

Final Report

for
COMPOTOOL LTD

MOISTURE EXPANSION MEASUREMENTS OF CT850 TOOLING BOARD SPECIMENS

September 5, 2014

Paul Hackett
TEL: +64 (9) 573-1970
FAX: +64 (9) 573-1973

COMPOTOOL LTD
39 Vestey Drive
Mt Wellington, Auckland 1060
New Zealand

PURCHASE ORDER NUMBER PO-0012

TESTING SERVICES PROVIDED BY
Precision Measurements and Instruments Corporation
3665 SW Deschutes Street
Corvallis, OR 97333 USA

TEL: 541-753-0607
FAX: 541-753-0610
EMAIL: info@pmiclab.com



MOISTURE EXPANSION MEASUREMENTS OF CT850 TOOLING BOARD SPECIMENS

WORK CONDUCTED FOR COMPOTOOL LTD
PURCHASE ORDER NUMBER PO-0012

September 5, 2014

Precision Measurements and Instruments Corporation determined the moisture absorption properties according to ASTM D5229 and the average coefficient of moisture expansion (CME) of CT850 Tooling Board test specimens. Results are presented in the enclosed table and graphs. A brief description of the test procedure and comments on the results follow.

Specimen Description

CompoTool Ltd provided the following specimens:

Specimen #	Description	Length	Width	Thickness
1	CT 850 Tooling Board	~101.6mm	~101.6mm	~50.8mm
2	CT 850 Tooling Board	~101.6mm	~50.8mm	~50.8mm

The specimens were measured in the length direction.

Test Description

q Specimen Check-in

The specimens were hand delivered at the SAMPE Seattle show. The specimens were checked for damage. No specimen damage was observed. The specimens were labeled and stored in a secure environment.

q Specimen Preparation

The specimens provided were also to be used for two other kinds of testing by PMIC. 7 samples of approximately 7x2x0.25 inches were prepared from the longer of the two provided specimens using a band saw and sander. They were then cleaned using acetone and began testing.

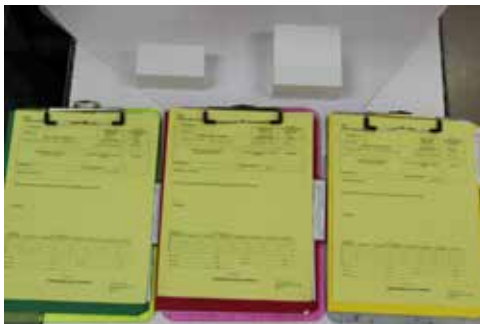


Figure 1: Specimens as Arrived

q Dry Equilibrium

The specimens were dried initially in vacuum at 60°C, and then in 0% RH at 24°C until mass stabilized to ± 0.3 mg over a 24 hour period. The specimens then began moisture absorption.

q Moisture Absorption

Mass change was monitored during absorption at 53% RH and 24°C for the time period indicated on the graphs and in the tables. The relative humidity of the chamber was controlled using an aqueous salt solution per ASTM 104.

q Strain Measurement

Specimen strain was measured from moisture saturation at 53% RH to partial dry at 0% RH. Strain measurements were conducted at 24°C. Strain change was measured between the two ends of the specimens over the L_0 indicated.

The measurements were made with LVDT based dilatometers. The specimens and LVDTs were supported on a zero CME, low CTE quartz test stand. The specimens' moisture is absorbed into desiccant in a stirred air environment. The LVDT measurement probes extended from the core of the LVDTs to the specimens and support plate using quartz rods (see figure 2).

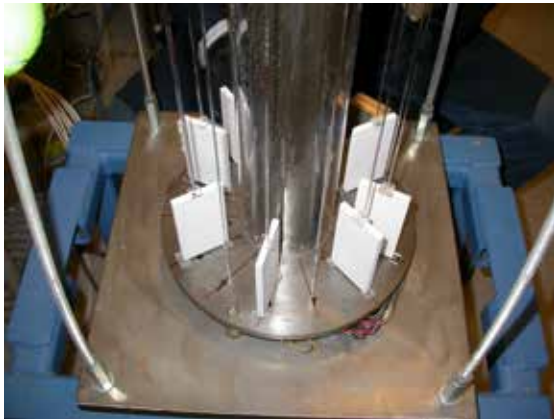


Figure 2: Specimens Installed in vertical CME Chamber

Data Analysis

The moisture content change during absorption is calculated using Equation 1.

$$M(t) = \frac{(weight(t) - dry\ weight)}{dry\ weight} \cdot 100 \quad [1]$$

The Average CME value (in the length direction) is determined by the following equation, where the total strain change corresponds to total moisture content change.

$$Avg. CME = \frac{total\ strain\ change\ (desorption)}{total\ moisture\ content\ change\ (desorption)} \quad [2]$$

The diffusivity is related to the initial slope of the linear portion of the percent moisture (%M) versus ($t^{1/2}$) curve by the following equation:

$$D = \rho \frac{h^2}{4M_m} \frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}} \quad [3]$$

Where (M_m) is the maximum % moisture content at saturation, (M_1) and (M_2) are the change in weight divided by the dry weight at time ($t_1^{1/2}$) and time ($t_2^{1/2}$) respectively, and h is the thickness of the specimen.

Uncertainty

The uncertainty in the mass measurement is only +/-0.3 mg. The uncertainty in the strain measurement is up to 6 microstrain, based on the LVDT drift and standard deviation.

Test Results

The enclosed table summarizes the results of the tests. The specimen identification, description, dimensions, dry and wet masses, maximum moisture content, total moisture content change during absorption, total moisture content change during desorption, total moisture induced strain, average coefficient of moisture expansion (CME), and diffusivity at 24°C are listed.

To calculate diffusivity using the Equation 3, a linear regression was performed to the initial data of the percent moisture (%M) versus ($t^{1/2}$). For this experiment, data was used through time starting at 0 sec^{0.5} to 65 sec^{0.5}. This is approximately 1 hour total.

The last 8 hours of data points were averaged to get the final strain value for the specimen. The final strain value minus the initial strain value is the total microstrain change. Averaging is utilized in order to extrapolate between LVDT sensor noise. It is insured that the final strain and initial strain values are for the same temperatures to within +/-0.3°C. The strain chamber does not instantaneously go from 53% RH to 0% RH. For this experiment, this transition took approximately 1 hour. Thus, initial desorption rates will differ from initial absorption rates, as absorption conditions go from 0% RH to 53% RH nearly instantaneously. Additionally, the strain values varied but for the most part were stable during that final 2 day period.

Note that the contract required the testing of 5 specimens and PMIC includes the results for 2 additional specimens at no additional charge. The additional specimens were prepared in case some of the specimens were found to be defective or to have non-representative results.

Please contact our technical staff at (541) 753-0607 if you have any questions or require any additional information regarding these measurements

Enclosures: 1 table of results
7 graphs of moisture content versus time
7 graphs of microstrain versus time

Submitted by:



Darrell Oakes
Project Engineer/Lab Manager



David Stumpff
Test Technician



Daylin Oakes
Test Technician

Precision Measurements and Instruments Corporation hereby claims that test results are obtained by techniques based on relevant ASTM standards, calibrations with NIST standard reference materials and/or published procedures. Thus, we accept no liability for test results beyond the cost of the contract rendered.

Quality Statement:

At PMIC, our policy is to consistently provide the maximum possible accuracy and reliability for materials properties test data, as requested by our customers. This level of quality is achieved through the adoption of a Quality Management System that reflects the competence of PMIC to existing customers, potential customers and independent auditing authorities.

