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CFS300A / CFS400A / CFS600A / CFS700A series of meters and CFT34A transmitter

Supplementary Instructions

Concentration information

CONTENTS

1.1 About concentration measurement

When measuring process fluids, the CFT34A transmitter allows the direct measurement of: mass flow; total mass flow; density and temperature. From the mass flow and density measurements, it is also possible to calculate values for volume flow and volume total. If the process fluid is a mixture of two components, the individual data of those components, together with the measured density, can be used to calculate the relative proportions. Where the two components have the same, or similar, individual densities the mixture will also have the same density, regardless of the relative proportions of the components. In such situations, concentration calculations will not be possible. As the difference between the component densities increases, it becomes easier to accurately measure the relative proportions of the components.

2.1 Introduction

Concentration measurement on the CFT34A is an optional extra that can be specified when ordering the meter, or purchased after delivery. If the option has been specified at the time of ordering the meter, it will be turned on during manufacture. If it is purchsed after delivery, a password is sent to the customer to allow the option to be turned on. When the option has been turned on, a range of concentration menus are available through C1.3.

Concentration status

The concentration status can be checked by entering the programme menu and C1.3.1. If the display tells the user how to obtain activation code the concentration measurement is not enabled. If you want to purchase the concentration option, please contact your nearest representative.

2.2 Turning on concentration measurement

Password sequence

Button	Screen		Description and setting
>	A	Quick Setup	Press and hold for 2.5 s, then release key
2 x ▼	C	Setup	Press down arrow twice
2 x >	C1	Flow	Press right arrow twice to enter Setup
2 x ▼	C1.3	Concentration	Press down arrow twice
>	C1.3.1	Concentration	Display tells user how to obtain activation code
↵	C1.3.2	Conc. Password	Display shows a row of zeros with the first zero highlighted
▼ / ▲ / >	C1.3.2	Conc. Password	Use ▼ and ▲ to change the value of each digit. Use the > key to move to the next digit and repeat above operation until the correct password has been entered.
↵	C2.1.2	Conc. Password	Concentration Enabled
3 x ↵	C	Setup	Save Configuration?
↵		Yes?	Save changes and activate concentration measurement

2.3 Concentration menu

When the concentration has been turned on, the Concentration menu is available to the user who can select from the available concentration modes through C1.3. The following table shows the available options.

Concentration menu

No	Function	Settings / description
C1.3.1	Conc. Data Sel.	Define which set of general concentration parameters are active. Select: Conc Data 1 / Conc Data 2
C1.3.2	Concentration 1	Defines the function of the concentration measurement. In the following description, x=2 for Concentration 1 settings, and x=3 for Concentration 2 settings
C1.3.3	Concentration 2	
C1.3.x	Conc Function	Sets the concentration measurement required. Select: Off / Brix / %Mass / %Volume / Baume 144 / Baume 145 / %NaOH / Plato / API / %Alcohol by mass / %Alcohol by volume
	Conc Offset	Sets an additional offset for the concentration measurement. Can be used to correct for differences between the measured Range: -10…10%
	Conc Product	Defines which general concentration product is display Select: % of Product A / % of Product B
C1.3.4	Conc. Data 1	Defines the concentration coefficients used for concentration parameter sets 1 & 2.In the following description: y=4 for Conc. Data 1 settings / y=5 for Conc. Data 2 settings.
C1.3.5	Conc. Data 2	
C1.3.y	CCF01	Defines the use of linear or non-linear coefficients to measure concentration. Select: Linear / Non Linear
	CCF02	Density of product A in g/cm^3
	CCF03	Temperature coefficient for Product A
	CCF04	Temperature coefficient squared for Product A
	CCF05	Defines Product B type. Select: Pure Water / Town Water / Other
	CCF06	Density of Product B in g/cm^3 (if CCF05 = Other)
	CCF07	Temperature coefficient squared for Product B (if CCF05 = Other)
	CCF08	Defines non-linear equation if CCF01 is set to Non Linear
	CCF09	Defines non-linear equation if CCF01 is set to Non Linear. Consult the manufacturer for settings.
	CCF10	
	CCF11	
	CCF12	

2.4 Concentration modes

The CFT34A transmitter has the ability to run two concentration modes at the same time, eg. °Brix and %Volume. It is also possible to view the percentage of Product A and the percentage of Product B in General Concentration mode. To set the concentration mode, use menus C1.3.2 Concentration 1 and C1.3.3 Concentration 2.

