P3000 Deadweight Tester Setup, Part 2: Full and Partial Correction Methods

19 May 2014 M. Daniels

This tutorial is for configuring a P3000 series (Pressurements) deadweight tester to be used with COMPASS for Pressure software in the *Full* or *Partial Correction* methods. A similar tutorial addresses configuring the software for the *Limited Partial Correction* method of operation.

In short, the *Full Correction* method uses COMPASS for Pressure to calculate the fundamental pressure equation for a deadweight tester, thus treating it as a piston-gauge – solving for the effective area of the piston-cylinder and the sum of the force acting on it. In the *Partial Correction* method, a correction is applied for the temperature of the piston-cylinder and a local gravity correction.

The user should be familiar with the P3000 Series Uncertainty Analysis technical note 2170TN13 -- "Guide for the Uncertainty Analysis in Pressure when using P3000 Series Deadweight Testers".

http://us.flukecal.com/literature/articles-and-education/pressure-calibration/application-notes/guideuncertainty-analysis-

The technical note defines several methods of operating a deadweight tester as a means to attain various levels of performance. The following three methods are described in 2170TN13: *Full Correction, Partial Correction,* and *No Correction*. Due to the structure of the COMPASS for Pressure Piston Gauge Calculator tool, a fourth term is introduced in Part 1 of this tutorial series -- "*Limited Partial Correction*".

Full Correction:

- The pressure is calculated for the influences of ambient conditions, piston-cylinder temperature, fluid head, and changes to the effective area of the piston due to deformation. This method is nearly identical to calculations required for a piston gauge.
- The P3000 device definitions are configured as a "Piston Gauge"
- This method is addressed in technical note 2170TN13.

Partial Correction:

- Corrections to the nominal pressure are limited to the temperature of the piston-cylinder, acceleration of local gravity, and DUT fluid head.
- The P3000 device definitions are configured as a "Piston Gauge"
- From an operations perspective with COMPASS for Pressure, there is not much difference between this and the *Full Correction* method other than not needing to update the ambient conditions.
- This method is addressed in technical note 2170TN13.

NOTE: Per technical note 2170TN13, the term *Partial Correction* is defined as correcting for local gravity and piston-cylinder temperature. In COMPASS, when the Platform Type selection is "Deadweight Tester", a correction for piston-cylinder temperature is <u>not</u> included. COMPASS limits the correction to local gravity (and fluid head) only. This is why the term *Limited Partial Correction* is used.

Limited Partial Correction:

- Only local gravity and a fluid head correction are applied.
- The P3000 device definitions are configured as a "Deadweight Tester".
- This term is not used in technical note 2170TN13.

No Correction:

- This method is referred to as "stack-and-spin" and does not require software. The nominal pressure values of the weights are summed together and represent the reference pressure.
- This method is addressed in technical note 2170TN13.

The required tasks for this setup include:

- ✓ Create the Piston-Cylinder definition
- ✓ Create the Mass Set definition
- ✓ Create the Mass Bell ("Weight Carrier") definition
- ✓ Create the Piston Gauge Platform definition
- ✓ Configuring local gravity

The screen shots are specific to a P3124, but are applicable to the P3000 Series models and the principles can be extended to other 3rd Party DWTs. With COMPASS for Pressure version 4.2 or older, the inverted piston negative gauge (vacuum) method of the P3011 and P302x models is not supported.

<u>Creating the Piston-Cylinder definition(s)</u>: [Setup],<Piston Gauge> \rightarrow "Piston-Cylinder" The critical selection is the "Piston-Cylinder Type". The choice of Piston Gauge fundamentally changes how COMPASS handles the metrology. The *Full* and *Partial Correction* methods require the Piston-Cylinder type to be "Piston Gauge". The metrological characteristics of the piston-cylinder assembly are required to calculate the pressure.

At a minimum only a serial number, Identification, or Customer ID is required for a valid setup. In this scenario the serial number of the piston is being used to uniquely identify the piston-cylinder instead of the top-level serial number of the P3124. The device label has been modified to make it clear that this piston-cylinder definition is different from the version that was made for use as a simple Deadweight Tester piston.

