

# Disc Pad Physical Properties vs. Porosity: the Question of Compressibility as an Intrinsic Physical Property

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## Abstract

Disc pad physical properties are believed to be important in controlling brake friction, wear and squeal. Thus these properties are carefully measured during and after manufacturing for quality assurance. For a given formulation, disc pad porosity is reported to affect friction, wear and squeal. This investigation was undertaken to find out how porosity changes affect pad natural frequencies, dynamic modulus, hardness and compressibility for a low-copper formulation and a copper-free formulation, both without underlayer, without scorching and without noise shims. Pad natural frequencies, modulus and hardness all continuously decrease with increasing porosity. When pad compressibility is measured by compressing several times as recommended and practiced, the pad surface hardness is found to increase while pad natural frequencies and modulus remain essentially unchanged. However, there is no consistent pattern in compressibility change with increasing porosity, and thus a question arises on the validity of compressibility measurement as an intrinsic physical property measurement. Also after 12-months of ageing at room temperature, all the properties are found to change significantly, but property change trends with increasing porosity remain the same except for compressibility. A large number of samples were prepared and measured. The results are presented and discussed.

## History

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## Introduction

**M**. Sriwiboon et al. [1] reported that pad hardness and natural frequencies continuously decreased with increasing pad porosity, but pad compressibility showed no consistent trends and no correlation to brake squeal. In addition, the authors reported that friction coefficient, pad wear, disc wear and brake squeal were all influenced by pad porosity [2,3]. As many engineers still believe there is a close correlation between pad compressibility and brake squeal, and many others dispute this belief, this investigation was undertaken to generate additional data using a large number of samples to help clarify the situation. In addition to measuring pad natural frequencies, hardness and compressibility, modulus measurements were added using the latest ultrasonic technique in order to answer the question of compressibility being an intrinsic material property or not.

## Experimental

### Disc Pads

2 production NAO formulas were selected for this investigation; low-copper and copper-free. The pads were suitable for the twin-piston caliper of a 3,200 kg pickup truck. Experimental pads were fabricated by traditional hot press molding, oven curing and finish grinding. 3 porosity levels were achieved by adjusting molding temperature, pressure and time; 13 v%, 18 v% and 22 v% porosity for each formula. These pads had no underlayer, no scorching and no noise shims in order to minimize variables. The total thickness of the pad assembly was 15.5 mm; the backing plate 5.5 mm. and the friction material 10.0 mm.

### Pad Physical Property Measurements

Pad thickness, pad-backing plate assembly natural frequencies, pad dynamic modulus, pad surface hardness and pad compressibility were measured. The measurement locations on the pad are shown in Figure 1.

### Pad Dynamic Modulus Measurement

The use of ultrasound to determine the mechanical properties of materials is based on the fundamental relationship between the ultrasonic velocity and the material elastic constants. These methods have been described in a number of books and review articles [4, 5, 6]. Equation 1 shows the relationship between the measured ultrasonic velocity and the dynamic modulus along the propagation path. Because the ultrasonic wave is in the MHz frequency regime, the dynamic modulus is measured using this technique.

$$E = kpV^2 \quad \text{Eq.1}$$

Where  $\rho$  is the density;  $V$  is the ultrasonic propagation velocity through the friction material, and the factor  $k$  is dependent upon the velocity mode (shear or longitudinal) and the Poisson's ratio. For shear modulus measurement, the value of  $k$  is unity. For Young's modulus measurements the value of  $k$  is 1.21 based on the historical analysis of more than 100 friction material formulations using the complete SAE J2725 protocol for anisotropic friction materials.

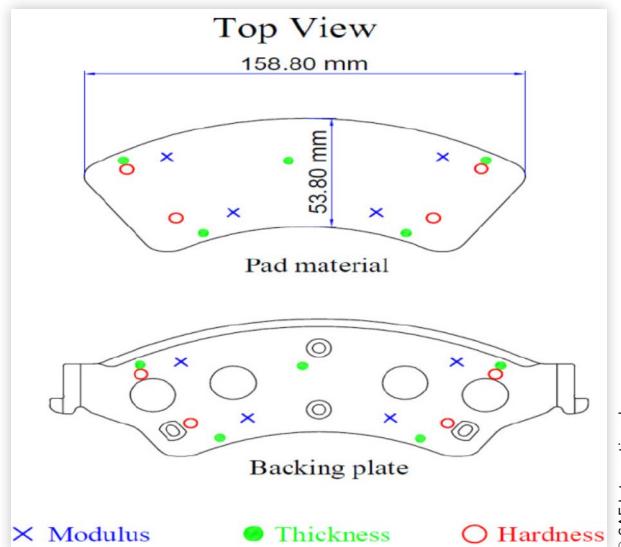
The ultrasonic technique used in this study to measure the dynamic modulus is a through-transmission technique. As illustrated in Figure 1, a short burst of high frequency sound, (~ 1 MHz) is generated from the transmitting transducer and propagates through the steel backing, then the friction material and finally to the receiving transducer. Precise measurements are made of the total time-of-flight,  $ToF_{pad}$ , from the transmitter to receiver. Ultrasonic velocity is calculated by combining this  $ToF$  measurement with the pad thickness. Using a signal digitization rate of 100 MHz, the precision of the  $ToF$  measurement is ~10 nanoseconds. Typical  $ToF$  for transmission through a brake pad is ~15 microseconds so the baseline precision of the method is on the order of 0.6%.

It is desirable to measure the properties of the friction material in an intact, as-manufactured brake pad. As described above, the baseline  $ToF$  is comprised of the transit-time through the steel backing,  $ToF_{steel}$  as well as the transit time through the friction material,  $ToF_{fm}$ , as shown in Equation 2.

$$ToF_{fm} = ToF_{pad} - \frac{X_{steel}}{C_{steel}} \quad \text{Eq.2}$$

Where  $X_{steel}$  is the steel thickness and  $V_{steel}$  is the steel backing ultrasonic velocity.

**FIGURE 1** Pad property measurement locations.



It is relatively straight forward to remove the influence of the steel backing as both the steel thickness and its velocity are known and well controlled. The velocity of the steel is typically 3 to 4 times that of the friction material while the thickness of the steel is about 2 times smaller than that of the friction material. Thus the elimination of the steel contribution from the measured ToF is typically a 10% correction. More importantly, because the modulus and density in the steel backing is well controlled. Any variation in the ToF can be attributed to the friction material.

The velocity in the friction material is given in [Equation 3](#) by:

$$V = \frac{X_{fm}}{ToF_{fm}} \quad \text{Eq.3}$$

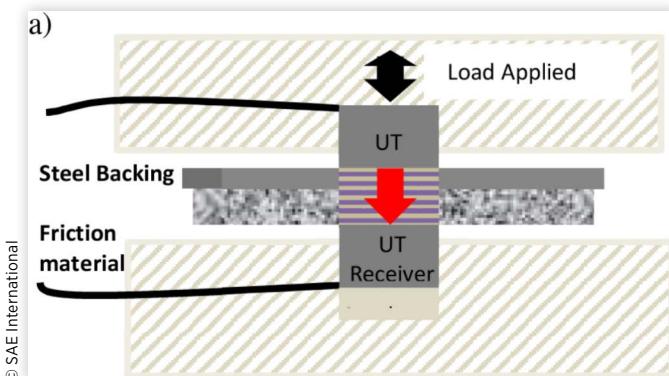
Where  $X_{fm} = X_{pad} - X_{Steel}$  is the thickness of the friction material.

This velocity is used in [Equation 1](#) to compute the dynamic modulus.

For the dynamic modulus measurements a commercially available iETEK measurement instrument depicted in [Figure 2](#) is used.<sup>4</sup> For this system, the transmitting sensor is attached to a stepper motor driven actuator to provide a user-defined preload. The pre-load is measured using a load cell mounted on the bottom surface of the receiving sensor. As illustrated in [Figure 1](#), the ultrasonic sensors are mounted in a co-linear configuration. The brake pad is inserted between the sensors and the user defined preload applied through the sensors. The “footprint” of the sensors is 15mm in diameter. The region influencing the ultrasonic propagation is the cylindrical volume directly beneath the sensors. As such, only a portion of the brake pad is measured for a single position of the brake pad. In order to obtain an average of the dynamic modulus in the pad, multiple positions are measured in each pad.

The iETEK is capable of measuring the dynamic modulus using a single user defined pre-load or continuously over pre-loads from 100 N to 800 N on both the loading and unloading portion of the pre-load cycle as illustrated in [Figure 2b](#).

**FIGURE 2** Measurement configuration for ultrasonic-based dynamic modulus measurements.



## Pad Property Measurement Sequence

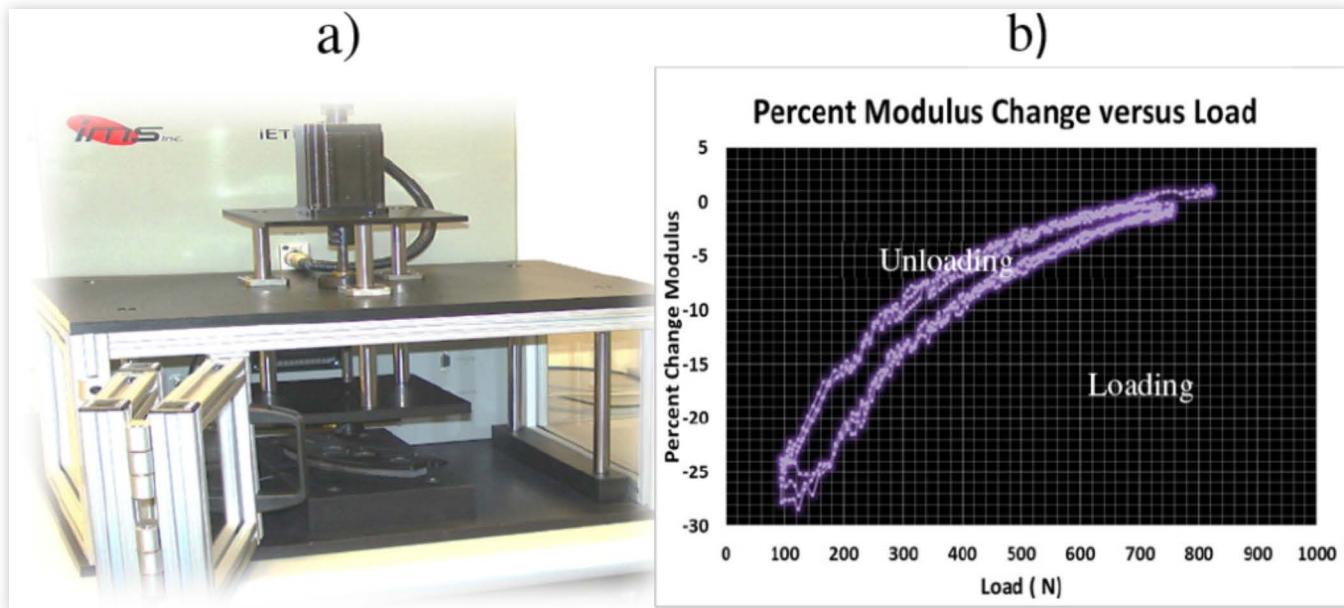
Pad thickness first, then the natural frequencies, surface hardness and compressibility by compressing once were measured. This sequence is designated as Cycle 1. Cycle 2 repeated the Cycle 1 on the same sample to detect any property changes taking place as the compressibility measurement technique requires 3 compressions. So the pad thickness, natural frequencies, modulus and hardness during the first cycle represent the pad properties before the first compression. The properties measured after the first compression appear in the second cycle, and so on.

## Results and Discussion UNIBRITE DF5B

Test results are summarized in Appendix 1-1 for 50 bars compression testing and Appendix 1-2 for 100 bars compression testing. From Appendix 1-2 of 100 bars compression series, the pad natural frequencies, modulus, pad surface hardness and compressibility are graphically shown in [Figure 4-1](#) for the low-copper samples and [Figure 4-2](#) for the copper-free samples. The pad thickness data are not shown here as they showed no measurable variations. As can be seen, the natural frequencies, modulus and hardness all decrease continuously and measurably with increasing porosity while the compressibility shows no general trends. When the porosity increases from 13 to 18%, the compressibility stays more or less the same or goes down slightly, not up, and then at 22%, the compressibility goes up in the case of the low-copper samples, but stays more or less the same in the case of copper-free samples. After 5 compressions, the natural frequencies and modulus show no significant changes, but the compressibility decreases in all cases while the pad surface hardness shows an increasing trend, which suggests the possibility of pad surface being compacted during compression. The results of 50 bars compression series follow similar trends. As high-frequency squeals (disc squeals) are usually observed under 5-30 bars of brake line pressure while low-frequency squeals (caliper-knuckle assembly squeals) are observed under 5-60 bars, the pressure of 50 bars represents a reasonable pressure for measurements rather than 100 or 160 bars.