CME TABLE 1

Date: 03SEP2014

Compo Tool Ltd CME Data (PMIC 14526)

PO# 0012

Material: CT850 Tooling Board

Specimen ID	CT850 Tooling Board	CT850 Tooling Board	CT850 Tooling Board	CT850 Tooling Board	CT850 Tooling Board
Specimen #	1	2	3	4	5
Length (in)	3.871	3.882	3.877	3.893	3.890
Width (in)	2.027	2.022	2.028	2.004	2.014
Thickness (in)	0.260	0.260	0.254	0.261	0.259

Moisture Content Measurement From Dry to Absorption at 53% RH, 24°C

Dry Mass (g)	28.2901	28.5751	27.9332	28.0314	28.4129
Wet Mass (g)	28.5198	28.8119	28.1630	28.2614	28.6438
Total Moisture Content Change (% mass gain)(absorption)	0.81	0.83	0.82	0.82	0.81
Initial slope of absorption curve (sec ^{1/2})	7.39E-03	7.66E-03	7.39E-03	8.09E-03	8.17E-03
Diffusivity (mm ² /sec)	7.12E-04	7.28E-04	6.61E-04	8.40E-04	8.62E-04

Moisture Induced Strain Measurement From Absorption at 53% RH, 24°C to Dry at 0%RH, 24°C

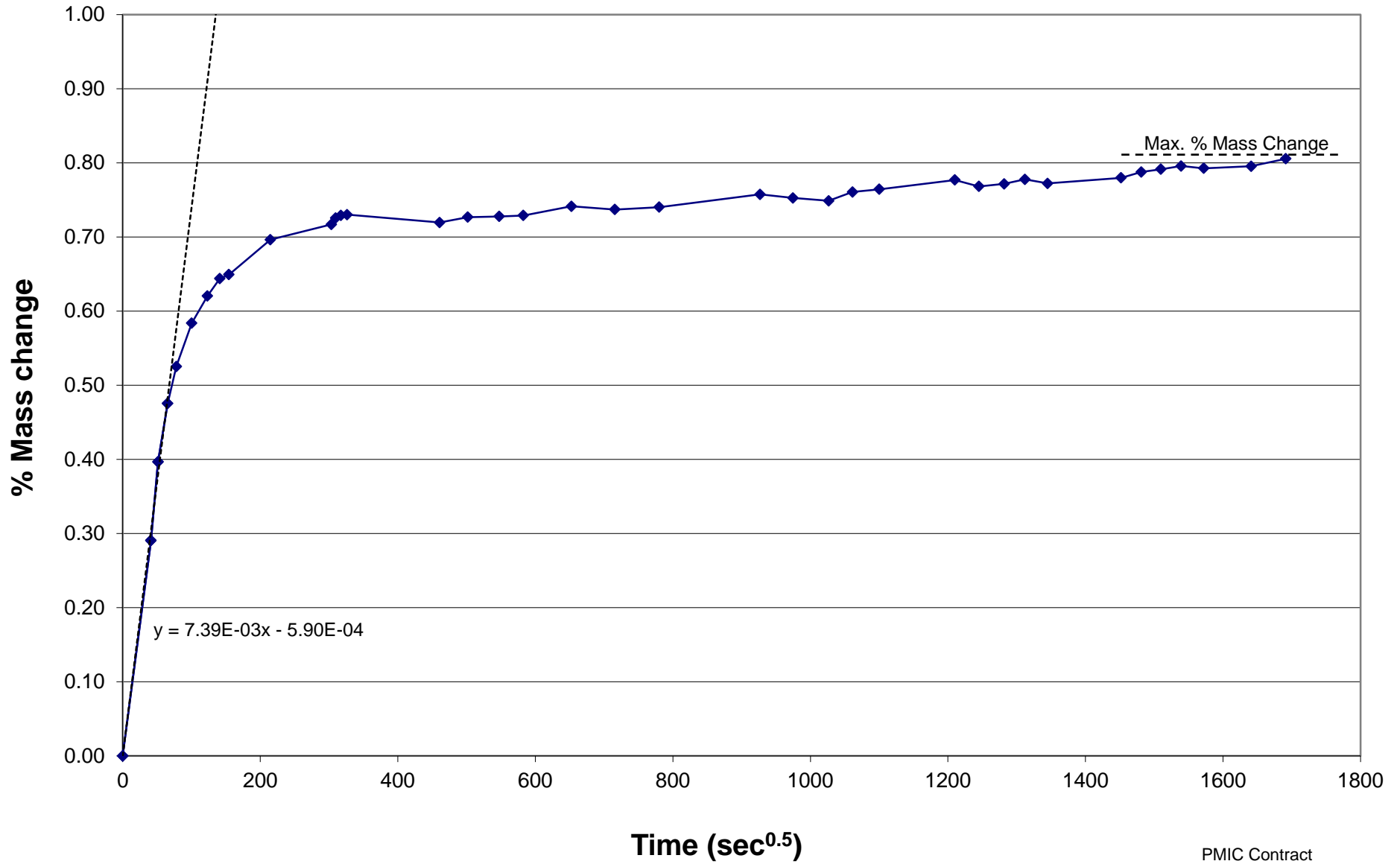
Gauge Length L ₀ (in)	3.871	3.882	3.877	3.893	3.890
Wet Mass (g)	28.5198	28.8119	28.1630	28.2614	28.6438
Patial Dry Mass (g)	28.3603	28.6474	27.9946	28.0836	28.4672
Total Moisture Content Change (% mass loss)(desorption)	-0.56	-0.57	-0.60	-0.63	-0.62
Total Microstrain Change ($\Delta L/L_0 \times 10^{-6}$)	-119	-110	-104	-100	-115
Avg. CME (total microstrain change)/(total % mass change)	213	192	174	159	186

CT850 Tooling Board	CT850 Tooling Board
6	7
3.885	3.865
2.021	2.028
0.257	0.262

28.4605	28.7240
28.6831	28.9345
0.78	0.73
7.70E-03	6.98E-03
8.16E-04	7.94E-04

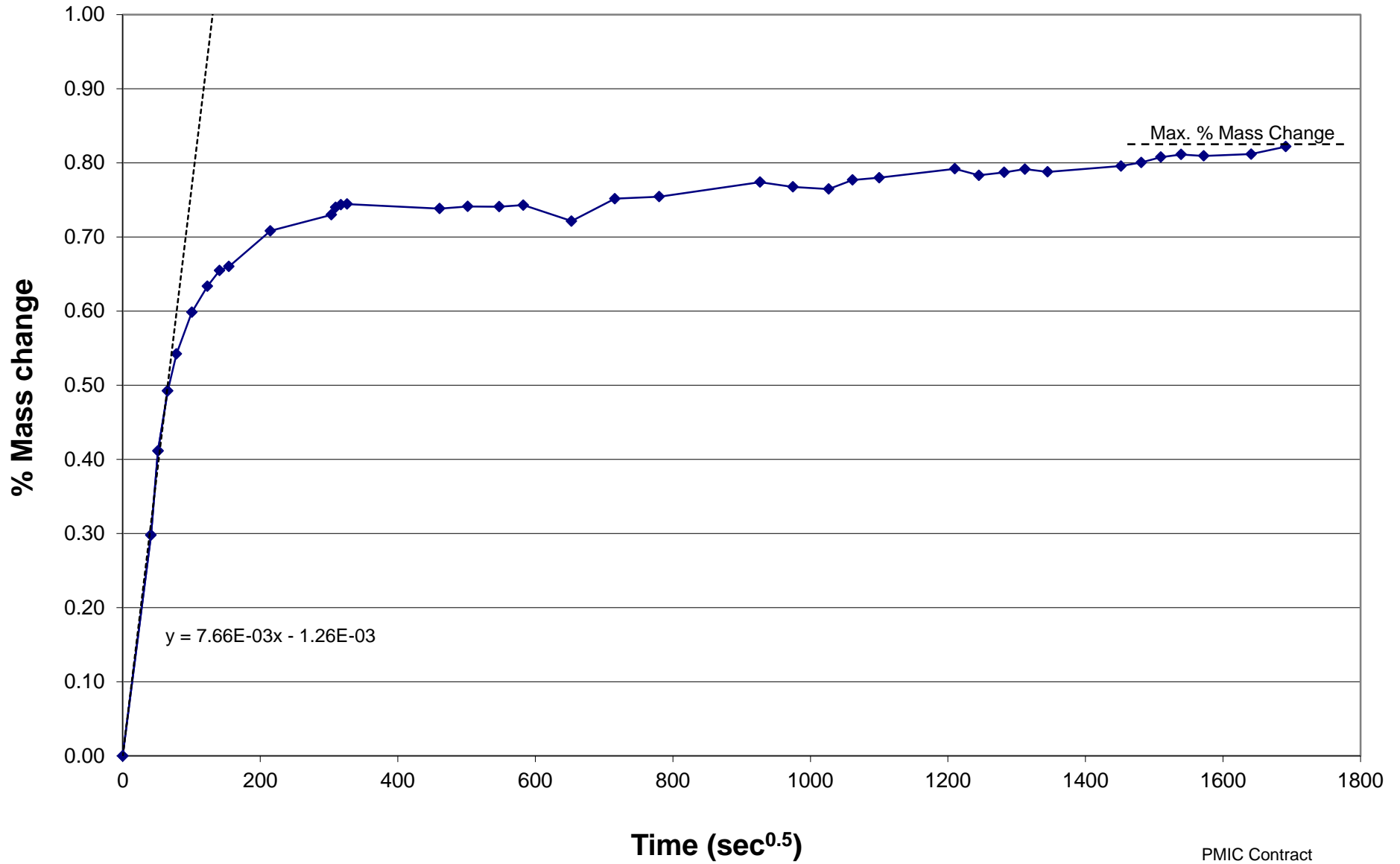
3.885	3.865
28.6831	28.9345
28.5513	28.7760
-0.46	-0.55
-113	-119
246	216