Piston-Cylinder Editor		×
Piston-Cylinder Label P3124 Hi P Piston, F	full Correction 42 / 42	D
Header Calibration Tolerance Character	istics	Ð
Manufacturer	Pressurements	20
Model	P3124	
Serial Number	x5190	×
Identification		• •
Customer ID		- <i>®</i> -
Piston-Cylinder Type	Piston Gauge	5
		2
	Close	

The fields in the Calibration tab are optional, and are not required for a valid setup.

Piston-	Cylinder Editor		×
Pist	on-Cylinder Label P3124, Hi P Piston	<u>35 / 41</u> ∢ ▶	
Header	Calibration Tolerance Characte	ristics	43
	Calibration Date	10/24/2013 💌	
	Calibration Due Date	10/24/2015	E 3
	Calibration Performed By		\sim
	Certification ID	1500128965	$ $ \wedge
	M&TE Device		
	Record Last Edited	5/7/2014 10:50:44 AM	
	Record Last Edited By	Admin	ā
		Close	

The tolerance specification reflects the uncertainty that can be attained when software is used to calculate the pressure using the *Full Correction* method.

Piston-Cylinder Editor	— ×
Piston-Cylinder Label P3124 Hi P Piston, Full Correction	D
Header Calibration Tolerance Characteristics	Ð
Effective Area Tolerance Type %FS (Greater Of) %Reading	\mathbb{N}
%FS 0.0008 Greater Of	x
%Reading 0.008	• `
	2
Close	

The Characteristics tab is populated from the calibration report. It describes the effective area and how it changes with changes in temperature and deformation. For P3000 piston-cylinders manufactured before July 2012 the Temperature Reference value is 20°C. These models are identified with the "P3000-n" nomenclature where "n" is an integer representing a unit of measure option such as 3 = psi, or 1 = Bar, etc. For P3000 piston-cylinders manufactured from July 2012 and thereafter the Temperature Reference value is 23°C. The model nomenclature was changed to "P3000-PSI" and similar for other units of measure.

Piston-Cylinder Editor					-X
Piston-Cylinder Label P3124 Hi P	Piston, Full Correction	35 / 42			D
		4	•		B.
Header Calibration Tolerance C	Characteristics				
Effective Area 8	3.032010E-6 m2 V	Piston Thermal Expansion	1.660E-5	IC.	
Temperature Reference	20 C 👻	Cylinder Thermal Expansion	0.000E0	/C	EO.
Mass 2	2.189580E-2 kg 🔻	Pressure Expansion	9.250E-7	/MPa 💌	
Mass Resolution 0).0000001 🔻 kg	Pressure Expansion 2nd	0.000E0	/MPa ²	\mathbf{X}
Average Density 7	'920 kg/m3 🔻	Reference Level Offset	0.000E0	mm 💌	
Min Rotation Rate (RPM)		L1	0.000E0	mm	H
		Surface Tension (N/m)	0	antria a	Ä
		Max Sink Rate	0		
		Close			
		Close			

Effective Area Temperature Reference *Mass	= = =	Reported in units of square meters. Be mindful of the exponent. Either 20°C or 23°C, depends on date of manufacture The mass of the piston corrected for the influences of fluid
		buoyancy, surface tension, and head correction.
		On some calibration reports, a small factor for "Residual Oil" is identified for informational purposes only. This influence has already been factored into the piston mass value.
Average Density	=	Use apparent mass density value
Min / Max Rotation	=	Typically not used with DWTs
Piston Thermal Expansion	=	A combination of the piston + cylinder
Cylinder Thermal Expansion	=	Typically set to 0.00 due to it being combined with the piston
Pressure Expansion	=	Elastic Deformation due to the applied pressure
Pressure Expansion 2 nd	=	Typically not used with DWTs
Reference Level Offset	=	Typically not used with DWTs
L1	=	Typically not used with DWTs
*Surface Tension	=	Combined with the piston mass
Max Sink Rate	=	Only applicable if an automated float position sensor is used

* Piston Mass: the calibration reports from Fluke Calibration provide a value for the piston mass. This represents the apparent mass of the piston. The report also provides corrections for the influences of surface tension, fluid buoyancy, and a small fluid head (the distance from the reference level of the piston to the o-ring seal on the test port). When used with COMPASS for Pressure, the piston mass must be modified by summing the four values together. Be careful to notice the Head Correction value is a negative value. (See section 5.11.4 of technical note 2170TN13).