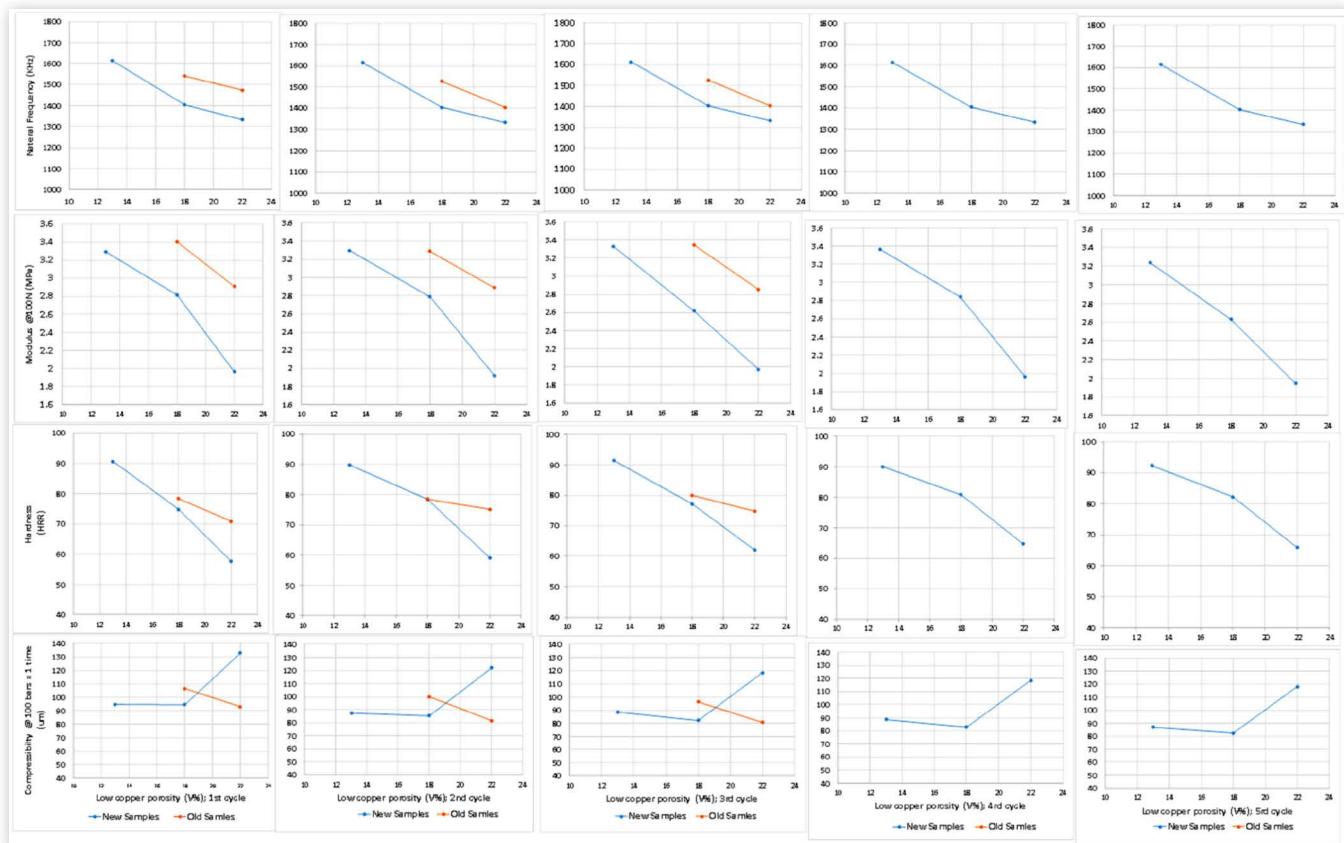
A limited number of samples were aged at room temperature for 12 months and then the properties were measured in order to see ageing effects if any. The results are summarized in Appendix 2. As these samples came from a separate lot, there is some degree of uncertainty, but directional trends would be still valid. The data are presented graphically in [Figures 4-1](#) and [4-2](#) (red lines). With ageing, the natural frequencies, modulus and hardness all increased, but the compressibility increased rather than decreasing. In the case of a high-copper formula as manufactured using a different process and scorched (not reported here), the hardness was

**FIGURE 3** a) iETEK instrument; b) Typical data showing % modulus variation as a function of pre-loading for both loading and unloading of pad at a single position.

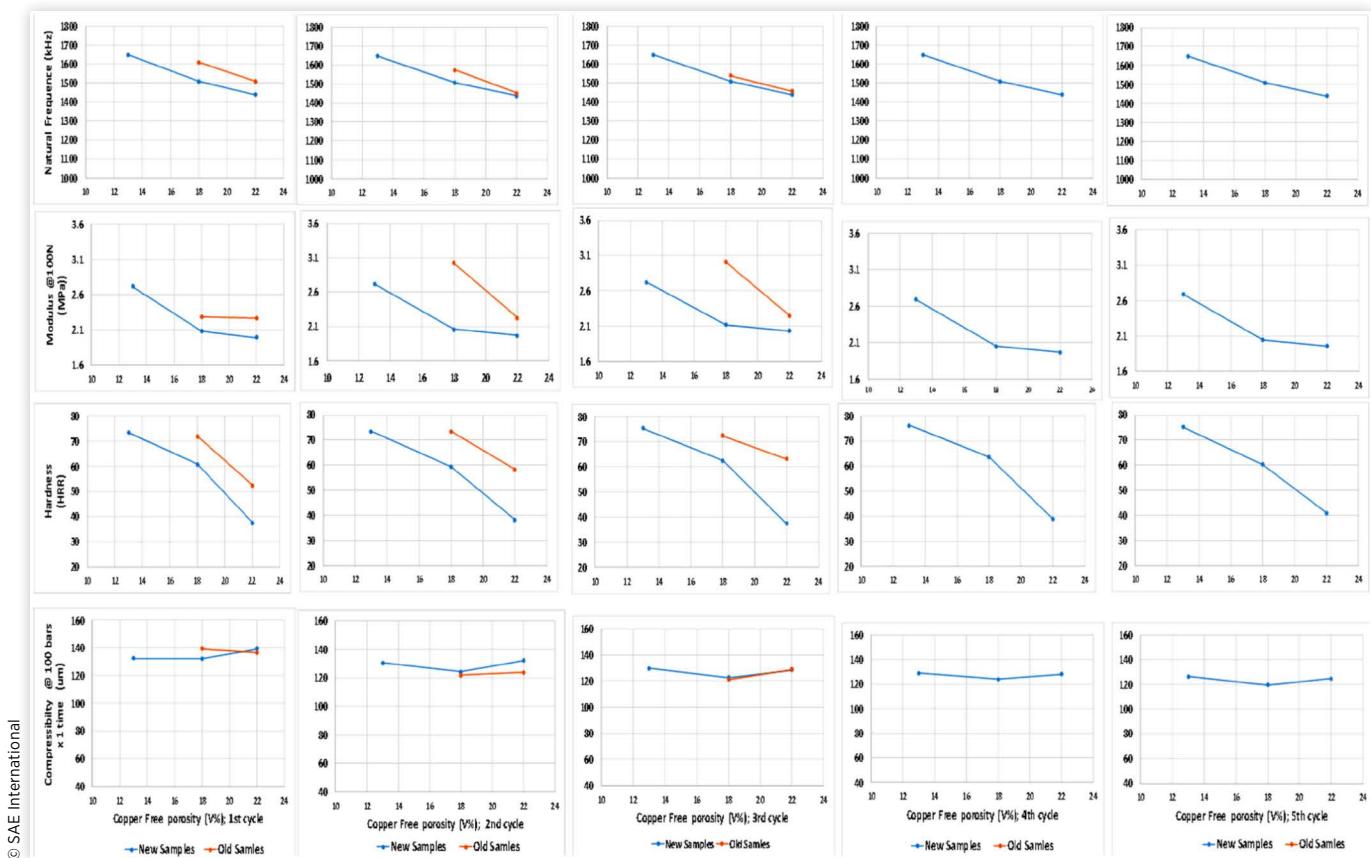


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**FIGURE 4-1** Low-Copper NAO pad physical properties; 13 v%, 18 v%, 22 v%; 5 test cycles; compression 100 bars.



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**FIGURE 4-2** Copper-Free NAO pad physical properties; 13 v%, 18 v% and 22 v%; 5 test cycles; compression 100 bars.

found to decrease, not increase, after 12 months. So one has to be careful not to generalize in terms of ageing effects.

Based on all the data, one has to question the validity of the compressibility measurement technique as measuring an intrinsic pad property such as electrical conductivity or thermal conductivity, etc., which is repeatable whether measured once or several times. If an intrinsic property is not being measured by the technique, then what is being measured? In turn, one has to question the validity of trying to relate pad compressibility to brake squeal generation.

As pad properties are found to age with time, one has to find out when the aging process comes to completion (1 day, 1 week, 1 month or longer?) and decide on the length of time to wait for complete aging /curing before testing. In other words, one has to ensure brake testing is done with fully cured/aged pads for consistent results.

- Pad natural frequencies, modulus and hardness continuously decrease with increasing pad porosity.
- Pad compressibility shows no clear trends vs. pad porosity. One has to question the validity of this method for measuring intrinsic material properties.
- As compressibility does not represent an intrinsic pad property, compressibility must not be used to relate to brake squeal.
- Pad surface hardness increases with successive compression.
- Pad natural frequencies and modulus remain essentially the same after increasing number of compressions, indicating physical changes taking place just on the surface of the pad after compression.
- After 12-months of aging at room temperature, pad natural frequencies, modulus and hardness all increased, but compressibility showed no trends.
- Fully cured/aged pads must be tested for consistent results.
- The ultrasonic technique is a convenient method for detecting pad porosity and pad porosity variations, and modulus.

## Summary and Conclusions

- Pad natural frequencies, modulus and hardness continuously decrease with increasing pad porosity.
- Pad compressibility shows no clear trends vs. pad porosity. One has to question the validity of this method for measuring intrinsic material properties.

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## Appendix

### Appendix 1-1: Physical Properties of Low-Copper and Copper-Free NAO Disc Pads (Newly Made Samples); 50 Bars Compression

**TABLES 1-1-1** 1st cycle, 2nd cycle, 3<sup>rd</sup> cycle, 4<sup>th</sup> cycle and 5<sup>th</sup> cycle of low copper 13% porosity samples.