For applications where multiple products are used, the transmitter can be set up with two sets of general concentration parameters. Use menus C1.3.4 Conc. Data 1 and C1.3.5 Conc. Data 2. To select the required concentration parameter, go to menu C1.3.1 > Conc.Data Sel. and use the ▲ and ▼ keys to select between Conc. Data 1 and Conc. Data 2

2.5 Concentration offset

In both concentration modes, the CFT34A allows the user to set a concentration offset. An offset may be needed where: a) there is a difference between the value measured by the massflow meter and measurements taken in a laboratory, b) the process data does not fit well with the transmitter's algorithms, or c) where there are differences between the standard Brix values and the customer's concentration. A good example is where pure water is not the carrier fluid, allowing for the use of additives, fruit juices etc. The offset can be up to ±100% and up to three decimal places, for fine corrections.

Setting the offset

To set the concentration offset, use menu option: C1.3.2 Conc. Offset (Concentration 1) or Conc. Offset (Concentration 2) and enter the required offset value. For example, if the meter's concentration value is 1% too low, enter the value of +001.000 %. This will add 1% to the calculated concentration value.

3.1 General concentration measurement

The general concentration mode allows the measurement to match the customer's product.

For general concentration measurement, the two parts of the solution are referred to as Product A and Product B.

Solutions have three main types, as shown in the following table:

Solution type	Details	Example
Suspension	Solids suspended in a liquid.	Slurry
Emulsion	Mixtures of two immiscible non-compressible components. In this case the two components do not mix / interact with each other.	Mixture of oil and water
Solution	Two components that mix or interact with each other.	Coffee dissolved in water

Use menu C1.3.x to measure the respective percentages of Product A and Product B in the solution.

3.2 Formulae

3.2.1 °Brix

°Brix is the concentration, by mass, of sucrose in pure water and is often used in the wine, sugar and carbonated drink industries. The °Brix is directly proportional to the percentage of sucrose by weight, so 10g of sugar in 100g of pure water has a value of 10 °Brix. The °Brix value of a solution does not vary with temperature which means that if a 100g solution contains 40g of sugar, the sugar content will remain at 40g regardless of any change in temperature.

The concentration of °Brix is shown as a percentage from 0...100% in the temperature range -20°C...+100°C / -4°F...+212°F

The concentration flow is calculated using the formula:

$$C_F = \frac{^\circ Bx}{100} \times M_F$$

C_F concentration flow
Bx Brix
M_F mass flow

Concentration total is the accumulation of concentration flow over time

3.2.2 °Brix accuracy

In practice, very few companies work with pure sugar solutions but they still use a refractometer to measure °Brix. Very often the solution will contain other components in addition to sucrose. Components such as: glucose; fructose; fruit acids; proteins and suspended particles are often present. Many of these components might affect the product's overall refractive index. Because of this, the refractometer reading becomes an approximate value of the actual sugar content.

CFS meters measure density and temperature. From these measurements and the known characteristics of sucrose solutions, a °Brix value can be calculated. As with the refractometer, if there are any other components present in the product, the displayed Brix value will only be approximate. The approximate values cannot be expected to match exactly the approximate refractor values. This is because the impurities might not have the same effect on the refractive index as they do on density. Solid particles in the product will not affect how light is refracted when passing through the rest of the liquid but they will affect its density.

It is possible to correct the °Brix measurement by using menu option C1.3.2 (Concentration 1) or C1.3.3 (Concentration 2) Conc.Offset

3.2.3 °Plato

°Plato is the concentration, by mass, of sucrose in pure water. The °Plato is directly proportional to the percentage of sucrose by weight, so 10g of sugar in 100g of pure water has a value of 10 °Plato. The °Plato value of a solution does not vary with temperature which means that if a 100g solution contains 40g of sugar, the sugar content will remain at 40g regardless of any change in temperature.

The concentration flow is calculated using the formula:

$$C_F = \frac{°P}{100} \times M_{FR}$$

C_F concentration flow
P Plato
M_{FR} mass flow rate

Concentration total is the accumulation of concentration flow over time

3.2.4 °Baumé

°Baumé is a concentration scale of sugar or starch in water. The °Baumé scale is based on the specific gravity of sucrose solutions $d^{15}/_{15}$ relative to water at 15.5°C / 60°F.

There are two °Baumé scales:

°Baumé commercial (US)	K_B = 145.0
°Baumé rational	K_B = 144.3

The concentration is calculated using the formula:

$$°Bé = K_B \left(1 - \frac{1}{d^{15}_{15}}\right) °Bé$$

Bé Baumé
K_B constant used for Baumé calculations

The concentration flow is calculated using the formula:

$$C_F = \frac{°Bé}{100} \times M_{FR}$$

C_F concentration flow
Bé Baumé
M_{FR} mass flow rate

3.2.5 Sodium Hydroxide (NaOH)

The NaOH algorithm fits the true characteristics of the product to one decimal place (±0.1). However, the fit is limited to a temperature range of 10...40°C / 50...104°F and a solution range of 0...50%. For information regarding the suitability of measuring tube materials, please refer to the supplementary instructions relating to corrosion and abrasion.

