Sniffer Data from the LAPD Argon Piston Purge

Hans Jostlein October 15, 2011

Abstract

The LAPD tank was recently purged with Argon gas as the first step in the Liquid Argon Purity Demonstration.
We had installed two sets of sampling gas capillaries, leading to oxygen sensors, to follow the rise of the Argon gas as it displaces the lighter room air.
The "central" set was at the tank axis, the "peripheral" set was 44 inches radially out. The sampling tube inlets were spaced 30 inches apart.
After a system description we show the fraction of room air left at each data point.
There are two horizontal scales, one in real time (hours), the other as the number of volume changes. They differ because the flow rate was different at different times. The flow rate was, however, constant during the Argon Piston phase.

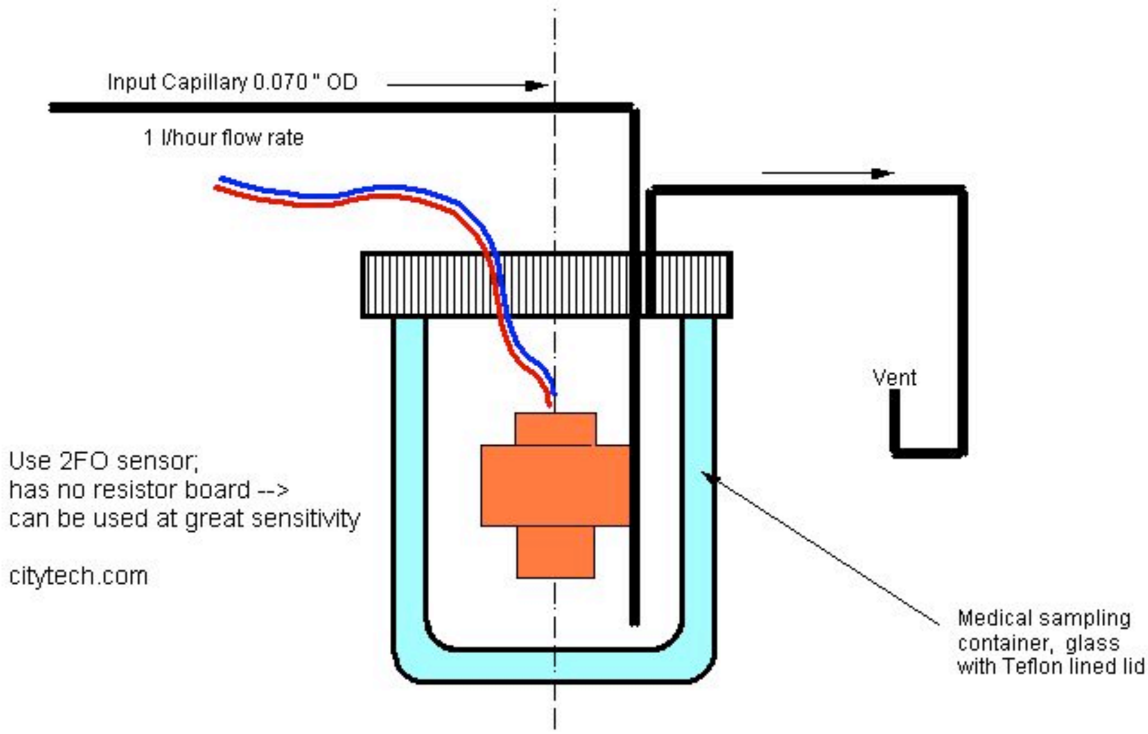
System Description

We installed capillary sampling tubes in the LAPD tank to measure purity at several locations.
We used two sets of sampling tubes, each with
7 tubes with 1/16” capillaries, employing bare oxygen sensors to monitor gas purging.

It is desirable to monitor closely the initial gas purge, down to well below 1 % oxygen. This includes the “Argon piston” phase and a few subsequent purge/ vent cycles.
We wanted to know not only the average gas purity, but also gain enough information for comparison to FEA flow models to validate or improve those models. The models will be important for future large detectors such as the LAr40 proposal for LBNE. We wanted temporal and spatial information. This will inform about the degree of diffusion and mixing during purges. Sampling was performed along the tank axis, and along a line 42” from the tank center.
We deployed 14 each industrial type oxygen sensors (Citicell model 2FO) , similar to those used in the original “Milk Can Argon Piston” test, but with an extended range of sensitivity. They were located in two strings of 7 each, one string near a wall, and the other near the tank center. Their vertical spacing is about 30 inches, similar to the spacing in the original test.
The sensors are inside glass “jam jars” with plastic coated lids. The sample tubes are 0.063” OD capillaries, and run continuously from the intake point through a CF flange to the jars. All capillaries are the same length, with the excess length coiled up above the feed-through flange, to assure matched time response. The jars are mounted on feed-through flanges.

Sensor Capsule Design

Each of the 14 capillaries terminated in one of these sensor capsules (jam jars) after exiting the tank flange.



Oxygen Monitor Capsule

Hans Jostlein
6/1/2010

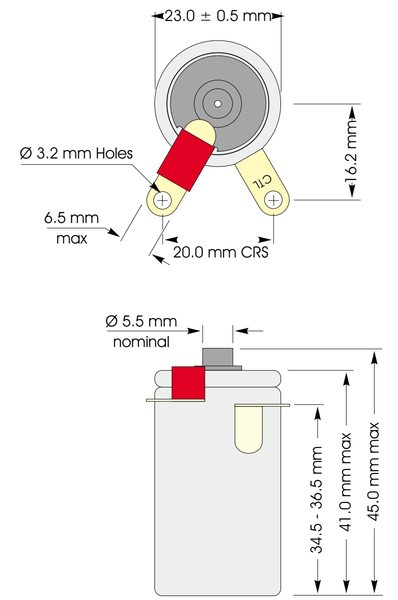
The sensor leads go to a Keithley Model 2700 scanning multimeter, which is read out by a dedicated PC running an Excel "add-in" program, "ExceLinx". The sensor specs are on the next page:

C/NLH CiTiceL®

Performance Characteristics

Nominal Range	0-2ppm
Max Overload	0-1000ppm
Expected Operating Life	See below
Output Signal	13-17mV in air across a 10Ω load resistor
T_{95} Response Time	<20 secs
Temperature Range	-20°C to +50°C
Temperature Coefficient	0.2% signal/°C
Pressure Range	Atmospheric±10%
Operating Humidity	0 to 99% RH non-condensing
Long Term Output Drift	<5% signal loss /year
Linearity	Linear
Purge Time (Ambient air to <10ppm)	<6hours
Storage Life	Six months in CTL container
Recommended Storage Temp.	0-20°C
Warranty Period	12 months from date of despatch

N.B. All performance data is based on conditions at 20°C, 50%RH, and 1013mBar



All tolerances ± 0.15mm unless otherwise stated

Operating Life

The operating life of a C/NLL Oxygen CiTiceL is inversely proportional to the amount of oxygen the sensor consumes. As City Technology has no knowledge of the operating conditions of any particular application, the company cannot give any guarantee with regard to the life of the sensor. However the following guidelines should be of use:

Under normal operating conditions (i.e. ppm levels) the sensor has a large excess capacity, and there will only be a gradual loss of sensitivity. It is recommended, however, that the sensor is changed every year to maintain the optimum sensitivity.

It is not advisable to use these sensors in ambient air, or to keep them on load in air for long periods. This will considerably decrease the life of the sensor.

Cross-interference

The **C/NLH** has been designed to have a **low hydrogen cross-interference**

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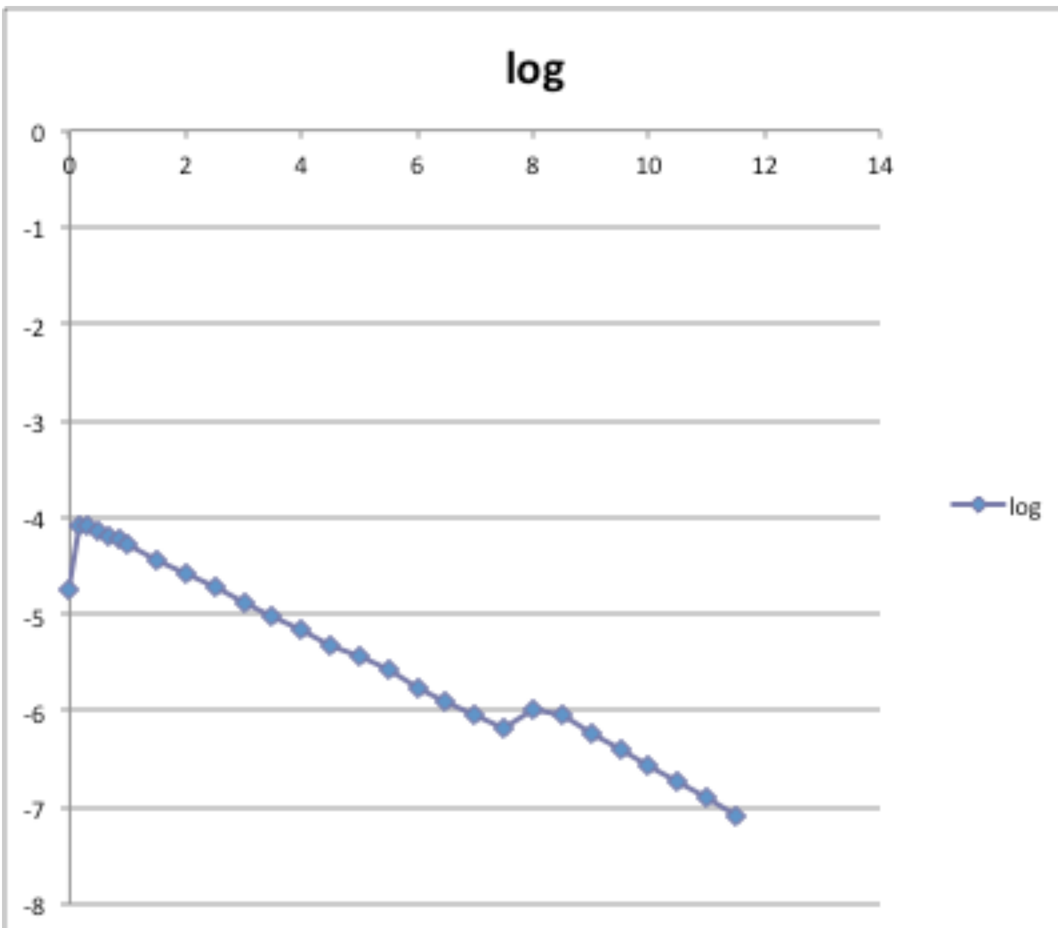
Oxygen Cell Response Time

Log of output voltage versus time in minutes, after a sudden change from Air to Argon.



The cells respond quickly, within one minute.

Flow Velocity and Delays

Sniffer gas flow and Response Time during the Argon Piston

At 1:20 PM the extraction of the sniffers began.

During the extraction argon gas flowed into the tank at 5-6 SCFM.

By 1:35 PM both sniffers were out of the tank.

During the extraction AE-991-V, AE-992-V, AE-993-V were switched

to argon utility gas as a precaution

because the bellows pump drawing gas from the tank

could pull a vacuum on the tank if the argon flow into the tank stopped.

After AE-991-V, AE-992-V, AE-993-V were switched back to tank gas

an increase of about 0.2 ppm O_2 and 0.4 ppm N_2 was observed.

With the sniffers out the make up gas flow has dropped

from ~0.35 SCFM to ~0.15 SCFM.

Plot of the extraction attached.

Thanks to Cary, Bill, and Kelly for a quick extraction.

The sniffer locations were measured and will be noted in a subsequent post.

