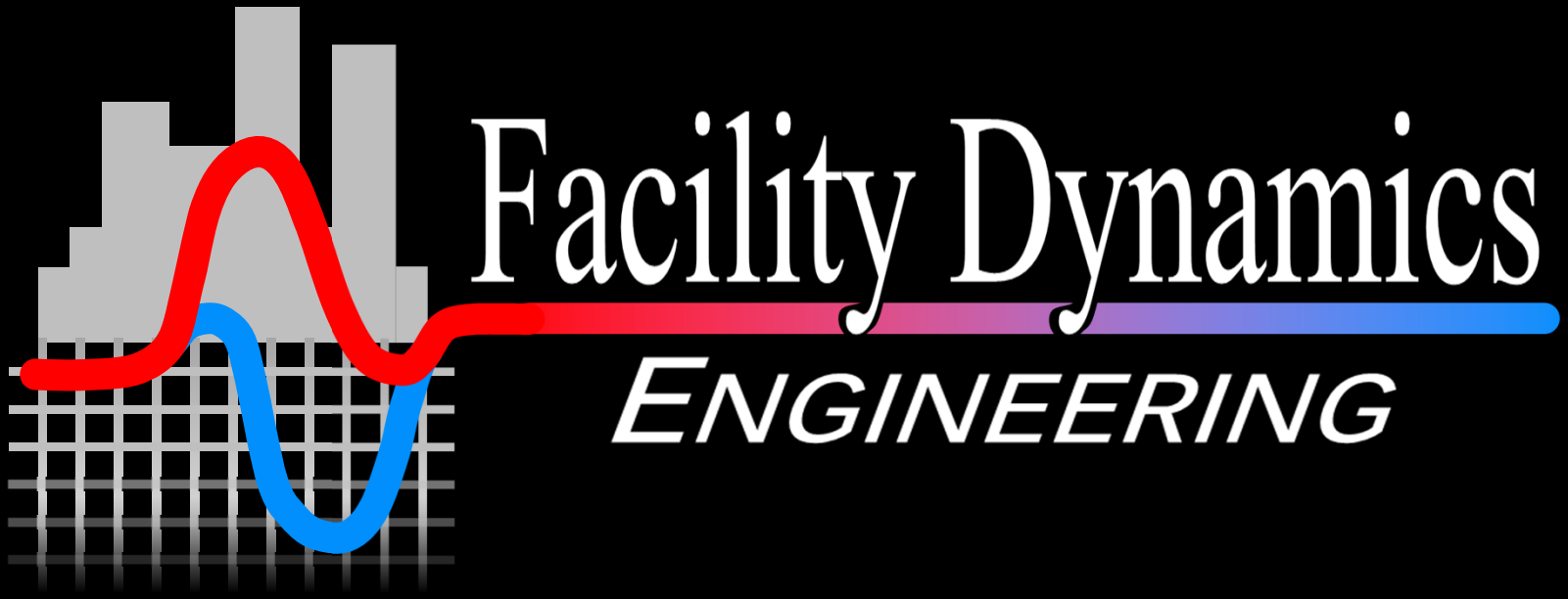


Inputs

Calibration and Accuracy

Presented By:

David Sellers, Facility Dynamics Engineering

Senior Engineer

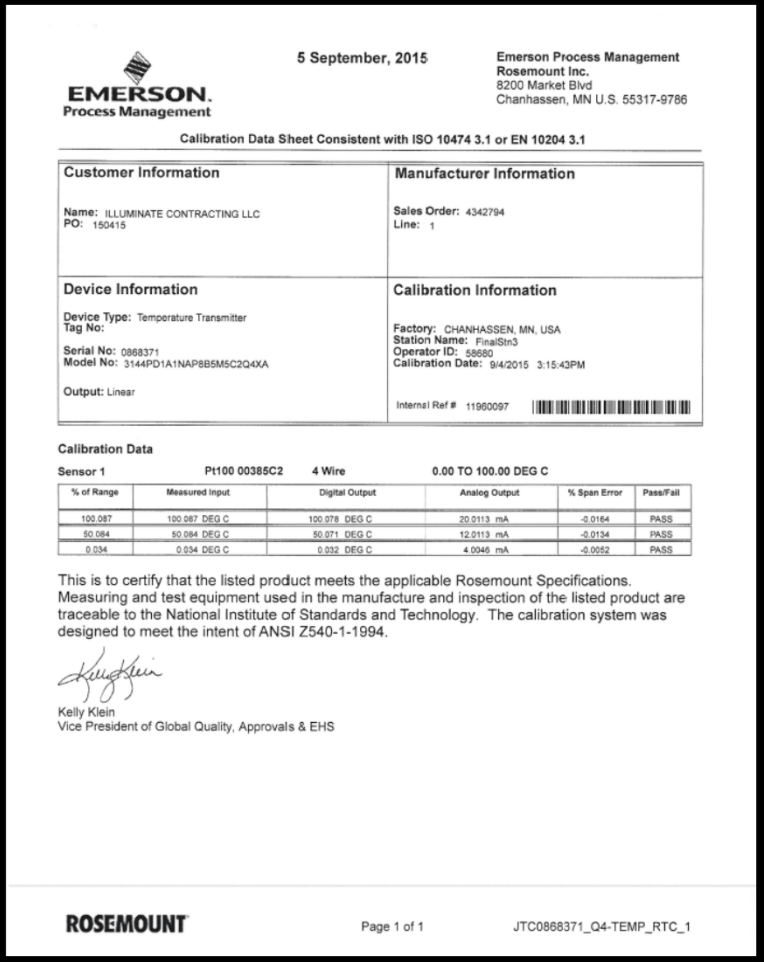
Revised 2016-11-20

Verify Input/Output Details

Calibration

Factory Calibration

- A good start
  - Addresses the factory provided components
  - Does not address the potential field impacts
    - Position effect
    - Lags
    - Lead resistance
    - A to D conversion
    - D to A conversion
    - COV limits
    - Bifocals



EMERSON. Process Management

5 September, 2015

Emerson Process Management
Rosemount Inc.
8200 Market Blvd
Chanhassen, MN U.S. 55317-9786

Calibration Data Sheet Consistent with ISO 10474 3.1 or EN 10204 3.1

Customer Information

Name: ILLUMINATE CONTRACTING LLC
PO: 150415

Manufacturer Information

Sales Order: 4342794
Line: 1

Device Information

Device Type: Temperature Transmitter
Tag No:
Serial No: 0868371
Model No: 3144PD1A1NAP8B5M5C2Q4XA
Output: Linear

Calibration Information

Factory: CHANHASSEN, MN, USA
Station Name: FinalStn3
Operator ID: 58680
Calibration Date: 9/4/2015 3:15:43PM
Internal Ref # 11960097

Calibration Data

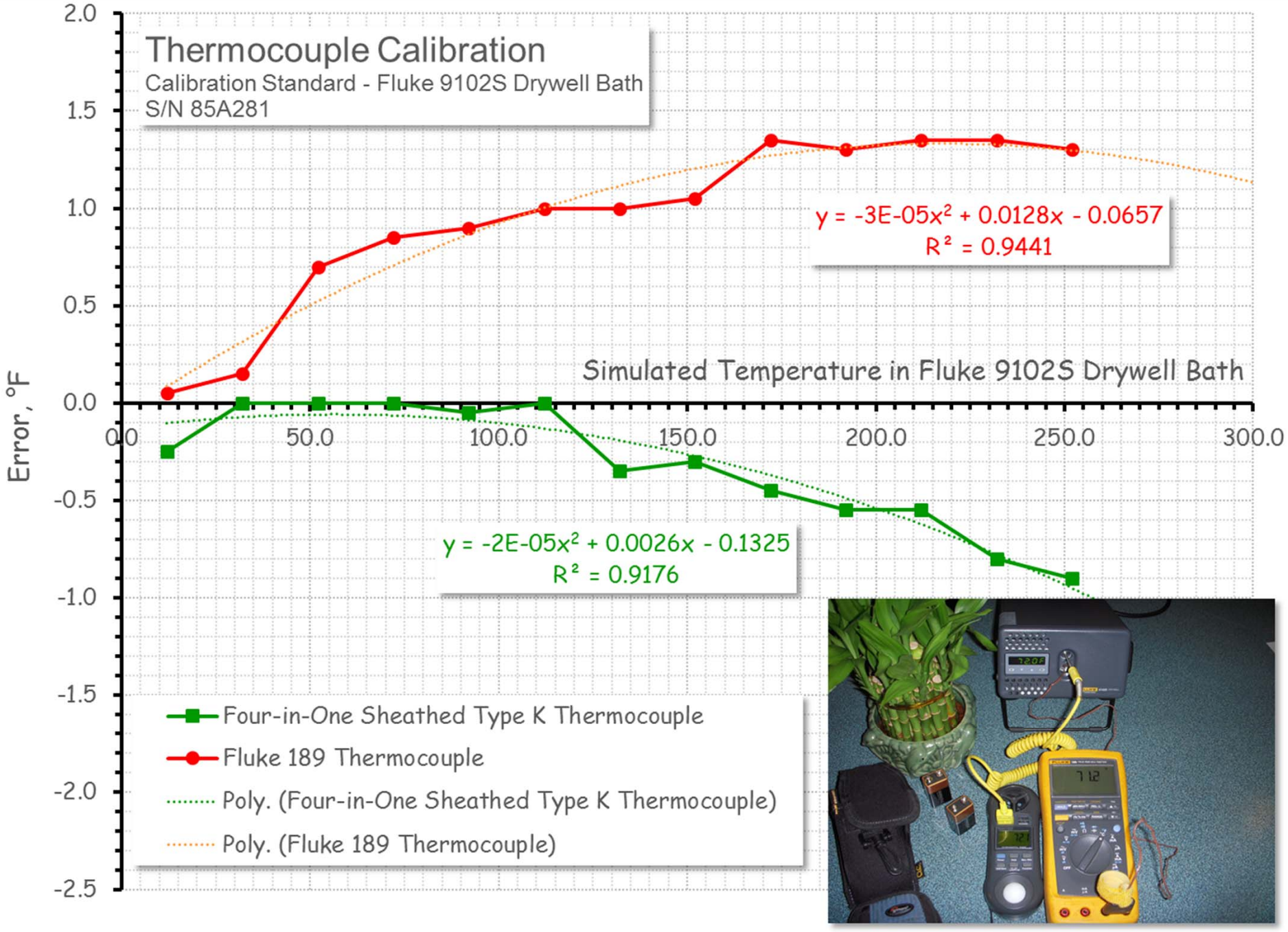
Sensor 1 Pt100 00385C2 4 Wire 0.00 TO 100.00 DEG C

% of Range	Measured Input	Digital Output	Analog Output	% Span Error	Pass/Fail
100.087	100.087 DEG C	100.078 DEG C	20.0113 mA	-0.0164	PASS
50.084	50.084 DEG C	50.071 DEG C	12.0113 mA	-0.0134	PASS
0.034	0.034 DEG C	0.032 DEG C	4.0046 mA	-0.0052	PASS

This is to certify that the listed product meets the applicable Rosemount Specifications. Measuring and test equipment used in the manufacture and inspection of the listed product are traceable to the National Institute of Standards and Technology. The calibration system was designed to meet the intent of ANSI Z540-1-1994.

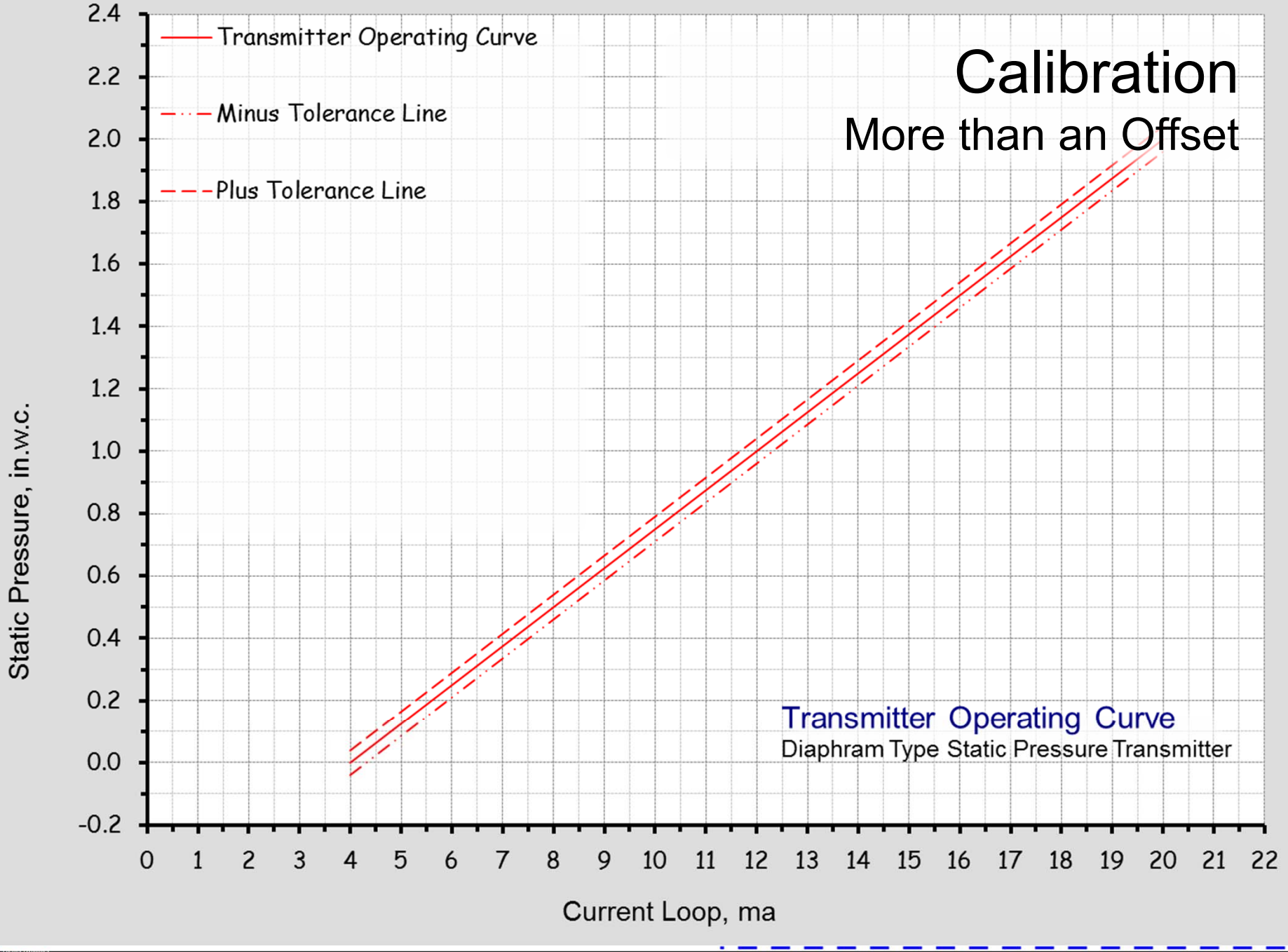
Kelly Klein
Vice President of Global Quality, Approvals & EHS

