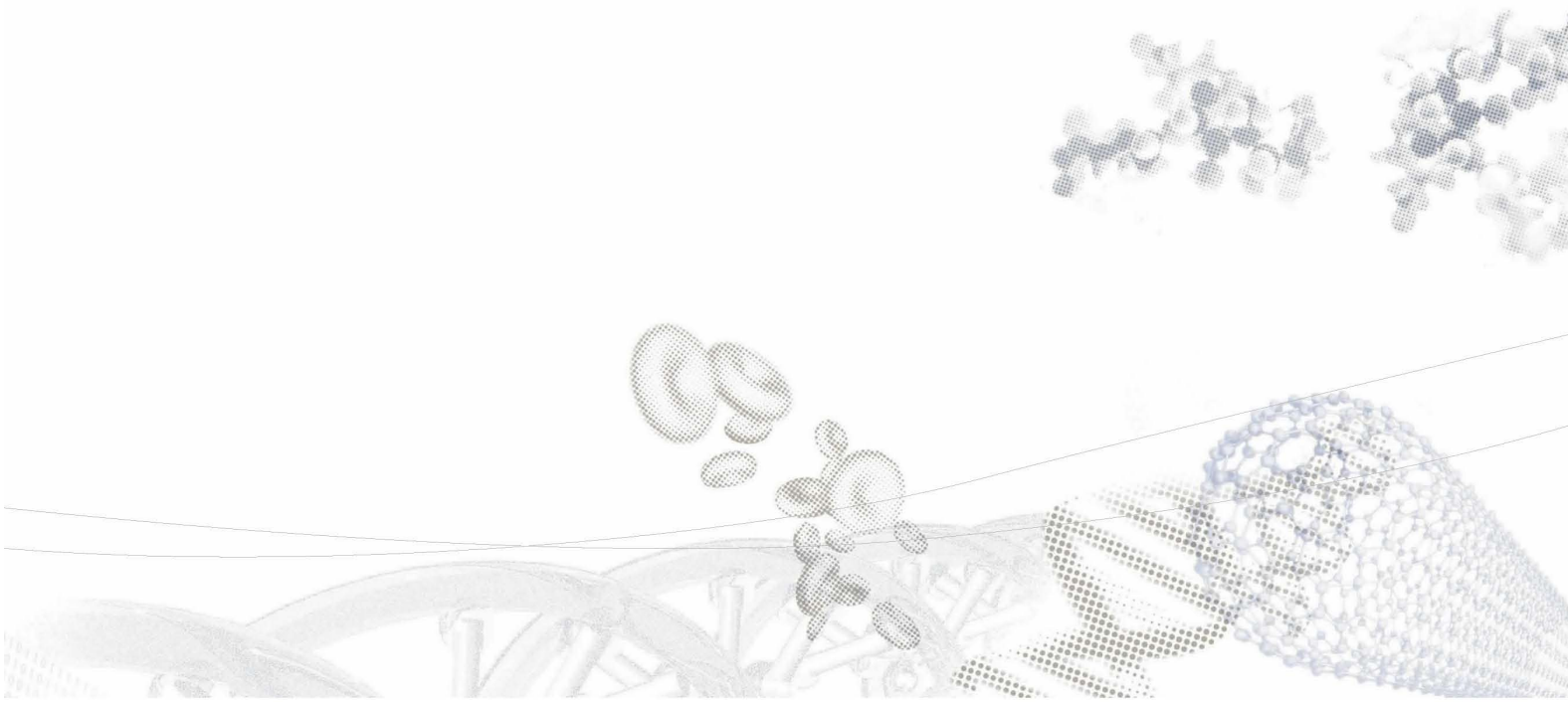
HORIBA
Explore the future

CFO-ONE (Dual Critical Flow Orifice) USER MANUAL

Release

GBUM220609V2

09/06/2022



Preface

This manual describes the operation of the CFO-ONE.

Be sure to read this manual before using the product to ensure proper and safe operation of the instrument. Also safely store the manual so it is readily available whenever necessary.

Product specifications and appearance, as well as the contents of this manual are subject to change without notice.