Moisture Absorption of CompoTool Ltd #1, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"



PMIC Contract
CompoTool 14526
Specimen 1
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #2, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"

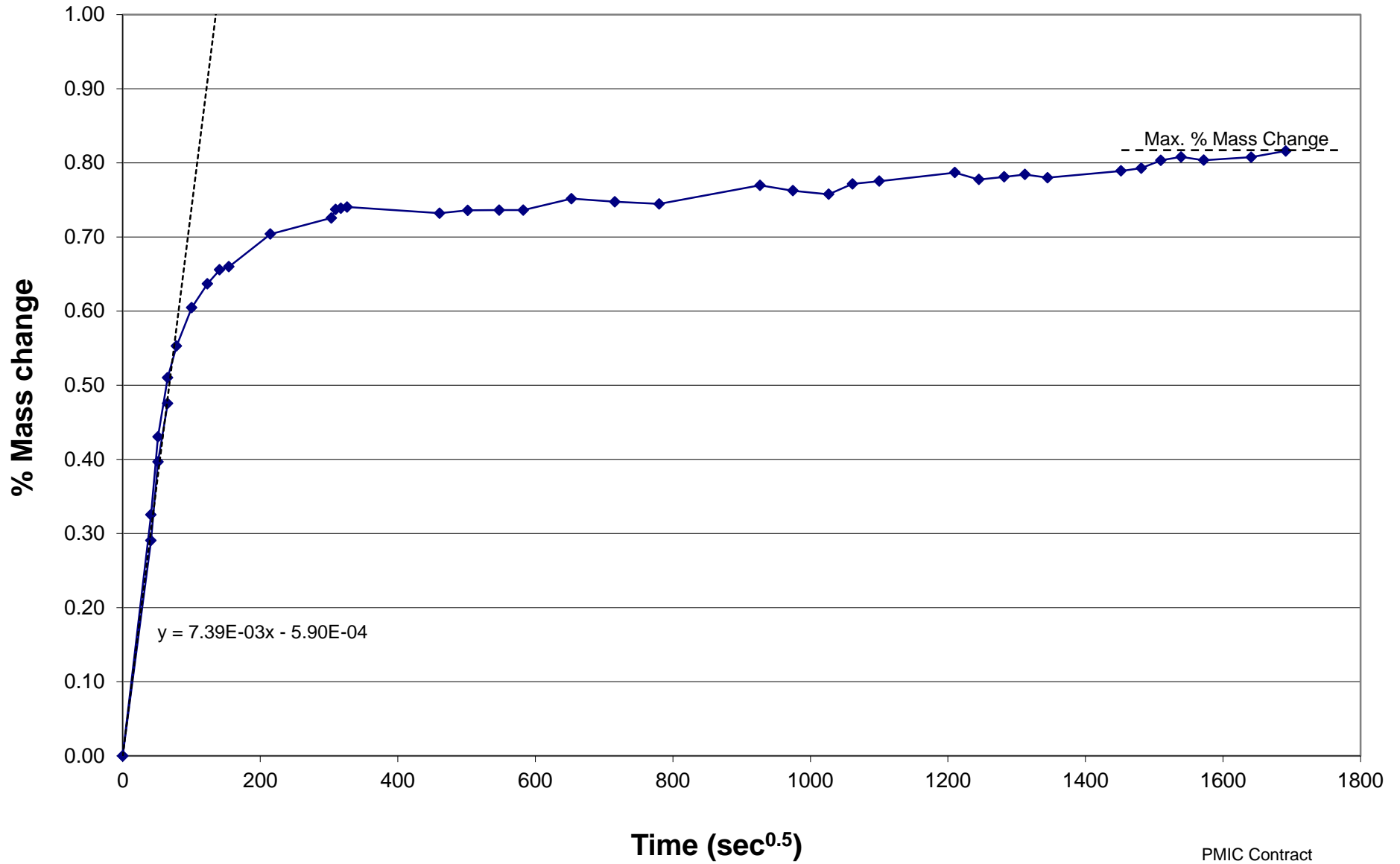


$y = 7.66E-03x - 1.26E-03$

Max. % Mass Change

PMIC Contract
CompoTool 14526
Specimen 2
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #3, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.25"

