ABL700 series reference manual

ABL700 series reference manual

RADIOMETER

Note to the users of the EML105, ABL5xx, ABL SYSTEM 6xx, ABL7xx Series, ABL800 FLEX and ABL800 BASIC analyzers

Introduction

This note to users outlines a change in the operator's and reference manual for your EML105, ABL5xx, ABL SYSTEM 6xx, ABL7xx Series, and/or ABL800 FLEX and ABL800 BASIC analyzer.

Brief overview of the change

Operator's manual:

Limitations of use and known interfering substances:

⚠ **CAUTION - *Known interfering substances***

Substance	Interference
ClO_4^- (drugs)	For ClO_4^-, interference on cCa^{2+} (1.25 mmol/L level) has been detected: cCa^{2+} (1.25 mmol/L level): –0.20*.

* Depending on the pH level

Reference manual:

Change/Description					
Interference on	For ClO_4^-, interference on cCa^{2+} (1.25 mmol/L level) has been detected. The interference results for ClO_4^- are as follows:				
Substance	**Test Conc.**	**Interference on…**			
		cK^+ (4 mmol/L level)	**cNa^+ (150 mmol/L level)**	**cCa^{2+} (1.25 mmol/L level)**	**cCl^- (110 mmol/L level)**
ClO_4^-	1.5 mmol/L	-	-	–0.20*	8-30

* Depending on the pH level

A "-" indicates that interference has not been measured on the respective parameter.

Technical documentation

The manual will be updated with the above information as part of the next manual update.

Instructions to user

Please place this note to the users in the binder of your manual.

995-521. 200912A.

RADIOMETER

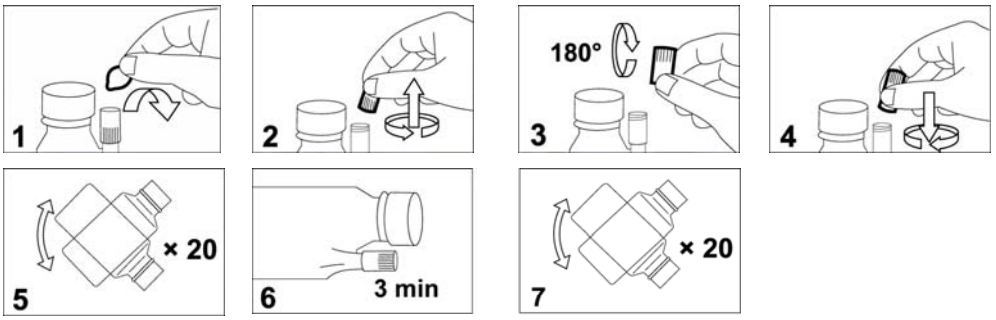
Note to users of the ABL700 Series analyzers

Mandatory upgrade of the manual

The manuals for the ABL700 Series analyzers must be upgraded with regard to the information on cleaning solution.

The procedure for adding cleaning additive has been changed for the above-mentioned analyzers and from now on the following instructions must be followed:

Cleaning solution with cleaning additive - installation



1. Remove the foil from the DosiCapZip and unscrew it (Figs. 1+2).
2. Turn the DosiCapZip upside down and screw it onto the container again (Figs. 3+4).

   CAUTION: *If the contents of the DosiCapZip or the container have been spilt by accident, both the container and the DosiCapZip should be discarded to prevent incorrect concentrations in the solution.*
3. Invert the container at least 20 times to dissolve the additive (Fig. 5).
4. Place the container horizontally so that the solution may enter the DosiCapZip and leave it for 3 minutes (Fig. 6).
5. Invert the container again at least 20 times to fully dissolve the additive (Fig. 7).
6. Unscrew the lid from the new solution container.
7. Remove the used solution container by holding it on the sides and pulling.
8. Scan the barcode of the new solution, using the barcode reader.
9. Place the new solution container in position on the analyzer and push it firmly onto the connector as far as possible.
10. For the ABL700 Series analyzers, sw. 3.836: Press ***Restart*** to restart the analyzer.

    For the ABL700 Series analyzers, sw. 6.00: Press ***Restart*** and ***Accept*** to restart the analyzer.

994-702. 200810A.

Cleaning solution with cleaning additive – general information

Item	Code No.	Type
Cleaning Solution 175 mL	944-123	S7375

Use: For cleaning the measuring system of the ABL700 Series analyzers.

Contains: Salts, buffer, anticoagulant, preservatives, surfactants and enzyme. Safety Data Sheet may be obtained from your local distributor.

Storage: At 2-10 °C.

Stability in use: The Cleaning Solution with the Cleaning Additive is stable for 2 months in use.

Analyzer: Perform cleaning every 8th hour.

CAUTION – Risk of personal injury

Do not breathe dust (S22). Avoid contact with skin (S24). Irritating to eyes and skin (R36/38). Wear suitable gloves (S37). May cause sensitization by inhalation and skin contact (R42/43). In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible) (S45).

Texts no longer valid in the manuals

Due to new cleaning solutions, information about Cleaning solution S7370 and Cleaning additive S5370 is no longer valid.

Below is a list of the sections in the manual that must be ignored.

ABL700 Series reference manual:

Chapter 7: Solutions and gas mixtures:

S7370 Cleaning Solution and S5370 Cleaning additive:	Text no longer relevant. See instruction about the new Cleaning Solution S7375 above instead.
Index:	Cleaning Additive references no longer relevant.

Technical documentation

The manuals for the ABL700 Series analyzers will be updated with the above information when reprinted.

Instructions to user

This update kit includes a note to the user with the changes and a new date of issue page of the manual. Please place the note to the user in the binder of the ABL700 Series reference manual and replace the date of issue page with the new corresponding page, then discard the old page.

ABL700 Series

Reference Manual

SYSTEM PERFORMANCE AND WARRANTY DISCLAIM

Radiometer cannot provide or verify instrument performance characteristics and accept warranty claims or product liability claims if the recommended procedures are not carried out, if accessories other than those recommended by Radiometer are used, or if instrument repairs are not carried out by authorized service representatives.

The instructions given in the Operator's Manual for the ABL700 Series must be observed in order to ensure proper instrument performance, and to avoid electrical hazards.

TRADEMARKS

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Contents

1. Introduction

Overview

This section gives an introduction to the documentation that accompanies your ABL700 Series analyzer. It describes how this particular manual is organized and explains the different notices that appear in it.

Contents

This chapter contains the following topics.

ABL700 Series Documentation

ABL700 Series Analyzers

The documentation that accompanies the ABL700 Series analyzers covers the series in general - each possible electrode combination is not considered individually.

Documentation

The table below describes the documentation that comes with each analyzer.

Documentation	Description
The Operator's Manual	Contains all the information required for everyday operation of the analyzer. Describes the functions of the analyzer and how to set it up according to customer needs and requirements. Explains error messages and gives troubleshooting procedures. Contains ordering information
The Reference Manual	Gives detailed information about the operating principles of the analyzer. Describes the measuring and calibrating principles. Lists all the parameters. Gives the equations from which the derived parameters are calculated. Gives information about how the performance of the analyzer is tested.
On-line Help	Summarizes the information found in the Operator's Manual. Gives hands-on help at the analyzer.

Design of Manual

Depending on the set up of your analyzer, the entire Reference Manual may not be applicable to it. However the manual is designed in such a way that it is easy to disregard or remove the sections that are not relevant to your instrument.

Warnings/Cautions and Notes

Definitions

The following table indicates the type of information given in warnings, cautions, and notes:

Notice	Definition
WARNING	Warnings alert users to potentially serious outcomes to themselves or to the patient (such as death, injury, or serious adverse events).
PRECAUTION	Precautions alert users to exercise the special care necessary for safe and effective use of the device. They may include actions to be taken to avoid effects situations on patients or users that may not be potentially life threatening or result in serious injury , but about which the user should be aware. Precautions may also alert the user to adverse effects on the device caused by use or misuse, and the care required to avoid such effects.
NOTE	Notes give practical information.

List of *WARNING/ CAUTION* Notices

All *WARNING/CAUTION* notices that appear in this manual, are listed below.

- ***S5370 Cleaning Additive****: May cause sensitization by inhalation and skin contact). Do not breathe dust. Avoid contact with skin. Wear suitable gloves. In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).*
- ***Gas Mixtures:*** *Not for drug use. High pressure gas. Do not puncture. Do not store near heat or open flame - exposure to temperatures above 52 ^{o}C (125 ^{o}F) may cause contents to vent or cause bursting.*
  Not for inhalation. Avoid breathing gas - mixtures containing carbon dioxide can increase respiration and heart rate. Gas mixtures containing less than 19.5 % oxygen can cause rapid suffocation.
  Store with adequate ventilation. Avoid contact with oil and grease.
  Only use with equipment rated for cylinder pressure.
  Use in accordance with Safety Data Sheet.

2. Electrodes

Introduction

This chapter describes the construction, measuring principle and calibration process for each of the electrodes in the ABL700 Series analyzers.

General sections covering the background theory used for measurements and calibrations are also presented here.

Contents

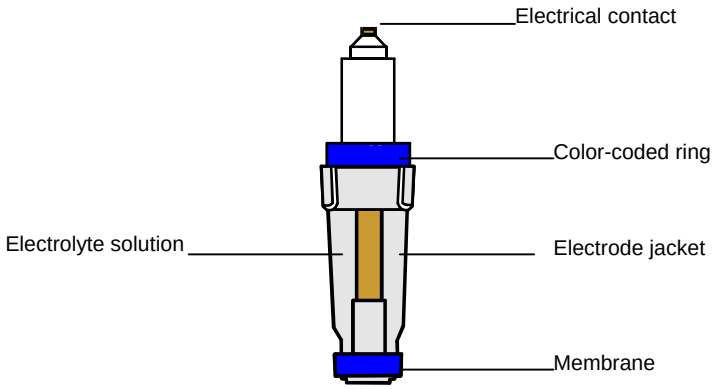
This chapter contains the following topics.

General Construction

An Electrode

In this manual and other Radiometer literature, the term electrode refers to the whole sensor unit, i.e. both the electrode and the electrode jacket. Radiometer electrodes are cordless, thereby limiting the level of noise picked up during the measuring process. The electrical signals from the electrodes are amplified by preamplifiers placed in each module.

A generalized diagram of a Radiometer electrode is given below.



The main electrode parts are described below.

Part	Description
Electrical contact	Provides electrical contact between the electrode and the analyzer.
Color-coded ring	Marks each electrode for easy recognition.
Electrode jacket	Holds the electrolyte solution and membrane, and protects the electrode.
Membrane	A thin sheet-like material to separate the sample from the electrode, that differentiates between the substances allowed to pass through it towards the electrode.
Electrolyte solution	A conducting solution to provide an electric contact between the electrode and the sample (also known as a salt-bridge solution).

More specific descriptions of the electrodes are found under the appropriate electrode titles in this chapter.

General Measuring Principles

Introduction

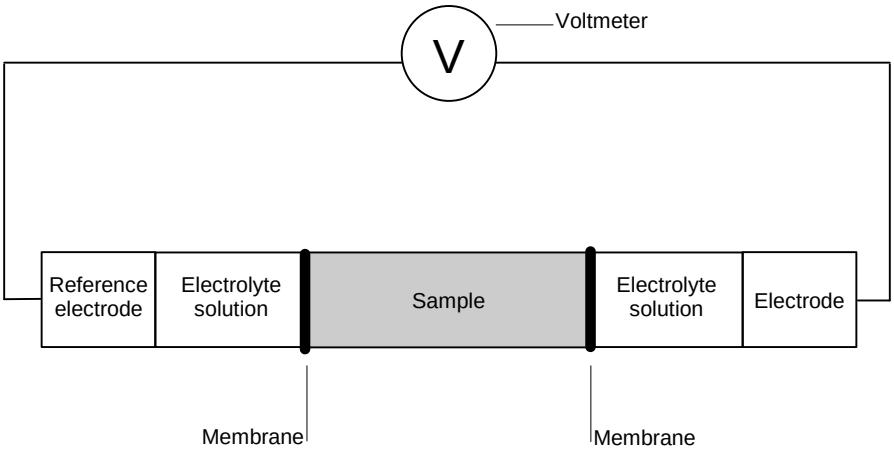
There are two different measuring principles employed for electrodes in the ABL700 Series.

- **Potentiometry:** The potential of an electrode chain is recorded using a voltmeter, and related to the concentration of the sample (the Nernst equation).
- **Amperometry:** The magnitude of an electrical current flowing through an electrode chain, which is in turn proportional to the concentration of the substance being oxidized or reduced at an electrode in the chain.

These two measuring principles are described in detail on the following pages.

Potentiometric Method

An electrode chain describes an electrical circuit consisting of a sample, electrode, reference electrode, voltmeter, membranes, and electrolyte solutions.



Every element in the electrode chain contributes a voltage to the total potential drop through the chain. Thus:

- When immersed in the appropriate electrolyte solution, both electrodes have separate potentials.
- The membrane junctions between the sample and electrolyte solutions also have separate potentials.

The complete electrode chain potential therefore, is the sum of these separate potentials and is the quantity measured by the voltmeter.

$$E_{total} = E_{sample} - E_{Ref}$$

where the final unknown potential (E_{sample}) can be calculated knowing the total electrode chain potential (E_{total}) and the reference potential (E_{Ref} that is constant between two subsequent calibrations).

Continued on next page

General Measuring Principles, *Continued*

Potentiometric Method *(continued)*

Having measured the unknown potential (E_{sample}), the Nernst equation is then applied to determine the activity (a_x) of the species under study:

$$E_{sample} = E_0 + \frac{2.3RT}{n\mathrm{F}} \log a_x$$

where:

E_0	=	standard electrode potential
R	=	gas constant (8.3143 $JK^{-1}mol^{-1}$)
T	=	absolute temperature (310 K (37 °C))
n	=	charge on the ion
F	=	Faraday constant (96487 C mol^{-1})
a_x	=	activity of x

The Nernst equation is rearranged to express the activity as a function of the potential E_{sample}. Having measured E_{sample} the activity can be calculated since all other quantities are already known. Finally the analyzer converts activity to concentration.

Strictly speaking, in potentiometry the potential of an electrode chain or the magnitude of current flowing through an electrical chain is related to the activity of a substance, and not its concentration.

Activity expresses the 'effective concentration' of a species, taking non-ideality of the medium into account.

Activity and concentration are related by the following equation:

$$a_x = \gamma\, c_x$$

where:

a_x	=	the activity of the species x
γ	=	the activity coefficient of species x under the measurement conditions (for ideal systems $\gamma = 1$)
c_x	=	the concentration of species x (mmol/L)

NOTE: *To be exact, activity is related to the molality of species x, i.e., the number of mmoles per kg of solvent. However molality is converted to concentration (molarity).*

ABL700 Series analyzers automatically convert activities into concentrations [1]. The term concentration is therefore used in explanations of the measuring principles for each of the electrodes further on in this chapter.

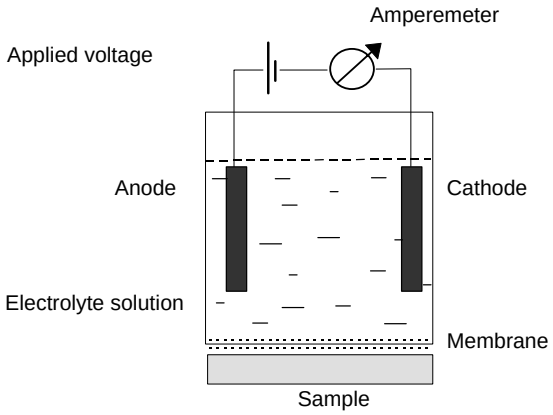
The potentiometric measuring principle is applied in the pH, pCO_2, and electrolyte electrodes. It is slightly different for the pCO_2 electrode, however, since the Nernst equation is not directly applied.

Continued on next page

General Measuring Principles, *Continued*

Amperometric Method

The electrode chain in amperometric measurements consists of the sample, the two electrodes (anode and cathode), an amperemeter, a voltage source, the membranes, and the electrolyte solutions.



Part	Function
Cathode	Negative electrode where a reduction reaction occurs and electrons are consumed.
Anode	Positive electrode where an oxidation reaction occurs and electrons are released.
Electrolyte solution	Provides electrical contact between the anode and cathode.
Membrane	Allows the appropriate molecules to pass through from the sample.
Sample	Contacts the membrane.
Applied voltage	Applies the necessary potential for the reduction or oxidation reaction under study.
Amperemeter	Measures the current flowing through the circuit.

To simplify the description of the measuring process in an amperometric electrode, we make the following assumptions:

- there is a species **A** in the sample which is reduced at the cathode to $\mathbf{A}^-$.
- there is a species **X** in the electrolyte which is oxidized at the anode to $\mathbf{X}^+$.

Continued on next page

General Measuring Principles, *Continued*

Amperometric Method *(continued)*

The membrane is selective to the species **A**, allowing no other species but it to pass through from the sample into the electrolyte solution.

As an appropriate potential is applied across the electrodes, the species **A** is reduced at the cathode according to the following reaction:

$$A + e^- \rightarrow A^-$$

The reduction of **A** produces a flow of electrons, i.e. an electrical current.

To complete the electrical circuit an oxidation reaction where electrons are released is necessary. Therefore species **X** is oxidized according to the following reaction:

$$X \rightarrow X^+ + e^-$$

The magnitude of the current flowing through the circuit is proportional to the concentration of the species being reduced, in this case species **A**. The analyzer thereby automatically calculates the concentration of **A** in the sample.

The amperometric measuring principle is applied in the pO_2, glucose, and lactate electrodes.

Calibration

Actual Electrode Condition

The electrodes are active elements and must be calibrated regularly as the signals from the electrodes change with, e.g. age or deposits on the membrane.

Calibration relates the electrode signals during the calibration sequence to the values of the calibrating solutions and must be performed at regular intervals so that the accuracy can be constantly refined after inevitable minor changes in the electrodes' behavior.

Actual electrode condition is described by status/zero point and sensitivity and compared with theoretical conditions for an "ideal" electrode. In addition to status and sensitivity, an electrode condition is described by drift.

Calibration Line

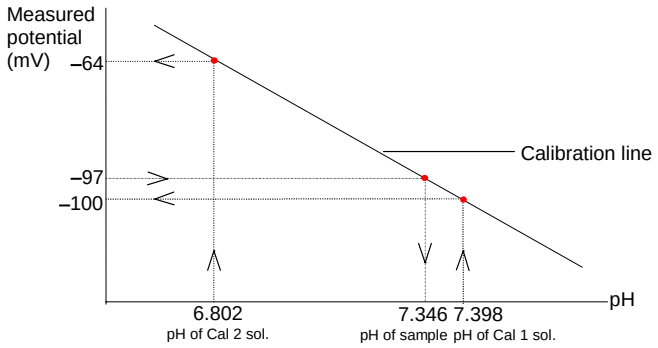
The calibration line expresses the relationship between the potential (or current) measured at an electrode, and the concentration of the species specific to the electrode. The calibration line forms the basis of the scale used by the analyzer to convert electrode chain potentials to concentrations. Each electrode has a different calibration line.

The pH electrode is used as an example to illustrate how this line is derived from two calibration solutions of known pH.

- Cal 1 solution has a pH of **7.398** that gives potential reading of **–100 mV**.
- Cal 2 solution has a pH of **6.802** that gives a potential reading of **–64 mV**.

These two values are plotted on a graph.

The relationship between potential and pH is linear so a line can be drawn between the two points, as shown below:



The calibration line now forms the scale used to convert the potential measured at the pH electrode during sample analysis to an actual pH value.

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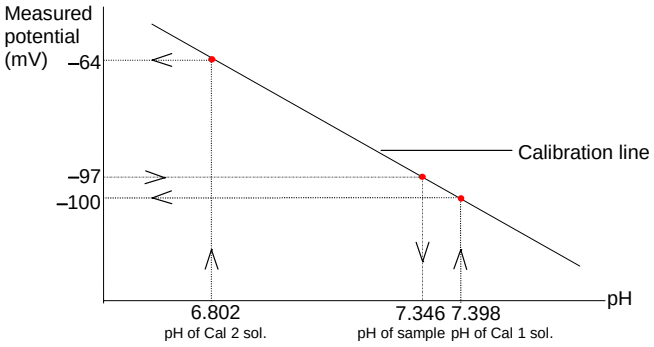
Calibration, *Continued*

Calibration Line *(continued)* A blood sample gives a potential reading of -97 mV at the pH electrode. Reading off from the calibration line shown below, this potential corresponds to a pH of 7.346.

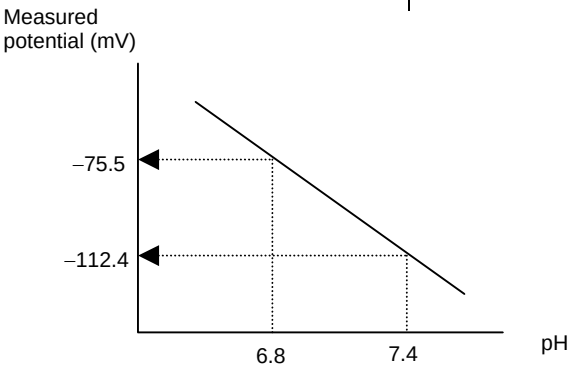


The calibration line is updated at every calibration. Drift describes the variation in the calibration line between consecutive calibrations.

Theoretical Calibration Line The theoretical calibration line is the relationship between potential and concentration in a potentiometric measurement, or the relationship between current and concentration in an amperemetric measurement.

In the ABL700 Series the theoretical calibration line for pH is defined by the following two points:

pH	Electrode potential (vs. Ref. potential)
6.800	–75.5 mV
7.400	–112.4 mV



The position and slope of the calibration line compared to the theoretical calibration line are described by the status and sensitivity respectively.

Continued on next page

Calibration, *Continued*

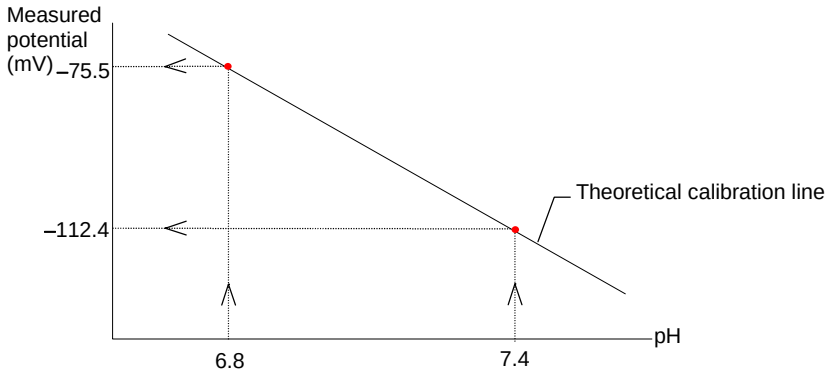
Sensitivity

Electrode sensitivity expresses how a real electrode measures compared with the specified values of the calibration material; it illustrates the slope of the calibration line derived from a 2-point calibration as a percentage (or fraction) of the slope of the theoretical calibration line, as determined by the Nernst equation of the ion in question.

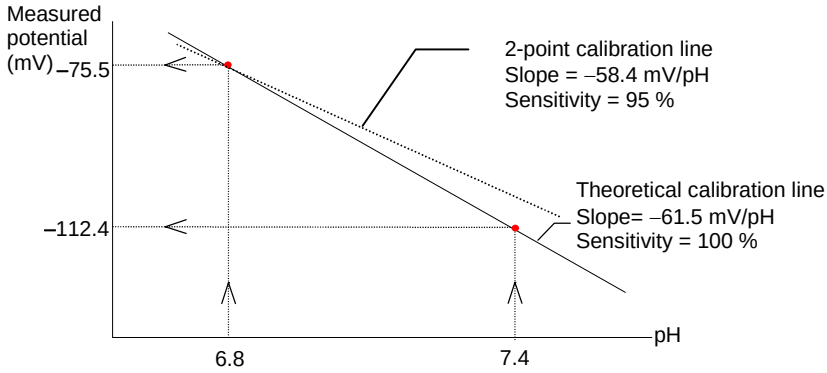
Calculating the sensitivity is a way of monitoring the deviation of the electrode sensitivity from the theoretical value.

Calculation of the sensitivity is shown, using the pH electrode as an example.

A theoretical calibration line for the pH electrode with a slope of –61.5 mV/pH is drawn:



The calibration line from a 2-point calibration is superimposed on the same graph:



The sensitivity of the electrode is calculated as the ratio between the slope of the 2-point calibration line and that of the theoretical line, expressed as a percentage or fraction.

If the theoretical calibration line is assumed to have a sensitivity of 100 %, the 2-point calibration line shown in the example will have a sensitivity of approximately 95 %.

Continued on next page

Calibration, *Continued*

Sensitivity *(continued)*

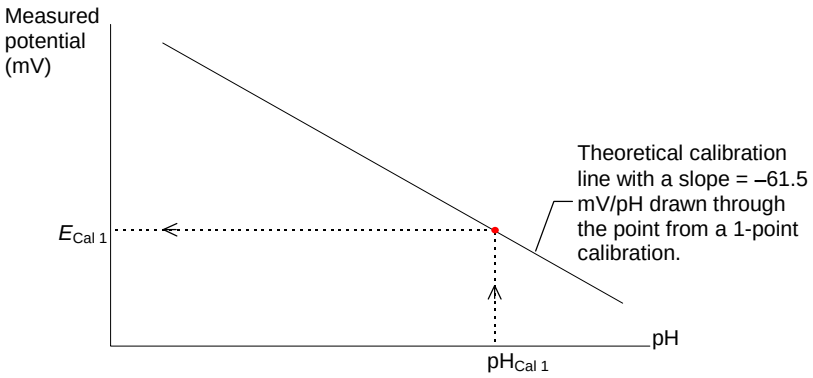
The sensitivity limits for the calibration are set for each electrode. If the sensitivity of any electrode falls outside the allowed limits, the message Calibration Sensitivity out of range appears in the Calibration Messages, with the particular electrode specified.

Status

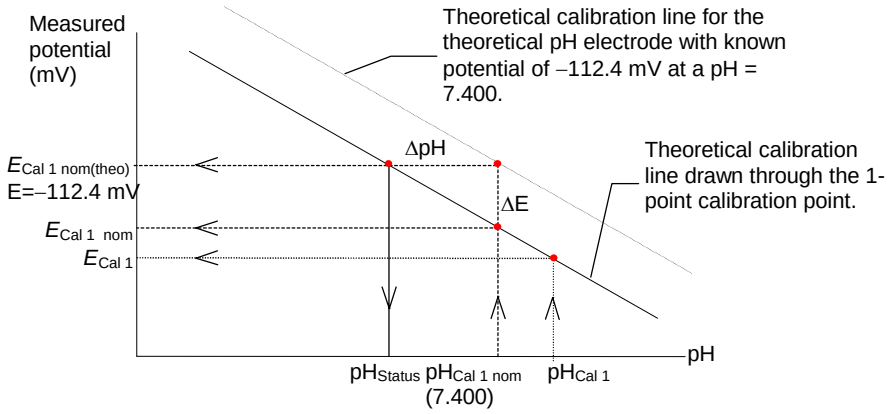
The electrode status is a measure of zero point of a complete electrode chain. Status of a real electrode reflects deviations from the conditions of a theoretical electrode, and define the position of the calibration line.

Calculating the status value of an electrode is a way of monitoring the position of the calibration line despite the fact that only a 1-point calibration has been carried out. The calculation of the status is shown, using the pH electrode as an example.

A calibration line with the same slope as the theoretical calibration line (–61.5 mV/pH) is drawn through this point. This theoretical calibration line is used since no 2-point calibration is performed which would otherwise give an actual calibration line.



A pH of 7.400, the nominal pH of Calibration Solution 1 ($pH_{Cal\ 1\ nom}$) is chosen. Its corresponding potential ($E_{Cal\ 1\ nom}$) is read off the theoretical calibration line that was drawn through the 1-point calibration point.



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Calibration, *Continued*

Status *(continued)*

A line from $pH_{Cal\ 1\ nom}$ is extrapolated up to the theoretical calibration line, and the corresponding potential ($E_{Cal\ 1\ nom(theo)}$) read off the theoretical calibration line.

The difference between $E_{Cal\ 1\ nom}$ and $E_{Cal\ 1\ nom(theo)}$ which corresponds to ΔE on the graph, represents the potential that should theoretically be obtained for a solution with pH = 7.400. This potential difference (ΔE) thus describes the deviation of the actual pH reference electrode system from a theoretical electrode system. Similarly ΔpH describes the deviation in pH values that would be produced between measurements with an actual electrode system and measurements with a theoretical electrode system.

The status of the pH electrode, pH(Status), is then calculated as:

$$\text{pH(Status)} = 7.4 + \frac{E_{\text{Cal 1 nom}} - E_{\text{Cal 1 nom(theo)}}}{61.5}$$

The status limits of the calibration are set for each electrode. If the status for any electrode falls outside the allowed limits, the message Calibration status out of limits appears in the Calibration Messages, with the particular electrode specified.

Calibration Materials

The following calibration materials are used:

Calibration Material	Used for...
Calibration Solutions 1 and 2: the exact composition of the calibration solutions is given in the bar code on the bottle label, which can be read into the analyzer using the bar code reader, or entered manually via the keyboard.	Calibration of the pH, and electrolyte electrodes
Calibration Solution 1:	Calibration of the metabolite electrodes and optical system
Gas 1 and Gas 2: each gas has a precise composition essential for determining the accuracy of the analyzer in each pCO_2 and pO_2 measurement.	Calibration of the pCO_2 and pO_2 electrodes
tHb Calibration Solution:	Calibration of the optical system

The Chemical Reference Laboratory at Radiometer is responsible for the accuracy of the calibrating solutions and gases.

Traceability certificates for individual solutions are presented in *Chapter 7* of this manual.

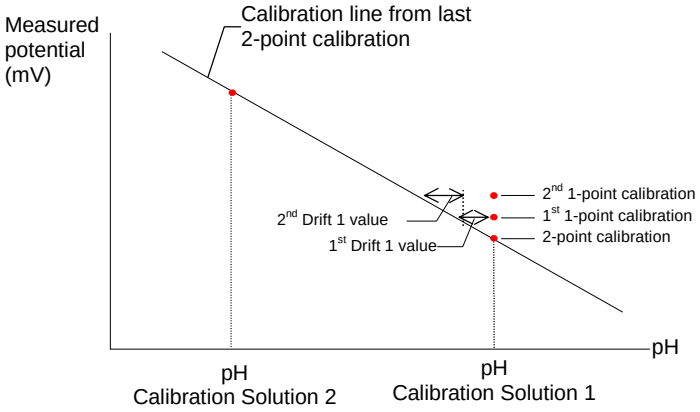
Continued on next page

Calibration, *Continued*

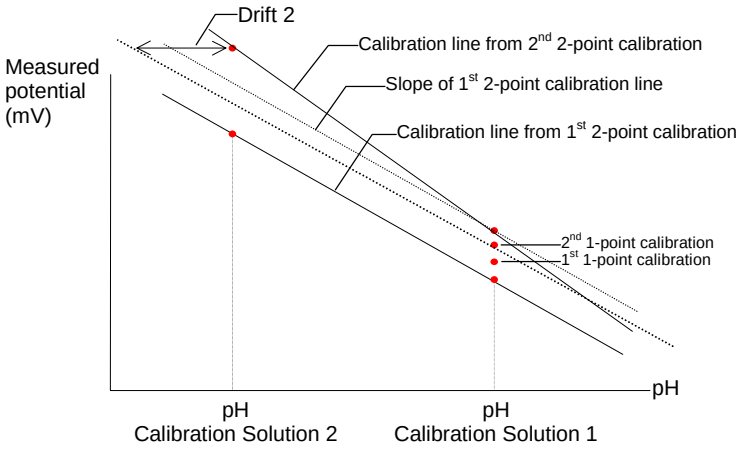
Drift

Drift is defined as the difference measured by the electrodes during last and previous calibrations, and is a measure of the electrode stability.

Drift 1 is obtained on Calibration Solution 1 and/or Gas 1 and is calculated as follows, using the pH electrode as an example:



Drift 2 is obtained after 2-point calibration. The pH electrode is used as an example and the calibration schedule is set so that each 2-point calibration is separated by two 1-point calibrations.



Drift tolerances express the extent to which drift values for an electrode can fluctuate before the electrode is deemed unstable and thus incapable of providing reliable calibrations.

The drift tolerances for each electrode are set in the analyzer's Setup programs. Radiometer recommends the use of the default drift tolerances, as too narrow drift tolerances will cause electrode drift errors even for normal electrode fluctuations. If the drift tolerances are too wide, significant measurement errors will result without warning.

Continued on next page

Calibration, *Continued*

Drift *(continued)* If the drift values for any electrode fall outside the drift tolerances, the message Calibration drift out of range appears in the Calibration Messages, with the particular electrode specified.

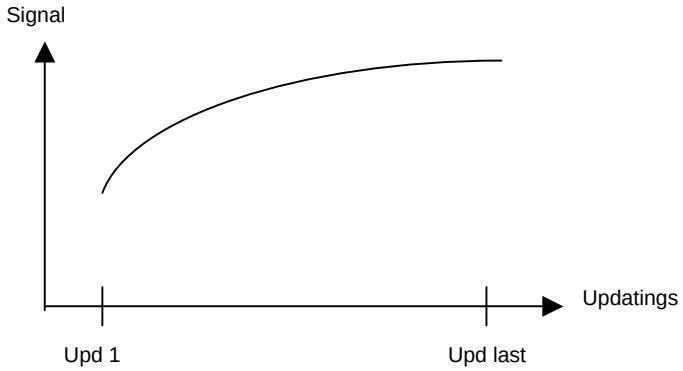
No drift values are reported for startup calibrations as there are no previous calibrations available for comparison.

Electrode Measuring Time and Updatings

Measuring Time In the ABL700 Series analyzers the measuring time of the electrode is independent of the electrode type. Electrode signals are registered at 0.982 second intervals during both calibrations and measurements. The registration of each electrode signal begins after the samples, calibration solutions, and calibration gases are in position in the measuring modules.

The duration of each calibration is predetermined, as is the number of updatings of the electrodes' signals.

Updatings In general, the updatings from an electrode response are numbered from 1 to *upd last*, where updating number 1 is the first updating and *upd last* is the last. The diagram below schematically illustrates the electrode response that is calculated on uncorrected electrode updating values in the ABL700 Series.



Reference Electrode

Electrode Description

The reference electrode is used in the measurement of pH and electrolyte parameters and is located in the pH/Blood Gas module.

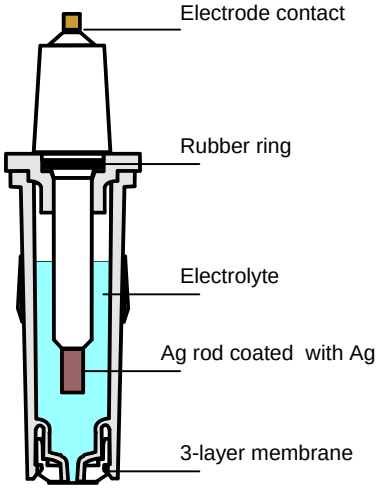
The reference electrode maintains a stable, fixed potential against which other potential differences can be measured. The potential is not altered by sample composition.

A fixed potential is maintained at the reference electrode by the following equilibrium reactions:

$$AgCl \Leftrightarrow Ag^{+} + Cl^{-}$$

$$Ag^{+} + e^{-} \Leftrightarrow Ag$$

These reactions are possible because the electrode is made from a Ag rod coated with Ag to provide the Ag/Ag^{+} equilibrium and determine the reference potential.



The electrolyte solution acts as a salt-bridge solution that maintains an electrical contact between the coated Ag wire and the sample. The solution is 4 M sodium formate (HCOONa), adjusted to pH 5.5 with hydrochloric acid.

The chloride concentration in the electrolyte solution is adjusted in accordance with the chloride concentration in the rinse solution, to reduce Cl^{-} exchange across the membrane, thereby obtaining a more stable potential.

The electrode is encased in the electrode jacket: The rubber ring seals the electrode in the jacket to prevent evaporation or leakage of the electrolyte solution.

The membrane consists of three separate membranes:

Membrane	Function
Inner	To limit diffusion through the membrane and stabilizes the whole membrane system.
Middle	To prevent protein interference.
Outer	To reduce the interchange of sample or rinse solution and HCOONa solution.

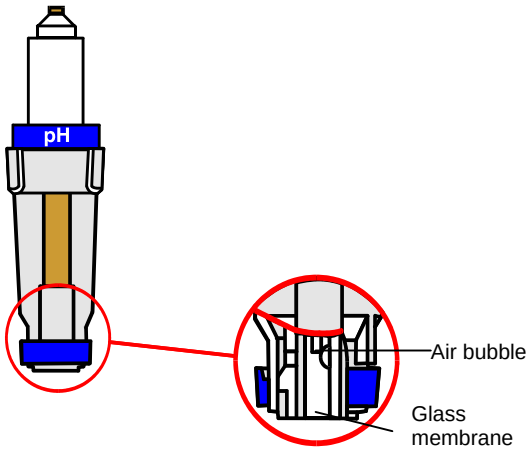
Packaging

The E1001 reference electrode comes in a box with an insert explaining the preparation of the electrode and its use.

pH Electrode

Description

The pH electrode (E777) is a pH-sensitive glass electrode. The pH-sensitive glass membrane is located at the tip and seals the inner buffer solution with a constant and known pH.



The air bubble allows for expansion of the inner buffer solution when the electrode is thermostatted to 37 °C.

The potential difference across the glass membrane is due to a change in the charge balance at the membrane.

The glass membrane is sensitive to H^+ ions. The metal ions in the glass are exchanged with protons on either side of the membrane, from the inner buffer solution on one side and the sample on the other.

A difference in the ion exchange on either side of the membrane occurs if the H^+ concentration (and therefore pH) is unequal on both sides. The number of positive and negative ions is no longer equal, so the potential difference across the membrane changes. If the H^+ concentrations on either side of the membrane are equal, the potential difference will theoretically be 0 mV.

Electrode Chain Potentials

The total potential across the electrode chain is the sum of the potential differences at each element in the chain:

Element	Potential	Symbol
Ag/AgCl electrode /electrolyte solution. (Reference electrode)	Known and constant when the Ag/AgCl wire is immersed in the electrolyte solution.	E_{ref}
Membrane junction between the electrolyte solution in the reference electrode and the sample.	Known and constant. Independent of sample composition.	E_{MJ}
pH-sensitive glass membrane between the sample and the pH electrode.	**Unknown**. Dependent on sample composition.	E_{Sample}
Ag/AgCl electrode/inner buffer solution (pH electrode)	Known and constant when the Ag/AgCl wire is immersed in the inner buffer solution.	E_E
Total potential	Measured by the voltmeter.	E_{tot}

Continued on next page

pH Electrode, *Continued*

Electrode Chain Potentials *(continued)*

The unknown potential difference across the pH-sensitive glass membrane is the difference between the measured total potential and the sum of the known potentials:

$$E_{sample} = E_{total} - (E_{ref} + E_{MJ} + E_E)\,mV$$

Nernst Equation

The theoretical sensitivity of the pH electrode at 37 °C being equal to –61.5 mV per pH unit, using pH = –log [H^+], and converting concentration to activity, the Nernst equation can be expressed as:

$$E_{sample} = E_0 - 61.5 \times pH \qquad mV$$

Sensitivity

The sensitivity of the pH electrode ($Sens_{pH}$) is obtained from the calibration line obtained from a 2-point calibration on Calibration Solutions 1 and 2 (Cal 1 and Cal 2), and is calculated from the following equation:

$$Sens(pH) = \frac{E(pH, Cal2) - E(pH, Cal1)}{-61.5 \times [pH(Cal2) - pH(Cal1)]} \qquad \text{(fraction)}$$

where:

E(pH,Cal2)	=	Potential of the pH electrode chain from a calibration measurement on Cal 2 solution
E(pH,Cal1)	=	Potential of the pH electrode chain from a calibration measurement on Cal 1 solution
–61.5 mV/pH	=	Theoretical sensitivity of the pH electrode at 37 °C
pH(Cal2)	=	Specific pH of Cal 2 solution
pH(Cal1)	=	Specific pH of Cal 1 solution

The sensitivity of the pH electrode should fall between 0.92 - 1.03 or 92 -103 %.

Status

The status of the pH electrode is calculated from the following equation:

$$Status(pH) = \frac{E(pH, Cal1) - E_0(pH, Cal1)}{-61.5} + 2\,pH(Cal1, nom) - pH(Cal1)$$

where:

E(pH,Cal1)	=	Potential of the pH electrode chain from a calibration on Cal 1 solution
E_0(pH,Cal1)	=	Standard potential of the pH electrode chain with a nominal pH = 7.4 (the approximate pH of Cal 1 solution)
–61.5 mV/pH	=	Theoretical sensitivity of the pH electrode at 37 °C

Continued on next page

pH Electrode, *Continued*

Status *(continued)*

pH(Cal1,nom)	=	Nominal pH of Cal 1 solution (pH = 7.4)
pH(Cal1)	=	Specific pH of Cal 1 solution

The status of the pH electrode should fall between a pH of 6.7 and 8.1.