<u>Creating the Mass Set definition:</u> [Setup],<Piston Gauge> \rightarrow "Mass Set"

The critical selection is the "Mass Set Type". The choice of Piston Gauge fundamentally changes how COMPASS handles the metrology. The *Full* and *Partial Correction* methods require Mass Set Type to be "Piston Gauge".

At a minimum only a serial number, Identification, or Customer ID is required for a valid setup. The device label has been modified to make it clear that this mass set is different from the version that was made for use as a simple Deadweight Tester weight set.

Mass Set E	ditor			—
1	Mass Set Label P3124 Weight Set,	Full Correction	22 / 28 ∢	D
Header	Collection Little Cat			Ð
Treader	Calibration Mass Set			
	Manufacturer	Pressurements		. K⊃
	Model	P3124		X
	Serial Number	68953		· · ·
	Identification			
	Customer ID			
	Mass Set Type	Piston Gauge	•	
		<u>C</u> lose		

The fields in the calibration tab are optional, and are not required for a valid setup.

The Mass Set tab is a summary of the individual weights and the associated pressure. The screen shot shows a completed mass set.

Mass Set Editor			-X
Mass Set Label P3124 Weight Set, F	Full Correction	22 / 28 ◀	ľ
Header Calibration Mass Set Individual Masses 20 psi #12 57.0000 g Image: Colored set of the se	Individual Mass Settings Mass Name* Nominal Mass True Mass* Tolerance* Mass Density* Makeup Mass Mass Unit Mass Density Unit Mass Set Resolution Mass Set Total	20 psi #12 57.0000 56.6995 0.0007 7920 9 ▼ kg/m3 ▼ 0.0001 ▼ 28294.6622 g	 □ × ★ ♦ ♦
	<u>C</u> lose		

Mass Name	=	A text field entry to describe the mass		
Nominal Mass	=	Optional field for summarizing the mass value (numeric entry only)		
True Mass	=	The mass value from the calibration report. The report provides an		
		Apparent Mass value for how much the mass would "weigh" if it		
		had a density of 7920 kg/m ³		
Tolerance	=	The uncertainty of the mass		
Mass Density	=	The apparent mass density		
Makeup Mass	=	Not typically used with a DWT		
Mass Unit	=	Choose from the drop down menu. Be consistent. Use the same		
		selection for all masses		
Mass Density Unit	=	Choose from the drop down menu. Be consistent. Use the same selection for all masses		
Mass Set Resolution	=	The resolution of the reported mass values		

When the Mass Set Editor is new all fields are blank. Each mass is treated as a separate entity which requires separate actions of clicking on the "New" and "Save" buttons. The goal is to create individual masses which are grouped together as the "P3124 Weight Set, Full Correction".

Mass Set Editor			— ×
Mass Set Label P3124 Weight Set, Fi	ull Correction	New Record	- Dì
	Editing New Record	∢ ▶	
Header Calibration Mass Set			
Individual Masses	Individual Mass Settings		
1.00000 kg	Mass Name*		
	Nominal Mass		N
	True Mass*		~
	Tolerance*		\sim
	Mass Density*	7920	18_
	Makeup Mass		
	Mass Unit		
X	Mass Density Unit		•
		kg/m3	
	Mass Set Resolution	0.0001	
	Mass Set Total	1.00000 kg	
	Close		

To create a new mass entry, click on the "New" button in the middle of the window. Fill in the data for the mass, then save using the "Save" button in the middle of the window. To create the next mass entry, click the "New" button (in the middle of the window) again. Repeat this process until all masses have been defined.

The following error message may appear when saving the individual masses. Click "OK" and resave the mass entry to clear the message.



<u>Creating the Mass Bell definition:</u> [Setup],<Piston Gauge> → "Mass Bell"

The Weight Carrier assembly consists of the weight carrier tube that fits over the piston and the small ring weight that slips over the tube and sits at the bottom. This assembly is considered to be the "Mass Bell". For low pressure units, there is not a weight carrier tube but a weight carrier table. This should be treated as the same.