Capillary gas flow calculations

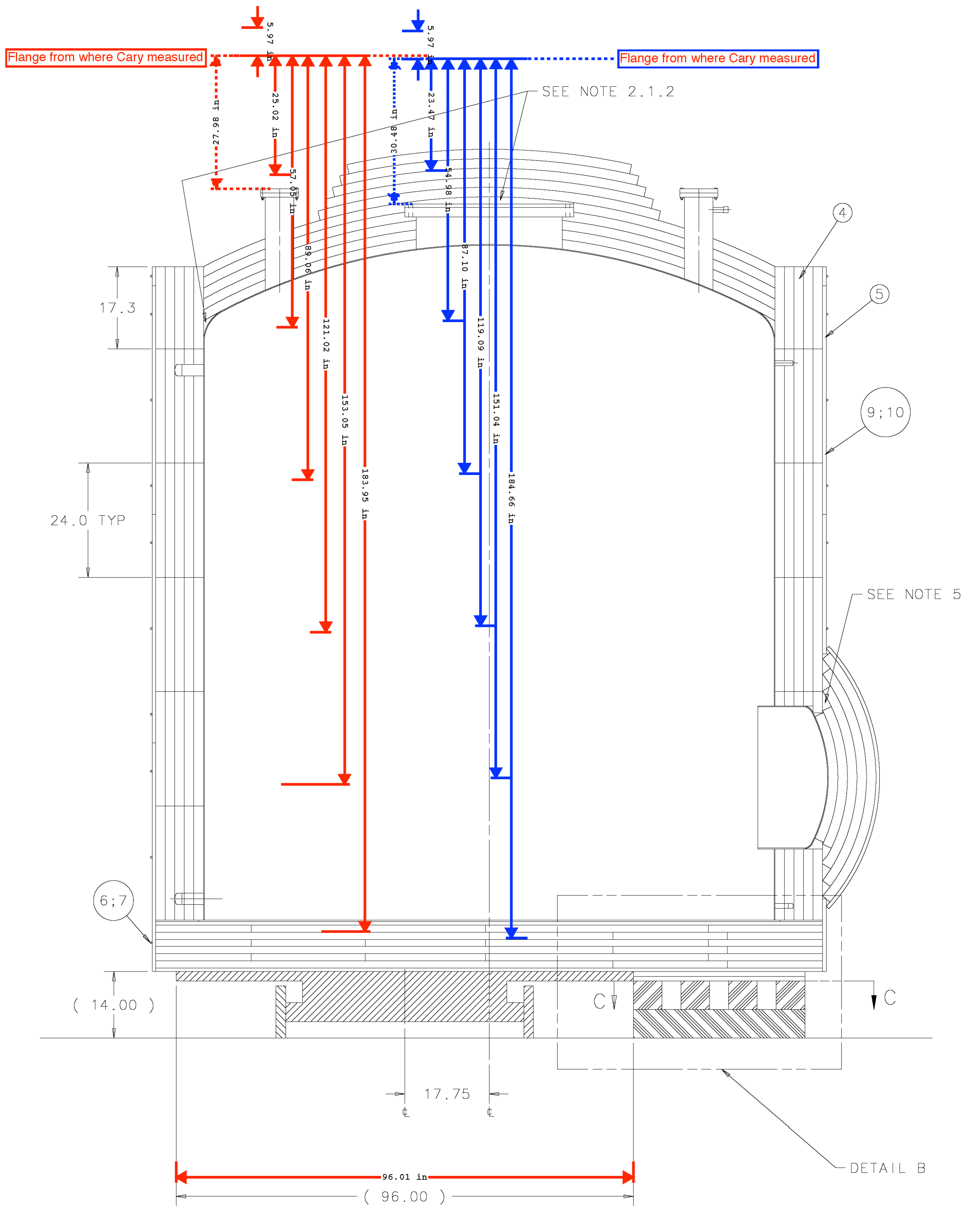
Total gas flow (14 capillaries) was 0,2 scfm as pewr Terry's Email (saved in LAPD data)

Gas flow	0.2	scf	9.44E-05	m^3 / s
Capillary ID	0.032	in	8.13E-04	m
Capillary area	0.000804248	in^2	5.18868E-07	m^2
# capillaries	14		14	
Gas velocity in capillaries			1.30E+01	m/s
Sensor jar ID	4.00	cm	0.04	m
Sensor jar height	5.00	cm	0.05	m
Sensor jar volume	12.57	cm^3	1.26E-05	m^3
Time to fill			0.13	s

We see that the sensor response time is not limited by the gas flow.

In July 2010 we calculated the flow rates and transit speed as follows:

1 in=	0.0254	m			
1 Pa=	0.000145	psi			
1 psi=	6894.757	Pa			
1 psi=					
Argon gas density at RT	1.67	kg/m^3			
Ar gas visosity	2.10E-05	Pa s			
Tube diameter	0.0315	in	0.0008	m	
Tube open area	0.000779	in^2	5.03E-07	m^2	
tube length	30	ft	9.144	m	
Pressure	1	psi	6894.757	Pa	
dp/32	215.4612	Pa			
d^2/mu L=	3.33E-03	m / (Pa s)			
Flow rate Q=	3.61E-07	m^3/s	1.30E+00	l/hr	
Linear velocity, average	7.18E-01	m/s			



Flange from where Cary measured
Flange from where Cary measured
5.97 in
5.97 in
27.98 in
25.02 in
57.05 in
89.06 in
121.02 in
153.05 in
183.95 in
30.48 in
23.47 in
54.98 in
87.10 in
119.09 in
151.04 in
184.66 in
SEE NOTE 2.1.2
4
5
9;10
17.3
24.0 TYP
SEE NOTE 5
6;7
(14.00)
C
C
17.75
DETAIL B
96.01 in
(96.00)

SECTION A-A

Tank Volume Note

By Terry Tope, approx. 9/25/2011

Tank argon purge sanity check…………
I referred to the tank as 785 ft^3.
That’s only the liquid volume.
The tank manufacturer lists the volume as 6,506 gallons which is 870 ft^3.
Thus at 5 SCFM a volume change happens every 174 minutes.
Check of mfg supplied volume:
The tank cylinder is 10 ft high and 10 ft in diameter.
Thus the cylinder volume is (pi/4)*(10^2)*(10) = 785 ft^3 (the liquid volume). >
The tank head is a 10 ft diameter ASME F&D head. http://www.brightontruedge.com/calculator/calculator.htm
The above web link calculates the head volume as 604 gallons which is 81 ft^3.
Thus the 785 ft^3 cylinder plus the 81 ft^3 head is 866 ft^3. Add on the risers and manways and 870 ft^3 is reasonable.
The mass flowmeter flow rate can be calculated from a pressure rise in the tank over a known period of time.
Thus a flow of 5 SCFM was applied to the tank and compared to the flow calculated from the pressure rise, time period, and tank volume.
1.252 psig and 9,168.94 ft3 total flow @ 5:10:11 PM.
2.004 psig and 9,214.28 ft3 total flow @ 5:18:50 PM. >
((2.004 + 14.4) – (1.252 + 14.4)) psia / (1.252 + 14.4) psia x 870 ft^3 = 41.80 ft^3
5:18:50 PM - 5:10:11 PM = 8.65 minutes.
41.80 ft^3 / 8.65 minutes = 4.83 ft^3 / min - the mass flowmeter flow is reasonably correct.
9,214.28 – 9,168.94 = 45.34 ft^3 – the flow totalizer is working reasonably - although it has some jogs in the plot I don't understand.

Sample Tube Elevations

After removing the two sets of sniffer tubes form LAPD we measured the tube lengths:

Sniffer Locations

Sniffer spool piece length	8.00	in	
Firs sniffer dist below flange	2.00	in	
Last sniffer below tank bottom	4		2.4
Bottom of spool above tank bottom	180.50		181.60

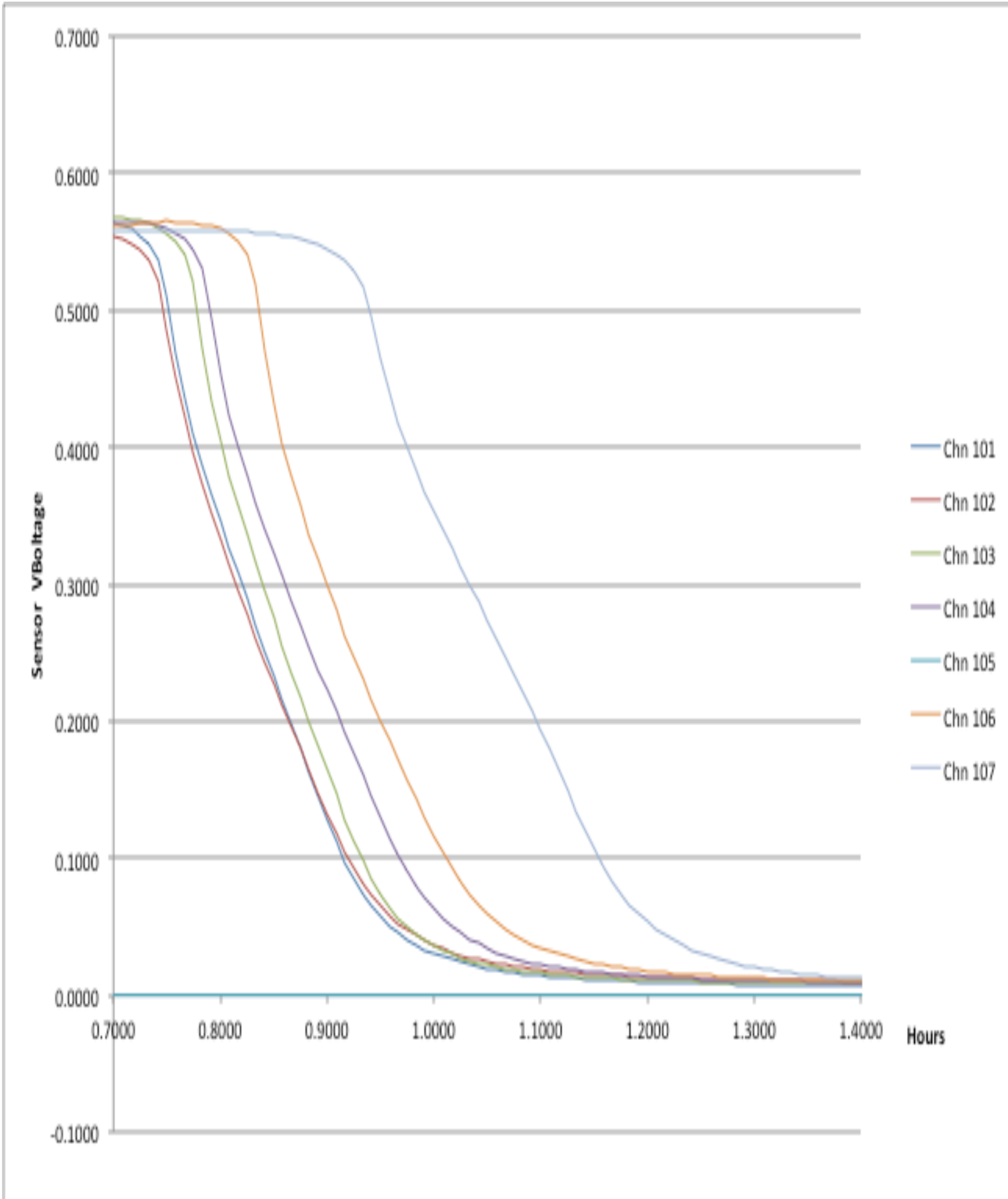
Terry's numbers Central	Primary data Channel	Primary data Coil turns	These seem correct Peripheral	Primary data Channel	Prima data Coil tu
184.5	209	0.50	184	101	0.5
151	210	0.50	153	102	0.5
119	208	next	121	103	3.5
87	207	next	89	104	6.5
55	206	next	57	105	10.5
23.5	205	next	25	106	secon mos
-6.00	204	longest	-6.00	107	most