Drift 1

Drift 1 is calculated from the following equation:

$$\text{Drift 1(pH)} = \frac{E(pH, Cal1) - E(pH, Cal1prev)}{-61.5 \times Sens(pH, prev)} - \left[pH(Cal1) - pH(Cal1, prev)\right]$$

where:

E(pH,Cal1)	=	Potential of the pH electrode chain from a calibration measurement on Cal 1 solution
E(pH,Cal1prev)	=	Potential of the pH electrode chain from the previous calibration measurement on Cal 1 solution
–61.5 mV/pH	=	Theoretical sensitivity of the pH electrode at 37 °C
E(pH,Cal1)	=	Potential of the pH electrode chain from a calibration on Cal 1 solution
Sens(pH,prev) fraction	=	Sensitivity of the pH electrode from the previous 2-point calibration
pH(Cal1)	=	pH of Cal 1 solution as specified in the bar code
pH(Cal1,prev)	=	pH of Cal 1 solution in the previous calibration measurement

NOTE: *Under normal circumstances,* pH(Cal1)–pH(Cal1,prev) = 0. *However in instances where the Cal 1 solution container has been replaced between two consecutive calibrations,* pH(Cal1)–pH(Cal1,prev) ≠ 0.

The default drift tolerances set by Radiometer for Drift 1 are ± 0.020.

Drift 2

Drift 2 is calculated from the following equation:

$$\text{Drift 2(pH)} = \frac{E(pH, Cal2) - E(pH, Cal1prev)}{-61.5 \times Sens(pH, prev)} - \left[pH(Cal2) - pH(Cal1, prev)\right]$$

where:

E(pH,Cal2)	=	Potential of the pH electrode chain from a calibration on Cal 2 solution
E(pH,Cal1prev)	=	Potential of the pH electrode chain from the previous calibration on Cal 1 solution

Continued on next page

pH Electrode, *Continued*

Drift 2 *(continued)*

−61.5 mV/pH	=	Theoretical sensitivity of the pH electrode at 37 °C
Sens(pH,prev) fraction	=	Sensitivity of the pH electrode from the previous 2-point calibration
pH(Cal2)	=	pH of Cal 2 solution
pH(Cal1,prev)	=	pH of Cal 1 solution used in the previous calibration

The default drift tolerances set by Radiometer for Drift 2 are ± 0.020.

Measurement

The sample pH is calculated as follows:

$$\text{pH(sample)} = \frac{\text{E(pH, sample)} - \text{E(pH, Cal1)}}{-61.5 \times \text{Sens(pH)}} + \text{pH(Cal1)}$$

where:

Parameter	Description
E(pH,sample)	Potential of the pH electrode chain from a measurement on the sample.
E(pH,Cal1)	Potential of the pH electrode chain from a calibration on Cal 1 solution.
−61.5 mV/pH	Theoretical sensitivity of the pH electrode at 37 °C.
Sens(pH)	Relative sensitivity of the pH electrode chain.
pH(Cal)	pH of Cal 1 solution.

pH is measured in the following syringe and capillary modes:

Analyzer	Syringe Modes	Capillary Modes
ABL735/725/715	195 µL 95 µL 85 µL	195 µL 95 µL 55 µL 35-85 µL
ABL730/720/710	85 µL	85 µL 55 µL 35-85 µL
ABL705	165 µL 95 µL 85 µL	165 µL 95 µL 55 µL 35-85 µL

Continued on next page

pH Electrode, *Continued*

Measurement *(continued)*

Analyzer	Syringe Modes	Capillary Modes
ABL700	85 µL	55 µL 35-85 µL

Corrections

The measured pH value is then corrected for systematic deviations from the reference method using the following equation:

$pH(sample,corr.) = A_0 \times pH(sample) + A_1$ **Equation A**

where:

pH(sample) = uncorrected pH value of the sample

pH(sample,corr.) = corrected pH value of the sample.

A_0 = instrument-dependent correction factor

A_1 = instrument-dependent interception constant

NOTE: *The 195 µL is used as the reference measuring mode for those ABL700 Series analyzers which do not have it. It is designated as "195 µL (ref.)" in the correction tables.*

Correction	ABL735/725/15 - Syringe modes: equals to….		
	195 µL	**95 µL**	**85 µL**
A_0	0.9964	0.9964	0.9964
A_1	0.0164	0.0164	0.0164
For all syringe modes, the measured pH value is corrected using Equation A.			
	ABL735/725/15 - Capillary modes: equals to….		
	195 µL	**95 µL**	**55 µL**
A_0	0.9964	0.9964	1.01379
A_1	0.0164	0.0164	–0.1030
For the 195 µL, 95 µL and 85 µL modes, the measured pH value is corrected using Equation A. For the 55 µL mode, the measured pH value is first corrected using Equation A and the constants for the 195 µL mode. The obtained result is then used in Equation A as pH(sample) together with the constants for the 55 µL mode to obtain pH(sample,corr).			

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pH Electrode, *Continued*

Corrections *(continued)*

Correction	ABL730/720/710 - Syringe modes: equals to…		
	85 µL		
A_0	0.9964		
A_1	0.0164		
For the 85 µL mode, the measured pH value is corrected using Equation A.			
	ABL730/720/710 - Capillary modes: equals to…		
	195 µL (ref.*)	85 µL	55 µL
A_0	0.9964	1.0047	1.01379
A_1	0.0164	–0.0316	–0.1030
For the 85 µL and 55 µL modes the measured pH value is first corrected using equation A and the constants for the 195 µL mode. The obtained result is then used in Equation A as pH(sample) together with the constants for the 85 µL and 55 µL modes to obtain pH(sample,corr).			

Correction	ABL705 - Syringe modes: equals to…			
	195 µL (ref.)	165 µL	95 µL	85 µL
A_0	0.9964	0.9964	0.9964	0.9964
A_1	0.0164	0.0164	0.0164	0.0164
For the 165 µL, 95 µL and 85 µL modes the measured pH value is corrected using equation A.				
	ABL705 - Capillary modes: equals to…			
	195 µL (ref.)	165 µL	95 µL	55 µL
A_0	0.9964	0.9964	0.9964	1.0161
A_1	0.0164	0.0164	0.0164	–0.1181
For the 165 µL and 95 µL modes the measured pH value is corrected using equation A. For the 55 µL mode, the measured pH value is first corrected using Equation A and the constants for the 195 µL mode. The obtained result is then used in Equation A as pH(sample) together with the constants for the 55 µL mode to obtain pH(sample,corr).				

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pH Electrode, *Continued*

Corrections *(continued)*

Correction	ABL700 - Syringe modes: equals to…	
	85 µL	
A_0	0.9964	
A_1	0.0164	
For the 85 µL mode, the measured pH value is first corrected using Equation A.		
	ABL700 - Capillary modes: equals to…	
	195 µL (ref.)	55 µL
A_0	0.9964	1.0161
A_1	0.0164	–0.1181
For the 55 µL mode, the measured pH value is first corrected using Equation A together with the constants for the 195 µL mode. The obtained result is then used in Equation A as pH(sample) together with the constants for the 55 µL mode to obtain pH(sample,corr).		

All ABL700 Series analysers (software 3.83 and higher) Capillary -pH only mode:

Correction	Capillary – pH only mode: equals to…		
	85 µL	55 µL	35 µL
A_0	1.015	1.02	1.03
A_1	–0.115	–0.153	–0.227
The measured pH value is first corrected using Equation A and the constants for the 195 µL mode. The obtained result is then used in Equation A as pH(sample) together with the constants for either the 85 µL, 55 µL or 35 µL modes to obtain pH(sample,corr).			

See *Chapter 5, Performance Specifications* for more information on reference methods.

Stability Criteria

The following stability criterion must be met to obtain a stable electrode response during 1- and 2-point **calibration**:

$$\left|\mathrm{pH(sample, upd.last)} - \mathrm{pH(sample, upd.i)}\right| \leq \mathrm{pH(limit)}$$

Continued on next page

pH Electrode, *Continued*

Stability Criteria *(continued)*

The following stability criterion must be met to obtain a stable electrode response during **measurement**:

$$\left|\mathrm{pH(sample, upd.last)} - \mathrm{pH(sample, upd.i)}\right| \leq \mathrm{pH(limit)}$$

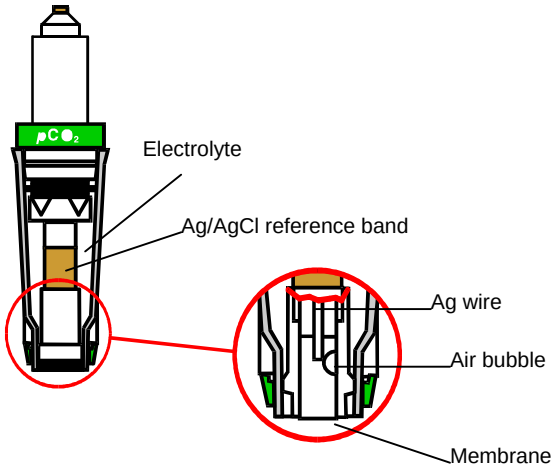
where:

pH(sample,upd.last) =	pH value from the last updating with a measurement on calibration solution or sample. (The last updating is number 30).
pH(sample,upd.i) =	pH value for a given updating with a measurement on calibration solution or sample. (The relationship must be fulfilled for at least one of the updating numbers 20 or 21).
pH(limit) =	pH limiting value for the stability criterion (0.005).

pCO_2 Electrode

Basic Description

The pCO_2 electrode (E788) is a combined pH and Ag/AgCl reference electrode mounted in a plastic jacket, which is filled with a bicarbonate electrolyte.



The jacket is covered by a 20 µm silicone membrane moulded on a 50 µm nylon net. The net both reinforces the silicone membrane and serves as a spacer in order to trap a layer of the electrolyte between the membrane and the glass tip of the electrode. The electrolyte also contains glycerol to prevent collection of air bubbles in the electrode jacket thus improving electrode stability.

The membrane allows any uncharged molecules of CO_2, O_2, N_2 to pass through it. Charged ions such as H^+ will not pass. Consequently, dissolved CO_2 from the sample will diffuse into the thin layer of bicarbonate electrolyte until the equilibrium is reached.

This produces carbonic acid:

$$H_2O + CO_2 \Leftrightarrow H_2CO_3$$

Carbonic acid dissociates according to the following equilibrium reaction:

$$H_2CO_3 \Leftrightarrow H^+ + H_2CO_3^-$$

The release of H^+ ions changes the H^+ concentration, and therefore the pH of the solution on one side of the pH-sensitive glass membrane.

The concentration gradient of H^+ ions on the other side of the membrane affects the potential difference across the glass membrane. This change in potential across the glass membrane is measured by the voltmeter.

Nernst Equation

The Nernst equation is used to convert the potential reading into a pH value:

$$E_{glass} = E_0 - 61.5 \times pH \ (mV)$$

where:

E_{glass} = potential difference across the glass membrane

E_0 = standard electrode potential

61.5 mV/pH = theoretical sensitivity of the pH electrode at 37 °C

Continued on next page

pCO_2 Electrode, *Continued*

Nernst Equation *(continued)*

The pH value is related to the partial pressure of CO_2 in the sample by the following equation:

$$pH = pK_a + \log \frac{cHCO_3^-}{pCO_2 \times \alpha_{CO_2}}$$

where:

pK_a = $-\log K_a$, the equilibrium constant for the dissociation of carbonic acid in water

α_{CO_2} = solubility coefficient for CO_2 in water

The bicarbonate concentration $[HCO_3^-]$ is so large compared to $[H^+]$ that it can be considered constant. At constant temperatures α_{CO_2} is also constant. So the equation can be simplified to:

$$pH = K' - \log pCO_2$$

where:

K' is a constant incorporating the equilibrium constant for carbonic acid (K_a), the bicarbonate concentration, and the solubility coefficient α_{CO_2}.

$K_a = \frac{cH^+ \times cHCO_3^-}{CO_2}$ is the equilibrium constant for carbonic acid.

pCO_2 of the sample is then calculated from the equation above.

Sensitivity

The pCO_2 electrode is calibrated on two gases with known CO_2 content.

Gas 1 contains 5.61 % CO_2 and Gas 2 contains 11.22 % CO_2.

The exact composition of the calibration gases is contained in their bar codes.

The partial pressures of CO_2 in the gas mixtures Gas 1 and Gas 2 are calculated from the following equations:

$$pCO_{2\,2}(Gas1) = FCO\ \ (Gas1) \times \left(B_{Gas\,1} - pH_2O\right) \quad \text{kPa}$$

$$pCO_{2\,2}(Gas2) = FCO\ \ (Gas2) \times \left(B_{Gas\,2} - pH_2O\right) \quad \text{kPa}$$

where:

pCO_2(Gas1), pCO_2(Gas2)	=	Pressure of CO_2 in Gas 1 or Gas 2 respectively
$B_{Gas\ 1\ or\ 2}$	=	Pressure inside the measuring chamber during a measurement on Gas 1 or Gas 2 respectively
pH_2O	=	Water vapor pressure (6.2571 kPa at 37 °C)

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pCO_2 Electrode, *Continued*

Sensitivity *(continued)*

FCO_2(Gas1), FCO_2(Gas2)	=	Fraction of CO_2 in Gas 1 or Gas 2 respectively

The relative sensitivity of the pCO_2 electrode is calculated as follows:

$$\text{Sens}(pCO_2) = \frac{E(CO_2,\text{Gas2}) - E(CO_2,\text{Gas1})}{\text{Sens}(pCO_2,\text{theo}) \times \log\frac{pCO_2(\text{Gas2})}{pCO_2(\text{Gas1})}}$$

where:

$E(CO_2,Gas2)$	=	Potential of the pCO_2 electrode from a measurement on Gas 2
$E(CO_2,Gas1)$	=	Potential of the pCO_2 electrode from a measurement on Gas 1
Sens(pCO_2,theo)	=	Theoretical (absolute) sensitivity of the pCO_2 electrode at 37 °C
pCO_2(Gas1)	=	Partial pressure of CO_2 in Gas 1
pCO_2(Gas2)	=	Partial pressure of CO_2 in Gas 2

The sensitivity of the pCO_2 electrode should fall between 0.85 -1.00 or 85 - 100 %.

Status

The status of the pCO_2 electrode is calculated as follows:

$$\text{Status}(pCO_2) = pCO_2(\text{Gas1}) \times 10^{\frac{E(CO_2,\text{Gas1}) - E_0(CO_2,\text{Gas1})}{\text{Sens}(pCO_2,\text{theo})}} \text{ kPa}$$

where:

pCO_2(Gas1)	=	Partial pressure of CO_2 in Gas 1 (see p*artial pressure* above)
$E(CO_2,Gas1)$	=	Potential of the pCO_2 electrode from a measurement on Gas 1
$E_0(CO_2,Gas1)$	=	Standard potential of the pCO_2 electrode with Gas 1
Sens(pCO_2,theo)	=	Theoretical (absolute) sensitivity of the pCO_2 electrode at 37 °C

The status of the pCO_2 electrode should fall between 6.2-260 mmHg /(0.83-34.66 kPa).

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pCO_2 Electrode, *Continued*

Drift

Drift 1 is calculated as follows:

$$\text{Drift 1}(pCO_2) = pCO_2(\text{Gas1}) \times 10^{\frac{E(CO_2,\text{Gas1}) - E(CO_2,\text{Gas1,prev})}{\text{Sens}(pCO_2,\text{prev}) \times \text{Sens}(pCO_2,\text{theo})}} - pCO_2(\text{Gas1,prev})\,\text{kPa}$$

Drift 2 is calculated as follows:

$$\text{Drift 2}(pCO_2) = pCO_2(\text{Gas2}) \times 10^{\frac{E(CO_2,\text{Gas2}) - E(CO_2,\text{Gas1,prev})}{\text{Sens}(pCO_2,\text{prev}) \times \text{Sens}(pCO_2,\text{theo})}} - pCO_2(\text{Gas2,prev})\,\text{kPa}$$

where:

pCO_2(Gas1,prev), pCO_2(Gas2,prev)	=	Partial pressure of CO_2 from the previous measurement on Gas 1 and Gas 2, respectively
$E(CO_2,Gas1)$, $E(CO_2,Gas2)$	=	Potential of the pCO_2 electrode from a measurement on Gas 1 and Gas 2, respectively
$E(CO_2,Gas1,prev)$	=	Potential of the pCO_2 electrode from the previous measurement on Gas 1
Sens(pCO_2,prev)	=	Relative sensitivity of the pCO_2 electrode from the previous 2-point calibration
Sens(pCO_2,theo)	=	Theoretical sensitivity (absolute) of the pCO_2 electrode at 37 °C
pCO_2(Gas1), pCO_2(Gas2)	=	Partial pressure of CO_2 in Gas 1 and in Gas 2, respectively

The default drift tolerances set by Radopmeter are as follows:

- for Drift 1 are ± 0.33 kPa (2.5 mmHg)
- for Drift 2 are ± 0.67 kPa (5.0 mmHg)

Measurement

The pCO_2 value for a sample is calculated from the following equations:

$$pCO_2(\text{sample,upd}i) = pCO_2(\text{gas}) \times 10^{\frac{E(CO_2\text{sample,upd}i) - E(CO_2\text{Gas1})}{\text{Sens}(pCO_2,\text{prev}) \times \text{Sens}(pCO_2,\text{theo})}}$$

$$\delta = \left| pCO_2(\text{sample, upd30}) - pCO\ (\text{sample, upd1}) \right|$$

$$\text{predict} = \frac{pCO_2(\text{sample, upd6}) \times pCO_2(\text{sample, upd30}) - \left[pCO_2(\text{sample, upd18})\right]^2}{pCO_2(\text{sample, upd6}) + pCO_2(\text{sample, upd30}) - 2 \times pCO_2(\text{sample, upd18})}$$

Continued on next page

pCO_2 Electrode, *Continued*

Measurement *(continued)*

where:

pCO_2(sample,upd.i) =	uncorrected pCO_2 value in the sample calculated from E(CO_2 sample,updi) for updating number "i".
E(CO_2 sample,upd.i) =	potential of the pCO_2 electrode from updating number i with a measurement on the sample.
E(CO_2,Gas1) =	potential of the pCO_2 electrode from a measurement on Gas 1.
Sens(CO_2,prev) =	relative sensitivity of the pCO_2 electrode determined from the last calibration on Gas 1 and Gas 2.
Sens(CO_2,theo) =	theoretical sensitivity of the pCO_2 electrode (= 61.5 mV) at 37 °C.
pCO_2 (Gas 1) =	partial pressure of CO_2 in Gas 1 known from the last calibration.
δ =	difference between pCO_2 (sample) from the first and last updatings.
predict =	extrapolated value for pCO_2.

For $\delta < 1.33$ kPa, $pCO_2(\text{sample}) = pCO_2(\text{sample,upd30})$

For 1.33 kPa < δ < 2.66 kPa

$$pCO_2(\text{sample}) = \frac{\text{predict} \times (\delta - 1.33) + pCO_2(\text{sample, upd30}) \times (2.66 - \delta)}{1.33}$$

For $\delta \geq 2.66$ kPa, pCO_2(sample) = predict.

pCO_2 is measured in the following syringe and capillary modes:

Analyzer	Syringe Modes	Capillary Modes
ABL735/725/715	195 µL, 95 µL 85 µL, Expired air	195 µL, 95 µL, 55 µL
ABL730/720/710	85 µL, Expired air	85 µL, 55 µL
ABL705	165 µL, 95 µL 85 µL, Expired air	165 µL, 95 µL, 55 µL
ABL700	85 µL, Expired air	55 µL

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pCO_2 Electrode, *Continued*

Corrections - Blood Samples

The pCO_2 measured on a sample is then corrected for systematic deviations from the reference method using the following equations:

$$pCO_2(\text{sample,corr}) = A_3 \times pCO_2(\text{sample})^3 + A_2 \times pCO_2(\text{sample})^2 + \\ + A_1 \times pCO_2(\text{sample}) + A_0 \times (B - pH_2O) \quad \textbf{Equation A}$$

and

$$pCO_2(\text{sample,corr}) = B_1 \times pCO_2(\text{sample}) + B_0 \quad \textbf{Equation B}$$

where:
- $pCO_2(\text{sample}) =$ uncorrected value of pCO_2 in the sample.
- $B =$ barometric pressure during the measurement
- $pH_2O =$ partial pressure of saturated water vapor (6.2571 kPa)
- $B_1 =$ instrument-dependent correction factor
- $B_0 =$ instrument-dependent interception constant

NOTE: *The 195 µL is used as the reference measuring mode for those ABL700 Series analyzers which do not have it. It is designated as "195 µL (ref.)" in the correction tables.*

ABL735/725/715 – Syringe mode:

A_3	A_2	A_1	A_0	$B_{1(95\ \mu L)}$	$B_{0(95\ \mu L)}$
-0.0000002	0.0051	1.1126	-0.003573	0.992	0.0089
Equation A is used to correct pCO_2 value measured on a sample in 195 µL and 85 µL modes. For the 95 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.					

ABL735/725/715 – Capillary mode:

A_3	A_2	A_1	A_0	$B_{1(55\ \mu L)}$	$B_{0(55\ \mu L)}$
-0.0000002	0.0051	1.1126	-0.003573	1.0937	–0.1463
Equation A is used to correct pCO_2 value measured on a sample in 195 µL and 95 µL modes. For the 55 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.					

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pCO_2 Electrode, *Continued*

Corrections – Blood Samples *(continued)*

ABL730/720/710 – Syringe mode:

A_3	A_2	A_1	A_0
-0.0000002	0.0051	1.1126	–0.00356
For the 85 µL mode, Equation A is used to correct the pCO_2 value measured on the sample.			

ABL730/720/710 – Capillary mode:

A_3	A_2	A_1	A_0	$B_{1(55\ \mu L)}$	$B_{0(55\ \mu L)}$	$B_{1(85\ \mu L)}$	$B_{0(85\ \mu L)}$
-0.0000002	0.0051	1.1126	-0.003573	1.0937	-0.1463	0.997	0.0743
For the 55 and 85 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.							

ABL705 – Syringe mode:

A_3	A_2	A_1	A_0	$B_{1(95\ \mu L)}$	$B_{0(95\ \mu L)}$
-0.0000002	0.0051	1.1126	–0.003573	0.992	0.0089
Equation A is used to correct pCO_2 value measured on a sample in 165 µL and 85 µL modes. For the 95 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.					

ABL705 – Capillary mode:

A_3	A_2	A_1	A_0	$B_{1(55\ \mu L)}$	$B_{0(55\ \mu L)}$
-0.0000002	0.0051	1.1126	–0.003573	1.0872	–0.0924
Equation A is used to correct pCO_2 value measured on a sample in 165 µL and 95 µL modes. For the 55 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.					

ABL700 – Syringe mode:

A_3	A_2	A_1	A_0
-0.0000002	0.0051	1.1126	–0.003573
For the 85 µL mode, Equation A is used to correct the pCO_2 value measured on the sample.			

ABL700 – Capillary mode:

A_3	A_2	A_1	A_0	$B_{1(55\ \mu L)}$	$B_{0(55\ \mu L)}$
-0.0000002	0.0051	1.1126	–0.003573	1.0872	–0.0924
For the 55 µL mode, the measured pCO_2 value is first corrected using Equation A. The obtained result is then used in Equation B to obtain the corrected pCO_2 value.					

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pCO_2 Electrode, *Continued*

Corrections - Expired Air Samples

The pCO_2 measured from the sample is then corrected for systematic deviations from the reference method using the following equation:

$$pCO_2(\text{sample,corr}) = A_{0,Gas} \times pCO_2(\text{sample}) + A_{1,Gas} \times (B - pH_2O)$$

where:

pCO_2(sample) =	uncorrected pCO_2 value of a gas sample
$A_{0,Gas}$ =	1.0196 (instrument dependent correction factor)
$A_{1,Gas}$ =	–0.00106 (instrument-dependent correction cut-off)
B =	barometric pressure during the measurement
pH_2O =	6.2751 kPa (partial pressure of saturated water vapour)

Stability Criteria

The following stability criterion must be met to obtain a stable electrode response during calibration:

$$\left| pCO_2(\text{sample,upd.last}) - pCO_2(\text{sample,upd.i}) \right| \le pCO_2(\text{limit})$$

This criterion is valid for calibrations using Gas 1 and Gas 2 where:

Parameter	**pCO_2 value from the last updating number...**	
	ABL7x5	**ABL7x0**
pCO_2(CalGas,upd.last)	92	62
pCO_2(CalGas,upd.i)	86 or 87	56 or 57
	(the relationship must be fulfilled for at least one of the updating numbers)	

pCO_2(limit) value for the stability criterion is 0.40 kPa/3.0 mmHg.

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pCO_2 Electrode, *Continued*

Stability Criteria *(continued)*

The following stability criteria must be met to obtain a stable electrode response during measurement:

$$\delta = \left| pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.i}) \right|$$

For δ	Criterion
a. ≤1.33 kPa	$\left\| pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.16}) \right\| \leq 0.40$
b. >1.33 kPa	$-0.1 \leq \frac{pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.16})}{pCO_2(\text{sample}, \text{upd.16}) - pCO_2(\text{sample}, \text{upd.1})} < 0.5$

For **b):**

if the following criteria are fulfilled, then no result is reported:

$$\frac{pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.16})}{pCO_2(\text{sample}, \text{upd.16}) - pCO_2(\text{sample}, \text{upd.1})} < -1.0$$

$$\frac{pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.16})}{pCO_2(\text{sample}, \text{upd.16}) - pCO_2(\text{sample}, \text{upd.1})} \geq 0.5$$

Expired air samples:

Measurement on an expired air sample is accepted if the following criterion is fulfilled:

$\left| pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.24}) \right| \leq 0.40$ kPa (3.0 mmHg)

or

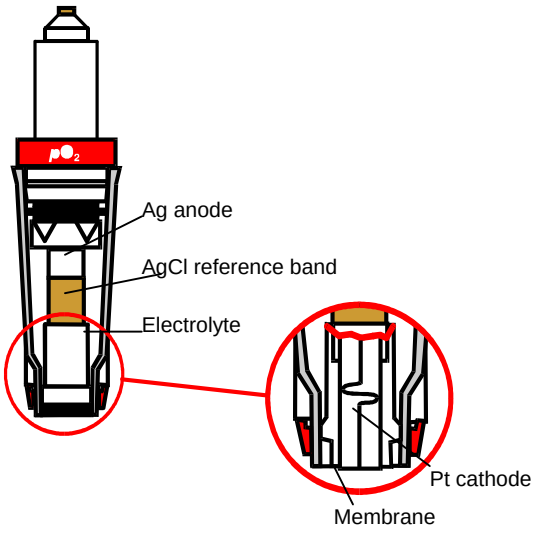
$\left| pCO_2(\text{sample}, \text{upd.30}) - pCO_2(\text{sample}, \text{upd.24}) \right| \leq 0.04 \times pCO_2(\text{sample}, \text{upd.30})$.

Error message "Measurement unstable" (= pCO_2 response fault during electrode monitoring in Expired air mode) is displayed if the stability criterion is not fulfilled.

pO_2 Electrode

Basic Description

The pO_2 electrode (E799) is an amperometric electrode which consists of a silver anode, platinum cathode and Ag/AgCl reference band, all protected by an electrode jacket which is filled with electrolyte solution. At the tip of the electrode jacket an oxygen-permeable membrane protects the Pt cathode from protein contamination and is covered on the inner side with Pt-black.



The electrode chain is polarized with constant voltage of -630 mV.

Oxygen from the sample diffuses across the membrane into the electrolyte and is reduced on the cathode (electrons are consumed) according to the following equation:

$$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$$

The H^+ ions come from the electrolyte solution.

This represents the complete reduction of O_2. Some of the O_2 however is only partially reduced according to the following equation:

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$$

In the presence of Pt- black, H_2O_2 produced by the incomplete reduction of O_2 at the cathode is immediately decomposed:

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

This oxygen is then also reduced at the cathode. The reduction of oxygen produces a flow of electrons (an electrical current) the size of this current, I, proportional to the amount of oxygen and measured by the amperemeter:

$$I = \text{Sens}(pO_2) \times pO_2 + I_o \qquad \text{pA}$$

where:

$\text{Sens}(pO_2)$ = Sensitivity of the pO_2 electrode
pO_2 = Partial pressure of O_2 in the sample
I_o = Zero current i.e. the current flowing through the circuit when pO_2 = 0 kPa (mmH

To complete the electrical circuit, an oxidation reaction where electrons are released is necessary. This reaction which occurs at the silver anode is the conversion of Ag to Ag^+:

$$Ag \rightarrow Ag^+ + e^-$$

In order to maintain a charge balance between the anode and cathode, 4 atoms of Ag need to be oxidized for one molecule of O_2 to be reduced.

Continued on next page

pO_2 Electrode, *Continued*

Basic Description *(continued)*

The Ag^+ ions are released into the electrolyte solution where they react with the Cl^- ions present, producing AgCl which is insoluble and forms a layer on the silver rod:

$$Ag^+ + Cl^- \rightarrow AgCl$$

Not all Ag+ ions can be removed from the solution. Some reach the cathode where they are converted back to Ag and form a deposit of silver. This deposit must be periodically removed with the brush provided in the electrode box.

Sensitivity

The pO_2 electrode is calibrated on two gases with known O_2 content.

Gas 1 contains 19.76 % O_2 and Gas 2 contains 0.0 % O_2.

The exact composition of the calibration gases is contained in their bar codes.

The sensitivity of the pO_2 electrode, Sens(pO_2), is calculated as follows:

$$\text{Sens}(pO_2) = \frac{I(O_2, \text{gas1}) - I(O_2, \text{gas2})}{pO_2(\text{gas1}) - pO_2(\text{gas2})} \text{ pA/kPa}$$

where:

$I(O_2,\text{gas1})$	=	Current recorded at the pO_2 electrode from a measurement on Gas 1
$I(O_2,\text{gas2})$	=	Current recorded at the pO_2 electrode from a measurement on Gas 2
$pO_2(\text{gas1})$	=	Partial pressure of O_2 in Gas 1
$pO_2(\text{gas2})$	=	Partial Pressure of O_2 in Gas 2

The partial pressures of O_2 in the gas mixtures Gas 1 and Gas 2 are calculated from the following equation:

$$pO_2(\text{gas1}) = FO_2(\text{gas1}) \times [B(\text{gas1}) - pH_2O] \text{kPa}$$

$$pO_2(\text{gas2}) = FO_2(\text{gas2}) \times [B(\text{gas2}) - pH_2O] \text{kPa}$$

where:

$FO_2(\text{gas1})$, $FO_2(\text{gas2})$	=	Fraction of O_2 in Gas 1 or Gas 2, respectively
$B(\text{gas1})$, $B(\text{gas1})$	=	Pressure inside the measuring chamber during a measurement on Gas 1 or Gas 2, respectively
pH_2O	=	Water vapor pressure = 6.2571 kPa at 37 °C.

The sensitivity of the pO_2 electrode should fall between 5 - 40 pA/mmHg or 37.5 - 300 pA/kPa.

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pO_2 Electrode, *Continued*

Zero Point

The zero point of the pO_2 electrode is the electrode current at pO_2=0. It is calculated from the current measured at the electrode with Gas 2 (0 % O_2), and the sensitivity:

$$\text{Zero point}(pO_2) = \frac{I(O_2, gas2)}{Sens(pO_2, prev)} \qquad kPa$$

where:

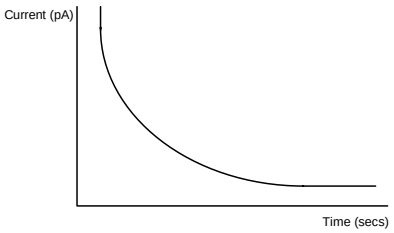
$I(O_2,gas2)$ = Current recorded at the pO_2 electrode from measurement on Gas 2, see *zero point current* below

$Sens(pO_2,prev)$ = Sensitivity of the pO_2 electrode measured at the previous 2-point calibration

The zero point value of the pO_2 electrode should be less than 6.0 mmHg or 0.80 kPa.

The zero point current is the current measured at the pO_2 electrode with Gas 2 in the measuring chamber. When the measurement on Gas 2 begins, a relatively high current is recorded due to residual O_2 from the rinse solution in the measuring chamber. This current falls exponentially with time while Gas 2 is present in the measuring chamber.

Forty seconds into the measurement the current reaches a steady state which is then considered as the zero point current.



Drift

Drift 1 is a measurement of the difference between two consecutive measurements on Gas 1, and is calculated from the following equation:

$$\text{Drift 1}(pO_2) = \frac{I(O_2, gas1) - I(O_2, gas2, prev)_{)}}{Sens(pO_2, prev)} - pO_2(gas1) \qquad kPa$$

Drift 2 reflects the change in sensitivity between 2-point calibrations and is calculated from the following equation:

$$\text{Drift 2}(pO_2) = \frac{I(O_2, gas2) - I(O_2, gas2, prev)_{)}}{Sens(pO_2, prev)} - pO_2(gas2) \qquad kPa$$

where:

$I(O_2,gas1)$, $I(O_2,gas2)$ = Current recorded at the pO_2 electrode from a measurement on Gas 1 and Gas 2, respectively

$I(O_2,gas2,prev)$ = Current recorded at the pO_2 electrode from the previous measurement on Gas 2

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pO_2 Electrode, *Continued*

Drift *(continued)* $Sens(pO_2,prev)$ = Sensitivity of the pO_2 electrode from the previous 2-point calibration

$pO_2(gas1)$, $pO_2(gas2)$ = Partial pressure of O_2 in Gas 1 and Gas 2, respectively

The default drift tolerances set by Radiometer are ± 0.80 kPa (6.0 mmHg) for Drift 1 and Drift 2. The Drift tolerances can, however, be user-defined in the Setup program.

Measurement The pO_2 value for a sample is calculated from the following equations:

$$pO_2(\text{sample},\text{updi}) = \frac{I(O_2,\text{sample},\text{upd.i}) - I(O_2,\text{gas2},\text{prev})}{Sens(pO_2)} \times K_1$$

Constant K_1 describes the gas/liquid relationship for the electrode.
This constant is defined as:

$$K_1 = 1 + 0.01\left(-5.8370 + \sqrt{21.712 + \frac{Sens(pO_2)}{3.66294}}\right)$$

$$\delta = \left|pO_2(\text{sample},\text{upd30}) - pO_2(\text{sample},\text{upd1})\right|$$

$$\text{predict} = \frac{pO_2(\text{sample},\text{upd.6}) \times pO_{2^-}(\text{sample},\text{upd.30}) - \left(pO_2(\text{sample},\text{upd.18})\right)^2}{pO_2(\text{sample},\text{upd.6}) + pO_{2^-}(\text{sample},\text{upd.30}) - 2 \times pO_2(\text{sample},\text{upd.18})}$$

where:

$I(O_2,sample,updi)$ = Current recorded at the pO_2 electrode from updating number *i* with a measurement on the sample.

$I(O_2,gas2,prev)$ = Current recorded at the pO_2 electrode from the previous measurement on Gas 2.

$Sens(pO_2)$ = Relative sensitivity of the pO_2 electrode determined from the last calibration on Gas 1 and Gas 2.

δ = Difference between pO_2(sample) from the first and last updatings.

predict = Extrapolated value for pO_2.

For $\delta < 2.66$ kPa,
$pO_2(sample) = pO_2(sample, upd.30)$

For 2.66 kPa < δ < 5.32 kPa

$$pO_2(\text{sample}) = \frac{\text{predict} \times (\delta - 2.66) + pO_2(\text{sample},\text{upd30}) \times (5.32 - \delta)}{2.66}$$

For $\delta \geq 5.32$ kPa
$pO_2(sample) = predict$

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pO_2 Electrode, *Continued*

Corrections - Blood Samples

The pO_2 measured from the sample is then corrected for systematic deviations from the reference method using the following equation:

$$pO_2(\text{sample,corr}) = \frac{-d_1 + \sqrt{d_1^2 - 4 \times \left(e_2 + e_3 \times pO_2(\text{sample, v1}) + e_4 \times pO\ (\text{sample, v1})^2\right)}}{2}$$

where:

$$pO_2(\text{sample, v1}) = pO_2(\text{sample}) + (k_1 - k_2 \times e^{k_3 \times pO_2(\text{sample})^2}) \times (100.398 - B)$$

Equation A

and

$d_1 = e_0 \times pO_2(\text{sample, v1}) + e_1$ **Equation B**

k_1 = 0.02614 (correction constant)

k_2 = 0.02107 (correction constant)

k_3 = –0.00281(correction constant)

pO_2 is measured in the following syringe and capillary modes:

Analyzer	Syringe Modes	Capillary Modes
ABL735/725/715	195 µL, 95 µL 85 µL, Expired air	195 µL, 95 µL, 55 µL
ABL730/720/710	85 µL, Expired air	85 µL, 55 µL
ABL705	165 µL, 95 µL 85 µL, Expired air	165 µL, 95 µL, 55 µL
ABL700	85 µL, Expired air	55 µL

NOTE: *The 195 µL is used as the reference measuring mode for those ABL700 Series analyzers which do not have it. It is designated as "195 µL (ref.)" in the correction tables.*

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pO_2 Electrode, *Continued*

Corrections - Blood Samples *(continued)*

Constant	ABL735/725/715 - Syringe mode		
	195 µL	**95 µL**	**85 µL**
e_0	–2.303	–2.303	–2.303
e_1	5.96942	5.96942	5.96942
e_2	0.83281	0.83281	0.83281
e_3	–6.0731	–6.0731	–6.0731
e_4	1.30565	1.30565	1.30565
Equations above are used to correct pO_2 value measured on a sample			
	ABL735/725/715 - Capillary mode		
	195 µL	**95 µL**	**55 µL**
e_0	–2.303	–2.303	–2.13930
e_1	5.96942	5.96942	6.11891
e_2	0.83281	0.83281	–0.16485
e_3	–6.0731	–6.0731	–5.54016
e_4	1.30565	1.30565	1.11462
Equations above are used to correct pO_2 value measured on a sample in 195 µL and 95 µL modes. For the 55 µL mode, the measured pO_2 value is first corrected using the equations and the constants for the 195 µL mode. The obtained result is then used in Equations A and B, together with the constants for 55 µL mode to obtain the corrected pO_2 value for this mode.			

Constant	ABL730/720/710 - Syringe mode
	85 µL
e_0	–2.303
e_1	5.96942
e_2	0.83281
e_3	–6.0731
e_4	1.30565
Equations above are used to correct pO_2 value measured on a sample.	

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pO_2 Electrode, *Continued*

Corrections - Blood Samples *(continued)*

Constant	ABL730/720/710 - Capillary mode		
	195 µL (ref.)	**85 µL**	**55 µL**
e_0	–2.303	–2.303	–2.13930
e_1	5.96942	5.96942	6.11891
e_2	0.83281	0.83281	–0.16485
e_3	–6.0731	–6.0731	–5.54016
e_4	1.30565	1.30565	1.11462
Equations are used to correct pO_2 value measured on a sample in 85 µL mode. For the 55 µL mode, the measured pO_2 value is first corrected using the equations and the constants for the 195 µL mode. The obtained result is then used in Equations A and B as pO_2 (Sample,v1) together with the constants for 55 µL mode to obtain the corrected pO_2 value for this mode			

Correction	ABL705 - Syringe modes			
	195 µL (ref.)	**165 µL**	**95 µL**	**85 µL**
e_0	–2.303	–2.303	–2.303	–2.303
e_1	5.96942	5.96942	5.96942	5.96942
e_2	0.83281	0.83281	0.83281	0.83281
e_3	–6.0731	–6.0731	–6.0731	–6.0731
e_4	1.30565	1.30565	1.30565	1.30565
Equations are used to correct pO_2 value measured on a sample in 165 µL, 95 µL and 85 µL modes.				
Correction	**ABL705 - Capillary modes**			
	195 µL (ref.)	**165 µL**	**95 µL**	**55 µL**
e_0	–2.303	–2.303	–2.303	–2.16691
e_1	5.96942	5.96942	5.96942	5.17310
e_2	0.83281	0.83281	0.83281	0.85016
e_3	–6.0731	–6.0731	–6.0731	–5.01679
e_4	1.30565	1.30565	1.30565	1.15746
Equations are used to correct pO_2 value measured on a sample in 165 µL and 95 µL modes. For the 55 µL mode, the measured pO_2 value is first corrected using the equations and the constants for the 195 µL mode. The obtained result is then used in Equations A and B as pO_2(Sample, v1) together with the constants for 55 µL mode to obtain the corrected pO_2 value for this mode.				

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pO_2 Electrode, *Continued*

Corrections - Blood Samples *(continued)*

Constant	ABL700 - Syringe mode
	85 µL
e_0	–2.303
e_1	5.96942
e_2	0.83281
e_3	–6.0731
e_4	1.30565
Equations are used to correct pO_2 value measured on a sample.	

Constant	ABL700 - Capillary mode	
	195 µL	**55 µL**
e_0	–2.303	–2.16691
e_1	5.96942	5.17310
e_2	0.83281	0.85016
e_3	–6.0731	–5.01679
e_4	1.30565	1.15746
For the 55 µL mode, the corrected pO_2 value in the sample is found by first calculating pO_2 (sample,corr.) for the 195 µL mode. The obtained result is then used in Equations A and B as pO_2 (sample, v1) together with the constants for the 55 µL mode to obtain pO_2 (sample,corr.) for this mode.		

