

Measurement Systems Corrector Prover: Programming, Testing and Calibration of Electronic

Corrector Systems

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Abstract

The following document outlines the basic operation, capability/flexibility and overall benefit for natural gas utilities that are currently or planning on utilizing electronic correctors in their gas measurement program. The Corrector Prover is an automated testing and calibration device specifically designed for Mercury/Honeywell and Eagle Research electronic correctors. The Corrector Prover is also capable of expediting the testing and calibration of all electronic corrector devices using the prover's software in conjunction with the manufacturer's provided software. The Corrector Prover uses Measurement Systems CorrectorCal software with integrated manufacturer's communication protocol to ensure electronic correctors are appropriately programmed with the customer's specified settings (CO₂, N₂, SG, Base Temperature/Pressure, ATM etc.), tested within customer specified limits and if necessary, calibrated for use in the field.

Measurement Systems Corrector Prover: Programming, Testing and Calibration of Electronic Corrector Systems

As Electronic Correctors are primarily used in gas measurement conditions with high volume usage or critical applications, it is of the utmost importance that the corrector is measuring accurately and observing the utilities' natural gas/locational specifications regarding specific gravity, base pressure/temperature, atmospheric pressure etc. The Measurement Systems Corrector Prover views the electronic corrector as the equivalent of the metering device itself. Enabling the operator to InTest, adjust (calibrate) and OutTest the corrector under laboratory conditions using an automated system that communicates directly with the corrector under test, utilizing traceable standards (temperature and pressure) and data saving capabilities with minimal operator interaction.

Principles of Operation

The Measurement Systems Corrector Prover compares the Prover's calculated correction factors to the corrector's reported correction factors. There are three possible correction factors that are available that make up the overall correction factor for each device: Pressure, Temperature and Supercompressibility.

Using the basic principle of Boyle's law, the corrector and prover will calculate the Pressure Correction Factor (P_{FACTOR}) to be used for calculating (at constant temperature) changes in volume of an ideal gas caused by differing flow pressure:

$$P_{FACTOR} = \frac{PSI_{gauge} + Atmospheric\ Pressure}{P_{BASE} (Absolute\ Pressure, psia)}$$

The base pressure (P_{BASE}) is an absolute pressure specification value that the customer maintains with the manufacturer/distributor that may vary between utilities. If the flow pressure deviates from the base pressure, a correction must be made for that deviation. For the following

example 14.92 psia will be used as the base pressure. Assuming the Corrector Prover/utilities' correctors are not equipped with an absolute pressure transducer, atmospheric pressure is programmed by the manufacturer/distributor specifically for the customer's location. For the example below, we will use 14.73 psia for the atmospheric pressure. With a measured value of 25.5 psig from the Crystal 0-300 psi gauge:

$$P_{FACTOR} = \frac{25.5 \text{ gauge} + 14.73 \text{ atm}}{14.92 \text{ base}} = 2.696$$

For the above example, the pressure correction factor is 2.696. To obtain a volume corrected for pressure, the ACF volume must be multiplied by 2.696 to solve for the equivalent volume corrected for pressure.

Using the principles of Charles' Law, the corrector and prover will calculate a Temperature Correction Factor (T_{FACTOR}) to be used for calculating (at constant pressure) changes in volume of an ideal gas with differing flow temperature. As temperature increases, the gas expands and as temperature decreases the gas contracts:

$$T_{FACTOR} = \frac{[T_{BASE} (^{\circ}\text{F}) + 460] (\text{Rankine})}{[\text{Measured Temperature } (^{\circ}\text{F}) + 460] (\text{Rankine})}$$

The base temperature (T_{BASE}) is the temperature value that the customer maintains with the manufacturer/distributor that may vary between utilities. When the flow temperature deviates from the base temperature, a correction must be made for that deviation. The most common base temperature is 60 degrees Fahrenheit, which will be used in our example. With a measured temperature of 85 degrees Fahrenheit:

$$T_{FACTOR} = \frac{[60 (^{\circ}\text{F}) + 460] (\text{Rankine})}{[85 (^{\circ}\text{F}) + 460] (\text{Rankine})} = 0.954$$

For the above example, the temperature correction factor is 0.954. To correct the volume for temperature, the ACF volume must be multiplied by this factor. Since the temperature has

caused the gas to expand, less gas can fit into the same space. Measured temperatures above the base temperatures will have a T_{FACTOR} less than 1.0, below will have a T_{FACTOR} greater than 1.0.