Warranty and Responsibility

HORIBA warrants that the Product shall be free from defects in material and workmanship and agrees to repair or replace free of charge, at HORIBA's option, any malfunctioned or damaged Product attributable to HORIBA's responsibility for a period of one (1) year from the delivery unless otherwise agreed with a written agreement. In any one of the following cases, none of the warranties set forth herein shall be extended;

- Any malfunction or damage attributable to improper operation
- Any malfunction attributable to repair or modification by any person not authorized by HORIBA
- Any malfunction or damage attributable to the use in an environment not specified in this manual
- Any malfunction or damage attributable to violation of the instructions in this manual or operations in the manner not specified in this manual
- Any malfunction or damage attributable to any cause or causes beyond the reasonable control of HORIBA such as natural disasters
- Any deterioration in appearance attributable to corrosion, rust, and so on
- Replacement of consumables

HORIBA SHALL NOT BE LIABLE FOR ANY DAMAGES RESULTING FROM ANY MALFUNCTIONS OF THE PRODUCT, ANY ERASURE OF DATA, OR ANY OTHER USES OF THE PRODUCT.

Trademarks

Generally, company names and brand names are either registered trademarks or trademarks of the respective companies.

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Regulations

Declaration of Conformity

HORIBA UK Ltd declares under our sole responsibility that this product is in conformity with the protection requirements of the following Directives and Standards:

Directives: EMC Directive 2014/30/EU
Low Voltage Directive 2014/35/EU
RoHS 2011/65/EU

Standards: BS EN 61326-1:2006 Electrical equipment for measurement, control and laboratory use. Class A
BS EN 61010-1:2001 Safety requirements for electrical equipment for measurement, control and laboratory use Part 1: General requirements

- Class 'A' - This equipment should not be used in the Residential, Commercial and Light Industrial environment. Any apparatus used within a 30 metre radius may suffer from interference.

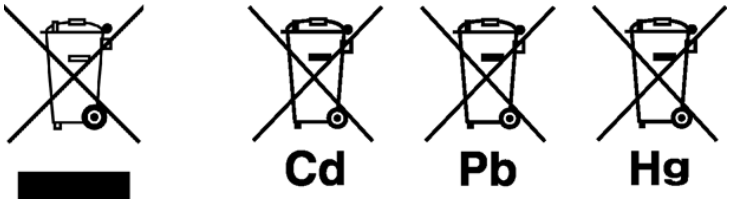
- **Information on Disposal of Electrical and Electronic Equipment and Disposal of Batteries and Accumulators**

The crossed out wheeled bin symbol with underbar shown on the product or accompanying documents indicates the product requires appropriate treatment, collection and recycle for waste electrical and electronic equipment (WEEE) under the Directive 2012/19/EU, and/or waste batteries and accumulators under the Directive 2013/56/EU in the European Union.

The symbol might be put with one of the chemical symbols below. In this case, it satisfies the requirements of the Directive 2013/56/EU for the object chemical.

This product should not be disposed of as unsorted household waste. Your correct disposal of WEEE, waste batteries and accumulators will contribute to reducing wasteful consumption of natural resources, and protecting human health and the environment from potential negative effects caused by hazardous substance in products.

Contact your supplier for information on applicable disposal methods.



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For Your Safety

Hazard Classification and Warning Symbols

Warning messages are described in the following manner. Read the messages and follow the instructions carefully.

- **Hazard classification**

⚠DANGER	This indicates and imminently hazardous situation which, if not avoided, will result in death or serious injury. This signal word is to be limited to the most extreme situations.
⚠WARNING	This indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.
⚠CAUTION	This indicates a potentially hazardous situation which, if not avoided, may result in minor or moderate injury. It may also be used to alert against unsafe practices.

- **Warning symbols**

Description of what should be done, or what should be followed

Description of what should never be done, or what is prohibited

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Safety Precautions

This section provides precautions to enable you to use the product safely and correctly and to prevent injury and damage. The terms of DANGER, WARNING and CAUTION indicate the degree of imminence and hazardous situations. Read the precautions carefully as it contains important safety messages.

⚠ WARNING	
	**MOVING OBJECT, PINCHING OBJECT HAZARD** Do not disassemble or modify the unit by yourself.
	**ELECTRIC SHOCK** Do not touch the inside to avoid electric shock.
	**ELECTRIC SHOCK** Maintain ground to avoid electric shock or fire.