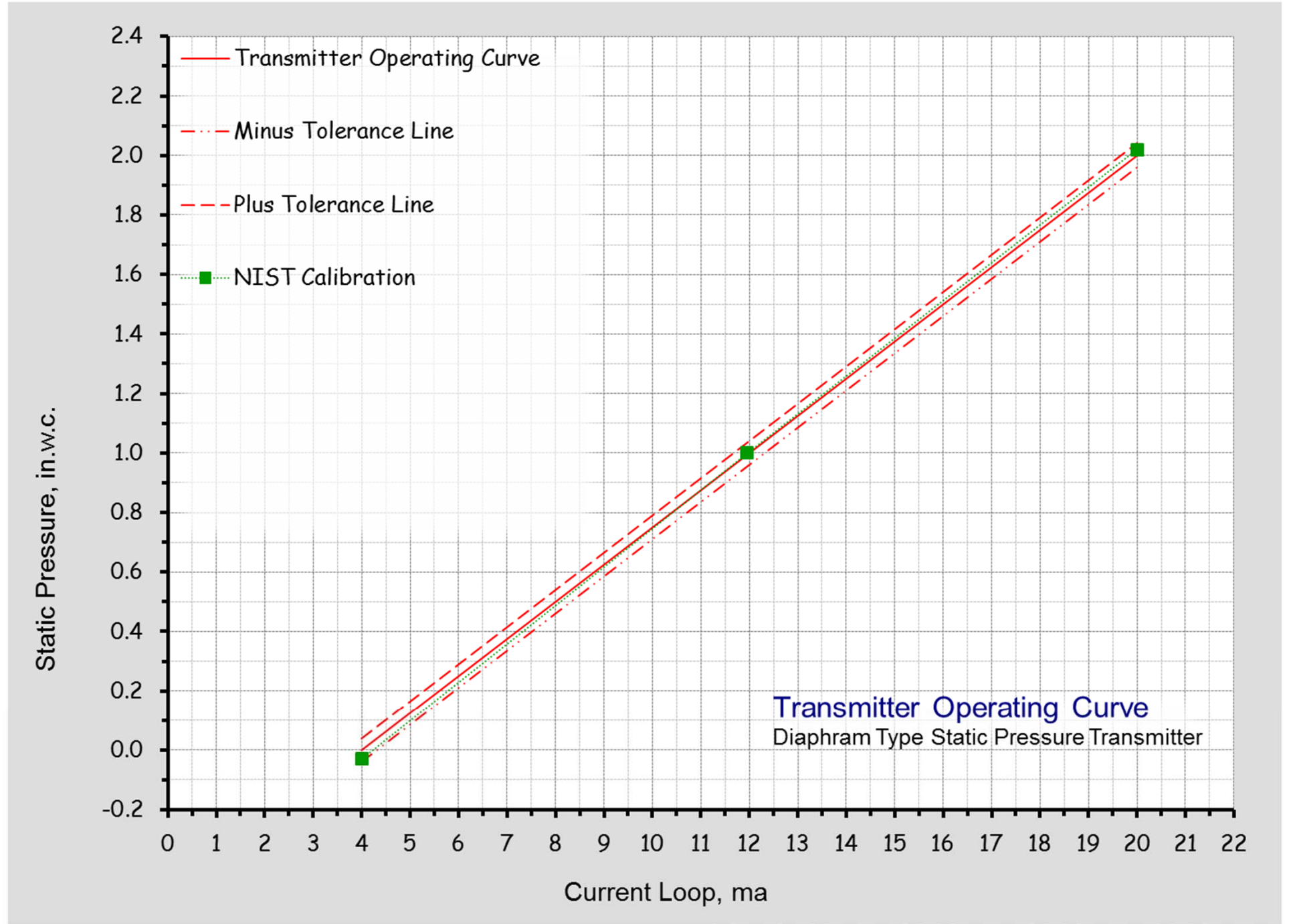
ROSEMOUNT Page 1 of 1 JTC0868371_Q4-TEMP_RTC_1


Thermocouple Calibration
Calibration Standard - Fluke 9102S Drywell Bath
S/N 85A281
y = -3E-05x² + 0.0128x - 0.0657
R² = 0.9441
y = -2E-05x² + 0.0026x - 0.1325
R² = 0.9176
Simulated Temperature in Fluke 9102S Drywell Bath
Error, °F
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
0.0
50.0
100.0
150.0
200.0
250.0
300.0
Four-in-One Sheathed Type K Thermocouple
Fluke 189 Thermocouple
Poly. (Four-in-One Sheathed Type K Thermocouple)
Poly. (Fluke 189 Thermocouple)

Calibration

More than an Offset

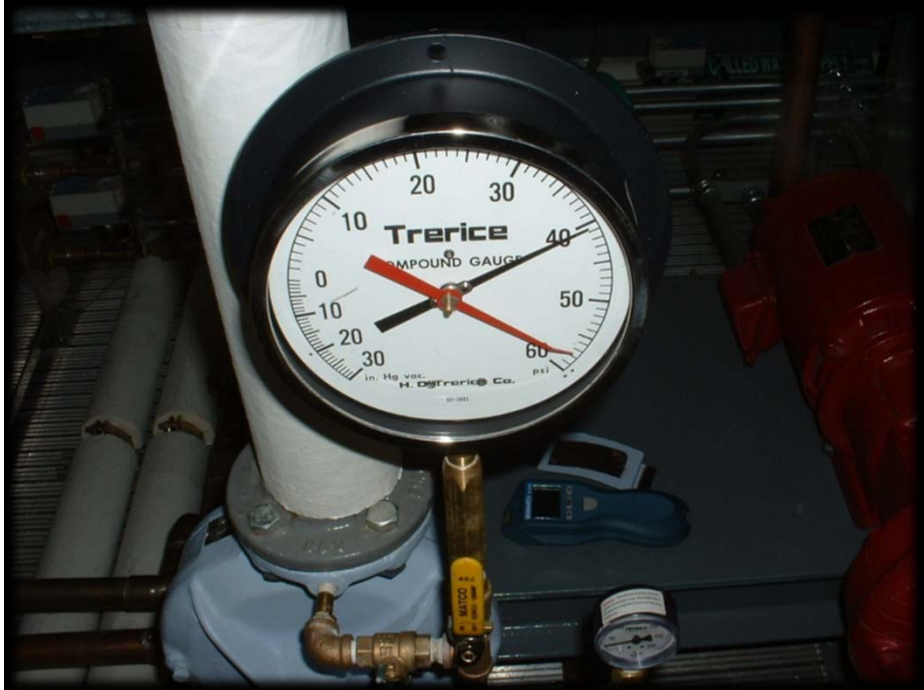



Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
NIST Calibration
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Current Loop, ma
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter

Un-Calibration

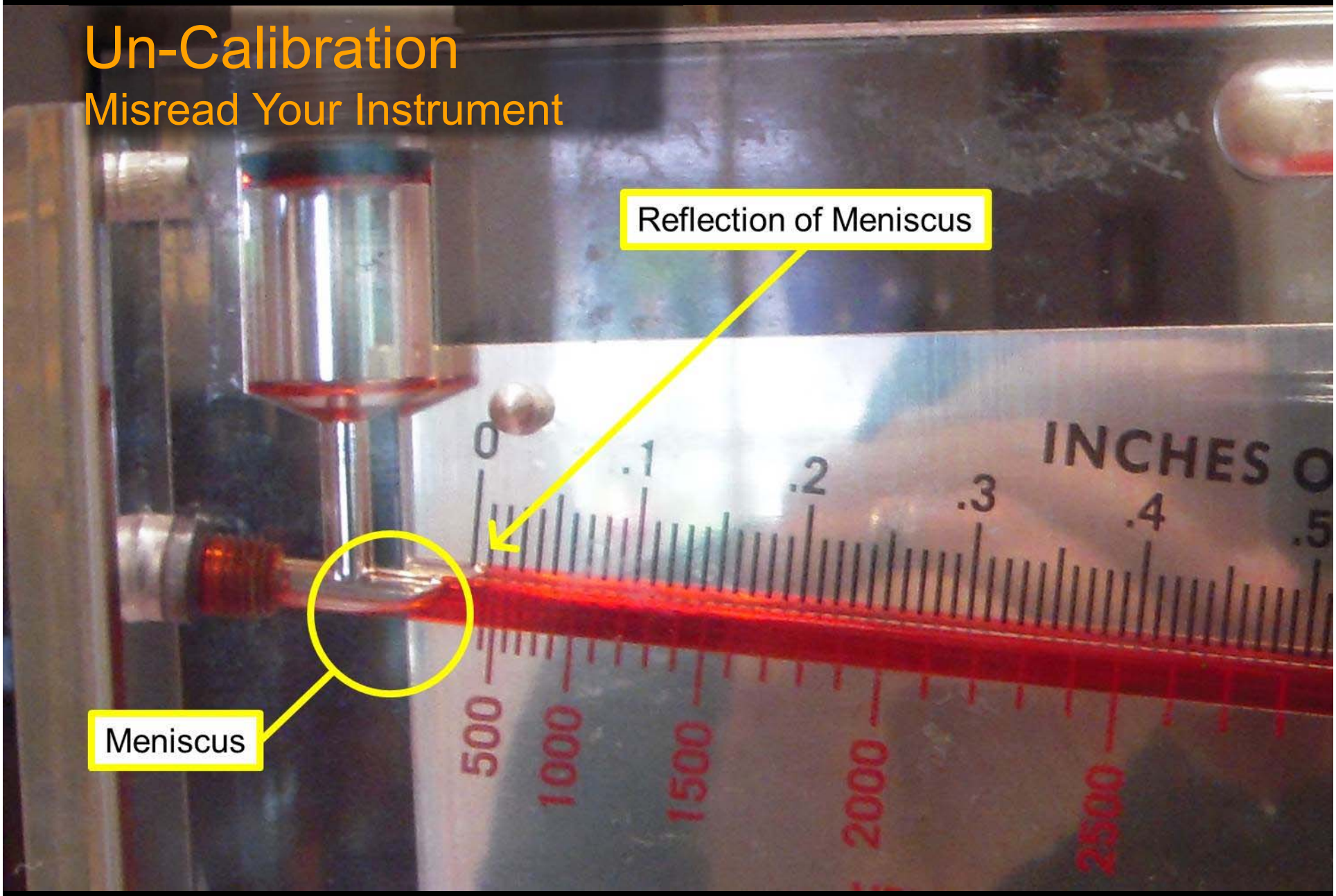
Use an Un-calibrated Standard

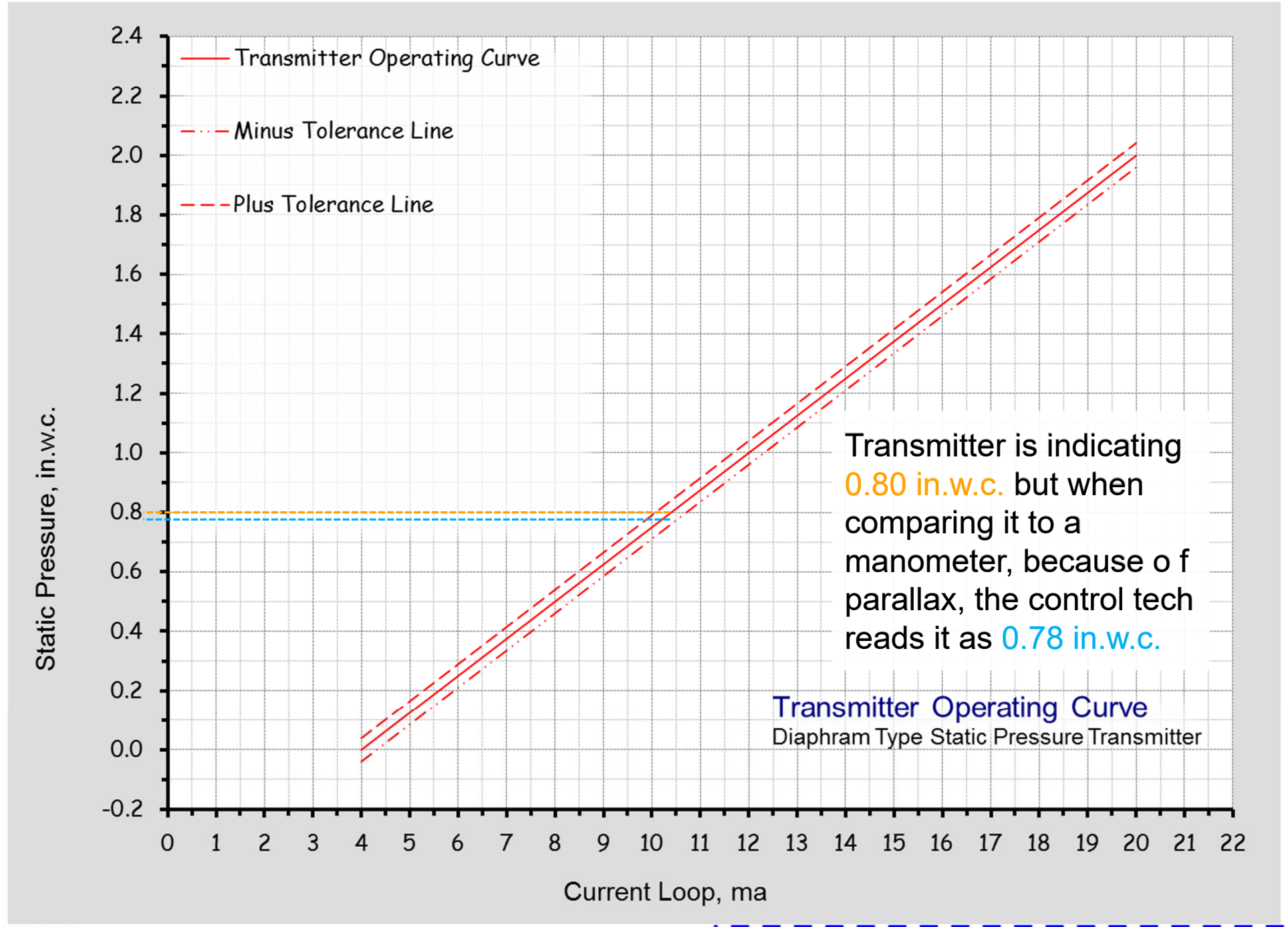
Un-Calibration
Misread Your Instrument

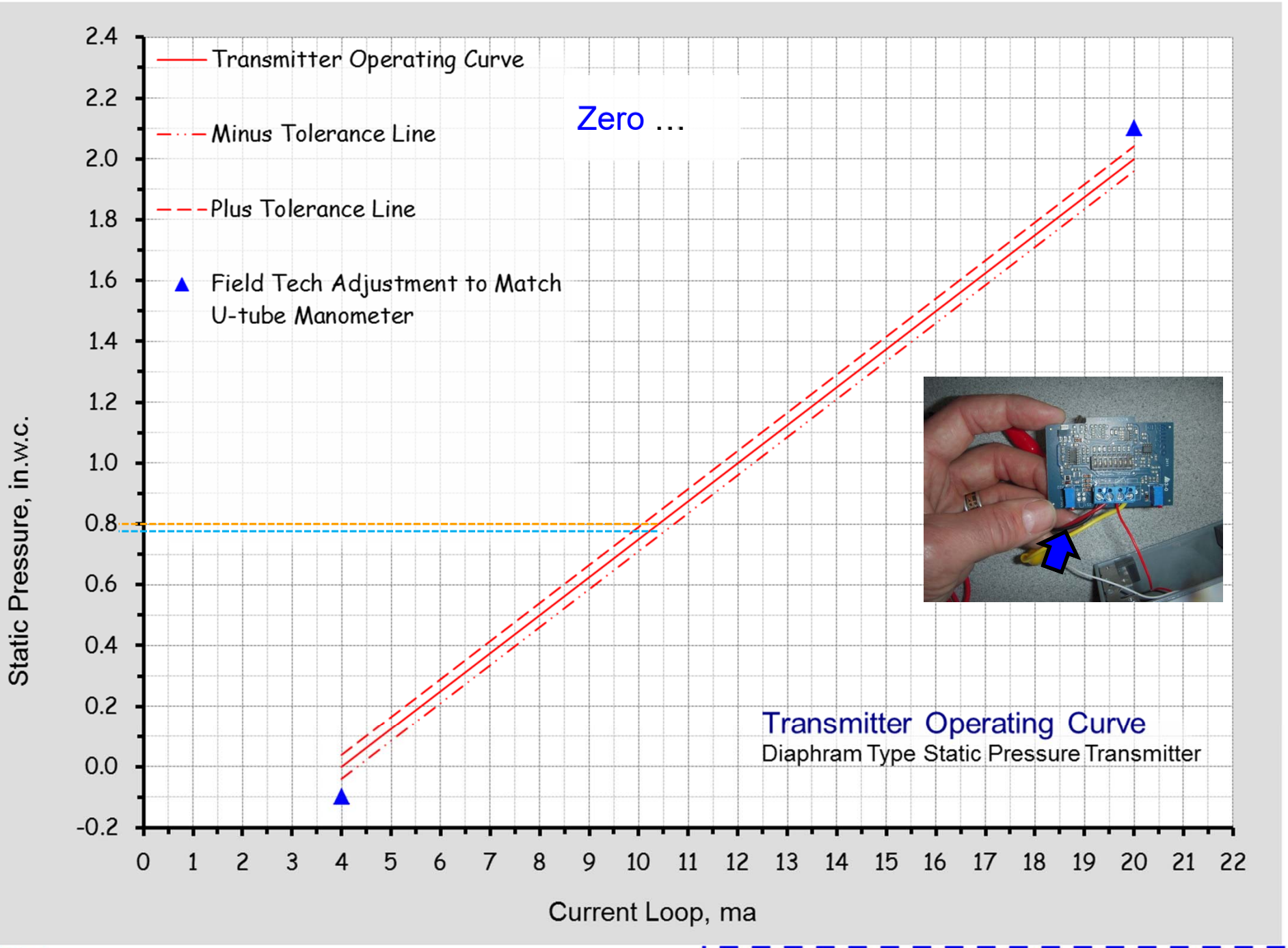


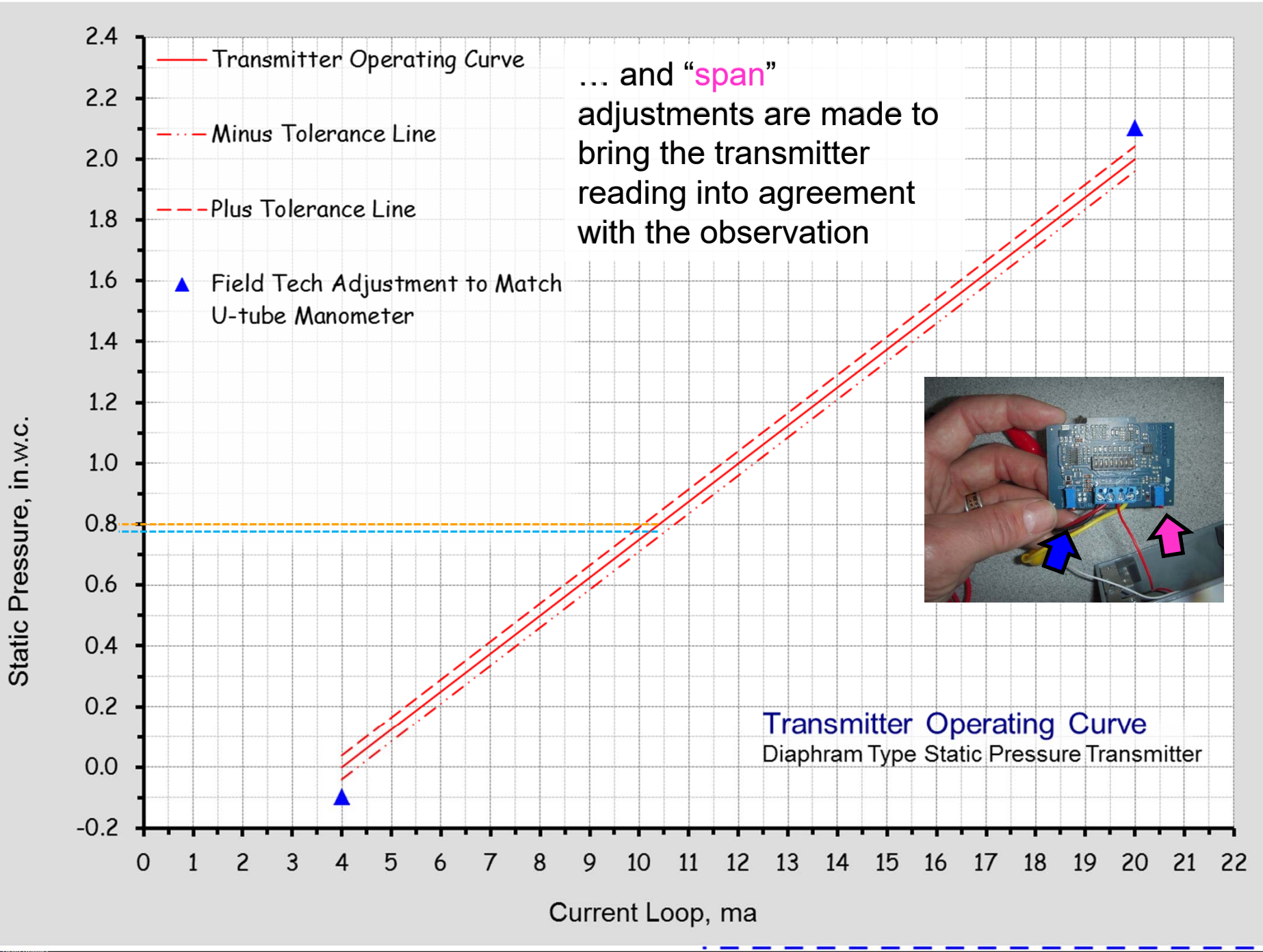
Un-Calibration

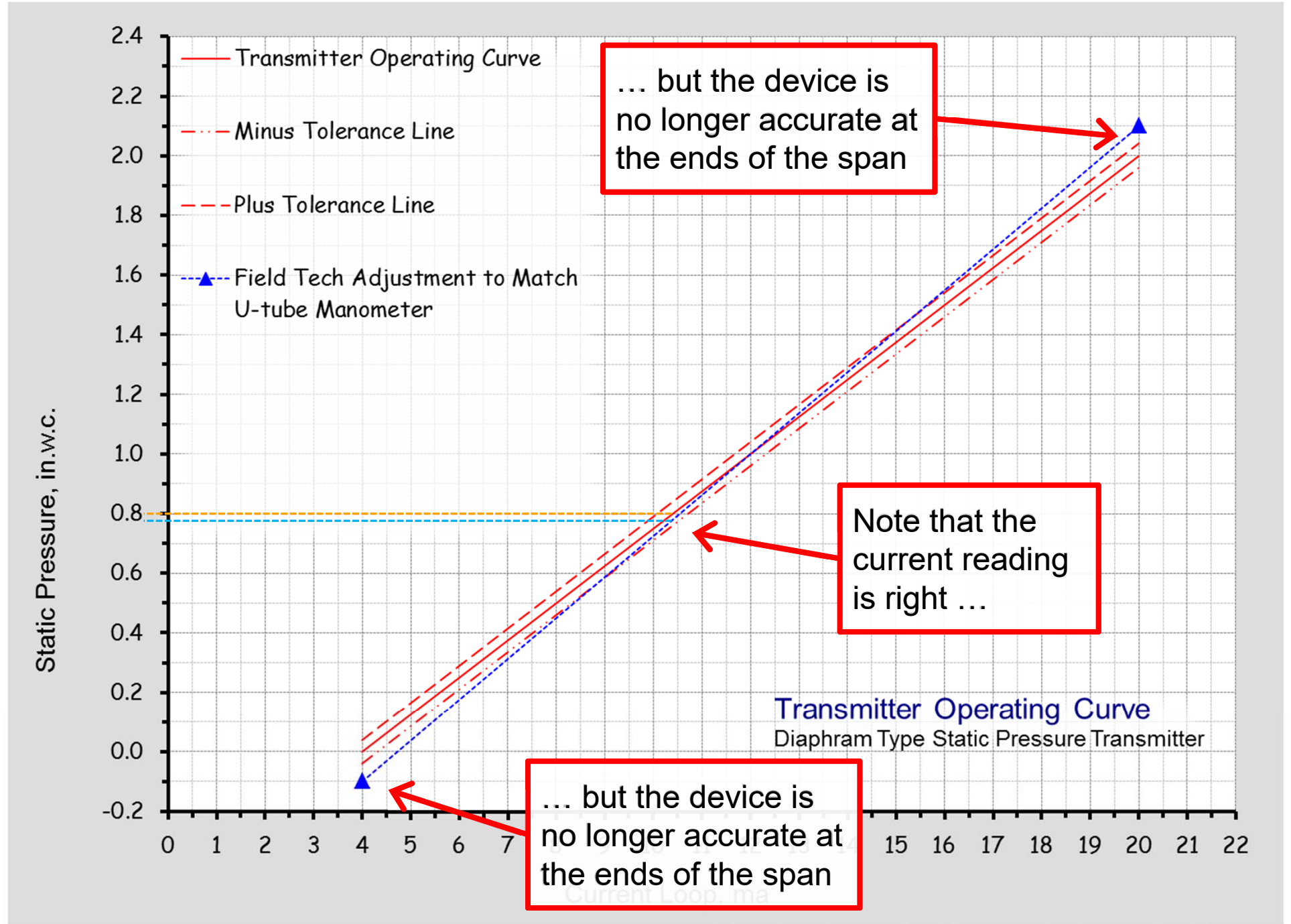
Misread Your Instrument

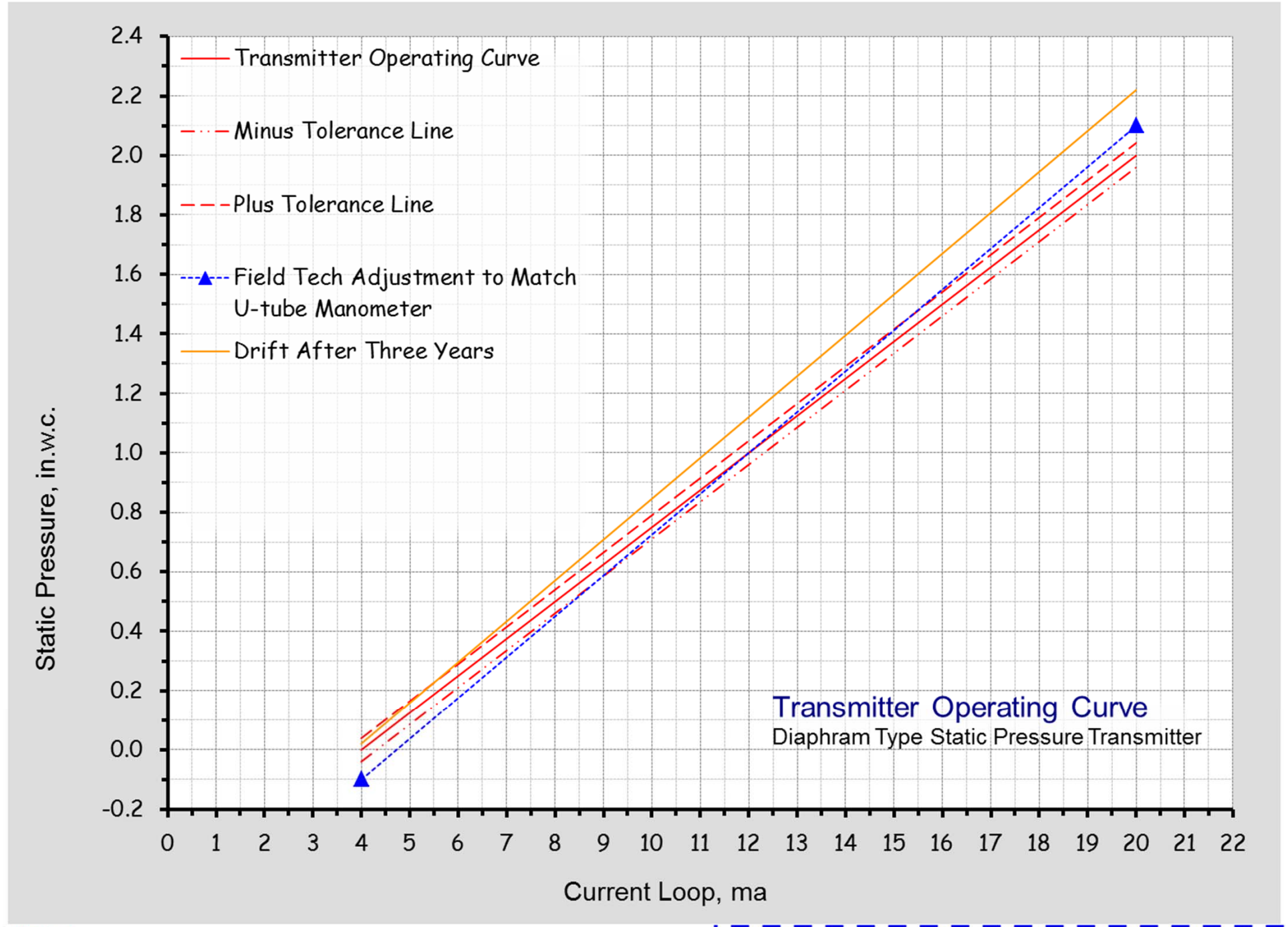


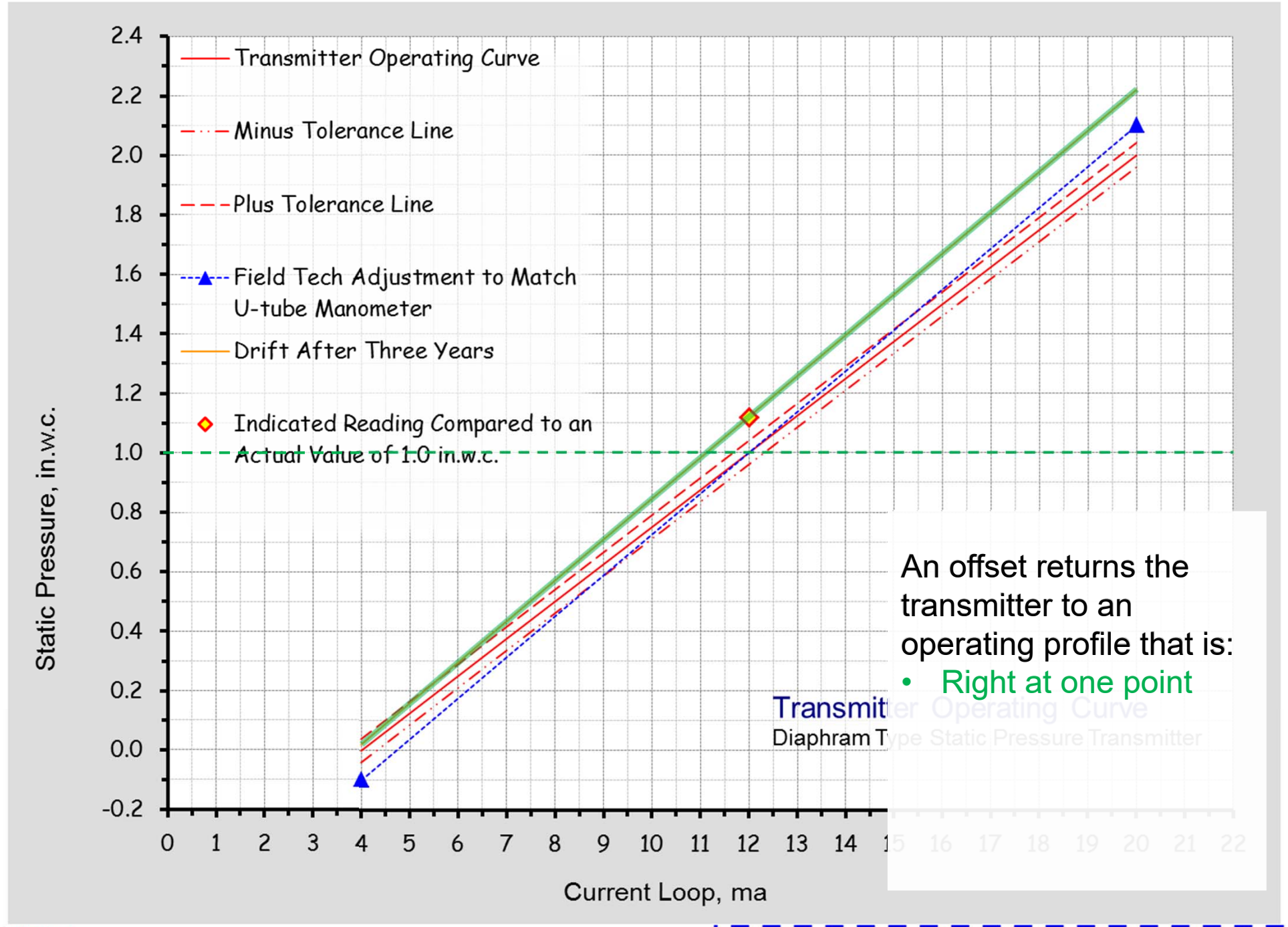

Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Current Loop, ma
Transmitter is indicating 0.80 in.w.c. but when comparing it to a manometer, because o f parallax, the control tech reads it as 0.78 in.w.c.
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter


Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match
U-tube Manometer
Zero …
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Current Loop, ma
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter


Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match U-tube Manometer
… and "span" adjustments are made to bring the transmitter reading into agreement with the observation
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Current Loop, ma
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter

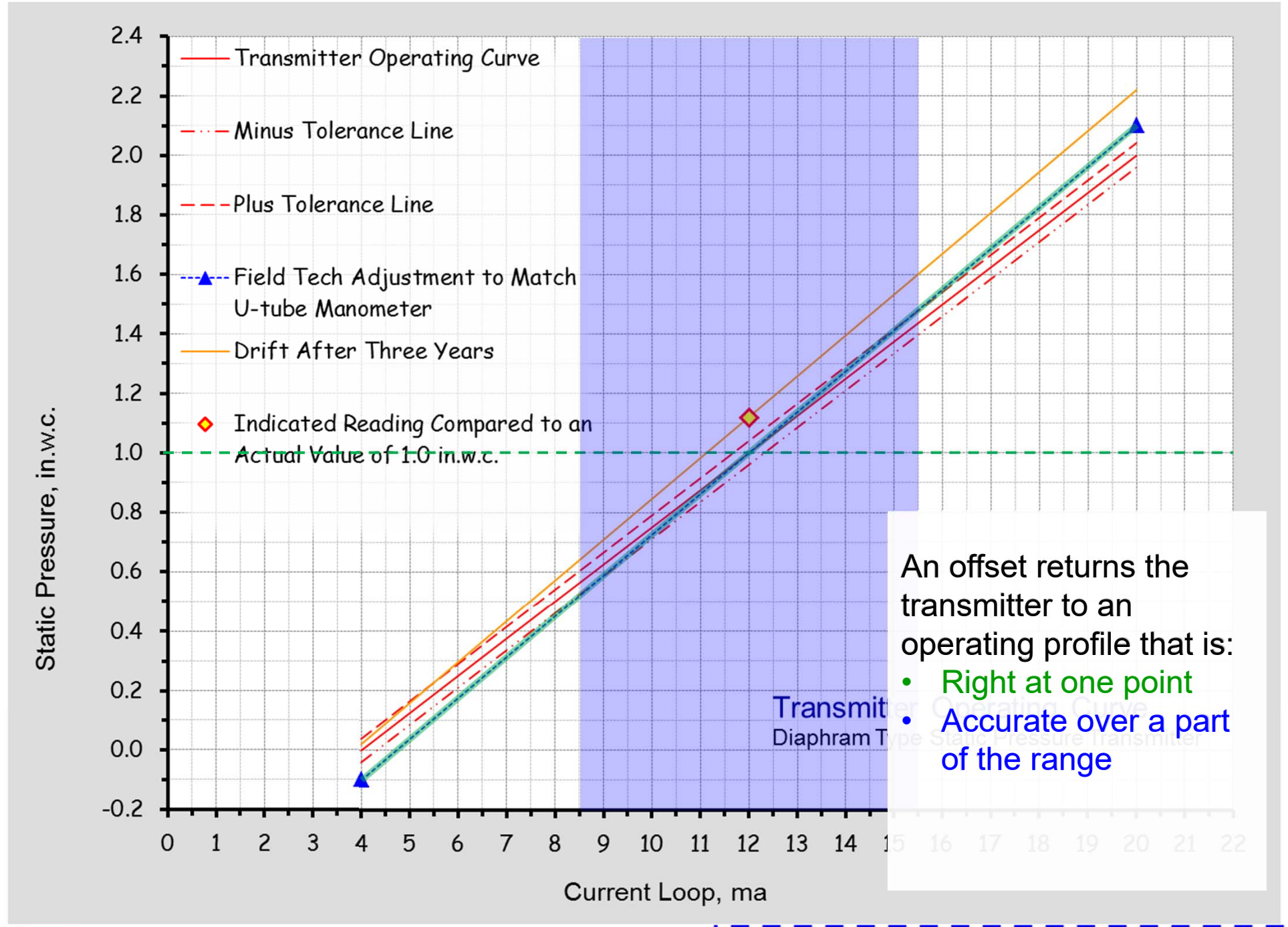

Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match U-tube Manometer
… but the device is no longer accurate at the ends of the span
Note that the current reading is right …
… but the device is no longer accurate at the ends of the span
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 15 16 17 18 19 20 21 22

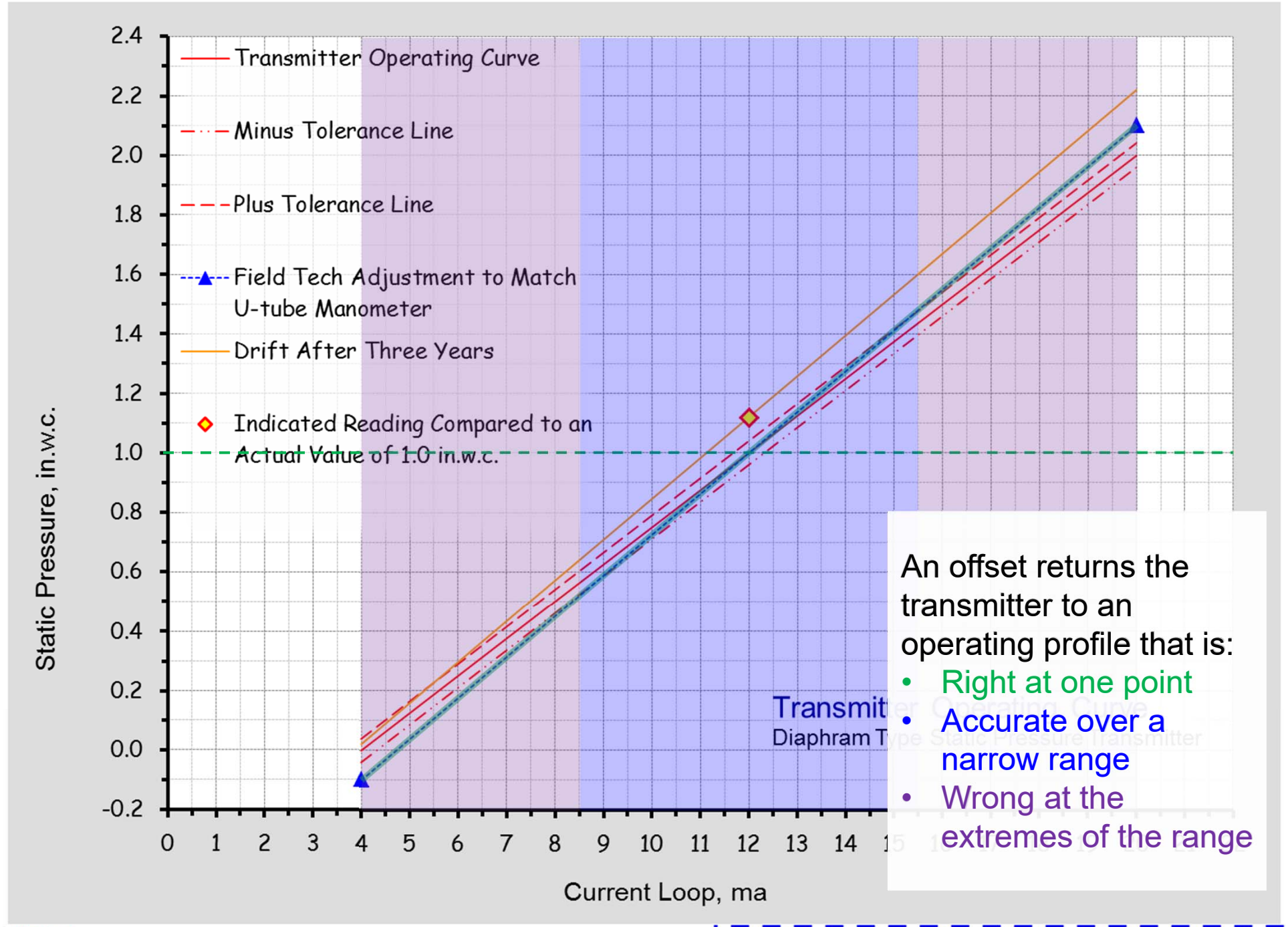

Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match
U-tube Manometer
Drift After Three Years
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Current Loop, ma
Transmitter Operating Curve
Diaphram Type Static Pressure Transmitter



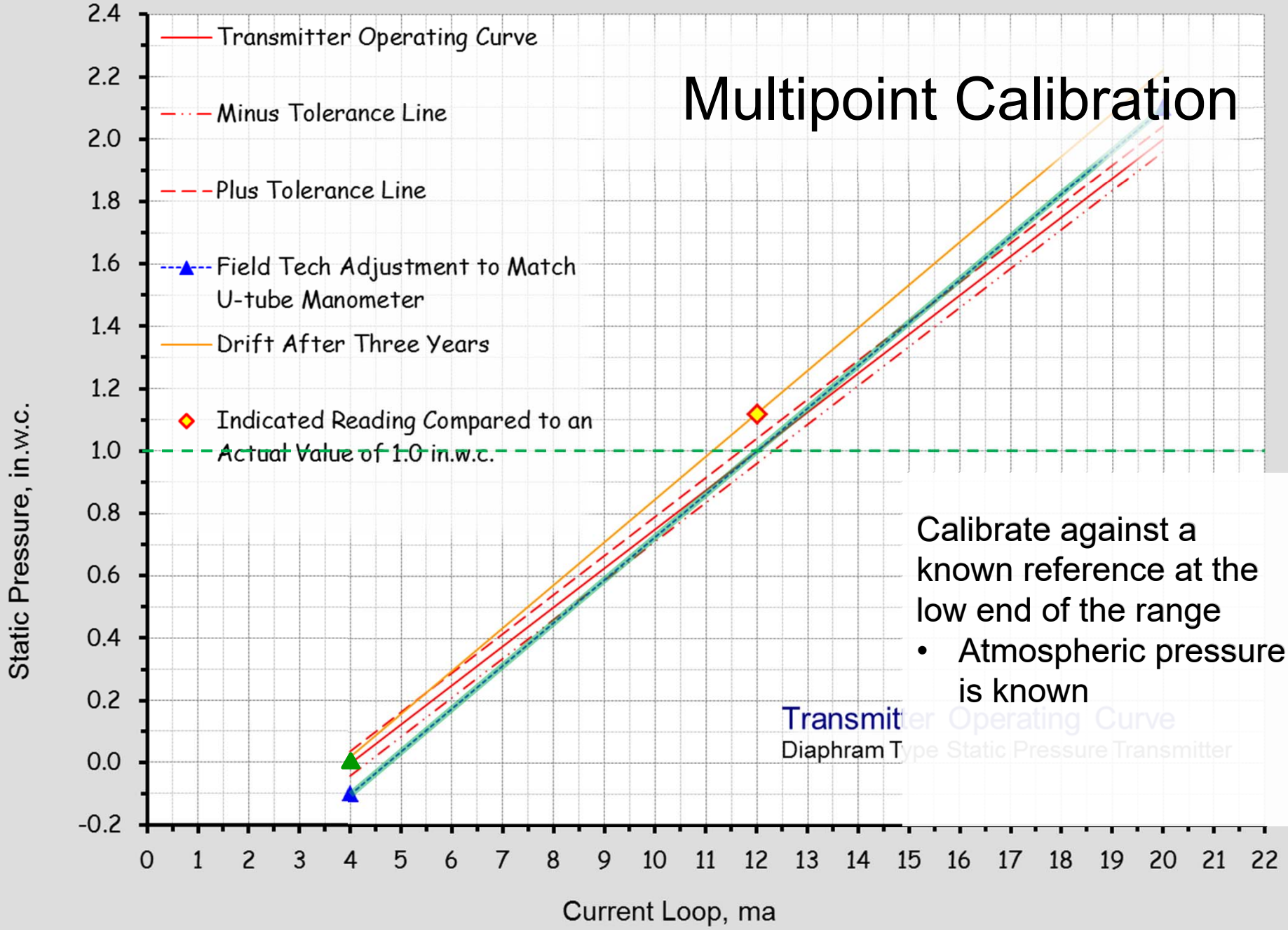
An offset returns the transmitter to an operating profile that is:

- Right at one point


Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match U-tube Manometer
Drift After Three Years
Indicated Reading Compared to an Actual Value of 1.0 in.w.c.
Static Pressure, in.w.c.
Current Loop, ma
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
An offset returns the transmitter to an operating profile that is:
• Right at one point
• Accurate over a part of the range

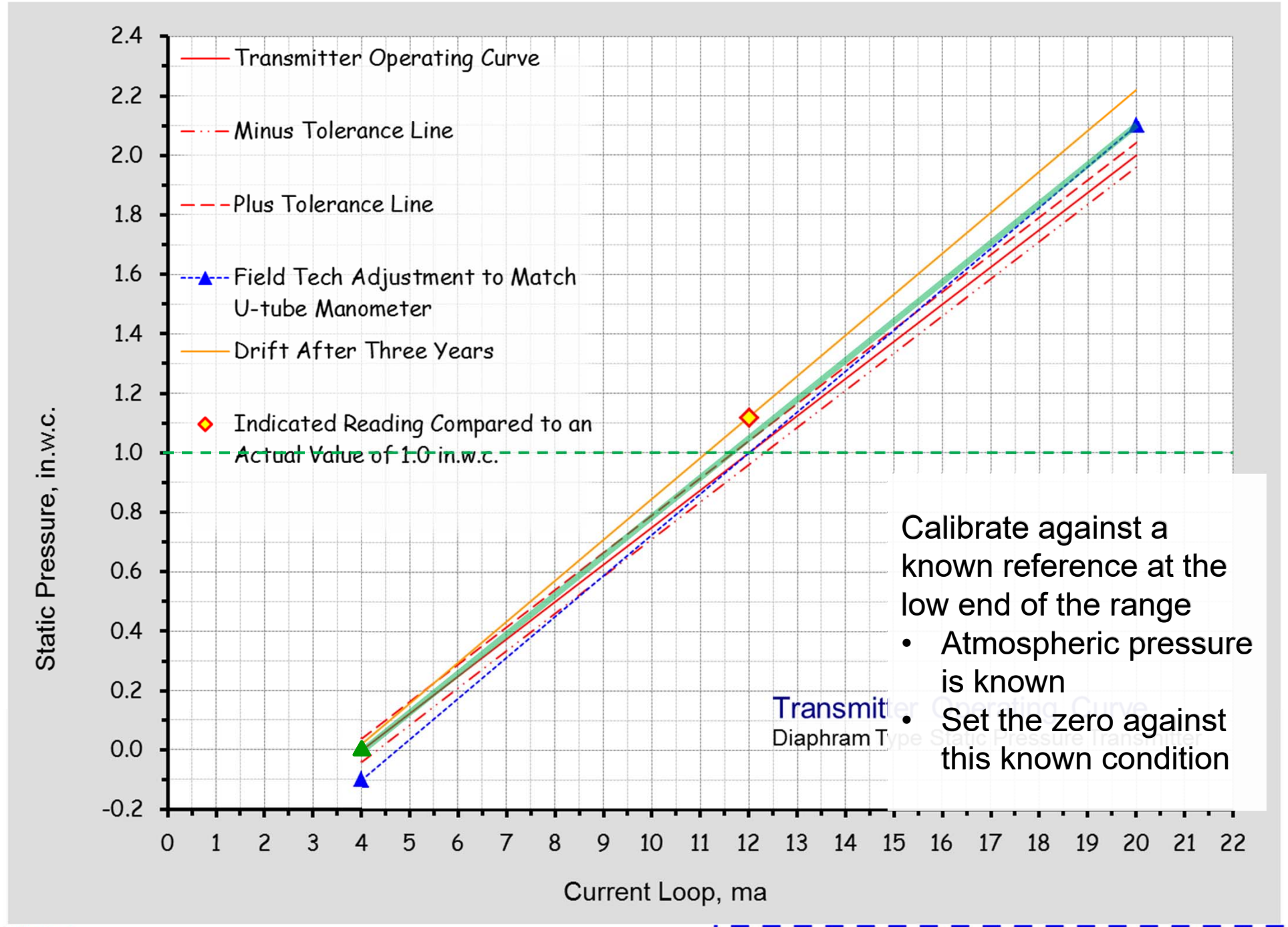

Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match U-tube Manometer
Drift After Three Years
Indicated Reading Compared to an Actual Value of 1.0 in.w.c.
Static Pressure, in.w.c.
Current Loop, ma
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
An offset returns the transmitter to an operating profile that is:
• Right at one point
• Accurate over a narrow range
• Wrong at the extremes of the range