Ideal gas laws are just that, laws that apply to ideal gasses. Natural gas composition is not an ideal gas, and as such does not follow strictly to the ideal gas laws (Charles'/Boyle's Laws). To compensate, electronic correctors use a Supercompressibility Factor (Z_{FACTOR}) (if enabled) for this correction. As stated above, the Z_{FACTOR} is dependent on gas composition (SG, %N₂, %CO₂ etc.), measured flow temperature and pressure. With the use of the previous examples' measured temperature, pressure and equivalent gas composition properties, the Z_{FACTOR} would be 1.003. In more simple terms, pressure has the greatest effect on the Z_{FACTOR} . Increasing the measured pressure from 25.5 psi to 250 psi changes the Z_{FACTOR} from 1.003 to 1.033. Changing the measured temperature from 85 to 0 °F (maintaining 25.5 psi measured pressure) the Z_{FACTOR} adjusts from 1.003 to 1.006. This represents a change of 3% versus 0.3% of gas volume with pressure and temperature change respectively.

The overall correction factor (OA_{FACTOR}) as measured by the Measurement Systems Corrector Prover is calculated by multiplying the above calculated factors, depending on whether the corrector under test has specified factors enabled:

$$OA_{Factor} = P_{FACTOR} \times T_{FACTOR} \times Z_{FACTOR}$$

Using the above example, the overall correction factor as calculated would be:

$$OA_{FACTOR} = 2.696 \times 0.954 \times 1.003 = 2.581$$

For this example, the overall correction factor at measured 'flow' conditions and specified parameters is 2.581. To obtain the measured volume corrected for pressure, temperature and supercompressibility we must now multiply our ACF volume by 2.581 to solve for the overall corrected volume of gas.

Basic Corrector Prover Operation

The following procedure summary and associated bracketed callouts are referencing Fig. 1: Basic Corrector Prover Schematic. The physical parts represented in the Fig. 1 schematic are contained within the 50" H x 42" W x 29" D envelope of the Corrector Prover (not including the Nitrogen Tank/Regulation System [12]). All red lines represent serial communications to the Corrector Prover Computer [2] from the following: Pressure Gauge [6], Temperature Calibrator(s) [13], Digital Brain Controller [3], ECUT [11] and Atmospheric Pressure Transducer [5] (if installed). Multiple Temperature Calibrators (three depicted) decrease time between configurable multi-point InTest/OutTest temperature set points as well as multi-point temperature calibrations. The ECUT is pressurized by means of the Nitrogen Tank/Regulation system [12], set to an operator specified pressure from within the CorrectorCal software that controls the Corrector Pressure Fill/Exhaust Solenoid Valve Bank [10] through the Digital Brain Controller [3]. This process automates the pressurization for all ECUT depending on the operator's programable corrector model. All transducer data, ECUT communications, InTest/OutTest data, Calibrations administered etc. are displayed on the Touch Screen Monitor [1].

InTest/OutTest.

The ECUT [11] is placed over the Clockwise/Counterclockwise Drive Motor [9] and secured in place. If the ECUT has an enabled temperature transducer, and depending on the parameters of the test, the blue line from Fig. 1: Basic Corrector Prover Schematic (ECUT Temperature Probe) is placed in the appropriate Temperature Calibrator ('Zero', 'Mid' or 'Span'). The Corrector Pressure Source Hose [7] and the Corrected/Uncorrected Pulse Output Cable [8] is connected to the ECUT. Using the CorrectorCal software, the appropriate corrector

model for the ECUT is selected and the InTest or OutTest button is pressed. The software initiates communication with the ECUT, collecting/displaying the Serial Number, Corrected/UnCorrected counts, correction parameters (Pressure, Temperature & Super Compressibility) and Battery Voltage. Prior to initiating the tests, the Corrector Prover compares the operator's programmable correction parameters (SG, %N₂, %CO₂, T_{BASE}, P_{BASE}, etc.) with the ECUT to ensure both are using equivalent parameters for correction. If there is a discrepancy, the operator is alerted and requested to update the ECUT (Fig. 2). The test(s) cannot be performed without updating the corrector's parameters to ensure a one-to-one comparison as well as ensuring the ECUT is appropriately programmed for use in the field. The updating process is automated through the CorrectorCal program, along with any default operator configured item codes/values (configured within the software) that will be 'pushed' to the ECUT. The operator will then be guided through the test with three user configurable pressure and temperature points ('Zero', 'Mid' and 'Span'). Results will be displayed on both the main test screen, represented in the configured display method (proof/accuracy/error) along with a more detailed result output in the data panel. Once the span test is completed and the ECUT maintains the configured span pressure, the Clockwise/Counterclockwise Drive Motor is activated. Through the Corrector Prover Computer, Digital Brain Controller and ECUT's Pulse Output Cable, the CorrectorCal program will 'jog' the ECUT until it has received ten corrected counts to ensure the corrector is outputting pulses appropriately. If the results are within the operator configurable limits and the ECUT is outputting corrected/uncorrected counts, the data may be saved as both an InTest and OutTest. If adjustments are required, the operator would continue to the calibration process.