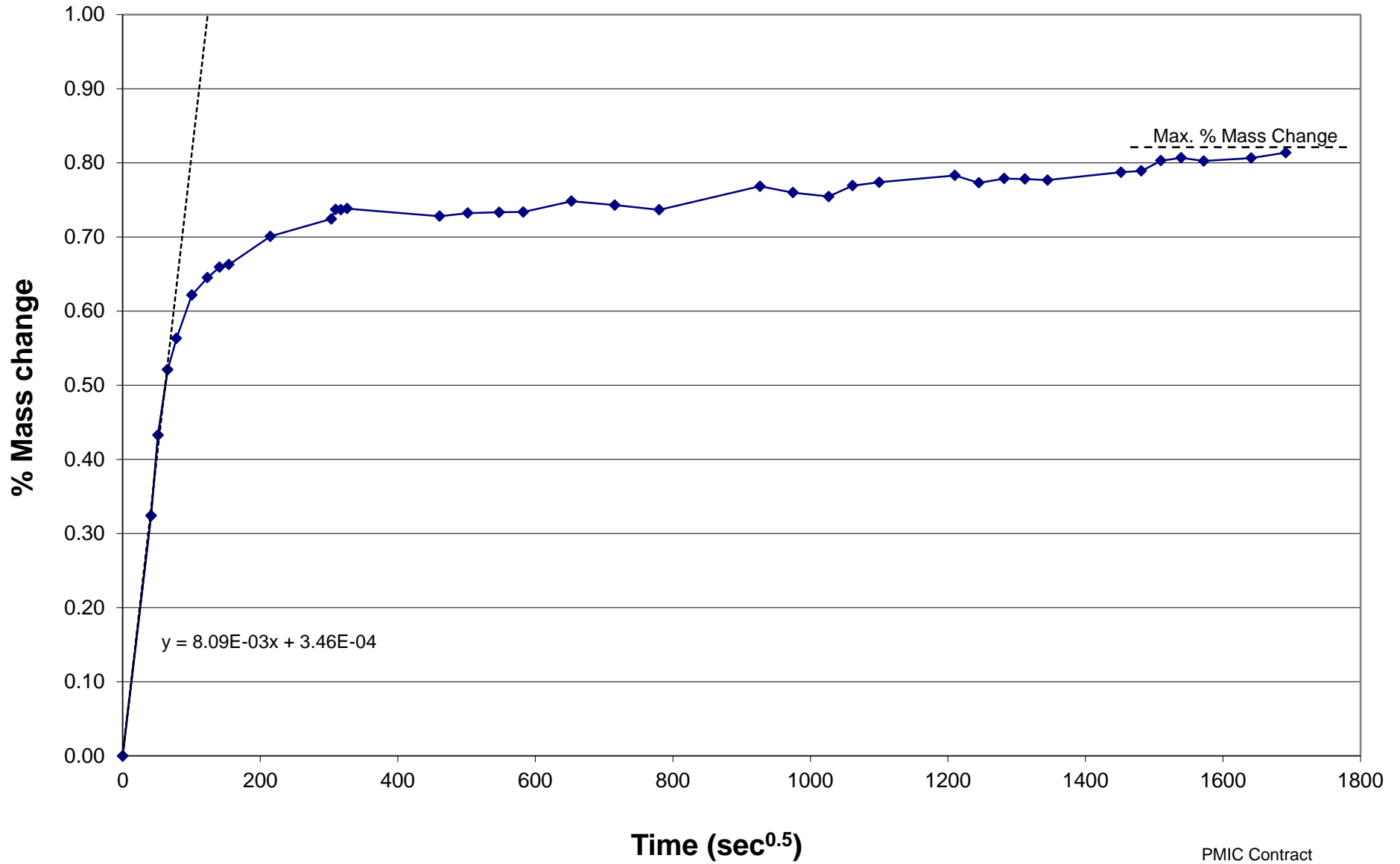


$y = 7.39E-03x - 5.90E-04$

Max. % Mass Change

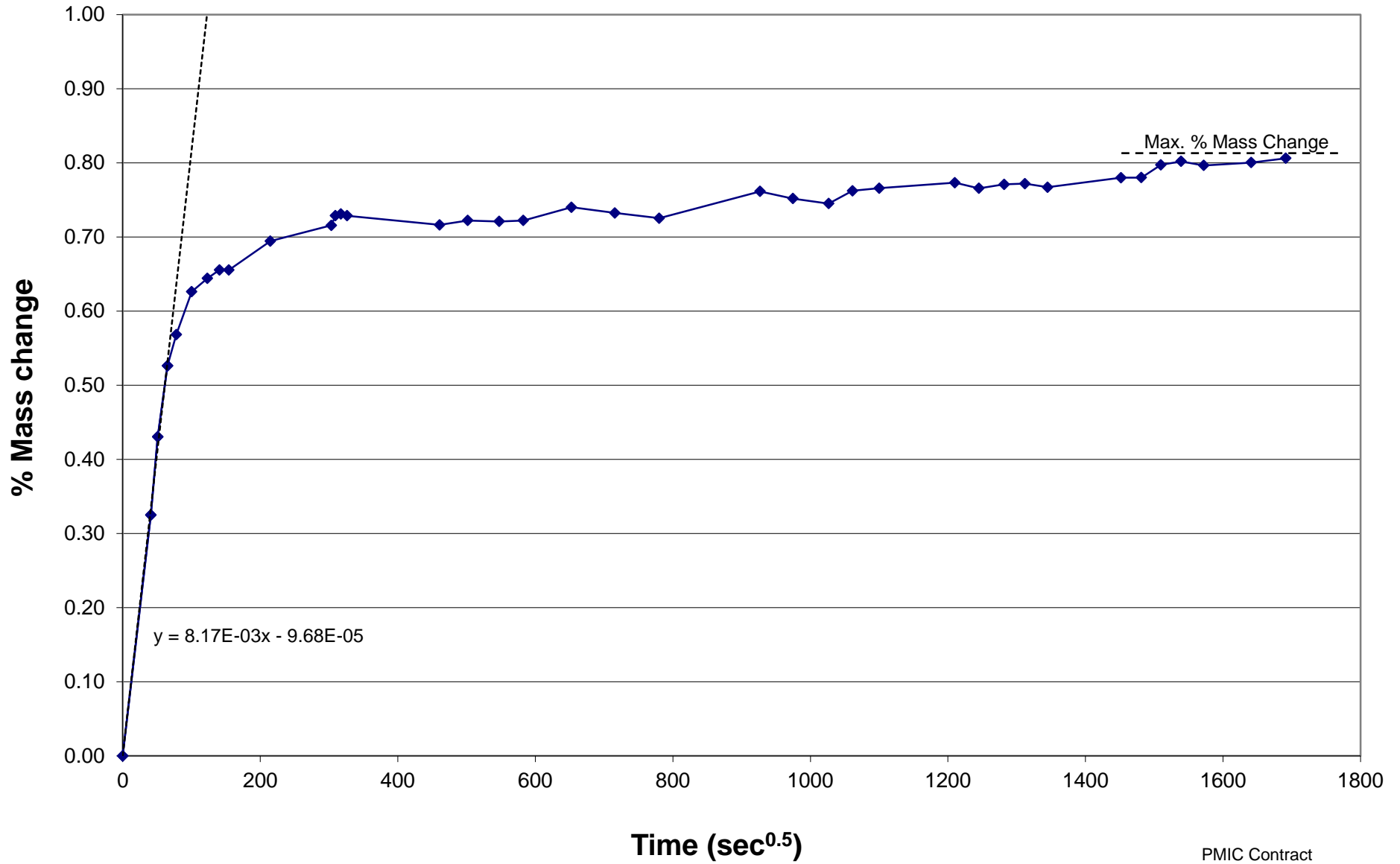
PMIC Contract
CompoTool 14526
Specimen 3
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #4, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"



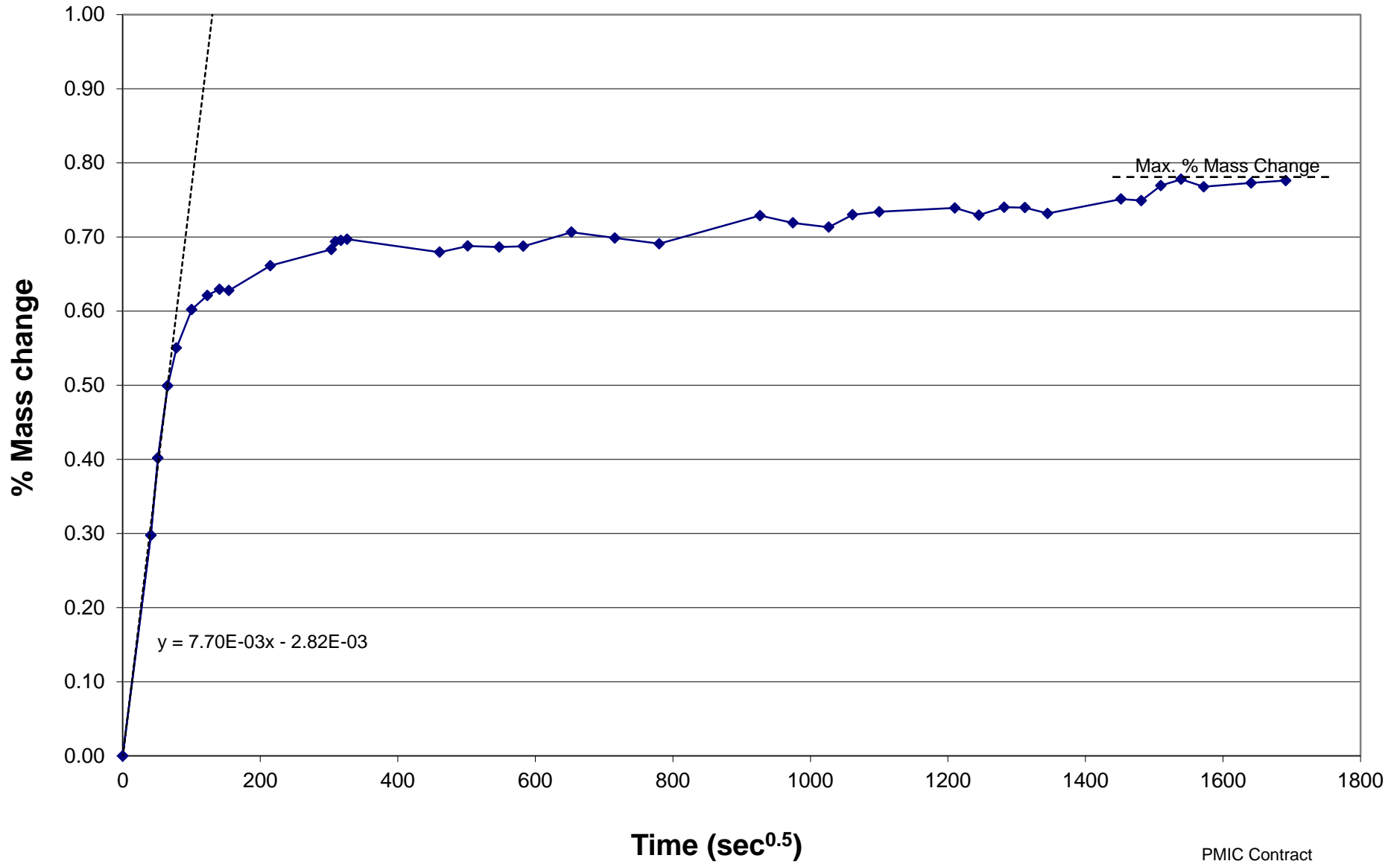
PMIC Contract
CompoTool 14526
Specimen 4
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #5, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"



