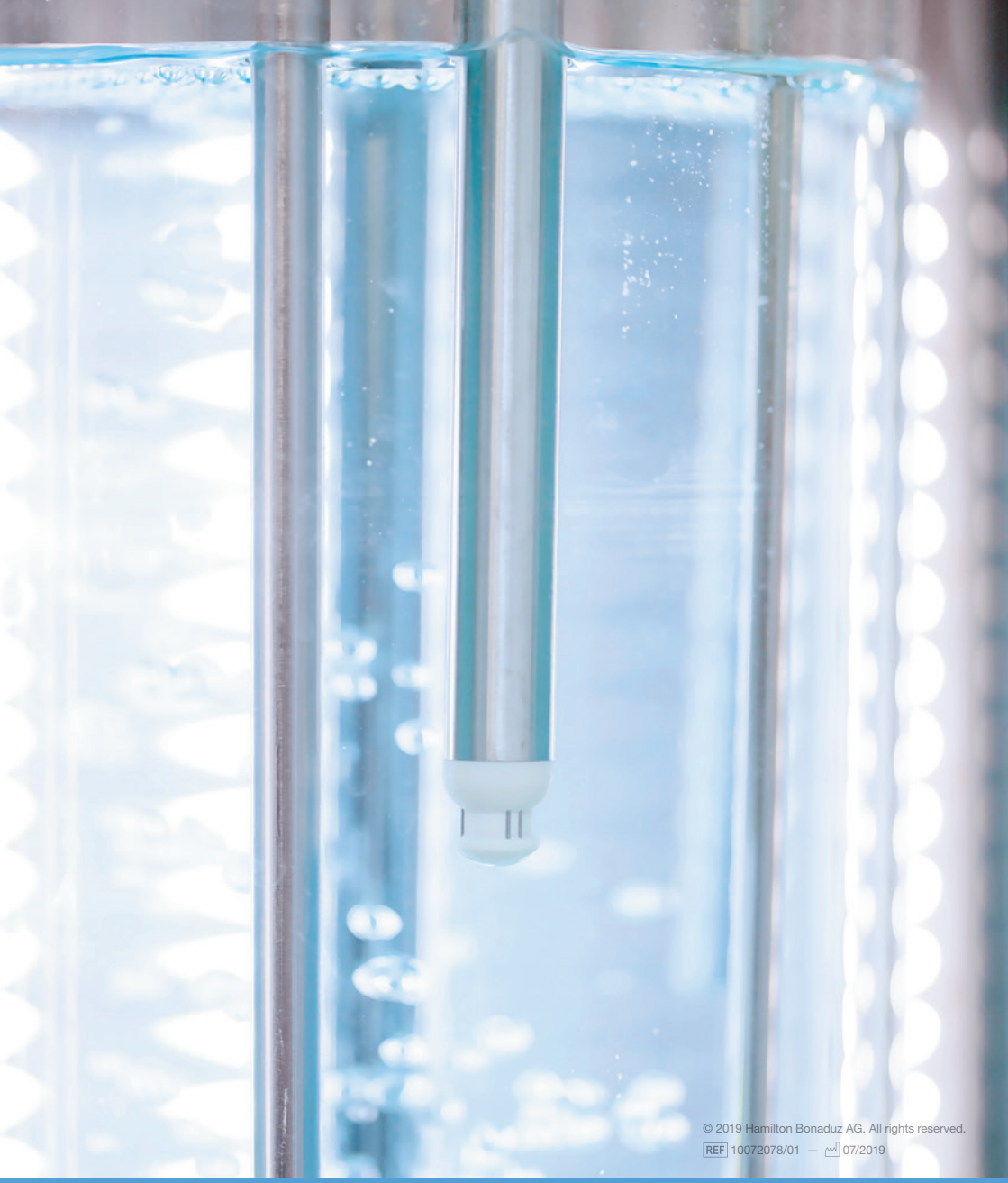
A content of solid particles higher than 10% (w/v) may interfere with the Incyte measurement, as the particles disturb the electrical field and may create a noise level.

Can contamination be detected with the Incyte sensor?

Not direct. The deviation of an expected growth may be visible and has to be analyzed. This analysis may indicate a contamination.

What is the sensor lifetime?

The lifetime of the Incyte Arc sensors is tested for at least 100 sterilization cycles. Temperature, pressure and chemicals may lead to the ageing of both the sensor electronic and sensing material.



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