Concentration total is the accumulation of concentration over time.

3.2.6 API

API gravity is a measure of specific gravity developed by the American Petroleum Institute (API) for measuring the relative density of various petroleum liquids.

The formula used is:

$$\text{API g} = \frac{141.5}{\rho} - 131.5$$

API g API gravity
ρ density

For correct API measurement, set the Density Mode to Standard Density. Configure the Referred Density temperature to 15°C / 59°F and set the k terms for the type of liquid being measured. For further information regarding configuration, please refer to the handbook for the CFT34A.

3.2.7 Alcohol

Alcohol concentration can be shown by either mass or volume. The measurement is calculated using density and temperature to determine the percentage of ethanol to water.

Alcohol by mass

The concentration of alcohol by mass is shown as a percentage from 0...100% in the temperature range -20°C...+40°C / -4°F...+104°F, according to OIML R22:1973 alcoholometric table 1.

Alcohol by volume

The concentration of alcohol by volume is shown as a percentage from 0...100% in the temperature range -20°C...+40°C / -4°F...+104°F, according to OIML R22:1973 alcoholometric table III. The reference point for concentration by volume is 20°C / 68°F

3.2.8 Concentration by mass

A mixture or solution with total mass (M_T) contains the mass (M) of one component. The concentration by mass (C_M) of that component is:

$$C_M = \frac{M}{M_T} \times 100$$

C_M concentration by mass
M mass
M_T mass total

Concentration by mass will not change with temperature.

This formula cannot be used in its current form in a continuous process because it's not possible to determine the mass of each component. However, if the density of each component is known, then it is possible to calculate the mass using the formula:

$$C_M = \frac{\rho_A}{\rho_M} \times \frac{\rho_M - \rho_B}{\rho_A - \rho_B} \times 100$$

C_M concentration by mass
ρ_A density of product A
ρ_B density of product B
ρ_M density of the mixture

3.2.9 Product A and Product B

The concentration formulae in previous sections requires the density of both Product A and Product B. Because the density of a product normally changes with temperature, the formulae for Product A and Product B have a temperature and temperature squared term to model this behaviour.

Product A is calculated using the formula:

Product A = density of Product_A at 20°C / 68°F + temperature coefficient_A x (temperature - 20) + temperature squared coefficient_A x $(\text{temperature} - 20)^2$

Where:

CCF02 = density of Product $_A$ at 20°C / 68°F
CCF03 = temperature coeffient_A
CCF04 = temperature squared coefficient_A

The density of Product B depends on the type of product. For ease of programming, the values of water are included in the software. Therefore, if Product B is pure water or town water, no data for Product B is required. Select either Pure Water or Town Water in menu C1.3.4 (CCF05) or C1.3.5 (CCF05)

If Product B is not water, select Other in menu C1.3.4 (CCF05) or C1.3.5 (CCF05). To calculate the density of Product B with changes in temperature, use the formula:

Product B = density of $Product_B$ at 20°C / 68°F + temperature $coefficient_B$ x (temperature - 20) + temperature squared $coefficient_B$ x $(temperature - 20)^2$

Where:

CCF06 = density of product $_B$ at 20°C / 68°F
CCF07 = temperature $coefficient_B$
CCF08 = temperature squared $coefficient_B$

3.2.10 Concentration flow

Concentration flow is calculated using the formula:

$$C_F = \frac{C_m}{100} \times M_{FR}$$

C_F concentration flow
C_M concentration by mass
M_{FR} mass flow rate

Concentration total is the accumulation of concentration flow over time

In all general concentration modes, use C1.3.2 or C1.3.3 to select which component in the concentration to measure.

3.3 Suspensions

A suspension is a solid suspended in a carrier. The solid does not dissolve into the carrier and the density does not change with temperature. Product B (carrier) can be set to water and so the solid density should be entered as Product A.

Transmitter settings where Product B is water

No	Function	Setting	Comments
C1.3.x	Conc Function	% Mass or % Volume	
	Conc Offset	0	If the concentration measurement produces a stable error, use this menu option to enter an offset that will correct the error.
	Conc Product	% of Product A or % of Product B	Select required product to be measured
C1.3.y	CCF01	Linear	
	CCF02	Density Product A (Solid) in g/cm^3	
	CCF03	0	No change with temperature
	CCF04	0	
	CCF05	Pure Water or Town Water	

Transmitter settings where Product B is not water

To produce the required concentration coefficiants, enter the density of the product at a number of temperature points. The minimum number of points required is two and the maximum is five. For more information regarding generating concentration coefficients, refer to the Practical considerations chapter.