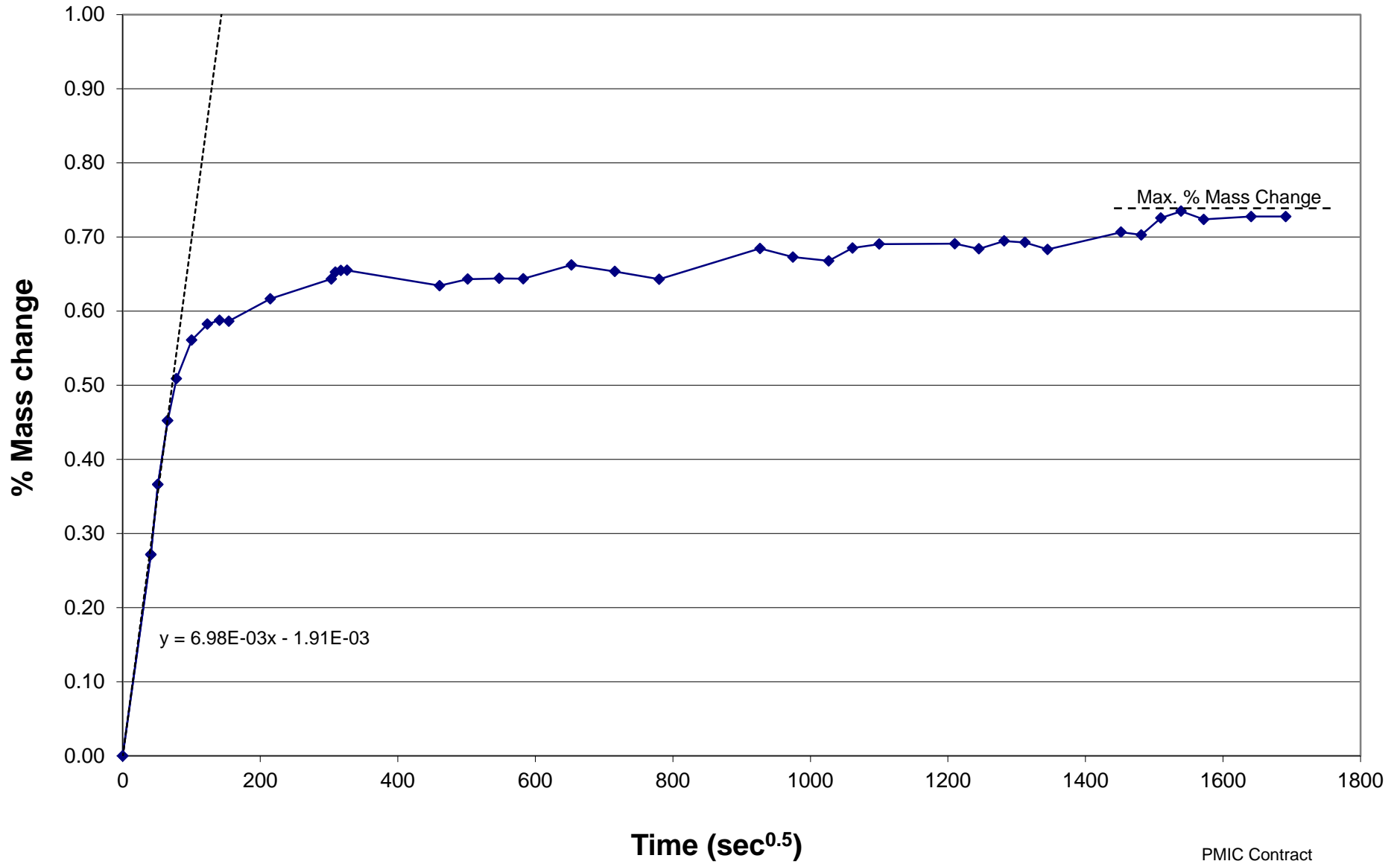
PMIC Contract
CompoTool 14526
Specimen 5
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #6, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"



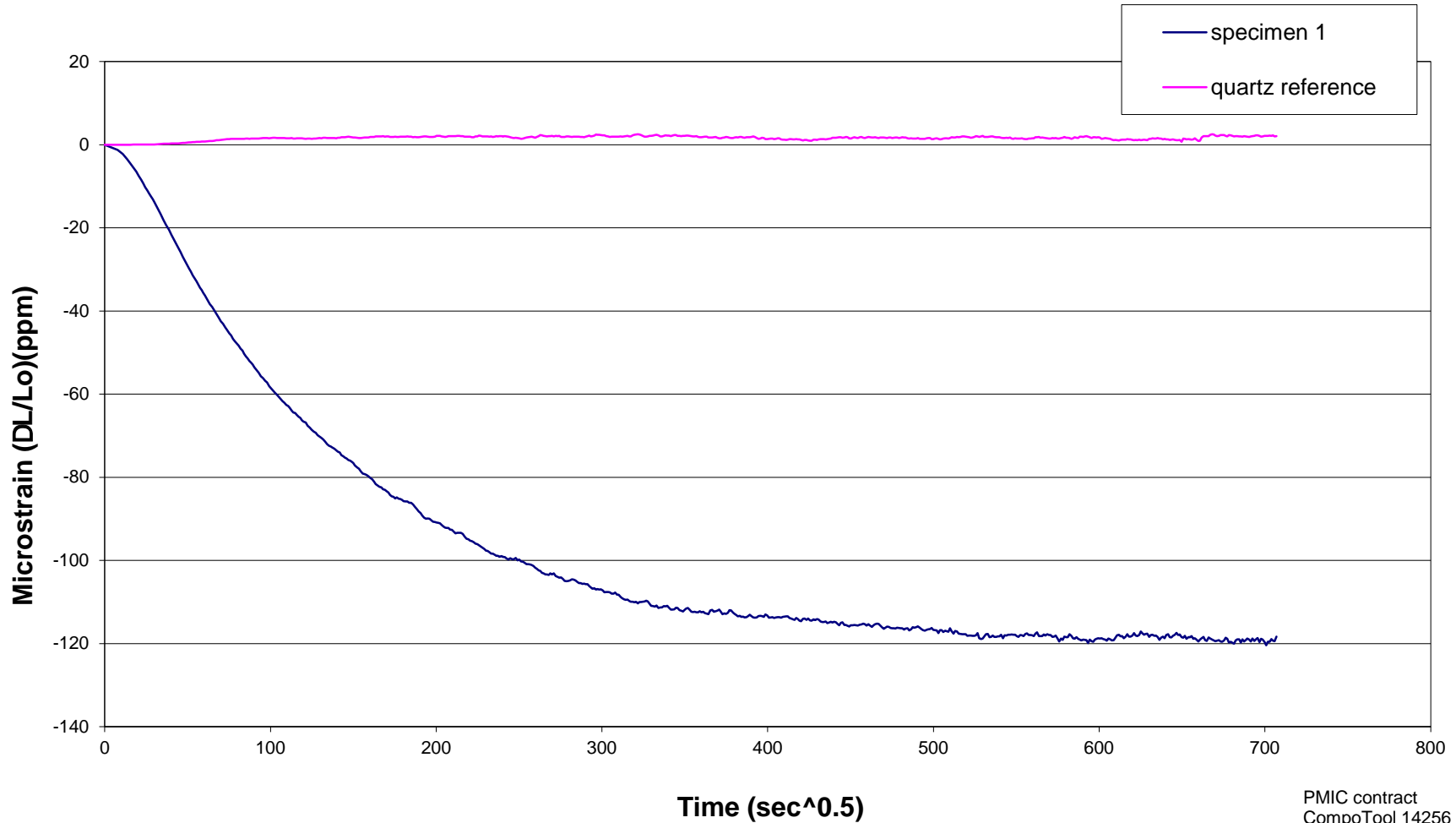
PMIC Contract
CompoTool 14526
Specimen 6
18JUL2014-
20AUG2014