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pO_2 Electrode, *Continued*

Corrections - Expired Air Samples

The pO_2 measured from the sample is then corrected for systematic deviations from the reference method using the following equation:

$$pO_2(\text{sample,corr}) = A_0 \times pO_2(\text{sample}) + A_1 \times (B - pH_2O)$$

where:

pO_2(sample)	= uncorrected pO_2 value of a gas sample
$A_{0,Gas}$	= 1.016 (instrument dependent correction factor)
$A_{1,Gas}$	= –0.004 (instrument-dependent correction cut-off)
B	= barometric pressure during the measurement
pH_2O	= 6.2571 kPa (partial pressure of saturated water vapor)

When measuring on gas samples, the constant K_1 which describes the gas/liquid relationship for the electrode, is equal 1.

Stability Criteria

The following stability criterion must be met to obtain a stable electrode response during **calibration**:

$$\left| pO_2(\text{sample,upd.last}) - pO_2(\text{sample,upd.i}) \right| \le pO_2 \text{ (limit)}$$

This criterion is valid for 1-point calibrations (Gas 2 contains no oxygen) where:

Parameter	***p*O₂ value from the last updating number...**	
	ABL7x5	**ABL7x0**
pO_2(Gas1,upd.last)	92	62
pO_2(Gas1,upd.i)	86 or 87	56 or 57
	(the relationship must be fulfilled for at least one of the updating numbers)	

pO_2(limit) value for the stability criterion is 0.80 kPa/6.0 mmHg.

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pO_2 Electrode, *Continued*

Stability Criteria *(continued)*

The following stability criteria must be met in order to obtain a stable electrode response during **measurement**:

$\delta = |pO_2(\text{sample,upd.30}) - pO_2(\text{sample,upd.1})|$

For δ	Criterion
a). ≤ 2.66 kPa	$\left\| pO_2(\text{sample}) - pO_2(\text{sample, upd.16}) \right\| \le 0.80$
b). > 2.66 kPa	$-0.2 \le \frac{pO_2(\text{sample, upd.30}) - pO_2(\text{sample, upd.18})}{pO_2(\text{sample, upd.18}) - pO_2(\text{sample, upd.6})} < 0.6$

For **b):**

if the following criteria are fulfilled then no result is reported:

$$\frac{pO_2(\text{sample, upd.30}) - pO_2(\text{sample, upd.18})}{pO_2(\text{sample, upd.18}) - pO_2(\text{sample, upd.6})} < -1.0$$

$$\frac{pO_2(\text{sample, upd.30}) - pO_2(\text{sample, upd.18})}{pO_2(\text{sample, upd.18}) - pO_2(\text{sample, upd.6})} \ge 0.6$$

Expired air samples:

Measurement on an expired air sample is accepted if the following criterion is fulfilled:

$\left| pO_2(\text{sample,upd.30}) - pO_2(\text{sample,upd.24}) \right| \le 0.80$ kPa/6.0 mmHg,

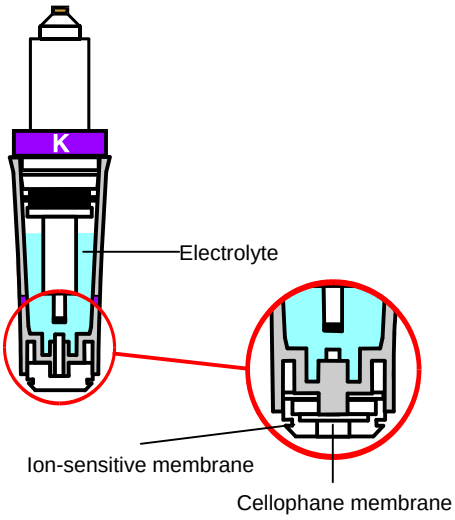
or

$\left| pO_2(\text{sample,upd30}) - pO_2(\text{sample,upd.24}) \right| \le 0.05 \times pO_2(\text{sample,upd.30})$.

Error message "Measurement unstable" (= pO_2 response fault during electrode monitoring in Expired air mode) is displayed if the stability criterion is not fulfilled.

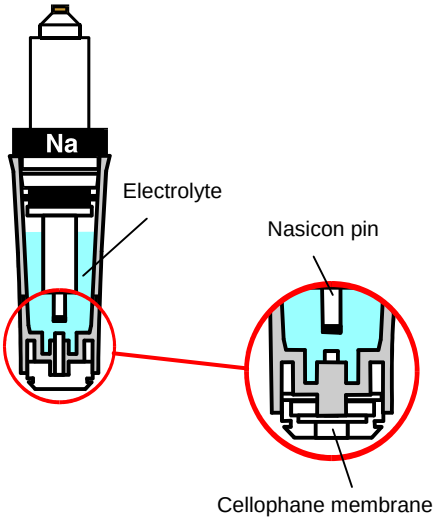
Electrolyte Electrodes

Basic Description



The K electrode (E722) is an ion-selective electrode whose sensing element is a PVC membrane containing a potassium-neutral ion carrier. The ion-sensitive membrane is covered with a cellophane membrane in order to protect it from the samples.

The electrolyte has a constant and known concentration of potassium ions. When a sample is brought in contact with the electrode, a potential develops across the PVC and cellophane membranes. The potential depends on the difference between the potassium (more precisely, activity) in the electrolyte and the sample. If the cK^+ in both solutions is the same, the potential across the electrode tip will be 0 V.



The Na electrode (E755) is an ion-selective electrode whose sensing element is a Na^+-sensitive ceramic pin is contained in the tip of the jacket.

The electrolyte has a constant and known concentration of sodium ions. When a sample is brought in contact with the electrode, a potential develops across the ceramic pin. The potential depends on the difference between the sodium (more precisely, activity) in the electrolyte and the sample. If the cNa^+ in both solutions is the same, the potential across the electrode tip will be 0 V.

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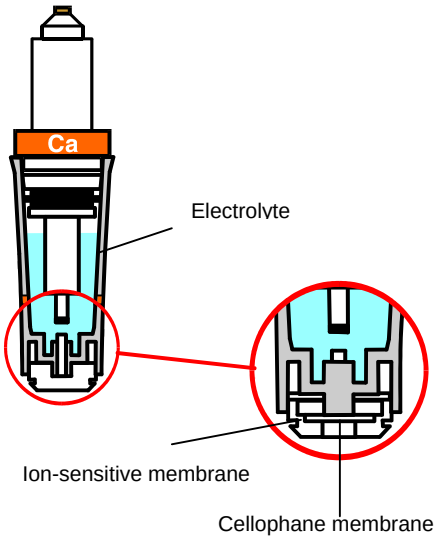
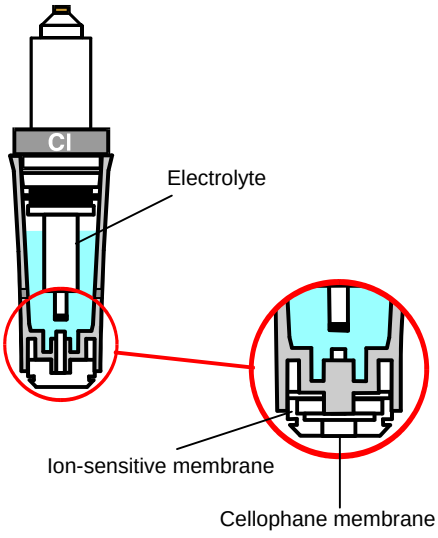
Electrolyte Electrodes, *Continued*

Basic Description *(continued)*



The Ca electrode (E733) is an ion-selective electrode whose sensing element is a PVC membrane containing a calcium-neutral ion carrier. The ion-sensitive membrane is covered with a cellophane membrane in order to protect it from the samples.

The electrolyte has a constant and known concentration of calcium ions. When a sample is brought in contact with the electrode, a potential develops across the PVC and cellophane membranes. The potential depends on the difference between the calcium (more precisely, activity) in the electrolyte and the sample. If the $c\mathrm{Ca}^{2+}$ in both solutions is the same, the potential across the electrode tip will be 0 V.



The Cl electrode (E744) is an ion-selective electrode whose sensing element is a PVC membrane containing a chloride ion carrier. The ion-sensitive membrane is covered with a cellophane membrane in order to protect it from the samples.

The electrolyte has a constant and known concentration of chloride ions. When a sample is brought in contact with the electrode, a potential develops across the PVC and cellophane membranes. The potential depends on the difference between the chloride (more precisely, activity) in the electrolyte and the sample. If the $c\mathrm{Cl}^{-}$ in both solutions is the same, the potential across the electrode tip will be 0 V.

Continued on next page

Electrolyte Electrodes, *Continued*

Electrode Chain Potential

The total potential across the electrode chain is a sum of the potential differences at each of the elements in the chain, all but one of which is known and constant. This is outlined in the following table.

Element	Potential	Symbol
Ag/AgCl electrode /electrolyte solution. (Reference electrode)	Known and constant when the Ag/AgCl wire is immersed in the electrolyte solution.	E_{ref}
Membrane junction between the electrolyte solution in the reference electrode and the sample.	Known and constant, independent of sample composition.	E_{MJ}
Ion-sensitive membrane (or pin) junction separating the sample and the electrode.	**Unknown**, dependent on sample composition.	E_{Sample}
Ag/AgCl electrode/inner buffer solution. (Electrolyte electrode)	Known and constant when the Ag/AgCl wire is immersed in the electrolyte solution.	E_E
Total potential.	Measured by the voltmeter.	E_{tot}

The unknown potential difference across the ion-sensitive membrane or pin is then the difference between the measured total potential and the sum of the known potentials:

$$E_{Sample} = E_{tot} - \left(E_{ref} + E_{MJ} + E_E\right) \qquad \text{mV}$$

Nernst Equation

The potential difference at the membrane (or pin) in the electrolyte electrodes can be expressed by the Nernst equation:

$$E_{Sample} = E_0 + \frac{2.3RT}{n\mathrm{F}} \times \log a_{ion} \qquad \text{mV}$$

where:

E_0 = standard electrode potential

R = gas constant (8.3143 $J \times K^{-1} mol^{-1}$)

T = absolute temperature (310.15 K at 37 °C)

n = charge on the ion (n = 1 for K^+ and Na^+, n = –1 for Cl^-, n = 2 for Ca^{2+})

F = Faraday constant (96487 $C mol^{-1}$)

a_{ion} = activity of the specific ion

Continued on next page

Electrolyte Electrodes, *Continued*

Calibration

The electrolyte electrodes are calibrated by determining the status and sensitivity from 1-point and 2-point calibrations respectively. Performance of the electrode from calibration to calibration is monitored by measuring the drift.

A 1-point calibration is performed using the calibration solution S1720 with the following nominal electrolyte concentrations:

$c\mathrm{K}^+$	4.0 mmol/L
$c\mathrm{Na}^+$	145 mmol/L
$c\mathrm{Ca}^{2+}$	1.25 mmol/L
$c\mathrm{Cl}^-$	102 mmol/L

The precise concentration of each electrolyte ion is contained in the solution's bar code.

A 2-point calibration is performed using the calibration solutions S1720 given above and S1730. Calibration Solution S1730 has the following nominal electrolyte concentrations:

$c\mathrm{K}^+$	40.0 mmol/L
$c\mathrm{Na}^+$	20.0 mmol/L
$c\mathrm{Ca}^{2+}$	5.0 mmol/L
$c\mathrm{Cl}^-$	50.0 mmol/L

The precise concentration of each electrolyte ion is contained in the solution's bar codes.

Sensitivity

The sensitivity of the electrolyte electrodes is calculated from the following equations:

K electrode

$$\mathrm{Sens(K)} = \frac{\mathrm{E(K,Cal1)} - \mathrm{E(K,Cal2)}}{61.5 \times \log \frac{c\mathrm{K}^+(\mathrm{Cal1})}{c\mathrm{K}^+(\mathrm{Cal2})}} \quad \text{(fraction)}$$

Na electrode

$$\mathrm{Sens(Na)} = \frac{\mathrm{E(Na,Cal1)} - \mathrm{E(Na,Cal2)}}{61.5 \times \log \frac{c\mathrm{Na}^+(\mathrm{Cal1})}{c\mathrm{Na}^+(\mathrm{Cal2})}} \quad \text{(fraction)}$$

Ca electrode

$$\mathrm{Sens(Ca)} = \frac{\mathrm{E(Ca,Cal1)} - \mathrm{E(Ca,Cal2)}}{30.75 \times \log \frac{c\mathrm{Ca}^{2+}(\mathrm{Cal1})}{c\mathrm{Ca}^{2+}(\mathrm{Cal2})}} \quad \text{(fraction)}$$

Continued on next page

Electrolyte Electrodes, *Continued*

Sensitivity *(continued)*

Cl electrode

$$\text{Sens(Cl)} = \frac{\text{E(Cl, Cal1)} - \text{E(Cl, Cal2)}}{-61.5 \times \log \frac{c\text{Cl}^-(\text{Cal1})}{c\text{Cl}^-(\text{Cal2})}} \quad \text{(fraction)}$$

where:

E(K/Na/Ca/Cl,Cal1)	=	Potential of the respective electrolyte electrode chain from a calibration on Cal 1 solution
E(K/Na/Ca/Cl,Cal2)	=	Potential of the respective electrolyte electrode chain from a calibrration on Cal 2 solution
61.5	=	Theoretical sensitivity of the K and Na electrodes at 37 °C
30.75	=	Theoretical sensitivity of the Ca electrode at 37 °C
–61.5	=	Theoretical sensitivity of the Cl electrode at 37 °C
$c\text{K}^+/c\text{Na}^+/c\text{Ca}^{2+}/c\text{Cl}^-$ (Cal1)	=	Specified concentration of the respective electrolyte in Cal 1 solution
$c\text{K}^+/c\text{Na}^+/c\text{Ca}^{2+}/c\text{Cl}^-$ (Cal2)	=	Specified concentration of the respective electrolyte in Cal 2 solution

The sensitivity limits of the electrolyte electrodes are as follows:

Electrode	Sensitivity Limits
K	92 - 105 %
Na	90 - 105 %
Ca	90 - 105 %
Cl	85 - 105 %

Status

The status of each of the electrolyte electrode is calculated from the following equations:

K electrode

$$\text{Status(K)} = \frac{10^{\frac{\text{E(K,Cal1)} - \text{E}_0\text{(K,Cal1)}}{61.5}} \times c\text{K}^+(\text{Cal1, nom})^2}{c\text{K}^+(\text{Cal1})} \quad \text{mmol / L}$$

Na electrode

$$\text{Status(Na)} = \frac{10^{\frac{\text{E(Na,Cal1)} - \text{E}_0\text{(Na,Cal1)}}{61.5}} \times c\text{Na}^+(\text{Cal1, nom})^2}{c\text{Na}^+(\text{Cal1})} \quad \text{mmol / L}$$

Continued on next page

Electrolyte Electrodes, *Continued*

Status *(continued)*

Ca electrode

$$\text{Status(Ca)} = \frac{10^{\frac{E(Ca,Cal1)-E_0(Ca,Cal1)}{30.75}} \times cCa^{2+}(Cal1,nom)^2}{cCa^{2+}(Cal1)} \quad \text{mmol / L}$$

Cl electrode

$$\text{Status(Cl)} = \frac{10^{\frac{E(Cl,Cal1)-E_0(Cl,Cal1)}{-61.5}} \times cCl^{-}(Cal1,nom)^2}{cCl^{-}(Cal1)} \quad \text{mmol / L}$$

where:

E(K/Na/Ca/Cl,Cal1)	=	Potential of the respective electrolyte electrode chain from a calibration on Cal 1 solution
E_0(K/Na/Ca/Cl,Cal1)	=	Standard potential of the respective electrolyte electrode chain with the following nominal electrolyte concentrations: cK^+ = 4.0 mmol/L cNa^+ = 145.0 mmol/L cCa^{2+} = 1.25 mmol/L cCl^- = 102.0 mmol/L (These concentrations correspond to the approximate concentrations of each of the electrolytes in Cal 1 solution).
$cK^+/cNa^+/cCa^{2+}/cCl^-$ (Cal1,nom)	=	Nominal concentration of the respective electrolyte ion in Cal 1 solution (*see above*)

The status limits of the electrolyte electrodes are as follows:

Electrode	Status Limits
K	0.5 - 12 mmol/L
Na	10 - 250 mmol/L
Ca	0.1 - 20 mmol/L
Cl	30 - 900 mmol/L

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Electrolyte Electrodes, *Continued*

Drift

Drift 1 is the difference between two consecutive calibrations on Cal 1 solution and is calculated for each of the electrolyte electrodes.

Drift 2 reflects the change in sensitivity between 2-point calibrations and is calculated for each of the electrolyte electrodes.

The drift equations are given below.

K electrode

$$\text{Drift 1(K)} = 10^{\frac{E(K,Cal1)-E(K,Cal1,prev)}{61.5\times Sens(K,prev)}} \times cK^{+}(Cal1,prev) - cK^{+}(Cal1) \quad \text{mmol / L}$$

$$\text{Drift 2(K)} = 10^{\frac{E(K,Cal2)-E(K,Cal1,prev)}{61.5\times Sens(K,prev)}} \times cK^{+}(Cal1,prev) - cK^{+}(Cal2) \quad \text{mmol / L}$$

Na electrode

$$\text{Drift 1(Na)} = 10^{\frac{E(Na,Cal1)-E(Na,Cal1,prev)}{61.5\times Sens(Na,prev)}} \times cNa^{+}(Cal1,prev) - cNa^{+}(Cal1) \quad \text{mmol / L}$$

$$\text{Drift 2(Na)} = 10^{\frac{E(Na,Cal2)-E(Na,Cal1,prev)}{61.5\times Sens(Na,prev)}} \times cNa^{+}(Cal1,prev) - cNa^{+}(Cal2) \quad \text{mmol / L}$$

Ca electrode

$$\text{Drift 1(Ca)} = 10^{\frac{E(Ca,Cal1)-E(Ca,Cal1,prev)}{30.75\times Sens(K,prev)}} \times cCa^{2+}(Cal1,prev) - cCa^{2+}(Cal1) \quad \text{mmol / L}$$

$$\text{Drift 2(Ca)} = 10^{\frac{E(Ca,Cal2)-E(Ca,Cal1,prev)}{30.75\times Sens(Ca,prev)}} \times cCa^{2+}(Cal1,prev) - cCa^{2+}(Cal2) \quad \text{mmol / L}$$

Cl electrode

$$\text{Drift 1(Cl)} = 10^{\frac{E(Cl,Cal1)-E(Cl,Cal1,prev)}{-61.5\times Sens(Cl,prev)}} \times cCl^{-}(Cal1,prev) - cCl^{-}(Cal1) \quad \text{mmol/L}$$

$$\text{Drift 2(Cl)} = 10^{\frac{E(Cl,Cal2)-E(Cl,Cal1,prev)}{-61.5\times Sens(Cl,prev)}} \times cCl^{-}(Cal1,prev) - cCl^{-}(Cal2) \quad \text{mmol/L}$$

where:

E(K/Na/Ca/Cl,Cal1), E(K/Na/Ca/Cl,Cal2)	=	Potential of the respective electrolyte electrode chain from a calibration on Cal 1 and Cal2 solution, respectively
E(K/Na/Ca/Cl,Cal1,prev)	=	Potential of the respective electrolyte electrode chain from the previous calibration on Cal 1 solution
61.5	=	Theoretical sensitivity of the K and Na electrodes at 37 °C

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Electrolyte Electrodes, *Continued*

Drift *(continued)*

30.75	=	Theoretical sensitivity of the Ca electrode at 37 °C
−61.5	=	Theoretical sensitivity of the Cl electrode at 37 °C
Sens(K/Na/Ca/Cl,prev)	=	Sensitivity of the respective electrolyte electrode from the last 2-point calibration
$c\mathrm{K}^+/c\mathrm{Na}^+/c\mathrm{Ca}^{2+}/c\mathrm{Cl}^-$(Cal1,prev)		Concentration of the respective electrolyte in Cal 1 solution in the previous calibration
$c\mathrm{K}^+/c\mathrm{Na}^+/c\mathrm{Ca}^{2+}/c\mathrm{Cl}^-$(Cal1), $c\mathrm{K}^+/c\mathrm{Na}^+/c\mathrm{Ca}^{2+}/c\mathrm{Cl}^-$(Cal2)		Specified concentration of the respective electrolyte in Cal 1 and Cal2 solution, respectively

NOTE: *If Cal 1 solution bottle has not been changed between two consecutive calibrations, the* cX(Cal1,prev) $-$ cX(Cal1) = *0, where X is the respective electrolyte ion.*

The default drift tolerances set by Radiometer are as follows:

Electrode	Drift 1 Tolerances	Drift 2 Tolerances
K	± 0.2 mmol/L	± 1.5 mmol/L
Na	± 3 mmol/L	± 1 mmol/L
Ca	± 0.05 mmol/L	± 0.2 mmol/L
Cl	± 2 mmol/L	± 3 mmol/L

Measurement

The electrolyte concentration in a sample is calculated from the following equation:

$$c\mathrm{X(sample)} = c\mathrm{X(Cal,prev)} \times 10^{\frac{\mathrm{E(X,sample)-E(X,Cal,prev)}}{\mathrm{Sens(theo)\times Sens(X,prev)}}}$$

where:

E(X,sample) =	Potential of the electrolyte electrode chain from a measurement on the sample.
E(X,Cal,prev) =	Potential of the electrolyte electrode chain from the previous calibration on Cal 1 solution.
cX(Cal 1) =	Specific (true) concentration of the electrolyte ion in Cal 1 solution.
Sens (theo) =	Theoretical sensitivity of the electrolyte electrode.
Sens(X,prev) =	Relative sensitivity of the electrolyte electrode chain from the last 2-point calibration.

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Electrolyte Electrodes, *Continued*

Corrections

The measured electrolyte concentration is then corrected for systematic deviations from the reference method by the following equations:

$$c\mathrm{X}(\mathrm{sample,corr})_{195\ \mu\mathrm{L}} = \mathrm{A}_{0(195\ \mu\mathrm{L})} \times c\mathrm{X}(\mathrm{sample}) + A_{1(195\ \mu\mathrm{L})} \qquad \textbf{Equation A}$$

and

$$c\mathrm{X}(\mathrm{sample,corr})_{95\ \mu\mathrm{L}} = \mathrm{A}_{0(95\ \mu\mathrm{L})} \times c\mathrm{X}(\mathrm{sample}) + A_{1(95\ \mu\mathrm{L})} \qquad \textbf{Equation B}$$

For the Cl electrode *only*, Equation A reads as:

$$c\mathrm{Cl}^{-}(\mathrm{sample,corr})_{195\ \mu\mathrm{L}} = \mathrm{A}_{0(195\ \mu\mathrm{L})} \times \left(c\mathrm{Cl}^{-}(\mathrm{sample}) - 0.0956 \times c\mathrm{HCO}_3^{-}\right) + A_{1(195\mu\mathrm{L})}$$

where:

cX(sample)	= uncorrected value of the electrolyte ion in the sample
$c\mathrm{HCO}_3^-$	= bicarbonate concentration of 24.5 mmol/L.
A_0	= instrument-dependent correction factor
A_1	= instrument-dependent interception constant

Correction	ABL735/725/715 - Syringe modes		
	Electrolyte Ion	**195 µL**	**95 µL**
A_0	K^+	0.984	1.0228
	Na^+	0.9942	0.9750
	Ca^{2+}	1.00415	1.0174
	Cl^-	1.247	0.991
A_1	K^+	–0.060	–0.0268
	Na^+	–2.6020	5.5365
	Ca^{2+}	–0.023	0.0155
	Cl^-	–30.756	0.887
For the 195 µL mode the measured electrolyte concentration is corrected using Equation A. For the 95 µL mode, the measured electrolyte concentration is first corrected using Equation A and the constants for the 195 µL mode. cX(sample,corr)$_{195\ \mu\mathrm{L}}$ obtained from this equation is then used in Equation B as cX(sample) to obtain the final corrected electrolyte concentration in the sample for this mode.			

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Electrolyte Electrodes, *Continued*

Corrections *(continued)*

Correction	ABL735/725/715 - Capillary modes		
	Electrolyte Ion	**195 µL**	**95 µL**
A_0	K^+	0.984	1.059
	Na^+	0.9942	0.999
	Ca^{2+}	1.00415	1.097
	Cl^-	1.247	0.991
A_1	K^+	–0.060	–0.179
	Na^+	–2.6020	3.190
	Ca^{2+}	–0.0230	–0.070
	Cl^-	–30.756	0.887

For the 195 µL mode the measured electrolyte concentration is corrected using Equation A.

For the 95 µL mode, the measured electrolyte concentration is first corrected using Equation A and the constants for the 195 µL mode. $cX(sample,corr)_{195\ \mu L}$ obtained from this equation is then used in Equation B as $cX(sample)$ to obtain the final corrected electrolyte concentration in the sample for this mode.

Correction	ABL705 - Syringe modes			
	Electrolyte Ion	**195 µL**	**165 µL**	**95 µL**
A_0	K^+	0.984	0.984	1.0228
	Na^+	0.9942	0.9942	0.975
	Ca^{2+}	1.00415	1.00415	1.0174
	Cl^-	1.247	1.247	0.991
A_1	K^+	–0.060	–0.060	–0.0268
	Na^+	–2.6020	–2.6020	5.5365
	Ca^{2+}	–0.0230	–0.0230	0.0155
	Cl^-	–30.756	–30.756	0.887

For the 165 µL mode the measured electrolyte concentration is corrected using Equation A.

For the 95 µL mode, the measured electrolyte concentration is first corrected using Equation A and the constants for the 195 µL mode. $cX(sample,corr)_{195\ \mu L}$ obtained from this equation is then used in Equation B as $cX(sample)$ to obtain the final corrected electrolyte concentration in the sample for this mode.

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Electrolyte Electrodes, *Continued*

Corrections *(continued)*

Correction	ABL705 - Capillary modes			
	Electrolyte Ion	195 µL	165 µL	95 µL
A_0	K^+	0.984	0.984	1.059
	Na^+	0.9942	0.9942	0.999
	Ca^{2+}	1.00415	1.00415	1.097
	Cl^-	1.247	1.247	0.991
A_1	K^+	–0.060	–0.060	–0.179
	Na^+	–2.6020	–2.6020	3.190
	Ca^{2+}	–0.0230	–0.0230	–0.070
	Cl^-	–30.756	–30.756	0.887
For the 165 µL mode the measured electrolyte concentration is corrected using Equation A. For the 95 µL mode, the measured electrolyte concentration is first corrected using Equation A and the constants for the 195 µL mode. cX(sample,corr)$_{195\ \mu L}$ obtained from this equation is then used in Equation B as cX(sample) to obtain the final corrected electrolyte concentration in the sample for this mode				

See *Chapter 5, Performance Specifications* for more information on reference methods.

Stability Criteria

The following stability criterion must be met to obtain a stable electrode response during calibration:

$$\left|c\mathrm{X}(\mathrm{sample},\mathrm{upd.last}) - c\mathrm{X}(\mathrm{sample},\mathrm{upd.i})\right| \le \mathrm{K} \times c\mathrm{X}(\mathrm{sample},\mathrm{upd.last})$$

This criterion is valid for calibrations using Cal 1 and Cal 2 solutions where:

cX(Cal,upd.last) =	Concentration of the electrolyte ion from the last updating when measuring on calibration solution. (The last updating is number 30).
cX(Cal,upd.i) =	Concentration of the electrolyte ion for a given updating when measuring on calibration solution. (The relationship must be fulfilled for at least one of the updating numbers 18 or 19).

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Electrolyte Electrodes, *Continued*

Stability Criteria *(continued)*

where (continued):

K = Constant for the stability criterion.

Electrolyte Ion	Cal1 solution	Cal2 solution
K^+	0.01	0.01
Na^+	0.01	0.02
Ca^{2+}	0.02	0.02
Cl^-	0.022	0.022

The following stability criterion must be met to obtain a stable electrode response during measurement:

$$\left|c\mathrm{X}(\mathrm{sample,upd.last}) - c\mathrm{X}(\mathrm{sample,upd.i})\right| \leq$$
$$\mathrm{K} \times \left(\left|c\mathrm{X}(\mathrm{sample,upd.last}) - c\mathrm{X}(\mathrm{Rinse})\right|\right) + c\mathrm{X}(\mathrm{Rinse})$$

where:

cX(sample,upd.last) =	Concentration of the electrolyte ion from the median of the last 5 updatings (for Ca^{2+}: 3 last updatings) when measuring on a sample. The last updating number is 30 (or 10 for some micromodes).
cX(sample,upd.i) =	Concentration of the electrolyte ion for a given updating when measuring on a sample. (The relationship must be fulfilled for at least one of the updating numbers shown below).

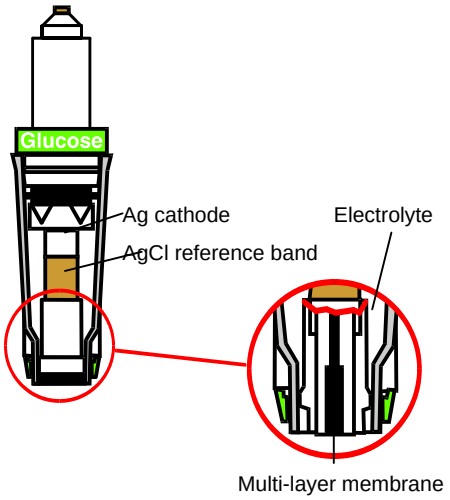
K^+	Na^+	Ca^{2+}	Cl^-
22	22	26	22
23	23	27	23

In some micromodes, substract 20 from number above.

K	Constant for the stability criterion; it equals to: $K^+ = 0.012$; $Na^+ = 0.012$; $Ca^{2+} = 0.022$; $Cl^- = 0.012$
$c\mathrm{X}_{\mathrm{Rinse}}$	Constant that includes the concentration of the electrolyte ion in rinse solution: $K^+ = 4.0$; $Na^+ = 130.0$; $Ca^{2+} = 1.25$; $Cl^- = 137.7$

Metabolite Electrodes

Basic Description



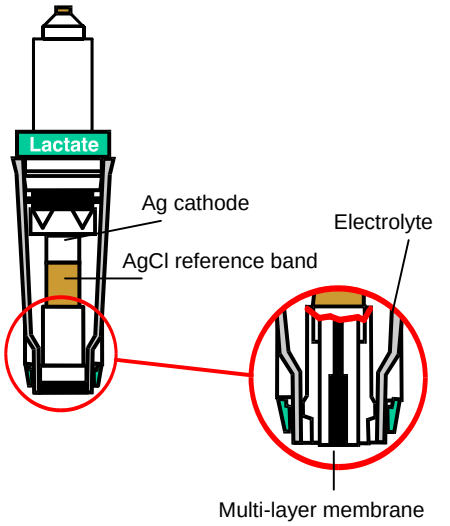
The glucose electrode (E7066) and the lactate electrode (E7077) have similar construction described below.

The electrode consists of a silver cathode and a platinum anode. The electrode is protected by an electrode jacket filled with electrolyte solution and a multi-layer membrane mounted at the tip.

The membrane consisting of three layers:

1. outer membrane layer permeable to glucose.
2. middle enzyme layer.
3. inner membrane layer permeable to H_2O_2.

A polarization voltage of 675 mV is applied to the electrode chain and the current through the chain is measured by an amperemeter.



Glucose or lactate molecules are transported across the outer membrane of the multi-layer membrane.

The enzyme glucose oxidase or lactate oxidase immobilized between the inner and outer membrane layers converts the glucose or lactate according to the following reactions:

glucose + O_2 → gluconic acid + H_2O_2

lactate + O_2 → pyruvate + H_2O_2

O_2 for this reaction is supplied by the outer membrane layer and also by the oxidation of H_2O_2 at the Pt anode.

The H_2O_2 produced by the enzyme reaction is transported across the inner membrane to the Pt anode.

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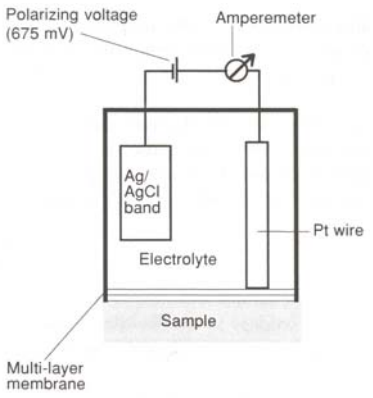
Metabolite Electrodes, *Continued*

Basic Description *(continued)*



$H_2O \rightarrow 2H^+ + O_2 + 2e^-$

When a potential is applied to the electrode chain, the oxidation of H_2O_2 produces an electrical current proportional to the amount of H_2O_2, which in turn is directly related to the amount of glucose or lactate.

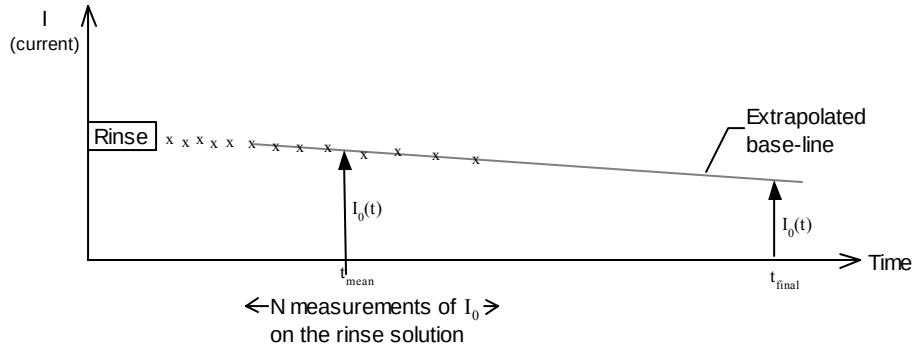
To complete the electrical circuit a reduction reaction (where electrons are consumed) at the cathode converts Ag^+ (from AgCl) to Ag:

$$Ag^+ + e^- \rightarrow Ag$$

In order to maintain a charge balance between the anode and the cathode, two Ag^+ ions need to be reduced for one molecule of H_2O_2 to be oxidized.

Zero Current

The zero current is a small background current measured at the electrode when no glucose or lactate is present in a solution. As the rinse solution contains no glucose or lactate, a baseline representing the zero current, I_0 as a function of time (I_0 = f(t)), is obtained from continuous measurements on the rinse solution.



This I_0 baseline is obtained as follows:

- At the end of a rinse, with the rinse solution in the measuring chamber, zero current of the metabolite electrodes is measured periodically (the intervals between these measurements become longer if the analyzer is idle).
- The previous N (N = 8) measurements on the rinse solution – before a calibration or a sample measurement starts - are used to obtain a baseline representing the time function of I_0.

Continued on next page

Metabolite Electrodes, *Continued*

Zero Current *(continued)*

- The baseline is extrapolated throughout the whole electrode calibration or sample measurement period, and represents the zero current time function.
- The I_0 baseline is used to determine the sensitivity of the metabolite electrode.

The extrapolated final zero current value at the metabolite electrodes at the last updating (illustrated by the I_0 baseline) is determined as follows:

$$I_0(\text{final}) = A_1 \times I_{slope} \times (t_{final} - t_{mean}) + I_0\ (\text{mean}) \quad \text{pA}$$

where:

A_1 = Empirical constant dependent on electrode and determined from tests against the reference method

t_{final} = Time of the last measurement updating on the calibration solution or sample.

t_{mean} = The mean time of the N zero current measurements on the rinse solution:

$$t_{mean} = \frac{\sum_{n=1}^{N} t_n}{N} \quad \text{sec}$$

where t_n is the time of the n^{th} measurement on the rinse solution.

$I_0(\text{mean})$ = The zero current at the mean time (t_{mean}):

$$I_0(\text{mean}) = \frac{\sum_{n=1}^{N} I_{0,n}}{N} \quad \text{pA}$$

where $I_{0,n}$ is the zero current at the n^{th} measurement on the rinse solution.

I_{slope} = The slope or gradient of the I_0 baseline

$$I_{slope} = \frac{\sum_{n=1}^{N} (t_n - t_{mean}) \times (I_{0,n} - I_0(\text{mean}))}{\sum_{n=1}^{N} (t_n - t_{mean})^2} \quad \text{pA/second}$$

If $I_{slope} > 0.0$, it is set to 0.0

The zero current of the metabolite electrodes should be less than 10000 pA.

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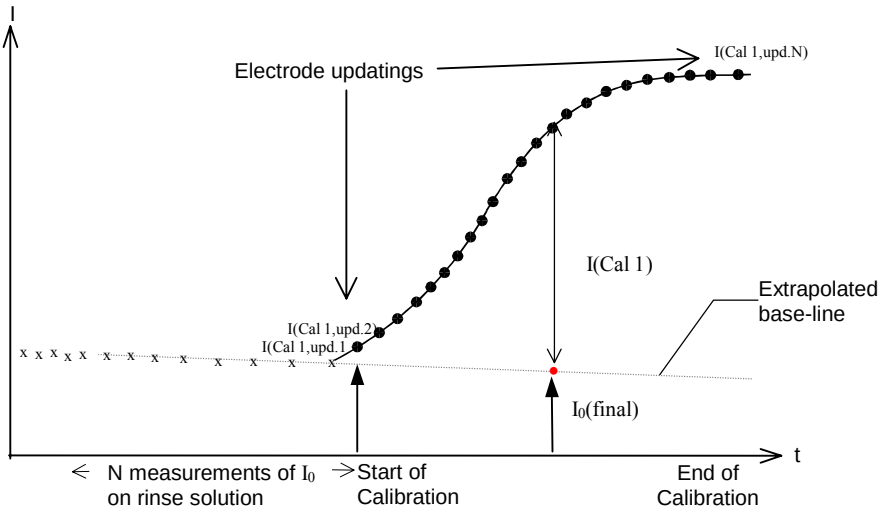
Metabolite Electrodes, *Continued*

Sensitivity

The sensitivities of the metabolite electrodes are calculated by measuring the current on Calibration Solution 1 (Cal 1) and then correcting for the zero current using the extrapolated I_0 baseline.

Cal 1 has a nominal glucose concentration of 10 mmol/L and a nominal lactate concentration of 4 mmol/L. The precise values are batch-individual and contained in the bar codes of the Cal 1 bottles.

The diagram below, together with the table, describes in principle how the sensitivities for the metabolite electrodes are obtained.



The current at the metabolite electrodes with Cal 1 in the measuring chamber, I(Cal 1), is measured 30 times at regular intervals. The current at the 15th updating is used to determine sensitivity of the glucose electrode, and the current at the 30th updating is used to determine sensitivity of the lactate electrode.

The current due to the glucose or lactate presence in the sample is then calculated as the difference between the current at the final updating (the 15th for the glucose and the30th for the lactate electrode) and the zero current at that time point:

$$I(\text{Cal 1}) = I(\text{Cal 1,final}) - I_0(\text{final})$$

The sensitivities of the electrodes are calculated as follows:

$$\text{Sens} = \frac{I(\text{Cal 1})}{c\text{X}(\text{Cal 1})}$$

Continued on next page

Metabolite Electrodes, *Continued*

Sensitivity *(continued)*

where:

cX(Cal 1)	=	Actual concentration of glucose/lactate in the Cal 1 solution.
I_0(final)	=	Extrapolated final zero current value of the metabolite electrode at the time of the last updating.
I(Cal 1)	=	electrode current due to presence of glucose/lactate.

The sensitivity limits of the metabolite electrodes are as follows:

Electrode	Sensitivity Limits
Glucose	100 - 1800 pA/mM
Lactate	150 - 2000 pA/mM

Drift

The drift in the sensitivity of the metabolite electrodes is calculated from the following equations:

$$\text{Drift} = \frac{\text{I(Cal 1, final)} - \text{I}_0\text{(final)}}{\text{Sens}} - c\text{X(Cal 1)}$$

where:

I(Cal 1,final)	=	Current at the final measurement on Cal 1 solution.
Sens	=	Sensitivity of the glucose/lactate electrode from the **previous** calibration.
cX(Cal 1)	=	Actual concentration of glucose/lactate in the Cal 1 solution.
I_0(final)	=	Extrapolated final zero current value of the metabolite electrode measured at the time of the last updating.

The default drift tolerances set by RADIOMETER for the metabolite electrodes are:

± 0.5 mM for the glucose electrode

± 0.2 mM for the lactate electrode.

Continued on next page

Metabolite Electrodes, *Continued*

Measurement

The glucose/lactate concentration in a sample is calculated from the following equation:

$$cX(\text{sample}) = \frac{I(\text{sample}) - I_0(\text{final})}{\text{Sens}}$$

where:

I(sample)	=	Current of the metabolite electrode measured on the sample.
I_0(final)	=	Extrapolated final zero current value of the metabolite electrode at the time of the last sample updating.
Sens	=	Relative sensitivity of the metabolite electrode.

Corrections

The measured metabolite concentration is corrected for systematic deviations from the reference method by the following equations:

$$cX(\text{sample},\text{corr})_{195\,\mu L} = A_{0(195\,\mu L)} \times cX(\text{sample}) + A_{1(195\,\mu L)} \qquad \textbf{Equation A}$$

and

$$cX(\text{sample},\text{corr})_{95\,\mu L} = A_{0(95/35\,\mu L)} \times cX(\text{sample}) + A_{1(95/35\,\mu L)} \qquad \textbf{Equation B}$$

where:

cX(sample) =	uncorrected measured glucose/lactate concentration from a sample
A_0 =	instrument-dependent correction factor
A_1 =	instrument-dependent interception constant

Continued on next page

Metabolite Electrodes, *Continued*

Corrections *(continued)*

Correction	ABL735/725/715 - Syringe modes		
	Metabolite	**195 µL**	**95 µL**
A_0	*c*Glu	0.93	1.0040
	*c*Lac	0.93	1.0082
A_1	*c*Glu	0.1	–0.0171
	*c*Lac	0.0268	0.0017

For the 195 µL mode the measured metabolite concentration is corrected using Equation A.