Samples	Modulus @ 100 N (GPa)										Hardness - HRR				Compressibility 1X (um)		
	Nat Freq(kHz)			Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 50 bar		
LC_13%	New Sample Cycle1	1614	5438.7	10736.8	3.3296	3.4224	3.6917	3.4462	3.4725	89.4	87.0	91.1	94.4	90.5	7.4	42.6	
	New Sample Cycle1	1614	5438.6	10736.8	3.3383	3.4312	3.7014	3.4550	3.4815	94.8	95.0	92.3	90.4	93.1	4.6	49.8	
	New Sample Cycle1	1614	5438.6	10736.8	3.3323	3.4251	3.6946	3.4489	3.4752	92.5	90.3	95.2	88.1	91.5	7.1	43.0	
	New Sample Cycle1	1614	5438.6	10736.8	3.3281	3.4201	3.6902	3.4448	3.4710	92.3	90.3	95.5	91.1	92.3	5.2	40.8	
<b>Avg</b>	<b>1614</b>	<b>5438.6</b>	<b>10736.8</b>	<b>3.321</b>	<b>3.4249</b>	<b>3.6945</b>	<b>3.4487</b>	<b>3.4750</b>	<b>90.7</b>	<b>93.5</b>	<b>91.0</b>	<b>91.9</b>	<b>91.9</b>	<b>6.1</b>	<b>44.1</b>		
<b>Range</b>	-	-	<b>0.0102</b>	<b>0.0102</b>	<b>0.0112</b>	<b>0.0102</b>	<b>0.0104</b>	<b>0.0104</b>	<b>5.4</b>	<b>8.0</b>	<b>4.4</b>	<b>6.3</b>	<b>2.7</b>	<b>2.8</b>	<b>9.0</b>		
LC_13%	New Sample1 Cycle 2	1614	5508.8	10666.7	3.3208	3.4132	3.6815	3.4370	3.4631	94.6	88.1	88.6	81.3	88.2	13.3	43.9	
	New Sample1 Cycle 2	1614	5508.8	10701.8	3.3262	3.4188	3.6873	3.4423	3.4686	90.5	91.1	92.4	91.1	91.3	1.9	44.5	
	New Sample1 Cycle 2	1614	5508.8	10666.7	3.3177	3.4098	3.6778	3.4336	3.4597	96.3	91.1	93.8	90.5	92.9	5.8	40.8	
	New Sample1 Cycle 2	1614	5508.8	10666.7	3.3250	3.4173	3.6858	3.4411	3.4673	89.7	92.3	95.1	97.2	93.6	7.5	39.3	
<b>Avg</b>	<b>1614</b>	<b>5508.8</b>	<b>10675.48</b>	<b>3.3224</b>	<b>3.4148</b>	<b>3.6831</b>	<b>3.4385</b>	<b>3.4647</b>	<b>92.8</b>	<b>90.7</b>	<b>92.5</b>	<b>90.0</b>	<b>91.5</b>	<b>7.1</b>	<b>42.1</b>		
<b>Range</b>	-	-	<b>0.0085</b>	<b>0.0090</b>	<b>0.0090</b>	<b>0.0095</b>	<b>0.0087</b>	<b>0.0089</b>	<b>6.6</b>	<b>4.2</b>	<b>6.5</b>	<b>15.9</b>	<b>5.4</b>	<b>11.4</b>	<b>5.2</b>		
LC_13%	New Sample 1 Cycle 3	1614	5508.8	10666.7	3.3255	3.4180	3.6866	3.4419	3.4680	88.2	87.3	91.0	95.9	90.6	8.6	44.9	
	New Sample 1 Cycle 3	1614	5508.8	10666.7	3.3223	3.4146	3.6829	3.4382	3.4645	94.8	90.3	93.3	85.6	91.0	9.2	41.9	
	New Sample 1 Cycle 3	1614	5508.8	10666.7	3.3228	3.4154	3.6836	3.4389	3.4652	93.9	95.3	99.2	92.7	95.3	6.5	42.5	
	New Sample 1 Cycle 3	1614	5508.8	10666.7	3.3289	3.4214	3.6902	3.4453	3.4714	87.9	91.4	96.0	93.5	92.2	8.1	42.3	
<b>Avg</b>	<b>1614</b>	<b>5508.8</b>	<b>10666.7</b>	<b>3.3248</b>	<b>3.4174</b>	<b>3.6858</b>	<b>3.4411</b>	<b>3.4673</b>	<b>91.2</b>	<b>91.1</b>	<b>94.9</b>	<b>91.9</b>	<b>92.3</b>	<b>8.1</b>	<b>42.9</b>		
<b>Range</b>	-	-	<b>0.0066</b>	<b>0.0066</b>	<b>0.0073</b>	<b>0.0068</b>	<b>0.0070</b>	<b>0.0069</b>	<b>6.9</b>	<b>8.0</b>	<b>8.2</b>	<b>10.3</b>	<b>4.7</b>	<b>2.7</b>	<b>3.0</b>		
LC_13%	New Sample 1 Cycle 4	1614	5508.8	10666.7	3.2834	3.3799	3.6567	3.4149	3.4337	92.4	90.8	92.4	89.9	91.4	2.5	44.1	
	New Sample 1 Cycle 4	1614	5508.8	10666.7	3.2827	3.3792	3.6559	3.4142	3.4330	92.3	94.1	91.5	88.9	91.7	5.2	44.6	
	New Sample 1 Cycle 4	1614	5508.8	10666.7	3.2793	3.3758	3.6523	3.4107	3.4295	94.2	94.1	90.5	88.9	91.9	5.3	49.6	
	New Sample 1 Cycle 4	1614	5508.8	10666.7	3.2834	3.3799	3.6567	3.4149	3.4337	98.8	99.2	91.7	94.2	96.0	7.5	42.2	
<b>Avg</b>	<b>1614</b>	<b>5508.8</b>	<b>10666.7</b>	<b>3.2822</b>	<b>3.3787</b>	<b>3.6554</b>	<b>3.4137</b>	<b>3.4325</b>	<b>94.4</b>	<b>91.5</b>	<b>90.5</b>	<b>92.7</b>	<b>5.1</b>	<b>45.1</b>			
<b>Range</b>	-	-	<b>0.0041</b>	<b>0.0041</b>	<b>0.0041</b>	<b>0.0041</b>	<b>0.0042</b>	<b>0.0042</b>	<b>6.5</b>	<b>8.4</b>	<b>1.9</b>	<b>5.3</b>	<b>4.6</b>	<b>5.0</b>	<b>7.4</b>		
LC_13%	New Sample 1 Cycle 5	1614	5508.8	10666.7	3.3233	3.4156	3.6836	3.4392	3.4654	104.7	95.0	92.0	93.1	96.2	12.7	45.6	
	New Sample 1 Cycle 5	1614	5508.8	10666.7	3.3245	3.4168	3.6851	3.4406	3.4668	91.6	95.5	91.4	88.0	91.6	7.5	44.9	
	New Sample 1 Cycle 5	1614	5508.8	10666.7	3.3199	3.4122	3.6800	3.4358	3.4620	100.1	99.2	94.2	94.2	95.9	10.1	45.9	
	New Sample 1 Cycle 5	1614	5508.8	10666.7	3.3264	3.4190	3.6873	3.4426	3.4688	93.1	94.2	100.1	100.9	97.1	7.8	45.1	
<b>Avg</b>	<b>1614</b>	<b>5508.8</b>	<b>10666.7</b>	<b>3.3235</b>	<b>3.4159</b>	<b>3.6840</b>	<b>3.4395</b>	<b>3.4657</b>	<b>97.4</b>	<b>93.7</b>	<b>94.1</b>	<b>95.2</b>	<b>95.5</b>	<b>9.5</b>	<b>45.4</b>		
<b>Range</b>	-	-	<b>0.0066</b>	<b>0.0068</b>	<b>0.0073</b>	<b>0.0068</b>	<b>0.0069</b>	<b>0.0069</b>	<b>5.5</b>	<b>8.7</b>	<b>12.9</b>	<b>5.4</b>	<b>5.2</b>	<b>1.0</b>			

**TABLES 1-1-2** 1st cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of low copper 18% porosity samples.

Samples	Modulus @ 100 N (GPa)						Hardness - HRR						Compressibility			
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 50 bar	
LC_18%	New Sample Cycle 1	1403.5	5122.8	10175	2.9118	2.8509	2.3883	2.4461	2.6493	77.5	72.9	69.6	67.2	71.8	10.3	62.6
	New Sample Cycle 1	1403.5	5122.8	10175	2.8948	2.8341	2.3742	2.4317	2.6337	63.3	64.5	62.2	60.0	62.5	4.5	63.6
	New Sample Cycle 1	1403.5	5122.8	10175	2.9030	2.8421	2.3810	2.4386	2.6412	70.5	74.5	65.4	65.7	69.0	9.1	66.7
	New Sample Cycle 1	1403.5	5122.8	10175	2.8683	2.8082	2.3524	2.4093	2.6096	78.3	78.4	62.1	64.0	70.7	16.3	71.7
	<b>Avg</b>	<b>1404</b>	<b>5122.8</b>	<b>10175</b>	<b>2.8945</b>	<b>2.8338</b>	<b>2.3740</b>	<b>2.4314</b>	<b>2.6334</b>	<b>72.4</b>	<b>72.6</b>	<b>64.8</b>	<b>64.2</b>	<b>68.5</b>	<b>10.1</b>	<b>66.2</b>
LC_18%	-	-	-	<b>0.0434</b>	<b>0.0427</b>	<b>0.0359</b>	<b>0.0368</b>	<b>0.0397</b>	<b>15.0</b>	<b>13.9</b>	<b>7.5</b>	<b>7.2</b>	<b>9.3</b>	<b>11.8</b>	<b>9.1</b>	
	New Sample Cycle 2	1403.5	5122.8	10175	2.9137	2.8525	2.3890	2.4468	2.6505	82.6	74.3	71.4	79.7	77.0	11.2	54.5
	New Sample Cycle 2	1403.5	5122.8	10175	2.9014	2.8403	2.3789	2.4365	2.6392	65.3	74.8	68.7	72.0	70.2	9.5	56.5
	New Sample Cycle 2	1403.5	5122.8	10175	2.9092	2.8478	2.3853	2.4431	2.6463	74.7	76.6	70.7	72.8	73.7	5.9	60.6
	New Sample Cycle 2	1403.5	5122.8	10175	2.8759	2.8155	2.3402	2.4152	2.6117	86.9	75.7	72.9	67.3	75.7	19.6	66.0
<b>Avg</b>	<b>1404</b>	<b>5122.8</b>	<b>10175</b>	<b>2.9000</b>	<b>2.8390</b>	<b>2.3733</b>	<b>2.4354</b>	<b>2.6369</b>	<b>77.4</b>	<b>75.4</b>	<b>70.9</b>	<b>73.0</b>	<b>74.2</b>	<b>11.6</b>	<b>59.4</b>	
<b>Range</b>	-	-	-	<b>0.0378</b>	<b>0.0371</b>	<b>0.0489</b>	<b>0.0316</b>	<b>0.0388</b>	<b>21.6</b>	<b>2.3</b>	<b>4.2</b>	<b>12.4</b>	<b>6.8</b>	<b>13.7</b>	<b>11.5</b>	
LC_18%	New Sample 1 Cycle 3	1403.5	5122.8	10175	2.9148	2.8537	2.3900	2.4480	2.6516	80.2	79.8	80.8	75.1	79.0	5.7	52.0
	New Sample 1 Cycle 3	1403.5	5122.8	10175	2.9019	2.8410	2.3794	2.4369	2.6398	74.0	77.8	87.8	77.1	79.2	13.8	60.5
	New Sample 1 Cycle 3	1403.5	5122.8	10175	2.9085	2.8473	2.3845	2.4424	2.6457	74.5	95.5	73.0	71.8	78.7	23.7	58.3
	New Sample 1 Cycle 3	1403.5	5122.8	10175	2.8771	2.8167	2.3590	2.4162	2.6172	72.5	68.9	72.2	64.3	69.5	8.2	64.8
	<b>Avg</b>	<b>1404</b>	<b>5122.8</b>	<b>10175</b>	<b>2.9006</b>	<b>2.8397</b>	<b>2.3782</b>	<b>2.4359</b>	<b>2.6386</b>	<b>75.3</b>	<b>80.5</b>	<b>78.5</b>	<b>72.1</b>	<b>76.6</b>	<b>12.9</b>	<b>58.9</b>
<b>Range</b>	-	-	-	<b>0.0378</b>	<b>0.0371</b>	<b>0.0489</b>	<b>0.0316</b>	<b>0.0388</b>	<b>21.6</b>	<b>2.3</b>	<b>4.2</b>	<b>12.4</b>	<b>6.8</b>	<b>13.7</b>	<b>11.5</b>	
LC_18%	New Sample 1 Cycle 4	1403.5	5122.8	10175	2.9160	2.8549	2.3907	2.4487	2.6526	88.8	67.9	77.7	62.7	74.3	26.1	53.8
	New Sample 1 Cycle 4	1403.5	5122.8	10175	2.9056	2.8445	2.3819	2.4308	2.6430	66.0	61.4	70.4	67.7	66.4	9.0	58.7
	New Sample 1 Cycle 4	1403.5	5122.8	10175	2.9139	2.8525	2.3888	2.4466	2.6505	69.5	71.8	77.3	77.7	74.1	8.2	60.6
	New Sample 1 Cycle 4	1403.5	5122.8	10175	2.8849	2.8242	2.3650	2.4223	2.6241	78.0	80.5	65.8	65.9	72.6	14.7	66.5
	<b>Avg</b>	<b>1404</b>	<b>5122.8</b>	<b>10175</b>	<b>2.9051</b>	<b>2.8440</b>	<b>2.3816</b>	<b>2.4394</b>	<b>2.6425</b>	<b>71.2</b>	<b>71.2</b>	<b>70.4</b>	<b>71.0</b>	<b>10.6</b>	<b>61.9</b>	
<b>Range</b>	-	-	-	<b>0.0312</b>	<b>0.0307</b>	<b>0.0257</b>	<b>0.0264</b>	<b>0.0285</b>	<b>12.0</b>	<b>19.1</b>	<b>11.5</b>	<b>11.8</b>	<b>7.7</b>	<b>6.5</b>	<b>7.8</b>	
LC_18%	New Sample 1 Cycle 5	1403.5	5122.8	10175	2.9023	2.8414	2.3808	2.4384	2.6407	86.6	70.1	83.4	76.6	79.2	16.5	52.5
	New Sample 1 Cycle 5	1403.5	5122.8	10175	2.8908	2.8301	2.3711	2.4284	2.6301	76.8	76.1	80.2	78.6	77.9	4.1	56.9
	New Sample 1 Cycle 5	1403.5	5122.8	10175	2.9007	2.8398	2.3794	2.4359	2.6392	80.2	90.1	74.2	76.6	80.3	15.9	59.8
	New Sample 1 Cycle 5	1403.5	5122.8	10175	2.8641	2.8042	2.3494	2.4063	2.6060	79.8	78.8	71.2	69.1	74.7	10.7	67.8
	<b>Avg</b>	<b>1404</b>	<b>5122.8</b>	<b>10175</b>	<b>2.8895</b>	<b>2.8289</b>	<b>2.3701</b>	<b>2.4275</b>	<b>2.6290</b>	<b>80.9</b>	<b>78.8</b>	<b>77.3</b>	<b>75.2</b>	<b>78.0</b>	<b>11.8</b>	<b>59.3</b>
<b>Range</b>	-	-	-	<b>0.0382</b>	<b>0.0373</b>	<b>0.0314</b>	<b>0.0321</b>	<b>0.0348</b>	<b>9.8</b>	<b>20.0</b>	<b>12.2</b>	<b>9.5</b>	<b>5.6</b>	<b>12.4</b>	<b>15.3</b>	