Calibration.

With the ECUT connected to the prover (communication, pulse output, pressure input, temperature probe if applicable), the calibration button is pressed and depending on the results from the InTest, the Pressure, Temperature (or both) Calibration button is selected.

With a 1 or 2-point pressure calibration (configured within the CorrectorCal software), the ECUT's pressure transducer is calibrated against the Corrector Prover's pressure standard(s) (see Table 1, Table 2 and Table 3 for specifications). As with the InTest/OutTest process, the Corrector Prover automatically pressurizes the ECUT to the specified 'Zero' and 'Span' values. The software displays the ECUT's live pressure reading and allows the operator to calibrate once the pressure has stabilized.

As with pressure, the temperature calibration may be configured as a 1 or 2-point calibration. Both the 'Zero' and 'Span' temperature calibration points are configured within the CorrectorCal software. The ECUT's temperature transducer (if available) is calibrated against the Corrector Prover's temperature standard(s) (see Table 4, Table 5 and Table 6 for specifications). Depending on the number of temperature calibrators, the operator will be prompted to move the ECUT temperature probe between calibrators for the 'Zero' or 'Span' calibration. The software will display the ECUT's live temperature reading and allows the operator to calibrate once the temperature has stabilized.

After the necessary calibration(s) have completed, the operator will initiate the OutTest (see above for process). The resulting InTest/OutTest data and calibrations completed may be saved by selecting the 'Save Data' button, see Fig. 3: Completed InTest, Calibration and OutTest for the resulting output from the CorrectorCal software.

Tables:

Table 1

Specifications: Ametek Crystal XP2i Pressure Gauge (0-100 psi)

Range	0-100 psig
Over-Pressure	2.0 x Range (200 psig)
Accuracy (0%-20% of Range)	$\pm 0.02\%$ of Full Scale (0-20 psig)
Accuracy (20%-110% of Range)	$\pm 0.1\%$ of Reading (20-110 psig)
Resolution	0.01
Operating Temperature	-10 to 50 °C
Weight	0.562 kg (1.2 lb)
Power	3 x AA Battery (AC Adapter Kit supplied)
Computer Interface	RS-232
Traceable Calibration	ISO 17025 Accredited Calibration Cert, NIST Traceable

Table 2

Specifications: Ametek Crystal XP2i Pressure Gauge (0-300 psi)

Range	0-300 psig
Over-Pressure	2.0 x Range (600 psig)
Accuracy (0%-20% of Range)	$\pm 0.02\%$ of Full Scale (0-60 psig)
Accuracy (20%-110% of Range)	$\pm 0.1\%$ of Reading (60-330 psig)
Resolution	0.01
Operating Temperature	-10 to 50 °C
Weight	0.562 kg (1.2 lb)
Power	3 x AA Battery (AC Adapter Kit supplied)
Computer Interface	RS-232
Traceable Calibration	ISO 17025 Accredited Calibration Cert, NIST Traceable

Table 3

Specifications: Mensor CPT6010 Barometer

Range	8 - 17 psia
Accuracy	0.020% of reading
Resolution	0.0001 psia
Compensated Temp. Range	15 to 45 °C (59 to 113 °F)
Size (HxW)	6.0 x 1.75 in
Weight	0.340 kg (0.75 lb)
Power	6-20 VDC, 45mA @ 12 VDC
Computer Interface	RS-232 Interface
Traceable Calibration	NIST-traceable calibration