The calibration report identifies the weight carrier assembly as mass ID "A" or "B". The reported mass value <u>does not</u> include the mass of the piston.

Mass Bell Editor	×
Mass Bell P3124 Weight Carrier, Full Correction 18 / 18	ſŊ
Header Calibration Mass Bell	벽비
Manufacturer Pressurements	
Model P3124	
Serial Number 68953	\mathbf{X}
Identification	
Customer ID	
	2
Close	

The fields in the calibration tab are optional, and are not required for a valid setup.

Mass Bell Editor	—
Mass Bell P3124 Weight Carrier, Full Correction	18 / 18
Header Calibration Mass Bell	
Mass * 545.3832	
Mass Resolution * 0.0001	• • • • • • • • • • • • • • • • • • •
Average Density * 7920	kg/m3 🔹 🗙
Mass Bell Tolerance * 3.000E-3	g
D (Hanger Mass Depth) 0.0000	
Sieeve Onser [0.0000	m
Close	

The Hanger Mass Depth and Sleeve Offset fields are for Ruska 2400 piston gauges and are not applicable to the P3000 Series.

<u>Creating the Piston Gauge Platform definition:</u> [Setup],<Piston Gauge> \rightarrow "Piston Gauge"

The critical selection is the "Platform Type". At a minimum only a serial number, Identification, or Customer ID is required for a valid setup.

Piston Gauge Platform Editor			×
Record Label P3124, Full 0	Correction	15 / 29	Γ
		• •	
Header Calibration P-C/MS Sources	Comment		벽송
Platform Device Type	Simple Device	_	
Hattorin Device Type	Simple Device		
Record Type	Individual	▼	
Manufacturer	Pressurements	- A	
Model	P3124	•	X
Serial Number	68953		
Identification			
Customer ID			₩¢
	This device can be used as a DUT.		\bigcirc
Platform Type	Piston Gauge	•	v
	*		
	Close		

The fields in the calibration tab are optional, and are not required for a valid setup.

The P-C/MS tab is where the piston-cylinder and the mass set are assigned for use with the P3124 platform.

Piston Gauge Platform Editor					×
Record Label P3124, Full Correction			15 / 29		\square
Header Calibration P-C/MS Sources Comment				t D	
Piston-Cylinder	P3124 Hi P Piston, Full Correction	-	<u>E</u> dit		
Mass Set	P3124 Weight Set, Full Correction	-	<u>E</u> dit		K)
Trim Mass Set	None	•	Edit		X
Mass Bell	P3124 Weight Carrier, Full Correction	•	Edit		
Default Medium	Default Medium ST-55			<u></u>	
	Limited to Defaul Medium				
Default Measurement Mode	Gauge	•			\mathbf{O}
	Limted to Default Measurement Mode				9
Close					

A new Platform Editor screen will have unpopulated drop down menus with "Support All" shown in them. The concept of "Support All" is to make every piston-cylinder and mass set in the database available for use with the P3124. In many situations this is not ideal. For example you would not want to use a hydraulic piston-cylinder with a gas operated DWT. Therefore, the idea is to assign which piston-cylinder(s) and mass set definitions can be used with the platform.

Piston Gauge Platform Editor				×
Record Label P3124, Full Correction		•	15 / 29	D
Header Calibration P-C/MS Sour	ces Comment			Ð
	1	C		
Piston-Cylinder	Support All	-	Edit	
Mass Set	Support All	-	Edit	KO
Trim Mass Set	Support All	-	Edit	x
Mass Bell	Support All	-	Edit	<u> </u>
Default Medium	ST-55	-		
	Limited to Defaul Medium			
Default Measurement Mode	Gauge	-		\mathbf{O}
	 Limted to Default Measurement Mode 			\bullet
	Close			

Click on the "Edit" button to the right of the Piston-Cylinder field to select the "P3124 Hi P Piston, Full Correction". If there is a definition for the low range piston (the P3124 model has both a Low and High pressure piston-cylinder) then select it at this time as well. Repeat the process for the Mass Set and Mass Bell.