Elevations above tank bottom

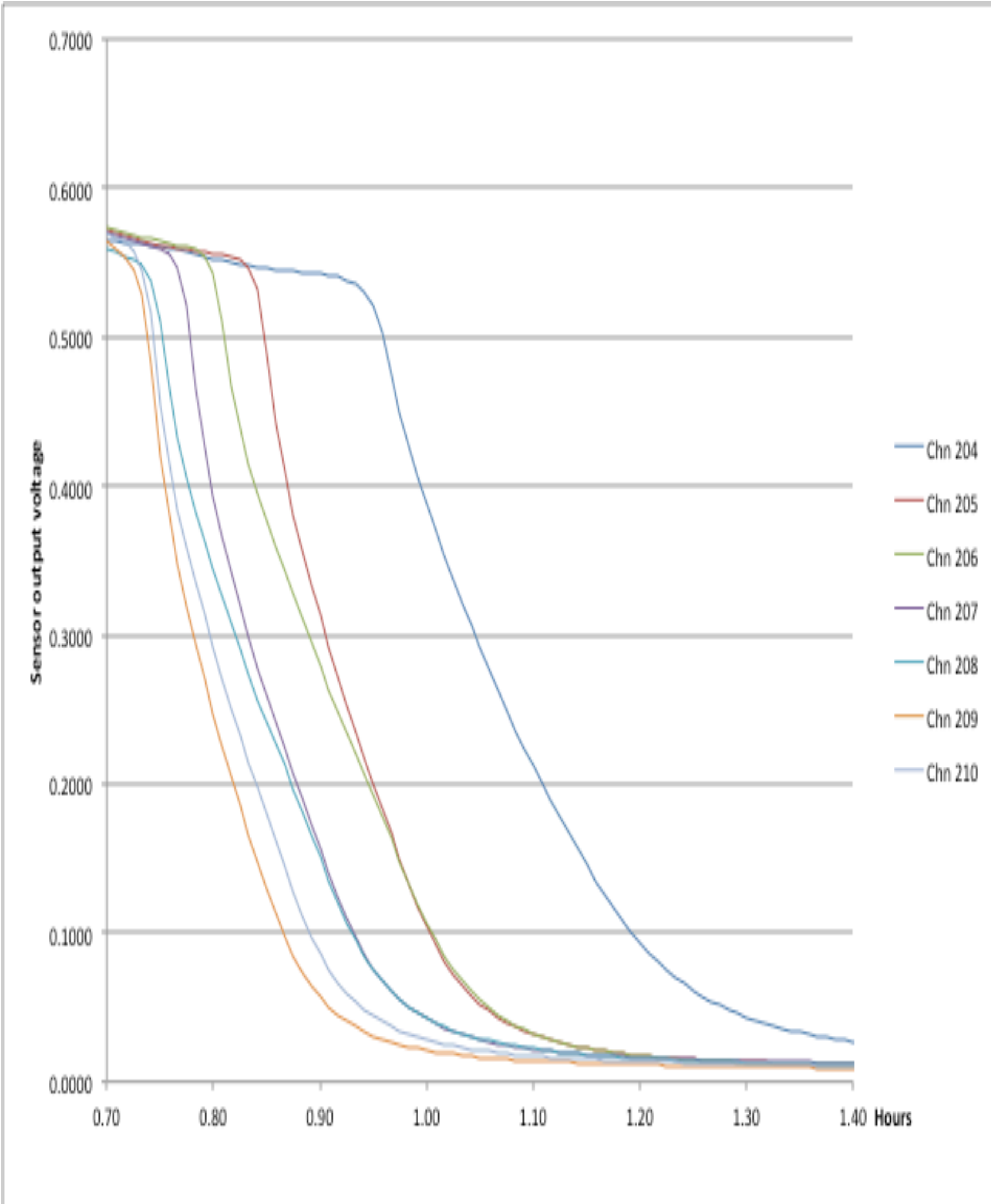
Central	Channel	Coil turns	Peripheral	Channel	Coil tu
-4.00	209	0.50	-2	101	0.50
29.50	210	0.50	29	102	0.50
61.50	208	next	61	103	3.50
93.50	207	next	93	104	6.50
125.50	206	next	125	105	10.5
157.00	205	next	157	106	secon mos
186.50	204	longest	188	107	most

Sniffer Test in a Tube Chamber (Micro Piston)

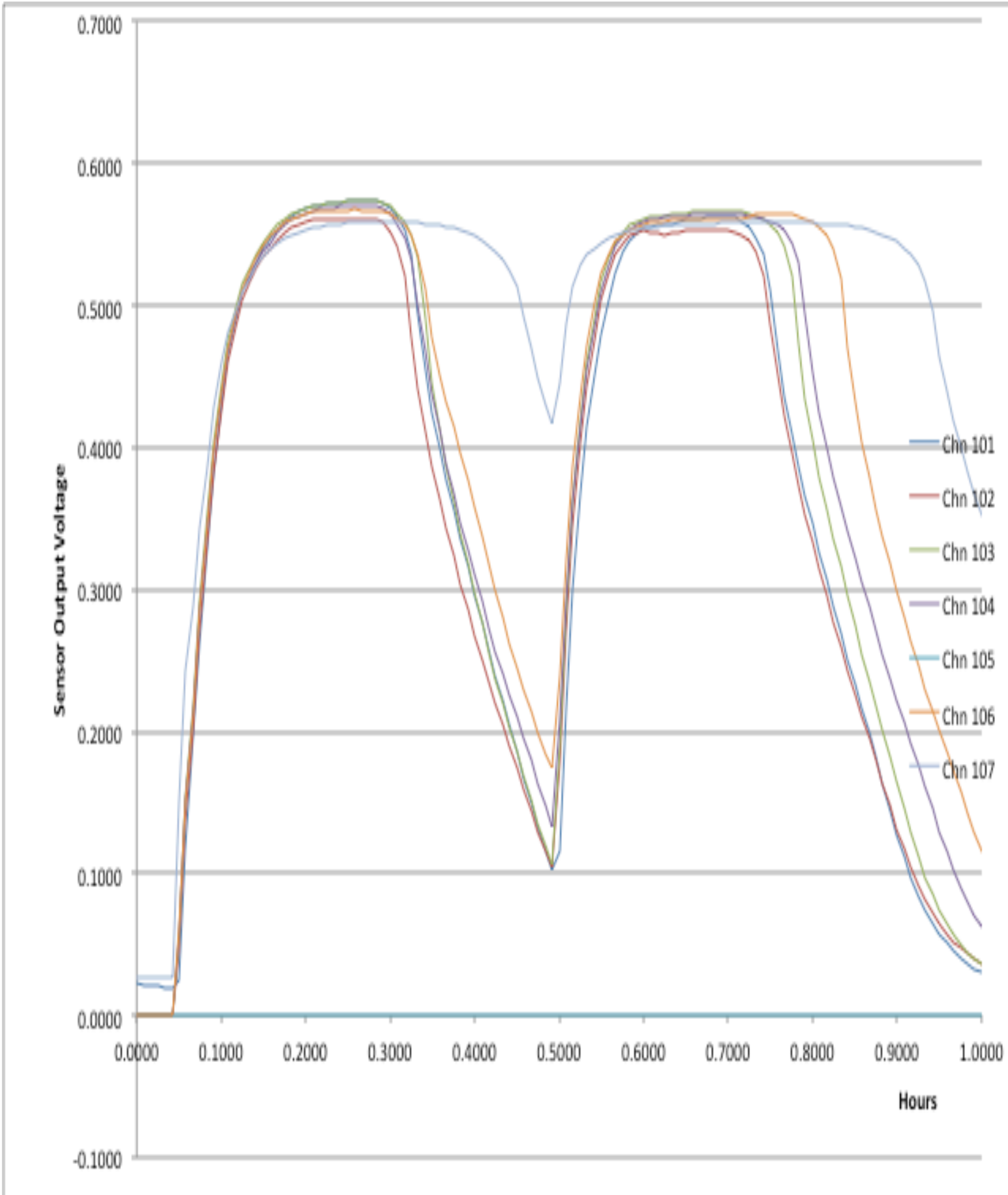
The sniffer sets were each installed in a separate 1” diameter SS tube that could be filled with room air by sucking on the bottom connection, or filled with Argon gas from the bottom through two flow meters.
Note that the only exhaust was through the capillaries; hence the gas flow is largest near thee bottom (7 capillaries’ flow adds up) and is smallest near the top, where only one capillary contributes. This moves the response curves more and more to the right for the later responders.
The test was done as an independent check on the sample tube elevations.
As in the LAPD data, we note that the first two sample tubes respond at nearly the same time. We have no explanation.



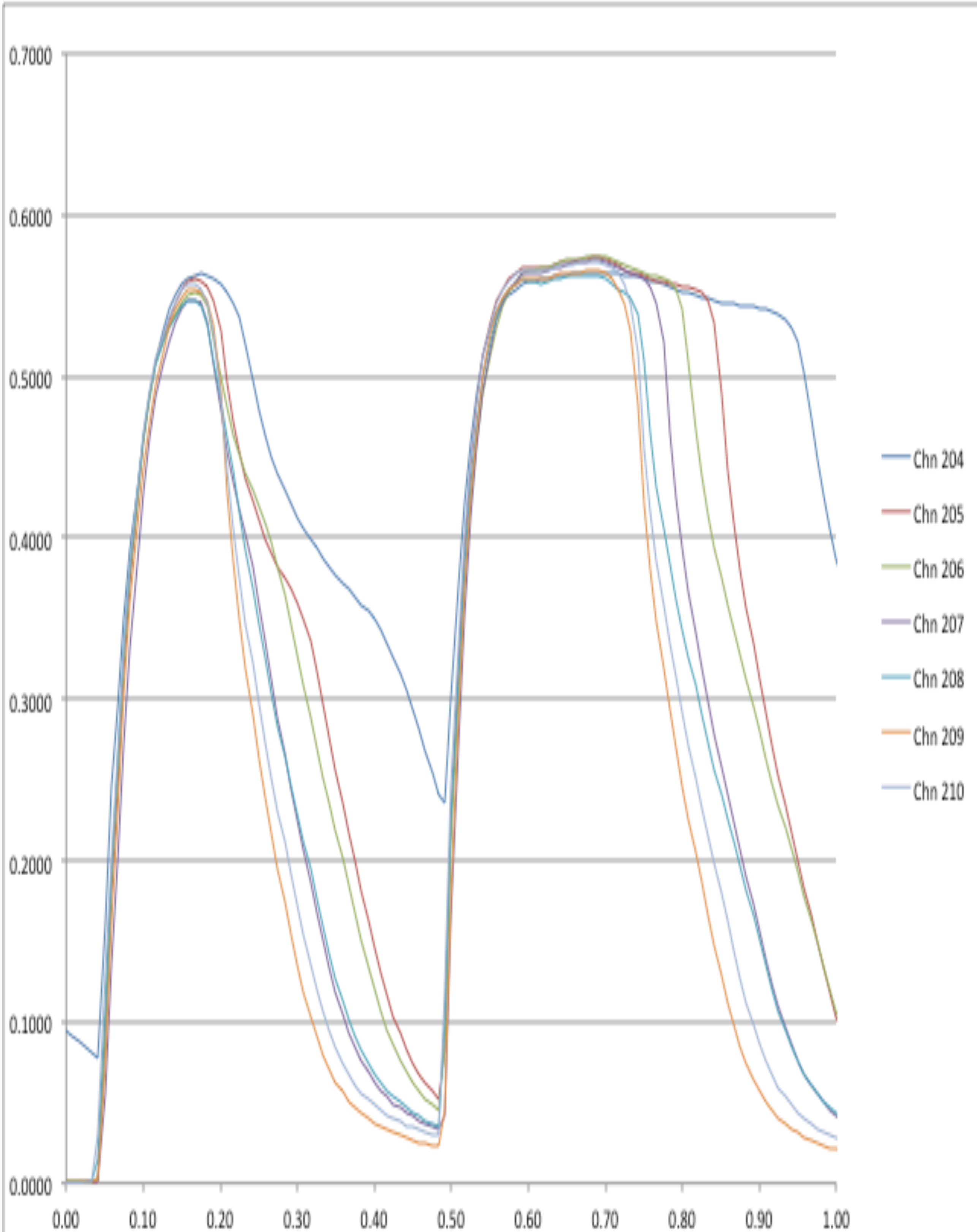
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
-0.1000
Sensor VBoltage
0.7000
0.8000
0.9000
1.0000
1.1000
1.2000
1.3000
1.4000
Hours
Chn 101
Chn 102
Chn 103
Chn 104
Chn 105
Chn 106
Chn 107