Multipoint Calibration



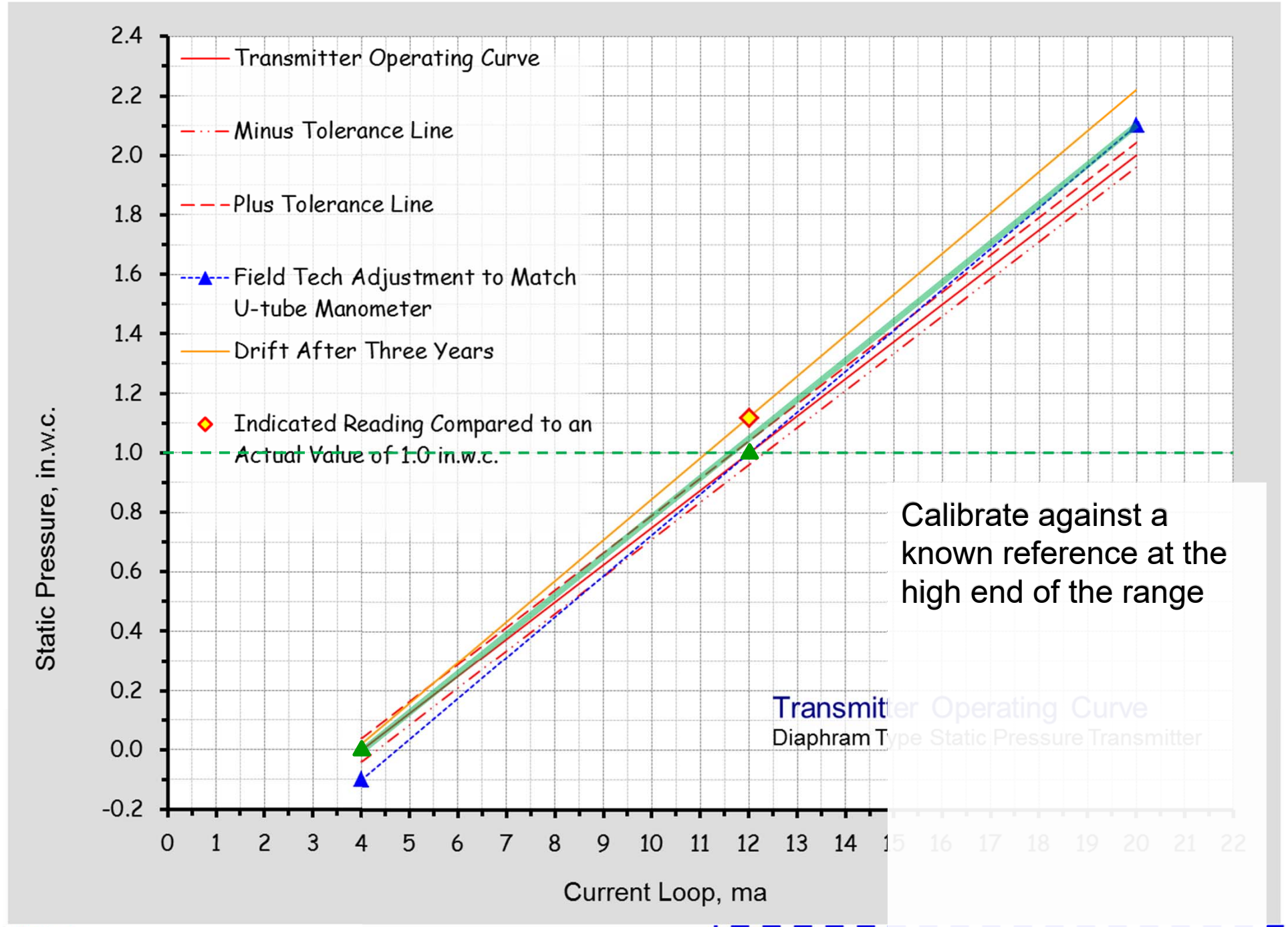
Calibrate against a known reference at the low end of the range

- Atmospheric pressure is known



Calibrate against a known reference at the low end of the range

- Atmospheric pressure is known
- Set the zero against this known condition


Transmitter Operating Curve
Minus Tolerance Line
Plus Tolerance Line
Field Tech Adjustment to Match U-tube Manometer
Drift After Three Years
Indicated Reading Compared to an Actual Value of 1.0 in.w.c.
Static Pressure, in.w.c.
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
Current Loop, ma
Calibrate against a known reference at the high end of the range

Static Pressure, in.w.c.

2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

Current Loop, ma

Transmitter Operating Curve

Diaphram Type Static Pressure Transmitter

Calibrate against a known reference at the high end of the range

- Quality of the reference = important

Calibrate against a known reference at the high end of the range

- Quality of the reference = important

Static Pressure, in.w.c.

2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
-0.2

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22

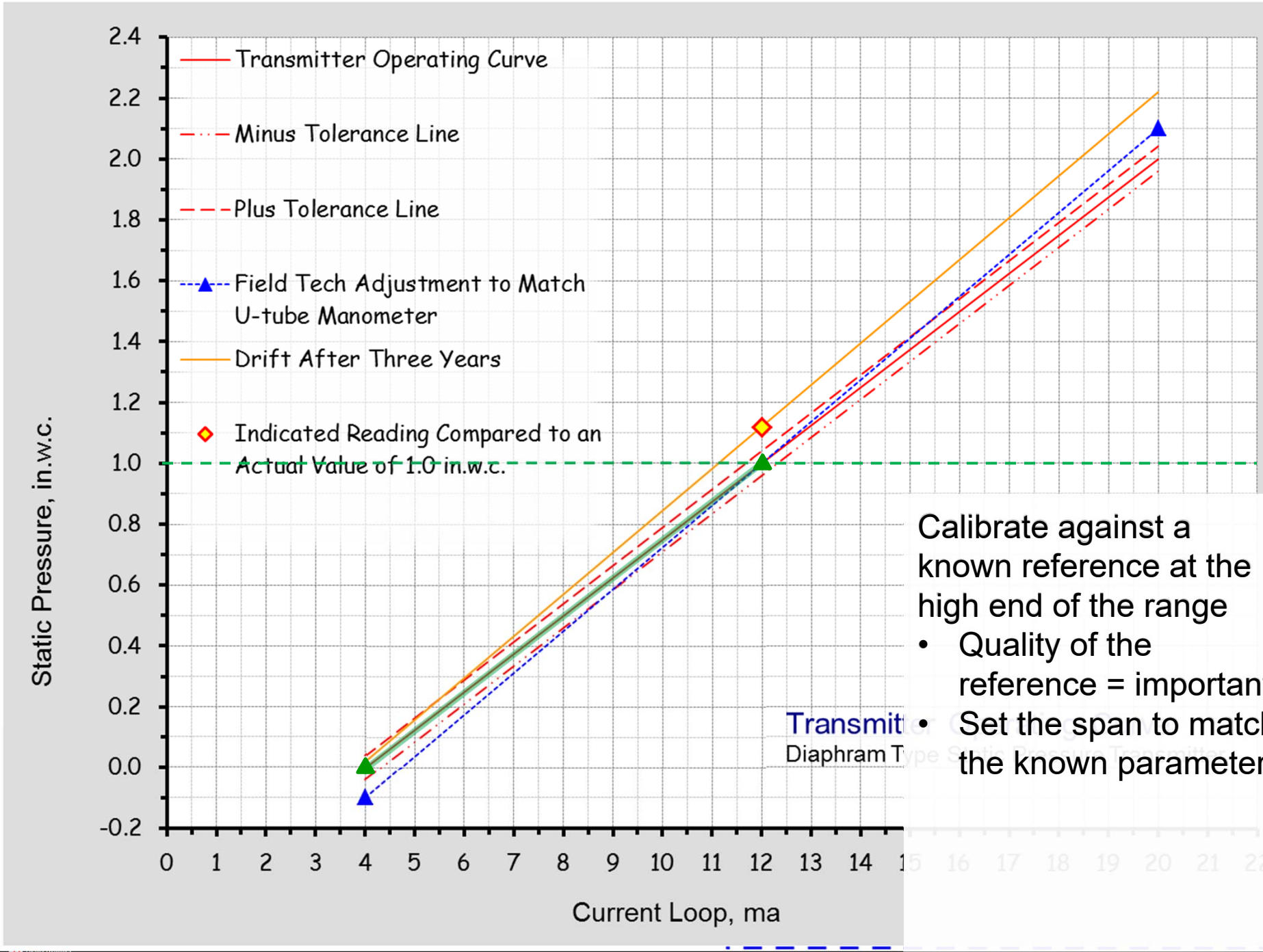
Current Loop, ma

Transmitter Operating Curve

Diaphram Type Static Pressure Transmitter

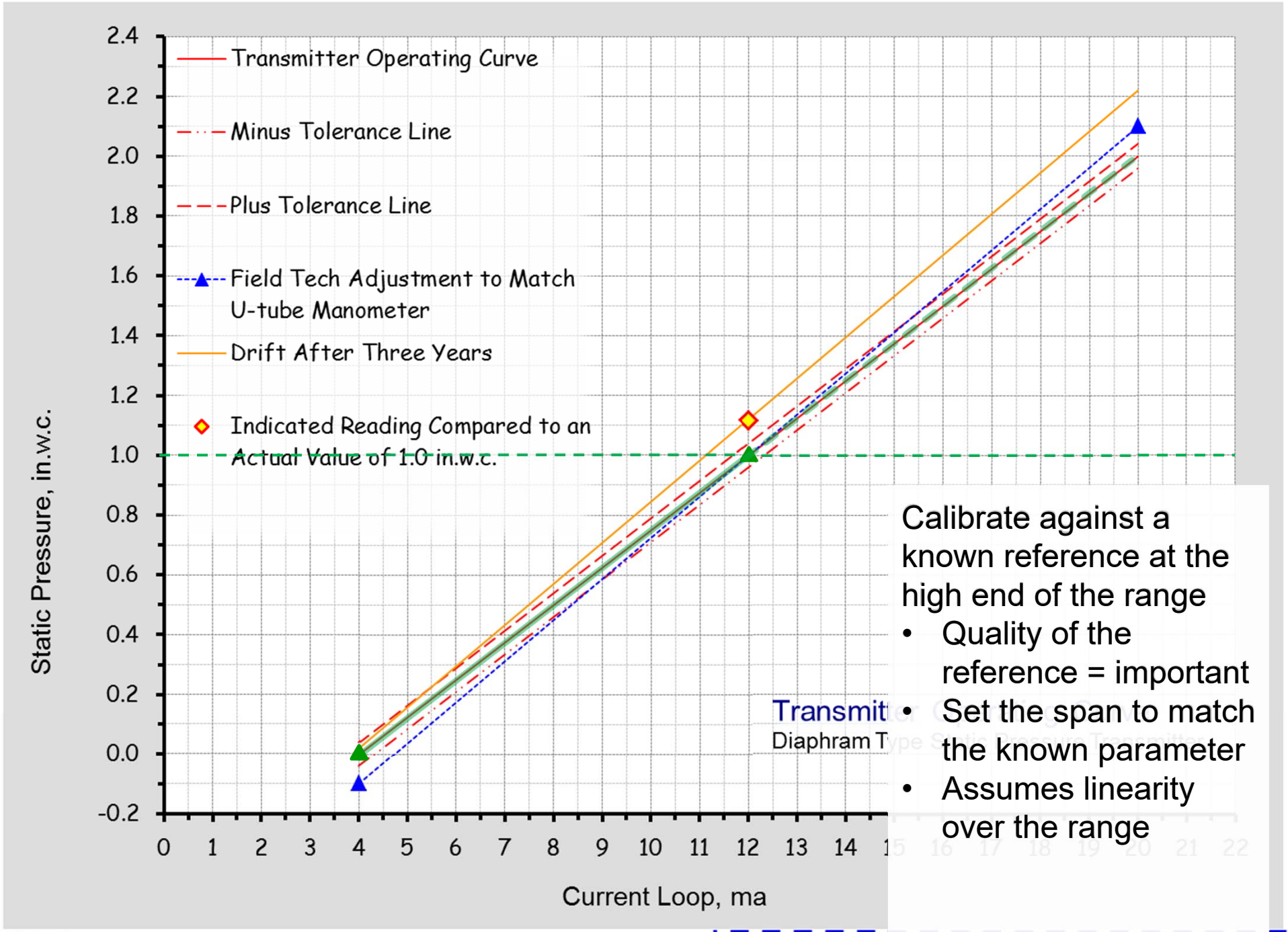
Calibrate against a known reference at the high end of the range

- Quality of the reference = important



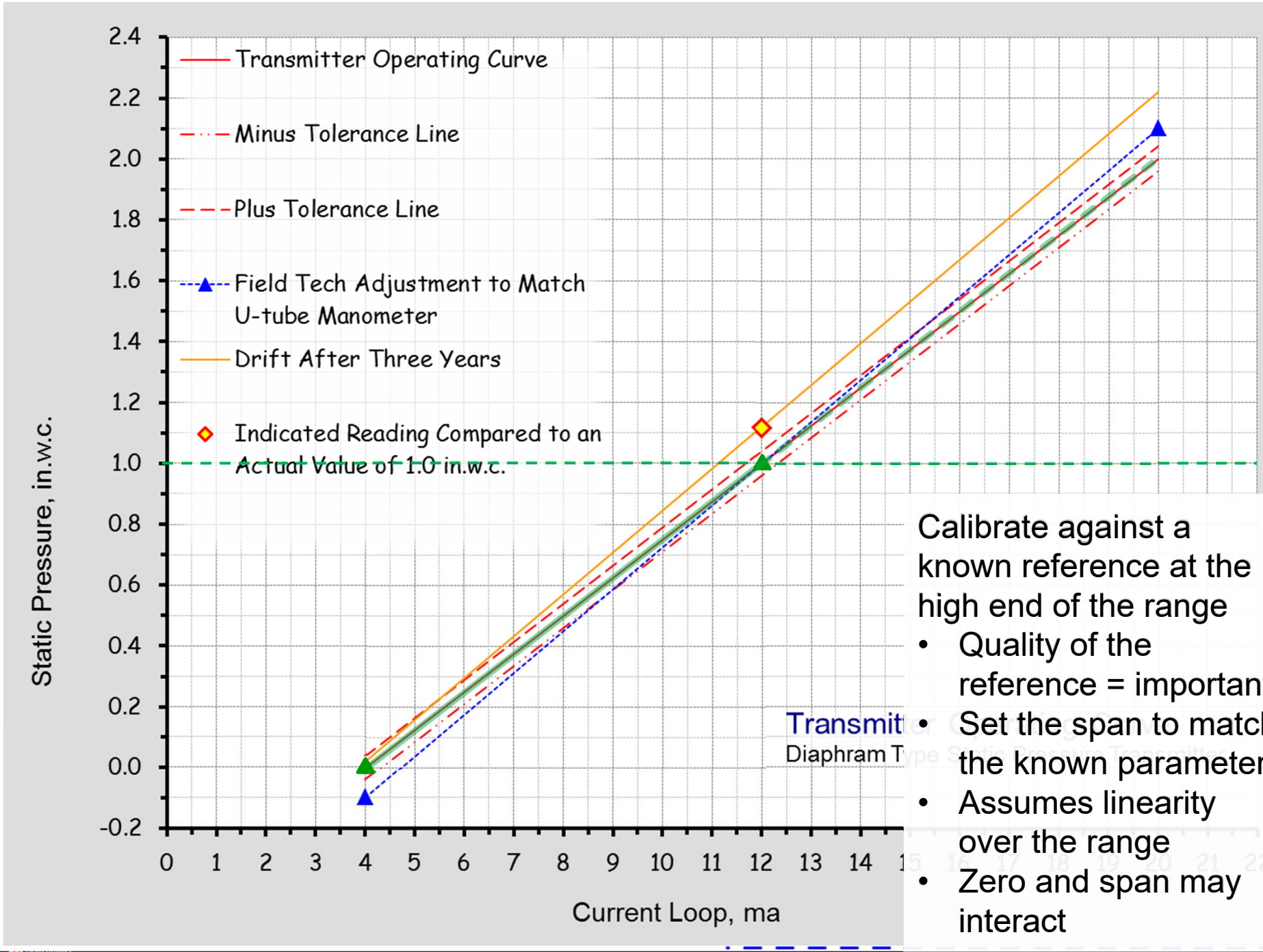
Calibrate against a known reference at the high end of the range

- Quality of the reference = important
- Set the span to match the known parameter



Calibrate against a known reference at the high end of the range

- Quality of the reference = important
- Set the span to match the known parameter
- Assumes linearity over the range

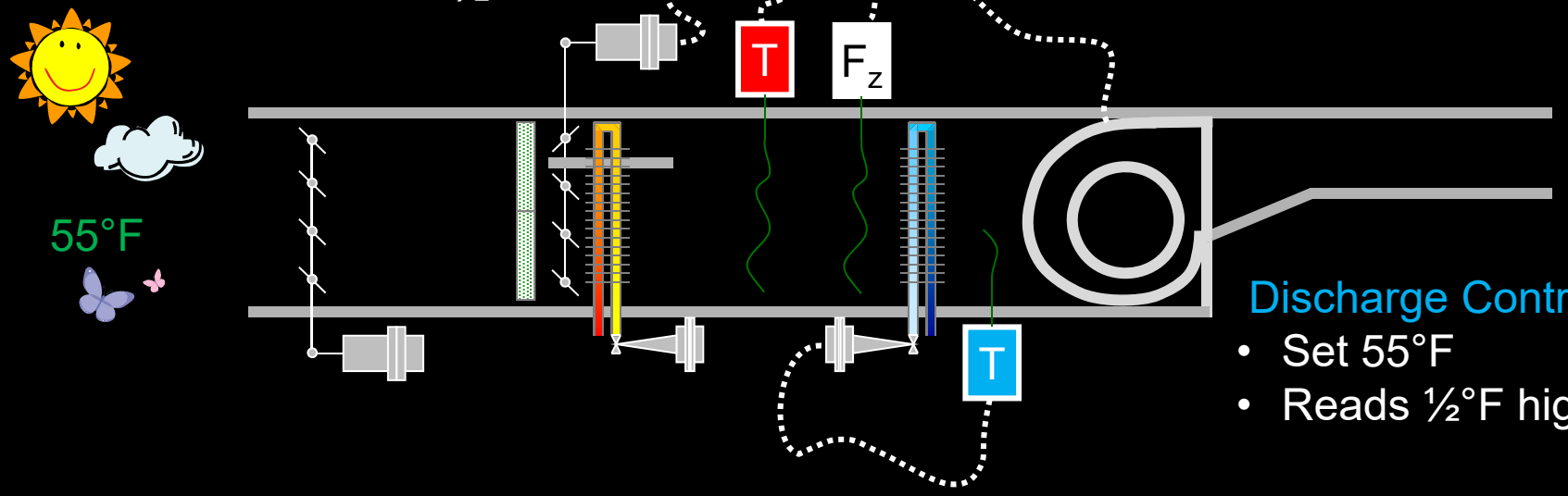


Calibrate against a known reference at the high end of the range

- Quality of the reference = important
- Set the span to match the known parameter
- Assumes linearity over the range
- Zero and span may interact