For the 95 µL mode, the measured metabolite concentration is first corrected using Equation A and the constants for the 195 µL mode. $cX(sample,corr)_{195\ \mu L}$ obtained from this equation is then used in Equation B as *c*X(sample) to obtain the final corrected metabolite concentration in the sample for this mode.

Correction	ABL735/725/715 - Capillary modes			
	Metabolite	**195 µL**	**95 µL**	**35 µL**
A_0	*c*Glu	0.93	1.053	1.1438
	*c*Lac	0.93	1.044	1.1724
A_1	*c*Glu	0.1	0.014	–0.0602
	*c*Lac	0.0268	–0.020	–0.0411

For the 195 µL mode the measured metabolite concentration is corrected using Equation A.

For the 95 µL and 35 µL modes, the measured metabolite concentration is first corrected using Equation A and the constants for the 195 µL mode. The obtained $cX(sample,corr)_{195\ \mu L}$ is then used in Equation B as *c*X(sample) to obtain the final corrected metabolite concentration in the sample for this mode.

Correction	ABL705 - Syringe modes			
	Metabolite	**195 µL**	**165 µL**	**95 µL**
A_0	*c*Glu	0.93	0.896	1.0040
	*c*Lac	0.93	0.900	1.0082
A_1	*c*Glu	0.1	0.1576	–0.0171
	*c*Lac	0.0268	0.0268	0.0017

For the 165 µL mode the measured metabolite concentration is corrected using Equation A.

For the 95 µL mode, the measured metabolite concentration is first corrected using Equation A and the constants for the 195 µL mode. $cX(sample,corr)_{195\ \mu L}$ obtained from this equation is then used in Equation B as *c*X(sample) to obtain the final corrected metabolite concentration in the sample for this mode.

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Metabolite Electrodes, *Continued*

Corrections *(continued)*

Correction	ABL705 - Capillary modes				
	Metabolite	**195 µL**	**165 µL**	**95 µL**	**35 µL**
A_0	*c*Glu	0.93	0.896	1.053	1.1438
	*c*Lac	0.93	0.900	1.044	1.1724
A_1	*c*Glu	0.1	0.1576	0.014	–0.0602
	*c*Lac	0.0268	0.0268	–0.020	–0.0411

For the 165 µL mode the measured metabolite concentration is corrected using Equation A.

For the 95 µL and 35 µL mode, the measured metabolite concentration is first corrected using Equation A and the constants for the 195 µL mode. $cX(sample,corr)_{195\ \mu L}$ obtained from this equation is then used in Equation B as *c*X(sample) to obtain the final corrected metabolite concentration in the sample for this mode.

See *Chapter 5, Performance Characteristics* for more information on reference methods.

Stability Criteria

The following stability criteria must be met to obtain a stable electrode response during calibration:

$$I(Cal\ 1,upd.30) - I(Cal\ 1,\ upd.21) - 9 \times I_{slope} \leq 0$$

$$S_{d,zero} < S_{d,max}$$

$$\tau = \frac{-9.5}{\log \frac{I(Cal1,upd.1) - I(Cal1,upd.11)}{I(Cal1,upd.11) - I(Cal1,upd.21)}} \leq 50$$

All of the three criteria must be fulfilled for a calibration using Cal 1 solution where:

I(Cal 1,upd.30) I(Cal 1,upd.21) I(Cal 1,upd.11) I(Cal 1,upd.1)	=	Electrode current at the 30th/21st/11th/1st updating during measurement on Cal 1 solution, respectively.
$S_{d,zero}$	=	Spreading of the zero point current updatings around the regression line.
$S_{d,max}$	=	If Sens > 400 pA/mM, then $S_{d,max} = 0.025 \times Sens$, otherwise $S_{d,max} = 10.0$.

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Metabolite Electrodes, *Continued*

Stability Criteria *(continued)*

τ = Should be less than or equal to 50,

and

$$\log \frac{I(Cal1, upd.1) - I(Cal1, upd.11)}{I(Cal1, upd.11) - I(Cal1, upd.21)}$$

should be negative or equal zero.

The following stability criterion must be met to obtain a stable electrode response during measurement:

$S_{d,zero} < S_{d,max}$

where:

$S_{d,zero}$ = Spreading of the zero point current updatings around the regression line.

$S_{d,max}$ = If Sens > 400 pA/mM, then $S_{d,max} = 0.025 \times Sens$, otherwise $S_{d,max} = 10.0$.

The (glucose or lactate) in the sample is *c*X(sample,corr).

If the corrected concentration of the metabolite, *c*X(sample,corr) > 1, the following criteria must be fulfilled:

$$0 \le \frac{I(Cal1, upd.30) - I(Cal1, upd.21) - 9 \times I_{slope}}{I(sample, upd.30) - I_0(upd.30)} \le 0.20$$

otherwise

$$\left| \frac{I(sample, upd.30) - I(sample, upd.21) - 9 \times I_{slope}}{Sens} \right| \le 0.14$$

where:

I(Cal 1,upd.30)
I(Cal 1,upd.21) = Electrode current at the 30th/21st updating during measurement on sample, respectively.

Continued on next page

Metabolite Electrodes, *Continued*

Stability Criteria *(continued)*

If all the criteria below are fulfilled, then the result of the measurement will be marked with an interference error.

$$\frac{I(sample,upd.30) - I(sample,upd.23)}{I(sample,upd.16 - I(sample,upd.9)} \geq 1$$

$$I(sample,upd.16) > I(sample,upd.12)$$

$$I(sample,upd.12) > I(sample,upd.9)$$

$$cX(sample,corr) > 1.5 \text{ mmol/L}$$

where:

I(sample,upd.30) I(sample,upd.23) I(sample,upd.16) I(sample,upd.12) I(sample,upd.9)	=	Electrode current at the $30^{th}/23^{rd}/16^{th}/12^{th}/9^{th}$ updating during measurement on sample, respectively.
*c*X(sample,corr)	=	Corrected concentration of glucose or lactate in the sample.

References

List of References

List of the references for *Chapter 2, Electrodes:*

1. Linnet N. pH measurements in theory and practice. 1st ed. Copenhagen: Radiometer Medical A/S, 1970.

3. The Optical System

Introduction This chapter describes the optical system in the ABL700 Series analyzer, its construction, and the measuring method used.

Contents This chapter contains the following topics.

Measuring Principle

Introduction

The optical system of the ABL700 Series analyzer is designed to measure the following parameters:

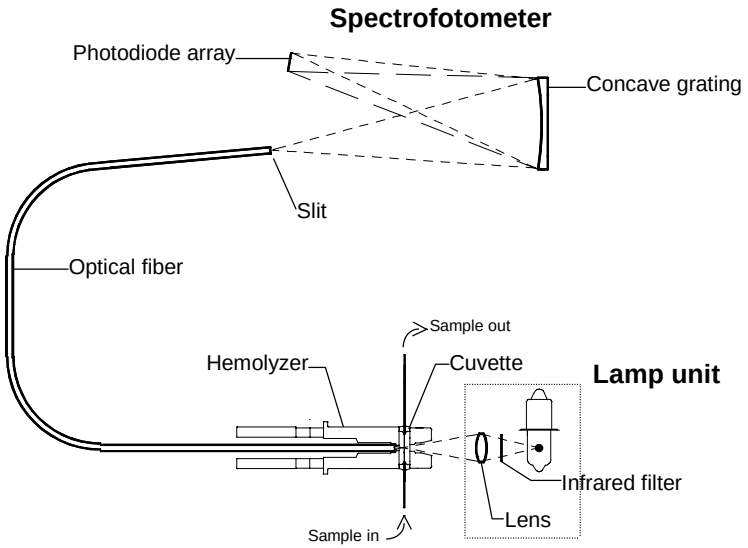
Parameter	Description
*c*tHb	concentration of total hemoglobin
sO_2	oxygen saturation
FO_2Hb	fraction of oxyhemoglobin
*F*COHb	fraction of carboxyhemoglobin
*F*HHb	fraction of deoxyhemoglobin
*F*MetHb	fraction of methemoglobin
*F*HbF	fraction of fetal hemoglobin
*c*tBil	concentration of total bilirubin (the sum of unconjugated and conjugated bilirubin) in plasma

NOTE: *c*tBil *can be measured on a whole blood or plasma sample. Plasma samples provide the optimal measurement performance. To obtain optimal accuracy when following a patient trend in c*tBil*, use the same aspiration mode and the same analyzer.*

*Hematocrit (*Hct*) is also available as a derived parameter.*

Optical System

The optical system is based on a 128-wavelength spectrophotometer with a measuring range of 478 - 672 nm. The spectrometer is connected via an optical fiber to a combined hemolyzer and measuring chamber.



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Measuring Principle, *Continued*

Optical System *(continued)* The method used in the ABL700 Series analyzer's optical system is visible absorption spectroscopy.

Step	Description
1	The blood sample is transported to the cuvette positioned in the hemolyzer unit. The temperature of the cuvette is regulated to 37 °C.
2	1 µL of the sample is ultrasonically hemolyzed in the cuvette at a frequency of about 30 kHz in order to rupture the walls of the red blood cells so that their content is mixed with the blood plasma, giving an optically clear solution. There is no bilirubin in the red blood cells, so after hemolyzation the red blood cell intracellular fluid dilutes the plasma bilirubin. The calculation discussed in *Measurement and Corrections* corrects for this dilution. To eliminate air bubbles in the sample and to enhance hemolyzation, an over-pressure of one atmosphere is maintained throughout hemolyzation and measurement.
3	Light from a 4 Watt halogen lamp is sent to the cuvette via an infra-red filter and a biconvex lens. The voltage across the halogen lamp is regulated by a thermostatted photodiode so that the amount of light sent to the cuvette has a constant intensity.
4	The light transmitted through the cuvette is guided to the spectrometer via an optical fiber.
5	The light passes through a slit that directs it towards a combined mirror and concave grating.
6	The grating separates the light into 128 single wavelengths and the mirror focuses the 128 light signals on a photodiode array.
7	The photodiode array has 128 diodes or pixels, one for each wavelength, which convert the monochromatic light signals to currents.
8	The currents and therefore the intensity of the light signals are measured at each of the 128 diodes, which form the basis for the absorption spectrum for a particular sample.
9	The spectrum is sent to the analyzer's computer, where the calculations of the oximetry parameter values are made.

Continued on next page

Measuring Principle, *Continued*

Lambert-Beer's Law

Absorption spectroscopy is based on Lambert-Beer's law which states that the measured absorbance for a single compound is directly proportional to the concentration of the compound and the length of the light path through the sample [1]:

$$A_y^{\lambda} = \varepsilon_y^{\lambda} \times c_y \times l$$

where:

A_y^{λ} = absorbance of compound y at wavelength λ

ε_y^{λ} = extinction coefficient of compound y at wavelength λ (a constant, characteristic of the compound)

c_y = concentration of compound y in sample

l = length of light path

Absorbance

The absorbance (A) of a compound is defined as the logarithm of the ratio of the light intensity before and after transmission through the compound.

In practice it is the logarithm of the ratio of the light intensity transmitted through water to the light intensity transmitted through the compound.

$$A = \log \frac{I_0}{I}$$

where:

I_0 = intensity of light transmitted through water (I_0 is measured as the intensity of light transmitted through the Cal 1 or Cal 2 solutions)

I = intensity of light transmitted through the compound

Total Absorbance

For samples containing more than one optically active compound, the total absorbance (A_{total}) is the sum of the individual compounds' absorbance, since absorbance is an additive quantity.

For example, if a sample contains 6 compounds y_1, y_2, ….y_6, the total absorbance measured for that sample at wavelength λ_1 is:

$$A_{total}^{\lambda_1} = A_{y_1}^{\lambda_1} + A_{y_2}^{\lambda_1} + A_{y_3}^{\lambda_1} + A_{y_4}^{\lambda_1} + A_{y_5}^{\lambda_1} + A_{y_6}^{\lambda 1}$$

$$= l\left(\varepsilon_{y_1}^{\lambda_1} c_{y_1} + \varepsilon_{y_2}^{\lambda_1} c_{y_2} + \varepsilon_{y_3}^{\lambda_1} c_{y_3} + \varepsilon_{y_4}^{\lambda_1} c_{y_4} + \varepsilon_{y_5}^{\lambda_1} c_{y_5} + \varepsilon_{y_6}^{\lambda_1} c_{y_6}\right)$$

If there are Y compounds and measurements are taken at *n* wavelengths, a general expression can be written for A_{total} at the wavelength λ_n:

$$A_{total}^{\lambda_n} = \sum_{y=1}^{Y} \varepsilon_y^{\lambda_n} \times c_y \times l$$

where:

λ_n = the individual wavelengths.

Continued on next page

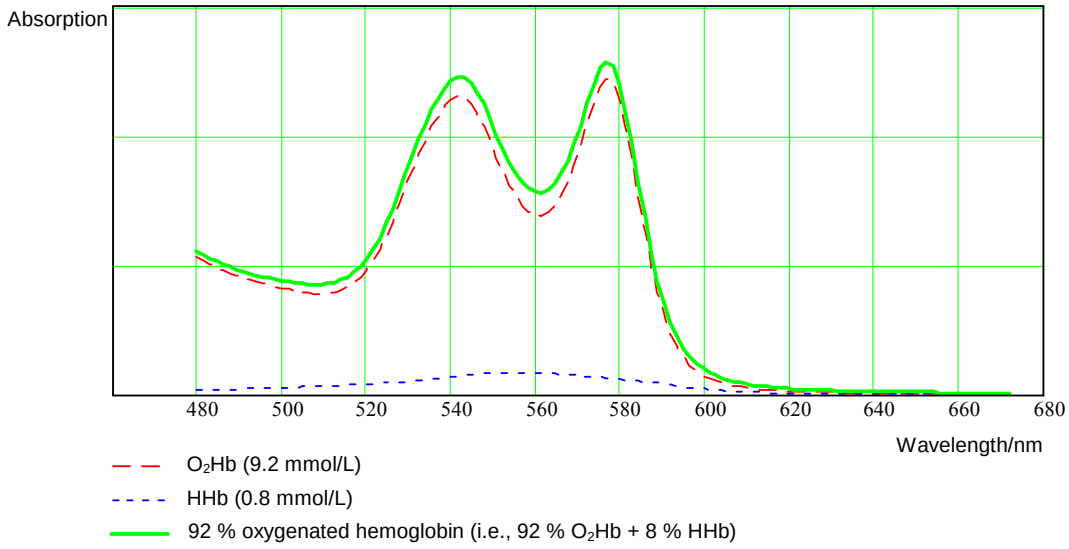
Measuring Principle, *Continued*

Continuous Spectrum

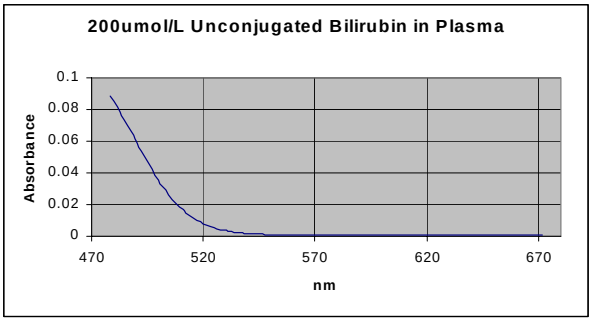
$A^{\lambda_n}_{total}$ can be depicted graphically as a function of wavelength, and if the differences between the wavelengths are small enough, a continuous spectrum is produced.

EXAMPLES:

The figure below shows three spectra; pure O_2Hb, pure HHb in a low concentration, a spectrum of 92 % oxygenated hemoglobin obtained by adding the spectra of O_2Hb and HHb. The additivity of absorption and the continuity of the spectra can clearly be seen.



Example of the spectrum obtained from unconjugated bilirubin at concentration of 200 µL.



The spectrum of conjugated bilirubin is slightly different.

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Measuring Principle, *Continued*

Determining Concentrations

In the spectrum taken of a sample, the absorption recorded at each wavelength contains contributions from each of the compounds in the sample. The task then is to determine the magnitude of that contribution and thereby the concentration of each compound in the sample.

The concentrations are determined using the following equation:

$$c_y = \sum_{n=1}^{128} K_y^{\lambda_n} \; A_{total}^{\lambda_n}$$

where:

$K_y^{\lambda_n}$ = a constant specific to compound y at wavelength λ_n.

Matrix of Constants

The constants ($K_y^{\lambda_n}$) are determined using Multivariate Data Analysis [2] where the spectra of the calibration compounds were considered together with the reference values of the calibration compounds. The essential interfering substances were also taken into account.

Correcting for Interferences

HbF vs. HbA

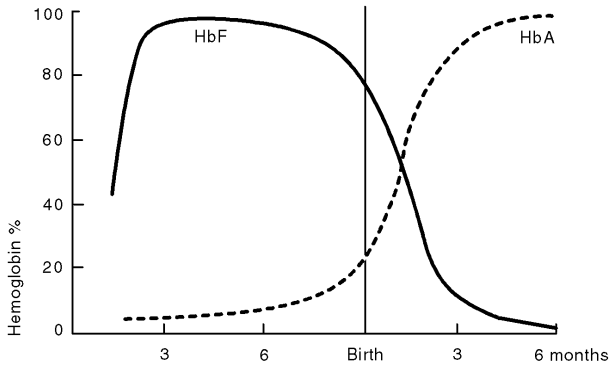
Fetal hemoglobin (HbF) does not have the same spectrum as adult hemoglobin (HbA) due to a slight variation in molecular structure. The presence of HbF in a sample will interfere with the result if it is not corrected for.

It is thus important when measuring hemoglobin levels in premature neonates and neonates aged 0 to 3 months, as well as adults suffering from thalassemia, to take into account this difference [3].

The ABL700 Series analyzer automatically corrects for HbF.

NOTE: *Hb types other than HbA and HbF interfere with hemoglobin measurements and are not compensated for in the ABL700 Series analyzers.*

The diagram below shows the transition from fetal hemoglobin to adult hemoglobin [4].



This graph is only schematic and cannot be used to determine *F*HbF.

Deviation of Results

If the difference between the two types of hemoglobin is not accounted for in measurements on samples containing HbF, e.g. from premature neonates and neonates aged 0 to 3 months, then a deviation in the measurement will arise.

The deviation is most important for measurements of oxygen saturation (sO_2) and the fraction of carboxyhemoglobin (*F*COHb), since inaccurate measurements of these parameters can lead to incorrect diagnostic interpretation of the results, and consequent risk of inappropriate treatment.

Detecting HbF

The presence of HbF in a sample is detected from the difference spectrum between fetal and adult oxyhemoglobin. From the size of the difference spectrum the concentration of fetal oxyhemoglobin, cO_2HbF, can be measured.

Correcting for HbF

The amount of cO_2HbF exceeding a certain level indicates HbF interference. The analyzer automatically corrects for this interference by subtracting the difference spectrum of fetal oxyhemoglobin from the measured spectrum. It then makes further calculations, using cO_2HbF to measure *F*HbF.

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Correcting for Interferences, *Continued*

Most Likely Interfering Substances

Fetal hemoglobin and non-hemoglobin substances present in blood that absorb light within the same wavelength range used to measure the oximetry parameters and bilirubin, will interfere with the true spectra of the blood samples.

The optical system in the ABL700 Series analyzers compensates for the most likely interfering substances by repressing their spectra.

The interference from following substances an ABL700 Series analyzer compensates for when measuring the oximetry parameters:

Intralipids (turbidity)

Sulfhemoglobin, SHb

Repressing Spectra

Repressing the spectra of the likely interfering substances is done in two ways depending on the substance:

- **Either** the substance is taken account of in the calculation of the matrix of constants, K (see the section *Measuring Principle* in this chapter). This applies to Intralipids and Sulfhemoglobin,
- **Or** the substance is detected, and the measured spectrum is corrected accordingly. This applies to HbF.

Residual Spectrum

A measured spectrum is compared to a model spectrum calculated from the determined concentrations. The difference between the two spectra is then called the residual spectrum. If the difference is too high a warning (Oxi spectrum mismatch) is issued on all the oximetry module parameters *c*tHb, sO_2, FO_2Hb, *F*COHb, *F*MetHb, *F*HHb, *F*HbF and *c*tBil.

The same action is taken if one of the following conditions exist and FHb_{deriv} is defined as one of the parameters *s*O2, FO_2Hb, *F*COHb, *F*MetHb, *F*HHb:

- *c*tHb<–0.1mmol/L or *c*tHb>25mmol/L.
- *F*Hb(deriv)<-2% or *F*Hb(deriv)>102%.
- Negative fraction of SHb<–2% is detected.
- Value of Turbidity<–0.5%.

Calibration

Calibration Materials

The optical system is calibrated in 2 points as follows:

- on the S1720 or S1730 Calibration Solution used for zero point calibration;
- on S7770 tHb Calibrating Solution with known *c*tHb and *c*tBil values

in order to determine the zero point, I_0, and the cuvette path length, *l*.

Zero Point

The zero point, I_0, is the current (or intensity) measured by the photodiode array on one of the transparent calibration solutions present in the cuvette. During a zero point calibration *c*tHb and *c*tBil are zero point calibrated.

I_0 is measured automatically during every calibration.

Cuvette Pathlength

The cuvette path length (i.e. the length of light path) is determined from Lambert-Beer's Law by measuring the absorbance of the colored dye present in the tHb Calibration Solution (S7770), which has a known equivalent hemoglobin and bilirubin concentration:

Beer's Law: $A = \varepsilon \times c\text{tHb} \times l$ or $A = \varepsilon \times c\text{tBil} \times l$

where:

A	=	absorbance
ε	=	extinction coefficient
*c*tHb	=	concentration of Hb
ctBil	=	concentration of total bilirubin
l	=	length of lightpath

tHb/tBil Calibration Frequency

It is recommended that a tHb calibration is performed every three months. Bilirubin is also calibrated during a tHb calibration.

Measurement and Corrections

Oximetry parameters

The oximetry parameters are calculated as follows:

Parameter	Equation
*c*tHb(meas)	= cO_2Hb + *c*COHb + *c*HHb + *c*MetHb
sO_2	$= \frac{cO_2Hb}{ceHb}$ *c*eHb = *c*HHb + cO_2Hb (effective hemoglobin)
FO_2Hb	$= \frac{cO_2Hb}{ctHb}$
*F*COHb	$= \frac{cCOHb}{ctHb}$
*F*HHb	$= \frac{cHHb}{ctHb}$
*F*MetHb	$= \frac{cMetHb}{ctHb}$
*F*HbF	$= \frac{cHbF}{ctHb}$

where:

cO_2Hb = concentration of oxyhemoglobin in the sample

*c*COHb = concentration of carboxyhemoglobin in the sample

*c*HHb = concentration of deoxyhemoglobin in the sample

*c*MetHb = concentration of methemoglobin in the sample

*c*HbF = concentration of fetal hemoglobin in the sample

Bilirubin

Bilirubin is calculated as follows:

$$ctBil(P) = \frac{ctBil(B)}{1 - Hct(calc)}$$

where:

*c*tBil(P) = concentration of total bilirubin in plasma

*c*tBil(B) = concentration of diluted plasma bilirubin after sample hemolyzation

Hct(calc) = calculated hematocrit (a fraction).

Continued on next page

Measurement and Corrections, *Continued*

Bilirubin *(continued)*

$$\mathrm{Hct(calc)} = \frac{0.0301}{\mathrm{g/dL}} \times c\mathrm{tHb}$$

For further details on Hct(calc) please refer to *Interference Tests* and the explanation of MCHC (Mean Corpuscular Hemoglobin Concentration) in *chapter 5* in this manual.

Restrictions

The following parameters will not be calculated:

Parameter	Is not calculated if…
$s\mathrm{O_2}$, *F*COHb, *F*MetHb, *F*HHb	*c*eHb = *c*HHb + $c\mathrm{O_2Hb}$< 0.75 mmol/L; *c*tHb< 1 mmol/L
*c*tBil	*c*tHb > 15.5 mmol/L

The following conditions are required to exclude HbF interference:

Parameter or Feature	Requirement
*c*eHb	> 3 mmol/L
*F*COHb	< 15 %
*F*MetHb	< 10 %
"HbF correction" has not been activated	If *c*tHb < 5 mmol/L, $c\mathrm{O_2HbF}$ should be more than 1 mmol/L. If *c*tHb > 5 mmol/L, $c\mathrm{O_2HbF}$/*c*tHb should be more than 0.2.
"HbF correction" has been activated	No lower limit value for $c\mathrm{O_2HbF}$ is required, i.e. even adult blood samples will be corrected for HbF. It may be of value when analyzing blood samples from newborns who received adult blood transfusion. In these cases *F*HbF can be lower than 20 % and significant deviations of oximetry parameters and bilirubin can occur.
HbF suppression has been activated	The *F*HbF value is displayed by the ABL735/730. Message "HbF detected" is displayed on the other analyzer versions with the oximetry module installed.
$s\mathrm{O_2}$<50 % or *c*tHb<5 mmol/L	Message "*F*HbF measurement is not possible" is displayed by the ABL735/730 if a HbF suppression has been activated.

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Measurement and Corrections, *Continued*

Corrections

The uncorrected measured total hemoglobin concentration, *c*tHb(sample), and total bilirubin concentration, *c*tBil(sample), are corrected for slight variations in the cuvette path length between individual analyzers, using the following equations:

$$c\text{tHb}(\text{sample},\text{corr}) = \frac{\text{ctHb}(\text{sample})}{F_{cuv\ \ dil}\ \ F} \quad \text{and} \quad c\text{tBil}(\text{sample}) = \frac{\text{ctBil}(\text{sample})}{F_{cuv\ \ dil}\ \ F}$$

where:

*c*tHb(sample) = Measured total hemoglobin concentration from a sample (uncorrected)

*c*tBil(sample) = Measured total bilirubin concentration from a sample (uncorrected)

F_{cuv} = Analyzer dependent constant determined at tHb calibrations

F_{dil} = Analyzer dependent constant determined during tests against the reference method, which corrects for Hb and bilirubin dilution in the different aspiration modes.

NOTE: *The constant F_{dil} is different for c*tHb *and c*tBil.

Corrections

Correction	ABL735/730/725/720/715/710 – Syringe modes		
	195 µL	**95 µL**	**85 µL**
F_{dil}	1.0000	0.9707	1.0050

Correction	ABL735/730/725/720/715/710 – Capillary modes				
	195 µL	**95 µL**	**85 µL**	**55 µL**	**35 µL**
F_{dil}	1.0057	0.9707	1.0050	0.9460	0.9650

See *Chapter 5, Performance Characteristics* for more information on specification tests.

References

List of References

The list of the references for *Chapter 3, The Optical System:*

1. Ewing GW. Instrumental methods of chemical analysis. 5th ed. McGraw-Hill, 1985.
2. Martens H. Multivariate calibration: quantitative interpretation of non-selective chemical data. Dr. Techn. Thesis, NTH Univ. of Trondheim, 1986.
3. Krzeminski A. Why correct for fetal hemoglobin in blood oximetry measurements? Radiometer Publication Info. No. 1992-3. Copenhagen: Radiometer Medical A/S, 1992.
4. Huehns ER, Beaven GH. Developmental changes in human hemoglobins. Clin Dev Med 1971; 37: 175-203.

4. User-Defined Corrections

Introduction This chapter describes the basis of the user-defined corrections available for all the parameters that are measured in the ABL700 Series analyzers.

Contents This chapter contains the following topics.

General Information

Purpose of Use User-defined corrections are most commonly implemented in situations where the values measured for a particular parameter by two or more analyzers, deviate consistently from each other.

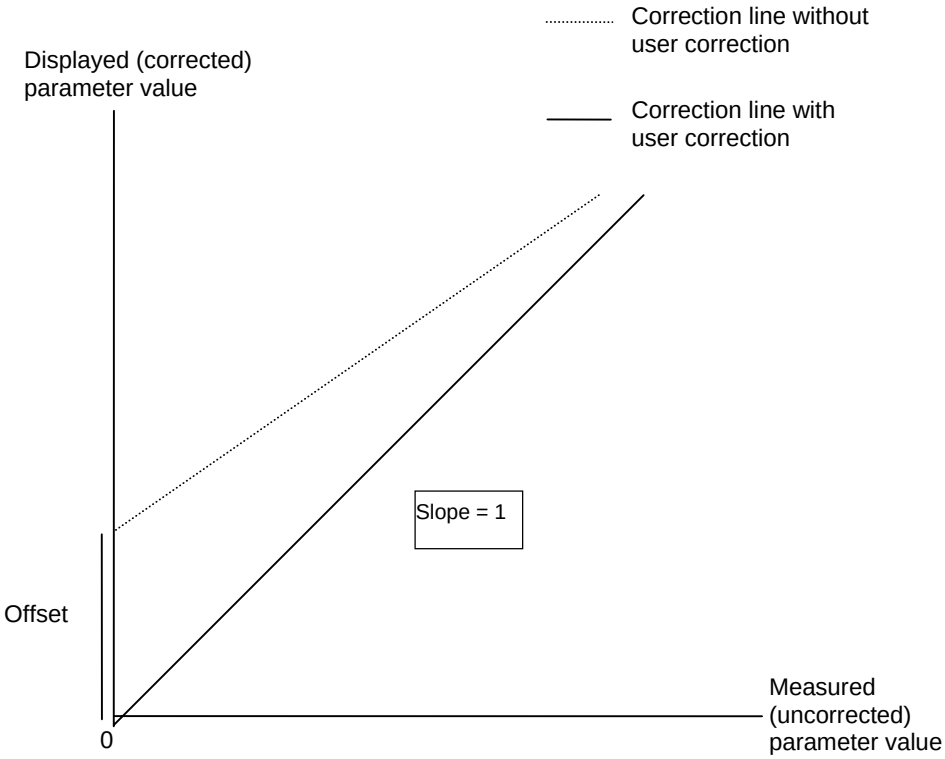
NOTE: *Since the performance of all ABL700 analyzers is tested as described in Chapter 5, Performance Characteristics, and each instrument is assumed to operate accurately and optimally, the unnecessary correction of parameter values by the user can lead to inaccurate measurements being reported.*

User-Defined Corrections User-defined corrections are based on a linear correlation between the measured values (without user-defined corrections) and the displayed values (with user-defined corrections).

The correction factors for each measured parameter are the slope and the offset of the correction line. With user-defined corrections it is possible to change the values of either one or both of these correction factors, depending on the parameter type.

$$\text{Corrected value} = \text{Slope} \times \text{Uncorrected value} + \text{Offset}$$

The diagram below is a schematic representation of the relationship between correction lines without and with user-defined correction.



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General Information, *Continued*

Entering User-Defined Corrections

In the ABL700 Series analyzers the slope and the offset for each parameter are configured via the **Parameters Setup** screen under General Setup. User corrected values are marked with a "*" after the result.

NOTE: *The user-defined corrections will also be applied to measurements on QC solution.*

For detailed instructions on how to enter user-defined corrections, refer to the section *Parameter Setup* in *Chapter 5* of the *Operator's Manual*.

Correction Factors for Oximetry Parameters and Bilirubin

Introduction The following corrections can be user-defined for the oximetry parameters and bilirubin:

Parameter	Allowed User-defined Corrections	
	Slope	**Offset**
***c*tHb**	Yes	No
***s*O$_2$**	Yes	Yes
***F*COHb**	No	Yes
***F*MetHb**	No	Yes
***F*O$_2$Hb**	No	No
***F*HHb**	No	No
***F*HbF**	Yes	Yes
***c*tBil**	Yes	Yes

NOTE: *In order to define the corrections accurately, the measurements of the oximetry parameters and bilirubin on the ABL700 Series analyzers should be made without any entered corrections. To avoid truncation errors from an enabled "Out of range suppression" function it is important to disable the function.*

***c*tHb** The following recommendations apply to *c*tHb:

Item	Description
Units	g/dL; g/L; mmol/L
Sample	Set *c*tHb of a SAT100 sample to ≈15 g/dL (9.3 mmol/L) and pH ≈ 7.4
*c*tHb, maximum point	Uncorrected or corrected: ≈ 15 g/dL or 9.3 mmol/L
Slope	0.950 - 1.050

Continued on next page

Correction Factors for Oximetry Parameters and Bilirubin, *Continued*

sO_2

The following recommendations apply to sO_2 :

Item	Description
Units	Fraction
Sample	Set *c*tHb of gas equilibrated SAT0 and SAT100 samples to ≈ 15 g/dL (9.3 mmol/L) and pH ≈ 7.4
Slope	0.900 - 1.100
Offset	± 0.050

***F*COHb**

The following recommendations apply to *F*COHb:

Item	Description
Units	Fraction
Sample	The zero point (*F*COHb ≈ 0) is saturated to approximately SAT100, and *c*tHb is set to ≈ 15 g/dL (9.3 mmol/L) and pH ≈ 7.4.
Offset	± 0.050

***F*MetHb**

The following recommendations apply to *F*MetHb:

Item	Description
Units	Fraction
Sample	The zero point (*F*MetHb ≈ 0) is saturated to approximately SAT100, and *c*tHb is set to ≈ 15 g/dL (9.3 mmol/L) and pH ≈ 7.4.
Offset	± 0.050

Continued on next page

Correction Factors for Oximetry Parameters and Bilirubin, *Continued*

***F*HbF**

The following recommendations apply to *F*HbF:

Item	Description
Units	Fraction
Sample	Radiometer recommends that *c*tHb in the adult samples (with *F*HbF = 0) and fetal samples (with high *F*HbF) is set to ≈ 15 g/dL (9.3 mmol/L), sO_2 ≈ 100 %, and pH ≈ 7.4. The "Correction for HbF levels less than 20 %" function should be enabled in order to have the *F*HbF value displayed for the adult sample. Averaging repeated measurements on blood from different donors gives an optimized accuracy of the correction. Averaging repeated measurements on blood from the same donor also improves the accuracy.
Slope	0.800 - 1.200
Offset	± 0.20

***c*tBil**

The following recommendations apply to *c*tBil:

Item	Description
Units	µmol/L
Sample	Radiometer recommends that human plasma or serum is used with pH ≈ 7.4 (the analyzer reading). Zero point sample could be adult sample (ctBil ≈ 0 µmol/L) and maximum point could be an unconjugated bilirubin sample with *c*tBil ≈ 300 - 400 µmol/L. Averaging repeated measurements on samples from different donors gives an optimized accuracy of the correction. Averaging repeated measurements on samples from the same donor also improves the accuracy. Commercial bilirubin standards can interfere with bilirubin measurement because they may have an absorbance spectrum different from that of human plasma.
Slope	0.5 - 1.5
Offset	± 100

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Correction Factors for Oximetry Parameters and Bilirubin, *Continued*

FO_2Hb and $FHHb$

The units for FO_2Hb and $FHHb$ are [Fraction].

After the user-defined corrections of the parameters sO_2, $FCOHb$ and $FMetHb$ have been carried out, FO_2Hb and $FHHb$ are automatically calculated using the formulae stated below, since the sum of the fractions $FCOHb$, $FMetHb$, FO_2Hb and $FHHb$ as defined must be equal to 1.0:

FO_2Hb:

$$FO_2Hb = (1 - FCOHb - FMetHb) \times sO_2$$

$FHHb$:

$$FHHb = (1 - FCOHb - FMetHb) \times (1 - sO_2)$$

Electrolyte and Metabolite Parameters

Introduction

This topic describes user-defined corrections for the electrolyte and metabolite parameters.

Preparatory Action

Prior to entering corrections for the electrolyte and metabolite parameters, the user must obtain the reference values for the chosen parameters using the method accepted in his/her laboratory.

It should be noted that in order to define corrections:

- Measurements should be taken on the ABL700 analyzer without user-defined corrections, and on the reference analyzer.
- A series of measurements that cover the entire measuring range should be performed.
- The measurements should be made simultaneously on the ABL700 and reference analyzers, and samples must be handled correctly.
- The slope and the offset must be calculated. The user may, for example, make a linear correlation between the values measured on the ABL700 and the reference analyzers, using the ABL700 as an independent variable.
- If the measurements are carried out on samples with values within the normal reference range, then the user may change the offset and leave the slope unchanged.
- The user must verify the corrections that are entered.

Details of these procedures may be found in the section *Testing Against a Reference Method* in *Chapter 5*.

Correcting the Slope

The following corrections to the slope are possible within the stated limits:

Parameter	Slope (mmol/L)
$c\mathrm{K}^{+}$	0.750 - 1.250
$c\mathrm{Na}^{+}$	0.850 - 1.150
$c\mathrm{Ca}^{2+}$	0.800 - 1.200
$c\mathrm{Cl}^{-}$	0.850 - 1.150
*c*Glu	0.750 - 1.250
*c*Lac	0.750 - 1.250

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Electrolyte and Metabolite Parameters, *Continued*

Correcting the Offset

The following corrections to the offset are possible within the stated limits:

Parameter	Offset (mmol/L)
$c\mathrm{K}^+$	± 0.3
$c\mathrm{Na}^+$	± 5
$c\mathrm{Ca}^{2+}$	± 0.05
$c\mathrm{Cl}^-$	± 5
*c*Glu	± 0.5
*c*Lac	± 0.5

Calculating Correction Constants

The correction constants are determined in mmol/L according to:

$$Y = A\,X + B$$

where:

X = Measured (uncorrected) parameter value

Y = Displayed (corrected) parameter value

A = Slope

B = Offset

Resetting Corrections to Default Values

The Radiometer default values for the electrolyte and metabolite parameters must be reset manually by the user to 1.000 for each parameter via the **Parameters Setup** screen.

5. Performance Characteristics

Introduction

This chapter describes the reference methods used to verify the performance of the ABL700 Series analyzer and how the correction constants for each parameter are determined.

It describes the performance tests carried out to determine the accuracy and precision of the analyzers under normal use.

Contents

This chapter contains the following topics.

General Information

Reference Methods

A reference method is an established procedure for measuring a particular parameter, to which the ABL700 Series analyzers can be compared.

The reference method comparisons lead to the determination of correction constants for each parameter in the ABL700 Series.

A description of the reference method used for each parameter is given in the section *Reference Methods.*

Radiometer Reference Methods

The reference methods Radiometer uses for each of the measured parameters in the analyzer are outlined on the following pages.

In cases where no recommended reference method exists, Radiometer has devised its own, the details of which are also found on the following pages.

Correcting for Systematic Deviations

The ABL700 Series measurements are corrected for systematic deviations as explained in the section *Testing Against a Reference Method*, bringing them in line with the reference method measurements.

Uncorrected measurements on the ABL700 Series analyzer may differ systematically from measurements by the reference method. This difference or deviation is mainly due to the fact that the analyzer is calibrated using aqueous solutions (with exception to oximetry parameters which are measured on blood), but measurements are taken on blood, a medium with different characteristics from aqueous solutions.

Performance Tests

Performance tests are performed to determine the precision of the ABL700 Series analyzers under normal use.

The test conditions and definitions of the criteria used for the performance tests are given in the section *Performance Tests*.

Definition of Terms and Test Conditions

Imprecision Parameters

Repeated measurements using one analyzer on samples assumed to be identical will not necessarily yield identical results. The degree of variation in the results is a measure of the precision of the analyzer.

The following table describes the parameters used to characterize precision during the performance tests on the ABL700 Series of analyzers.

Parameter	Description
S_0	**Repeatability** This is a standard deviation obtained from repeated measurements within a short interval of time using: • The same instrument and location • The same measurement procedure • Identical portions of the same sample • One operator per instrument S_0 for each level is pooled for all test instruments and test days.
S_D	**Day-to-day variation** This is a standard deviation obtained from repeated measurements over all test days. Includes contributions from differences in calibration states of the analyzers throughout the test days.
S_{ABL}	**Uncertainty of bias on a random instrument** S_{ABL} is used for repeated determinations on one sample. This standard deviation include the inter-instrument variations, sample variations, and uncertainties from standard solutions and reference methods.
S_X	**Uncertainty of bias on a random instrument for a single measurement** Sx is a standard deviation which includes S_{ABL}, S_D and S_0 .

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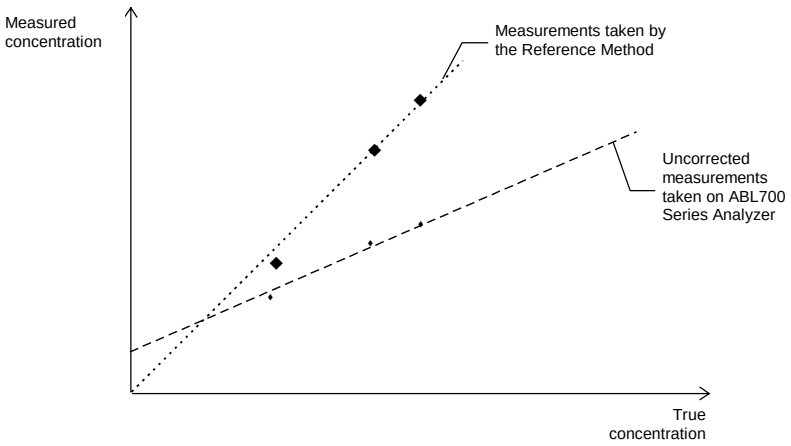
Definition of Terms and Test Conditions, *Continued*

Bias

The bias of a quantity is defined as the mean difference between the measured value on a group of test instruments and the estimated true value (as assayed by the reference method):

$$\text{Bias} = X_{\text{analyzer}} - X_{\text{REF.}}$$

The method of testing the analyzers against a reference method is described below.