**TABLES 1-1-3** 1st Cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of low copper 22% porosity samples.

Samples	Nat Freq(kHz)			Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility 1X (um)					
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 50 bar		
LC_22%	New Sample Cycle 1	1333.3	4736.8	9719.3	2.1869	2.2952	1.9330	1.9436	2.0897	68.2	72.7	48.3	57.5	<b>61.7</b>	24.4	57.1	
	New Sample Cycle 1	1333.3	4736.8	9719.3	2.1556	2.2623	1.9053	1.9157	2.0597	54.8	67.0	66.4	62.2	<b>62.6</b>	12.2	56.5	
	New Sample Cycle 1	1333.3	4871.2	9929.8	2.1719	2.2794	1.9197	1.9302	2.0753	63.8	74.5	61.4	56.4	<b>64.0</b>	18.1	56.6	
	New Sample Cycle 1	1333.3	4871.2	9929.8	2.1622	2.2692	1.9112	1.9216	2.0660	50.1	73.2	58.1	49.8	<b>57.8</b>	23.4	56.2	
<b>Avg</b>									<b>0.0279</b>					<b>56.5</b>	<b>61.5</b>	<b>19.5</b>	<b>56.6</b>
<b>Range</b>		-	-	<b>0.0313</b>	<b>0.0329</b>	<b>0.0277</b>	<b>0.0279</b>	<b>0.0300</b>	<b>18.1</b>	<b>7.5</b>	<b>71.9</b>	<b>58.6</b>	<b>12.4</b>	<b>6.2</b>	<b>12.2</b>	<b>0.9</b>	
LC_22%	New Sample1 Cycle 2	1333.3	4736.8	9719.3	2.1879	2.2964	1.9336	1.9442	2.0905	66.6	69.8	52.4	52.1	<b>60.2</b>	17.7	51.2	
	New Sample1 Cycle 2	1333.3	4736.8	9719.3	2.1592	2.2662	1.9082	1.9186	2.0630	56.6	70.2	68.8	66.6	<b>65.6</b>	13.6	46.9	
	New Sample1 Cycle 2	1333.3	4736.8	9719.3	2.1671	2.2745	1.9152	1.9257	2.0706	64.8	72.4	66.6	54.2	<b>64.5</b>	18.2	48.7	
	New Sample1 Cycle 2	1333.3	4736.8	9719.3	2.1649	2.2722	1.9132	1.9237	2.0685	52.1	68.8	62.1	52.1	<b>58.8</b>	16.7	50.1	
<b>Avg</b>		<b>1333.3</b>	<b>4736.8</b>	<b>9719.3</b>	<b>2.1698</b>	<b>2.2773</b>	<b>1.9175</b>	<b>1.9280</b>	<b>2.0732</b>	<b>60.0</b>	<b>70.3</b>	<b>62.5</b>	<b>56.3</b>	<b>62.3</b>	<b>16.6</b>	<b>49.2</b>	
<b>Range</b>		-	-	<b>0.0288</b>	<b>0.0302</b>	<b>0.0254</b>	<b>0.0256</b>	<b>0.0275</b>	<b>14.5</b>	<b>3.6</b>	<b>16.4</b>	<b>14.5</b>	<b>6.8</b>	<b>4.6</b>	<b>4.3</b>		
LC_22%	New Sample1 Cycle 3	1333.3	4736.8	9719.3	2.1757	2.2598	1.9183	1.9157	2.0674	65.8	74.2	56.8	60.2	<b>64.3</b>	17.4	49.1	
	New Sample1 Cycle 3	1333.3	4736.8	9719.3	2.1471	2.2301	1.8931	1.8905	2.0402	55.5	68.8	66.4	60.1	<b>62.7</b>	13.3	58.9	
	New Sample1 Cycle 3	1333.3	4736.8	9719.3	2.1559	2.2392	1.9008	1.8982	2.0485	66.3	74.2	66.1	60.2	<b>66.7</b>	14.0	48.0	
	New Sample1 Cycle 3	1333.3	4736.8	9719.3	2.1515	2.2347	1.8969	1.8944	2.0444	55.5	69.8	59.8	52.3	<b>59.4</b>	17.5	47.8	
<b>Avg</b>		<b>1333.3</b>	<b>4736.8</b>	<b>9719.3</b>	<b>2.1576</b>	<b>2.2410</b>	<b>1.9023</b>	<b>1.8997</b>	<b>2.0501</b>	<b>60.8</b>	<b>71.8</b>	<b>62.3</b>	<b>58.2</b>	<b>63.3</b>	<b>15.6</b>	<b>51.0</b>	
<b>Range</b>		-	-	<b>0.0286</b>	<b>0.0297</b>	<b>0.0252</b>	<b>0.0252</b>	<b>0.0272</b>	<b>10.8</b>	<b>5.4</b>	<b>9.6</b>	<b>7.9</b>	<b>7.4</b>	<b>4.2</b>	<b>11.1</b>		
LC_22%	New Sample1 Cycle 4	1333.3	4736.8	9719.3	2.1713	2.2551	1.9145	1.9119	2.0632	65.5	55.5	52.8	47.1	<b>55.2</b>	18.4	50.0	
	New Sample1 Cycle 4	1333.3	4736.8	9719.3	2.1419	2.2246	1.8886	1.8860	2.0353	57.5	61.2	62.7	62.2	<b>60.9</b>	5.2	46.0	
	New Sample1 Cycle 4	1333.3	4736.8	9719.3	2.1533	2.2364	1.8986	1.8960	2.0461	65.1	64.3	68.8	50.3	<b>62.1</b>	18.5	52.1	
	New Sample1 Cycle 4	1333.3	4736.8	9719.3	2.1519	2.2350	1.8975	1.8949	2.0448	67.9	72.5	73.9	54.2	<b>67.1</b>	19.7	48.0	
<b>Avg</b>		<b>1333.3</b>	<b>4736.8</b>	<b>9719.3</b>	<b>2.1546</b>	<b>2.2378</b>	<b>1.8998</b>	<b>1.8972</b>	<b>2.0473</b>	<b>64.0</b>	<b>63.4</b>	<b>64.6</b>	<b>53.5</b>	<b>61.3</b>	<b>15.5</b>	<b>49.0</b>	
<b>Range</b>		-	-	<b>0.0294</b>	<b>0.0306</b>	<b>0.0259</b>	<b>0.0259</b>	<b>0.0280</b>	<b>10.4</b>	<b>17.0</b>	<b>21.1</b>	<b>15.1</b>	<b>11.9</b>	<b>14.5</b>	<b>6.1</b>		
LC_22%	New Sample1 Cycle 5	1333.3	4736.8	9719.3	2.1712	2.2550	1.9146	1.9120	2.0632	66.6	69.8	55.4	54.9	<b>61.7</b>	14.9	49.4	
	New Sample1 Cycle 5	1333.3	4736.8	9719.3	2.1379	2.2204	1.8852	1.8827	2.0316	58.2	64.4	60.2	61.1	<b>61.0</b>	6.2	44.6	
	New Sample1 Cycle 5	1333.3	4736.8	9719.3	2.1488	2.2317	1.8949	1.8923	2.0419	64.8	68.8	56.6	58.9	<b>62.3</b>	12.2	47.2	
	New Sample1 Cycle 5	1333.3	4736.8	9719.3	2.1431	2.2258	1.8899	1.8873	2.0365	62.4	70.2	55.5	60.1	<b>62.1</b>	14.7	46.9	
<b>Avg</b>		<b>1333.3</b>	<b>4736.8</b>	<b>9719.3</b>	<b>2.1503</b>	<b>2.2332</b>	<b>1.8962</b>	<b>1.8936</b>	<b>2.0433</b>	<b>63.0</b>	<b>68.3</b>	<b>56.9</b>	<b>58.8</b>	<b>61.7</b>	<b>12.0</b>	<b>47.0</b>	
<b>Range</b>		-	-	<b>0.0333</b>	<b>0.0346</b>	<b>0.0294</b>	<b>0.0294</b>	<b>0.0317</b>	<b>8.4</b>	<b>5.8</b>	<b>6.2</b>	<b>6.2</b>	<b>1.3</b>	<b>8.7</b>	<b>4.8</b>		

**TABLES 1-1-4** 1st cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of Copper Free 13% porosity samples.

Samples	Nat Freq(kHz)						Modulus @ 100 N (GPa)						Hardness - HRR						Compressibility		
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	Position 3	Position 4	Avg	Range	1 X (um)	@ 50 bar	
CF_13%	New Sample Cycle 1	1649.1	5614	1157.9	2.7030	2.7294	2.5556	2.6639	2.6630	80.6	75.1	84.0	83.0	80.7	8.9	83.0	80.7	8.9	68.5	68.5	
	New Sample Cycle 1	1649.1	5614	1157.9	2.7034	2.7301	2.5561	2.6643	2.6635	83.9	80.0	74.5	75.9	78.6	9.4	86.3	83.6	80.1	9.1	67.6	67.6
	New Sample Cycle 1	1649.1	5614	1157.9	2.6984	2.7249	2.5513	2.6596	2.6586	82.5	79.9	74.5	83.6	80.1	9.1	86.3	81.1	9.5	65.5	65.5	
	New Sample Cycle 1	1649.1	5614	1157.9	2.7167	2.7434	2.5687	2.6774	2.6766	80.6	76.8	80.6	86.3	80.1	9.1	86.3	81.1	9.5	75.6	75.6	
	<b>Avg</b>	<b>1649.1</b>	<b>5614.0</b>	<b>11158</b>	<b>2.7054</b>	<b>2.7319</b>	<b>2.5579</b>	<b>2.6663</b>	<b>2.6654</b>	<b>81.9</b>	<b>78.0</b>	<b>78.4</b>	<b>82.2</b>	<b>80.1</b>	<b>9.2</b>	<b>86.3</b>	<b>89.3</b>	<b>9.2</b>	<b>69.3</b>	<b>69.3</b>	
CF_13%	-	-	-	<b>0.0183</b>	<b>0.0185</b>	<b>0.0174</b>	<b>0.0179</b>	<b>0.0180</b>	<b>3.3</b>	<b>4.9</b>	<b>9.5</b>	<b>10.4</b>	<b>2.5</b>	<b>0.6</b>	<b>10.1</b>	<b>10.1</b>	<b>10.1</b>	<b>10.1</b>	<b>10.1</b>	<b>10.1</b>	
	New Sample Cycle 2	1649.1	5614	11052.6	2.7077	2.7344	2.5599	2.6686	2.6676	84.0	79.7	85.2	94.7	85.9	15.0	94.7	85.9	15.0	68.8	68.8	
	New Sample Cycle 2	1649.1	5614	11052.6	2.7073	2.7339	2.5595	2.6682	2.6672	88.4	81.0	76.1	72.6	79.5	15.8	81.0	79.5	15.8	67.0	67.0	
	New Sample Cycle 2	1649.1	5614	11052.6	2.7312	2.7579	2.5521	2.6917	2.6907	82.7	81.5	87.7	80.9	83.2	6.8	80.9	83.2	6.8	64.7	64.7	
	New Sample Cycle 2	1649.1	5614	11052.6	2.7179	2.7445	2.5694	2.6783	2.6775	87.1	75.6	78.7	74.0	78.9	13.1	75.6	78.9	13.1	66.2	66.2	
Avg	<b>1649.1</b>	<b>5614.0</b>	<b>11053</b>	<b>2.7160</b>	<b>2.7427</b>	<b>2.5677</b>	<b>2.6767</b>	<b>2.6758</b>	<b>85.6</b>	<b>79.5</b>	<b>81.9</b>	<b>80.6</b>	<b>81.9</b>	<b>12.7</b>	<b>81.9</b>	<b>80.6</b>	<b>81.9</b>	<b>12.7</b>	<b>66.7</b>	<b>66.7</b>	
	-	-	-	<b>0.0240</b>	<b>0.0240</b>	<b>0.0226</b>	<b>0.0235</b>	<b>0.0235</b>	<b>5.7</b>	<b>5.9</b>	<b>11.6</b>	<b>22.1</b>	<b>7.1</b>	<b>9.0</b>	<b>4.1</b>	<b>22.1</b>	<b>7.1</b>	<b>9.0</b>	<b>4.1</b>	<b>4.1</b>	<b>4.1</b>
	New Sample 1 Cycle 3	1649.1	5614	11052.6	2.7084	2.7351	2.5606	2.6691	2.6683	82.7	79.6	82.0	83.8	83.3	9.2	83.8	83.3	9.2	70.6	70.6	
	New Sample 1 Cycle 3	1649.1	5614	11052.6	2.7095	2.7362	2.5615	2.6702	2.6693	77.6	85.4	83.7	77.5	81.1	7.9	85.4	83.7	7.9	67.6	67.6	
	New Sample 1 Cycle 3	1649.1	5614	11052.6	2.7305	2.7574	2.5816	2.6910	2.6901	81.4	82.7	100.0	91.4	88.9	18.6	91.4	88.9	18.6	64.8	64.8	
Avg	<b>1649.1</b>	<b>5614.0</b>	<b>11053</b>	<b>2.7175</b>	<b>2.7443</b>	<b>2.5692</b>	<b>2.6781</b>	<b>2.6773</b>	<b>79.5</b>	<b>81.6</b>	<b>84.7</b>	<b>84.4</b>	<b>82.6</b>	<b>10.6</b>	<b>68.0</b>	<b>84.4</b>	<b>82.6</b>	<b>10.6</b>	<b>5.8</b>	<b>5.8</b>	
	-	-	-	<b>0.0221</b>	<b>0.0224</b>	<b>0.0210</b>	<b>0.0219</b>	<b>0.0219</b>	<b>6.4</b>	<b>6.7</b>	<b>26.9</b>	<b>13.9</b>	<b>11.9</b>	<b>11.8</b>	<b>5.8</b>	<b>13.9</b>	<b>11.9</b>	<b>11.8</b>	<b>7.1</b>	<b>7.1</b>	
	New Sample 1 Cycle 4	1649.1	5614	11052.6	2.7134	2.7400	2.5651	2.6740	2.6731	82.6	82.7	82.9	90.1	84.6	7.5	82.9	84.6	7.5	71.9	71.9	
	New Sample 1 Cycle 4	1649.1	5614	11052.6	2.7134	2.7400	2.5651	2.6740	2.6731	87.1	92.0	83.9	73.5	84.1	18.5	92.0	84.1	18.5	69.2	69.2	
	New Sample 1 Cycle 4	1649.1	5614	11052.6	2.7366	2.7635	2.5872	2.6971	2.6961	77.1	78.3	78.9	78.8	78.3	1.8	78.9	78.3	1.8	66.4	66.4	
Avg	<b>1649.1</b>	<b>5614.0</b>	<b>11053</b>	<b>2.7218</b>	<b>2.7486</b>	<b>2.5731</b>	<b>2.6824</b>	<b>2.6815</b>	<b>82.5</b>	<b>87.5</b>	<b>82.0</b>	<b>79.3</b>	<b>82.8</b>	<b>12.5</b>	<b>69.7</b>	<b>82.8</b>	<b>12.5</b>	<b>20.4</b>	<b>5.5</b>	<b>5.5</b>	
	-	-	-	<b>0.0233</b>	<b>0.0235</b>	<b>0.0221</b>	<b>0.0231</b>	<b>0.0231</b>	<b>10.0</b>	<b>18.7</b>	<b>5.0</b>	<b>16.6</b>	<b>6.3</b>	<b>20.4</b>	<b>5.5</b>	<b>16.6</b>	<b>6.3</b>	<b>20.4</b>	<b>5.5</b>	<b>5.5</b>	
	New Sample 1 Cycle 5	1649.1	5614	11052.6	2.6991	2.7256	2.5520	2.6600	2.6592	85.9	82.1	83.5	83.2	83.7	3.8	83.5	83.2	3.8	68.3	68.3	
	New Sample 1 Cycle 5	1649.1	5614	11052.6	2.7018	2.7283	2.5547	2.6627	2.6619	88.1	86.5	78.0	82.7	82.7	10.1	86.5	82.7	10.1	67.8	67.8	
	New Sample 1 Cycle 5	1649.1	5614	11052.6	2.7206	2.7473	2.5723	2.6813	2.6804	95.4	89.9	94.7	79.5	89.9	15.9	89.9	89.9	15.9	64.2	64.2	
Avg	<b>1649.1</b>	<b>5614.0</b>	<b>11053</b>	<b>2.7076</b>	<b>2.7341</b>	<b>2.5601</b>	<b>2.6685</b>	<b>2.6676</b>	<b>87.0</b>	<b>85.3</b>	<b>86.6</b>	<b>78.3</b>	<b>84.3</b>	<b>11.9</b>	<b>66.5</b>	<b>84.3</b>	<b>11.9</b>	<b>8.9</b>	<b>14.0</b>	<b>4.1</b>	
	<b>Avg</b>	<b>1649.1</b>	<b>5614.0</b>	<b>11053</b>	<b>-</b>	<b>-</b>	<b>0.0215</b>	<b>0.0203</b>	<b>0.0212</b>	<b>16.7</b>	<b>7.8</b>	<b>16.7</b>	<b>10.8</b>	<b>8.9</b>	<b>14.0</b>	<b>4.1</b>	<b>8.9</b>	<b>14.0</b>	<b>4.1</b>	<b>4.1</b>	<b>4.1</b>