Trim Mass Sets are not typically used with a Deadweight Tester, but could be used when the *Full Correction* method is used. Choose the appropriate fluid medium and measurement mode.

The Sources tab is used to associate external devices for use with the P3124. In this example, a model 1620A has been defined and assigned for use as the ambient temperature source. The selections can be later changed when a test is initialized, but by associating them with the P3000 Platform they become the default selection. This provides an extra measure to ensure that the correct support devices are used with the P3124. The P3000's uncertainty analysis assumes that the piston-cylinder temperature will be similar to ambient temperature.

Piston Gauge Platform Editor	— ×
Record Label P3124, Full Correction 15 / 29	D
Header Calibration P-C/MS Sources Comment	Ð
Platform Condition Sources	
Reference Vacuum None	
P-C Temperature 1620A "DewK" / Temperature	N J
Piston Position None	\sim
Piston Rotation Rate None	
	2
Close	

Configuring local gravity:

The biggest source of potential error when using a pressure balance, be it a piston-gauge or a DWT, is having the wrong value for the local acceleration of gravity. When operating the P3000 in *Full* or *Partial Correction* method the local gravity is handled differently than it is with a regular DWT (e.g. *Partial Limited Correction* method). It's a variable in the force component and it must be known for the location where the P3000 is being operated.

The input for local gravity is located under the [Tools],<Options...> menu \rightarrow "Piston Gauge" tab.

An application note is available at <u>www.Flukecal.com</u> to help determine local acceleration of gravity:

http://download.flukecal.com/secure/4218960B_EN_Accounting_For_Gravity_w.pdf?nvb=2014050720 0439&nva=20140507201939&token=0d431b7f84ff2c15956e9

COMPASS Options	—	
Data File Data In File Data Header Interface	Localization MET/TRACK	
Ambient Conditions Initialize Test Run Test End Test	Piston Gauge Data Grid	
Include mass bell in minimum PG pressure	V	
Suggest 2nd fluid medium		
List mass set masses by semical mass		
List mass set masses by nonlinal mass.		
List mass set masses by the mass.	0	
Default mass loading resolution 10g	-	
2465 Barometer Source for ADM Internal LEM Sens	or 💌	
DHI PG7000 metrological element calibration interval (months)	2	
DHI PG7000 piston-cylinder fall rate limit	0.0	
Local Gravity (m/s^2) 9.79474		
Default piston position target(mm).	2	
Expected reference vacuum value (mTorr)	100	
	Cancel	

When running a test the Piston Gauge Calculator tool is used to indicate the mass load and the corresponding pressure with corrections for environmental and system influences. The corrected Reference Pressure is given as 1193.2359 psi. The Mass List window shows the masses that should be used to attain this pressure. The window can be expanded to see a sequential list \implies of the mass load.

le Piston Gauge Calculator	
Piston Gauge Platform	P3124, Full Correction
Piston-Cylinder P3124 Hi P Piston, Full Correction	
Mass Set	P3124 Weight Set, Full Correction
Trim Mass Set	
Mass Bell	P3124 Weight Carrier, Full Correction
Medium	ST-55
Measurement Mode	Gauge
	·
Ambient Temperature (C)	23.0 Mass List >>
Ambient Humidity(%RH)	47.0 Piston 0.0220000 kg
Ambient Pressure (psi)	14 28
Ambient Pressure Height (cm)	0.00
Vent Height (cm)	0.0 2 0 psi #13 57.0000 g
Head Height (cm)	Q 0 0 20 psi #11 57.0000 g
neud neight (en)	I 100 psi 284.0000 g I 100 psi #0 567 0000 g
P-C Temperature (C)	23.0 200 psi #8 567.0000 g
	200 psi #7 567.0000 g
Diston Desition (mm)	200 psi #6 567.0000 g
Piston Position (mm)	0 2000 psi_2 5670.0000 g
Mass Loading Desolution	2000 psi_4 5670.0000 g ▼
	10g •
Pressure Display Resolution	0.0001
Pressure (psi)	1200 1193.2359
True Mass (d)	6747 8415
(g)	
Nominal Mass (g)	6748.0000
	Pressure is Ready