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Product Handling Information

Operational Precautions

Use of the equipment in a manner not specified by the manufacturer may impair the protection provided by the equipment. It may also reduce equipment performance.

- If trouble occurs, contact either HORIBA service section or the dealer where the equipment was purchased.

Post Test

When tests are finished the CFO system must be disconnected from any gas lines. This will prevent the following;

- Damage to the system
- Leakage of dangerous gases

Disposal of the Product

When disposing of the product, follow the related laws and/or regulations of your country for disposal of the product.

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Contents

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Overview

Introduction

The purpose of this guide is to describe the equipment and guide required to perform a Propane Injection test to verify the accuracy and integrity of the Constant Volume Sampler (CVS).

A known mass of propane gas is injected into the system and is compared to the mass indicated by detection of a Flame Ionization Detector (FID). This test guide is commonly referred to as a CFO Injection. The calibration verification is performed weekly, or after any maintenance which could alter calibration, to ensure that the equipment has not shifted out of acceptable tolerance limits.

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Principle of Operation

Constant Volume Sampler Checks:

The procedure for checking the overall accuracy of the Constant Volume Sampler (CVS) is to introduce a known amount of a test gas (usually propane) into the exhaust system and compare the calculated concentration with that indicated by an approved hydrocarbon analyser. The gas is introduced via a calibrated orifice as provided in the CFO kit.

The volumetric flow rate through a standard CVS- CFV (critical flow Venturi) is given thus:

$$Q = \left(\frac{V}{t}\right) \times 60 \qquad (1)$$

Where:

V = Volume in standard cubic feet. This is read from the CVS control panel.

t = Time interval in seconds read from the CVS control panel.

60 = Conversion constant to yield *Q* in standard cubic feet per minute.

If *q* is the flow in SCFM of the sample gas as injected by the CFO, then the computed sample gas concentration is:

$$C_{calc} = \left(\frac{q}{Q}\right) \times 3^{*} \qquad (2)$$

*multiply computed sample gas concentration by 3 if C_{obs} in equation (3) below is measured in ppm carbon instead of ppm propane. The system error in percentage is given as:

$$E = \left(\left(\frac{C_{obs}}{C_{calc}}\right) - 1\right) \times 100 \qquad (3)$$

Where C_{obs} is the measured concentration in the bag sample obtained during the run.

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The Critical Flow Orifice Principle

The flow rate of a gas through a given orifice is given determined by the inlet pressure, temperature and the outlet or backpressure on the orifice. For given inlet conditions, as the backpressure is decreased, the gas velocity in the orifice throat and hence the flow rate, continues to increase. At a sufficiently low backpressure (approximately 0.5 the inlet pressure) the throat velocity reaches sonic conditions and further decrease on the back pressure would have no effect on the flow rate. This is the so called “choked or critical flow” condition. The practical advantage of operating a metering orifice in critical flow is that the flow rate is determined from a single high pressure level reading and is not affected by changes in backpressure.

It can be shown that for an ideal gas the critical flow rate would be

$$q = \frac{K \times A \times P}{\sqrt{T}} \qquad (4)$$

Where

q = Flow rate.

K = Constant derivable from the gas constant and the specific heat ratio.

A = Orifice throat area.

P = Inlet absolute pressure.

T = Inlet absolute temperature.

Note that the flow rate varies directly with the inlet pressure. Because of real gas effects and the inability to precisely measure A, equation (4) cannot be directly applied in practice and it is necessary to calibrate each orifice individually. The apparatus used for this purpose consists of essentially of an accurately ground glass cylinder provided with a loosely fitting plastic piston. The piston has a circumferential slot filled with mercury which provides a low drag gas seal against the cylinder bore. In use the gas to be measured pushes the piston upwards and the time of travel between two precisely known levels is measured to 0.01sec. Using this time measurement and the measured pressure and temperature of the gas in the cylinder, the delivery rate in CFM through the orifice is calculated. The calibration accuracy is better that 0.3%.