**TABLES 1-1-5** 1st cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of Copper Free 18% porosity samples.

Samples	Nat Freq(kHz)			Modulus @ 100 N (GPa)				Compressibility						
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range
														@ 50 bar
CF_18%	New Sample Cycle 1	1508.8	5263.2	10526.3	2.0084	2.1989	2.3990	2.5521	<b>2.2896</b>	54.3	61.4	55.8	57.3	<b>57.2</b>
	New Sample Cycle 1	1508.8	5263.2	10526.3	2.0907	2.2889	2.4972	2.6565	<b>2.3833</b>	53.8	63.2	62.7	61.5	<b>60.3</b>
	New Sample Cycle 1	1508.8	5263.2	10526.3	2.0441	2.2380	2.4416	2.7562	<b>2.3700</b>	76.4	64.3	56.4	60.2	<b>64.3</b>
	New Sample Cycle 1	1508.8	5263.2	10526.3	2.0400	2.2335	2.4367	2.5922	<b>2.3256</b>	65.7	61.2	67.8	62.0	<b>64.2</b>
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10526</b>	<b>2.0458</b>	<b>2.2398</b>	<b>2.4436</b>	<b>2.6393</b>	<b>2.3421</b>	<b>62.6</b>	<b>60.7</b>	<b>60.3</b>	<b>61.5</b>	<b>10.8</b>
CF_18%	-	-	-	<b>0.0822</b>	<b>0.0900</b>			<b>0.2041</b>	<b>0.0937</b>	<b>22.6</b>	<b>3.1</b>	<b>12.0</b>	<b>4.7</b>	<b>7.1</b>
	New Sample Cycle 2	1508.8	5263.2	10526.3	2.0358	2.2286	2.4312	2.5860	<b>2.3204</b>	57.6	56.6	74.1	61.3	<b>62.4</b>
	New Sample Cycle 2	1508.8	5263.2	10526.3	2.0884	2.2863	2.4940	2.6529	<b>2.3804</b>	53.2	65.8	66.4	73.5	<b>64.7</b>
	New Sample Cycle 2	1508.8	5263.2	10561.4	2.0419	2.2354	2.4384	2.5937	<b>2.3274</b>	71.7	77.0	62.0	60.6	<b>67.8</b>
	New Sample Cycle 2	1508.8	5263.2	10526.3	2.0452	2.2388	2.4423	2.5980	<b>2.3311</b>	67.0	64.0	67.1	64.4	<b>65.6</b>
CF_18%	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10535</b>	<b>2.0529</b>	<b>2.2473</b>	<b>2.4515</b>	<b>2.6077</b>	<b>2.3398</b>	<b>62.4</b>	<b>65.9</b>	<b>67.4</b>	<b>65.0</b>	<b>65.1</b>
	-	-	-	<b>0.0526</b>	<b>0.0577</b>	<b>0.0628</b>	<b>0.0669</b>	<b>0.0600</b>	<b>18.5</b>	<b>20.4</b>	<b>12.1</b>	<b>12.9</b>	<b>5.4</b>	<b>17.2</b>
	New Sample 1 Cycle 3	1508.8	5263.2	10526.3	2.0558	2.2286	2.4312	2.5860	<b>2.3204</b>	65.0	63.3	57.6	63.8	<b>62.4</b>
	New Sample 1 Cycle 3	1508.8	5263.2	10526.3	2.0922	2.2904	2.4985	2.6576	<b>2.3847</b>	57.0	70.6	64.6	77.8	<b>67.5</b>
	New Sample 1 Cycle 3	1508.8	5263.2	10568.0	2.0219	2.2135	2.4146	2.5684	<b>2.3046</b>	76.3	82.2	94.5	66.0	<b>79.8</b>
CF_18%	New Sample 1 Cycle 3	1508.8	5263.2	10526.3	2.0592	2.2542	2.4591	2.6156	<b>2.3470</b>	69.9	78.9	69.4	68.8	<b>71.8</b>
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10537</b>	<b>2.0523</b>	<b>2.2467</b>	<b>2.4508</b>	<b>2.6069</b>	<b>2.3392</b>	<b>67.1</b>	<b>73.8</b>	<b>71.5</b>	<b>69.1</b>	<b>70.4</b>
	-	-	-	<b>0.0702</b>	<b>0.0769</b>	<b>0.0839</b>	<b>0.0892</b>	<b>0.0801</b>	<b>19.3</b>	<b>18.9</b>	<b>36.9</b>	<b>14.0</b>	<b>17.3</b>	<b>21.1</b>
	New Sample 1 Cycle 4	1508.8	5263.2	10526.3	2.0419	2.1543	2.5049	2.4161	<b>2.2793</b>	71.8	67.6	60.1	62.7	<b>65.6</b>
	New Sample 1 Cycle 4	1508.8	5263.2	10526.3	2.0923	2.2073	2.5664	2.4757	<b>2.3354</b>	83.0	63.3	62.7	66.9	<b>69.0</b>
CF_18%	New Sample 1 Cycle 4	1508.8	5263.2	10561.4	2.0485	2.1613	2.5128	2.4239	<b>2.2866</b>	70.4	71.6	73.8	67.1	<b>70.7</b>
	New Sample 1 Cycle 4	1508.8	5263.2	10526.3	2.0498	2.1626	2.5145	2.4254	<b>2.2881</b>	71.2	71.3	60.4	65.6	<b>67.1</b>
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10535</b>	<b>2.0581</b>	<b>2.1714</b>	<b>2.5246</b>	<b>2.4353</b>	<b>2.2974</b>	<b>74.1</b>	<b>68.5</b>	<b>64.3</b>	<b>65.6</b>	<b>68.1</b>
	-	-	-	<b>0.0503</b>	<b>0.0530</b>	<b>0.0616</b>	<b>0.0596</b>	<b>0.0561</b>	<b>12.6</b>	<b>8.3</b>	<b>13.7</b>	<b>4.4</b>	<b>5.2</b>	<b>13.6</b>
	New Sample 1 Cycle 5	1508.8	5263.2	10526.3	2.0356	2.2284	2.4308	2.5854	<b>2.3200</b>	71.1	65.3	65.4	60.1	<b>65.5</b>
CF_18%	New Sample 1 Cycle 5	1508.8	5263.2	10526.3	2.0929	2.2910	2.4989	2.6580	<b>2.3852</b>	72.7	66.8	60.3	68.1	<b>67.0</b>
	New Sample 1 Cycle 5	1508.8	5263.2	10561.4	2.0369	2.2297	2.4322	2.5869	<b>2.3214</b>	72.7	71.1	75.1	68.8	<b>71.9</b>
	New Sample 1 Cycle 5	1508.8	5263.2	10526.3	2.0380	2.2365	2.4395	2.5948	<b>2.3247</b>	72.7	71.1	75.1	68.8	<b>71.9</b>
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10535</b>	<b>2.0484</b>	<b>2.2464</b>	<b>2.4504</b>	<b>2.6063</b>	<b>2.3378</b>	<b>72.3</b>	<b>68.6</b>	<b>69.0</b>	<b>66.5</b>	<b>69.1</b>
	<b>Range</b>	-	-	<b>0.0649</b>	<b>0.0626</b>	<b>0.0682</b>	<b>0.0726</b>	<b>0.0652</b>	<b>1.6</b>	<b>5.8</b>	<b>14.8</b>	<b>8.7</b>	<b>6.5</b>	<b>7.1</b>