Moisture Absorption of CompoTool Ltd #7, CT850 Tooling Board, 0°
From Dry at 0%RH, 24°C to Absorption at 53%RH, 24°C
3.9" x 2.0" x 0.26"



PMIC Contract
CompoTool 14526
Specimen 7
18JUL2014-
20AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #1
From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C
Specimen tested in the length direction
3.9" x 2.0" x 0.26"



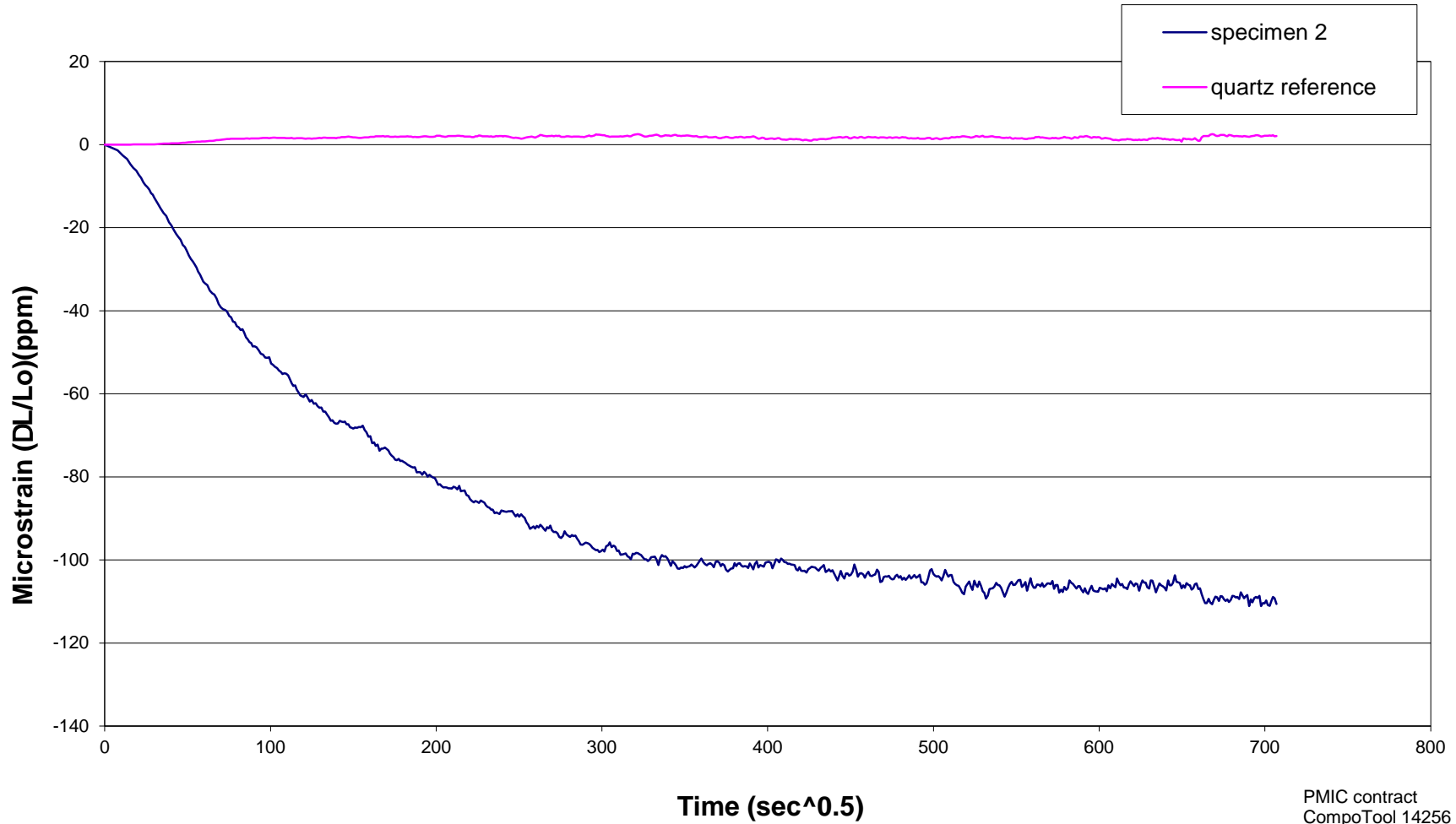
PMIC contract
CompoTool 14256
Specimen 1
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #2

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.26"



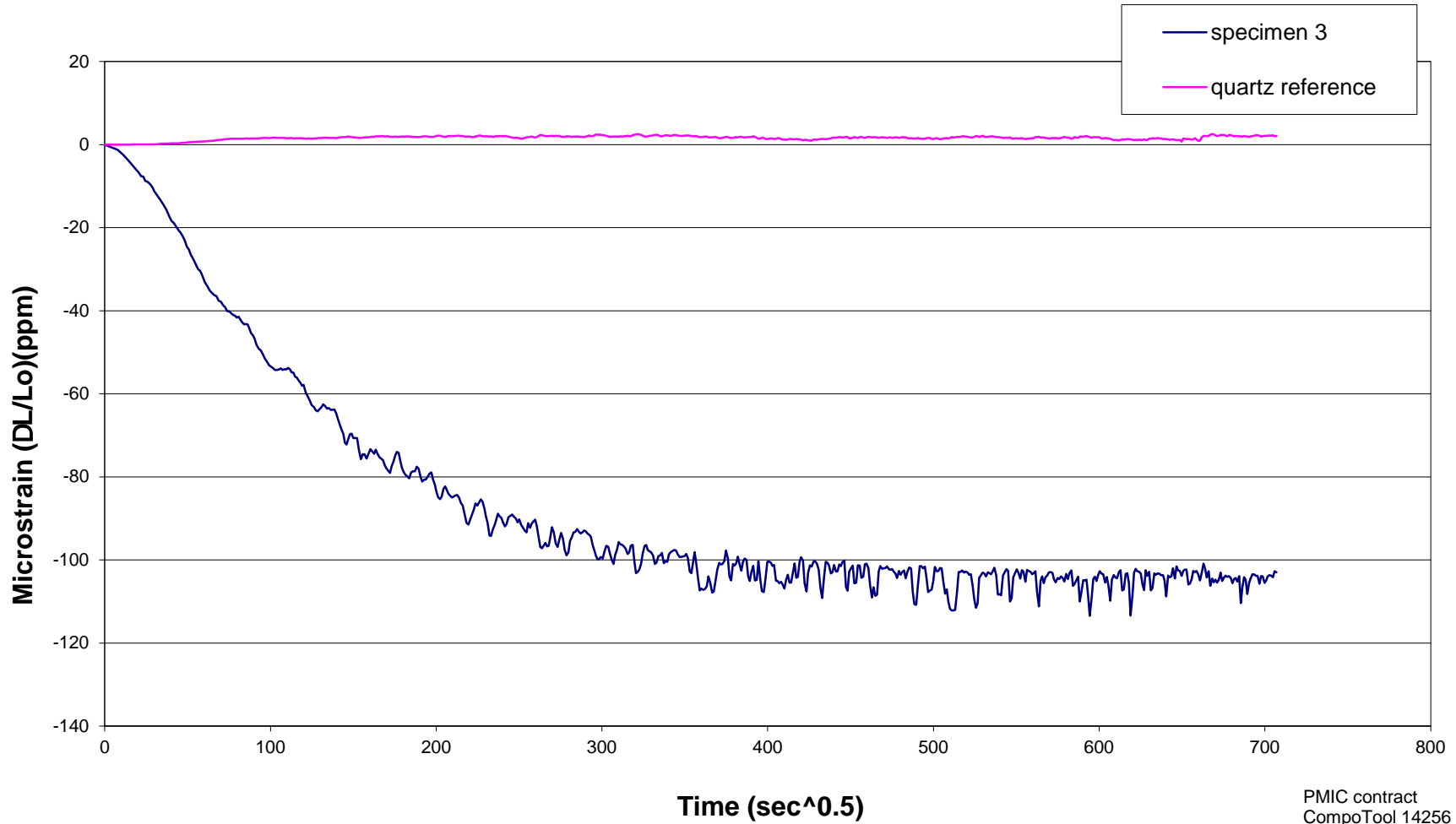
PMIC contract
CompoTool 14256
Specimen 2
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #3