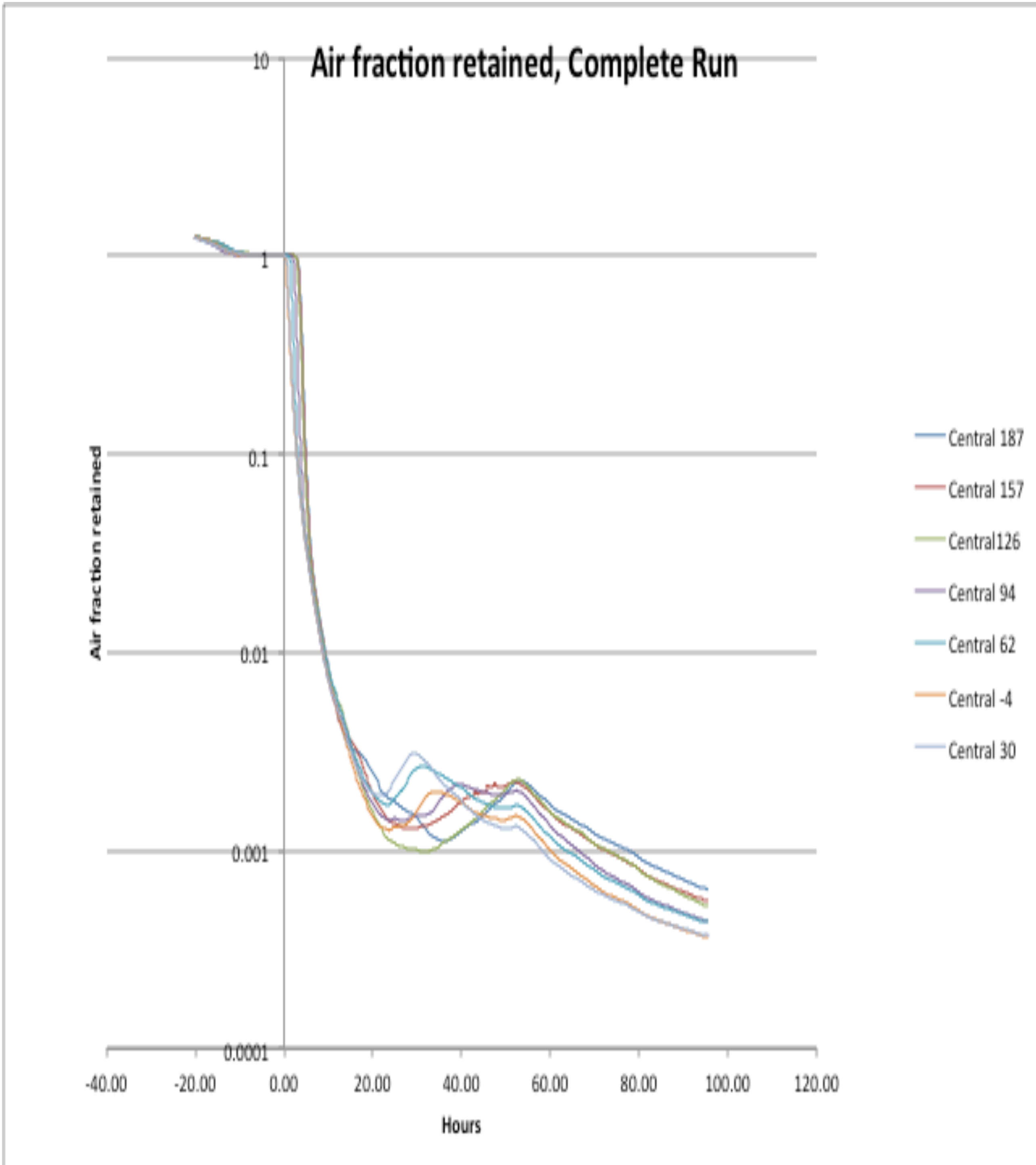
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
Sensor output voltage
0.70
0.80
0.90
1.00
1.10
1.20
1.30
1.40
Hours
Chn 204
Chn 205
Chn 206
Chn 207
Chn 208
Chn 209
Chn 210



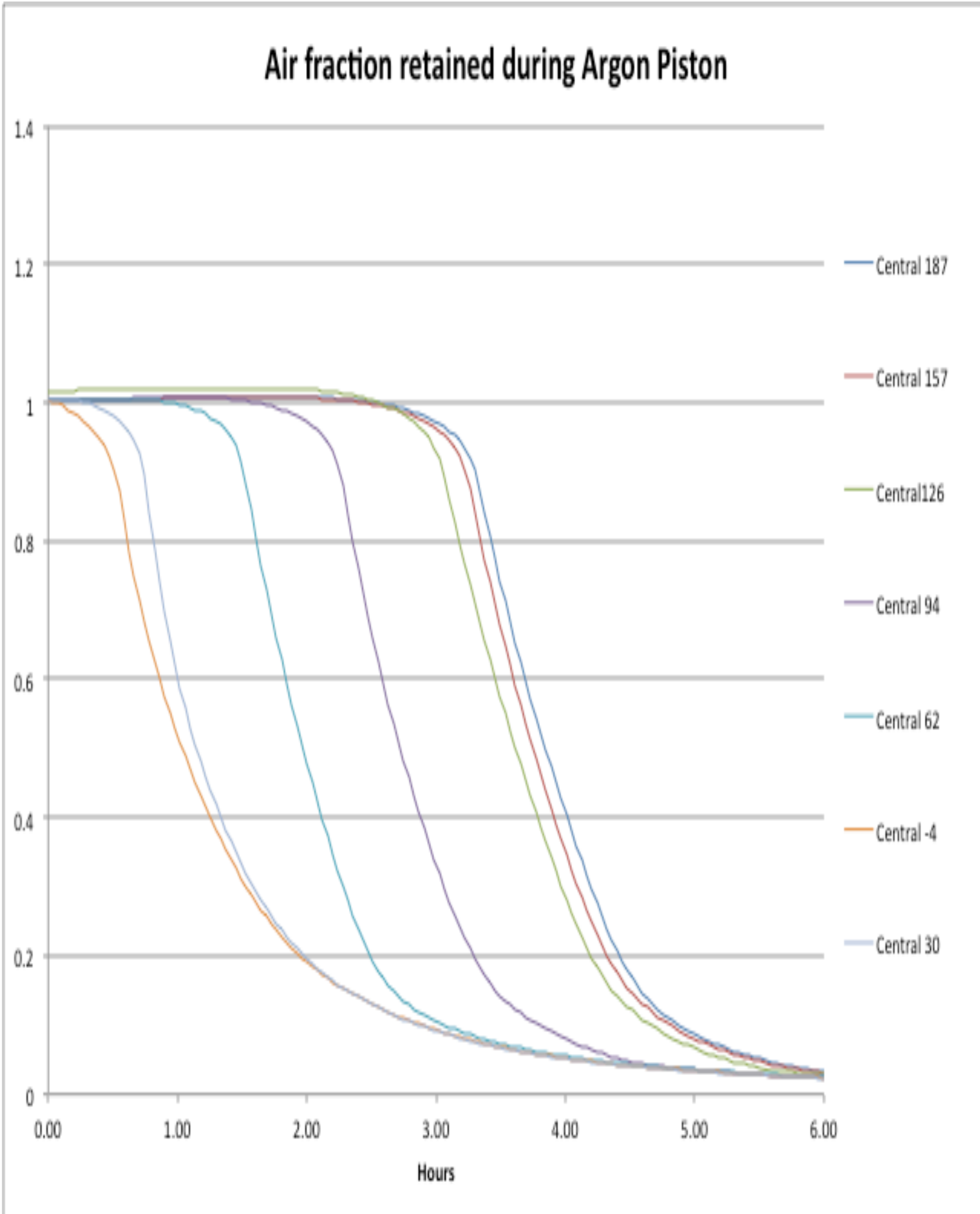
0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
-0.1000
Sensor Output Voltage
0.0000
0.1000
0.2000
0.3000
0.4000
0.5000
0.6000
0.7000
0.8000
0.9000
1.0000
Hours
Chn 101
Chn 102
Chn 103
Chn 104
Chn 105
Chn 106
Chn 107


0.7000
0.6000
0.5000
0.4000
0.3000
0.2000
0.1000
0.0000
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
Chn 204
Chn 205
Chn 206
Chn 207
Chn 208
Chn 209
Chn 210