**TABLES 1-1-6** 1st cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of Copper Free 22% porosity samples.

Samples	Modulus @ 100 N (GPa)										Hardness - HRR				Compressibility 1X (um)		
	Nat Freq(kHz)			Position 1			Position 2			Position 3			Position 4			Avg	Range
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 1	Position 2	Position 3	Position 4	Position 1	Position 2	Position 4	Avg	@ 50 bar		
CF_18%	New Sample Cycle1	1438.6	5017.5	1075.4	2.0485	2.2356	1.9921	2.2570	2.1343	50.6	52.1	44.2	49.2	7.9	63.0		
	New Sample Cycle1	1438.6	5017.5	1075.4	2.0369	2.2269	1.9808	2.2442	2.1222	54.6	55.5	50.1	48.9	52.3	6.6		
	New Sample Cycle1	1411.4	4957	9948.4	2.0166	2.2048	1.9611	2.2219	2.1011	42.2	46.3	50.4	32.1	42.8	18.3		
	New Sample Cycle1	1438.6	5017.5	1075.4	2.0183	2.2065	1.9627	2.2237	2.1028	55.5	46.2	50.3	48.8	50.2	9.3		
<b>Avg</b>	<b>1431.8</b>	<b>5002.4</b>	<b>10119</b>	<b>2.0301</b>	<b>2.2194</b>	<b>1.9742</b>	<b>2.2367</b>	<b>2.1151</b>	<b>50.7</b>	<b>50.0</b>	<b>48.8</b>	<b>44.9</b>	<b>48.6</b>	<b>10.5</b>	<b>64.7</b>		
	-	-	<b>0.0319</b>	<b>0.0348</b>	<b>0.0310</b>	<b>0.0351</b>	<b>0.0332</b>	<b>13.3</b>	<b>9.3</b>	<b>6.2</b>	<b>17.7</b>	<b>9.5</b>	<b>11.7</b>	<b>3.8</b>			
CF_18%	New Sample1 Cycle 2	1438.6	5017.5	1075.4	2.0336	2.2257	2.0247	2.1952	2.198	49.8	55.2	48.6	50.2	51.0	6.6		
	New Sample1 Cycle 2	1438.6	5017.5	1075.4	2.0131	2.2032	2.0042	2.1730	2.0984	49.8	58.8	52.1	46.9	51.9	11.9		
	New Sample1 Cycle 2	1438.6	5017.5	9964.9	1.9975	2.1862	1.9887	2.1563	2.0822	45.2	45.1	50.2	36.8	44.3	13.4		
	New Sample1 Cycle 2	1438.6	5017.5	1075.4	1.9902	2.1782	1.9814	2.1483	2.0745	50.1	49.8	50.6	47.1	49.4	3.5		
	<b>Avg</b>	<b>1438.6</b>	<b>5017.5</b>	<b>10123</b>	<b>2.0086</b>	<b>2.1983</b>	<b>1.9998</b>	<b>2.1682</b>	<b>2.0937</b>	<b>48.7</b>	<b>52.2</b>	<b>50.4</b>	<b>45.3</b>	<b>49.1</b>	<b>8.9</b>		
CF_18%	-	-	<b>0.0434</b>	<b>0.0475</b>	<b>0.0432</b>	<b>0.0469</b>	<b>0.0453</b>	<b>4.9</b>	<b>13.7</b>	<b>3.5</b>	<b>13.4</b>	<b>7.6</b>	<b>9.9</b>	<b>6.1</b>			
	New Sample 1 Cycle 3	1438.6	5017.5	1075.4	2.0559	2.2482	1.9992	2.2447	2.1370	56.8	54.2	40.8	53.0	51.2	16.0		
	New Sample 1 Cycle 3	1438.6	5017.5	1075.4	2.0422	2.2332	1.9859	2.2297	2.1227	58.6	60.9	45.1	49.6	53.6	15.8		
	New Sample 1 Cycle 3	1438.6	5017.5	9948.6	2.0243	2.2136	1.9685	2.2102	2.1042	47.5	45.0	39.8	34.8	41.8	12.7		
	New Sample 1 Cycle 3	1438.6	5017.5	1075.4	2.0518	2.2436	1.9952	2.2402	2.1327	56.9	57.0	52.3	48.3	55.4	4.7		
<b>Avg</b>	<b>1438.6</b>	<b>5017.5</b>	<b>10119</b>	<b>2.0436</b>	<b>2.2347</b>	<b>1.9872</b>	<b>2.2312</b>	<b>2.1242</b>	<b>55.0</b>	<b>54.3</b>	<b>44.5</b>	<b>45.8</b>	<b>50.5</b>	<b>12.3</b>	<b>55.9</b>		
	-	-	<b>0.0316</b>	<b>0.0346</b>	<b>0.0307</b>	<b>0.0345</b>	<b>0.0328</b>	<b>11.1</b>	<b>15.9</b>	<b>12.5</b>	<b>18.2</b>	<b>13.6</b>	<b>11.3</b>	<b>8.3</b>			
CF_18%	New Sample 1 Cycle 4	1438.6	5017.5	1075.4	2.0516	2.2433	1.9951	2.2399	2.1325	58.9	58.2	59.6	50.8	56.9	8.8		
	New Sample 1 Cycle 4	1438.6	5017.5	1075.4	2.0396	2.2302	1.9834	2.2267	2.1200	54.3	60.7	52.5	50.5	54.5	10.2		
	New Sample 1 Cycle 4	1438.6	5017.5	9964.9	2.0197	2.2084	1.9640	2.2050	2.0993	49.6	48.6	41.4	40.2	45.0	9.4		
	New Sample 1 Cycle 4	1438.6	5017.5	1075.4	2.0185	2.2071	1.9628	2.2036	2.0980	50.1	56.1	52.0	54.4	53.2	6.0		
	<b>Avg</b>	<b>1438.6</b>	<b>5017.5</b>	<b>10123</b>	<b>2.0323</b>	<b>2.2222</b>	<b>1.9763</b>	<b>2.2188</b>	<b>2.1124</b>	<b>53.2</b>	<b>55.9</b>	<b>51.4</b>	<b>49.0</b>	<b>52.4</b>	<b>8.6</b>		
<b>Avg</b>	-	-	<b>0.0332</b>	<b>0.0363</b>	<b>0.0323</b>	<b>0.0345</b>	<b>9.3</b>	<b>12.1</b>	<b>18.2</b>	<b>14.2</b>	<b>11.9</b>	<b>4.2</b>	<b>7.0</b>				
	New Sample 1 Cycle 5	1438.6	5017.5	1075.4	2.0482	2.2394	1.9918	2.2360	2.1288	57.6	52.4	42.6	45.4	49.5	15.0		
	New Sample 1 Cycle 5	1438.6	5017.5	1075.4	2.0361	2.2253	1.9801	2.2228	2.1163	54.4	60.2	52.1	49.8	54.1	10.4		
	New Sample 1 Cycle 5	1438.6	5017.5	9964.4	2.0163	2.2045	1.9608	2.2011	2.0957	50.2	42.1	42.3	40.2	43.7	10.0		
	New Sample 1 Cycle 5	1438.6	5017.5	1075.4	2.0134	2.2014	1.9580	2.1980	2.0927	52.1	50.2	49.8	50.1	50.6	2.3		
<b>Avg</b>	<b>1438.6</b>	<b>5017.5</b>	<b>10123</b>	<b>2.0285</b>	<b>2.2179</b>	<b>1.9727</b>	<b>2.2145</b>	<b>2.1084</b>	<b>53.6</b>	<b>51.2</b>	<b>46.7</b>	<b>46.4</b>	<b>49.5</b>	<b>9.4</b>	<b>55.1</b>		
	-	-	<b>0.0348</b>	<b>0.0380</b>	<b>0.0338</b>	<b>0.0380</b>	<b>0.0362</b>	<b>7.4</b>	<b>18.1</b>	<b>9.8</b>	<b>9.9</b>	<b>10.4</b>	<b>12.7</b>	<b>8.1</b>			

## Appendix 1-2: Physical Properties of Low-Copper and Copper-Free NAO Pads: 100 Bars Compression

**TABLES 1-2-1** 1st cycle, 2nd cycle, 3rd cycle, 4<sup>th</sup> cycle and 5<sup>th</sup> cycle of low copper 13% porosity samples.

Samples	Nat Freq(kHz)				Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility 1X (um)				
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range			
LC_13%	New Sample Cycle 1	1614	54387.7	10736.9	3.1798	3.2893	3.1692	3.0107	3.1623	91.5	91.8	88.5	92.6	91.1	4.1	111.6	
	New Sample Cycle 1	1614	54387.7	10736.9	3.1903	3.1957	3.1690	3.4398	3.2487	82.5	92.9	84.8	91.6	88.0	10.4	93.5	
	New Sample Cycle 1	1614	54387.7	10736.9	3.2190	3.3595	3.5093	3.3945	3.3706	93.7	95.1	88.8	87.3	91.2	7.8	89.2	
	New Sample Cycle 1	1614	54387.7	10736.9	3.3099	3.4745	3.5678	3.2374	3.3974	87.6	93.8	93.4	92.2	6.2		85.0	
<b>Avg</b>		<b>1614</b>	<b>54387.7</b>	<b>10737</b>	<b>-</b>	<b>0.1301</b>	<b>0.2788</b>	<b>0.3558</b>	<b>3.2706</b>	<b>3.2947</b>	<b>88.8</b>	<b>93.4</b>	<b>89.0</b>	<b>91.2</b>	<b>90.6</b>	<b>7.1</b>	<b>94.8</b>
<b>Range</b>																	<b>26.6</b>
LC_13%	New Sample Cycle 2	1614	54035.5	10526.3	3.2034	3.3420	3.1980	2.9603	3.1759	86.9	90.7	82.0	96.1	88.9	14.1	99.7	
	New Sample Cycle 2	1614	54035.5	10526.3	3.1850	3.1797	3.1324	3.3913	3.2221	84.2	91.7	78.2	94.0	87.0	15.8	87.1	
	New Sample Cycle 2	1614	54035.5	10526.3	3.2171	3.3622	3.5112	3.4030	3.3754	92.3	97.7	82.1	92.9	91.3	15.6	83.2	
	New Sample Cycle 2	1614	54035.5	10526.3	3.2878	3.5044	3.5983	3.2656	3.4140	96.0	97.2	77.9	96.6	91.9	19.3	79.4	
<b>Avg</b>		<b>1614</b>	<b>54035.5</b>	<b>10526</b>	<b>3.2233</b>	<b>3.3471</b>	<b>3.3600</b>	<b>3.2551</b>	<b>3.2964</b>	<b>89.9</b>	<b>94.3</b>	<b>80.1</b>	<b>94.9</b>	<b>89.8</b>	<b>16.2</b>	<b>87.4</b>	
<b>Range</b>																	<b>20.3</b>
LC_13%	New Sample 1 Cycle 3	1614	54035.5	10526.3	3.1863	3.3689	3.2455	2.9889	3.1974	93.4	92.0	82.1	86.8	88.6	11.3	97.9	
	New Sample 1 Cycle 3	1614	54035.5	10526.3	3.2074	3.1967	3.1807	3.4869	3.2679	92.4	95.6	93.0	96.7	94.4	4.3	85.2	
	New Sample 1 Cycle 3	1614	54035.5	10526.3	3.2203	3.3652	3.5448	3.4834	3.4034	95.0	93.4	79.7	89.7	89.5	15.3	81.3	
	New Sample 1 Cycle 3	1614	54035.5	10526.3	3.3513	3.5174	3.5797	3.3285	3.4442	97.2	94.4	89.7	93.4	93.7	7.5	76.5	
<b>Avg</b>		<b>1614</b>	<b>54035.5</b>	<b>10526</b>	<b>3.2413</b>	<b>3.3620</b>	<b>3.3877</b>	<b>3.3219</b>	<b>3.3282</b>	<b>94.5</b>	<b>93.9</b>	<b>86.1</b>	<b>91.7</b>	<b>91.5</b>	<b>9.6</b>	<b>85.2</b>	
<b>Range</b>																	<b>21.4</b>
LC_13%	New Sample 1 Cycle 4	1614	54035.5	10526.3	3.22381	3.4135	3.2876	3.0359	3.2438	89.4	91.7	78.8	93.4	88.3	14.6	99.3	
	New Sample 1 Cycle 4	1614	54035.5	10526.3	3.2755	3.2317	3.1888	3.4659	3.2905	92.2	90.6	88.0	86.3	89.3	5.9	86.5	
	New Sample 1 Cycle 4	1614	54035.5	10526.3	3.2811	3.4124	3.5518	3.5331	3.4446	97.0	94.6	86.5	89.4	91.9	10.5	81.6	
	New Sample 1 Cycle 4	1614	54035.5	10526.3	3.3941	3.5952	3.62727	3.3252	3.4854	79.8	96.6	89.0	96.4	90.5	16.8	87.1	
<b>Avg</b>		<b>1614</b>	<b>54035.5</b>	<b>10526</b>	<b>3.2972</b>	<b>3.4132</b>	<b>3.4138</b>	<b>3.3400</b>	<b>3.3661</b>	<b>89.6</b>	<b>93.4</b>	<b>85.6</b>	<b>91.4</b>	<b>90.0</b>	<b>12.0</b>	<b>88.6</b>	
<b>Range</b>																<b>17.7</b>	
LC_13%	New Sample 1 Cycle 5	1614	54387.7	10736.9	3.2581	3.3476	3.2200	2.9859	3.2029	91.5	95.2	81.3	94.5	90.6	13.9	98.6	
	New Sample 1 Cycle 5	1614	54387.7	10736.9	3.2317	3.1729	3.1572	3.4539	3.2539	91.6	96.2	92.6	90.4	92.7	5.8	86.9	
	New Sample 1 Cycle 5	1614	54387.7	10736.9	3.2143	3.3760	3.5317	3.5132	3.4088	96.0	93.0	94.0	91.1	93.5	4.9	82.1	
	New Sample 1 Cycle 5	1614	54387.7	10736.9	2.9886	3.1867	3.1923	2.9835	3.0878	89.9	93.5	90.4	94.8	92.2	4.9	79.8	
<b>Avg</b>		<b>1614</b>	<b>54387.7</b>	<b>10737</b>	<b>3.1732</b>	<b>3.2708</b>	<b>3.2753</b>	<b>3.2341</b>	<b>3.2384</b>	<b>94.5</b>	<b>89.6</b>	<b>92.7</b>	<b>92.3</b>	<b>7.4</b>	<b>86.9</b>		
<b>Range</b>																<b>18.8</b>	

**TABLES 1-2-2** 1st cycle, 2nd cycle, 3<sup>rd</sup> cycle, 4<sup>th</sup> cycle and 5<sup>th</sup> cycle of low copper 18% porosity samples.

Samples	Nat Freq(kHz)						Modulus @ 100 N (GPa)						Hardness - HRR						Compressibility 1X (um)															
	Peak 1			Peak 2	Peak 3	Peak 4	Position 1			Position 2	Position 3	Position 4	Avg	Position 1			Position 2	Position 3	Position 4	Avg	Range													
	LC_18%	New Sample Cycle 1	1403.5	5122.8	10175.4	2.6488	2.5811	3.0706	3.0256	2.8315	78.8	86.8	67.3	73.1	76.5	19.5	94.3	New Sample Cycle 1	1403.5	5122.8	10175.4	2.6942	2.7448	3.0655	2.9418	2.8631	79.1	90.0	73.5	69.6	78.1	20.4	91.2	
<b>Avg</b>	<b>Range</b>	New Sample Cycle 1	1403.5	5122.8	10175.4	2.8622	2.8668	2.5718	2.6111	2.7280	69.4	69.8	70.0	77.7	71.7	8.3	98.1	New Sample Cycle 1	1403.5	5122.8	10175.4	2.6971	2.7311	2.9611	2.8853	2.8138	77.1	80.3	69.1	72.5	74.8	16.0	94.6	
		New Sample1 Cycle 2	1403.5	5122.8	10175.4	2.4876	2.6787	3.1282	2.9730	2.8169	82.1	85.9	85.9	71.9	81.5	14.0	86.7	New Sample1 Cycle 2	1403.5	5122.8	10175.4	2.6193	2.5450	3.0950	2.9610	2.8051	80.7	84.4	89.9	72.5	81.9	17.4	87.4	
<b>Avg</b>	<b>Range</b>	New Sample1 Cycle 2	1403.5	5122.8	10175.4	2.6566	2.7230	3.0150	2.9472	2.8354	78.4	90.7	60.4	69.3	74.7	30.3	85.5	New Sample1 Cycle 2	1403.5	5122.8	10175.4	2.8395	2.5486	2.5525	2.6950	2.627	78.9	61.1	79.5	75.6	75.6	21.6	82.4	
		New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.6508	2.6966	2.9467	2.8584	2.7881	81.0	85.0	74.3	73.3	78.4	20.8	85.5	New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.5181	2.6789	3.1848	3.0160	2.8494	82.0	77.2	64.0	79.8	75.8	18.0	84.4	
<b>Avg</b>	<b>Range</b>	New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.5767	3.0937	3.0087	2.8410	2.7840	79.2	85.4	62.7	81.3	77.2	22.7	84.0	New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.6861	2.6944	3.1623	2.9759	2.8797	82.5	93.3	66.5	78.4	80.2	26.8	81.0	
		New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.8566	2.8475	2.5749	2.5365	2.7039	68.4	69.8	80.0	84.3	75.6	15.9	79.4	New Sample1 Cycle 3	1403.5	5122.8	10175.4	2.6864	3.0039	2.8843	2.8185	2.8185	78.0	81.4	81.0	77.2	20.9	82.2	5.0	
<b>Avg</b>	<b>Range</b>	New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.6099	0.2708	0.3585	0.4795	0.1758	14.1	23.5	17.3	5.9	4.6	10.9	5.0	New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.5235	2.6850	3.1982	3.0283	2.8588	87.3	89.7	61.9	84.2	80.8	27.8	88.7	
		New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.6857	2.5659	3.1521	3.0149	2.8546	86.9	89.0	71.6	77.9	81.4	17.4	83.8	New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.7200	2.7454	3.1367	3.0203	2.9056	84.5	89.3	76.4	78.3	82.1	12.9	80.0	
<b>Avg</b>	<b>Range</b>	New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.9038	2.8946	2.6123	2.5648	2.7489	80.7	73.5	76.3	86.0	79.1	12.5	78.7	New Sample1 Cycle 4	1403.5	5122.8	10175.4	2.8813	2.9038	2.9227	2.0248	2.9121	84.9	85.4	71.6	81.6	80.8	17.7	82.8	
		New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.6840	2.7233	2.0175	2.3045	0.3287	83.0	85.9	14.5	8.1	3.0	15.3	10.0	New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.6250	2.5328	2.6953	3.1637	3.0160	2.8520	84.4	90.0	64.3	74.5	78.3	25.7	85.5
<b>Avg</b>	<b>Range</b>	New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.6250	2.5778	3.1467	3.0002	2.8374	84.1	86.6	85.0	71.0	81.7	15.6	84.8	New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.6971	2.7391	2.5773	3.0878	3.0980	2.9055	78.0	86.5	85.2	87.4	84.3	9.4	80.2
		New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.8813	2.5648	2.5773	2.5734	2.7283	88.5	72.3	85.4	92.2	84.6	19.9	78.3	New Sample1 Cycle 5	1403.5	5122.8	10175.4	2.7233	2.9939	2.9219	2.8308	2.8308	83.8	80.0	81.3	82.2	17.7	82.2	7.2	
<b>Avg</b>	<b>Range</b>	-	-	-	-	0.3485	0.3035	0.5865	0.5246	0.1772	10.5	17.7	21.1	21.2	21.2	6.3	16.3	-	-	-	-	-	-	-	-	-								