Table 4

Specifications: Fluke Calibration 7102 Micro-Bath

Range	-5°C to 125°C (23°F to 257°F)
Accuracy	±0.25°C
Uniformity	±0.02°C
Resolution	0.01°C/°F
Heating time	25°C to 100°C: 30 minutes
Cooling time	25°C to 0°C: 30 minutes
Well size	64 mm dia. x 140 mm deep (2.5 x 5.5 in)
Size (W x H x D)	180 x 310 x 240 mm (7.2 x 12 x 9.5 in)
Weight	6.8 kg (15 lb) with fluid
Volume	0.75 L (1.6 pints)
Power	115 V AC (±10%), 1.8 A 50/60 Hz, 200 W
Computer interface	RS-232 Interface
Traceable Calibration	NIST-traceable calibration

Table 5

Specifications: Fluke Calibration 9171 Field Metrology Well

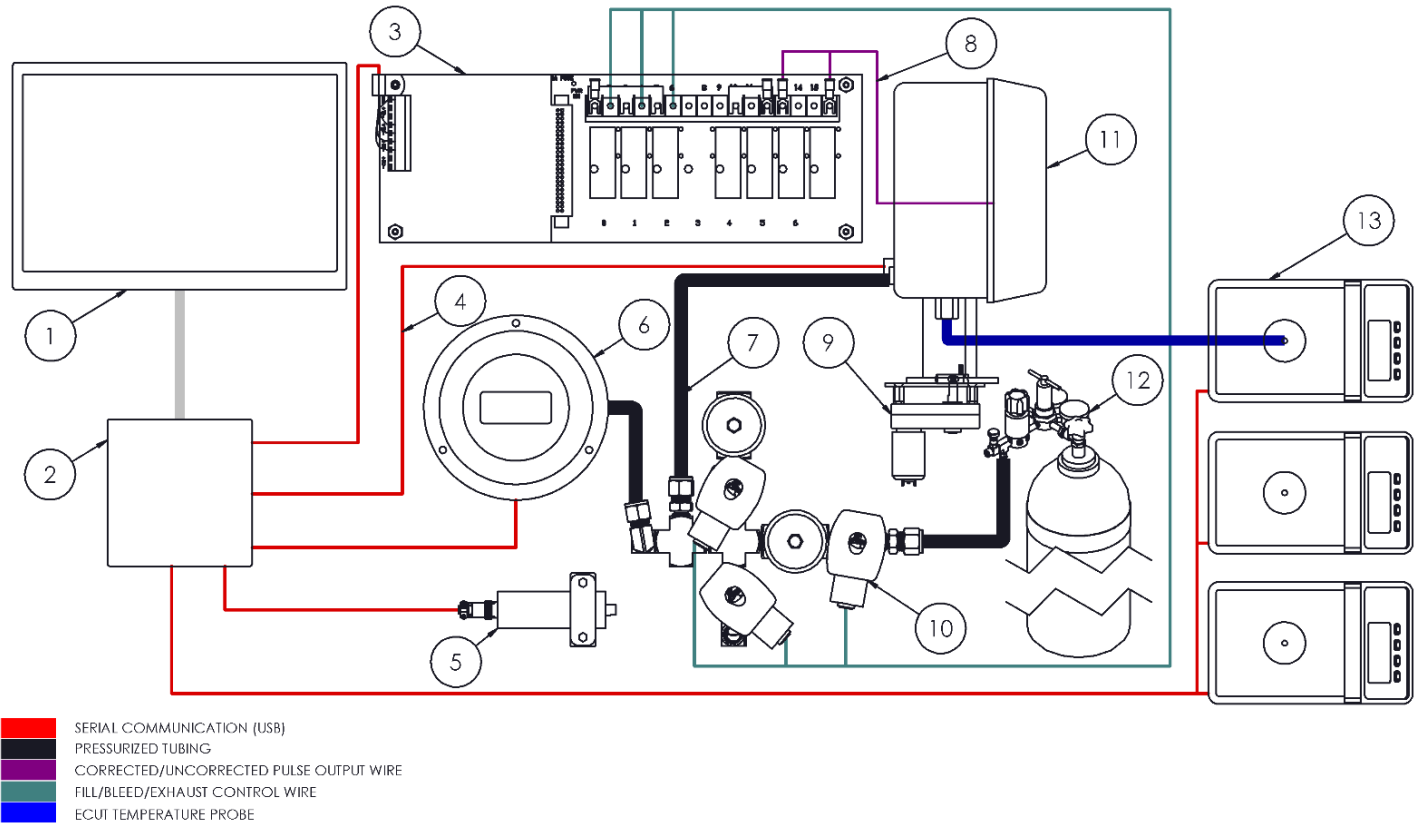
Range	-30 °C to 155 °C
Display Accuracy	± 0.1 °C full range
Stability	± 0.005 °C full range
Radial Uniformity	± 0.01 °C full range
Hysteresis	0.025 °C
Well Depth	203 mm (8 in)
Resolution	0.001 °C
Cooling Time	30 min: 23 °C to -30 °C
Heating Time	44 min: 23 °C to 155 °C
Size (HxWxD)	366 x 203 x 323 mm (14.4 x 8 x 12.7 in)
Weight	15 kg (33 lb)
Power	115 V ac (± 10 %)
Computer Interface	RS-232 Interface
Traceable Calibration	NIST-traceable calibration