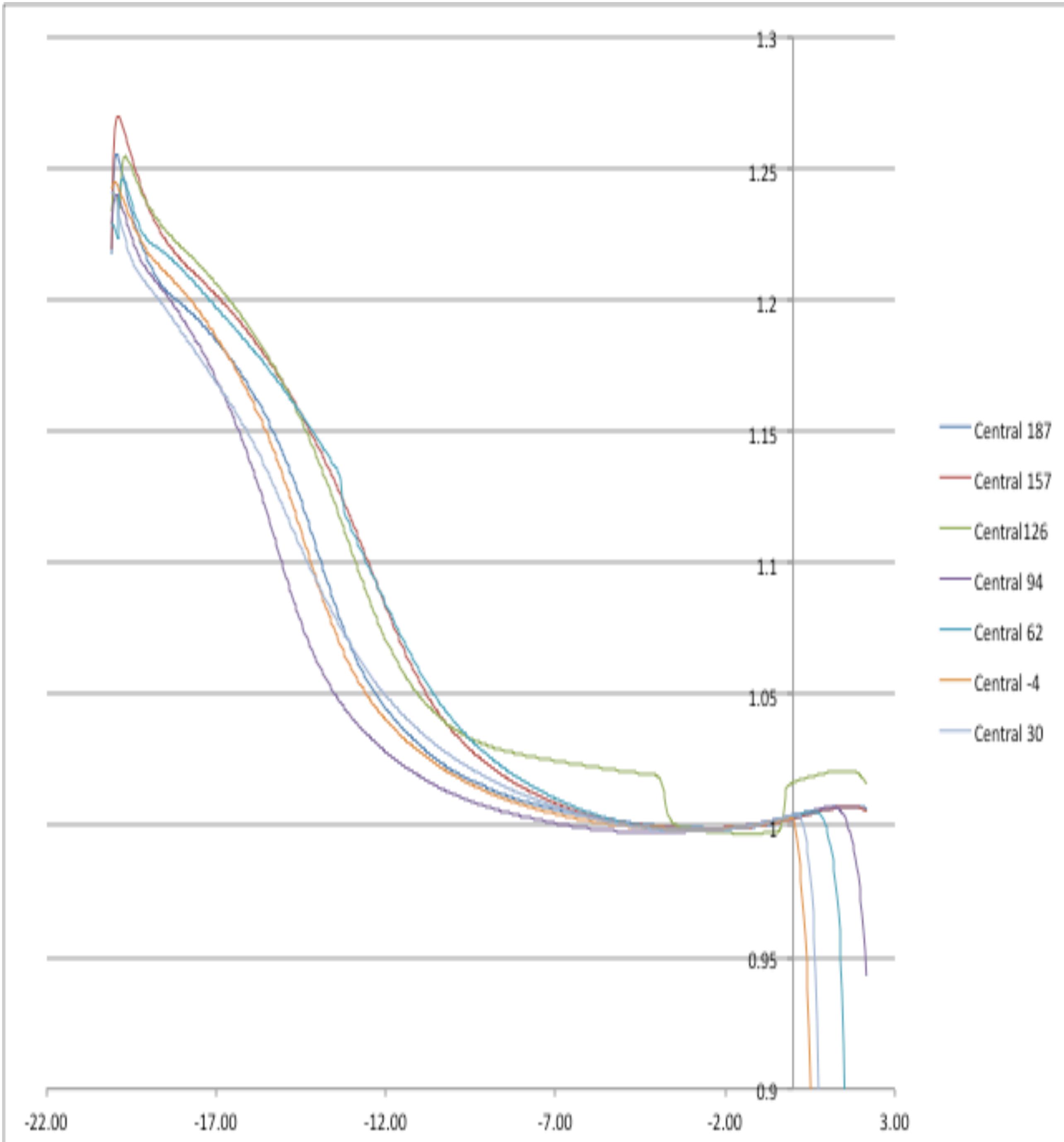
CENTRAL VERSUS HOURS



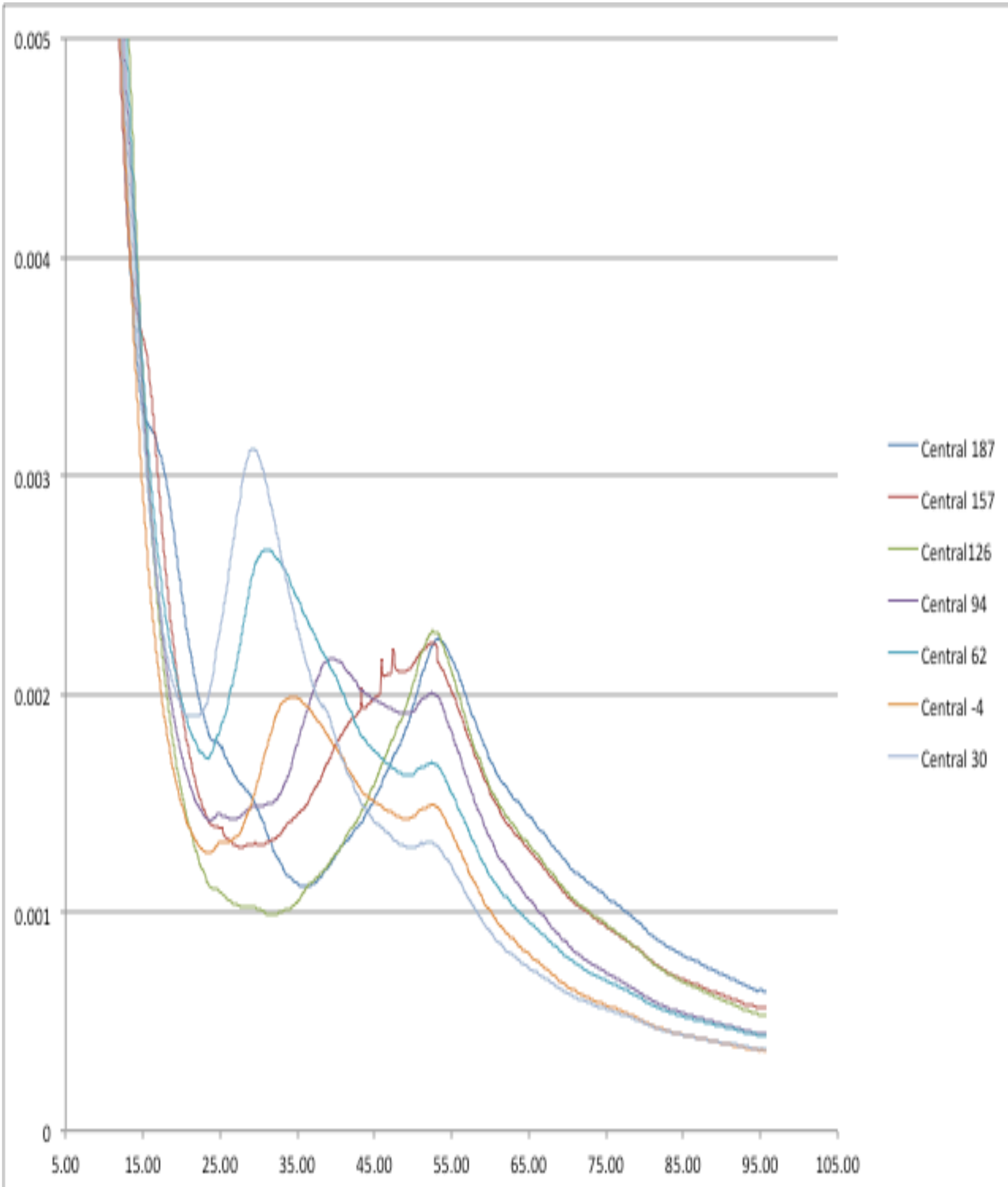
Central versus hours



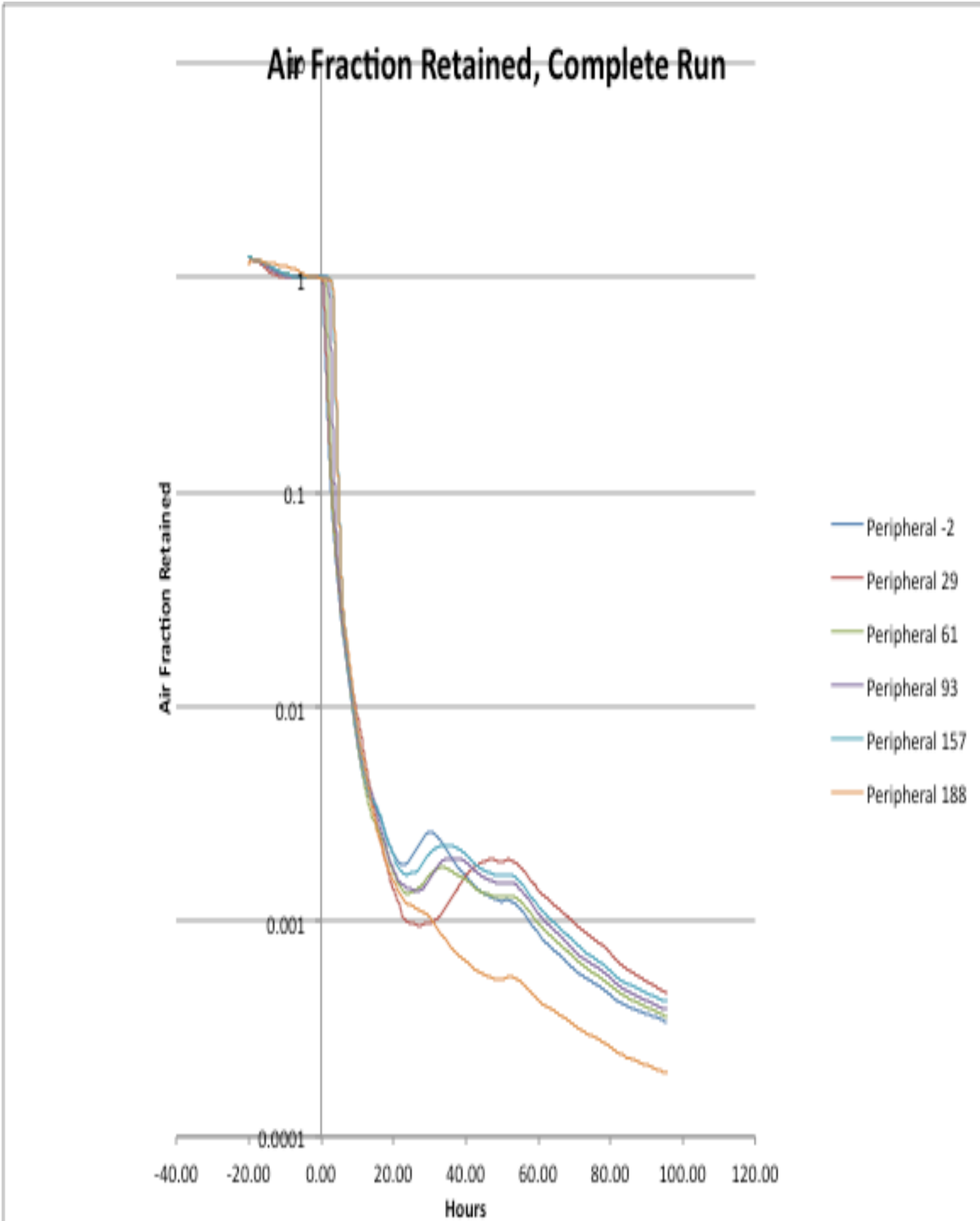
CENTRAL VERSUS HOURS



Central versus hours



PERIPHERAL VERSUS HOURS



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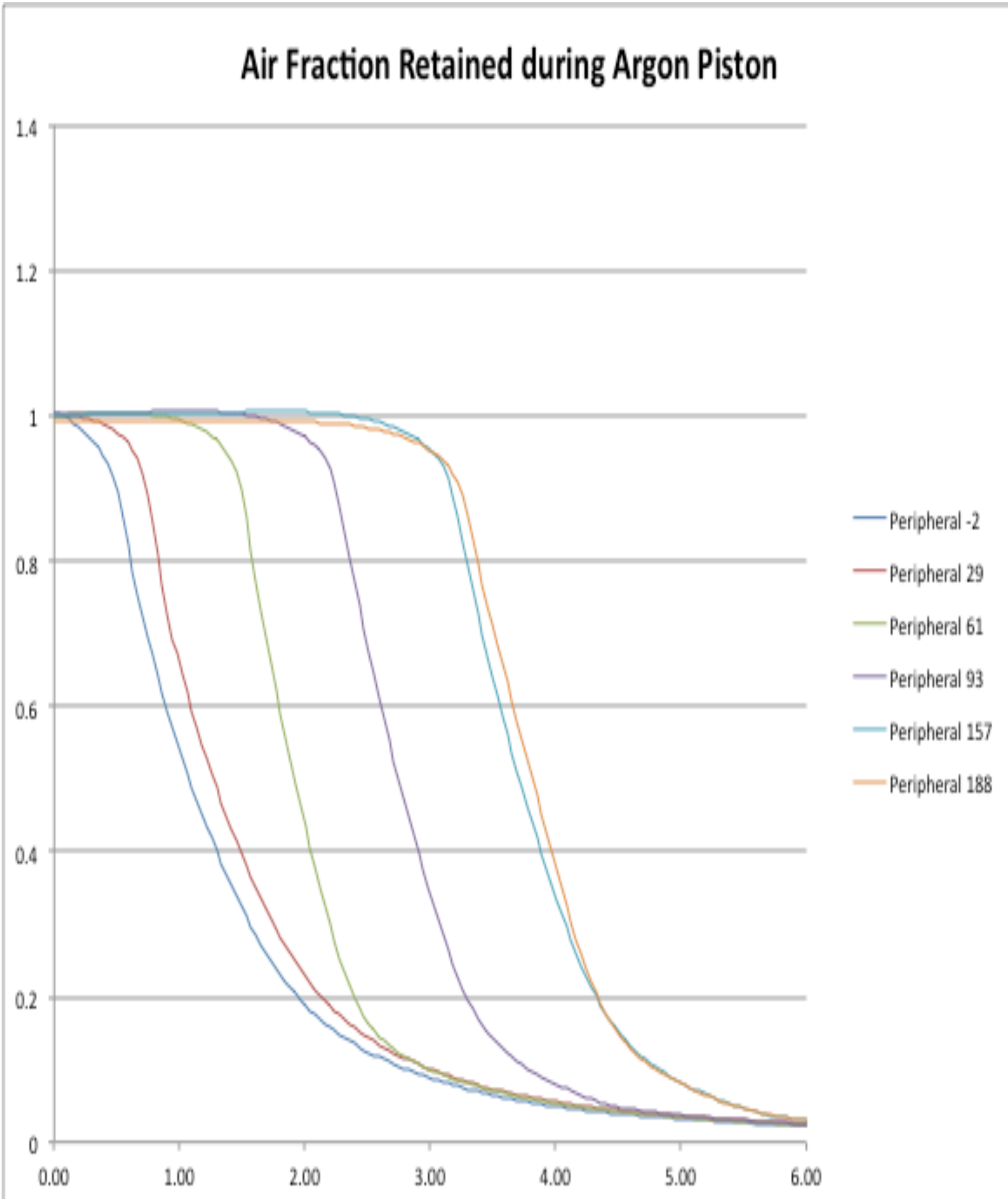