Stage	Description
1.	A blood sample from a normal healthy adult is taken.
2.	The blood sample is treated to give high and low level concentrations of the parameter under study.
3.	Simultaneous measurements of the specific parameter are taken on the blood sample, using the reference method and the uncorrected analyzer. The two sets of measurements are plotted on the same axis, as shown in the following example:  *This example shows how measurements at 3 different levels of a parameter may systematically differ using the uncorrected ABL700 analyzer and the reference method.*
4.	A comparison of the plots from the two sets of measurements is made. The systematic deviations of the ABL700 Series measurements from the reference method are corrected by the following equation: $$c\text{X(Sample,corr)} = k_n \, c\text{X(Sample)} + k_m$$

Continued on next page

Definition of Terms and Test Conditions, *Continued*

Bias *(continued)*

Stage	Description

where:

*c*X(Sample,corr)	=	Parameter value measured on analyzer corrected for systematic deviations from the reference method
k_n and k_m	=	Correction constants determined by comparison with the parameter value measured using the reference method
cX(Sample)	=	Parameter value measured on the analyzer (uncorrected)

5. The correction constants in the above equation are determined, bringing the results from the ABL700 Series measurements in line with the reference method results.

The measured value of the sample will deviate from the true value by a maximum of: Bias $\pm 2 \times S_X$

Test Measurements

For the test measurements against the reference method the 195 µL capillary measuring mode (C195) on the analyzer is used, with all the parameters enabled.

The other measuring modes are tested on the ABL725 against the C195, after the correction constants have been determined.

Test	Description
Reference	To verify that the correction constants have been accurately determined, 10 new analyzers with all parameters available are tested in C195 mode against the reference methods. Each parameter is tested on 3 - 6 levels over at least 3 days, with 5 repetitions on each day. (5 new analyzers with all parameters available were tested against the reference methods for *c*tBil and *F*HbF.) Bias for each parameter in the C195 measuring mode against the reference methods is determined.
Verification	6 - 10 new analyzers are tested over at least 2 days for all levels. Bias for the given mode is calculated as difference compared with the C195 µL mode. Bias against the reference method is determined as follows: Bias = bias against C195 + C195 bias against reference method.

Continued on next page

Definition of Terms and Test Conditions, *Continued*

Test Measurements *(continued)*

Test	Description
Verification (cont.)	The following parameters: sO_2, *F*COHb, *F*MetHb and FO_2Hb, are measured directly against the reference built in the analyzer, and these parameters are independent of the reference method.
Reduced verification	6 - 10 new analyzers are used over at least 1 day for selected levels. Bias for the tested mode is calculated as follows: Bias = bias against C195 + C195 bias against reference method. Modes which are not tested are described as "N/A".
Simple verification	6-10 analyzers are tested at one extreme level over 1 day. Bias is not determined; bias values for the modes with similar wet section programs are used.

The measuring modes were tested as follows:

Test	Analyzer/mode	
Reference	ABL735/25/15	C195
Verification	ABL735/25/15	S195, S95, S85, C95, C55, C35 MET, C35 OXI, Expired air
	ABL730/20/10	C85, Expired air
	ABL705	S85, Expired air
	ABL700	S85, C55, Expired air
Reduced verification	ABL730/20/10	S85
Simple verification	ABL730/20/10	C55, C35 OXI
	ABL705	S165, S95, C165, C95, C55, C35 MET

Test Conditions The following test conditions are maintained:

Item	Description
Blood samples	The blood samples are heparinized blood samples from healthy, voluntary donors. The blood is prepared to obtain the different concentration levels of each measured parameter.

Continued on next page

Definition of Terms and Test Conditions, *Continued*

Test Conditions *(continued)*

Item	Description
Blood measurements	The measurements are performed by different operators. QUALICHECK™ 5+ is measured daily during test period.
Calibration solutions and gases	The true compositions of the calibration solutions and gases used for the ABL700 Series analyzers and those used for the reference methods are determined, by measuring them against solutions and gases traceable to Primary Reference Standards. Traceability certificates for the calibration solutions are found at the end of *Chapter 7, Solutions*.
Experimental conditions	• Ambient temperature 22 - 25 °C • Relative humidity 30 - 50 % • Average CO_2 content in atmospheric air.

Test Measurements for Capillary – pH only Mode

Test measurements for Capillary – pH only mode are as follows:

Test	Description		
Reference	To verify that the correction constants have been accurately determined, 5 analyzers with the Capillary – pH only mode enabled are tested. The largest capillary mode of each analyzer has been used as a reference:		
	Analyzer	**Reference mode**	**Number of analyzers**
	ABL700	C55	1
	ABL705	C165	1
	ABL730	C85	1
	ABL735	C195	2
	Total:		**5**
	The bias for Capillary – pH only mode has indirectly been tested against the reference methods.		
Verification	5 analyzers with Capillary – pH only mode enabled are tested on three pH levels, using four capillary tube types with volumes between 34 µL – 85 µL, with two repetitions for each combination. Bias for each combination is established by computing the difference to the reference mode and adding its own bias.		

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Definition of Terms and Test Conditions, *Continued*

Test Conditions for Capillary – pH only Mode

Test conditions for Capillary – pH only mode are as follows:

Item	Description
Blood samples	The blood samples are heparinized blood samples from healthy, voluntary donors. The blood is prepared to obtain the following pH levels: • 7.0 • 7.4 • 7.7
Blood measurements	The measurements are performed by different operators. QUALICHECK™ 5+ is measured daily during test period.
Calibration solutions and gases	The true compositions of the calibration solutions and gases used for the ABL700 Series analyzers and those used for the reference methods are determined, by measuring them against solutions and gases traceable to Primary Reference Standards. Traceability certificates for the calibration solutions are found at the end of *Chapter 7, Solutions*.
Experimental conditions	• Ambient temperature 22 - 25 °C • Relative humidity 30 - 50 % • Cleaning Solution for all analyzers is prepared with Cleaning Additive (streptokinase) • The cleaning interval is set to 8 hours.

NOTEs:

- *The solutions used in the performance tests are those recommended by Radiometer. Performances using other solutions cannot be verified.*
- *The tests were performed using the CLINITUBES from Radiometer with mixing wires and clot catches.*
- *The performance tests are performed under conditions where the analyzers are not influenced by electromagnetic fields.*
- *Bias values are the values obtained during performance tests; the imprecision values show the range within which the imprecision values should be kept.*

Reference Methods for the ABL700 Series

Overview of Reference Methods

The reference methods used for each of the parameters measured by the analyzer are as follows:

Parameter	Reference Method
pH, cK$^+$, cNa$^+$	These parameters are tested against the ABL SYSTEM 625 analyzers whose performance specifications (including the corrections) have been determined and validated according to the reference methods outlined below.
pH	Capillary-type glass pH electrode with a saturated calomel reference electrode and a liquid junction saturated with KCl (BMS™ Mk2) [1,2]. The calibration standards are traceable to the Primary Reference Standards for pH.
cK$^+$ and cNa$^+$	Flame photometry (FLM™3), as recommended by NCCLS [4]. The standard sodium and potassium solutions are traceable to NIST certified Standard Reference Material SRM 919a (NaCl) and 999 (KCl).
cCa^{2+}	RADIOMETER method used. The standard calcium solutions used are validated against corresponding NIST standard SRM 915 [5].
cCl$^-$	Coulometric titration (CMT™10). The standard chloride solutions are traceable to NIST Standard Reference Material SRM 999.
pCO$_2$ and pO$_2$	Tonometry [3]. The gases used for tonometry are traceable to NIST certified Standard Reference Material SRM 1701a, 1702a, 1703a.
cGlu	Spectrophotometry, using the hexokinase (HK) method recommended by NCCLS [6]. The standard glucose solutions are traceable according to NIST SRM 917a.
cLac	Spectrophotometry using a lactate dehydrogenase (LDH) method, measured on serum.

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Reference Methods for the ABL700 Series, *Continued*

Overview of Reference Methods *(continued)*

Parameter	Reference Method
Oximetry	The reference method established for the oximetry parameters uses modified ABL520 analyzers as the field reference instruments. The ABL520 analyzers have been validated and their performance specifications determined according to primary reference methods. The modified ABL520 analyzers are used in accordance with IFCC's recommendations for traceability of reference methods. The reference methods used for the oximetry parameters on the ABL520 analyzers are those presented below.
*c*tHb	HiCN method recommended by NCCLS [7].
sO_2	Tonometry: whole blood is tonometered with a gas mixture containing 94.4 % O_2 and 5.6 % CO_2.
*F*HHb	The standard is blood (*c*tHb = 13 - 15 g/dL) treated with dithionite.
*F*COHb	Gas chromatography. The standards are carbon monoxide mixtures with atmospheric air, whose purity is validated in accordance with NIST SRM 1678 (50 ppm CO in N_2).
*F*MetHb	Spectrometry, modified Evelyn-Malloy method [8].
*F*HbF	Alkali denaturation method [10]. Corresponds to NCCLS guideline [11].
*c*tBil	Hitachi 717 wet chemistry analyzer. Uses Boeringer-Mannheim reagency kit, DPD method [12]. The Hitachi is used as a linear sensor and is periodically calibrated on 4 levels of NIST SRM916a unconjugated bilirubin standard material.

ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes

Tested Modes The following macromodes have been tested for pH/blood gases:

Sample from…	ABL735/725/715	ABL730/720/710	ABL705
Syringe	195 µL	85 µL	165 µL
Capillary	195 µL		165 µL

The following macromodes have been tested for electrolytes and metabolites:

Sample from…	ABL735/725/715	ABL705
Syringe	195 µL	165 µL
Capillary	195 µL	165 µL

The following macromodes have been tested for oximetry parameters:

Sample from…	ABL735/725/715	ABL730/20/10
Syringe	195 µL	85 µL
Capillary	195 µL	

pH

	Bias				
	ABL735/25/15		ABL730/20/10	ABL705	
pH	S195	C195	S85	S165	C165
7.0	0.003	0.0041	0.003	0.003	0.003
7.4	–0.002	–0.0011	N/A	–0.002	–0.002
7.7	0.003	0.0033	0.003	0.003	0.003

pH	S_0	S_D	S_{ABL}	S_X
7.0	0.0035	0.0025	0.0063	0.0077
7.4	0.0020	0.0015	0.0080	0.0084
7.7	0.0030	0.0015	0.0104	0.0110

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

pCO_2 (mmHg)

pCO_2	Bias				
	ABL735/25/15		ABL730/20/10	ABL705	
	S195	C195	S85	S165	C165
15	–0.18	–0.08	–0.39	–0.18	–0.18
40	0.15	0.05	N/A	0.15	0.15
60	0.75	0.46	N/A	0.75	0.75
80	0.21	–0.07	0.22	0.21	0.21
150	N/A	1.51	3.00	N/A	N/A

pCO_2	S_0	S_D	S_{ABL}	S_X
15	0.25	0.35	0.8	0.9
40	0.40	0.30	0.5	0.7
60	0.50	0.35	1.7	1.8
80	0.70	1.15	2.0	2.4
150	1.80	2.20	3.1	4.2

pO_2 (mmHg)

pO_2	Bias				
	ABL735/25/15		ABL730/20/10	ABL705	
	S195	C195	S85	S165	C165
15	N/A	0.57	1.02	N/A	N/A
50	0.37	0.33	N/A	0.37	0.37
150	–1.14	–1.39	–0.77	–1.14	–1.14
250	0.65	–0.52	N/A	0.65	0.65
530	1.75	2.91	–7.37	1.75	1.75

pO_2	S_0	S_D	S_{ABL}	S_X
15	0.40	0.25	0.58	0.75
50	0.45	0.40	0.60	0.85
150	0.90	0.75	0.94	1.50
250	3	2	3.03	4.71
530	7	7	15.03	18.0

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

cCl^- (mmol/L)

cCl^-	Bias			
	ABL735/25/15		ABL705	
	S195	C195	S165	C165
85	1.2	1.4	1.2	1.2
105	–0.9	–0.5	–0.9	–0.9
140	0.9	1.0	0.9	0.9

cCl^-	S_0	S_D	S_{ABL}	S_X
85	0.5	0.7	1.15	1.5
105	0.5	0.7	1.10	1.4
140	0.5	1.0	1.59	2.0

cCa^{2+} (mmol/L)

cCa^{2+}	Bias			
	ABL735/25/15		ABL705	
	S195	C195	S165	C165
0.5	0.002	0.005	0.002	0.002
1.25	–0.005	–0.008	–0.005	–0.005
2.5	0.007	0.003	0.007	0.007

cCa^{2+}	S_0	S_D	S_{ABL}	S_X
0.5	0.008	0.007	0.010	0.015
1.25	0.008	0.006	0.011	0.015
2.5	0.010	0.010	0.034	0.037

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

cK^+ (mmol/L)

cK^+	Bias			
	ABL735/25/15		ABL705	
	S195	C195	S165	C165
2	–0.024	0.010	–0.024	–0.024
4	0.008	0.020	0.008	0.008
8	–0.004	0.010	–0.004	–0.004

cK^+	S_0	S_D	S_{ABL}	S_X
2	0.04	0.020	0.09	0.10
4	0.04	0.025	0.10	0.12
8	0.05	0.025	0.11	0.13

cNa^+ (mmol/L)

cNa^+	Bias			
	ABL735/25/15		ABL705	
	S195	C195	S165	C165
120	–0.07	0.13	–0.07	–0.07
140	–0.27	–0.22	–0.27	–0.27
180	0.17	0.07	0.17	0.17

cNa^+	S_0	S_D	S_{ABL}	S_X
120	0.4	0.50	0.99	1.2
140	0.4	0.50	0.97	1.2
180	0.5	0.40	1.25	1.4

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

***c*Glu (mmol/L)**

	Bias			
	ABL735/25/15		ABL705	
***c*Glu**	**S195**	**C195**	**S165**	**C165**
2	0.02*	0.01	0.02	0.02
5	0.02*	0.00	0.02	0.02
15	–0.6*	–0.7	–0.6	–0.6

***c*Glu**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
2	0.10	0.07	0.13	0.18
5	0.10	0.08	0.20	0.24
15	0.40	0.25	0.44	0.65

***c*Lac (mmol/L)**

	Bias			
	ABL735/25/15		ABL705	
***c*Lac**	**S195**	**C195**	**S165**	**C165**
0.3	–0.03*	–0.03	–0.03	–0.03
2	–0.12*	–0.12	–0.12	–0.12
10	–1.0*	–1.1	–1.0	–1.0

***c*Lac**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
0.3	0.10	0.08	0.12	0.18
2	0.10	0.08	0.13	0.19
10	0.20	0.15	0.37	0.45

* Bias has been measured on the serum pool.

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

***c*tHb (g/dL)**

***c*tHb (g/dL)**	***s*O$_2$ (%)**	**Bias**		
		ABL735/25/15		**ABL730/20/10**
		S195	**C195**	**S85**
15	0	0.12	0.18	0.08
7	100	–0.08	0.03	N/A
15	100	0.22	0.26	0.09
25	100	0.90	0.82	N/A

***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	0	0.15	0.10	0.35	0.40
7	100	0.10	0.10	0.30	0.35
15	100	0.15	0.10	0.35	0.40
25	100	0.15	0.10	0.50	0.55

***s*O$_2$ (%)**

***s*O$_2$ (%)**		**Bias**		
		ABL735/25/15		**ABL730/20/10**
***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S195**	**C195**	**S85**
15	0	0.00	0.05	–0.02
7	100	0.01	0.22	N/A
15	100	0.01	–0.08	0.00
25	100	0.00	–0.29	N/A

***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	0	0.05	0.05	0.25	0.30
7	100	0.10	0.10	0.25	0.30
15	100	0.05	0.10	0.25	0.30
25	100	0.05	0.10	0.30	0.35

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

FO_2Hb (%)

FO_2Hb		Bias		
		ABL735/25		ABL730/20
*c*tHb (g/dL)	FO_2Hb (%)	S195	C195	S85
15	0	0.00	–0.04	–0.02
7	100	–0.07	N/A	N/A
15	100	–0.03	N/A	–0.15
25	100	–0.05	N/A	N/A

*c*tHb (g/dL)	FO_2Hb (%)	S_0	S_D	S_{ABL}	S_X
15	0	0.05	0.05	0.25	0.30
7	100	0.25	0.20	0.50	0.60
15	100	0.15	0.15	0.45	0.50
25	100	0.10	0.10	0.40	0.45

***F*COHb (%)**

*F*COHb			Bias		
			ABL735/25		ABL730/20
*c*tHb (g/dL)	sO_2 (%)	*F*COHb (%)	S195	C195	S85
15	100	0	0.03	0.08	0.12
7	100	20	N/A	0.47	N/A
15	100	20	N/A	0.10	N/A
25	100	20	N/A	–0.47	N/A

*c*tHb (g/dL)	sO_2 (%)	*F*COHb (%)	S_0	S_D	S_{ABL}	S_X
15	100	0	0.05	0.10	0.35	0.40
7	100	20	0.10	0.10	0.75	0.80
15	100	20	0.05	0.10	0.70	0.75
25	100	20	0.05	0.10	0.70	0.75

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

***F*MetHb (%)**

*F*MetHb			Bias		
			ABL735/25		ABL730/20
***c*tHb (g/dL)**	***s*O$_2$ (%)**	***F*MetHb (%)**	**S195**	**C195**	**S85**
15	100	0	0.01	–0.03	0.06
15	100	20	N/A	0.10	N/A

***c*tHb (g/dL)**	***s*O$_2$ (%)**	***F*MetHb (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	100	0	0.10	0.10	0.25	0.30
15	100	20	0.05	0.10	0.35	0.40

***F*HHb (%)**

*F*HHb		Bias		
		ABL735/25		ABL730/20
***F*HHb (%)**	***c*tHb (g/dL)**	**S195**	**C195**	**S85**
0	15	-0.01	0.08	–0.05

***F*HHb (%)**	***c*tHb (g/dL)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
0	15	0.05	0.10	0.30	0.35

***F*HbF (%)**

Adult blood:

*F*HbF		Bias		
		ABL735		ABL730
***F*HbF (%)**	***c*tHb (g/dL)**	**S195**	**C195**	**S85**
0	10	3.3	3.3	3.3
0	15	5.5	5.5	5.5
0	20	5.6	5.6	5.6

***F*HbF (%)**	***c*tHb (g/dL)**	**sO$_2$ (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
0	10	100	4	4	5	8
0	15	100	2	3	7	8
0	20	100	2	2	10	11

NOTES: a, b.

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ABL735/30/25/20/15/10/05 Performance Test Results - Macromodes, *Continued*

F*HbF (%) *(continued)

Fetal blood:

***F*HbF**		**Bias**		
		ABL735		**ABL730**
***F*HbF (%)**	***c*tHb (g/dL)**	**S195**	**C195**	**S85**
80	10	5.9	5.9	5.9
80	15	3.3	3.3	3.3
80	20	2.6	2.6	2.6

***F*HbF (%)**	***c*tHb (g/dL)**	**sO_2 (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
80	10	100	4	5	5	9
80	15	100	3	3	6	8
80	20	100	2	3	6	7

NOTES: a, b.

Contribution to Imprecision Specifications from S7770

The following corrections should be geometrically added to S_{ABL} and S_X for the analyzer's wavelength calibrated with the S7770:

Parameter	**Mode**	**Level**	**Correction (percentage point)**
*c*tHb	Macromode	All	0
	Micromode	All	0
sO_2	All	sO_2 (100 %)	0.23
FO_2Hb	All	FO_2Hb (100 %)	0.15
*F*COHb	All	*F*COHb (20 % and 0 %)	0.40
*F*HHb	All	*F*HHb (0 %)	0.23

ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes

Tested Modes The following micromodes have been tested for the pH/blood gas:

Sample from…	ABL735/25/15	ABL730/20/10	ABL705
Syringe	95 µL; 85 µL		95 µL, 85 µL
Capillary	95 µL; 55 µL	85 µL; 55 µL	95 µL; 55 µL

The following micromodes have been tested for the electrolytes and metabolites:

Sample from…	ABL735/25/15	ABL705
Syringe	95 µL	95 µL
Capillary	95 µL; 35 µL MET	95 µL; 35 µL MET

The following micromodes have been tested for the oximetry parameters:

Sample from…	ABL735/25/15	ABL730/20/10
Syringe	95 µL; 85 µL	
Capillary	95 µL; 55 µL; 35 µL OXI	85 µL; 55 µL; 35 µL OXI

pH

pH	Bias			
	ABL735/25/15			
	S95	C95	S85	C55
7.0	0.002	0.004	0.004	0.005
7.4	–0.002	–0.002	–0.002	–0.003
7.7	0.003	0.003	0.003	0.001

pH	Bias					
	ABL730/20/10		ABL705			
	C85	C55	S95	C95	S85	C55
7.0	0.003	0.005	0.002	0.004	0.005	0.003
7.4	0.000	–0.003	–0.002	–0.002	0.000	–0.001
7.7	0.005	0.001	0.003	0.003	0.005	0.004

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

pH *(continued)*

pH	S_0	S_D	S_{ABL}	S_X
7.0	0.0050	0.0040	0.0077	0.0100
7.4	0.0030	0.0023	0.0082	0.0090
7.7	0.0050	0.0023	0.0118	0.0130

***p*CO$_2$ (mmHg)**

*p*CO$_2$	Bias			
	ABL735/25/15			
	S95	C95	S85	C55
15	–0.01	–0.56	–0.08	–1.05
40	0.33	0.04	0.04	–0.04
60	1.09	0.41	0.38	0.71
80	0.69	–0.38	–0.23	–0.31
150	3.34	1.28	1.28	0.21

*p*CO$_2$	Bias					
	ABL730/20/10		ABL705			
	C85	C55	S95	C95	S85	C55
15	–0.27	–1.05	–0.20	–0.56	0.04	–0.79
40	–0.18	–0.04	–0.08	0.04	0.02	–0.06
60	N/A	0.71	0.51	0.41	0.47	0.33
80	–0.48	–0.31	–0.05	–0.38	–0.26	–0.48
150	0.66	0.21	2.04	1.28	0.24	0.44

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

pCO_2 (mmHg) *(continued)*

pCO_2	S_0	S_D	S_{ABL}	S_X
15	0.4	0.6	1.1	1.4
40	0.6	0.45	0.7	1.1
60	0.75	0.75	2.5	2.7
80	1.05	1.3	3.3	3.6
150	2.7	3.0	5.1	6.3

pO_2 (mmHg)

pO_2	Bias			
	ABL735/25/15			
	S95	C95	S85	C55
15	0.35	0.65	0.55	1.16
50	0.16	0.86	0.36	–1.39
150	–1.14	–0.67	–0.58	–1.45
250	0.63	–0.92	–0.30	–0.32
530	13.25	–5.51	4.38	2.94

pO_2	Bias					
	ABL730/20/10		ABL705			
	C85	C55	S95	C95	S85	C55
15	0.85	1.16	0.35	0.65	0.25	1.26
50	N/A	–1.39	0.16	0.86	–0.14	–1.10
150	–0.67	–1.45	–1.14	–0.67	–1.79	0.06
250	–2.25	–0.32	0.63	–0.92	–0.81	–1.18
530	–10.66	2.94	13.25	–5.51	9.43	–4.42

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

pO_2 (mmHg) *(continued)*

pO_2	S_0	S_D	S_{ABL}	S_X
15	0.7	0.4	1.50	1.71
50	0.7	0.6	1.05	1.40
150	1.4	1.1	1.60	2.40
250	4.5	3.0	4.44	7.00
530	10.5	10.5	14.03	20.5

cCl^- (mmol/L)

cCl^-	Bias			
	ABL735/25/15		ABL705	
	S95	C95	S95	C95
85	1.1	1.5	1.1	1.5
105	–1.0	–0.5	–1.0	–0.5
140	0.7	1.0	0.7	1.0

cCl^-	S_0	S_D	S_{ABL}	S_X
85	0.8	1.1	1.55	2.1
105	0.8	1.1	1.44	2.0
140	0.8	1.5	2.10	2.7

cCa^{2+} (mmol/L)

cCa^{2+}	Bias			
	ABL735/25/15		ABL705	
	S95	C95	S95	C95
0.5	0.001	0.005	0.001	0.005
1.25	–0.011	–0.007	–0.011	–0.007
2.5	–0.004	0.003	–0.004	0.003

cCa^{2+}	S_0	S_D	S_{ABL}	S_X
0.5	0.012	0.011	0.020	0.026
1.25	0.012	0.011	0.015	0.023
2.5	0.015	0.023	0.041	0.050

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

cK^+ (mmol/L)

cK^+	Bias			
	ABL735/25/15		ABL705	
	S95	C95	S95	C95
2	0.000	0.015	0.000	0.015
4	0.003	0.012	0.003	0.012
8	0.011	0.013	0.011	0.013

cK^+	S_0	S_D	S_{ABL}	S_X
2	0.06	0.03	0.10	0.12
4	0.06	0.05	0.12	0.15
8	0.08	0.04	0.15	0.18

cNa^+ (mmol/L)

cNa^+	Bias			
	ABL735/25/15		ABL705	
	S95	C95	S95	C95
120	–0.60	0.23	–0.60	0.23
140	–0.47	–0.24	–0.47	–0.24
180	0.23	0.16	0.23	0.16

cNa^+	S_0	S_D	S_{ABL}	S_X
120	0.6	0.75	1.27	1.6
140	0.6	0.75	1.26	1.6
180	0.8	0.60	1.41	1.8

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

***c*Glu (mmol/L)**

***c*Glu**	**Bias**					
	ABL735/25/15			**ABL705**		
	S95	**C95**	**C35**	**S95**	**C95**	**C35**
2	0.01	N/A	0.01	0.01	N/A	0.01
5	0.01	N/A	–0.04	0.01	N/A	–0.04
15	–0.7	N/A	–0.7	–0.7	N/A	–0.7

***c*Glu**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
2	0.15	0.01	0.13	0.2
5	0.15	0.01	0.27	0.3
15	0.60	0.38	0.59	1.0

***c*Lac (mmol/L)**

***c*Lac**	**Bias**					
	ABL735/25/15			**ABL705**		
	S95	**C95**	**C35**	**S95**	**C95**	**C35**
0.3	–0.03	N/A	–0.03	–0.03	N/A	–0.03
2	–0.10	N/A	–0.17	–0.10	N/A	–0.17
10	–1.0	N/A	–1.0	–1.0	N/A	–1.0

***c*Lac**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
0.3	0.15	0.01	0.16	0.22
2	0.15	0.01	0.17	0.23
10	0.30	0.23	0.60	0.71

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

***c*tHb (g/dL)**

***c*tHb**		**Bias**							
		ABL735/25/15					**ABL730/20/10**		
***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S95**	**C95**	**S85**	**C55**	**C35**	**C85**	**C55**	**C35**
15	0	0.26	–0.08	0.20	0.08	0.10	N/A	0.08	0.10
7	100	–0.09	0.05	N/A	0.14	0.09	N/A	0.14	0.09
15	100	0.26	0.08	0.25	0.23	0.18	–0.07	0.23	0.18
25	100	0.64	–0.32	N/A	–0.42	–0.02	N/A	–0.42	–0.02

***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S$_0$**	**S$_D$**	**S$_{ABL}$**	**S$_X$**
15	0	0.20	0.10	0.45	0.55
7	100	0.20	0.10	0.35	0.45
15	100	0.20	0.10	0.50	0.55
25	100	0.30	0.20	0.60	0.70

***s*O$_2$ (%)**

***s*O$_2$**		**Bias**							
		ABL735/25/15					**ABL730/20/10**		
***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S95**	**C95**	**S85**	**C55**	**C35**	**C85**	**C55**	**C35**
15	0	–0.04	–0.02	-0.02	-0.03	-0.03	N/A	–0.03	–0.03
7	100	–0.10	–0.19	N/A	-0.22	-0.10	N/A	–0.22	–0.10
15	100	–0.10	–0.16	0.00	-0.16	-0.10	-0.05	–0.16	–0.10
25	100	–0.10	–0.17	N/A	-0.14	-0.09	N/A	–0.14	–0.09

***c*tHb (g/dL)**	***s*O$_2$ (%)**	**S$_0$**	**S$_D$**	**S$_{ABL}$**	**S$_X$**
15	0	0.05	0.05	0.25	0.30
7	100	0.10	0.10	0.25	0.30
15	100	0.05	0.10	0.25	0.30
25	100	0.05	0.10	0.30	0.35

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

***F*O$_2$Hb (%)**

***F*O$_2$Hb**		**Bias**				
		ABL735/25				
***c*tHb (g/dL)**	***F*O$_2$Hb (%)**	**S95**	**C95**	**S85**	**C55**	**C35**
15	0	–0.04	–0.02	–0.02	–0.03	–0.03
7	100	–0.47	–0.39	N/A	–0.48	–0.18
15	100	–0.33	–0.40	–0.15	–0.39	–0.31
25	100	–0.29	–0.46	N/A	–0.36	–0.33

***F*O$_2$Hb**		**Bias**		
		ABL730/20		
***c*tHb (g/dL)**	***F*O$_2$Hb (%)**	**C85**	**C55**	**C35**
15	0	N/A	–0.03	–0.03
7	100	N/A	–0.48	–0.18
15	100	–0.16	–0.39	–0.31
25	100	N/A	–0.36	–0.33

***c*tHb (g/dL)**	***F*O$_2$Hb (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	0	0.05	0.05	0.25	0.30
7	100	0.25	0.20	0.50	0.60
15	100	0.15	0.15	0.45	0.50
25	100	0.10	0.10	0.40	0.45

***F*COHb (%)**

***F*COHb**			**Bias**				
			ABL735/25				
***c*tHb (g/dL)**	***s*O$_2$ (%)**	***F*COHb (%)**	**S95**	**C95**	**S85**	**C55**	**C35**
15	100	0	0.10	0.10	0.12	0.08	0.08
7	100	20	N/A	N/A	N/A	N/A	N/A
15	100	20	N/A	N/A	N/A	N/A	N/A
25	100	20	N/A	N/A	N/A	N/A	N/A

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

F*COHb (%) *(continued)

***F*COHb**			**Bias**		
			ABL730/20		
***c*tHb (g/dL)**	***s*O_2 (%)**	***F*COHb (%)**	**C85**	**C55**	**C35**
15	100	0	–0.02	0.08	0.08
7	100	20	N/A	N/A	N/A
15	100	20	N/A	N/A	N/A
25	100	20	N/A	N/A	N/A

***c*tHb (g/dL)**	***s*O_2 (%)**	***F*COHb (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	100	0	0.05	0.10	0.35	0.40
7	100	20	0.10	0.10	0.75	0.80
15	100	20	0.05	0.10	0.70	0.75
25	100	20	0.05	0.10	0.70	0.75

***F*MetHb (%)**

***F*MetHb**			**Bias**				
			ABL735/25				
***c*tHb (g/dL)**	***s*O_2 (%)**	***F*MetHb (%)**	**S95**	**C95**	**S85**	**C55**	**C35**
15	100	0	0.13	0.14	0.06	0.16	0.14
7	100	20	N/A	N/A	N/A	N/A	N/A
15	100	20	N/A	N/A	N/A	N/A	N/A
25	100	20	N/A	N/A	N/A	N/A	N/A

***F*MetHb**			**Bias**		
			ABL730/20		
***c*tHb (g/dL)**	***s*O_2 (%)**	***F*MetHb (%)**	**C85**	**C55**	**C35**
15	100	0	0.13	0.16	0.14
7	100	20	N/A	N/A	N/A
15	100	20	N/A	N/A	N/A
25	100	20	N/A	N/A	N/A

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ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

F*MetHb (%) *(continued)

***c*tHb (g/dL)**	***s*O$_2$ (%)**	***F*MetHb(%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	100	0	0.10	0.10	0.25	0.30
15	100	20	0.05	0.10	0.35	0.40

***F*HHb (%)**

***F*HHb**		**Bias**							
		ABL735/25					**ABL730/20**		
***c*tHb (g/dL)**	***F*HHb (%)**	**S95**	**C95**	**S85**	**C55**	**C35**	**C85**	**C55**	**C35**
15	0	0.09	N/A	N/A	0.15	0.10	N/A	N/A	0.10

***c*tHb (g/dL)**	***F*HHb (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
15	0	0.05	0.10	0.30	0.35

***F*HbF (%)**

Adult blood:

***F*HbF**		**Bias**							
		ABL735					**ABL730**		
***c*tHb (g/dL)**	***F*HbF (%)**	**S95**	**C95**	**S85**	**C55**	**C35**	**C85**	**C55**	**C35**
10	0	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
15	0	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
20	0	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6

***c*tHb (g/dL)**	***F*HbF (%)**	***s*O$_2$ (%)**	**S_0**	**S_D**	**S_{ABL}**	**S_X**
10	0	100	4	4	5	8
15			2	3	5	7
20			2	2	10	11

NOTES: a, b.

Continued on next page

ABL735/30/25/20/15/10/05 Performance Test Results - Micromodes, *Continued*

F*HbF (%) *(continued)

Fetal blood:

***F*HbF**		**Bias**							
		ABL735					**ABL730**		
***c*tHb (g/dL)**	***F*HbF (%)**	**S95**	**C95**	**S85**	**C55**	**C35**	**C85**	**C55**	**C35**
10	80	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
15	80	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
20	80	2.6	2.6	2.6	2.6	2.6	2.6	2.6	2.6

***F*HbF (%)**	***c*tHb (g/dL)**	***s*O_2 (%)**	S_0	S_D	S_{ABL}	S_X
80	10	100	4	5	6	9
	15		3	3	6	8
	20		2	3	6	7

NOTES: a, b.

NOTES:

a. pH = 7.4 ± 0.1. *F*HbF is adjusted with the pH sensitivity to a nominal pH=7.4. For further details please refer to the *Interference Tests* section for oximetry parameters.

b. Specifications for imprecision are derived from worst-case values found during internal laboratory tests. 40 % relative is then added as a safety factor.

ABL700 Performance Test Results

Introduction This section lists the performance test results for each parameter measured by the ABL700 analyzers.

The tests were conducted in the following modes:

Sample from…	ABL700
Syringe	85 µL
Capillary	55 µL

NOTE: *The solutions used in the performance tests are those recommended by Radiometer. Performances using other solutions cannot be verified.*

The performance tests are performed under conditions where the analyzers are not influenced by electromagnetic fields.

pH

pH	Bias	
	S85	C55
7.0	0.001	0.003
7.4	–0.003	–0.001
7.7	0.002	0.004

pH	S_0	S_D	S_{ABL}	S_X
7.0	0.0050	0.0040	0.0077	0.010
7.4	0.0030	0.0023	0.0092	0.010
7.7	0.0050	0.0023	0.0106	0.012

***p*CO_2 (mmHg)**

pCO_2	Bias	
	S85	C55
15	–0.68	–0.80
40	–0.08	–0.09
60	0.38	0.30
80	0.45	–0.52
150	3.24	0.42

Continued on next page

ABL700 Performance Test Results, *Continued*

pCO_2 (mmHg) ***(continued)***

pCO_2	S_0	S_D	S_{ABL}	S_X
15	0.40	0.53	0.88	1.10
40	0.60	0.45	0.51	0.91
60	0.75	0.45	0.82	1.20
80	1.10	0.60	0.71	1.44
150	1.50	1.60	3.23	3.91

pO_2 (mmHg)

pO_2	Bias	
	S85	C55
15	0.92	1.26
50	0.13	–1.10
150	–1.31	0.06
250	0.63	–1.18
530	5.72	–4.42

pO_2	S_0	S_D	S_{ABL}	S_X
15	0.7	0.4	1.14	1.4
50	0.7	0.6	0.87	1.3
150	1.4	1.1	1.30	2.2
250	4.5	3.0	4.44	7.0
530	10.5	10.5	14.0	20.5

ABL735/30/25/20/15/10/05/00 Expired Air Mode

NOTE: *The solutions used in the performance tests are those recommended by Radiometer. Performances using other solutions cannot be verified.*

The performance tests are performed under conditions where the analyzers are not influenced by electromagnetic fields

pCO_2 (mmHg)

pCO_2	Bias
	ABL735/30/25/20/15/10/05/00
15	0.2
40	–0.2
60	–0.4
80	–0.2
150	1.6

pCO_2	S_0	S_D	S_{ABL}	S_X
15	0.25	0.35	0.59	0.73
40	0.40	0.30	0.43	0.66
60	0.50	0.35	0.79	1.00
80	0.70	0.40	1.10	1.44
150	1.00	1.10	3.07	3.41

pO_2 (mmHg)

pO_2	Bias
	ABL735/30/25/20/15/10/05/00
15	0.8
40	0.4
130	–0.4
230	–0.9
570	4.2

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ABL735/30/25/20/15/10/05/00 Expired Air Mode, *Continued*

p*O$_2$ (mmHg) *(continued)

***p*O$_2$**	**S$_0$**	**S$_D$**	**S$_{ABL}$**	**S$_X$**
15	0.3	0.3	1.2	1.3
40	0.3	0.3	1.0	1.1
130	0.3	0.3	0.7	0.8
230	2	2	3	4
570	5	5	13	15

ABL735/30/25/20/15/10/05/00 Capillary - pH Only Mode

pH

pH	Bias
	ABL735/30/25/20/15/10/05/00
7.0	-0.001
7.4	-0.007
7.7	0.000

pH	S_0	S_D	S_{ABL}	S_X
7.0	0.0070	0.0040	0.0075	0.011
7.4	0.0005	0.0023	0.0083	0.010
7.7	0.0070	0.0023	0.0107	0.013

NOTE: *These performance specifications refer to the ABL700 Series, software version 3.83 and higher.*

ABL735/30 Performance Test Results - Bilirubin

Field Test Results

The ABL735/30 performance specifications for bilirubin were made as a field test the purpose of which was to optimize bilirubin algorithm for neonatal blood samples.

For neonatal use: The bilirubin method has been evaluated on whole blood and plasma. The allowed analytical error is ± 10 % to satisfy average clinical requirements for bilirubin measurement [1,2,3,4,5]. This requirement is fulfilled for plasma. For whole blood the analytical error is slightly higher. The clinicians and clinical chemists have evaluated bilirubin measurement on whole blood, the conclusion being that the ABL735/30 has satisfactory performance and can substitute other bilirubin measuring methods.

For adult use:

Adult samples within reference range:

The uncertainty in the bilirubin measurement on whole blood can, in some cases, exceed the level required to measure normal bilirubin levels for children older than 3 months and adults (bilirubin reference range 4-22 μmol/L). In these cases it is recommended to measure bilirubin on plasma or serum.

Adult samples with an increased bilirubin level:

Adult field tests were typically performed on samples with 80 % of the total bilirubin in the conjugated form. For these highly conjugated samples the field tests showed a negative bias of 7 % on both plasma and whole blood samples.

The patient samples represented typical variations in *c*tBil, *c*tHb, sO_2, pH and MCHC values.

A Hitachi calibrated with NIST SRM 916a standards was used as a reference. *c*tBil was measured in μmol/L. Each field test place had its own ABL735.

Continued on next page

ABL735/30 Performance Test Results - Bilirubin, *Continued*

Field Test Results *(continued)*

The field test results are given below.

Pos.	Field test place	Type	N	Slope	Inter-cept µmol/L	R^2	S_{yx} µmol/L	Range µmol/L
1	A	Plasma, neonatal	46	1.026	0.0	0.9914	5.1	18 – 258
2	B		56	0.986	–1.3	0.9939	5.8	10 – 334
3	D		4	1.014	–1.4	0.9984	4.5	22 – 236
4	E		47	0.945	1.2	0.9937	5.1	4 – 253
5	D	Plasma, adult	16	0.950	–0.5	0.9977	5.2	18 – 313
6	B		59	0.924	1.4	0.9981	3.8	2 – 366
7	F		52	0.904	5.6	0.9932	12.0	4 – 635
			45 (a)	0.942	2.6	0.9941	5.3	4 – 300
8	A	Blood, neonatal	46	1.075	9.6	0.9661	10.7	18 – 258
9	B		100	1.057	–1.6	0.9819	12.0	3 – 297
10	D		32	1.000	–5.6	0.9715	14.4	3 – 254
11	C		52	0.993	–5.0	0.9790	11.3	6 – 309
12	E		47	1.019	–10.2	0.9827	9.5	4 – 253
13	D	Blood, adult	18	0.950	–6.8	0.9974	5.6	18 – 313
14	B		55	0.909	3.2	0.9974	4.6	2 – 366
15	F		25	0.939	4.9	0.9967	10.0	21 – 635

Regression table: Regression results from field tests. N = #samples, S_{yx} is standard deviation about regression line.