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Flow data are obtained for a range of inlet pressures and a least square curve fit is made .All kits have first degree and second degree curve fits applied to the data for propane**. Use the first degree fit when calculating data manually; use the second degree fit when a microprocessor is used for calculations**. The corresponding orifice calibration is of the form:

First degree:

$$q = A + \frac{B \times P}{\sqrt{(460+t)}} \qquad (5)$$

Second degree:

$$q = A + (B \times P) + \frac{C \times P^2}{\sqrt{(460+t)}} \qquad (6)$$

Where:

q = Flow rate in SCFM at 29.92” Hg and 528°R.

A, *B*, *C* = Calibration constant furnished with each kit.

P = Absolute orifice inlet pressure, PSIA which equals gauge reading + (0.4912 x Barometer, inches of Mercury).

T = Orifice inlet temperature, °F.

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Pre-Operation

Precautions

Before taking further steps, ensure that:

- The test cell floor is checked for fuel spills.
- The CVS blower must be operating when performing the test.
- Cylinders containing compressed gases are used for this procedure. The technician must be familiar with the “Customer Site Safety Manual” sections dealing with the safe handling, storage, and use of compressed gas cylinders.
- Safety precautions must be followed when using compressed gases.
- The CFO kit must be in the test cell prior to the start of the calibration for a minimum` of 20 minutes to ensure the kit is at room temperature.

Visual Inspection

- Ensure the test cell floor is checked for fuel spills.
- There should be no running vehicle(s) on the dynamometer(s) and the test cell door is closed.
- The test cell air handler should be on and test cell ambient conditions are stable. The gas cylinder and equipment is checked for leakage, damage, and cleanliness.
- The CFO pressure display should read barometric while the kit is not operating.
- Calibrations are checked as valid by verifying that the calibration due dates have not been exceeded for the CFO kit.
- The power is turned on for the HC analyser (i.e. FID) and related equipment. The FID is lit and allowed to warm-up for a minimum of 30 minutes.

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Test Preparation & Execution

Hardware

- Ensure that the air handling system in the test cell is turned on and test cell ambient conditions are stable.
- Ensure that the CVS Blower is turned on.
- Connect CFO Kit output hose to LLRMT (low loss remote mixing tee) mixing point provided.
- Connect the Propane cylinder hose to CFO Kit Inlet port. These are colour coded to prevent operator error.
- Open the regulator and ensure that the outlet pressure is > 7bar (100psi). This is to ensure that the correct target ppmC can be achieved. Lower outlet pressures can be used; however the customer must adjust the target ppmC to a lower value.
- Check the gas cylinder and equipment for leakage, damage, and cleanliness.
- Connect the supplied LAN cable to the CFO Kit and the other end to the LAN port on the LLRMT.
- Connect the supplied power adaptor to the 13amp mains socket on the LLRMT and in turn use this to power on the CFO Kit. Make sure the extraction fan on the CFO kit is working.

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Software

Auto Mode

1. Open CFO host software
2. Ensure no alarms are shown
3. Input CVS flow rate & Target PPM
4. Click on System Icon & choose Run

CFO will begin flowing gas through the system and into the CVS
End test when required by selecting Standby.

Manual Mode

1. Open CFO host software
2. Ensure no alarms are shown
3. Click on System Icon & choose Manual Mode

Under Orifice Settings,

4. Select gas type
5. Specify orifice size to use (low, high, low & high)
6. Input pressure value in psiA

CFO will begin flowing gas through the system and into the CVS
End test when required by selecting Standby