Preheat Controller

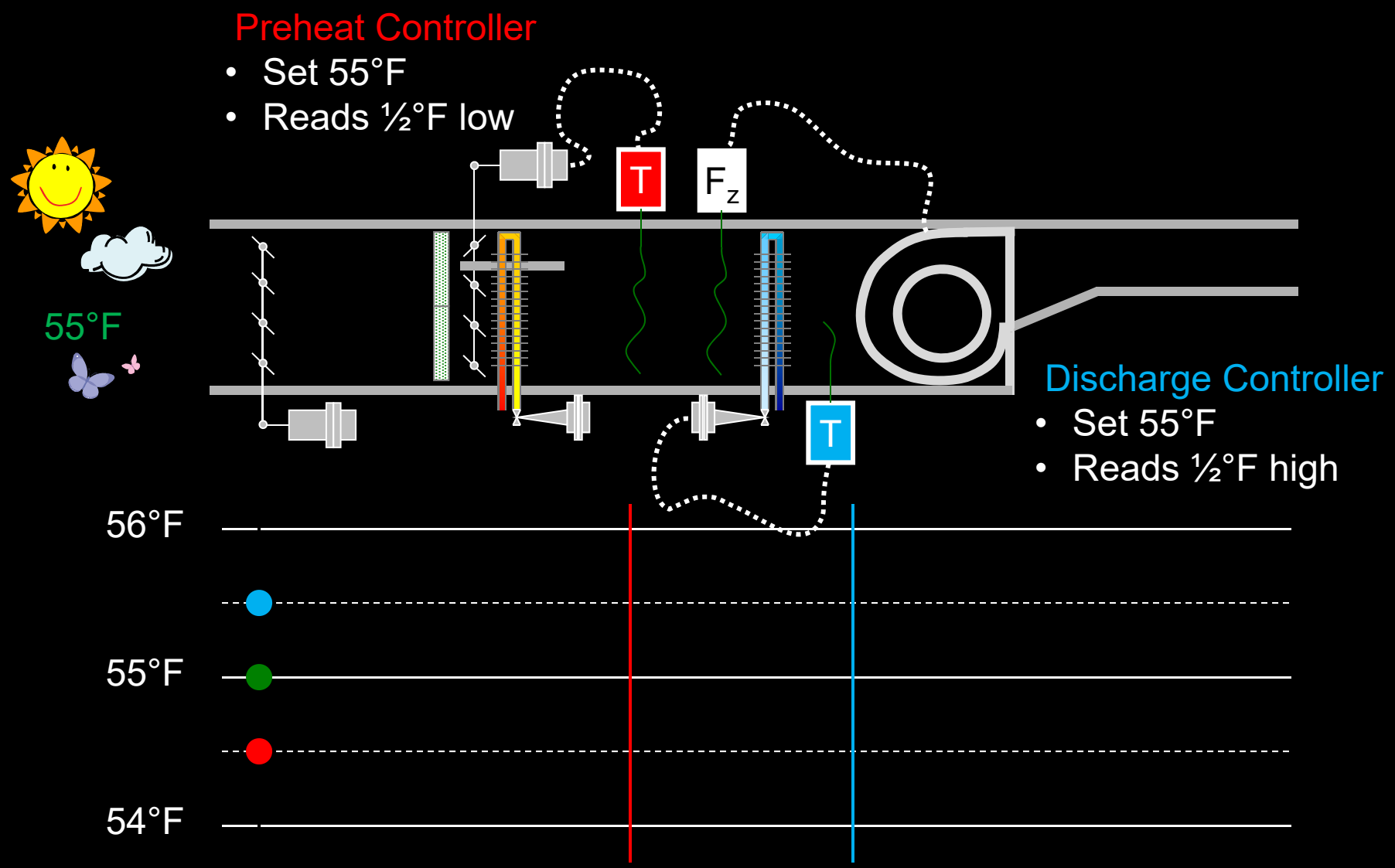
- Set 55°F
- Reads ½°F low



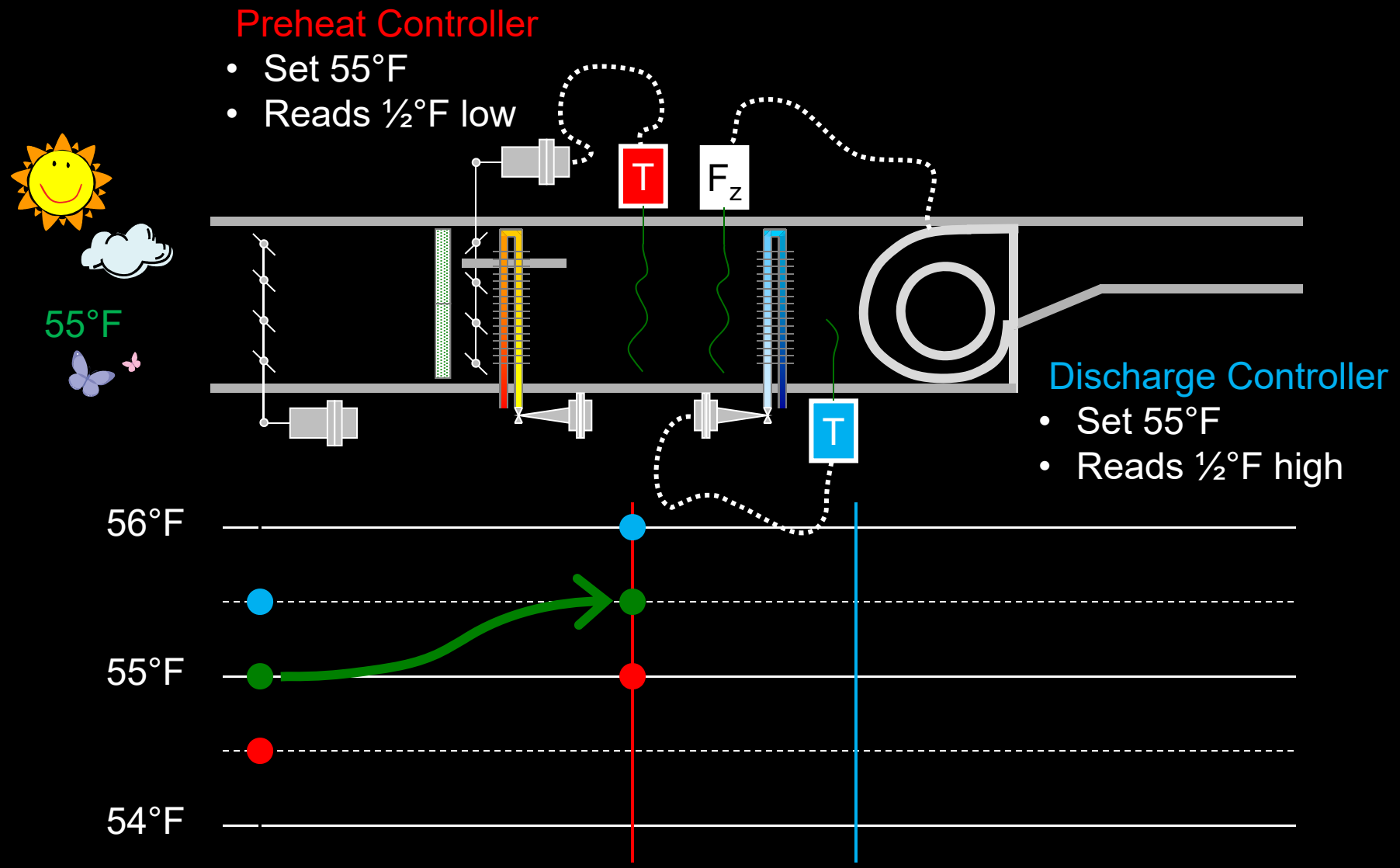
Discharge Controller

- Set 55°F
- Reads ½°F high

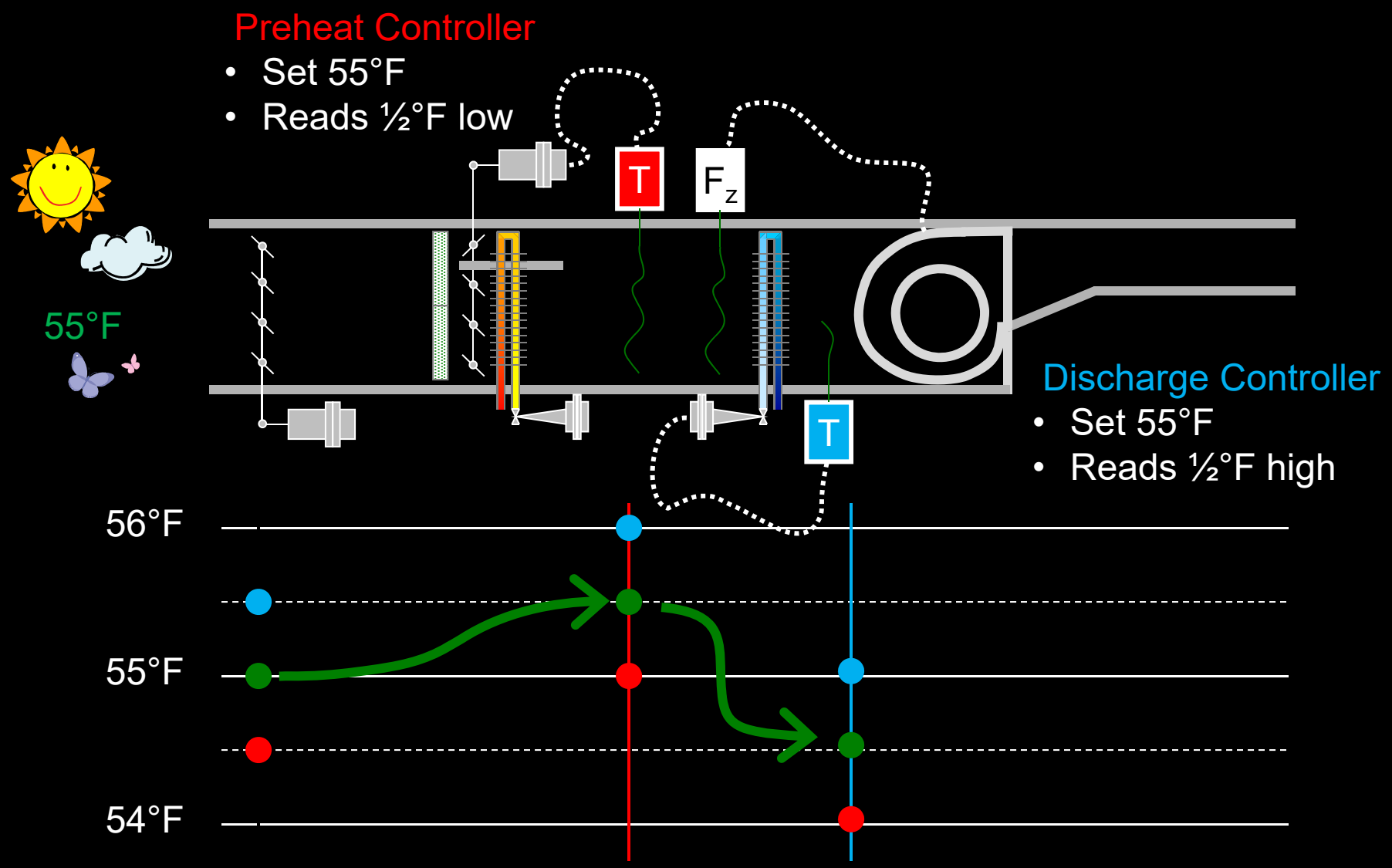
Relative Calibration/Accuracy



Relative Calibration/Accuracy

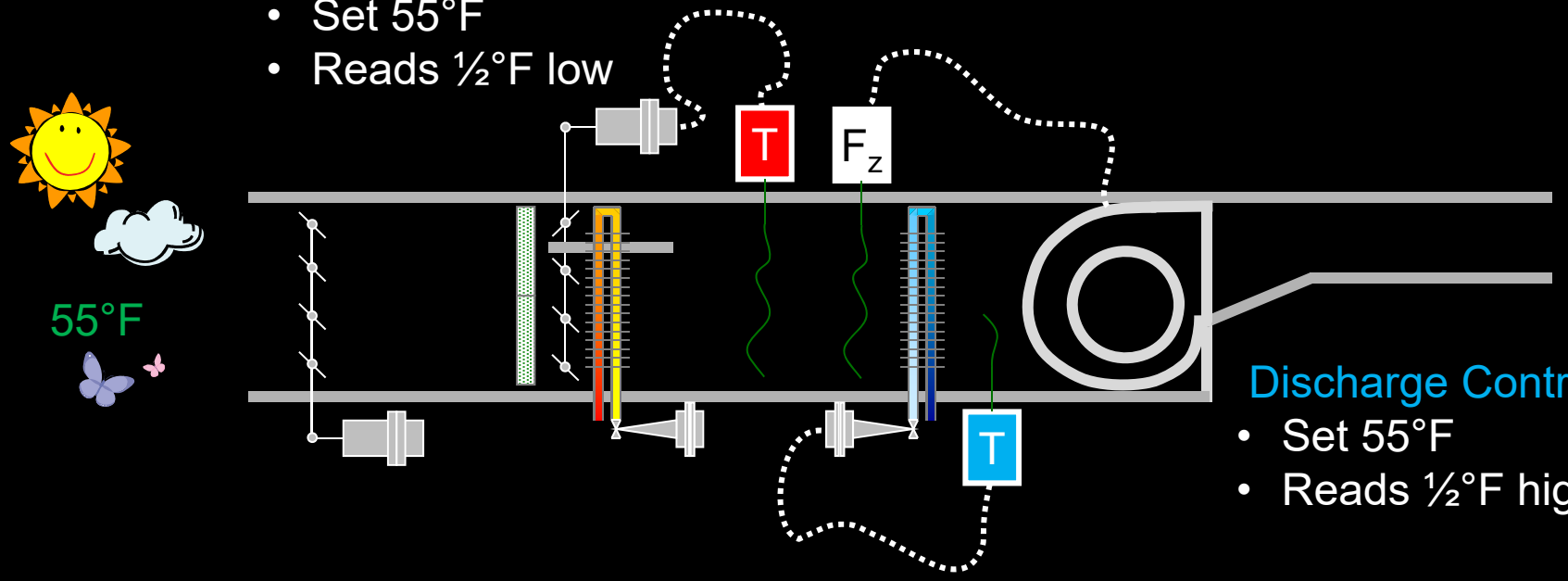


Relative Calibration/Accuracy



Relative Calibration/Accuracy

Preheat Controller
- Set 55°F
- Reads ½°F low



Discharge Controller
- Set 55°F
- Reads ½°F high

Bottom Line:

Because of relative vs. absolute accuracy, two sensors that met their specs (+/-0.5°F accuracy) took air that was the temperature you desired and used energy to heat and cool it to deliver it at the wrong temperature