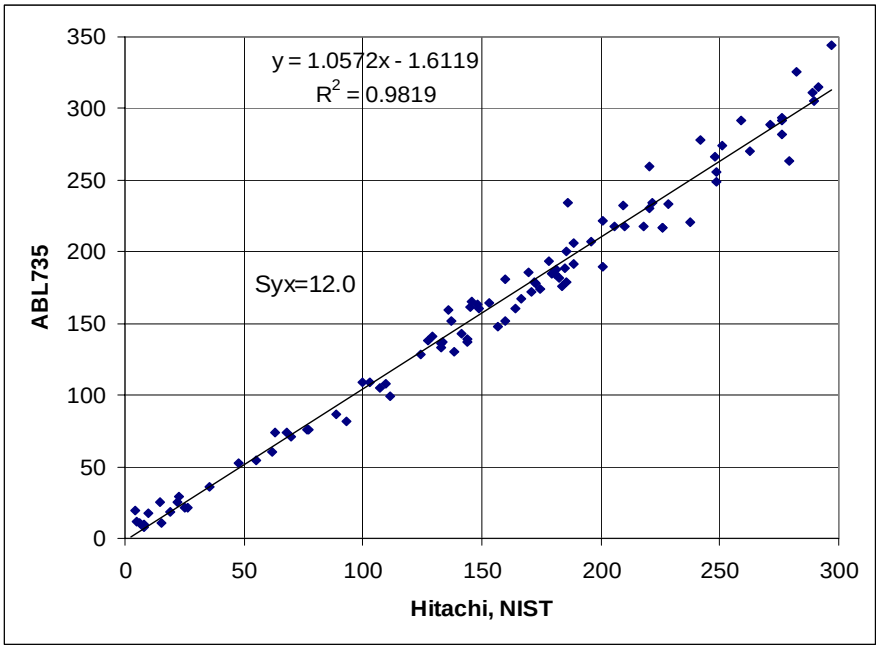
NOTE: (a) Datasubset excluding samples above 300 µmol/L.

Continued on next page

ABL735/30 Performance Test Results - Bilirubin, *Continued*

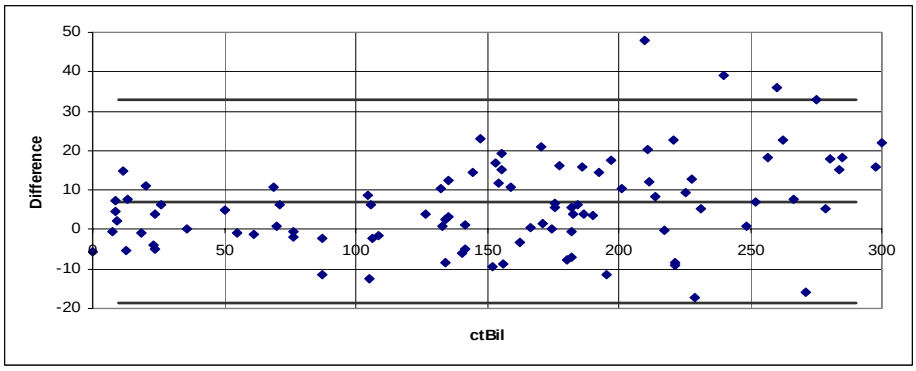
Regression and Bland-Altman Plot

Data set position 9 from regression table.



Actual field test from a neonatal critical care hospital using whole blood. Values are in µmol/L.

The same data as above but depicted in a Bland-Altman plot below.



Lines indicate Mean, Mean+2SD and Mean-2SD. Values are in µmol/L.
Difference = ABL735 – Hitachi,NIST.

Continued on next page

ABL735/30 Performance Test Results - Bilirubin, *Continued*

Imprecision Parameters

The following parameters are used to describe performance of the ABL735/30 analyzers for bilirubin measurements.

S_0: Repeatability. Measurement short time interval variation on the same sample.

S_D: Day-to-day variation

S_T: Patient-to-patient variation

S_I: ABL-to-ABL instrumental variation

S_{ABL}: ABL uncertainty. Variation including S_T, S_I and reference uncertainty

S_X: Reproducibility. Total variation including S_0, S_D and S_{ABL}

The above field test regression statistics S_{yx} include variations from S_0, S_D and S_T.

Performance Test Results for Bilirubin

Macromodes: 195 µL and 85 µL from syringe and capillary:

*c*tBil (µmol/L)	*c*tHb (g/dL)	sO_2 (%)	S_0	S_D	S_T	S_I	S_{ABL}	S_X
≈0	Plasma		1.1	1.4	2.2	0.4	2.3	2.9
≈0	10	100	1.9	3.1	4.0	3.2	5.1	6.3
≈0	15	100	2.3	2.9	7.4	5.5	9.2	9.9
≈0	20	100	3.4	2.6	10.9	13.0	17.0	17.5
≈200	Plasma		1.3	1.7	3.1	4.7	7.4	7.7
≈200	10	100	2.4	4.4	5.8	6.6	10.1	11.3
≈200	15	100	2.6	3.7	8.5	9.3	13.6	14.4
≈200	20	100	4.2	5.0	12.1	15.4	20.4	21.4
≈400	Plasma		1.7	2.5	4.8	9.3	12.0	12.3
≈400	10	100	3.5	6.8	9.3	12.0	16.5	18.2
≈400	15	100	3.4	5.3	11.4	15.9	20.8	21.7
≈400	20	100	6.0	8.8	15.0	21.0	27.1	29.2

Notes: a, b, c

Continued on next page

ABL735/30 Performance Test Results - Bilirubin, *Continued*

Performance Test Results for Bilirubin *(continued)*

Micromodes: 95 µL (syringe and capillary), 55 µL (capillary) and 35 µL (capillary):

*c*tBil (µmol/L)	*c*tHb (g/dL)	sO_2 (%)	S_0	S_D	S_T	S_I	S_{ABL}	S_X
≈0	Plasma		1.1	1.4	2.2	0.4	2.3	2.9
≈0	10	100	1.9	3.1	4.0	3.2	5.1	6.3
≈0	15	100	2.3	2.9	7.4	5.5	9.2	9.9
≈0	20	100	3.4	2.6	10.9	13.0	17.0	17.5
≈200	Plasma		2.0	1.7	2.9	3.9	6.8	7.3
≈200	10	100	3.7	3.9	6.0	5.6	9.6	11.0
≈200	15	100	4.4	4.2	9.3	7.9	13.2	14.6
≈200	20	100	5.6	5.9	13.0	16.3	21.6	23.1
≈400	Plasma		3.5	2.5	4.3	7.8	10.6	11.4
≈400	10	100	6.7	5.7	9.9	9.6	15.2	17.6
≈400	15	100	7.9	6.7	13.5	12.5	19.7	22.3
≈400	20	100	9.5	10.9	17.8	23.6	30.7	33.9

Notes: a, b, c

NOTES:

a. Adult/fetal blood, pH = 7.4 ± 0.1, normal MCHC and albumin variation, Spiked with unconjugated bilirubin.

b. *c*tBil specification at level 200 µmol/L is interpolated from the measured specifications at 0 and 400 µmol/L.

c. The performance specifications apply to measurements performed using CLINITUBES with clot catchers and mixing wire from Radiometer.

References

1. Fraser CG. The application of theoretical goals based on biological variation data in proficiency testing. Arch Pathol Lab Med 1988; 112: 402-15.

2. Ehrmeyer SS, Laessig RH, Leinweber JE, Oryall JJ. 1990 Medicare/CLIA final rules for proficiency testing: minimum intralaboratory performance characteristics (CV and bias) needed to pass. Clin Chem 1990; 36, 10: 1736-40.

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ABL735/30 Performance Test Results - Bilirubin, *Continued*

References *(continued)*

3. Fraser CG, Petersen PH, Ricos C, Haeckel R. Proposed quality specifications for the imprecision and inaccuracy of analytical systems for clinical chemistry. Eur J CLin Chem Clin Biochem 1992; 30: 311-17.

4. Westgard JO, Seehafer JJ, Barry PL. Allowable imprecision for laboratory test based on clinical and analytical test outcome criteria. Clin Chem 1994; 40, 10: 1909-14.

5. Vanderline RE, Goodwine J, Koch D, Scheer D, Steindel S, Cembrowski G. Guidelines for providing quality stat laboratory services. 1987 Laboratory Quality Assurance Commitee.

Interference Tests

Introduction This section gives an outline of the interfering substances and the results of interference tests on the ABL700 series analyzers.

pH/Blood Gas The following table gives the substances against which the pH and blood gas electrodes (only pO_2 electrode) were tested for interference, and the results of those tests:

Substance	Test Conc.	Interference on pO_2 Electrode
Halothane	3 %	5 % increased sensitivity

Intralipid (20 % solution) in a concentration greater than 4 % (the final Intralipid level being 0.8 %) will give interference on pH measurements.

Electrolytes The following interference results are found on the electrolyte electrodes:

Substance	Test Conc.	Interference on…			
		cK^+ (4 mmol/L level)	cNa^+ (150 mmol/L level)	cCa^{2+} (1.25 mmol/L level)	cCl^- (110 mmol/L level)
Li^+	4 mmol/L	0	0	0	
K^+	12 mmol/L		–1	–0.01	
Na^+	100 - 180 mmol/L	0.1 to –0.1			
NH_4^+	1 mmol/L	0	0		
Ca^{2+}	5 mmol/L		0		
Mg^{2+}	5 mmol/L	0	0	0.05	
Br^-	10 mmol/L				41
F^-	1 mmol/L				0
I^-	3.0 mmol/L				30-90 mmol/L
ClO_4^-	1.5 mmol/L				8-30 mmol/L
HCO_3^-	25-50 mmol/L				0.1 mmol/L Cl^- per mmol/L HCO_3^-
Lactate	10 mmol/L				0
Acetyl-salicylic acid	3.0 mmol/L				2

Continued on next page

Interference Tests, *Continued*

Electrolytes *(continued)*

Substance	Test Conc.	Interference on…			
		cK^+ (4 mmol/L level)	cNa^+ (150 mmol/L level)	cCa^{2+} (1.25 mmol/L level)	cCl^- (110 mmol/L level)
Ascorbic acid	1.0 mmol/L				0
pH ≤ 7.2	7.2	0	0	0.01	–1
pH ≥ 7.6	7.6	0	0	–0.01	1

Sulphide will give erroneously high cCl^- results.

Metabolites

The following table gives the substances against which the metabolite electrodes (Glucose, Lactate) were tested for interference, and the results of those tests:

Substance	Test Conc. (mmol/L)	Interference on …	
		*c*Glucose (mmol/L) (4mmol/L level)	*c*Lactate (mmol/L) (1.5 mmol/L level)
Acetoacetic acid	2	<| 0.1|	<| 0.1|
Acetylsalicylic acid	3	<| 0.1|	<| 0.1|
Ascorbic acid	2	<| 0.1|	<| 0.1|
Bilirubin (conjugated)	0.46	<| 0.1|	<| 0.1|
Bilirubin (unconjugated)	0.34	<| 0.1|	<| 0.1|
Chlorpromazine HCl	0.2	<| 0.1|	<| 0.1|
Citrate	50	–0.37	0.19
Creatinine	3	<| 0.1|	<| 0.1|
D-glucose	67		<| 0.1|
Dopamine HCl	1.0	<| 0.1|	<| 0.1|
EDTA	3	<| 0.1|	<| 0.1|
Ethanol	79	<| 0.1|	<| 0.1|
Fluoride	50	–0.36	<| 0.1|
Galactose	3.3	up to 1.88*	
Glucosamine	2	up to 1.06*	

Continued on next page

Interference Tests, *Continued*

Metabolites *(continued)*

Substance	Test Conc. (mmol/L)	Interference on …	
		*c*Glucose (mmol/L) (4mmol/L level)	*c*Lactate (mmol/L) (1.5 mmol/L level)
Glycolic acid	1	<| 0.1|	Interference
Heparin	8000 IU/dL	<| 0.1|	<| 0.1|
Ibuprofen	2	<| 0.1|	<| 0.1|
Lactic acid	12	<| 0.1|	
Maltose	5	up to 0.4*	
Mannose	1	up to 0.4*	
Oxalate	90	–0.47	0.14
Paracetamol-4-acetamidophenol	2	<| 0.1|	<| 0.1|
Pyruvate	2	<| 0.1|	<| 0.1|
Salicylic acid	4	<| 0.1|	<| 0.1|
Thiocyanic acid	24	Interference	Interference
Urea	84	<| 0.1|	<| 0.1|
Uric acid	1.5	<| 0.1|	<| 0.1|
Xylose	1	up to 0.34*	

* Values determined at *c*Glu = 0 mmol/L. Interference at *c*Glu 4.0 mmol/L is expected to be the same.

Hematocrit %	Δ*c*Lactate % at :	
	5 mmol/L level	15 mmol/L level
0	0.7 %	0.7 %
45	0.0 %	0.0 %
60	–0.5 %	–2.0 %
75	–2.2 %	–5.0 %

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Interference Tests, *Continued*

Oximetry Parameters

The following table lists the substances against which the oximetry parameters (*c*tHb, *s*O_2, *F*O_2Hb, *F*COHb, *F*MetHb, *F*HHb, *F*HbF) and *c*tBil were tested for interference, and the results of those tests.

SAT100 blood reference test sample: *c*tHb=15 g/dL, *s*O_2=100 %, *F*COHb=0.7 %, *F*MetHb=0.5 %, *c*tBil=0, pH=7.4. Parameter sensitivity from the influence on the absorbance spectrum from various substances.

Substance	Test conc.	Change on …							
		***c*tHb (g/dL)**	***s*O_2 (%)**	***F*O_2Hb (%)**	***F*COHb (%)**	***F*MetHb (%)**	***F*HHb (%)**	***F*HbF *(%)***	***c*tBil *(μmol/L)***
Intralipid	4 Vol % [e]	–0.5	0.1	–1.3	0.5	0.9	–0.1	11	0 4 [b]
Intralipid	2 Vol % [f]	–0.4	0.1	–0.3	0.3	0.1	–0.1	11	7 2 [b]
HbF [a), c)]	20 %	–0.02	1.17	0.04	0.73	0.37	–1.14	0	–14
*S*Hb	10 %	0	–1.0	0.9	–0.1	0.1	–0.9	Not tested	
pH	7.1 7.9	–0.5 –0.6	–0.5 0.6	–0.2 –0.5	–0.4 1.0	0.1 0.1	0.5 –0.6	–19 13	0 –5
Cardio Green [c)]	5 mg/L	–0.16	0.29	1.14	0.07	–0.93	–0.29	–5	–20
Evans Blue [c)]	5 mg/L	–0.04	0.14	0.28	–0.20	–0.20	0.14	–5	5
Betacarotene in plasma [c)]	3.7 μmol/L	0.0	–0.02	0.03	–0.01	–0.04	0.02	0.1	–0.2
Patent Blue V [c)]	10 mg/L	–0.16	0.39	0.86	–0.47	0.00	–0.38	–21	38
Methylene Blue [c)]	30 mg/L	–0.7	–3.4	5.6	–3.0	–6.2	3.6	–37	–25
HiCN [c)]	0.11 mmol/L	0.26	–1.5	–3.0	–0.5	0.5	1.5	24	47
MCHC [c), d)] newborn range	320 g/L 350 g/L	No interference							–12 17
Sedimentation rate	100 arb. Units	≤ ± 0.5	No interference						Not tested

Notes:

a) If function “Correction for HbF levels less than 20 %” is activated, the change is 0 for all parameters.

b) Plasma sample.

c) Calculated value from mathematical superposition of measured pure interference spectrum on measured reference spectrum.

d) *c*tBil = 400 μmol/L.

e) Intralipid (20 % solution) at 4 Vol % gives final test level of 0.8 %.

f) Intralipid (20 % solution) at 2 Vol % gives final test level of 0.4 %.

There is no interference from fetal hemoglobin (HbF) when the analyzer applies HbF correction.
There is no interference from bilirubin (conjugated/unconjugated) up to 1000 μmol/L.

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Interference Tests, *Continued*

Contribution to Imprecision Specifications from HbF Correction

The process of HbF correction introduces additional noise compared to measurement on adult samples. The following tables list the extra contribution which must be added geometrically to the imprecision specifications for adult samples in order to obtain the imprecision specifications for fetal samples (also for adult samples if function "Correction for HbF levels less than 20 %" is activated).

$S_{fetal} = \sqrt{S_{adult}^2 + S_{HbF}^2}$; geometrical addition of imprecision

where S_{fetal} is the calculated fetal imprecision; S_{adult} is the corresponding adult imprecision; S_{HbF} is the extra contribution from HbF correction which is listed in the following tables.

HbF correction contribution to 10 g/dL SAT100 fetal sample:

	S_0	S_D	S_{ABL}	S_X
sO_2 %	0.15	0.20	0.19	0.31
*F*HHb %	0.14	0.19	0.19	0.30
FO_2Hb %	0.01	0.01	0.01	0.01
*F*COHb %	0.09	0.13	0.12	0.20
*F*MetHb %	0.05	0.06	0.06	0.10

HbF correction contribution to 15 g/dL SAT100 fetal sample:

	S_0	S_D	S_{ABL}	S_X
sO_2 %	0.09	0.12	0.29	0.33
*F*HHb %	0.09	0.11	0.28	0.32
FO_2Hb %	0.00	0.00	0.01	0.01
*F*COHb %	0.06	0.07	0.18	0.21
*F*MetHb %	0.03	0.04	0.09	0.11

HbF correction contribution to 20 g/dL SAT100 fetal sample:

	S_0	S_D	S_{ABL}	S_X
sO_2 %	0.09	0.12	0.20	0.25
*F*HHb %	0.09	0.11	0.19	0.25
FO_2Hb %	0.00	0.00	0.01	0.01
*F*COHb %	0.06	0.07	0.13	0.16
*F*MetHb %	0.03	0.04	0.06	0.08

Continued on next page

Interference Tests, *Continued*

FHbF Sensitivity for pH Changes

FHbF is sensitive to pH deviations from the nominal value of pH = 7.4. If pH is converted into $c\mathrm{H}^+$ (hydrogen ion concentration), the relationship between the changes in $c\mathrm{H}^+$ and FHbF is linear as seen from the following equation:

$$\Delta F\mathrm{HbF} = -0.48\ \%/(\mathrm{nmol/L}) \times (c\mathrm{H}^+ - 40\ \mathrm{nmol/L})$$

where pH = 7.4 corresponds to $c\mathrm{H}^+ = 40$ nmol/L.

EXAMPLE: pH = 7.25 corresponds to $c\mathrm{H}^+ = 56$ nmol/L. Then:

$$\Delta F\mathrm{HbF} = -0.48 \times (56 - 40) = -7.7\ \%.$$

ctBil Sensitivity for MCHC Variations

MCHC (Mean Corpuscular Hemoglobin Concentration) is used to estimate hematocrit, Hct, which is used in the ctBil measurement. MCHC is an average Hb concentration in the red blood cell (RBC). If the RBC volume decreases, MCHC increases. If a RBC has iron deficit, MCHC decreases.

Hct is determined from ctHb as follows:

$$\mathrm{Hct} = \frac{c\mathrm{tHb}}{\mathrm{MCHC}}$$

A standard value of 332 g/L is assumed for MCHC which gives

Hct = ctHb x 0.0301 if the unit for ctHb is g/dL.

MCHC can, however, deviate from this standard value as illustrated in the following table (see the next page).

Erythrocytometric values given for “apparently healthy” white and black subjects of different ages are taken from: “Geigy Scientific Tables, Physical Chemistry, Composition of Blood, Hematology, Somametric Data”, CIBA-GEIGY, 1984; 3, 207.

Continued on next page

Interference Tests, *Continued*

ctBil Sensitivity for MCHC Variations *(continued)*

Subjects	Age	Hct mean	Hct 95 % range	MCHC mean, g/L	MCHC 95 % range, g/L
Men	Adults	0.47	0.39 - 0.55	340	310 - 370
Women	Adults	0.42	0.36 - 0.48	330	300 - 360
Boys	Newborn	0.59	0.53-0.65	330	320-340
	1 month	0.50	0.44-0.56	320	310-330
	3 months	0.45	0.39-0.52	330	320-340
	6 months	0.46	0.39-0.51	300	290-310
	9 months	0.45	0.39-0.52	280	270-300
	1 year	0.41	0.37-0.45	290	280-300
	2 years	0.40	0.36-0.47	300	280-310
	4 years	0.37	0.30-0.44	280	270-290
	8 years	0.41	0.37-0.45	290	280-300
	14 years	0.41	0.36-0.46	300	290-310
Girls	Newborn	0.58	0.51-0.65	340	330-350
	1 month	0.49	0.42-0.56	320	310-330
	3 months	0.44	0.39-0.51	330	320-340
	6 months	0.44	0.39-0.50	320	310-330
	9 months	0.43	0.37-0.50	300	290-310
	1 year	0.43	0.37-0.49	300	290-310
	2 years	0.43	0.36-0.50	300	290-310
	4 years	0.43	0.36-0.51	280	270-290
	8 years	0.40	0.36-0.46	280	270-290
	14 years	0.40	0.36-0.47	290	280-300

If ΔMCHC is defined as ΔMCHC = 332 g/L – MCHC, then the contribution to the relative error on the *c*tBil measurement is as follows:

$$\frac{\Delta c\text{tBil}}{c\text{tBil}} = -\frac{\text{Hct}}{1-\text{Hct}} \times \frac{\Delta\text{MCHC}}{\text{MCHC}}$$

A worst-case example, using 95 % confidence values:

A newborn girl with Hct = 0.58, MCHC = 350 g/L and ctBil = 400 µmol/L. *c*tHb may be derived as Hct x MCHC = 0.58 x 350 g/L = 20.3 g/dL (reference range is 18.0 – 21.0 g/dL).

Continued on next page

Interference Tests, *Continued*

ctBil Sensitivity for MCHC Variations *(continued)*

$$\frac{\Delta c\text{tBil}}{c\text{tBil}} = -\frac{0.58}{1-0.58} \times \frac{-18}{350} = +0.071$$ And Δ*c*tBil = 0.071 x 400 = 28 µmol/L.

If the reference value for Hct is known, it is possible to correct the displayed *c*tBil value, using the following equation:

$$c\text{tBil(corrected)} = c\text{tBil(displayed)} \times \frac{1 - c\text{tHb(displayed)} \times 0.0301}{1 - \text{Hct(reference)}}$$

*c*tHb is measured in g/dL.

ctBil Sensitivity for pH Changes

*c*tBil is slightly sensitive to pH deviations from the nominal value of pH = 7.4.

The following table shows the changes in Δ*c*tBil compared to the value at pH = 7.4.

Sample Type	***c*tHb g/dL**	**Nominal ctBil µmol/L**	**ΔctBil (7.4→7.1) µmol/L**	**ΔctBil (7.4→7.9) µmol/L**
Adult/fetal plasma	0	0	3	0
Adult blood, sO_2 = 100 %	15	0	0	–5
Fetal blood, sO_2 = 100 %	15	0	–13	4
Adult/fetal plasma spiked with unconjugated bilirubin	0	400	–2	–1
Adult/fetal plasma spiked with conjugated bilirubin	0	400	9	–11
Adult blood spiked with unconjugated bilirubin, sO_2 = 100 %	15	400	10	–26
Fetal blood spiked with unconjugated bilirubin, sO_2 = 100 %	15	400	–4	–16
Adult blood spiked with conjugated bilirubin, sO_2 = 100 %	15	400	14	–35
Fetal blood spiked with conjugated bilirubin, sO_2 = 100 %	15	400	0	–26

References

List of References

1. Kristensen HB, Salomon A, Kokholm G. International pH scales and certification of pH.
2. Definition of pH scales, standard reference values, measurement of pH and related terminology (Recommendations 1994). Pure and Appl Chem 1985; 57, 3: 531 - 42.
3. Burnett RW, Covington AK, Mas AHJ, Müller-Plathe O *et al*. J Clin Chem Clin Biochem 1989; 27: 403 - 08.
4. Standardization of sodium and potassium ion-selective electrode systems to the flame photometric method. Approved Standard, NCCLS Publication C29A. Villanova, Pa,: NCCLS, 1995.
5. IFCC reference methods and materials for measurement pH, gases and electrolytes in blood. Scand J Clin Lab Invest 1993; 53, Suppl 214: 84 - 94.
6. Glucose. NCCLS Publication RS1-A. Villanova, Pa: NCCLS, 1989.
7. Reference and selected procedures for the quantitative determination of hemoglobin in blood. 2nd ed, Approved Satndard, NCCLS Publication H15-2A. Villanova, Pa: NCCLS, 1994.
8. Evelyn K, Malloy H. Microdetermination of oxyhemoglobin, methemoglobin and sulfhemoglobin in a single sample of blood. Biological Chem 1938; 126: 655 - 62.
9. Evaluation of precision performance of clinical chemistry devices. NCCLS Publication EP2-T, 2nd ed. Villanova, Pa: NCCLS, 1979; 2, 19: 555 - 98.
10. Kristoffersen K. An improved method for the estimation of small quantities of alkali-resistant hemoglobin in blood. Scand J Clin Lab Invest 1961; 13: 402.
11. Quantitative measurement of fetal hemoglobin using the alkali denaturation method. Approved Guideline. NCCLS Publication H13-A 1989; 9, 18.
12. Wahlefeld AW *et al*. Bile pigments: Technical aspects, modification of Malloy-Evelyn method for a simple, reliable determination of total bilirubin in serum. Scand J Clin Lab Invest 1972; 29, Suppl 126: Hitach, Abstr 11.12.

6. Parameters

Introduction This chapter defines all the measured, input, and derived parameters available with the ABL700 Series analyzer. It gives the symbols, and units for each of the parameters, together with the equations used in deriving the parameters. It lists the suggested reference ranges for the measured parameters.

Contents This chapter contains the following topics.

General Information

The Deep Picture™

The Deep Picture developed by Radiometer [1], expands traditional pH and blood gas analysis by evaluating the capability of arterial blood to carry sufficient oxygen to tissues and to release it. It simplifies interpretation by dividing the process into steps:

Step	Description
Oxygen Uptake	Oxygen uptake in the lungs indicates whether the pulmonary gas exchange is efficient enough to oxygenate arterial blood. The uptake of oxygen in the lungs can be described by parameters in combination, primarily the arterial oxygen tension (pO_2(a)), fraction of O_2 in dry inspired air (FO_2(I)), and shunt fraction of perfused blood ($\dot{Q}_s/\dot{Q}_t$) However other parameters may also be used, such as the difference in alveolar air and arterial blood oxygen tension (pO_2(A-a)).
Oxygen Transport	Oxygen transport reveals whether arterial blood contains sufficient oxygen. The oxygen concentration of arterial blood (ctO_2(a)) also termed oxygen content is determined by the concentration of total hemoglobin (ctHb(a)), the fraction of oxygenated hemoglobin (FO_2Hb(a)), and the arterial oxygen tension (pO_2(a)). Other parameters which should be known are the oxygen saturation (sO_2 (a)) and the fractions of dyshemoglobins (FCOHb(a) and FMetHb(a)).
Oxygen Release	Oxygen release describes the ability of arterial blood to release oxygen to the tissues. The release of oxygen from capillaries to tissues is determined by the oxygen tension gradient between the two. This release of oxygen is also influenced by the hemoglobin-oxygen affinity, which is indicated by the oxygen tension at 50 % saturation, p50.

Symbols

The symbols for the parameters are based on the principles described by Wandrup [2].

When temperature symbols are not stated, the temperature is assumed to be 37 °C.

Each symbol consists of three parts, described below:

Part	Description	Examples
Quantity	A symbol in italics describing the quantity	p for pressure c for concentration F for fraction V for volume

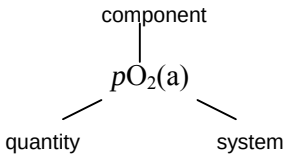
Continued on next page

General Information, *Continued*

Symbols *(continued)*

Part	Description	Examples
Component	An abbreviation of the component name	O_2 for oxygen CO_2 for carbon dioxide COHb for carboxyhemoglobin
(system)	Specification of the system	B for blood P for plasma a for arterial blood $\bar{v}$ for mixed venous blood A for alveolar air *T* for patient temperature

Example:



The ABL700 Series parameters are listed by symbol in three groups: measured, input, and derived parameters.

Units

The units given for each parameter refer to the units available on the analyzer for that parameter.

Measuring Ranges

The measuring range for each parameter refers to the range which the analyzer accepts.

Reference Ranges

"Reference ranges are valuable guidelines for the clinician, but they should not be regarded as absolute indicators of health and disease. Reference ranges should be used with caution since values for 'healthy' individuals often overlap significantly with values for persons afflicted with disease. In addition, laboratory values may vary significantly due to methodological differences and mode of standardization" [10].

Ref. 10 has been the source for the reference ranges given in this section. In some cases the values are taken from other sources marked by their reference number.

When possible the reference ranges for arterial blood have been listed. Reference ranges must be used with caution as they depend on a number of factors, such as sex, age, and normal physiological condition.

Continued on next page

General Information, *Continued*

Critical Limits

User-defined critical limits can also be entered into the analyzer software. Refer to *Chapter 5, Reference Ranges and Critical Limits* in the *Operator's Manual*.

Derived Parameters

Derived parameters are calculated according to the equations stated.

If…	Then…
the required measured or input values are unknown	default values are used, unless a measured parameter does not have a value or is outside the measuring range.
all values are known	the derived parameter is designated *calculated* and a 'c' is added to the result.
a default value is used	the derived parameter is designated *estimated* and an 'e' is added to the result.

If one or more default values have been used in the calculation, the result may deviate significantly from the true value. The deviation on "estimated" oxygen status parameters may become particularly significant if default values are used instead of measured blood oximetry data.

In some cases however, the default value is not accepted as the input for the calculation. This is because the actual values of the missing parameter may deviate significantly from the default value, thus making the estimation clinically inappropriate. If sO_2 cannot be measured due to severe errors, it will be calculated.

Measurable Parameters

Some of the listed parameters are measurable, depending on the analyzer configuration. In these cases the equation given only applies if that parameter is *not* directly measured by the analyzer.

Sample Type

Unless otherwise stated, a parameter will be calculated or estimated irrespective of the choice in the **Patient Identification** screen: 'Arterial', 'Capillary', 'Venous', 'Mixed venous', or 'Not specified'. Some parameters however are defined for arterial samples only; they will be calculated only for sample types entered as 'Arterial' or 'Capillary'.
The symbol for system (blood (B) or plasma (P)) is not stated in the equations unless it is important for the calculation.

Default Values

The default values used in the ABL700 analyzer are listed at the end of this chapter in the section *Default Values Used*.

Equations

All equations are based on SI units. If 'T' for patient temperature is not stated, the calculation is based on a temperature of 37.0 °C.

The following SI units are used:

concentration in mmol/L

temperature in °C

Continued on next page

General Information, *Continued*

Equations *(continued)*

pressure in kPa

fractions (not %)

The following symbols are used in the equations:

$\log(x) = \log_{10}(x)$

$\ln(x) = \log_e(x)$

Acid-base Parameters

List of Acid-Base Parameters

Traditional pH and blood gas analysis establishes the acid-base status of blood by measuring pH, pCO_2 and occasionally ctHb, and gives partial information concerning the oxygen status of blood by measuring pO_2.

All acid-base parameters are listed below. In the **Type** column the following symbols are used:

- ms for measured parameters
- dv for derived parameters

The **Eq.** column gives the number of the equation used to calculate the parameter - see *List of Equations* in this chapter.

Symbol	Definition	Type	Eq.
Baro	Ambient barometric pressure (p(amb)).	ms	
pH	Indicates the acidity or alkalinity of the sample.	ms	
cH^+	Concentration of hydrogen ions in blood.	ms	
pH(T)	pH of blood at patient temperature.	dv	**1**
$cH^+(T)$	Concentration of hydrogen ions in blood at patient temperature.	dv	**2**
pCO_2	Partial pressure (or tension) of carbon dioxide in blood. High and low pCO_2 values of arterial blood indicate blood hypercapnia and hypocapnia respectively.	ms	
pCO_2	Carbon dioxide tension in a gaseous sample.	ms	
$pCO_2(T)$	Partial pressure (or tension) of carbon dioxide at patient temperature.	dv	**3**
$cHCO_3^-$(P)	Concentration of hydrogen carbonate in plasma (also termed actual bicarbonate).	dv	**4**
cBase(B) or ABE	Actual Base Excess, the concentration of titrable base when the blood is titrated with a strong base or acid to a plasma pH of 7.40, at pCO_2 of 5.33 kPa (40 mmHg) and 37 ^oC, at the actual oxygen saturation [4,5]. Positive values (base excess) indicate a relative deficit of noncarbonic acids; negative values (base deficit) indicate a relative excess of non-carbonic acids.	dv	**5**

Continued on next page

Acid-base Parameters, *Continued*

List of Acid-Base Parameters *(continued)*

Symbol	Definition	Type	Eq.
*c*Base(B,ox)	*c*Base(B) of fully oxygenated blood.	dv	**6**
*c*Base(Ecf) or SBE	Standard Base Excess, an *in vivo* expression of base excess [5, 6]. It refers to a model of the extracellular fluid (one part of blood is diluted by two parts of its own plasma) and is calculated using a standard value for the hemoglobin concentration of the total extracellular fluid.	dv	**7**
*c*Base(Ecf,ox)	*c*Base(Ecf) of fully oxygenated blood.	dv	**8**
$cHCO_3^-$(P,st)	Standard Bicarbonate, the concentration of hydrogen carbonate in the plasma from blood which is equilibrated with a gas mixture with pCO_2 = 5.33 kPa (40 mmHg) and $pO_2 \geq$ 13.33 kPa (100 mmHg) at 37 °C [4,5].	dv	**9**
$ctCO_2$(P)	Concentration of total carbon dioxide, (free CO_2 + bound CO_2) in plasma.	dv	**10**
$ctCO_2$(B)	Concentration of total carbon dioxide in whole blood (also termed CO_2 content). Calculated based on the total CO_2 concentrations in the two phases: plasma and erythrocyte fluid [5].	dv	**11**
pH(st)	Standard pH (or eucapnic pH), defined as the pH of plasma of blood equilibrated to pCO_2 = 5.33 kPa (40 mmHg). By ensuring the normal value of pCO_2, the respiratory influence from pH is removed, and pH(P,st) therefore reflects the metabolic status of the blood plasma.	dv	**12**
VCO_2/V(dry air)	The volume fraction of carbon dioxide in dry air.	dv	**51**

Oximetry Parameters

List of Oximetry Parameters

All oximetry parameters are listed below. In the **Type** column the following symbols are used:

- ms for measured parameters
- dv for derived parameters

The **Eq.** column gives the number of the equation used to calculate the parameter - see *List of Equations* in this chapter.

Symbol	Definition	Type	Eq.
*c*tHb	Concentration of total hemoglobin in blood. Total hemoglobin includes all types of hemoglobin: deoxy-, oxy-, carboxy-, met-.	ms	
*F*HHb	Fraction of deoxyhemoglobin in total hemoglobin in blood. Deoxyhemoglobin is the part of total hemoglobin which can bind oxygen forming oxyhemoglobin. It is also termed reduced hemoglobin, RHb.	ms/dv	**41**
FO_2Hb	Fraction of oxyhemoglobin in total hemoglobin in blood.	ms/dv	**40**
*F*COHb	Fraction of carboxyhemoglobin in total hemoglobin in blood.	ms	
*F*MetHb	Fraction of methemoglobin in total hemoglobin in blood.	ms	
sO_2	Oxygen saturation, the ratio between the concentrations of oxyhemoglobin and the hemoglobin minus the dyshemoglobins.	ms/dv	**39**
*F*HbF	Fraction of fetal hemoglobin in total hemoglobin in blood *	ms	**49**
Hct	Hematocrit, the ratio between the volume of erythrocytes and the volume of whole blood.	dv	**13**

* For limitations please refer to chapter 3 in this manual.

Oxygen Parameters

List of Oxygen Parameters

All the oxygen parameters are listed below. In the **Type** column the following symbols are used:

- ms for measured parameters
- dv for derived parameters
- in for input parameters

The **Eq.** column gives the number of the equation used to calculate the parameter - see *List of Equations* in this chapter.

Symbol	Definition	Type	Eq.
pO_2	Partial pressure (or tension) of oxygen in blood. High and low pO_2 values of arterial blood indicate blood hyperoxia and hypoxia respectively.	ms	
pO_2	Oxygen tension in a gaseous sample.	ms	
$pO_2(T)$	Partial pressure (or tension) of oxygen at patient temperature.	dv	**14**
pO_2(A)	Partial pressure (or tension) of oxygen in alveolar air.	dv	**15**
pO_2 (A,T)	Partial pressure (or tension) of oxygen in alveolar air at patient temperature.	dv	**16**
pO_2(a)/ FO_2(I)	Oxygen tension ratio of arterial blood and the fraction of oxygen in dry inspired air	dv	**17**
pO_2(a,T)/ FO_2(I)	Oxygen tension ratio of arterial blood at patient temperature and the fraction of of oxygen in dry inspired air	dv	**18**
$p50$	Partial pressure (or tension) of oxygen at half saturation (50 %) in blood. High and low values indicate decreased and increased affinity of oxygen to hemoglobin, respectively.	dv	**19**
$p50(T)$	Partial pressure (or tension) of oxygen at half saturation (50 %) in blood at patient temperature.	dv	**20**

Continued on next page

Oxygen Parameters, *Continued*

List of Oxygen Parameters *(continued)*

Symbol	Definition	Type	Eq.
$p50$(st)	Partial pressure (or tension) of oxygen at half saturation (50 %) in blood at standard conditions: temperature = 37 °C pH = 7.40 pCO_2 = 5.33 kPa *F*COHb, *F*MetHb, *F*HbF set to 0 $p50$(st) may however vary due to variations in 2,3-DPG concentration or to the presence of abnormal hemoglobins.	dv/in	**21**
pO_2(A–a)	Difference in the partial pressure (or tension) of oxygen in alveolar air and arterial blood. Indicates the efficacy of the oxygenation process in the lungs.	dv	**22**
pO_2(A–a,*T*)	Difference in the partial pressure (or tension) of oxygen in alveolar air and arterial blood at patient temperature.	dv	**23**
pO_2(a/A)	Ratio of the partial pressure (or tension) of oxygen in arterial blood and alveolar air. Indicates the efficacy of the oxygenation process in the lungs.	dv	**24**
pO_2(a/A,*T*)	Ratio of the partial pressure (or tension) of oxygen in arterial blood and alveolar air at patient temperature.	dv	**25**
pO_2(x) or p_x	Oxygen extraction tension of arterial blood. Reflects the integrated effects of changes in the arterial pO_2(a), ctO_2, and $p50$ on the ability of arterial blood to release O_2 to the tissues [8].	dv	**26**
pO_2(x,*T*) or p_x(*T*)	Oxygen extraction tension of arterial blood at patient temperature.	dv	
ctO_2(B)	Total oxygen concentration of blood. Also termed O_2 content.	dv	**27**
ctO_2(a–$\bar{v}$)	Oxygen concentration difference between arterial and mixed venous blood.	dv	**28**
BO_2	Hemoglobin oxygen capacity; the maximum concentration of oxygen bound to hemoglobin in blood saturated, so that all deoxyhemoglobin is converted to oxyhemoglobin.	dv	**29**

Continued on next page

Oxygen Parameters, *Continued*

List of Oxygen Parameters *(continued)*

Symbol	Definition	Type	Eq.
$ctO_2(x)$	Extractable oxygen concentration of arterial blood. Defined as the amount of O_2 which can be extracted per liter of arterial blood at an oxygen tension of 5.0 kPa (38 mmHg), maintaining constant pH and pCO_2 [8].	dv	**30**
$\dot{D}O_2$	Oxygen delivery; the total amount of oxygen delivered to the whole organism per unit of time.	dv	**31**
$\dot{Q}_t$	Cardiac output; volume of blood delivered from the left ventricle into the aorta per unit of time. Also termed CO or C.O.	dv/in	**32**
$\dot{V}O_2$	Oxygen consumption; total amount of oxygen utilized by the whole organism per unit of time.	dv/in	**33**
$FO_2(I)$	Fraction of oxygen in dry inspired air.	in	
*F*Shunt	Relative physiological shunt or concentration-based shunt [5,8,9]. Calculated from the pulmonary shunt equation: $\frac{\dot{Q}_s}{\dot{Q}_t} = \frac{1}{1 + \frac{ctO_2(a-\bar{v})}{ctO_2(A) - ctO_2(a)}}$ if both arterial and mixed venous blood samples are used. May be estimated from one arterial sample by assuming a constant difference in the concentrations of total oxygen in arterial and mixed venous blood: $ctO_2(a-\bar{v}) = 2.3$ mmol / L (5.1 mL / dL)	dv	**34**
*F*Shunt (*T*)	*F*Shunt at patient temperature.	dv	**35**
RI	Respiratory Index; ratio between the oxygen tension difference of alveolar air and arterial blood and the oxygen tension of arterial blood.	dv	**36**
RI(*T*)	Respiratory Index; ratio between the oxygen tension difference of alveolar air and arterial blood and the oxygen tension of arterial blood at patient temperature.	dv	**37**

Continued on next page

Oxygen Parameters, *Continued*

List of Oxygen Parameters *(continued)*

Symbol	Definition	Type	Eq.
RQ	Respiratory quotient, ratio between the CO_2 production and the O_2 consumption.	in	
VO_2/V(dry air)	Volume fraction of oxygen in dry air.	dv	**52**
Q_x	Cardiac oxygen compensation factor of arterial blood defined as the factor by which the cardiac output should increase to allow release of 2.3 mmol/L (5.1 mL/dL) oxygen at a mixed venous pO_2 of 5.0 kPa (38 mmHg) [5,8].	dv	**38**
*V*CO	Volume of carbon monoxide added to the patient for measurement and calculation of *V*(B) [5].	in	
V(B)	Volume of blood, calculated when *F*COHb and *V*(CO) values are keyed in [5].	dv	**42**
$pO_2(\bar{v})$	Oxygen tension of mixed venous blood.	in	
$sO_2(\bar{v})$	Oxygen saturation of mixed venous blood	in	
*F*COHb(1)	The fraction of COHb measured before the CO-injection.	in	
*F*COHb(2)	The fraction of COHb measured after the CO-injection.	in	

Bilirubin

Bilirubin Bilirubin is measured by the ABL735 and ABL730 analyzers.