See figure 1 on next page for overview of software layout

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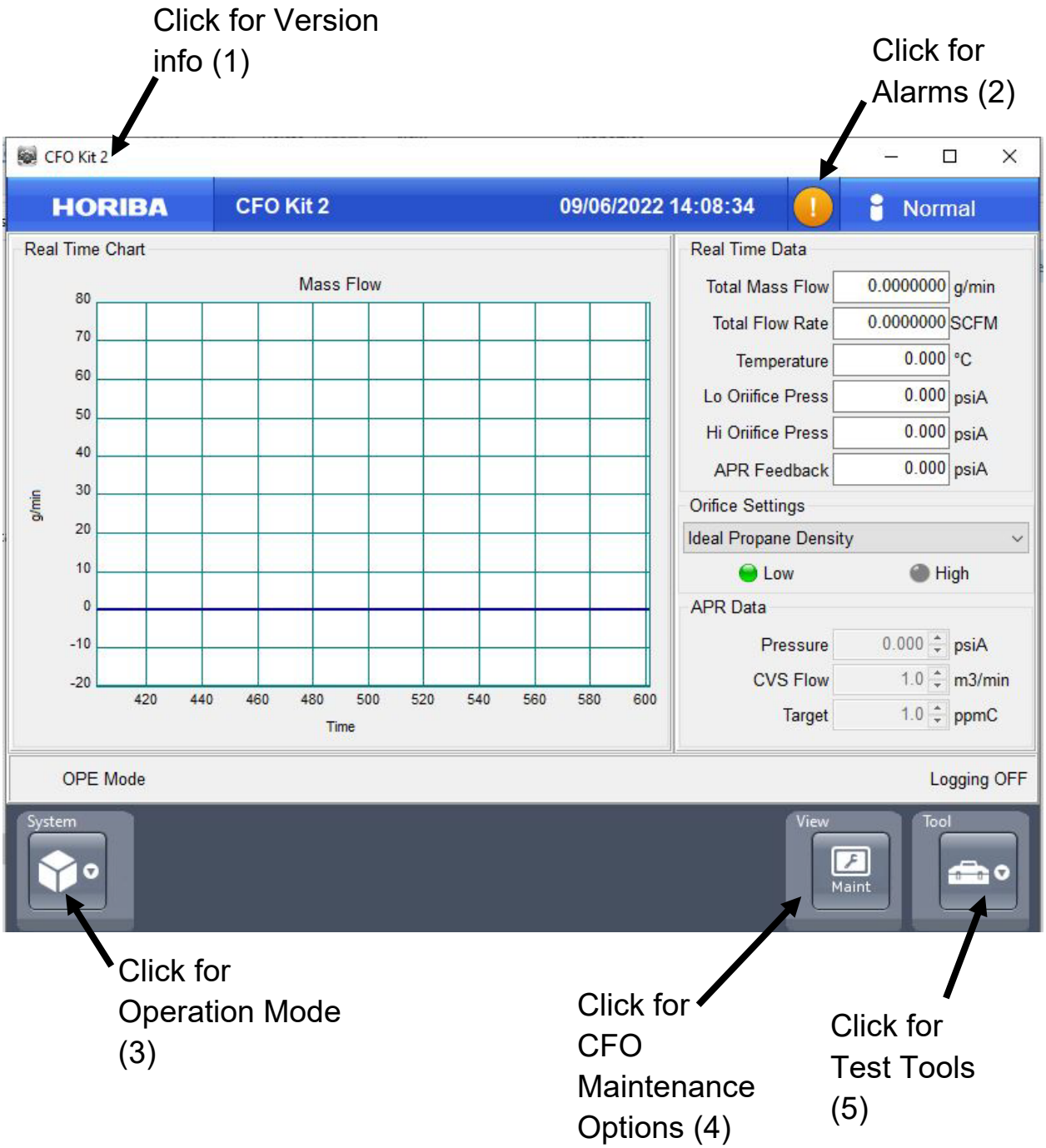

Figure 1 – Main Screen

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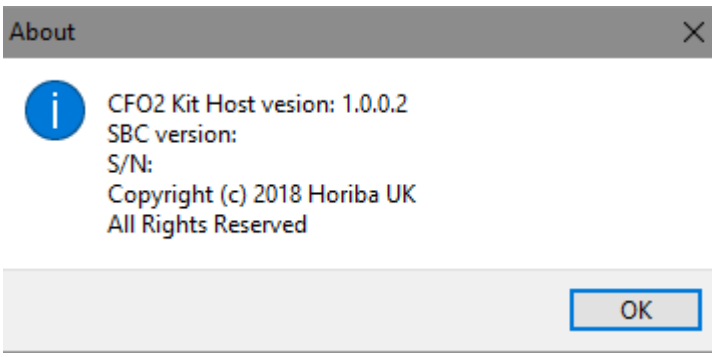
(1)