**TABLES 1-2-3** 1st Cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of low copper 22% porosity samples.

Samples	Nat Freq(kHz)				Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility				
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 100 bar		
LC_22%	New Sample Cycle 1	1333.3	4738.6	9649.1	1.7606	1.9601	2.2867	2.1396	<b>2.0367</b>	67.3	59.8	40.5	57.0	<b>56.2</b>	26.8	138.3	
	New Sample Cycle 1	1333.3	4738.6	9649.1	1.7224	1.5323	2.3693	2.0963	<b>1.9301</b>	70.4	69.2	32.7	45.6	<b>54.5</b>	37.7	127.9	
	New Sample Cycle 1	1333.3	4738.6	9649.1	1.9288	1.6143	2.2798	2.0611	<b>1.9710</b>	62.0	69.4	55.6	61.9	<b>62.2</b>	13.8	133.2	
	New Sample Cycle 1	1333.3	4738.6	9649.1	1.6702	1.6514	2.3498	1.9707	<b>1.9105</b>	70.0	70.7	43.3	46.7	<b>57.7</b>	27.4	132.5	
	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>1.7705</b>	<b>1.6895</b>	<b>2.3214</b>	<b>2.0669</b>	<b>1.9621</b>	<b>67.4</b>	<b>67.3</b>	<b>43.0</b>	<b>52.8</b>	<b>57.6</b>	<b>26.4</b>	<b>133.0</b>	
LC_22%	New Sample Cycle 2	1333.3	4738.6	9649.1	-	<b>0.2587</b>	<b>0.4278</b>	<b>0.0896</b>	<b>0.1688</b>	<b>0.1262</b>	<b>8.4</b>	<b>10.9</b>	<b>22.9</b>	<b>16.3</b>	<b>7.8</b>	<b>23.9</b>	<b>10.4</b>
	New Sample Cycle 2	1333.3	4738.6	9649.1	-	-	-	-	-	-	-	-	-	-	-	-	
	New Sample Cycle 2	1333.3	4738.6	9649.1	1.6429	1.5166	2.3290	2.0677	<b>1.8890</b>	78.4	65.9	32.6	41.0	<b>54.5</b>	45.8	117.0	
	New Sample Cycle 2	1333.3	4738.6	9649.1	1.8863	1.5991	2.2853	2.0143	<b>1.9462</b>	74.6	69.2	54.6	58.5	<b>64.2</b>	20.0	122.1	
	New Sample Cycle 2	1333.3	4738.6	9649.1	1.6404	1.6120	2.3065	1.8646	<b>1.8558</b>	69.7	69.3	49.6	51.0	<b>59.9</b>	20.1	122.9	
Avg	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>1.7204</b>	<b>1.6719</b>	<b>2.2818</b>	<b>2.0017</b>	<b>1.9190</b>	<b>71.3</b>	<b>67.3</b>	<b>46.9</b>	<b>50.5</b>	<b>59.0</b>	<b>25.0</b>	<b>122.1</b>	
	New Sample 1 Cycle 3	1333.3	4738.6	9649.1	-	<b>0.2459</b>	<b>0.4433</b>	<b>0.1224</b>	<b>0.2031</b>	<b>0.1289</b>	<b>16.0</b>	<b>4.5</b>	<b>22.0</b>	<b>17.5</b>	<b>9.7</b>	<b>31.9</b>	<b>9.5</b>
	New Sample 1 Cycle 3	1333.3	4738.6	9649.1	1.7321	1.9637	2.2616	2.0930	<b>2.0126</b>	70.9	57.4	51.1	65.2	<b>61.2</b>	19.8	122.3	
	New Sample 1 Cycle 3	1333.3	4738.6	9649.1	1.6986	1.5197	2.3834	2.0699	<b>1.9179</b>	75.1	72.9	31.2	51.5	<b>57.7</b>	43.9	113.3	
	New Sample 1 Cycle 3	1333.3	4738.6	9649.1	1.9158	1.6153	2.7238	2.0490	<b>2.0760</b>	74.0	79.4	53.1	64.0	<b>67.6</b>	26.3	118.1	
Avg	New Sample 1 Cycle 3	1333.3	4738.6	9649.1	1.6808	1.6109	2.3240	1.9046	<b>1.8801</b>	71.3	72.9	55.5	47.6	<b>61.8</b>	25.3	120.4	
	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>1.7568</b>	<b>1.6774</b>	<b>2.4232</b>	<b>2.0291</b>	<b>1.9716</b>	<b>72.8</b>	<b>70.7</b>	<b>47.7</b>	<b>57.1</b>	<b>62.1</b>	<b>28.8</b>	<b>118.5</b>	
	New Sample 1 Cycle 4	1333.3	4738.6	9649.1	-	<b>0.2350</b>	<b>0.4440</b>	<b>0.4632</b>	<b>0.1884</b>	<b>0.1959</b>	<b>4.2</b>	<b>22.0</b>	<b>24.3</b>	<b>17.6</b>	<b>10.0</b>	<b>24.1</b>	<b>9.0</b>
	New Sample 1 Cycle 4	1333.3	4738.6	9649.1	1.7337	2.0040	2.2679	2.1073	<b>2.0283</b>	72.4	62.1	55.6	67.6	<b>64.4</b>	16.8	121.7	
	New Sample 1 Cycle 4	1333.3	4738.6	9649.1	1.7180	1.5548	2.3836	2.0963	<b>1.9382</b>	70.5	74.5	39.9	40.5	<b>56.4</b>	34.6	116.1	
Avg	New Sample 1 Cycle 4	1333.3	4738.6	9649.1	1.9242	1.6339	2.3165	2.0612	<b>1.9839</b>	76.0	70.7	67.4	62.9	<b>69.3</b>	13.1	117.1	
	New Sample 1 Cycle 4	1333.3	4738.6	9649.1	1.6885	1.6426	2.3473	1.9167	<b>1.8983</b>	75.2	79.9	67.2	50.8	<b>68.3</b>	29.1	118.6	
	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>1.7656</b>	<b>1.7088</b>	<b>2.3288</b>	<b>2.0454</b>	<b>1.9622</b>	<b>73.5</b>	<b>71.8</b>	<b>57.5</b>	<b>55.5</b>	<b>64.6</b>	<b>23.4</b>	<b>118.4</b>	
	New Sample 1 Cycle 5	1333.3	4738.6	9649.1	-	<b>0.2377</b>	<b>0.4493</b>	<b>0.1157</b>	<b>0.1907</b>	<b>0.1300</b>	<b>5.5</b>	<b>17.8</b>	<b>27.5</b>	<b>27.1</b>	<b>12.9</b>	<b>21.5</b>	<b>5.6</b>
	New Sample 1 Cycle 5	1333.3	4738.6	9649.1	1.7296	1.9189	2.2420	2.0929	<b>1.9959</b>	75.0	61.1	64.8	65.5	<b>66.6</b>	13.9	121.8	
Avg	New Sample 1 Cycle 5	1333.3	4738.6	9649.1	1.6876	1.4995	2.3651	2.0608	<b>1.9032</b>	70.0	76.0	49.5	53.6	<b>62.3</b>	26.5	113.0	
	New Sample 1 Cycle 5	1333.3	4738.6	9649.1	1.8828	1.7652	2.2921	2.0551	<b>1.9988</b>	68.8	72.2	70.3	70.1	<b>70.4</b>	3.4	117.4	
	New Sample 1 Cycle 5	1333.3	4738.6	9649.1	1.6526	1.6280	2.3088	1.9189	<b>1.8771</b>	70.2	79.1	50.6	57.3	<b>64.3</b>	28.5	119.3	
	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>1.7381</b>	<b>1.7029</b>	<b>2.3020</b>	<b>2.0319</b>	<b>1.9437</b>	<b>71.0</b>	<b>72.1</b>	<b>58.8</b>	<b>61.6</b>	<b>65.9</b>	<b>18.1</b>	<b>117.9</b>	
	<b>Avg</b>	<b>1333.3</b>	<b>4738.6</b>	<b>9649.1</b>	<b>-</b>	<b>-</b>	<b>0.2303</b>	<b>0.4193</b>	<b>0.1231</b>	<b>0.1741</b>	<b>6.2</b>	<b>18.0</b>	<b>20.8</b>	<b>16.5</b>	<b>8.1</b>	<b>25.1</b>	<b>8.8</b>

**TABLES 1-2-4** 1st cycle, 2nd cycle, 3<sup>rd</sup> cycle, 4<sup>th</sup> cycle and 5<sup>th</sup> cycle of Copper Free 13% porosity.