Symbol	Definition	Type	Eq.
*c*tBil	Concentration of total bilirubin in plasma. Total bilirubin includes its two forms: conjugated and unconjugated.	ms	

Electrolyte Parameters

List of Electrolyte Parameters

Electrolyte analysis establishes the patient's electrolyte status by measuring plasma concentrations of K^+, Na^+, Ca^{2+} and Cl^- ions by means of ion-selective electrodes.

All the electrolyte parameters are listed below. In the **Type** column the following symbols are used:

- ms for measured parameters
- dv for derived parameters

The **Eq.** column gives the number of the equation used to calculate the parameter - see *List of Equations* in this chapter.

Symbol	Definition	Type	Eq.
cK^+	Concentration of potassium ions in plasma.	ms	
cNa^+	Concentration of sodium ions in plasma.	ms	
cCa^{2+}	Concentration of calcium ions in plasma.	ms	
cCl^-	Concentration of chloride ions in plasma.	ms	
$cCa^{2+}(7.40)$	Concentration of calcium ions in plasma at pH 7.40.	dv	**45**
Anion Gap, K^+	Concentration difference between $cK^+ + cNa^+$ and $cCl^- + cHCO_3^-$.	dv	**43**
Anion Gap	Concentration difference between cNa^+ and $cCl^- + cHCO_3^-$.	dv	**44**

Metabolite Parameters

List of Metabolite Parameters

Metabolite analysis establishes the patient's plasma glucose and lactate concentrations by means of electrodes with enzymatic membranes.

In the **Type** column the following symbols 'ms' are used:

- ms for measured parameters
- dv for derived parameters

The following table lists the metabolite parameters:

Symbol	Definition	Type	Eq.
*c*Glu	Concentration of D-glucose in plasma.	ms	
*c*Lac	Concentration of L-lactate in plasma.	ms	
*m*Osm	Plasma osmolality	dv	**48**

Measured Parameters

Table The following table lists all the measured parameters available on the analyzer, independent of configuration.

	Unit	Measuring range	Reference range for adults' arterial blood at 37 °C (Ref. 10 unless otherwise stated)	Sex
Baro	mmHg, torr	450 - 800	-	-
	kPa	60.0 - 106.7	-	-
pH	-	6.300 - 8.000	7.35 - 7.45	m, f
cH^+	nmol/L	10.0 - 199.9	35.5 - 44.7	m, f
pCO_2*	mmHg, torr	5.0 - 99.9 100 - 250	35 – 48 32 - 45	m f
	kPa	0.67 - 9.99 10.0 - 33.3	4.67 - 6.40 4.27 - 6.00	m f
pO_2*	mmHg, torr	0.0 - 99.9 100 - 800	83 – 108	m, f
	kPa	0.00 - 9.99 10.0 - 99.9 100 - 107	11.07 - 14.40	m, f
ctHb	g/dL	0.00 - 0.99 1.0 - 27.7	13.5 - 17.5 12.0 - 16.0	m f
	g/L	0.0 - 9.9 10 - 277	135 - 175 120 - 160	m f
	mmol/L	0.00 - 0.99 1.0 - 17.2	8.4 - 10.9 7.4 - 9.9	m f
sO_2	%	0 - 100	95 - 99	m,f [11]
	fraction	0.0 - 1.000	0.95 - 0.99	m,f [11]
	mmHg, torr	* Gaseous samples included.		

Continued on next page

Measured Parameters, *Continued*

Table
(continued)

	Unit	Measuring range	Reference range for adults' arterial blood at 37 °C (Ref. 10 unless otherwise stated)	Sex
FO_2Hb	%	0 - 100	94 - 98	m,f
	fraction	0.0 - 1.000	0.94 - 0.98	
*F*COHb	%	0 – 100	0.5 - 1.5	m,f
	fraction	0.0 - 1.000	0.005 - 0.015	
*F*MetHb	%	0 – 100	0.0 - 1.5	m,f
	fraction	0.0 - 1.000	0.000 - 0.015	
cK^+	mmol/L meq/L	0.5 - 25.0	3.4 – 4.5	m,f
cNa^+	mmol/L, meq/L	7 - 350	136 - 146	m,f
cCa^{2+}	mmol/L	0.20 - 9.99	1.15 - 1.29	m,f [12]
	meq/L	0.40 - 19.8	2.30 - 2.58	m,f
	mg/dL	0.8 – 40.04		
cCl^-	mmol/L, meq/L	7 - 350	98 - 106	m,f
*c*Glucose	mmol/L	0.0 - 24.9 25 - 60	3.89 - 5.83	m,f
	mg/dL	0 - 1081	70 - 105	m,f
*c*Lactate	mmol/L	0.0 - 14.9 15 - 30	0.5 - 1.6	m,f
	mg/dL	0 - 270	4.5 - 14.4	m,f
	meq/L	0.0 - 14.9 15 - 30		

Continued on next page

Measured Parameters, *Continued*

Newborns and Infants The following measured parameters are applicable to newborns and infants. The age is specified under the parameter name.

Symbol	Unit	Measuring range	Reference range for neonatal arterial blood at 37 °C (Ref. 10 unless otherwise stated)		Sex
*F*HbF	%	0 - 100	≈80		m,f
	fraction	0.0 - 1.000	≈0.80		
*c*tBil (≤24 hrs)	µmol/L	0 - 1000	Premature	17 - 137	m,f
	mg/dL	0.0 – 58.5		1.0 - 8.0	
	mg/L	0 - 585		10 - 80	
	µmol/L	0 - 1000	Full-term	34 - 103	m,f
	mg/dL	0.0 – 58.5		2.0 - 6.0	
	mg/L	0 - 585		20 - 60	
*c*tBil (≤48 hrs)	µmol/L	0 - 1000	Premature	103 - 205	m,f
	mg/dL	0.0 – 58.5		6 - 12	
	mg/L	0 - 585		60 - 120	
	µmol/L	0 - 1000	Full-term	103 - 171	m,f
	mg/dL	0.0 – 58.5		6 - 10	
	mg/L	0 - 585		6 - 100	
*c*tBil (3-5 days)	µmol/L	0 - 1000	Premature	171 - 239	m,f
	mg/dL	0.0 – 58.5		10 - 14	
	mg/L	0 - 585		100 - 140	
	µmol/L	0 - 1000	Full-term	68 - 137	m,f
	mg/dL	0.0 – 58.5		4 - 8	
	mg/L	0 - 585		40 - 80	
*c*tBil (>1 month)	µmol/L	0 - 1000	3.4 - 17		m,f
	mg/dL	0.0 – 58.5	0.2 - 1.0		
	mg/L	0 - 585	2 - 10		

Input Parameters

Definition Input parameters are the parameters keyed in by the operator on the Patient Identification screen, or transferred from an interfaced database.

Table The table below lists all the input parameters available on the analyzer, independent of configuration.

Symbol	Unit	Input range
T	°C	15.0 - 45.0
	°F	59.0 - 113.0
$FO_2(I)$	%	0.0 - 100.0
	fraction	0.000 - 1.000
*c*tHb (if not measured)	g/dL	0.0 - 33.0
	g/L	0 - 330
	mmol/L	0.0 - 20.5
RQ	-	0.00 - 2.00
$pO_2(\bar{v})$	mmHg, torr	0.0 - 750.0
	kPa	0.00 - 100
$sO_2(\bar{v})$	%	0.0 - 100.0
	fraction	0.000 - 1.000
$\dot{Q}_t$	L/min	0.0 - 1000.0
$\dot{V}O_2$	mL/min	0 - xxxx
	mmol/min	0.0 - xxx.x
*V*CO	mL	0.0 - 1000.0
*p*50(st)	mmHg, torr	0.01 - 100.00
	kPa	0.001 - 13.332
*F*COHb(1), *F*COHb(2)	%	0.0 - 100.0
	fraction	0.000 - 1.000

Units for Derived Parameters

Definition

Derived parameters are calculated or estimated on the basis of measured and keyed in data. Calculations are made using equations programmed into the analyzer. The accuracy of the calculations depends on the input parameters keyed into the analyzer's computer.

Calculated Versus Estimated Parameters

If the calculation of a parameter requires input from the operator, but this input is not forthcoming, the analyzer will use certain default values (refer to the section *Default Values* in this chapter).

Not all input parameters are stored as defaults. In these instances the dependent derived parameter will not be reported if the relevant input parameter(s) is/are *not* entered.

If the default values are used in the calculation of a parameter, then a parameter is considered to be *estimated* ("e") rather than *calculated* ("c").

Acid-base Parameters

The table below lists the acid-base derived parameters.

(ABL73X corresponds to an ABL72X, but it can measure *c*tBil and *F*HbF).

Symbol	Unit	ABL 70X	ABL71X	ABL72X/ 73X	Input parameter	Sample type
pH(*T*)	-	c	c	c	*T*	
$cH^+(T)$	nmol/L	c	c	c	*T*	
$pCO_2(T)$	mmHg; torr	c	c	c	*T*	
	kPa	c	c	c		
$cHCO_3^-$(P)	mmol/L	c	c	c		
*c*Base(B)	mmol/L	c	c	c	*c*tHb	
		e	c	c		
*c*Base(B,ox)	mmol/L	e	c	c	*c*tHb	
		e	c	c		
*c*Base(Ecf)	mmol/L	c	c	c		
*c*Base(Ecf,ox)	mmol/L	e	c	c		
$cHCO_3^-$(P,st)	mmol/L	c	c	c	*c*tHb	
		e	c	c		
$ctCO_2$(P)	Vol %, mL/dL, mmol/L	c	c	c		

Continued on next page

Units for Derived Parameters, *Continued*

Acid-base Parameters *(continued)*

Symbol	Unit	ABL 70X	ABL 71X	ABL72X/73X	Input parameter	Sample type
*c*tCO_2(B)	Vol %, mL/dL, mmol/L	c	c	c	*c*tHb	
pH(st)	-	c	c	c		
VCO_2/*V*(dry air)	%	c	c	c		
	fraction					

Oximetry Parameters

The table below lists the oximetry derived parameters.

(ABL73X corresponds to an ABL72X, but it can measure *c*tBil and *F*HbF).

Symbol	Unit	ABL 70X	ABL 71X	ABL72X/73X	Input parameter	Sample type
Hct	%				*c*tHb	
	fraction	c	c	c		
sO_2	%					
	fraction	e				
FO_2Hb	%					
	fraction	e	e	c		
*F*HHb	%					
	fraction	e	e	c		

Continued on next page

Units for Derived Parameters, *Continued*

Oxygen Parameters

The table below lists the oxygen derived parameters.

(ABL73X corresponds to an ABL72X, but it can measure *c*tBil and *F*HbF).

Symbol	Unit	ABL 70X	ABL 71X	ABL72X/ 73X	Input parameter	Sample type
$pO_2(T)$	mmHg; torr	e	e	c	*T*	
	kPa					
pO_2(A)	mmHg; torr	c	c	c	FO_2(I)+RQ	Arterial,
	kPa	e	e	e		capillary
pO_2(A,*T*)	mmHg; torr	c	c	c	FO_2(I)+RQ+*T*	Arterial, capillary
	kPa	e	e	e		
*p*50	mmHg; torr	e	e	e*		
	kPa					
*p*50(*T*)	mmHg; torr	e	e	c*	*T*	
	kPa					
*p*50(st)	mmHg; torr	e	e	c*		
	kPa					
pO_2(A–a)	mmHg; torr	c	c	c	FO_2(I)+ RQ	Arterial,
	kPa	e	e	e		capillary
pO_2(A–a,*T*)	mmHg; torr	e	e	c	FO_2(I)+RQ+*T*	Arterial,
	kPa	e	e	e		capillary
pO_2(a/A)	%	c	c	c	FO_2(I)+RQ	Arterial,
	fraction	e	e	e		capillary
pO_2(a/A, *T*)	%	c	c	c	FO_2(I)+RQ+*T*	Arterial,
	fraction	e	e	e		capillary
pO_2(a)/FO_2(I)	%	c	c	c	FO_2(I)	Arterial,
	fraction					capillary
pO_2(a,*T*)/	%	c	c	c	FO_2(I)+*T*	Arterial,
FO_2(I)	fraction					capillary

Continued on next page

Units for Derived Parameters, *Continued*

Oxygen Parameters *(continued)*

Symbol	Unit	ABL 70X	ABL 71X	ABL72X/ 73X	Input parameter	Sample type
pO_2(x)	mmHg, torr	e	e*	c*	*c*tHb+*p*50(st)	Arterial, capillary
	kPa	-	e*	c*		
pO_2(x,*T*)	mmHg, torr	e	e*	c*	*c*tHb+*p*50(st)+*T*	Arterial, capillary
	kPa	-	e*	c*		
ctO_2(B)	Vol %, mL/dL, mmol/L	e	e	c	*c*tHb	
$ctO_2(a-\bar{v})$	Vol %, mL/dL, mmol/L	e	e	c	*c*tHb	Venous + Arterial
BO_2	Vol %, mL/dL, mmol/L	e	e	c	*c*tHb	
ctO_2(x)	Vol %, mL/dL, mmol/L	e	e*	c*	*c*tHb +*p*50(st)	Arterial, capillary
$\dot{D}O_2$	mL/min	e	e	c	$\dot{Q}_t$	Arterial, capillary
	mmol/min					
$\dot{Q}_t$	L/min	e	e	c	$\dot{V}O_2$	Venous + arterial
$\dot{V}O_2$	mL/min	e	e	c	$\dot{Q}_t$	Venous + arterial
	mmol/min					
*F*Shunt	%	e	e	c*	*c*tHb	Venous + arterial
	fraction					
*F*Shunt(*T*)	%	e	e	c*	*c*tHb + *T*	Venous + arterial
	fraction					
RI	%	c	c	c	FO_2(I)+RQ	Arterial, capillary
	fraction	e	e	e		

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Units for Derived Parameters, *Continued*

Oxygen Parameters *(continued)*

(ABL73X corresponds to an ABL72X, but it can measure *c*tBil and *F*HbF).

Symbol	Unit	ABL 70X	ABL 71X	ABL72X/ 73X	Input parameter	Sample type
RI(*T*)	%	e	e	c	FO_2(I)+RQ+*T*	Arterial, capillary
	fraction	e	e	e	*T*	
VO_2/*V*(dry air)	%	c	c	c		
	fraction					
Q_x	-	e	e*	c*	*c*tHb[1)]+*p*50(st) [1)]	Arterial, capillary
		e	e*	c*		
V(B)	L	c	c	c	*c*tHb+*V*CO+*F*COHb(1) +*F*COHb(2)	

***** If the sO_2 value for establishing the ODC is greater than 0.97, the calculation of the parameter is not performed unless the *p*50(st) value is keyed in.

[1)] If not measured, e.g. *c*tHb (or derived by analyzer, e.g. *p*50(st)).

Electrolyte Parameters

The table below lists the electrolyte derived parameters.

Symbol	Unit	ABL7X5	Input parameter	Sample type
Anion Gap, K^+	meq/L, mmol/L	c[2)]		
Anion Gap	meq/L, mmol/L	c[3)]		
cCa^{2+}(7.4)	meq/L, mg/dL, mmol/L	c[4)]		

2) If the analyzer includes K, Na and Cl electrodes.

3) If the analyzer includes Na and Cl electrodes.

4) If the analyzer includes Ca electrode.

List of Equations

Units and Symbols

All definitions and equations are based on SI units. If 'T' for patient temperature is not stated, the calculation is based on a temperature of 37.0 °C.

The following SI units are used:

concentration in mmol/L

temperature in °C

pressure in kPa

fractions (not %)

The following symbols are used in the equations:

$\log(x) = \log_{10}(x)$

$\ln(x) = \log_e(x)$

pH(*T*) **Eq. 1** [13]:

$$\mathrm{pH}(T) = \mathrm{pH}(37) - \left[0.0146 + 0.0065 \times \left(\mathrm{pH}(37) - 7.40\right)\right]\left[T - 37\right]$$

***c*H$^+$(*T*)** **Eq. 2**:

$$c\mathrm{H}^+(T) = 10^{(9 - \mathrm{pH}(T))}$$

***p*CO$_2$(*T*)** **Eq. 3** [4]:

$$p\mathrm{CO}_2(T) = p\mathrm{CO}_2(37) \times 10^{\left[0.021 \times (T - 37)\right]}$$

***c*HCO$_3^-$(P)** **Eq. 4** [5]:

$$c\mathrm{HCO}_3^-(\mathrm{P}) = 0.23 \times p\mathrm{CO}_2 \times 10^{(\mathrm{pH} - \mathrm{pK}_p)}$$

where

$$\mathrm{pK}_p = 6.125 - \log\left[1 + 10^{(\mathrm{pH} - 8.7)}\right]$$

*c*HCO$_3^-$(P) includes ions of hydrogen carbonate, carbonate, and carbamate in the plasma.

***c*Base(B)** **Eq. 5** [4,14]:

$$c\mathrm{Base(B)} = 0.5 \times \left(\frac{8a' - 0.919}{a'}\right) + 0.5 \times \sqrt{\left(\frac{0.919 - 8a'}{a'}\right)^2 - 4 \times \frac{24.47 - c\mathrm{HCO}_3^-(5.33)}{a'}}$$

Continued on next page

List of Equations, *Continued*

cBase(B) *(continued)*

where

Eq.	Description
5.1	$a' = 4.04 \times 10^{-3} + 4.25 \times 10^{-4}\, c\mathrm{tHb}$
5.2	$c\mathrm{HCO_3^-}(5.33) = 0.23 \times 5.33 \times 10^{\left[\frac{(\mathrm{pH(st)} - 6.161)}{0.9524}\right]}$
5.3	$\mathrm{pH(st)} = \mathrm{pH} + \log\left(\frac{5.33}{p\mathrm{CO_2}}\right) \times \left(\frac{\mathrm{pH(Hb)} - \mathrm{pH}}{\log p\mathrm{CO_2(Hb)} - \log(7.5006\, p\mathrm{CO_2})}\right)$
5.4	$\mathrm{pH(Hb)} = 4.06 \times 10^{-2}\, c\mathrm{tHb} + 5.98 - 1.92 \times 10^{(-0.16169\, c\mathrm{tHb})}$
5.5	$\log p\mathrm{CO_2(Hb)} = -1.7674 \times 10^{-2}\, c\mathrm{tHb} + 3.4046 + 2.12 \times 10^{(-0.15158\, c\mathrm{tHb})}$

cBase(B,ox) **Eq. 6** [4]:

$$c\mathrm{Base(B,ox)} = c\mathrm{Base(B)} - 0.3062 \times c\mathrm{tHb} \times (1 - s\mathrm{O_2})$$

If *c*tHb is not measured or keyed in, the default value will be used.

If $s\mathrm{O_2}$ is not measured, it will be calculated from equation 39.

cBase(Ecf) **Eq. 7** [5]:

*c*Base(Ecf) = *c*Base(B) for *c*tHb = 3 mmol/L

cBase(Ecf,ox) **Eq. 8**:

*c*Base(Ecf,ox) = *c*Base(B,ox) for *c*tHb = 3 mmol/L

cHCO₃⁻(P,st) **Eq. 9** [4,14]:

$$c\mathrm{HCO_3^-(P,st)} = 24.47 + 0.919 \times Z + Z \times a' \times (Z - 8)$$

where

Eq.	Description
9.1	$a' = 4.04 \times 10^{-3} + 4.25 \times 10^{-4} \times c\mathrm{tHb}$
9.2	$Z = c\mathrm{Base(B)} - 0.3062 \times c\mathrm{tHb} \times (1 - s\mathrm{O_2})$

ctCO₂(P) **Eq. 10** [4,5]:

$$c\mathrm{tCO_2(P)} = 0.23 \times p\mathrm{CO_2} + c\mathrm{HCO_3^-(P)}$$

Continued on next page

List of Equations, *Continued*

$ctCO_2(B)$ **Eq. 11** [5]:

$$ctCO_2(B) = 9.286 \times 10^{-3} \times pCO_2 \times ctHb \times \left[1 + 10^{(pH_{Ery} - pK_{Ery})}\right] + ctCO_2(P) \times \left(1 - \frac{ctHb}{21.0}\right)$$

where

Eq.	Description
9.1	$pH_{Ery} = 7.19 + 0.77 \times (pH - 7.40) + 0.035 \times (1 - sO_2)$
9.2	$pK_{Ery} = 6.125 - \log\left[1 + 10^{(pH_{Ery} - 7.84 - 0.06 \times sO_2)}\right]$

pH(st) **Eq. 12** [14]:

pH(st): see equations 5.3 - 5.5.

Hct **Eq. 13** [15]:

$Hct = 0.0485 \times ctHb + 8.3 \times 10^{-3}$

Hct cannot be calculated on the basis of a default *c*tHb value.

$pO_2(T)$ **Eq. 14** [16,17]:

The standard Oxygen Dissociation Curve (ODC) is used (i.e. *p*50(st) = 3.578 kPa) at actual values of pH, pCO_2, *F*COHb, *F*MetHb, *F*HbF (see equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*).

$pO_2(T)$ is calculated by a numerical method using:

$$t_i(T) = ctHb \times (1 - FCOHb - FMetHb) \times sO_{2,i}(T) + \alpha O_2(T) \times pO_{2,i}(T)$$

where

Eq.	Description	See…
14.1	S = ODC(P,A,*T*)	Eq. 47
14.2	$sO_{2,i}(T) = \frac{S \times (1 - FMetHb) - FCOHb}{1 - FCOHb - FMetHb}$	Eq. 46.12
14.3	$pO_{2,i}(T) = \frac{P}{1 + \frac{FCOHb}{sO_{2,i}(T) \times (1 - FCOHb - FMetHb)}}$	Eq. 46.10

Continued on next page

List of Equations, *Continued*

p*O$_2$(*T*) *(continued)

Eq.	Description	See…
14.4	$\alpha O_2 = 9.83\times10^{-3}\, e^{\left[-1.15\times10^{-2}(T\text{-}37.0)+2.1\times10^{-4}\times(T\text{-}37.0)^2\right]}$	
14.5	P is the variable during iteration.	
14.6	$A = ac\text{-}1.04\times\frac{\partial pH}{\partial T}\times(T\text{-}37.0)$	
14.7	T= patient temperature in °C (keyed-in).	
14.8	$\frac{\partial pH}{\partial(T)} = -1.46\times10^{-2} - 6.5\times10^{-3}\times(pH(37)-7.40)$ When $t_i(T) = t_i(37.0)$, then $pO_{2,i}(T) = pO_2(T)$	

***p*O$_2$(A)**

Eq. 15 [5]:

$$pO_2(A) = FO_2(I)\times(p(amb)\text{-}6.275) - pCO_2\times\left[RQ^{-1} - FO_2(I)\times(RQ^{-1}-1)\right]$$

If $FO_2(I)$ and RQ are not keyed in, they are set to the default values.

The calculation requires entering the sample type as "Arterial" or "Capillary".

***p*O$_2$(A,*T*)**

Eq. 16 [4,5,18]:

$$pO_2(A,T) = FO_2(I)\times[p(amb)\text{-}pH_2O(T)] - pCO_2(T)\times\left[RQ^{-1} - FO_2(I)\times(RQ^{-1}-1)\right]$$

$$pH_2O(T) = 6.275\times10^{\left[2.36\times10^{-2}\times(T-37.0)-9.6\times10^{-5}\times(T-37.0)^2\right]}$$

If $FO_2(I)$ and RQ are not keyed in, they are set to the default values.

The calculation requires entering the sample type as "Arterial" or "Capillary".

Continued on next page

List of Equations, *Continued*

***p*O$_2$(a)/*F*O$_2$(I)** **Eq. 17**:

$$pO_2(a)/FO_2(I) = \frac{pO_2(a)}{FO_2(I)}$$

The calculation cannot be performed on the basis of the default $FO_2(I)$ value, and the calculation requires entering the sample as “Arterial” or “Capillary”.

***p*O$_2$(a,*T*)/*F*O$_2$(I)** **Eq. 18**:

$$pO_2(a,T)/FO_2(I) = \frac{pO_2(a,T)}{FO_2(I)}$$

The calculation cannot be performed on the basis of the default $FO_2(I)$ value, and the calculation requires entering the sample as “Arterial” or “Capillary”.

***p*50** **Eq. 19** Refer to Eq. 46.10:

The ODC is determined as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*.

$$p50 = \frac{P}{1 + \frac{FCOHb}{0.5 \times (1 - FCOHb - FMetHb)}}$$

where

Description	See...
P = ODC(S,A,*T*)	Eq. 47
$S = \frac{0.5 \times (1 - FCOHb - FMetHb) + FCOHb}{1 - FMetHb}$	Eq. 46.11
A = a	
T = 37.0 °C	Eq. 46.13

***p*50(*T*)** **Eq. 20**:

The ODC is determined as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*.

$$p50(T) = \frac{P}{1 + \frac{FCOHb}{0.5 \times (1 - FCOHb - FMetHb)}}$$

where

Continued on next page

List of Equations, *Continued*

p*50(*T*) *(continued)

Description	See…
P = ODC(S,A,*T*)	Eq. 47
$S = \frac{0.5 \times \left(1 - F\text{COHb} - F\text{MetHb}\right) + F\text{COHb}}{1 - F\text{MetHb}}$	Eq. 46.11
$A = a - 1.04 \times \frac{\partial \text{pH}}{\partial (T)} \times \left(T - 37.0\right)$	
$\frac{\partial \text{pH}}{\partial (T)} = -1.46 \times 10^{-2} - 6.5 \times 10^{-3} \times \left(\text{pH}(37) - 7.40\right)$	
T = patient temperature in °C (keyed-in)	

***p*50(st)**

Eq. 21:

*p*50 is calculated for pH = 7.40, pCO_2 = 5.33 kPa, *F*COHb = 0, *F*MetHb = 0, *F*HbF = 0.

The ODC is determined as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*, see equation 47.

*p*50(st) = ODC(S,A,*T*)

where

Description	See…
S = 0.5	Eq. 46.11
A = a6 corresponds to pH = 7.40, pCO_2 = 5.33 kPa, *F*COHb = 0, *F*MetHb = 0, *F*HbF = 0	Eq. 46.13
T = 37.0 °C	

***p*O₂(A-a)**

Eq. 22:

$$pO_2(\text{A} - \text{a}) = pO_2(\text{A}) - pO_2(\text{a})$$

The calculation requires entering the sample type as “Arterial” or “Capillary”.

***p*O₂(A-a,*T*)**

Eq. 23:

$$pO_2(\text{A} - \text{a}, T) = pO_2(\text{A}, T) - pO_2(\text{a}, T)$$

The calculation requires entering the sample type as “Arterial” or “Capillary”.

Continued on next page

List of Equations, *Continued*

***p*O$_2$(a/A)** **Eq. 24**:

$$pO_2(a/A) = \frac{pO_2(a)}{pO_2(A)}$$

The calculation requires entering the sample type as "Arterial" or "Capillary".

***p*O$_2$(a/A,*T*)** **Eq. 25**:

$$pO_2(a/A,T) = \frac{pO_2(a,T)}{pO_2(A,T)}$$

The calculation requires entering the sample type as "Arterial" or "Capillary".

***p*O$_2$(x)** **Eq. 26** [8]:

(or p_x) The ODC is determined as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*.

*p*O$_2$(x) is calculated by a numerical method, using:

Eq.	Description	See…
26.1	S = ODC(P,A,*T*)	Eq. 47
26.2	$sO_{2,i} = \frac{S \times (1 - FMetHb) - FCOHb}{1 - FCOHb - FMetHb}$	Eq. 46.12
26.3	$pO_{2,i} = \frac{P}{1 + \frac{FCOHb}{sO_{2,i} \times (1 - FCOHb - FMetHb)}}$	Eq. 46.10
26.4	$t_i = ctHb \times (1 - FCOHb - FMetHb) \times sO_{2,i} + 9.83 \times 10^{-3} \times pO_{2,i}$	
26.5	A = a	
26.6	T = 37 °C	

When $t_i = ctO_2 - 2.3$ mmol/L, then $pO_{2,i} = pO_2(x)$, where *c*tO$_2$ is determined as described in equation 27.

*p*O$_2$(x) cannot be calculated on the basis of a default *c*tHb value.

*p*O$_2$(x) can only be calculated if the measured *s*O$_2$(a) ≤ 0.97 (or *p*50(st) keyed in).

The calculation requires entering the sample type as "Arterial" or "Capillary".

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List of Equations, *Continued*

ctO_2

Eq. 27 [5]:

$$ctO_2 = \alpha O_2 \times pO_2 + sO_2 \times (1 - FCOHb - FMetHb) \times ctHb$$

αO_2 is the concentrational solubility coefficient for O_2 in blood (here set to 9.83 x 10^{-3} mmol$L^{-1}$$kPa^{-1}$ at 37 °C [5,19].

ctO_2 cannot be calculated on the basis of a default *c*tHb value.

$ctO_2(a-\bar{v})$

Eq. 28:

$$ctO_2(a - \bar{v}) = ctO_2(a) - ctO_2(\bar{v})$$

where $ctO_2(a)$ and $ctO_2(\bar{v})$ are calculated from equation 27 for arterial and mixed venous blood, respectively. The calculation requires two measurements.

BO_2

Eq. 29 [7]:

$$BO_2 = ctHb \times (1 - FCOHb - FMetHb)$$

BO_2 cannot be calculated on the basis of a default *c*tHb value.

$ctO_2(x)$ (or c_x)

Eq. 30 [8]:

The ODC is determined, as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*.

$$ctO_2(x) = ctO_2(a) - t_i$$

where

Eq.	Description	See…
30.1	$t_i = ctHb \times (1 - FCOHb - FMetHb) \times sO_{2,i} + 9.83 \times 10^{-3} \times pO_2(5)$	
30.2	$pO_2(5) = 5.00$ kPa	
30.3	S = ODC(P,A,*T*)	Eq. 47
30.4	$P = pO_2(5) \times \left[1 + \frac{FCOHb}{sO_{2,i} \times (1 - FCOHb - FMetHb)}\right]$	Eq. 46.9
30.5	$sO_{2,i} = \frac{S \times (1 - FMetHb) - FCOHb}{(1 - FCOHb - FMetHb)}$	Eq. 46.12
30.6	A = a	
30.7	T = 37.0 °C	

Continued on next page

List of Equations, *Continued*

$ctO_2(x)$ (or c_x) *(continued)*

$ctO_2(a)$ is determined as described in equation 27.

$ctO_2(x)$ cannot be calculated on the basis of a default *c*tHb value.

$ctO_2(x)$ can only be calculated if the measured $sO_2(a) \leq 0.97$ (or if *p*50(st) is keyed in).

The calculation requires entering the sample type as "Arterial" or "Capillary".

$\dot{D}O_2$

Eq. 31:

$$\dot{D}O_2 = ctO_2 \times \dot{Q}_t$$

$\dot{Q}_t$ is the cardiac output and is an input parameter for calculation of $\dot{D}O_2$.

If $\dot{Q}_t$ is not keyed in, $\dot{D}O_2$ will not be calculated.

The calculation requires entering the sample type as "Arterial" or "Capillary".

$\dot{Q}_t$

Eq. 32:

$$\dot{Q}_t = \frac{\dot{V}O_2}{ctO_2(a - \bar{v})}$$

If $\dot{V}O_2$ is not keyed in, $\dot{Q}_t$ will not be calculated.

$\dot{V}O_2$

Eq. 33:

$$\dot{V}O_2 = \dot{Q}_t \times ctO_2(a - \bar{v})$$

If $\dot{Q}_t$ is not keyed in, $\dot{V}O_2$ will not be calculated.

***F*Shunt**

Eq. 34 [5]:

$$F\text{Shunt} = \frac{ctO_2(c) - ctO_2(a)}{ctO_2(c) - ctO_2(\bar{v})}$$

and

Eq.	Description
34.1	$F\text{Shunt} \cong \frac{ctO_2(A) - ctO_2(a)}{ctO_2(A) - ctO_2(\bar{v})}$

Continued on next page

List of Equations, *Continued*

F*Shunt *(continued)

Eq.	Description
34.2	$FShunt = \left[1 + \frac{ctO_2(a) - ctO_2(\bar{v})}{ctO_2(A) - ctO_2(a)}\right]^{-1}$

where

$ctO_2(c)$: total oxygen in pulmonary capillary blood

$ctO_2(a)$: total oxygen in arterial blood

$ctO_2(A)$: total oxygen in alveolar air. Oxygen tension = $pO_2(A)$

$ctO_2(\bar{v})$: total oxygen in mixed venous blood

34.3 $$ctO_2(a) = 9.83 \times 10^{-3}\, pO_2(a) + ctHb \times \left(1 - FCOHb - FMetHb\right) \times sO_2(a)$$

34.4 $$ctO_2(A) = 9.83 \times 10^{-3}\, pO_2(A) + ctHb \times \left(1 - FCOHb - FMetHb\right) \times sO_2(A)$$

34.5 $$ctO_2(\bar{v}) = 9.83 \times 10^{-3}\, pO_2(\bar{v}) + ctHb \times \left(1 - FCOHb - FMetHb\right) \times sO_2(\bar{v})$$

where:

$pO_2(a)$: oxygen tension in arterial blood; measured.

$pO_2(A)$: oxygen tension in alveolar blood. See equation 15.

$pO_2(\bar{v})$: oxygen tension in mixed venous blood; measured and then entered.

$sO_2(a)$: oxygen saturation in arterial blood; can be measured.

$sO_2(A)$: oxygen saturation in (alveolar) blood calculated from equation 39 where P = $pO_2(A)$. If $sO_2(a) > 0.97$, a keyed-in $p50(st)$ will be used to determine the ODC. If $sO_2(a) > 0.97$ and no $p50(st)$ has been keyed in, the default value (3.578 kPa) will be used to determine the ODC.

$sO_2(\bar{v})$: oxygen saturation in mixed venous blood.

If not keyed in, it will be calculated from equation 39 where P = $pO_2(\bar{v})$. If $sO_2(a) > 0.97$, a keyed-in $p50(st)$ will be used to determine the ODC.

The calculation requires entering the sample type as “Arterial” or “Capillary”.
If $sO_2(a) > 0.97$ and no $p50(st)$ has been keyed in, the default value (3.578 kPa) will be used to estimate the ODC.

If no venous sample is measured, *F*Shunt is estimated assuming:

$ctO_2(a) - ctO_2(\bar{v})$ = 2.3 mmol/L in equation 34.2

Continued on next page

List of Equations, *Continued*

***F*Shunt(*T*)** **Eq. 35** [5,16]:

$$F\text{Shunt}(T) = \left[1 + \frac{c\text{tO}_2(\text{a},T) - c\text{tO}_2(\bar{\text{v}},T)}{c\text{tO}_2(\text{A},T) - c\text{tO}_2(\text{a},T)} \right]^{-1}$$

where

$c\text{tO}_2(\text{a},T)$: total oxygen in arterial blood at patient temperature

$c\text{tO}_2(\text{A},T)$: total oxygen in alveolar blood at patient temperature $c\text{tO}_2(\bar{\text{v}},T)$: total oxygen in mixed venous blood at patient temperature

Eq.	Description	See…
35.1	$c\text{tO}_2(\text{a},T) = c\text{tO}_2$ calculated from equation 25 for arterial $p\text{O}_2$ and $s\text{O}_2$ values at 37 °C.	
35.2	$c\text{tO}_2(\text{A},T) = \alpha\text{O}_2(T) \times p\text{O}_2(\text{A},T) + c\text{tHb} \times \left(1 - F\text{COHb} - F\text{MetHb}\right) \times s\text{O}_2(\text{A},T)$	
35.3	$\alpha O_2(T) = 9.83 \times 10^{-3} \text{e}^{\left[-1.15\times10^{-2}\times(T-37.0)+2.1\times10^{-4}\times(T-37.0)^2\right]}$	
35.4	$p\text{O}_2(\text{A},T)$ is calculated from equation 15.	
35.5	$s\text{O}_2(\text{A},T) = \text{S}$	
35.6	$\text{S} = \text{ODC}(\text{P},\text{A},T)$	Eq. 47
35.7	$\text{P} = p\text{O}_2(\text{A},T)$	
35.8	$\text{A} = \text{a} - 1.04 \times \frac{\partial \text{pH}}{\partial(T)} \times \left(T - 37.0\right)$	
35.9	T = patient temperature (keyed-in)	
35.10	$\frac{\partial \text{pH}}{\partial(T)} = 1.46 \times 10^{-2} - 6.5 \times 10^{-3}\left(\text{pH}(37) - 7.40\right)$ If $s\text{O}_2(\text{a}) > 0.97$, a keyed-in $p50$(st) will be used to determine the ODC. If $s\text{O}_2(\text{a}) > 0.97$ and no $p50$(st) has been keyed in, the default value (3.578 kPa) will be used to determine the ODC.	
35.11	$c\text{tO}_2(\bar{\text{v}},T) = c\text{tO}_2(\bar{\text{v}})$ at 37 °C is calculated from equation 27 for mixed venous blood values of $p\text{O}_2$ and $s\text{O}_2$. If $s\text{O}_2(\bar{\text{v}}) > 0.97$, a keyed-in $p50$(st) will be used to determine the ODC. If $s\text{O}_2(\bar{\text{v}}) > 0.97$ and no $p50$(st) has been keyed in, the default value (3.578 kPa) will be used to estimate the ODC. If no mixed venous sample is measured, the FShunt(T) is estimated assuming $c\text{tO}_2(\text{a},T) - c\text{tO}_2(\bar{\text{v}},T) = 2.3$ mmol/L in equation 35.	

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List of Equations, *Continued*

RI **Eq. 36**:

$$\mathrm{RI} = \frac{p\mathrm{O}_2(\mathrm{A}) - p\mathrm{O}_2(\mathrm{a})}{p\mathrm{O}_2(\mathrm{a})}$$

The calculation requires entering the sample type as "Arterial" or "Capillary".

RI(*T*) **Eq. 37**:

$$\mathrm{RI}(T) = \frac{p\mathrm{O}_2(\mathrm{A},T) - p\mathrm{O}_2(\mathrm{a},T)}{p\mathrm{O}_2(\mathrm{a},T)}$$

The calculation requires entering the sample type as "Arterial" or "Capillary".

Q_x **Eq. 38** [8]:

The ODC is determined as described in equations 46 - 47 in the section *Oxyhemoglobin Dissociation Curve*.

$$Q_x = \frac{2.3}{c\mathrm{tO}_2(\mathrm{a}) - \mathrm{t_i}}$$

Eq.	Description	See…
38.1	$\mathrm{t_i} = c\mathrm{tHb} \times \left(1 - F\mathrm{COHb} - F\mathrm{MetHb}\right) \times s\mathrm{O}_{2,\mathrm{i}} + 9.83 \times 10^{-3}\, p\mathrm{O}_2(5)$	
38.2	$p\mathrm{O}_2(5) = 5.00$ kPa	
38.3	$\mathrm{S} = \mathrm{ODC}(\mathrm{P},\mathrm{A},T)$	
38.4	$P = p\mathrm{O}_2(5) \times \left[1 + \frac{F\mathrm{COHb}}{s\mathrm{O}_{2,\mathrm{i}} \times \left(1 - F\mathrm{COHb} - F\mathrm{MetHb}\right)}\right]$	Eq. 46.9
38.5	$s\mathrm{O}_{2,\mathrm{i}} = \frac{\mathrm{S} \times \left(1 - F\mathrm{MetHb}\right) - F\mathrm{COHb}}{1 - F\mathrm{COHb} - F\mathrm{MetHb}}$	Eq. 46.12
38.6	$\mathrm{A} = \mathrm{a}$	
38.7	$T = 37.0\ ^{\circ}\mathrm{C}$	

$c\mathrm{tO}_2(\mathrm{a})$ is determined as described in equation 27.

Qx cannot be calculated on the basis of a default *c*tHb value.

Qx can only be calculated if the measured $s\mathrm{O}_2(\mathrm{a}) \le 0.97$ (or if $p50(\mathrm{st})$ is keyed in).

The calculation requires entering the sample type as "Arterial" or "Capillary".

Continued on next page

List of Equations, *Continued*

sO_2

Eq. 39:

The ODC is determined as described in equation 46 (points I and III). See the section *Oxyhemoglobin Dissociation Curve*.

$$sO_2 = \frac{S \times (1 - FMetHb) - FCOHb}{1 - FCOHb - FMetHb}$$

where

Description	See…
S = ODC(P,A,*T*)	
$P = pO_2 + \frac{pO_2 \times FCOHb}{sO_2 \times (1 - FCOHb - FMetHb)}$	Eq. 46.9
A = a	
$T = 37.0\ ^{o}C$	

FO_2Hb

Eq. 40:

$$FO_2Hb = sO_2 \times (1 - FCOHb - FMetHb)$$

If sO_2 is not measured, it will be calculated from equation 39.

If dyshemoglobins (*F*COHb, *F*MetHb) are not known, they are set to the default values.

***F*HHb**

Eq. 41:

$$FHHb = 1 - sO_2 \times (1 - FCOHb - FMetHb) - FCOHb - FMetHb$$

If sO_2 is not measured, it will be calculated from equation 39.