Order of Info

- Software Version
- Firmware Version
- CFO Serial Number



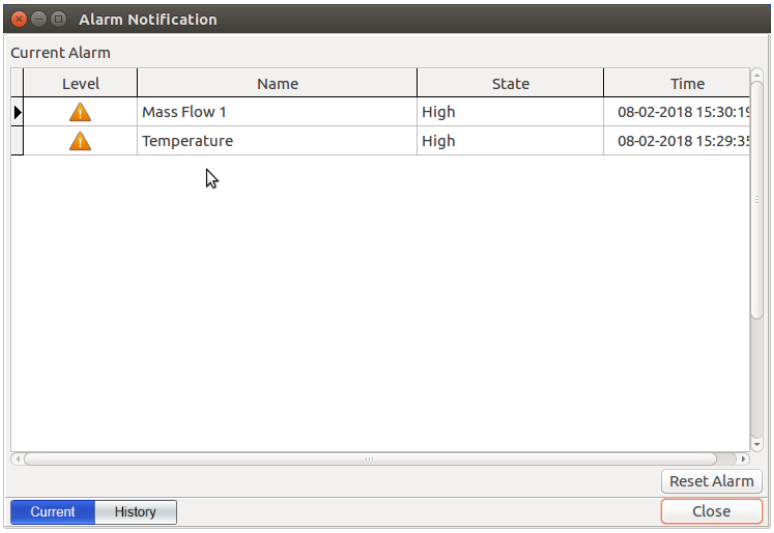
(2)

Order of Info

- Alarm Level

 = Action Needed

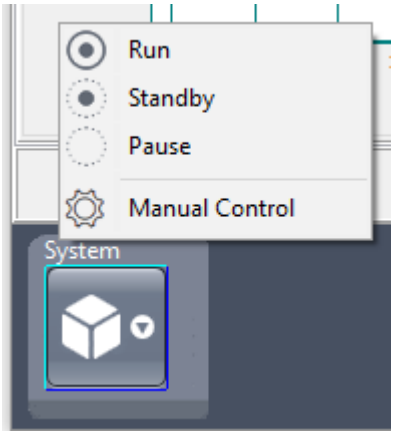
- Description of Alarm
- Alarm State
  High = Action Needed
  Normal – Warning
- Time of Alarm



(3)

Order of Info

- Run - All Valves Activated
- Standby - APR closed
- Pause - All Valves Closed
- Manual Control – Activates Manual Mode



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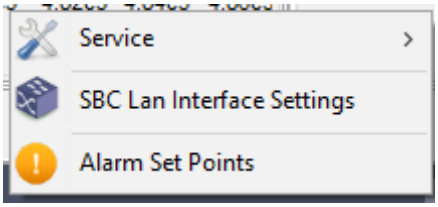
(4)

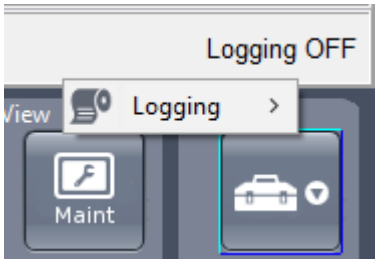
Order of Info



- Service – features for service personnel only
- SBC LAN Interface Settings
  Setup custom IP address for CFO
- Alarm Set Points
  Set when Alarms will flag up e.g. temperature range

(5)

Order of Info



- Logging – To log data

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Interpreting Results

Assuming ±2% accuracy in the calibration bottles and ±1% in the CVS pump absolute air flow calibration, it follows that a value for *E* in equation (3) earlier of ±3% or less can be expected. Larger discrepancies from this would require corrective action.

Error Analysis

Following is a list of possible sources of error as based on the sign of the final result.

Positive Error:

- Venturi flow rate is less than the calibrated value.
    - Original bulk stream calibration in error, or
    - Leakage has developed between blower and Venturi
- Venturi inlet temperature transducer is reading low
- Venturi inlet pressure transducer is reading high
- Background concentration reading is too low. Check analyser zero.
- Barometer reading is high, check the pressure transducer.
- Flow computer output is high.

Negative Error

- Venturi flow rate is greater that calibration value
    - Original bulk stream calibration in error or,
    - Leakage has developed between vehicle inlet and the inlet to the bulk stream Venturi.
- Venturi inlet temperature transducer reading high.
- Venturi inlet pressure transducer reading low.
- Background concentration reading is too high.
- Analyser is reading too low. Check analyser span.
- Barometer is reading too low, check the pressure transducer.
- Air leak into the bag sampling system, between the bags and the bag sample pump.