Table 6

Specifications: Ametek Jofra Calibration CTC-155 Temperature Calibrator

Range	-25 °C to 155 °C
Display Accuracy	± 0.3 °C
Stability	± 0.04 °C full range
Radial Uniformity	± 0.03 °C full range
Well Depth	100 mm (3.9 in)
Resolution	0.01
Cooling Time	16 min: 23 °C to -25 °C
Heating Time	13 min: 23 °C to 155 °C
Size (HxWxD)	248 x 148 x 305 mm (9.76 x 5.83 x 12.01 in)
Weight	5.5 kg (12.1 lb)
Power	115 V ac (± 10 %), or
Computer Interface	RS-232/USB 2.0 Interface
Traceable Calibration	Traceable Certificate to International Standards

Figures:



Item	Description
1	Touch Screen Monitor
2	Corrector Prover Computer (USB Based, SSD, Micro Computer)
3	Digital Brain Controller
4	Corrector Communication Cable
5*	Atmospheric Pressure Transducer
6	Crystal XP2i Pressure Gauge
7	Corrector Pressure Source Hose
8	Corrected/Uncorrected Pulse Output Cable
9	Clockwise/Counterclockwise Drive Motor
10	Corrector Pressure Fill/Exhaust Solenoid Valve Bank
11	Electronic Corrector Under Test [ECUT]
12	Nitrogen Tank/Regulation System
13**	Temperature Bath(s)/Dry Block(s) Calibrators