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.25"



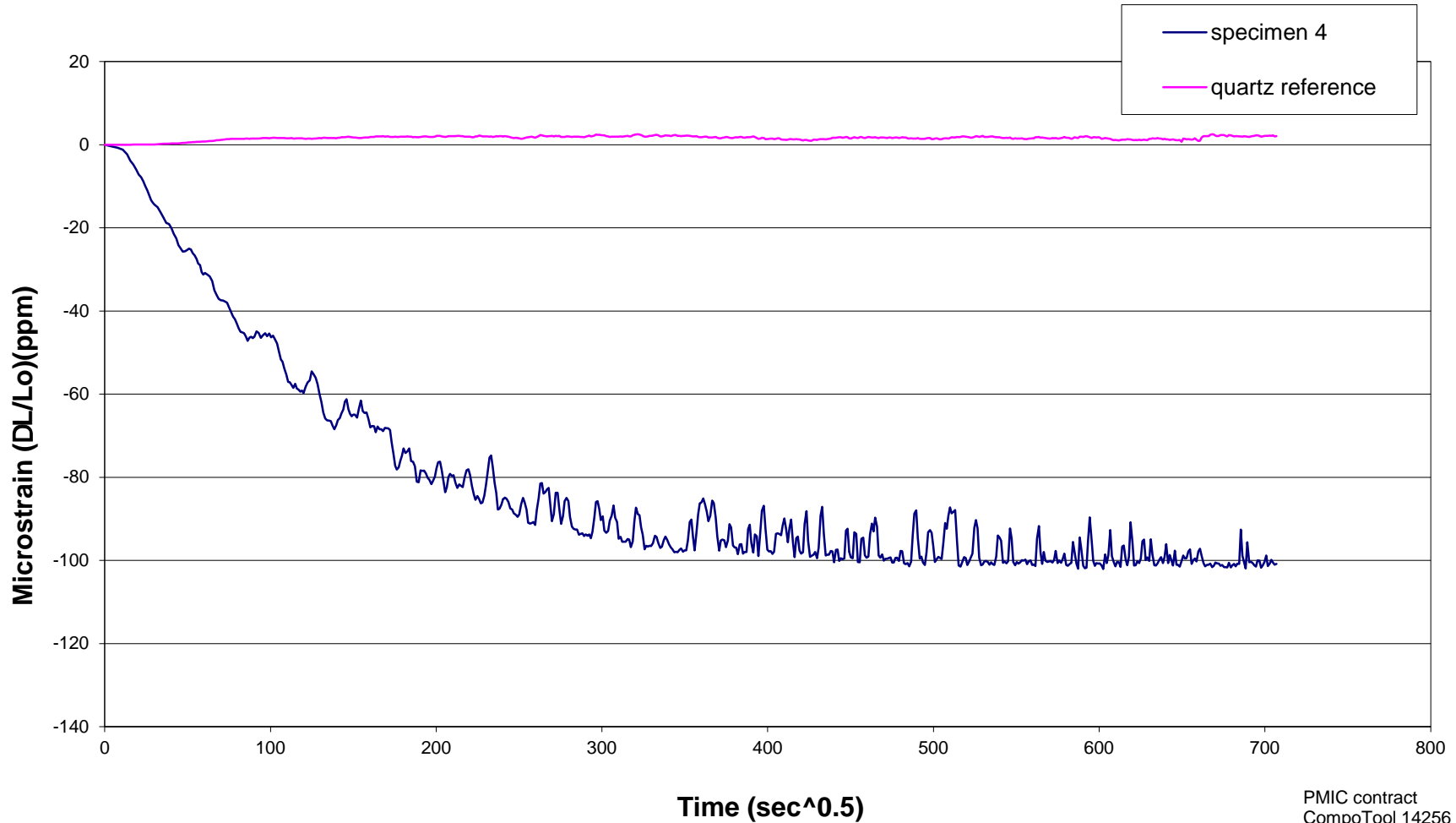
PMIC contract
CompoTool 14256
Specimen 3
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #4

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.26"



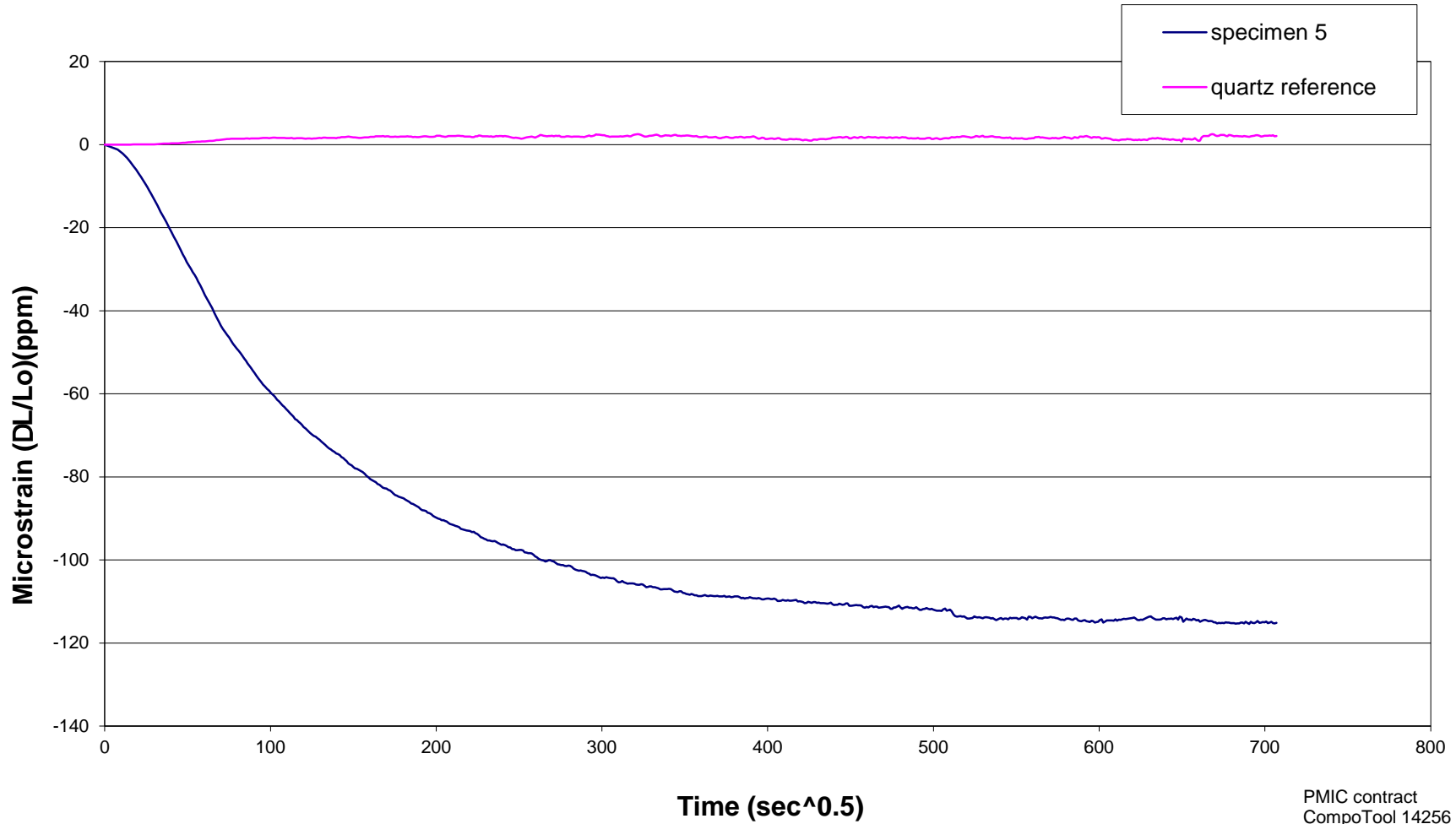
PMIC contract
CompoTool 14256
Specimen 4
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #5

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.26"