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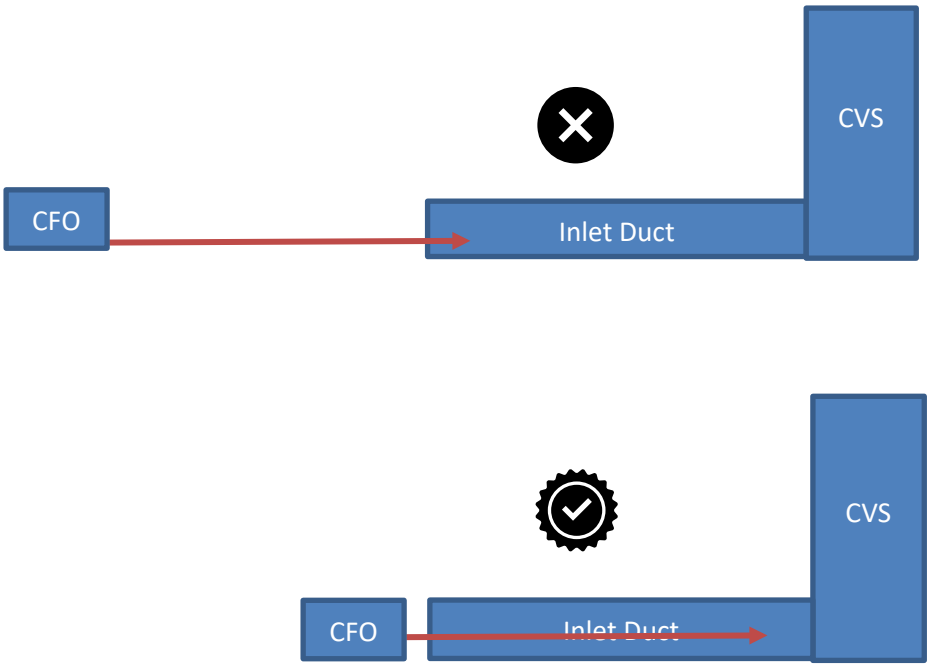
Ensure location of CFO Outlet Pipe is as far into the Transfer Tube as possible



Maintenance

In order that the equipment stays in calibration and maintains accuracy, it should be kept away from EMC sources. The unit should not be dropped or thrown around and care should be taken during its transport.

Because of the very small size of sample gas orifice, precaution should be taken to maintain cleanliness in the gas line system leading to the kit inlet connection.

The gas outlet should be kept clean to avoid introducing Hydrocarbons other than the propane injected. The filter in the kit would take care of particulates but can pass moisture or Oil vapour, which in form deposits in the Orifice.

The connecting gas lines should be stored in the case when not in use. If contamination is suspected, the connecting lines should be rinsed with acetone and blown out with clean, dry gas, such as bottled air or nitrogen.

If the unit has been exposed to contamination, or if for any other reason, a change in flow characteristic is apparent, the complete unit should be returned for recalibration to HORIBA UK Limited.

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It is highly recommend the kit is returned to HORIBA UK Limited for calibration annually to compensate for any drift in the pressure, temperature of flow calibrations.

Reference: Projected C3H8 concentrations vs CVS flow (Indication Only)

CVS Flow (m3)	6	9	12	18	22
CFO Pressure (psia)	Projected Propane Concentrations (ppmC) CFO Orifice = 0.0040"				
40	121	81	61	40	33
45	132	88	66	44	36
50	143	96	72	48	39
55	154	103	77	51	42
60	166	110	83	55	45
65	177	118	88	59	48
70	188	125	94	63	51
75	199	133	99	66	54
80	210	140	105	70	57
85	221	147	110	74	60
90	232	155	116	77	63

Assumptions:

1. Barometric pressure = 14.7 PSIA
2, Temperature = 20degC

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HORIBA

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[Design Concept]
The HORIBA Group application images are collected in a collage of the following design:
Beginning from a nano-sized element, the scale of our story enlarges all the way up to the earth, incorporating a sinuous flow of water.