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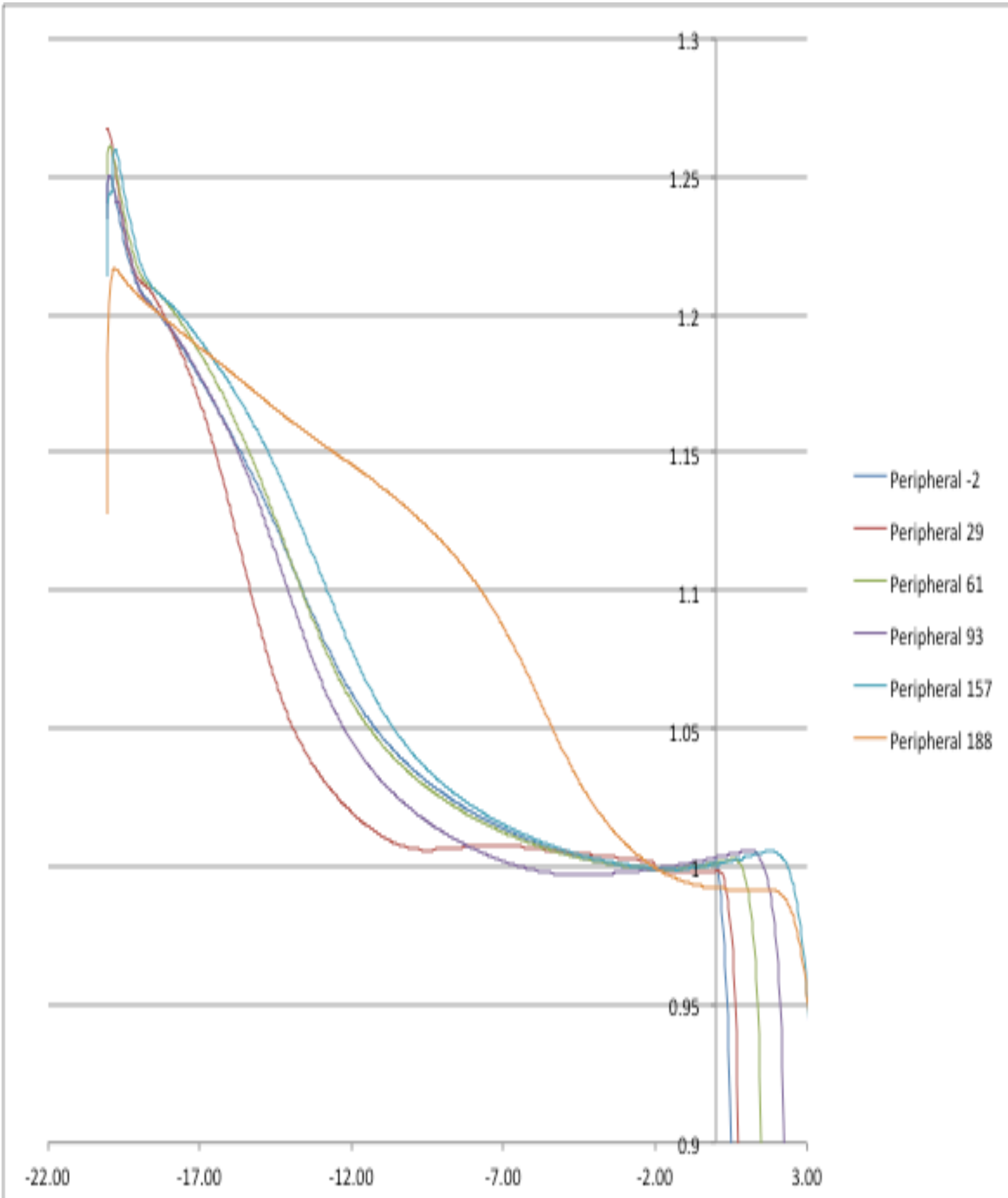

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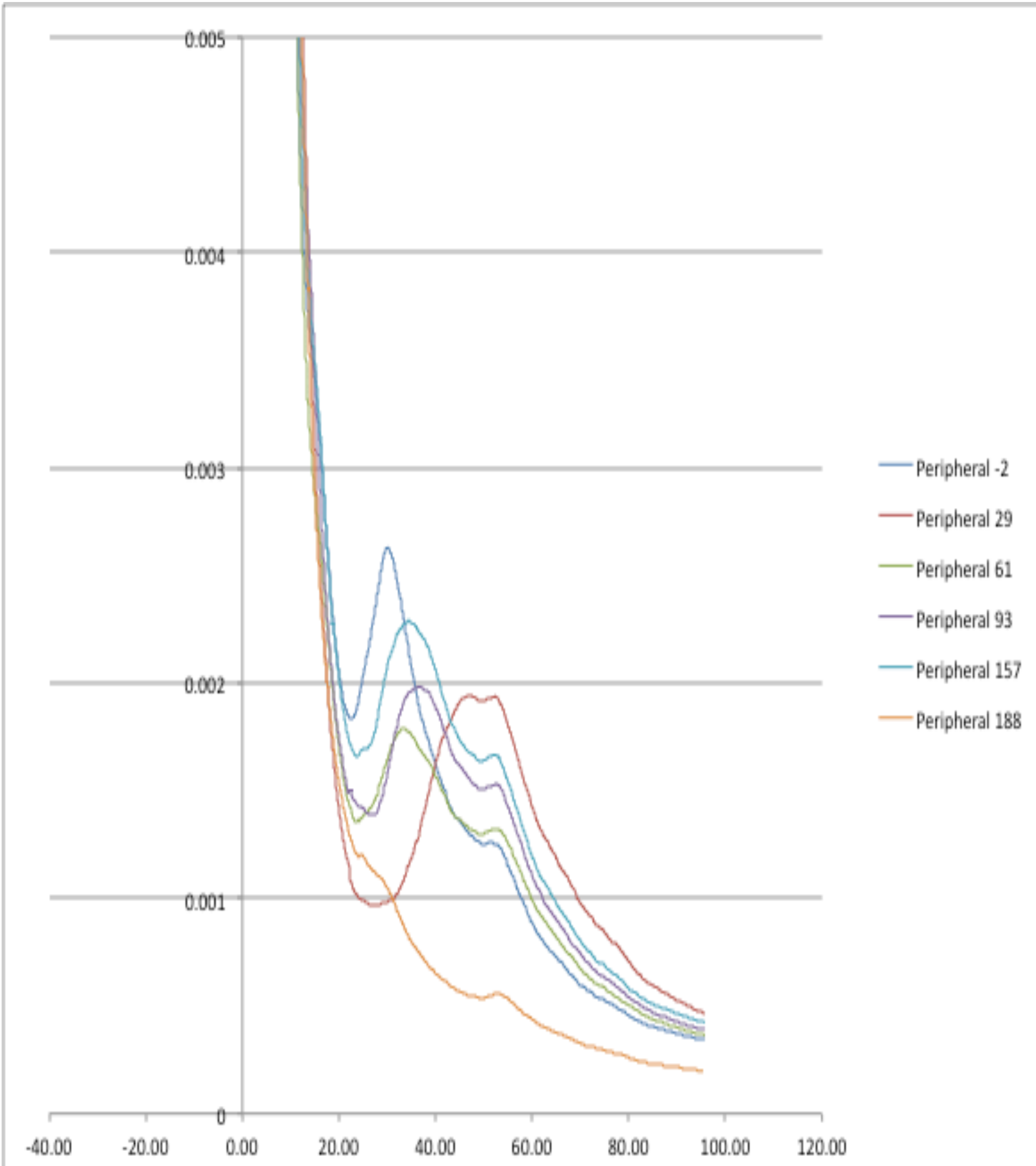
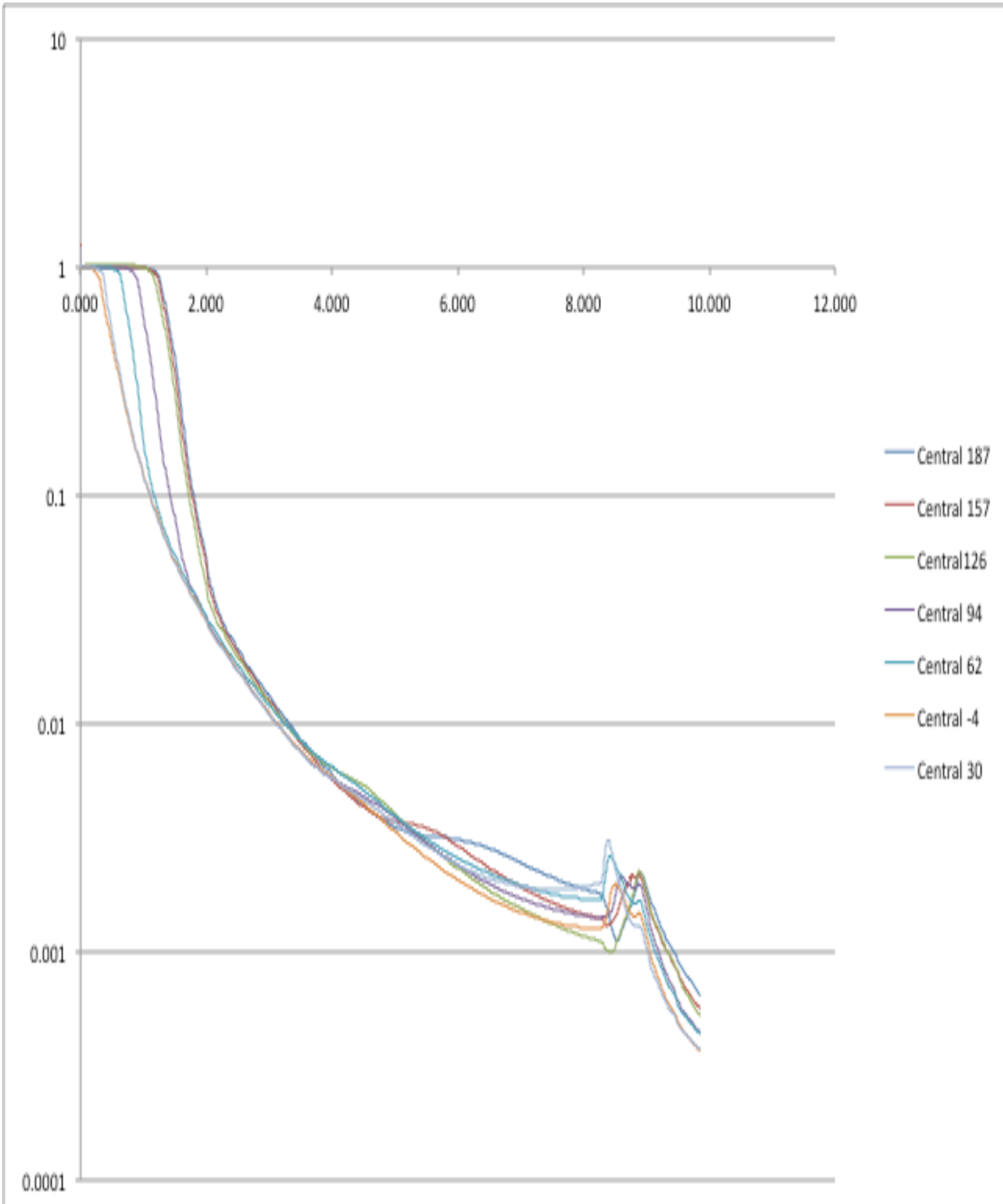
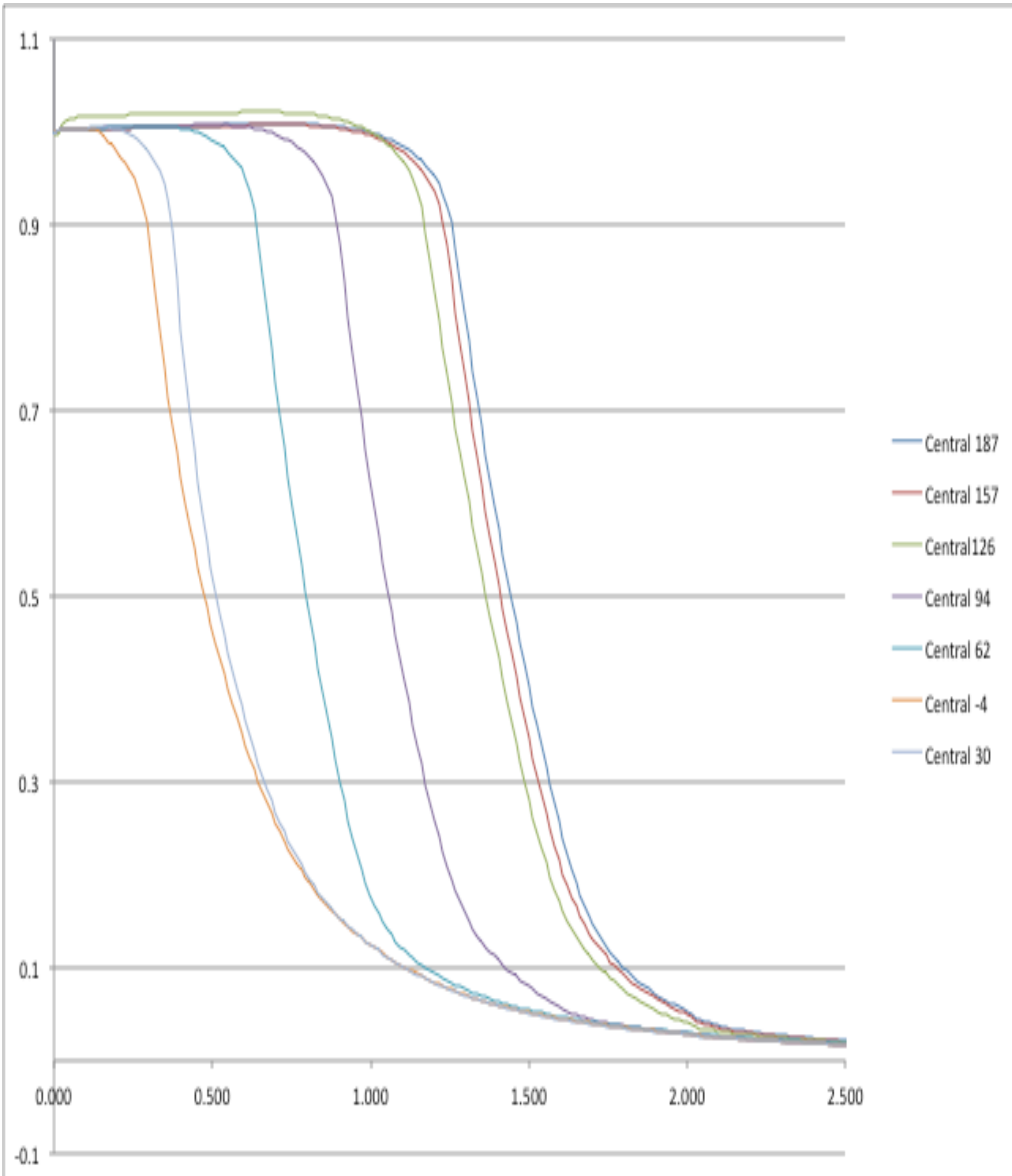