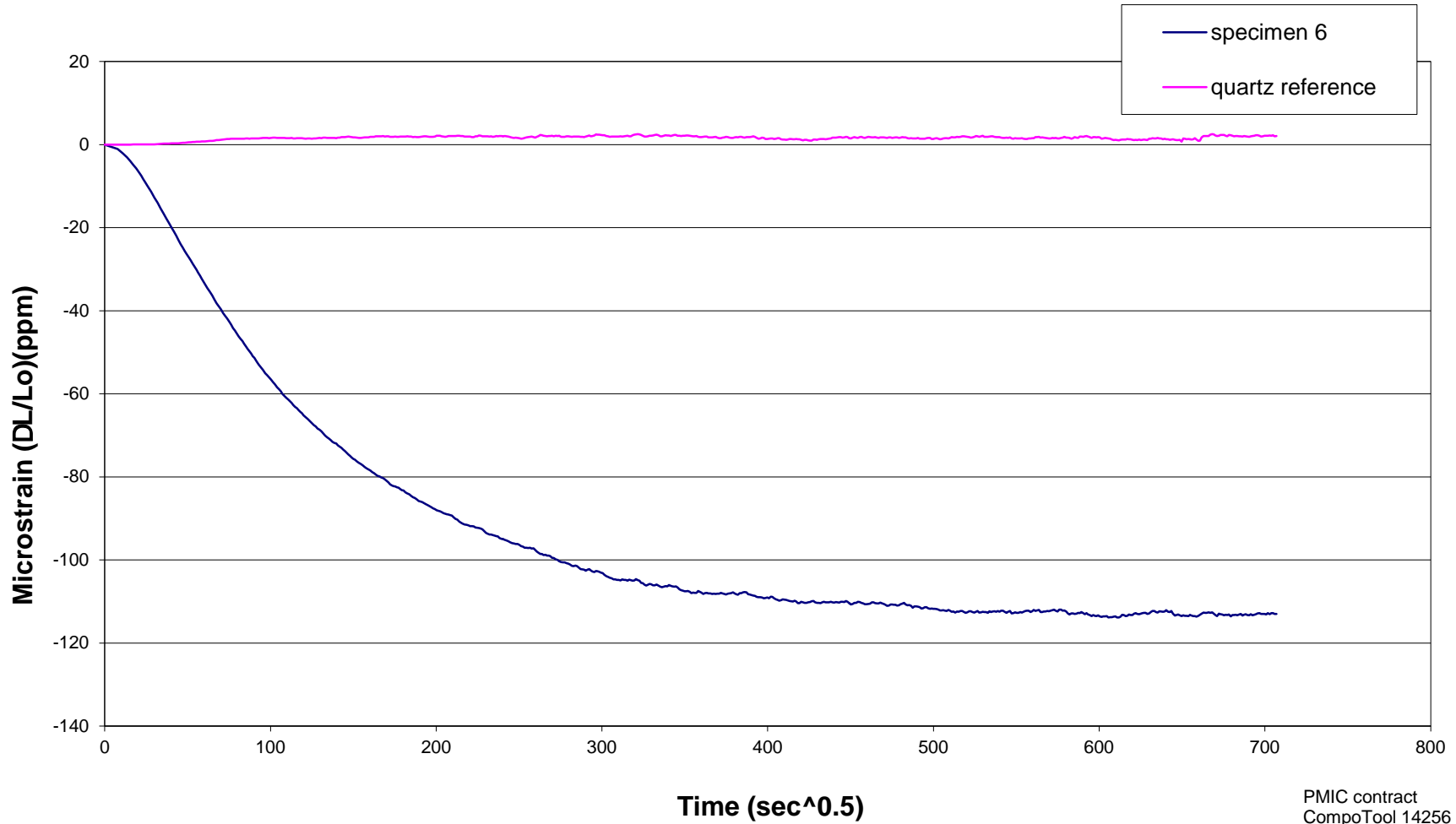
PMIC contract
CompoTool 14256
Specimen 5
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #6

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.26"



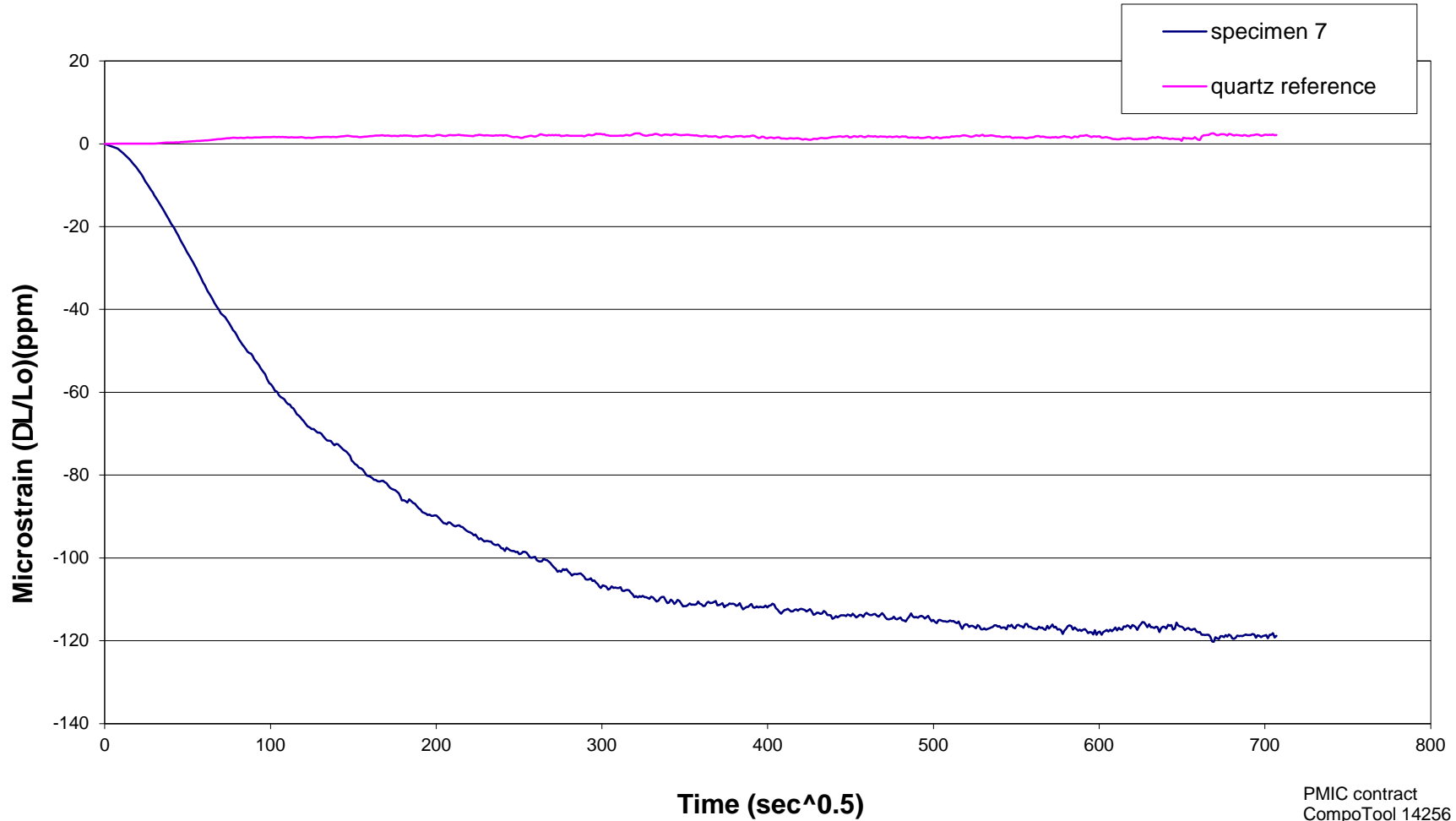
PMIC contract
CompoTool 14256
Specimen 6
20AUG2014-
26AUG2014

Moisture Induced Strain of CompoTool Ltd, CT850 Tooling Board, 0° #7

From Saturation at 53% RH, 24°C to Dry at 0% RH, 24°C

Specimen tested in the length direction

3.9" x 2.0" x 0.26"



PMIC contract
CompoTool 14256
Specimen 7
20AUG2014-
26AUG2014