Fig. 1: Basic Corrector Prover Schematic

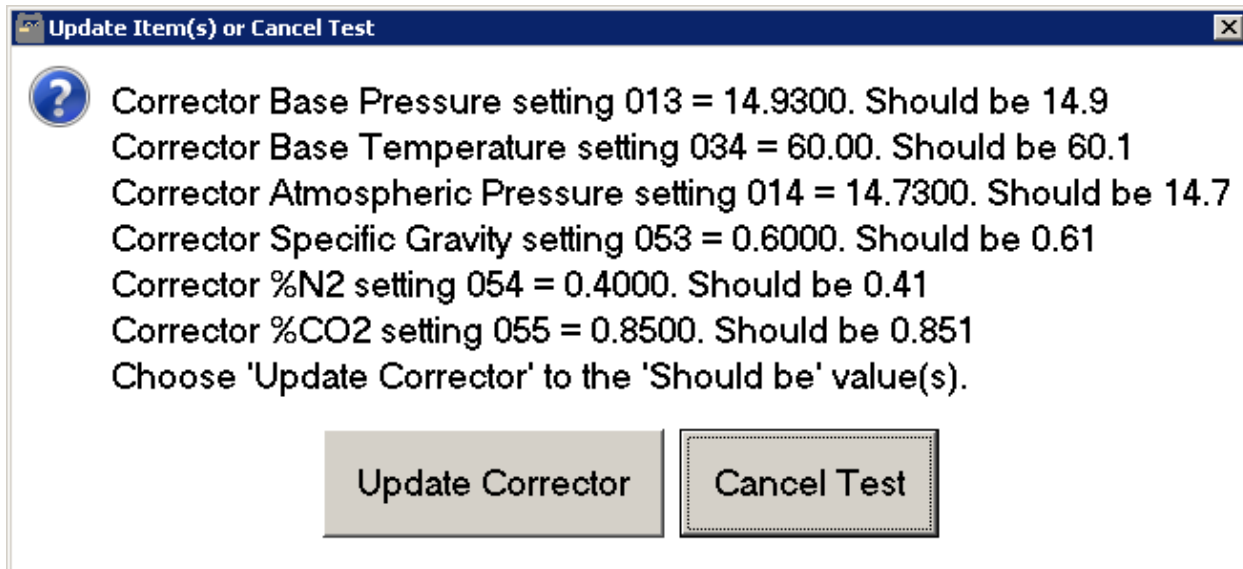


Fig. 2: Test Parameters Message Box

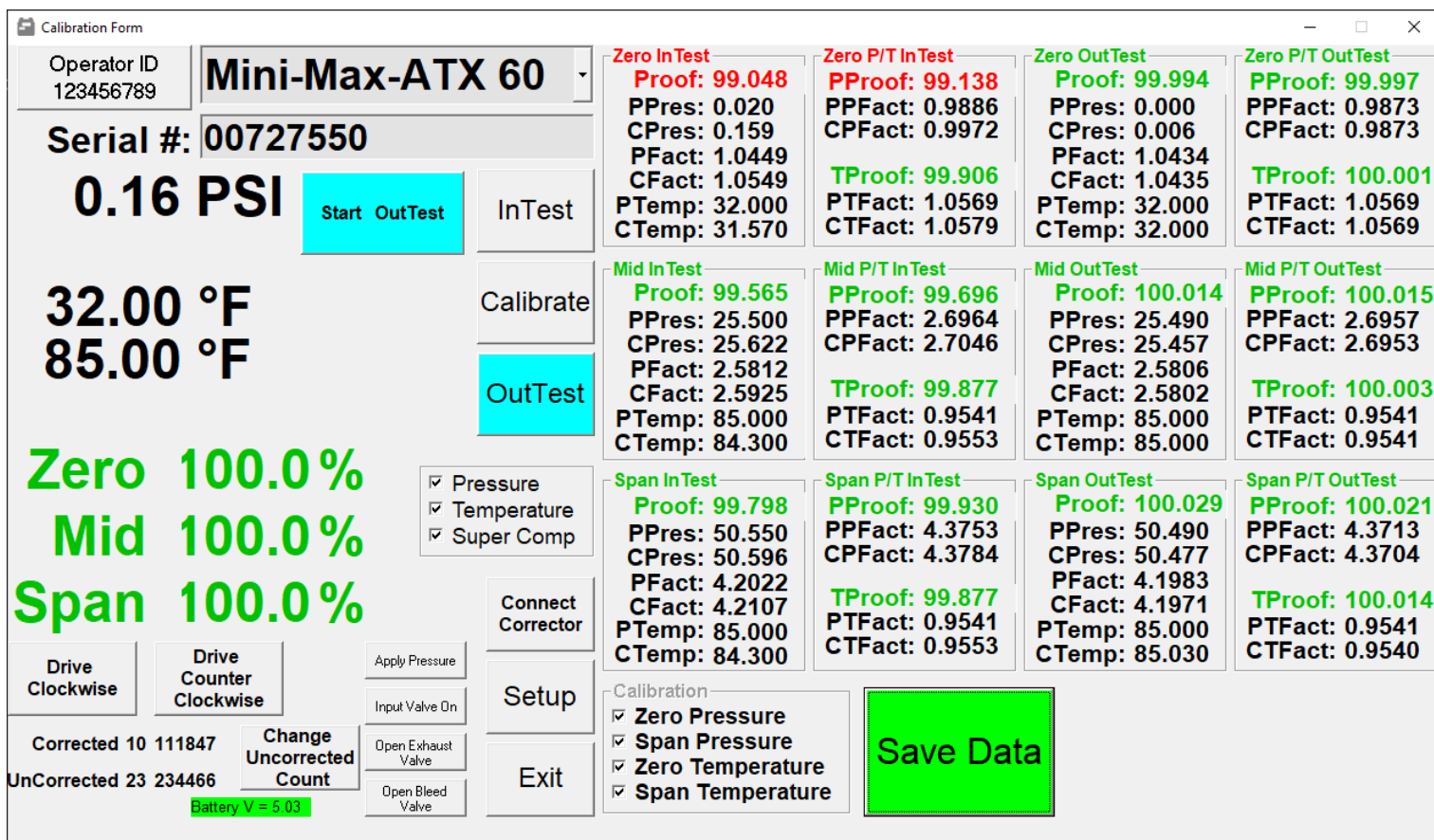


Fig. 3: Completed InTest, Calibration and OutTest