Relative Calibration/Accuracy

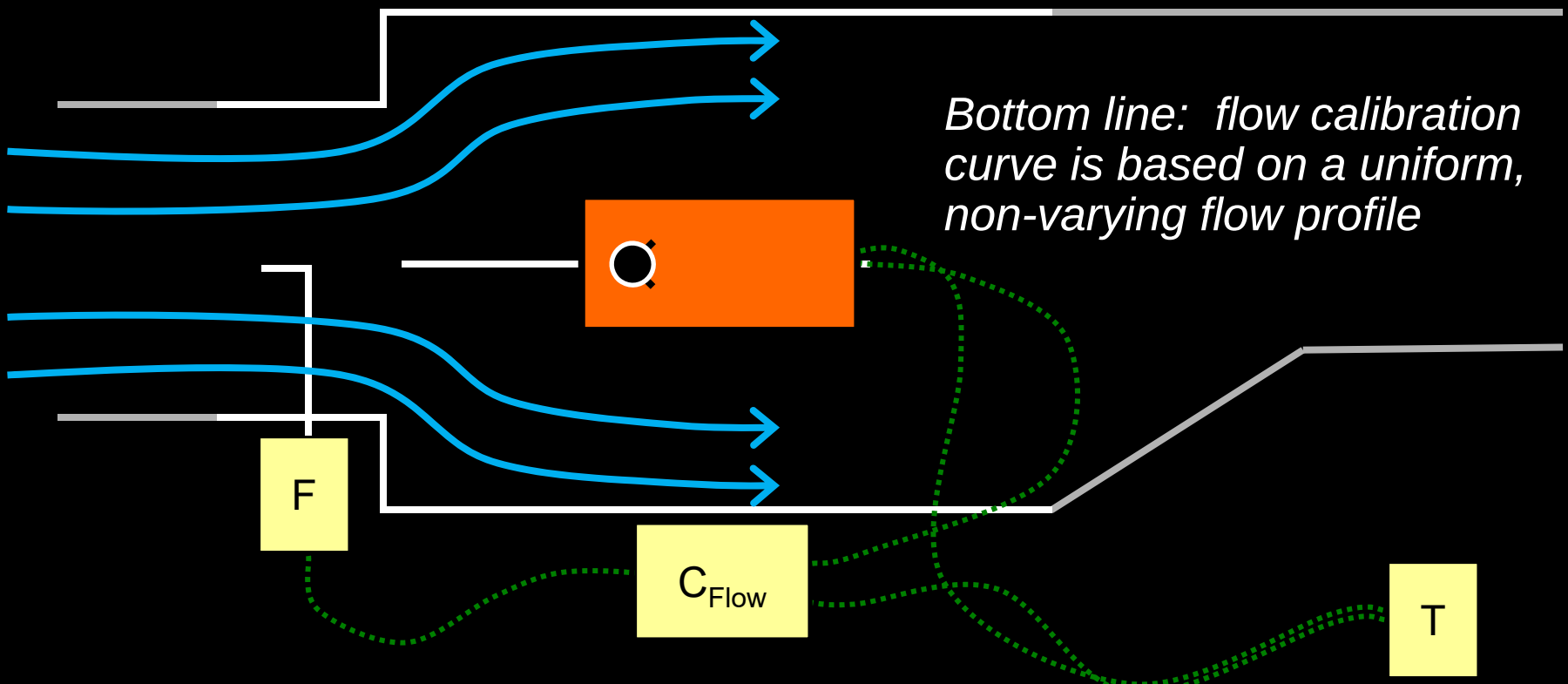
Similar Issues Exist for Other Sensing Technologies; Measuring Flow For Example

- Many flow measurement systems are velocity pressure based
  - Velocity pressure varies as the square of the flow
  - A 50% flow reduction reduces the measured signal to 25% of what it was at 100% flow

  Flow sensors assume a uniform velocity profile
  - For many HVAC systems, the conditions entering and leaving the flow sensor can distort the flow profile and thus the accuracy of the measurement
  - In the video that follows, watch the waves in the stream as the water approaches and departs from the rocks in it


http://tinyurl.com/3bsy6bj

Flow Calibration; One Point *Doesn't* Fit All



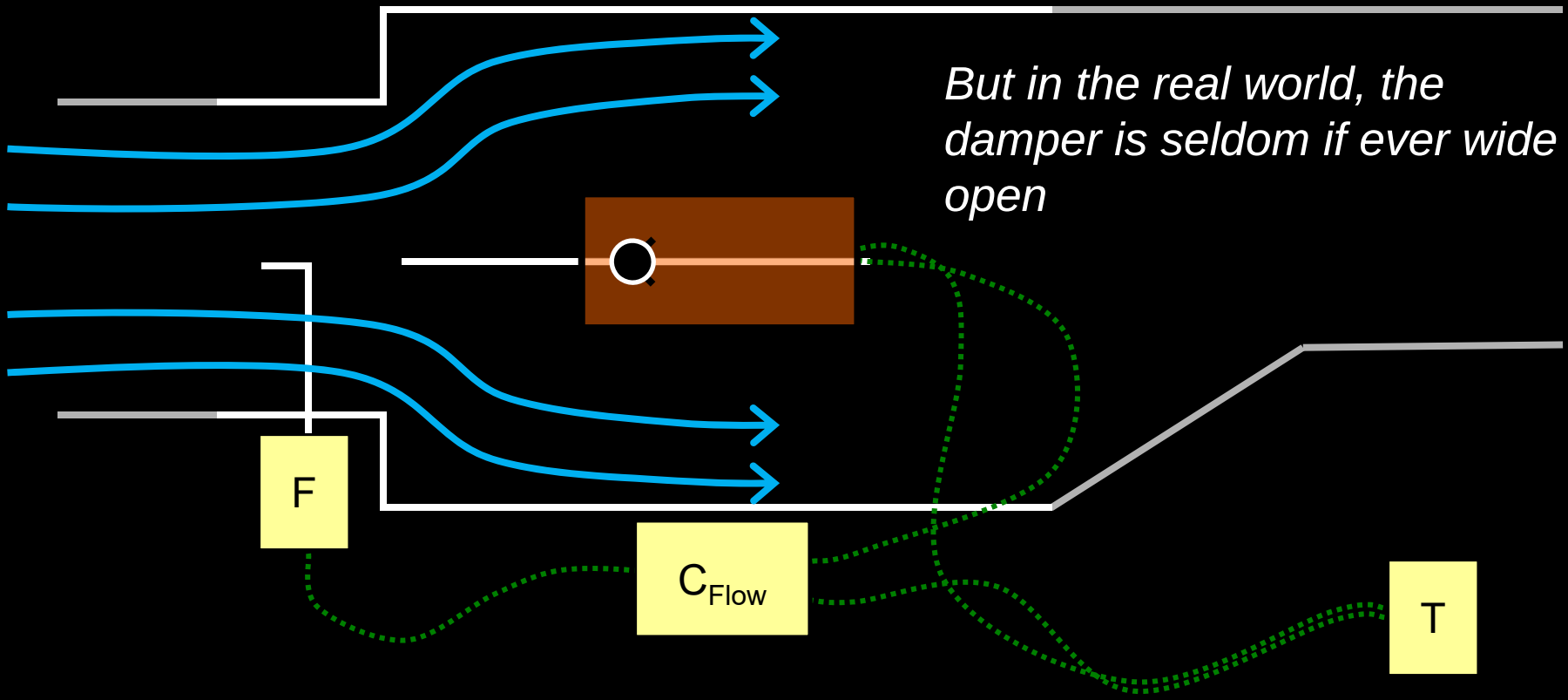
Bottom line: flow calibration curve is based on a uniform, non-varying flow profile

Flow sensors calibration curves established by factory test

Damper held fully open for the entire flow range

Flow varied by varying fan speed on the fan in the test rig

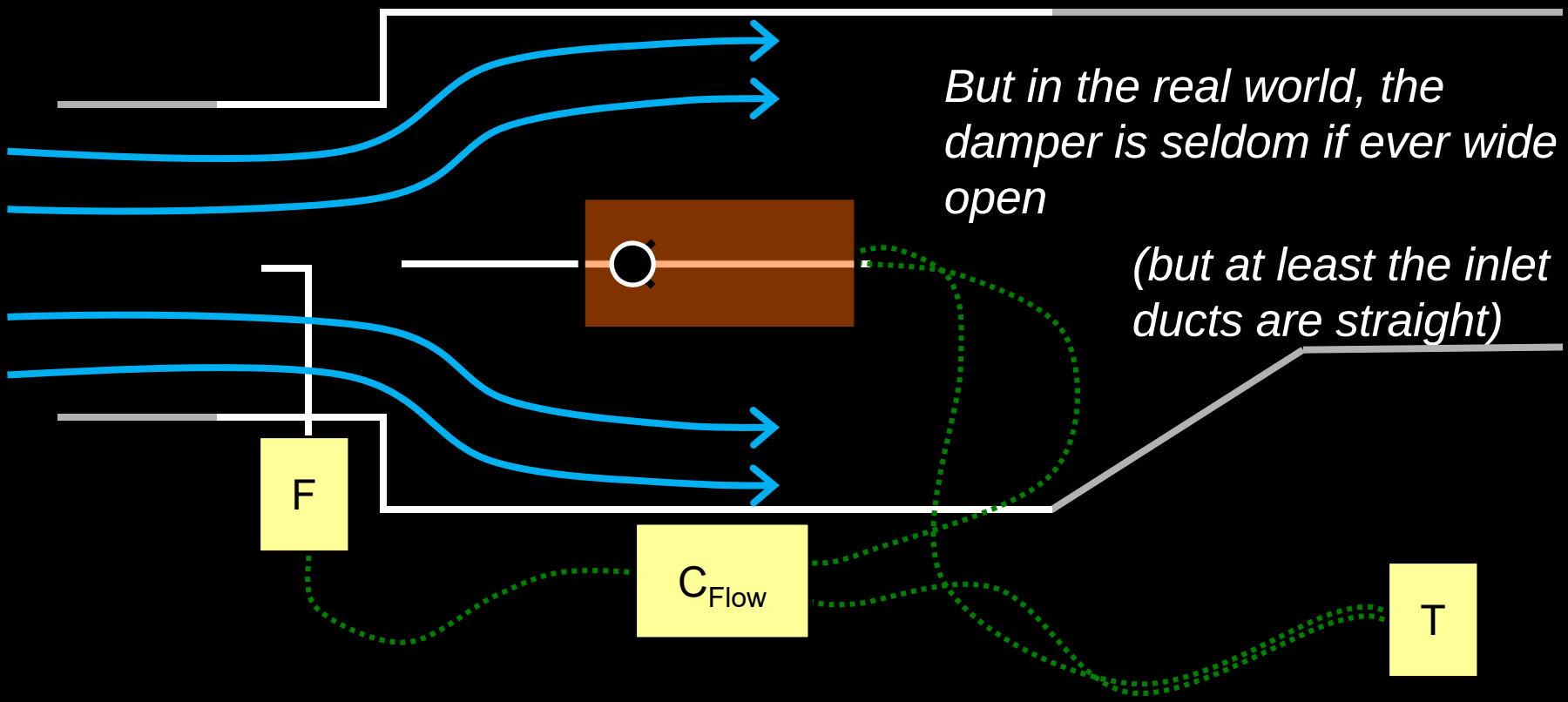
Flow Calibration; One Point *Doesn't* Fit All



But in the real world, the damper is seldom if ever wide open

In the real world, with a good inlet condition and a wide open damper, things tend to match up pretty well

Flow Calibration; One Point *Doesn't* Fit All



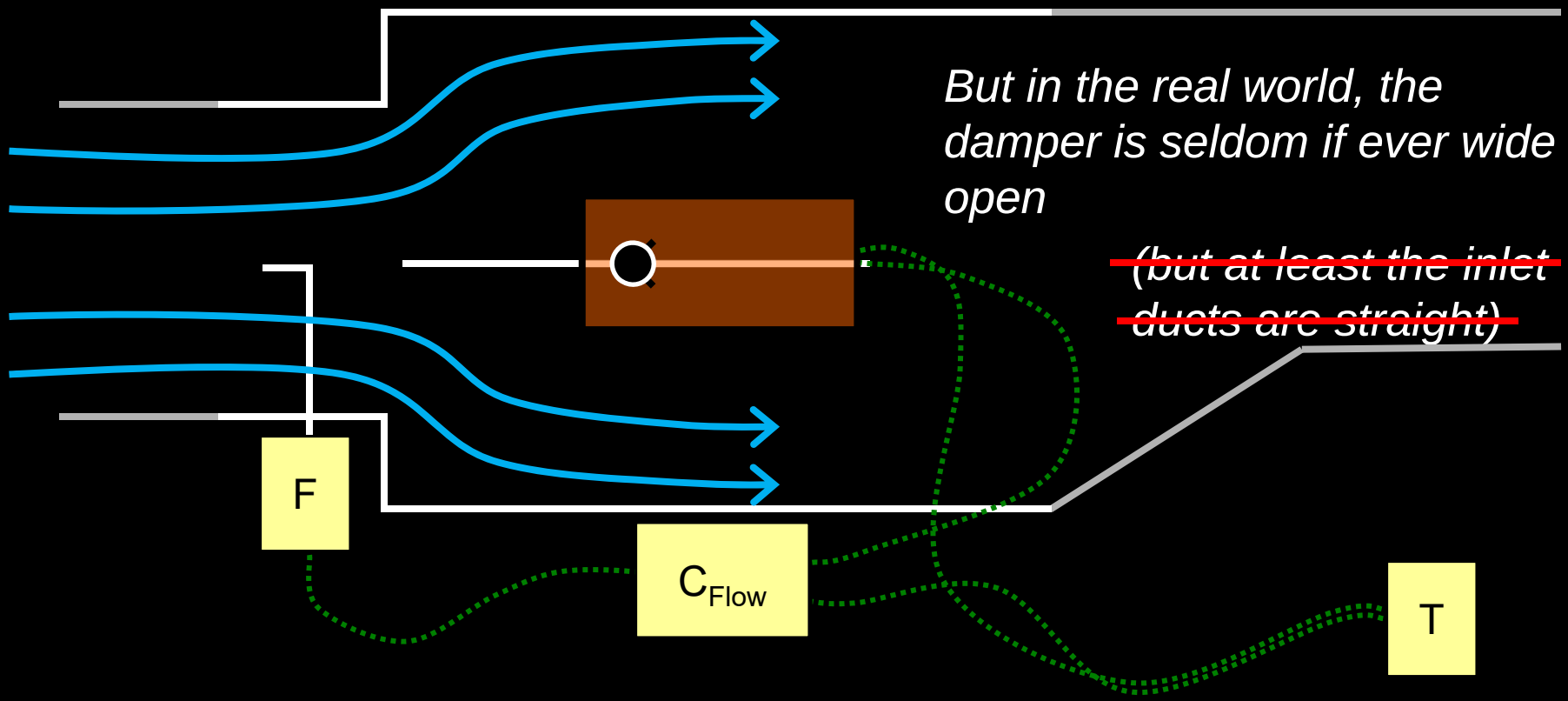
But in the real world, the damper is seldom if ever wide open

(but at least the inlet ducts are straight)

In the real world, with a good inlet condition and a wide open damper, things tend to match up pretty well