Central versus Volume Changes



CENTRAL VERSUS VOLUME CHANGES



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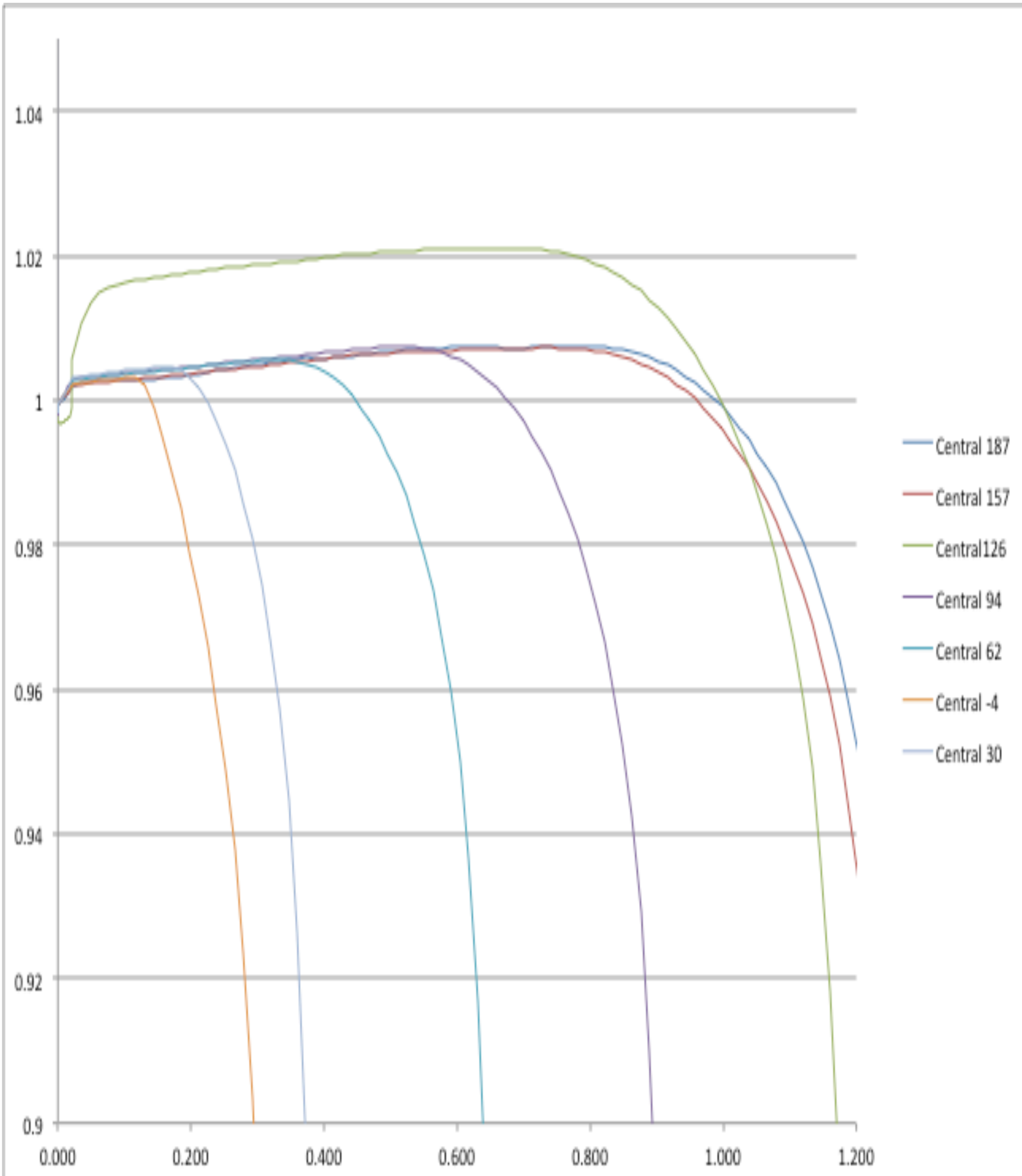