If dyshemoglobins (*F*COHb, *F*MetHb) are not known, they are set to the default values.

***V*(B)**

Eq. 42 [5]:

$$V(B) = \frac{1 \times 10^3 \times V(CO)}{24 \times (FCOHb(2) - FCOHb(1)) \times 0.91 \times ctHb}$$

Continued on next page

List of Equations, *Continued*

V*(B) *(continued)

Eq.	Action
42.1	$V(B) = \frac{V(\mathrm{CO})}{2.184 \times 10^{-2} \times \left(F\mathrm{COHb}(2) - F\mathrm{COHb}(1)\right) \times c\mathrm{tHb}}$
42.2	V(CO) = volume (in mL) of carbon monoxide injected according to the procedure and the value keyed-in.
42.3	FCOHb(1) = fraction of COHb measured before the CO injection
42.4	FCOHb(2) = fraction of COHb measured after the CO injection

Anion Gap,K^+ **Eq. 43**:

$$\text{Anion Gap},\mathrm{K}^+ = c\mathrm{Na}^+ + c\mathrm{K}^+ - c\mathrm{Cl}^- - c\mathrm{HCO}_3^-(\mathrm{P})$$

Anion Gap **Eq. 44:**

$$\text{AnionGap} = c\mathrm{Na}^+ - c\mathrm{Cl}^- - c\mathrm{HCO}_3^-(\mathrm{P})$$

***c*Ca^{2+}(7.4)** **Eq. 45** Ref. [12]:

$$c\mathrm{Ca}^{2+}(7.4) = c\mathrm{Ca}^{2+}\left[1 - 0.53 \times \left(7.40 - \mathrm{pH}\right)\right]$$

Due to biological variations this equation can only be used for a pH value in the range 7.2 - 7.6.

Eq. 46-47 See Oxyhemoglobin Dissociation Curve (ODC) further in this chapter.

***m*Osm** **Eq. 48:**

$$m\mathrm{Osm} = 2c\mathrm{Na}^+ + c\mathrm{Glu}$$

***F*HbF** **Eq. 49:**

An iterative method is used to calculate FHbF. The input parameters are $s\mathrm{O}_2$, ceHb (effective hemoglobin concentration), and $c\mathrm{O}_2$HbF (concentration of fetal oxyhemoglobin).

In the calculations the following are assumed: pH = 7.4, $p\mathrm{CO}_2$ = 5.33 kPa, FCOHb = 0, FMetHb = 0, cDPG = 5 mmol/L, and temp = 37 °C.

Step	Description	
1.	An estimate of FHbF is made: $F\mathrm{HbF}_{est}$ = 0.8	
2.	$p\mathrm{O}_{2,est}$ = ODC ($s\mathrm{O}_2$,A,T); where the constant A depends on FHbF = $F\mathrm{HbF}_{est}$	See Eq. 47

Continued on next page

List of Equations, *Continued*

F*HbF *(continued)

Step	Description	
3.	sO_2 (for fetal blood) = ODC ($pO_{2,est}$, A,*T*); where *F*HbF = 1	See Eq.47
4.	$cO_2HbF_{est} = sO_2$ (fetal blood) × *c*eHb × $FHbF_{est}$	
5.	$\Delta FHbF_{est} = \frac{cO_2HbF_{meas.} - cO_2HbF_{est}}{c\text{eHb}}$	
6.	If $\lvert\Delta FHbF_{est}\rvert \geq 0.001$, proceed to step **7**. If $\lvert\Delta FHbF_{est}\rvert < 0.001$, proceed to step 9.	
7.	$FHbF_{est,\,new} = FHbF_{est,\,old} + \Delta FHbF_{est}$	
8.	Return to step **2**.	
9.	End of iteration. The value for *F*HbF has converged.	

***p*O$_2$(x,*T*)**

Eq. 50 [8]:

The ODC is determined as described in equations 46 - 47 in *Oxyhemoglobin Dissociation Curve*.

$pO_2(x)$ is calculated by a numerical method, using:

Eq.	Description	See…
50.1	S = ODC(P,A,*T*)	Eq. 47
50.2	$sO_{2,i}(T) = \frac{S \times (1 - FMetHb) - FCOHb}{1 - FCOHb - FMetHb}$	Eq. 46.12
50.3	$pO_{2,i}(T) = \frac{P}{1 + \frac{FCOHb}{sO_{2,i}(T) \times (1 - FCOHb - FMetHb)}}$	Eq. 46.10
50.4	$t_i(T) = ctHb \times (1 - FCOHb - FMetHb) \times sO_{2,i}(T) + \alpha O_2(T) \times pO_{2,i}(T)$	
50.5	A = a	
50.6	*T* = patient temperature	
50.7	$\alpha O_2(T) = 0.00983 \times e^{\left[-0.115 \times (T-37) + 21 \times 10^{-5} \times (T-37)^2\right]}$	

Continued on next page

List of Equations, *Continued*

p*O$_2$(x,*T*) *(continued)

Eq.	Description	See…
50.8	$pO_{2,i} = pO_2(x,T)$ when $t_i(T) = ctO_2(37\ °C) - 2.3$ mmol/L	

*p*O$_2$(x,*T*) is calculated in accordance with OSA V3.0.

*p*O$_2$(x,*T*) can only be calculated if the measured *s*O$_2$(a) ≤ 0.97 (or *p*50(st) keyed in).

*p*O$_2$(x,*T*) is tagged with "?" if any of the following parameters: *s*O$_2$, *F*MetHb, *F*COHb, *p*O$_2$, *p*CO$_2$, pH or *c*tHb is tagged with "?".

The calculation requires entering the sample type as “Arterial” or “Capillary”.

***V*CO$_2$/*V*(dry air)** **Eq. 51**:

$$VCO_2/V(\text{dry air}) = \frac{pCO_2}{p(\text{amb}) - 6.275}$$

***V*O$_2$/*V*(dry air)** **Eq. 52**:

$$VO_2/V(\text{dry air}) = \frac{pO_2}{p(\text{amb}) - 6.275}$$

Oxyhemoglobin Dissociation Curve (ODC)

ODC Equations

These equations account for the effect of *F*COHb on the shape of the Oxyhemoglobin Dissociation Curve (ODC) in accordance with the Haldane equation.

Eq. 46 [16,18]:

$$y - y^{o} = (x - x^{o}) + h \times \tanh\left[k^{o}\left(x - x^{o}\right)\right]$$

where $k^{o} = 0.5343$

Eq.	Description
46.1	$x = \ln p$
46.2	$y = \ln \frac{s}{1 - s}$
46.3	$y^{o} = \ln \frac{s^{o}}{1 - s^{o}}$ where $s^{o} = 0.867$
46.4	$x^{o} = x^{oo} + a + b = \ln(p^{oo}) + a + b$ where $p^{oo} = 7$ kPa

The actual position of the ODC in the coordinate system (ln(s/(1–s)) vs ln(*p*)) used in the mathematical model, is expressed by equations 46.3 and 46.4.

The symbols 'a' and 'b' reflect the ODC displacement from the reference position to its actual position in this coordinate system:

'a' describes the displacement at 37 °C.
'b' the additional displacement due to the patient temperature difference from 37 °C.

The ODC Reference Position

The reference position of the ODC was chosen to be the one that corresponds to the default value for *p*50(st) = 3.578 kPa, which is traditionally considered the most likely value of *p*50 for adult humans under standard conditions, namely:

pH = 7.40

pCO_2 = 5.33 kPa

*F*COHb, *F*MetHb, *F*HbF = 0

*c*DPG = 5 mmol/L

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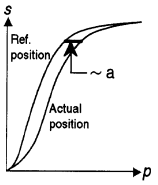
Oxyhemoglobin Dissociation Curve (ODC), *Continued*

The ODC Displacement

The ODC displacement which is described by 'a' and 'b' in the coordinate system ($\ln(s/(1-s))$ vs $\ln(p)$), is given by the change in $p50$ from the default to its actual value in a more common coordinate system (sO_2, pO_2).

Eq.	Description
46.5	$x - x^o = \ln\frac{p}{7} - a - b$
46.6	$h = h^o + a$ where $h^o = 3.5$
46.7	$b = 0.055 \times (T - T^o)$ $T^o = 37\ ^oC$
46.8	$p = pO_2 + M \times pCO$ where M×*p*CO is taken from the Haldane equation [20]: $\frac{pO_2}{cO_2Hb} = M \times \frac{pCO}{cCOHb}$, to give eq. 46.9
46.9	$p = pO_2 + \frac{pO_2}{sO_2} \times \left[\frac{FCOHb}{1 - FCOHb - FMetHb}\right]$ or equation 46.10
46.10	$pO_2 = \frac{p \times \left[sO_2 \times (1 - FCOHb - FMetHb)\right]}{1 + FCOHb}$



The ordinate, *s*, may loosely be termed the combined oxygen/carbon monoxide saturation of hemoglobin and is described by equation 46.11 below:

Eq.	Description
46.11	$s = \frac{cO_2Hb + cCOHb}{cO_2Hb + cCOHb + cHHb}$ or $= \frac{sO_2 \times (1 - FCOHb - FMetHb) + FCOHb}{1 - FMetHb}$
46.12	$sO_2 = \frac{s \times (1 - FMetHb) - FCOHb}{1 - FCOHb - FMetHb}$

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Oxyhemoglobin Dissociation Curve (ODC), *Continued*

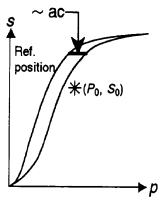
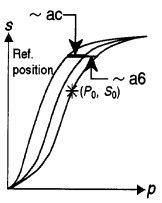
The Actual ODC Position

The actual position of the ODC at 37 °C for a given sample is, in principle, determined in two steps:

1. The calculation of the combined effect on the ODC position at 37 °C of all known causes for displacement (= ac in equation 46.13), and based on this position:
2. The computation by a numerical method of the actual position of the ODC curve by shifting it to pass through the known set of coordinates (P_0, S_0).

Eq.	Description
46.13	$a = ac + a6$
46.14	$ac = a1 + a2 + a3 + a4 + a5$
46.15	$a1 = -0.88 \times (pH - 7.40)$
46.16	$a2 = 0.048 \times \ln \frac{pCO_2}{5.33}$
46.17	$a3 = -0.7 \times F\text{MetHb}$
46.18	$a4 = (0.06 - 0.02\,F\text{HbF}) \times (c\text{DPG} - 5)$
46.19	$a5 = -0.25 \times F\text{HbF}$

Determining the Actual Displacement

Step	Description
(I):  	pO_2, sO_2 can be used. If $sO_2 > 0.97$, the calculation is based on (II) or (III) - *see below*. Coordinates (P_0, S_0) are calculated from equations (46.9) and (46.11). If *F*COHb and *F*MetHb are not known, the default values are used. The ODC is shifted from the reference position to a position which corresponds to the effect of all measured parameters according to step (I). The magnitude of the shift is "ac". The ODC is then further shifted to pass through the point (P_0, S_0). The magnitude of the shift is "a6".

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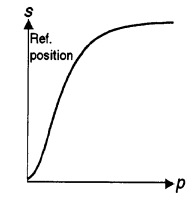
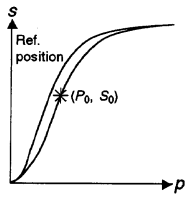
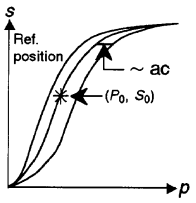
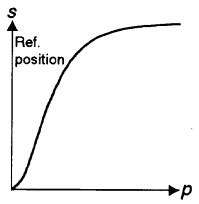
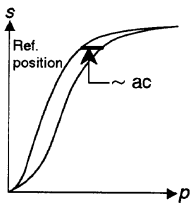
Oxyhemoglobin Dissociation Curve (ODC), *Continued*

Determining the Actual Displacement *(continued)*

Step	Description
(II): 	sO_2 > 0.97 (or erroneous) and p50(st) is keyed in. Coordinates (P_0, S_0) are calculated from (p50(st), 0.5) using equations 46.9 and 46.11. Reference position of the ODC.
	The ODC is shifted from the reference position to pass through the point (P_0, S_0). In this position, the ODC reflects the p50(st) of the patient, i.e., the particular patient but at standard conditions.
	The ODC is further shifted, as determined by the effect of the measured parameters ("ac"), to its actual position. This position reflects the p50(act) of the patient.
(III): 	sO_2 > 0.97 (or erroneous) and no p50(st) has been keyed in. Reference position of the ODC.
	The position of the actual ODC can now be approximated from the reference position, using the actual values of pH, pCO$_2$, FCOHb, FMetHb and FHbF to determine the shift 'ac'.

NOTE: *The curves are used only to illustrate the principles of the ODC determination*

Continued on next page

Oxyhemoglobin Dissociation Curve (ODC), *Continued*

Coordinates on the ODC

Calculation of a set of coordinates on the ODC is symbolized by:

Eq. 47:

S = ODC(P, A, *T*) or P = ODC(S, A, *T*)

These equations are symbolic representations of the relationship between saturation (S), tension (P), displacement (A), and temperature (*T*).

To calculate S or P and to further calculate sO_2 and pO_2, the other variables should be specified. S and P are calculated using numerical methods.

P is input to equation 46.1.

S is input to equation 46.2.

A is input to equation 46.5.

T is input to equation 46.7.

Conversion of Units

SI-units

The equations stated above are based on the SI-unit-system. If parameters are known in other units, they must be converted into a SI-unit before entering the equations. The result will be in a SI-unit.

After the calculation the result may be converted to the desired unit. Conversion of units may be performed, using the equations stated below:

Temperature

$$T\,°\mathrm{F} = \frac{9}{5}T\,^{o}C + 32$$

$$T\,°\mathrm{C} = \frac{5}{9}(T\,^{o}F - 32)$$

***c*K$^+$, *c*Na$^+$, *c*Cl$^-$**

cX (meq/L) = cX (mmol/L) where X is K^+, Na^+ or Cl^-.

***c*Ca^{2+}**

$c\mathrm{Ca}^{2+}$ (meq/L) = 2 × $c\mathrm{Ca}^{2+}$ (mmol/L) or

$c\mathrm{Ca}^{2+}$ (mg/dL) = 4.008 × $c\mathrm{Ca}^{2+}$ (mmol/L)

$c\mathrm{Ca}^{2+}$ (mmol/L) = 0.5 × $c\mathrm{Ca}^{2+}$ (meq/L)or

$c\mathrm{Ca}^{2+}$ (mmol/L) = 0.2495 × $c\mathrm{Ca}^{2+}$ (mg/dL)

Pressure

p (mmHg) = p (torr) = 7.500638 × p (kPa)

p (kPa) = 0.133322 × p(mmHg) = 0.133322 × p (torr)

***c*tHb**

[4]

ctHb (g/dL) = 1.61140 × ctHb (mmol/L)

ctHb (g/L) = 16.1140 × ctHb (mmol/L) or

ctHb (mmol/L) = 0.62058 × ctHb (g/dL)

ctHb (mmol/L) = 0.062058 × ctHb (g/L)

***c*tCO$_2$, *c*tO$_2$, *c*tO$_2$(a–$\bar{v}$), *B*O$_2$**

x (Vol %) = 2.241 × x (mmol/L)

x (Vol %) = x (mL/dL)

x (mmol/L) = 0.4462 × (mL/dL)

where x is $c\mathrm{tCO}_2$, $c\mathrm{tO}_2$, $c\mathrm{tO}_2(a-\bar{v})$, $B\mathrm{O}_2$

Continued on next page

Conversion of Units, *Continued*

$\dot{V}O_2$ $\dot{V}O_2$ (mmol/L)/min = $\dot{V}O_2$/22.41 (mL/dL)/ min

***c*Glucose** [22]

*c*Glucose (mg/dL) = 18.016 × *c*Glucose (mmol/L) or

*c*Glucose (mmol/L) = 0.055506 × *c*Glucose (mg/dL)

***c*Lactate** [22]

*c*Lactate (mg/dL) = 9.008 × *c*Lactate (mmol/L) or

*c*Lactate (mmol/L) = 0.11101 × *c*Lactate (mg/dL)

*c*Lactate (meq/L) = *c*Lactate (mmol/L)

(conversion based on the molecular weight of lactic acid)

***c*tBil**

*c*tBil (µmol/L) = 17.1 × *c*tBil (mg/dL)

*c*tBil (µmol/L) = 1.71 × *c*tBil (mg/L) or

*c*tBil (mg/dL) = 0.0585 × *c*tBil (µmol/L)

*c*tBil (mg/L) = 0.585 × *c*tBil (µmol/L)

NOTE: *All conversions of units are made by the analyzer.*

Default Values

Values

The following default values are used in the ABL700 Series analyzers, if other values are not keyed-in.

T	=	37.0 °C (99 °F)
FO_2(I)	=	0.21 (21.0 %)
RQ	=	0.86
*c*tHb	=	9.3087 mmol/L, (15.00 g/dL or 150 g/L)
*F*COHb	=	0.004 (0.4 %)
*F*MetHb	=	0.004 (0.4 %)
*p*50(st)	=	3.578 kPa (26.84 mmHg)

Altitude Correction

Equation for Altitude Correction

The barometric pressure is measured by the analyzer's built-in barometer, and the effect of barometric pressure on blood samples is compensated by the analyzer's software.

Quality control result for pO_2 obtained on aqueous quality control solutions at low barometric pressure (at high altitudes) is affected as the properties of aqueous solutions differ from those of blood. The deviation from the pO_2 value obtained at sea level can be expressed by an altitude correction that can be added to the control ranges.

The relationship between the altitude and barometric pressure can be expressed by the following equation:

$$A = 16000 \times (1 + 0.004T) \times \frac{B_{ref} - B_{act}}{B_{ref} + B_{act}}$$

where:

A = altitude in m

T = temperature in °C

B_{ref} = standard barometric pressure at sea level = 760 mmHg

B_{act} = actual barometric pressure in mmHg.

Reference:

Kokholm G, Larsen E, Jensen ST, ChristiansenTF. 3rd ed. Blood gas measurements at high altitudes. Copenhagen: Radiometer Medical A/S, 1991. Available as AS109.

References

List of References

1. The Deep Picture™, critical information from blood gas analysis. Copenhagen: Radiometer Medical A/S, 1993: 1-14.
2. Wandrup JH. Physicochemical logic and simple symbol terminology of oxygen status. Blood Gas News 1993; 2,1: 9-11.
3. Siggaard-Andersen O, Durst RA, Maas AHJ. Approved recommendation (1984) on physicochemical quantities and units in clinical chemistry. J Clin Chem Clin Biochem 1987; 25: 369-91.
4. Siggaard-Andersen O. The acid-base status of the blood. 4th revised ed. Copenhagen: Munksgaard, 1976.
5. Siggaard-Andersen O, Wimberley PD, Fogh-Andersen N, Gøthgen IH. Measured and derived quantities with modern pH and blood gas equipment: calculation algorithms with 54 equations. Scand J Clin Lab Invest 1988; 48, Suppl 189: 7-15.
6. Burnett RW, Noonan DC. Calculations and correction factors used in determination of blood pH and blood gases. Clin Chem 1974; 20,12: 1499-1506.
7. Wimberley PD, Siggaard-Andersen O, Fogh-Andersen N, Zijlstra WG, Severinghaus JW. Hemoglobin oxygen saturation and related quantities: definitions, symbols and clinical use. Scand J Clin Lab Invest 1990; 50: 455-59. Available as AS104.
8. Siggaard-Andersen O, Gøthgen IH, Wimberley PD, Fogh-Andersen N. The oxygen status of the arterial blood revised: relevant oxygen parameters for monitoring the arterial oxygen availability. Scand J Clin Lab Invest 1990; 50, Suppl 203: 17-28. Available as AS108.
9. Wandrup JH. Oxygen uptake in the lungs. Blood Gas News 1992; 1,1: 3-5.
10. Tietz NW, Logan NM. Reference ranges. In: Tietz NW, ed. Fundamentals of clinical chemistry. 3rd ed. Philadelphia: WB Saunders Company, 1987: 944-75.
11. Siggaard-Andersen O, Wimberley PD, Fogh-Andersen N, Gøthgen IH. Arterial oxygen status determined with routine pH/blood gas equipment and multi-wavelength hemoximetry: reference values, precision and accuracy. Scand J Clin Lab Invest 1990; 50, Suppl 203: 57-66. Available as AS106.
12. Siggaard-Andersen O, Thode J, Wandrup JH. The concentration of free calcium ions in the blood plasma ionized calcium. In: Siggaard-Andersen O, ed. Proceedings of the IFCC expert panel on pH and blood gases held at Herlev Hospital 1980. Copenhagen: Radiometer Medical A/S, 1981: 163-90. Available as AS79.
13. Severinghaus JW. Blood gas calculator. J Appl Physiol 1966; 21,3: 1108-16. Available as ST36.
14. Christiansen TF. An algorithm for calculating the concentration of the base excess of blood. In: Siggaard-Andersen O, ed. Proceedings of the IFCC expert panel on pH and blood gases held at Herlev Hospital 1980. Copenhagen: Radiometer Medical A/S, 1981: 77-81.

Continued on next page

References, *Continued*

List of References *(continued)*

15. Kokholm G. Simultaneous measurements of blood pH, pCO_2, pO_2 and concentrations of hemoglobin and its derivatives - a multicenter study. Scand J Clin Lab Invest 1990; 50, Suppl 203: 75-86. Available as AS107.
16. Siggaard-Andersen O, Wimberley PD, Gøthgen IH, Siggaard-Andersen M. A mathematical model of the hemoglobin-oxygen dissociation curve of human blood and of the oxygen partial pressure as a function of temperature. Clin Chem 1984; 30: 1646-51.
17. Siggaard-Andersen O, Wimberley PD, Gøthgen IH, Fogh-Andersen N, Rasmussen JP. Variability of the temperature coefficients for pH, pCO_2 and pO_2 in blood. Scand J Clin Lab Invest 1988; 48, Suppl 189: 85-88.
18. Siggaard-Andersen O, Siggaard-Andersen M. The oxygen status algorithm: a computer program for calculating and displaying pH and blood gas data. Scand J Clin Lab Invest 1990; 50, Suppl 203: 29-45.
19. Bartels H, Christoforides C, Hedley-Whyte J, Laasberg L. Solubility coefficients of gases. In: Altman PL, Dittmer DS, eds. Respiration and circulation. Bethesda, Maryland: Fed Amer Soc Exper Biol, 1971: 16-18.
20. Roughton FJW, Darling RC. The effect of carbon monoxide on the oxyhemoglobin dissociation curve. Am J Physiol 1944; 141: 17-31.
21. Engquist A.. Fluids electrolytes nutrition. Copenhagen: Munksgaard, 1985: 56-68 and 118.
22. Olesen H. *et al*. A proposal for an IUPAC/IFCC recommendation, quantities and units in clinical laboratory sciences. IUPAC/IFCC Stage 1, Draft 1, 1990: 1-361.

7. Solutions and Gas Mixtures

Introduction

This chapter gives information about all the solutions and gases used with the ABL700 Series analyzer, their composition, use, and consumption.

The Certificates of Traceability for the calibrating solutions are found at the end of the chapter.

Contents

This chapter contains the following topics.

General Information

Introduction The ABL700 Series analyzers and their electrodes utilize various solutions and gases, the compositions and uses of which are described in this chapter.

Solution Numbers Each solution has a number for identification purposes. The number starts with S (for solution) and is followed by 4 or 5 digits. The name of the solution comes after the number.

Example: S7370 Cleaning Solution

Gas Names The two gases or gas mixtures used by the analyzer are named Gas 1 and Gas 2.

***In Vitro* Diagnostic Use** All the solutions described in this chapter are for *in vitro* diagnostic use.

Expiration Date The expiration date of a solution found on the label or on a sticker on the side of the container is stated as a month and year. Do not use a product after its expiration date.

Safety Data Sheets Safety Data Sheets for all solutions are available from your Radiometer distributor.

Re-ordering Information for re-ordering solutions from Radiometer can be found in the ABL700 Series Operator's Manual, *Chapter 14*.

S1720 and S1730 Calibration Solutions

Use Calibration solutions for pH, electrolyte and metabolite electrodes in the ABL700 Series analyzers.

Quantity 200 mL

Composition Solutions contain the following substances with the stated nominal concentrations:

Solution	Substance	Concentration (mmol/L)
S1720	K^+	4
	Na^+	145
	Ca^{2+}	1.24
	Cl^-	102
	*c*Glu	10
	*c*Lac	4
	buffer	Maintains a pH of 7.4
S1730	K^+	40
	Na^+	20
	Ca^{2+}	5
	Cl^-	50
	buffer	Maintains a pH of 6.8

NOTE: *The exact values are included in the bar code.*

Additives Contain preservatives and surfactants.

Storage At 2-25 ^{o}C (36-77 ^{o}F).

Stability Expiration date and Lot No. are printed on a label.

Stability in use: S1720: 4 weeks.
S1730: 8 weeks.

S4970 Rinse Solution

Use	Rinse solution in the ABL700 Series analyzers.
Quantity	600 mL
Composition	Contains salts, buffer, anticoagulant, preservative, and surfactants.
Storage	At 2-32 ^{o}C (36-90 ^{o}F).
Stability	Expiration date and Lot No. are printed on a separate label. Stability in use: 6 months.

S7370 Cleaning Solution and S5370 Cleaning Additive

S7370 Cleaning Solution

Use:	Cleaning solution in the ABL700 Series analyzers.
Quantity:	200 mL
Composition:	Contains salts, buffer, anticoagulant, preservatives, and surfactants.
Storage:	At 2-25 ^{o}C (36-77 ^{o}F).
Stability	Expiration date and Lot No. are printed on a separate label.

S5370 Cleaning Additive

Use:	An additive to the S7370 Cleaning solution in the ABL700 Series analyzers.
Composition:	Contains Powdered streptokinase.
Storage:	At 2-10 °C (36-50 °F).
Stability:	Expiration date and Lot No. are printed on a separate label. The Cleaning Solution with the Cleaning Additive is stable for 2 months in use.
WARNING/ CAUTION:	*May cause sensitization by inhalation and skin contact). Do not breathe dust. Avoid contact with skin. Wear suitable gloves. In case of accident or if you feel unwell, seek medical advice immediately (show the label where possible).*

S7770 tHb Calibration Solution

Use For calibration of the cuvette optical path length in the ABL700 Series analyzers. The calibrated value can be *c*tHb, *c*tHb and *c*tBil, or *c*tBil depending on the analyzer version.

Quantity 2 mL

Composition Contains salts, a buffer, preservative and a coloring agent.

Storage Keep in a dark place at 2 - 25 ^{o}C (36 - 77 ^{o}F).

Stability Expiration date and Lot No. are printed on a separate label.

After opening the solution must be used at once.

Gas Mixtures (Gas 1 and Gas 2)

Use Calibration gases for the pCO_2 and pO_2 electrodes in the ABL700 Series analyzers.

Cylinder Type The analyzers employ different types of Gas 1 cylinders depending on the geographical location in which the analyzer is to be used.

The following table gives details of the two gas cylinders.

	Gas 1			**Gas 2**
	EU	USA	Japan	
Cylinder Volume	1 L	1 L	1 L	1 L
Gas Volume	10 L	33 L	25 L	10 L
Fill Pressure at 25 °C	140 psi (10 bar)	500 psi (34 bar)	375 psi (26 bar)	140 psi (10 bar)
Composition	19.76 % O_2, 5.60 % CO_2 74.64 % N_2			< 0.04 % O_2, 11.22 % CO_2 88.78 % N_2

WARNING/ CAUTION: *Not for drug use.*
High pressure gas. Do not puncture. Do not store near heat or open flame - exposure to temperatures above 52 °C (125 °F) may cause contents to vent or cause bursting.
Not for inhalation. Avoid breathing gas - mixtures containing carbon dioxide can increase respiration and heart rate. Gas mixtures containing less than 19.5 % oxygen can cause rapid suffocation.
Store with adequate ventilation. Avoid contact with oil and grease.
Only use with equipment rated for cylinder pressure.
Use in accordance with Safety Data Sheet.

NOTE: *The percentages given in the table above are more accurately given in the bar code on the gas cylinder label. The barcode is read into the analyzer by the bar code reader or entered manually via the keyboard.*

Stability Gas 1 and Gas 2 are stable for 25 months from the date of filling.

Storage The gas cylinders should be stored between 2 - 32 °C (36 - 90 °F).

Electrolyte Solutions

List of Electrolyte Solutions

This section lists the electrolyte solutions contained in the electrode jackets of the RADIOMETER electrodes that are used in the ABL700 Series analyzers.

Electrolyte for…	Quantity	Composition
E1001 reference electrode	0.6 mL in 4 pre-filled electrode jackets per D711 Membrane Box	Organic compounds and inorganic salts.
E788 pCO_2 electrode	0.6 mL in 4 pre-filled electrode jackets per D788 Membrane Box	Inorganic salts, buffer, hygroscopic compound, preservative and surfactant.
E799 pO_2 electrode	0.6 mL in 4 pre-filled electrode jackets per D799 Membrane Box	Inorganic salts, organic compounds, buffer, preservative and surfactant.
E722 K electrode	0.6 mL in 4 pre-filled electrode jackets per D722 Membrane Box	Organic compounds and inorganic salts, buffer, acid, and preservative.
E755 Na electrode	0.6 mL in 4 pre-filled electrode jackets per D755 Membrane Box	Inorganic salts, organic compounds, preservative and surfactant.
E733 Ca electrode	0.6 mL in 4 pre-filled electrode jackets per D733 Membrane Box	Inorganic salts, organic compounds, buffer, preservative and surfactant.
E744 Cl electrode	0.6 mL in 4 pre-filled electrode jackets per D744 Membrane Box	Inorganic salts, organic compounds, preservative, surfactant and hygroscopic products.
E7066 Glucose and E7077 Lactate electrodes	0.6 mL in 5 plastic capsules to fill the electrode jackets (4 units) per D7066 and D7077 Membrane Boxes	Buffer, inorganic salts, thickening agent, preservative and surfactant.

Storage

Temperature:	Electrode:
2 - 25 °C (36 - 77 °F)	Glucose
2 - 10 °C (36 - 50 °F)	Lactate
2 - 32 °C (36 - 90 °F)	All other

Stability

Expiration date and Lot No. are printed on a label on the side of the membrane box.

S5362 Hypochlorite Solution

S5362 Hypochlorite Solution

Use:	For protein removal and decontamination according to the procedures described in the Operator's Manual, chapter 4: *Analyzer Menus and Programs*.
Quantity:	100 mL. Delivered with a 1 mL syringe.
Composition:	Contains sodium hypochlorite (pH ≈12).
Storage:	Keep in a dark place at 2-8 °C (36-45 °F). After use, keep the bottle tightly capped to avoid contamination and decomposition.
Stability:	Expiration date and Lot No. are printed on a separate label on the bottle.

Certificates of Traceablility

Certificate of Traceability

Product name: Calibrating Solution 1

Type: S1720

Code: 944-064

Traceability of parameters:

Parameter	Unit	Traceable to	Expanded Uncertainty
pH		The IUPACK pH scale and the NIST pH scale. The Chemical Reference Laboratory of Radiometer Medical A/S, which is the primary Danish national laboratory within pH, establishes the IUPAC pH scale under accreditation No. 119, granted by Danish Accreditation (DANAK).	0,009
cK^+	mmol/L (37 °C)	NIST SRM	0,03
cNa^+	mmol/L (37 °C)	NIST SRM	0,8
cCa^{2+}	mmol/L (37 °C)	Calcium transfer standards according to IFCC	0,01
cCl^-	mmol/L (37 °C)	NIST SRM	1,3
*c*Glucose	mmol/L (37 °C)	NIST SRM	0,3
*c*Lactate	mmol/L (37 °C)	L8+) Lactici AcidLithium Salt. SIGMA L-2250	0,2

Certification: Each lot of this product has been tested, and the control limits, specified on the insert included with this product, have been established with the above traceability.

Helle Søderstrøm
Head of Production Laboratory

Bjarne Kristensen
H.B. Kristensen
Head of Chemical Reference Laboratory

The traceability of the above parameters is fully described in booklet AS 117: *Traceability to the Primary Reference Standards at Radiometer*, available from Radiometer.

RADIOMETER COPENHAGEN

Certificate of Traceability

Product name: Calibration Solution 2

Type: S1730

Code: 944-025

Traceability of parameters:

Parameter	Unit	Traceable to	Expanded Uncertainty
pH		The IUPACK pH scale and the NIST pH scale. The Chemical Reference Laboratory of Radiometer Medical A/S, which is the primary Danish national laboratory within pH, establishes the IUPAC pH scale under accreditation No. 119, granted by Danish Accreditation (DANAK).	0,006
cK^+	mmol/L (37 °C)	NIST SRM	0,37
cNa^+	mmol/L (37 °C)	NIST SRM	0,4
cCa^{2+}	mmol/L (37 °C)	Calcium transfer standards according to IFCC	0,06
cCl^-	mmol/L (37 °C)	NIST SRM	0,5

Certification: Each lot of this product has been tested, and the control limits, specified on the insert included with this product, have been established with the above traceability.

Helle Søderstrøm
Head of Production Laboratory

Bjarne Kristensen
H.B. Kristensen
Head of Chemical Reference Laboratory

The traceability of the above parameters is fully described in booklet AS 117: *Traceability to the Primary Reference Standards at Radiometer*, available from Radiometer.

RADIOMETER COPENHAGEN

Certificate of Traceability

Product name: tHB Calibration Solution

Type: S7770

Code: 944-021

Traceability of parameters:

Parameter	Unit	Traceable to	Expanded Uncertainty
*c*tHb	g/dl	NIST SRM (absorbance, wavelength). Hemoglobin-cyanide standard. J.T. Baker (Product No. 3061)	0.2
sO_2	%	NIST SRM (absorbance, wavelength). NIST SRM gas, whole blood sample, pH = 7.4, *c*tHb = 15 g%, sO_2 = 100 %	0.4

Certification: Each lot of this product has been tested, and the control limits, specified on the insert included with this product, have been established with the above traceability.

Helle Søderstrøm
Head of Production Laboratory

H.B. Kristensen
Head of Chemical Reference Laboratory

The traceability of the above parameters is fully described in booklet AS 117: *Traceability to the Primary Reference Standards at Radiometer*, available from Radiometer.

RADIOMETER COPENHAGEN

Certificate of Traceability

Product name: Calibration Gas 1, EUR

Type: Gas mixture, 1 L

Code: 962-169

Traceability of parameters:

Parameter	Unit	Traceable to	Expanded Uncertainty
CO_2	mol %	Primary, gravimetrically prepared standards. Traceable to NIST traceable weights.	0.03
O_2	mol %	Primary, gravimetrically prepared standards. Traceable to NIST traceable weights.	0.03

Certification: Each lot of this product has been tested, and the nominal values, specified on the label of this product, have been established with the above traceability.

Bjarne Kristensen

H.B. Kristensen
Head of Chemical Reference Laboratory

The traceability of the above parameters is fully described in booklet AS 117: *Traceability to the Primary Reference Standards at Radiometer*, available from Radiometer.

Certificate of Traceability

Product name: Calibration Gas 2, EUR

Type: Gas mixture, 1 L

Code: 962-170

Traceability of parameters:

Parameter	Unit	Traceable to	Expanded Uncertainty
CO_2	mol %	Primary, gravimetrically prepared standards. Traceable to NIST traceable weights.	0.03
O_2	mol %	Primary, gravimetrically prepared standards. Traceable to NIST traceable weights.	0.03

Certification: Each lot of this product has been tested, and the nominal values, specified on the label of this product, have been established with the above traceability.

Bjarne Kristensen

H.B. Kristensen
Head of Chemical Reference Laboratory

The traceability of the above parameters is fully described in booklet AS 117: *Traceability to the Primary Reference Standards at Radiometer*, available from Radiometer.

8. Interfacing Facilities

Introduction This chapter provides information about the external connections that may be made to the ABL700 Series analyzer.

Contents This chapter contains the following topics.

Connecting a Mouse

Scope of Use

A mouse connected to the ABL700 analyzer may be used to activate all the analyzer's screen functions instead of the operator touching the screen.

Material Required

A standard PS/2 port mouse is the sole item that is required for connection to the analyzer.

Procedure for Connecting the Mouse

Follow the instructions below to connect the mouse to the analyzer.

Step	Action
1.	Switch off the analyzer.
2.	Connect the mouse to the mouse port at the rear of the analyzer.
3.	Switch on the analyzer.

Connecting an Alphanumeric Keyboard

Scope of Use

An external alphanumeric keyboard connected to the ABL700 analyzer may be used instead of the on-screen keyboard to enter data such as a patient's name and identification, and to edit parameter information in the screens. However, to select individual touch-keys on the analyzer's screen, a mouse must be used or the operator must touch the analyzer's screen.

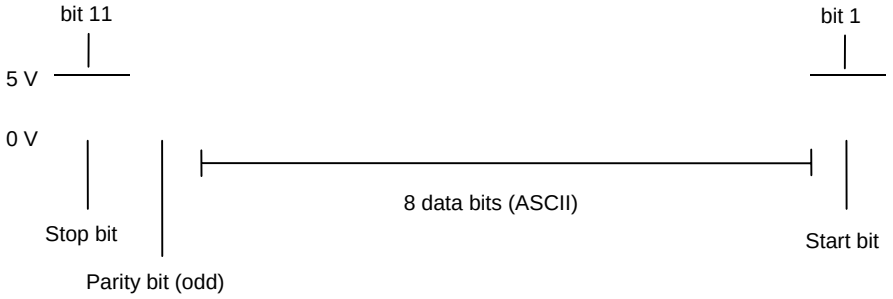
Material Required

An IBM enhanced personal computer keyboard is the sole item that is required for connection to the analyzer.

NOTE: *The keyboard layout must correspond to the language version used by the analyzer.*

Transmission Format

The communication conditions for an alphanumeric keyboard are depicted below:



Pin Designation

The pins on the connector of the cable are assigned as follows:

Pin 1 - Clock in/out

Pin 2 - Data in/out

Pin 3 - Not connected

Pin 4 - Ground

Pin 5 - +5 V

Pin 6 - Not connected

Procedure for Connecting the Keyboard

Follow the instructions below to connect the keyboard to the analyzer.

Step	Action
1.	Switch off the analyzer.
2.	Connect the keyboard to the keyboard port at the rear of the analyzer.
3.	Switch on the analyzer.

Connecting the Bar Code Reader

Scope of Use

A bar code reader connected to the ABL700 analyzer may be used to read in bar coded information quickly and accurately. The type of information that is stored in bar codes include the expiration date for consumable items, product lot numbers, Radiometer-determined product identification, and user passwords. Bar codes may be scanned into the analyzer anytime the bar code symbol appears in a screen.

Material Required

The items that are required to connect a bar code reader to the analyzer are:

- A bar code reader
  It should incorporate a decoder for reading EAN and UPC codes as WPC symbols, and NW-7, CODE39, ITF (Interleaved 2 of 5), STF (Standard 2 of 5), CODE93 and CODE128 codes as industrial symbols.
- A cable for connecting the bar code reader to the analyzer
  This should have shielded wires and be no more than 3 m in length.

NOTE: *The bar code reader which has a RS232C interface must be connected to the analyzer in accordance with the EN50022/4.1987, EN50082-1/1992 standards.*

Transmission Format

The communication conditions for the bar code reader are outlined in the table below:

Item	Standard Specification
Method of transmission	Start-stop synchronization method
Transmission character set	7 bits ASCII code
Data bit	7 bits
Parity bit	Odd
Stop bit	2 bits
Transmission speed	9600 bps (bits per second)

Pin Designation

The pins on the connector of the cable are assigned as follows:

Pins 1, 4, 7, 6, 8 - Not connected

Pin 2 - RxD

Pin 3 - TxD

Pin 5 - Ground

Pin 9 - +5 V

Power Source - Max 0.5 A

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Connecting the Bar Code Reader, *Continued*

Procedure for Connecting the Bar Code Reader

Follow the instructions below to connect the bar code reader to the analyzer.

Step	Action
1.	Switch off the analyzer.
2.	Connect the bar code reader to the bar code reader port (COM3) at the rear of the analyzer.
3.	Switch on the analyzer.

Connecting a Network

Scope of Use

Many hospitals utilize a computer controlled information system such as the Hospital Information System (HIS) or the Laboratory Information System (LIS). The connection of the ABL700 analyzer to such an information system by means of a network enables the user to exercise greater control over amount of patient data circulating within the hospital.

For example, the user may use the central computer's network connection to lock (and unlock) a remotely placed analyzer. Alternatively, it may be used to request a patient's accession number, a unique number given to a particular patient sample by the HIS that contains measurement criteria and patient identification.

Type of Data Transmitted

The types of information that can be communicated via a network between the central computer controlling the information system and the analyzer are:

- Patient results
- Quality control results
- Calibration data
- System messages

Material Required

To connect the analyzer to a network, a shielded data cable with an RJ45 connector should be used.

Linking the Analyzer to a Network

The analyzer is first connected to the computer controlling the information system, via one of the following two interfaces:

- A Serial Line (RS232 Interface)
- An Ethernet Interface (TCP / IP)

Once the analyzer has been physically connected to the network, one of two of the protocols stated below is used for communication with the central computer.

- ASTM
- HL7

For further information refer to the *ASTM Communication Protocol for Radiometer ABL700 Series Analyzers* (code number 989-329).

Radiometer recommends that the connection of a network to the ABL700 Series analyzer is carried out by a qualified service technician.

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