UNION MADE
INSULATION THICKNESS – NOM.
THERMAL CONDUC
SMOKE DEVELOPED –
FLAME SPREAD – LESS THAN 25
FRONT

Flow Calibration; One Point *Doesn't* Fit All

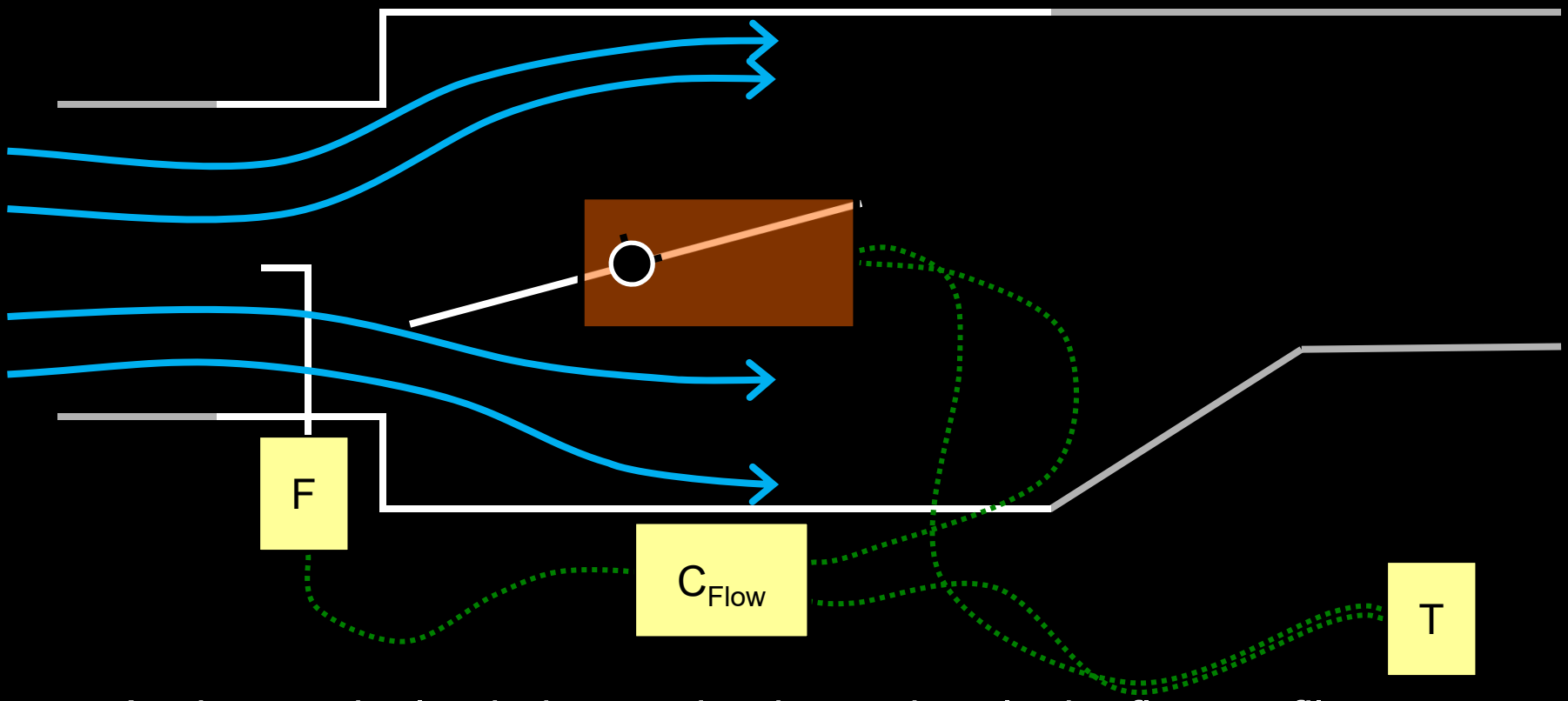


But in the real world, the damper is seldom if ever wide open

~~*(but at least the inlet ducts are straight)*~~

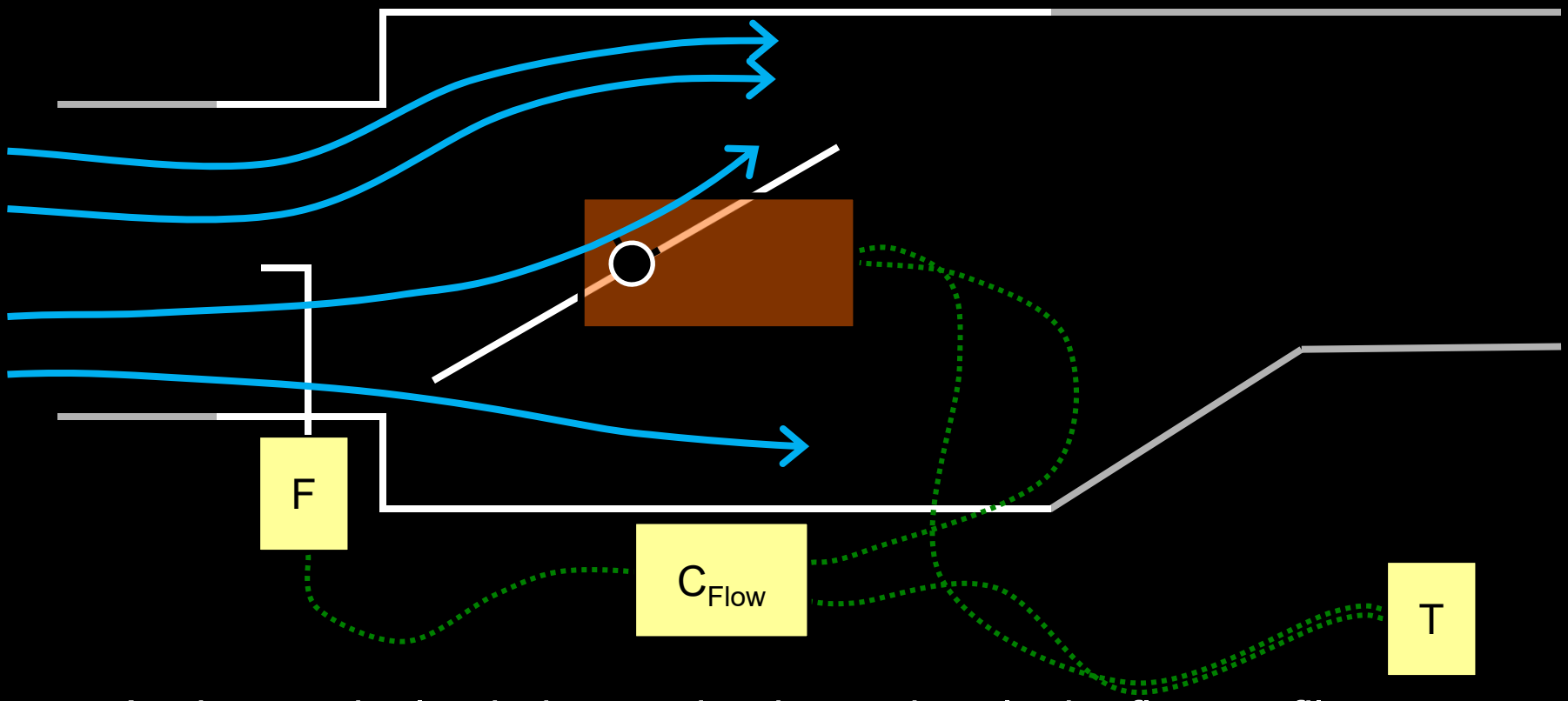
In the real world, with a good inlet condition and a wide open damper, things tend to match up pretty well

Flow Calibration; One Point *Doesn't* Fit All



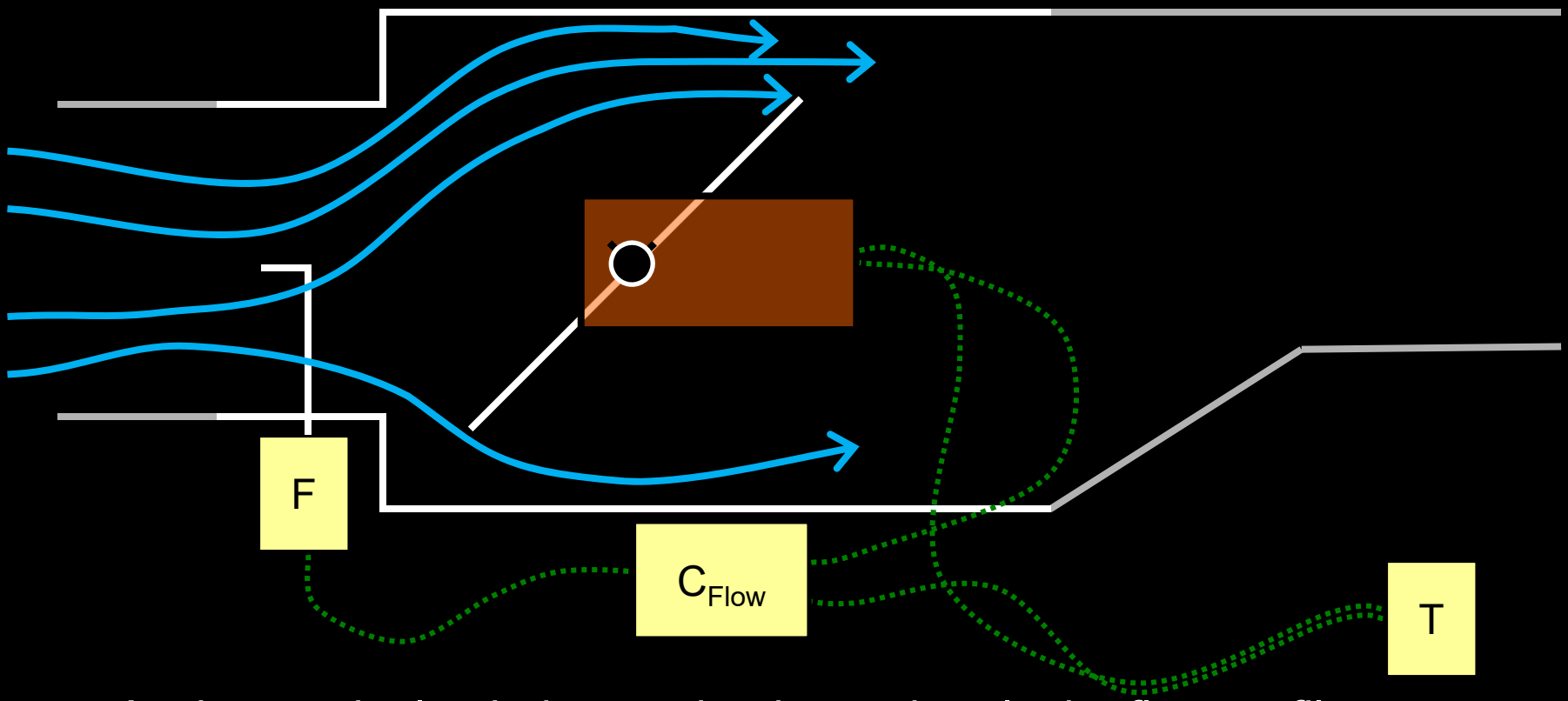
As the terminal unit damper begins to throttle the flow profile upstream of it begins to distort because the air is directed towards the sides of the box and accelerated by the closing damper

Flow Calibration; One Point *Doesn't* Fit All



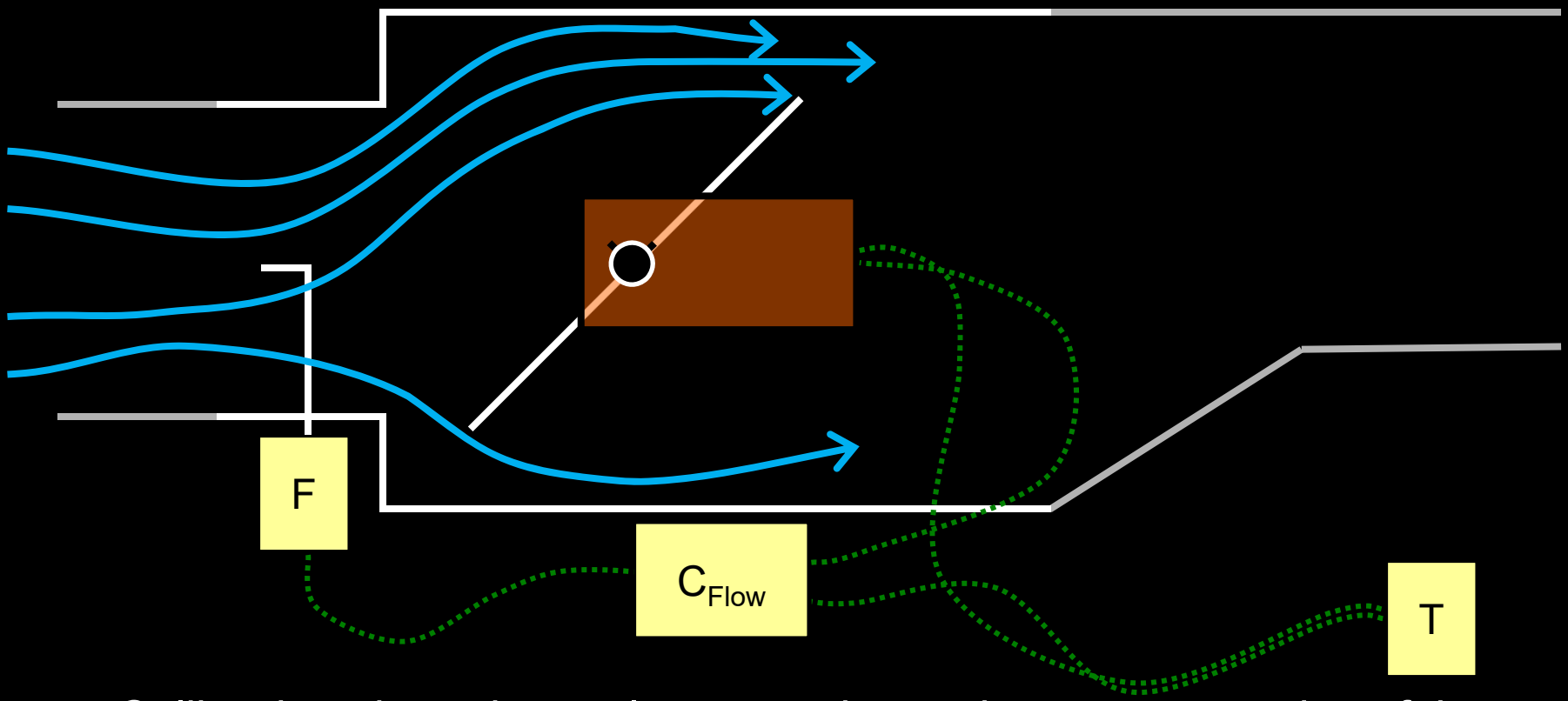
As the terminal unit damper begins to throttle the flow profile upstream of it begins to distort because the air is directed towards the sides of the box and accelerated by the closing damper

Flow Calibration; One Point *Doesn't* Fit All



As the terminal unit damper begins to throttle the flow profile upstream of it begins to distort because the air is directed towards the sides of the box and accelerated by the closing damper

Flow Calibration; One Point *Doesn't* Fit All



Calibrations based on at least two data points representative of the actual extreme operating conditions of the terminal unit will generally provide better results vs. a one point calibration

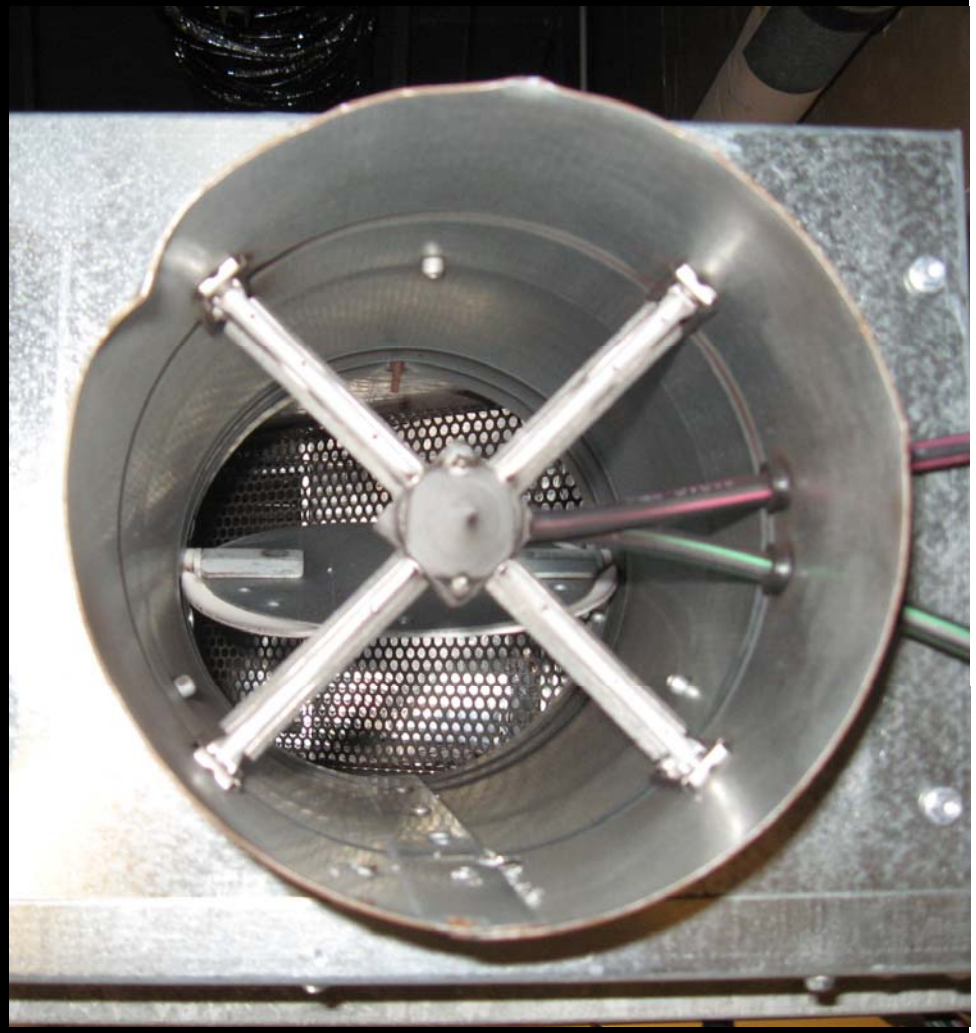
Field Data from the “Show Me” State

Building Control System Data

Set point	1,800 cfm
Indicated Flow	1,835 cfm
	(102% of set point)
Set point	700 cfm
Indicated flow	717 cfm
	(102% of set point)

Field Test Data (Traverse basis)

Set point	1,800 cfm
Traversed flow	1,962 cfm
	(107% of indicated)
Set point	700 cfm
Traversed flow	1,125 cfm
	(157% of indicated)



Field Data from the “Show Me” State

Read the paper and the presentation from NCBC 2013 at http://tinyurl.com/RonNCBC2013Presentation and http://tinyurl.com/RonNCBC2013Paper