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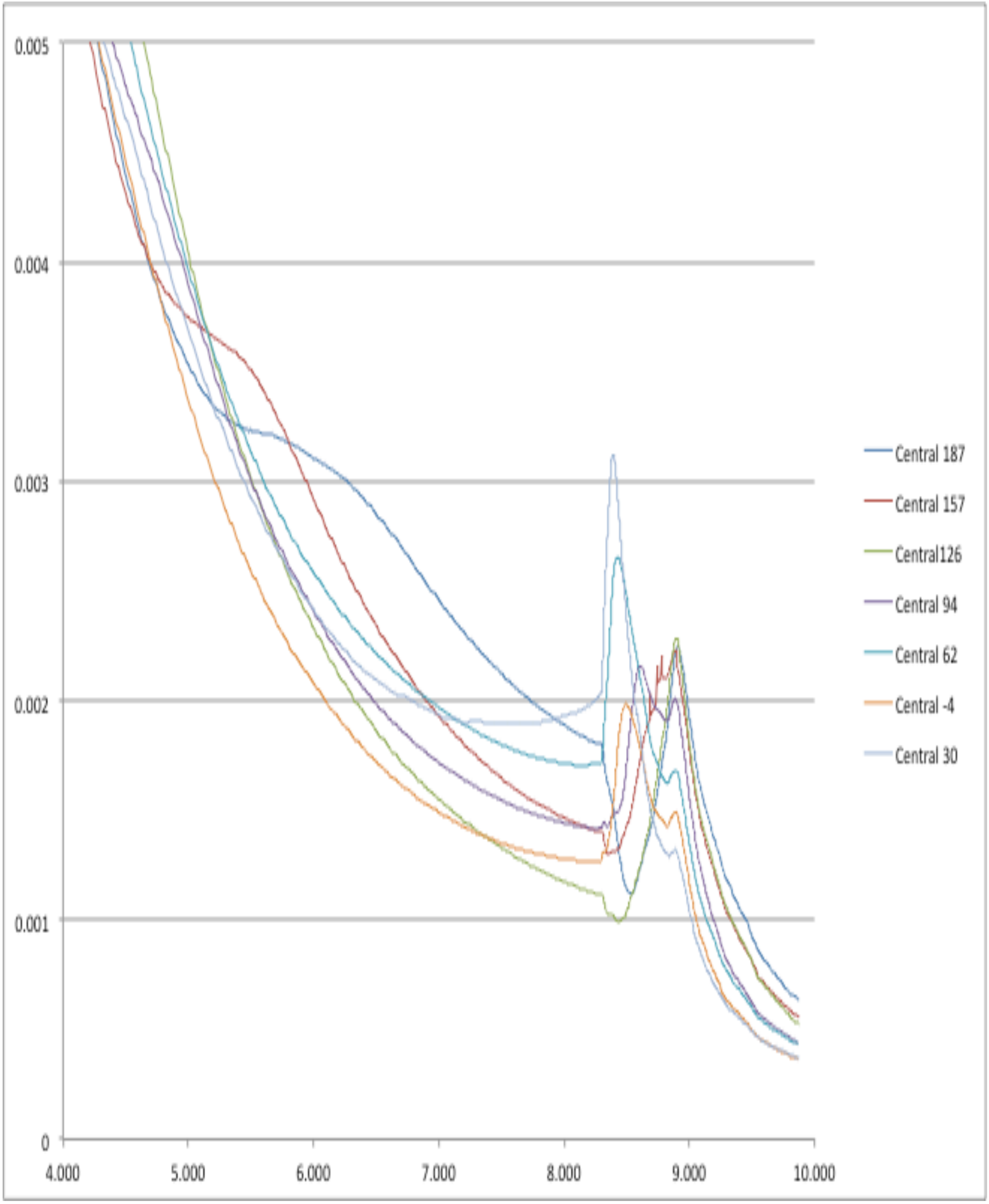
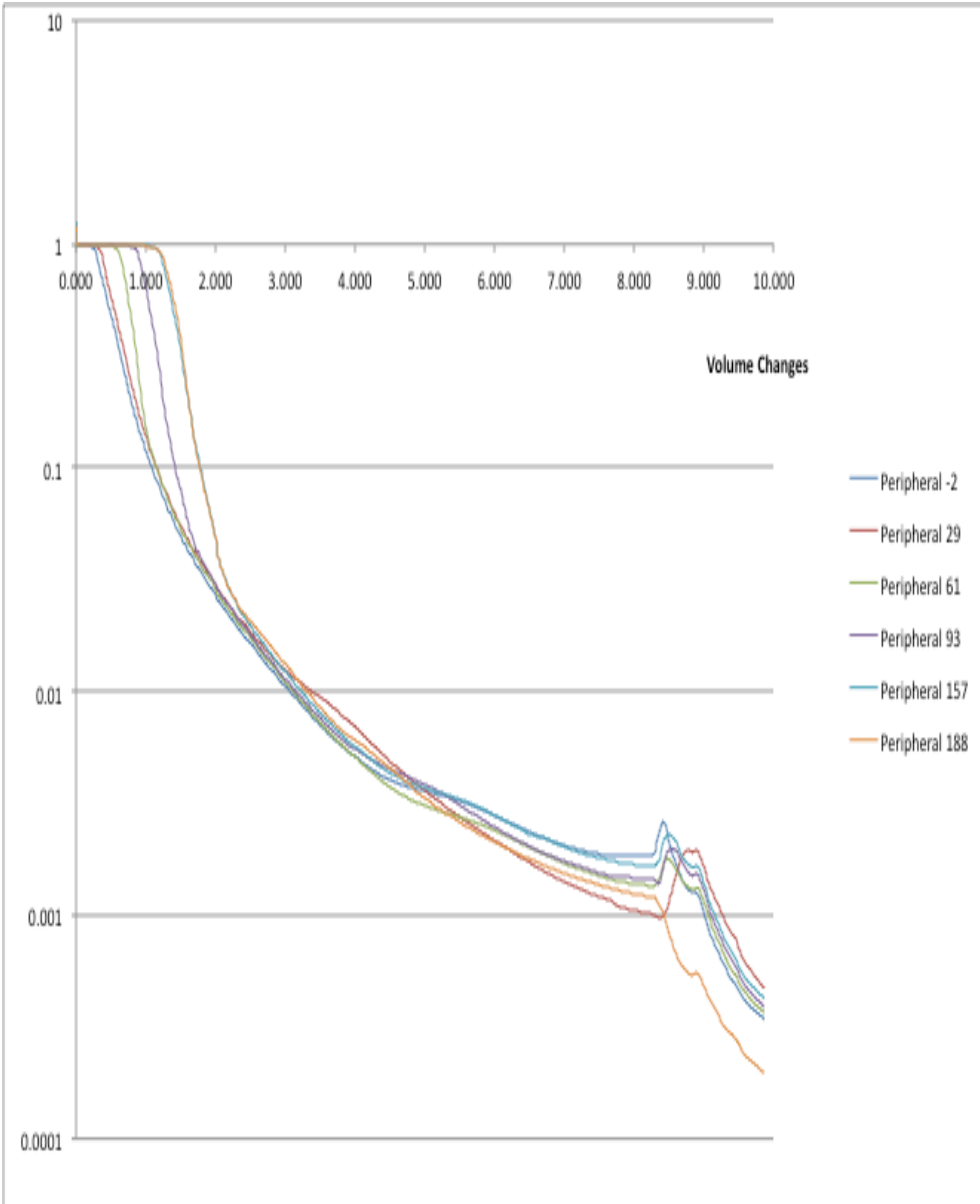


Peripheral versus Volume Changes



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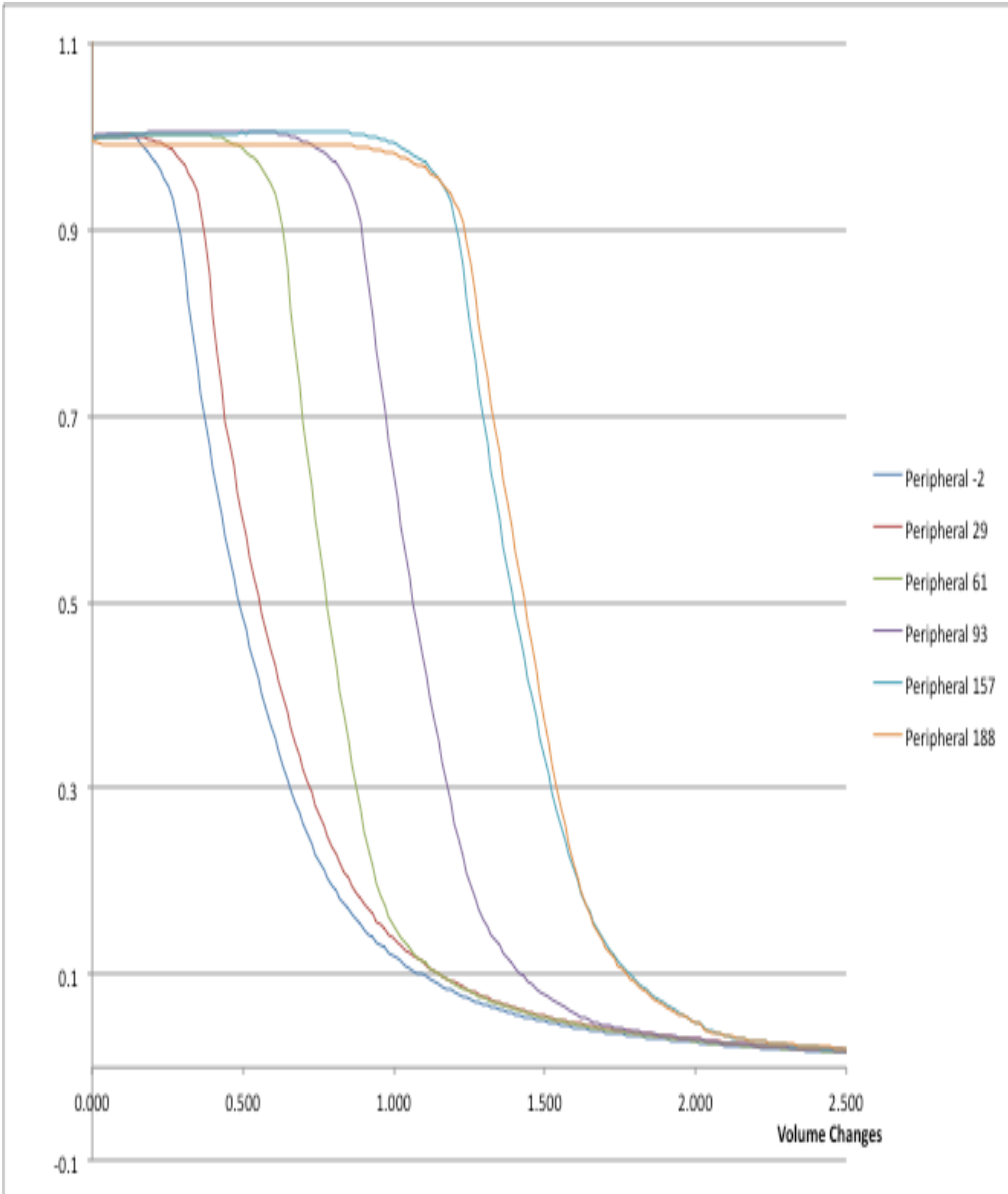

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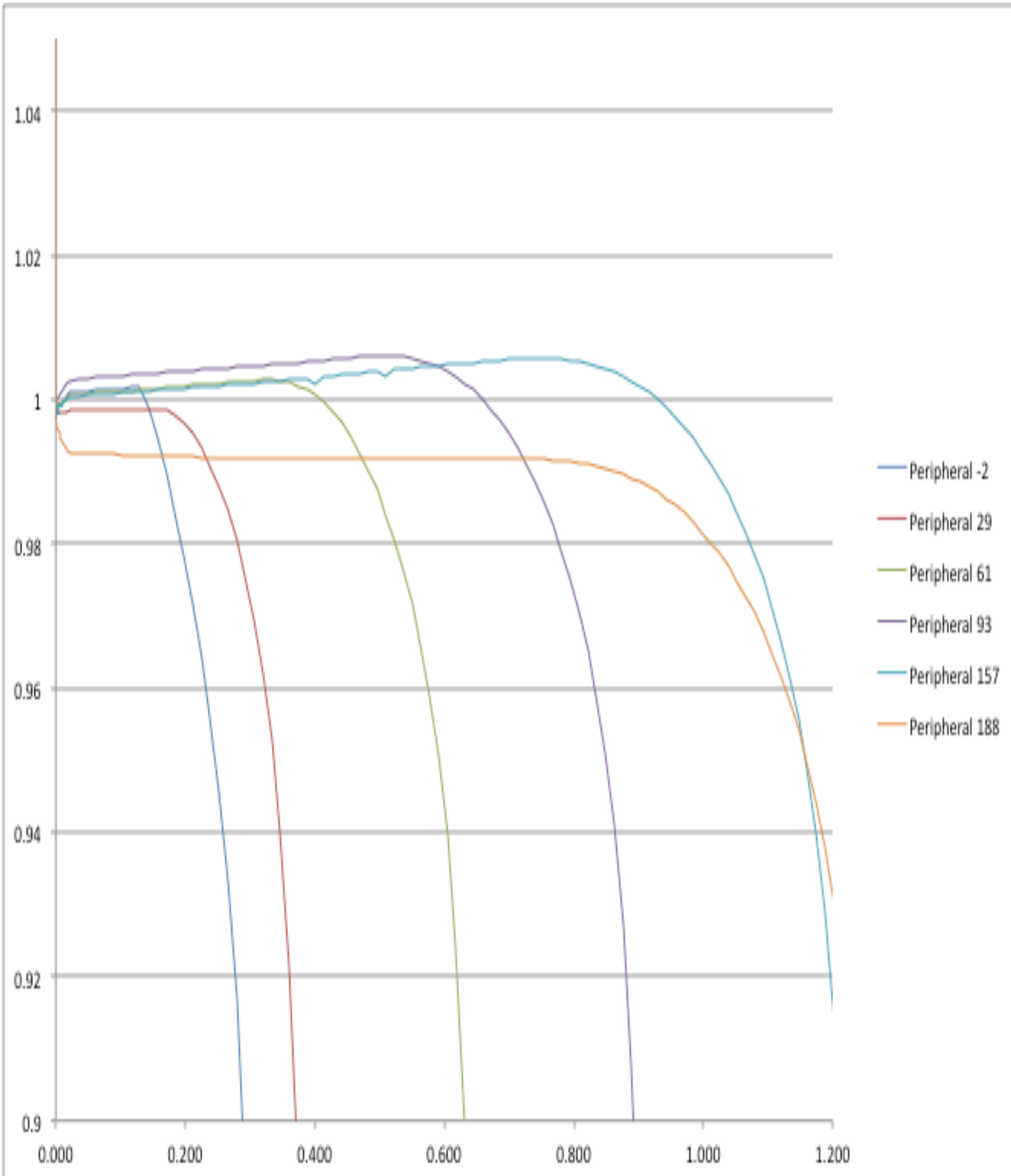

PERIPHERAL VERSUS VOLUME CHANGES