No	Function	Setting	Comments
C1.3.x	Conc Function	% Mass or % Volume	
	Conc Offset	0	If the concentration measurement produces a stable error, use this menu option to enter an offset that will correct the error.
	Conc Product	% of Product A or % of Product B	Select required product to be measured
C1.3.y	CCF01	Linear	
	CCF02	Density Product A (Solid) in g /cm^3	
	CCF03	0	No change with temperature
	CCF04	0	
	CCF05	Other	
	CCF06	Density Product B in g /cm^3	
	CCF07	Product B Temperature term	
	CCF08	Product B Temperature squared term	

3.4 Emulsions

Emulsions have the two components (products) that do not mix or interact with each other. For example, oil / water. If one of the products is water, enter this as product B. To produce the required concentration coefficients, enter the density of product A (and product B if it is not water) at a number of temperature points. The minimum number of points required is two and the maximum is five. For more information regarding generating concentration coefficients, refer to the Practical considerations chapter.

Transmitter settings for emulsions

No	Function	Setting	Comments
C1.3.x	Conc. Function	% Mass or % Volume	
	Conc. Offset	0	If the concentration measurement produces a stable error, use this menu option to enter an offset that will correct the error.
	Conc. Product	% of Product A or % of Product B	Select required product to be measured
C1.3.y	CCF01	Linear	
	CCF02	Density Product A at 20°C in g/cm^3	
	CCF03	Product A Temperature term	
	CCF04	Product A Temperature squared term	
	CCF05	Pure Water / Town Water / Other	
	CCF06	Density Product B in g /cm^3	If CCF05 = Other
	CCF07	Product B Temperature term	
	CCF08	Product B Temperature squared term	

3.5 Solutions

When two liquids mix or dissolve together they are said to be miscible. The two components may also have a strong chemical interaction. Because the equation does not take into account any interaction, using the densities of the two products will only give an approximate value. In the majority of cases a linear equation can be used to calculate a set of coefficients in order to fit the application data. To do this, a minimum of two and a maximum of five temperature points with two density / concentration values per temperature point are required. The temperature points should cover the temperature range of the concentration, over which the maximum level of accuracy is required.In some cases, complex interaction between the two components means that a linear equation cannot be used to calculate the coefficients. In such cases, a non-linear equation can be used by the manufacturer to produce a set of coefficients for the application. Please contact your local representative for further assistance.

3.6 Generating concentration coefficients

To generate the coefficients, use the Concentration Calculator. The data required to generate these coefficients depends on the type of products. Please refer to the Suspensions, Emulsions and Solutions sections and to the templates in appendix C to choose the concentration type that best suits your product. The application will give the results of all the values that need to be programmed into the concentration menus.

4.1 Accuracy of concentration estimation

The results of the concentration estimation depend on the accuracy of the density measurements and on the “fit” of the algorithm used to infer the concentration value. Of the two factors the density measurement itself is the most critical. In order to assess the effect of inaccuracies in the density measurement, it is necessary to consider the amount that density will change over a given range of measurement. The concentration accuracy is given by the equation.

$$C_{Accy} = \pm \frac{\Delta_C}{\Delta_\rho} \times \rho_{Accy}$$

C_{Accy} concentration accuracy
Δ_C change in concentration
Δ_ρ change in density
ρ_{Accy} density accuracy

For instance, it is required to measure concentrations in the range 5...10% by mass. Over this range density varies from 1.018 to 1.038 g/cm3, a change of 0.020 g/cm3. If the density accuracy of the flow meter is 0.002g/cm3, then, assuming that the variation of density with concentration is linear, the approximate accuracy of the measurement will be:

$$C_{Accy} = \pm \frac{5}{0.02} \times 0.002 = \pm 0.5$$

C_{Accy} concentration accuracy

Obviously this simple calculation takes no account of temperature, or of the fit of the algorithm, but it very quickly gives an indication of what is achievable with any given density meter. There are other factors that also limit the ability of the meter to read an accurate density figure.

Air / gas inclusions

If the process fluid has significant gas content this will cause the Coriolis meter to under-read density. This is not a fault of the meter but a problem with the application. If it is not possible to prevent air getting into the fluid various measures can be taken to try to minimise the effect. The meter should be installed vertically to prevent air collecting within it (this may not help with bent tube instruments). Try pressurising the line so that the any air bubbles are compressed.

To ensure a good density measurement:

- Install the meter as directed in the Master Instruction
- make sure that the process product is free from entrained bubbles
- Carry out on site calibration of the density measurement, preferably at the normal operating temperature for the process product being measured. For more information on calibration, please refer to the relevant transmitter Master Instruction.

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