Samples		Modulus @ 100 N (Gpa)						Compressibility 1X (um)						
		Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg
CF_13%	New Sample Cycle 1	1649.1	5298.2	10701.8	2.1949	2.9267	2.4756	2.4291	72.3	75.0	66.0	69.7	70.8	9.0
	New Sample Cycle 1	1649.1	5614	10807	2.8671	2.8071	2.7155	2.8002	80.6	73.7	71.1	76.0	75.4	9.5
	New Sample Cycle 1	1649.1	5614	10807	3.0848	3.0324	2.9218	3.0067	3.0115	70.6	74.8	67.3	72.1	7.5
	New Sample Cycle 1	1649.1	5614	10807	2.5495	2.6001	2.5646	2.7066	2.6052	77.2	73.0	80.0	76.9	7.0
	<b>Avg</b>	<b>1649.1</b>	<b>5535.1</b>	<b>10781</b>	<b>2.6551</b>	<b>2.6596</b>	<b>2.8050</b>	<b>2.7261</b>	<b>2.7115</b>	<b>75.2</b>	<b>69.4</b>	<b>74.5</b>	<b>73.5</b>	<b>8.3</b>
CF_13%	-	-	<b>0.9658</b>	<b>0.8376</b>	<b>0.3621</b>	<b>0.5311</b>	<b>0.5824</b>	<b>10.0</b>	<b>3.5</b>	<b>7.0</b>	<b>10.3</b>	<b>6.1</b>	<b>2.5</b>	<b>58.4</b>
	New Sample1 Cycle 2	1649.1	5543.9	10701.8	2.2408	2.3390	2.8181	2.4326	2.4576	72.0	77.7	58.8	70.9	69.9
	New Sample1 Cycle 2	1649.1	5614	11017.5	2.9133	2.8749	2.8606	2.6978	2.8357	74.2	66.6	71.4	74.7	8.1
	New Sample1 Cycle 2	1649.1	5614	11017.5	3.0453	2.9687	2.8902	2.9438	2.9620	78.2	73.2	77.1	76.8	76.3
	New Sample1 Cycle 2	1649.1	5614	11052.6	2.5601	2.5964	2.5842	2.7147	2.6139	76.0	78.9	68.8	81.3	76.3
CF_13%	<b>Avg</b>	<b>1649.1</b>	<b>5596.5</b>	<b>10947</b>	<b>2.6899</b>	<b>2.6948</b>	<b>2.7883</b>	<b>2.6972</b>	<b>2.7175</b>	<b>75.1</b>	<b>74.1</b>	<b>69.0</b>	<b>75.9</b>	<b>11.1</b>
	<b>Range</b>	-	-	<b>0.8045</b>	<b>0.6297</b>	<b>0.3059</b>	<b>0.5112</b>	<b>0.5044</b>	<b>6.2</b>	<b>12.3</b>	<b>18.3</b>	<b>10.4</b>	<b>6.5</b>	<b>13.9</b>
	New Sample 1 Cycle 3	1649.1	5543.9	10701.8	2.2597	2.3035	2.7894	2.4391	2.4479	69.3	76.5	69.3	71.4	71.6
	New Sample 1 Cycle 3	1649.1	5614	10982.5	2.9496	2.8720	2.8911	2.6908	2.8508	74.5	73.3	71.4	79.2	74.6
	New Sample 1 Cycle 3	1649.1	5614	10982.5	3.0715	2.9838	2.8568	2.9241	2.9590	79.0	75.0	78.7	79.0	77.9
CF_13%	New Sample 1 Cycle 3	1649.1	5614	10947.4	2.5566	2.6341	2.5606	2.7372	2.6221	76.8	81.5	72.4	79.2	77.5
	<b>Avg</b>	<b>1649.1</b>	<b>5596.5</b>	<b>10904</b>	<b>2.7093</b>	<b>2.6983</b>	<b>2.7745</b>	<b>2.6978</b>	<b>2.7200</b>	<b>74.9</b>	<b>76.6</b>	<b>73.0</b>	<b>77.2</b>	<b>75.4</b>
	<b>Range</b>	-	-	<b>0.8118</b>	<b>0.6803</b>	<b>0.3305</b>	<b>0.4851</b>	<b>0.5111</b>	<b>9.7</b>	<b>8.2</b>	<b>9.4</b>	<b>7.8</b>	<b>6.3</b>	<b>5.1</b>
	New Sample 1 Cycle 4	1649.1	5543.9	10701.8	2.2431	2.3276	2.7533	2.4022	2.4316	80.8	85.5	64.0	83.1	78.4
	New Sample 1 Cycle 4	1649.1	5614	10982.5	2.9004	2.8386	2.8386	2.6644	2.8105	75.4	71.8	66.2	84.0	74.4
CF_13%	New Sample 1 Cycle 4	1649.1	5614	10982.5	3.0333	2.9721	2.8646	2.9030	2.9433	70.8	70.2	68.7	83.2	73.2
	New Sample 1 Cycle 4	1649.1	5614	10947.4	2.5211	2.5566	2.5486	2.6849	2.5778	85.3	84.0	64.9	80.5	78.7
	<b>Avg</b>	<b>1649.1</b>	<b>5596.5</b>	<b>10904</b>	<b>2.6745</b>	<b>2.6737</b>	<b>2.7513</b>	<b>2.6637</b>	<b>2.6908</b>	<b>78.1</b>	<b>77.9</b>	<b>66.0</b>	<b>82.7</b>	<b>76.2</b>
	<b>Range</b>	-	-	<b>0.7902</b>	<b>0.6446</b>	<b>0.3160</b>	<b>0.5008</b>	<b>0.5117</b>	<b>14.5</b>	<b>15.3</b>	<b>4.7</b>	<b>3.5</b>	<b>5.5</b>	<b>7.0</b>
	New Sample 1 Cycle 5	1649.1	5543.9	10701.8	2.2217	2.3186	2.7775	2.3928	2.4276	74.4	75.6	69.3	84.2	75.9
CF_13%	New Sample 1 Cycle 5	1649.1	5614	10982.5	2.9133	2.8418	2.8512	2.6720	2.8196	70.1	76.0	63.1	78.8	72.0
	New Sample 1 Cycle 5	1649.1	5614	10982.5	3.0662	2.9687	2.8710	2.9144	2.9551	63.6	75.3	75.6	74.1	71.7
	New Sample 1 Cycle 5	1649.1	5614	10947.4	2.5119	2.5515	2.5277	2.6588	2.5625	85.2	75.8	78.8	84.8	81.2
	<b>Avg</b>	<b>1649.1</b>	<b>5596.5</b>	<b>10904</b>	<b>2.6783</b>	<b>2.6702</b>	<b>2.7568</b>	<b>2.6595</b>	<b>2.6912</b>	<b>73.3</b>	<b>75.2</b>	<b>71.7</b>	<b>80.5</b>	<b>75.2</b>
	<b>Range</b>	-	-	<b>0.8445</b>	<b>0.6501</b>	<b>0.3434</b>	<b>0.5216</b>	<b>0.5274</b>	<b>21.6</b>	<b>2.7</b>	<b>15.7</b>	<b>10.7</b>	<b>9.5</b>	<b>6.3</b>

**TABLES 1-2-5** 1st cycle, 2nd cycle, 3rd cycle, 4th cycle and 5th cycle of Copper Free 18% porosity.

Samples	Nat Freq(kHz)					Modulus @ 100 N					Hardness - HRR					Compressibility	
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 100 bar	1X	
CF_18%	New Sample 1 Cycle1	1508.8	5263.2	10842.1	1.0728	1.0566	1.0712	1.0679	<b>1.0671</b>	59.3	60.1	67.3	60.5	<b>61.8</b>	8.0	135.8	
	New Sample 1 Cycle1	1508.8	5263.2	10842.1	1.0580	1.1411	1.1629	1.1501	<b>1.1280</b>	58.2	55.3	53.4	57.1	<b>56.0</b>	4.8	104.2	
	New Sample 1 Cycle1	1508.8	5263.2	10912.3	1.1521	1.1341	1.1217	1.1288	<b>1.1342</b>	69.8	64.9	60.4	66.3	<b>65.4</b>	9.4	131.2	
	New Sample 1 Cycle1	1508.8	5263.2	10982.5	1.1300	1.1100	1.0000	1.0600	<b>1.0600</b>	57.0	54.9	64.5	66.1	<b>60.6</b>	11.2	157.6	
<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10912</b>	<b>1.1134</b>	<b>1.1284</b>	<b>1.0949</b>	<b>1.0929</b>	<b>1.1074</b>	<b>61.7</b>	<b>58.4</b>	<b>59.4</b>	<b>63.2</b>	<b>60.7</b>	<b>8.5</b>	<b>131.0</b>		
	-	-	<b>0.0941</b>	<b>0.0310</b>	<b>0.1629</b>	<b>0.1501</b>	<b>0.0742</b>	<b>12.8</b>	<b>10.0</b>	<b>11.1</b>	<b>9.2</b>	<b>9.3</b>	<b>6.4</b>	<b>53.4</b>			
CF_18%	New Sample 1 Cycle2	1508.8	5263.2	10491.2	1.0606	1.0658	1.0687	1.0494	<b>1.0606</b>	62.4	62.9	56.8	57.2	<b>59.8</b>	6.1	127.3	
	New Sample 1 Cycle2	1508.8	5263.2	10526.3	1.0724	1.1092	1.1682	1.1161	<b>1.1165</b>	62.8	51.6	61.1	53.5	<b>57.3</b>	11.2	95.8	
	New Sample 1 Cycle2	1508.8	5263.2	10550.9	1.1582	1.1656	1.1206	1.1241	<b>1.1421</b>	62.2	56.8	54	57.4	<b>57.6</b>	8.2	125.8	
	New Sample 1 Cycle2	1508.8	5263.2	10982.5	1.0816	1.0934	0.9837	0.9680	<b>1.0317</b>	58.9	54	65.9	71.4	<b>62.6</b>	17.4	147.7	
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10588</b>	<b>1.0932</b>	<b>1.1080</b>	<b>1.0853</b>	<b>1.0644</b>	<b>1.0877</b>	<b>61.6</b>	<b>56.3</b>	<b>59.5</b>	<b>59.9</b>	<b>59.3</b>	<b>10.7</b>	<b>124.2</b>	
CF_18%	-	-	<b>0.0977</b>	<b>0.1018</b>	<b>0.1845</b>	<b>0.1561</b>	<b>0.1105</b>	<b>3.9</b>	<b>11.3</b>	<b>11.9</b>	<b>17.9</b>	<b>5.3</b>	<b>11.3</b>	<b>51.9</b>			
	New Sample 1 Cycle3	1508.8	5263.2	10350.9	1.0658	1.0789	1.0839	1.0561	<b>1.0711</b>	67.6	70.1	55.9	57.3	<b>62.7</b>	14.2	125.5	
	New Sample 1 Cycle3	1508.8	5263.2	10526.3	1.0652	1.0733	1.1601	1.1224	<b>1.1053</b>	57	55.2	63.1	51.3	<b>56.7</b>	11.8	94.6	
	New Sample 1 Cycle3	1508.8	5263.2	10526.3	1.1621	1.1566	1.1367	1.1208	<b>1.1441</b>	68.3	61.4	64.9	70.1	<b>66.2</b>	8.7	124	
	New Sample 1 Cycle3	1508.8	5263.2	10526.3	1.1019	1.0900	1.0028	0.9881	<b>1.0457</b>	60.3	59.4	68.3	69.9	<b>64.5</b>	10.5	146	
CF_18%	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10482</b>	<b>1.0987</b>	<b>1.0997</b>	<b>1.0959</b>	<b>1.0719</b>	<b>1.0915</b>	<b>63.3</b>	<b>61.5</b>	<b>63.1</b>	<b>62.2</b>	<b>62.5</b>	<b>11.3</b>	<b>122.5</b>	
	-	-	-	<b>0.0969</b>	<b>0.0833</b>	<b>0.1573</b>	<b>0.1543</b>	<b>0.0984</b>	<b>11.3</b>	<b>14.9</b>	<b>12.4</b>	<b>18.8</b>	<b>9.5</b>	<b>5.5</b>	<b>51.4</b>		
	New Sample 1 Cycle4	1508.8	5263.2	10350.9	1.0439	1.0663	1.0811	1.0486	<b>1.0600</b>	64.3	64.8	61.2	59.5	<b>62.5</b>	5.3	130.7	
	New Sample 1 Cycle4	1508.8	5263.2	10526.3	1.0429	1.0350	1.1462	1.0919	<b>1.0790</b>	58.7	50.2	50.1	61.5	<b>55.1</b>	11.4	95.3	
	New Sample 1 Cycle4	1508.8	5263.2	10526.3	1.1548	1.1733	1.1297	1.1192	<b>1.1443</b>	63	78.7	89.9	67.6	<b>74.8</b>	26.9	125	
CF_18%	New Sample 1 Cycle4	1508.8	5263.2	10526.3	1.1035	1.0135	0.9976	0.9703	<b>1.0437</b>	57.9	54.4	64.5	71.3	<b>62.0</b>	16.9	144.2	
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10482</b>	<b>1.0863</b>	<b>1.0945</b>	<b>1.0886</b>	<b>1.0575</b>	<b>1.0817</b>	<b>61.0</b>	<b>62.0</b>	<b>66.4</b>	<b>65.0</b>	<b>63.6</b>	<b>15.1</b>	<b>123.8</b>	
	-	-	<b>0.1120</b>	<b>0.1383</b>	<b>0.1487</b>	<b>0.1489</b>	<b>0.1005</b>	<b>6.4</b>	<b>28.5</b>	<b>39.8</b>	<b>11.8</b>	<b>19.7</b>	<b>21.6</b>	<b>48.9</b>			
	New Sample 1 Cycle5	1508.8	5263.2	10350.9	1.0711	1.0662	1.0678	1.0360	<b>1.0603</b>	61	59.9	52.6	62.5	<b>59.0</b>	9.9	123.6	
	New Sample 1 Cycle5	1508.8	5263.2	10526.3	1.0732	1.0831	1.1729	1.1258	<b>1.1137</b>	53.2	57.5	60.5	52.4	<b>55.9</b>	8.1	92.2	
CF_18%	New Sample 1 Cycle5	1508.8	5263.2	10526.3	1.1246	1.1459	1.1004	1.1176	<b>1.1221</b>	72.4	56.3	51.9	72	<b>63.2</b>	20.5	120.7	
	New Sample 1 Cycle5	1508.8	5263.2	10526.3	1.0713	0.9608	0.9622	1.0164	<b>1.0164</b>	57.6	57.3	60.7	76.9	<b>63.1</b>	19.6	141.3	
	<b>Avg</b>	<b>1508.8</b>	<b>5263.2</b>	<b>10482</b>	<b>1.0850</b>	<b>1.0916</b>	<b>1.0755</b>	<b>1.0604</b>	<b>1.0781</b>	<b>61.1</b>	<b>57.8</b>	<b>56.4</b>	<b>66.0</b>	<b>60.3</b>	<b>14.5</b>	<b>119.5</b>	
<b>Range</b>	-	-	<b>0.0535</b>	<b>0.0798</b>	-	-	-	-	-	<b>3.6</b>	<b>8.8</b>	<b>24.5</b>	<b>7.3</b>	<b>12.4</b>	<b>49.1</b>		

**TABLES 1-2-6** 1st cycle, 2nd cycle, 3<sup>rd</sup> cycle, 4<sup>th</sup> cycle and 5<sup>th</sup> cycle of Copper Free 22% porosity.

Samples	Nat Freq(kHz)						Modulus @ 100 N (GPa)						Compressibility 1X (um)								
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 100 bar
CF_22%	New Sample Cycle 1	1438.6	4561.4	9614	1.9931	2.0683	1.8678	1.9137	1.9607	25.7	35.0	35.2	35.3	19.5	35.3	141.2	35.2	17.5	35.2	17.5	129.7
	New Sample Cycle 1	1438.6	4561.4	9614	2.0229	2.1742	1.8012	1.9335	1.9829	27.7	30.1	37.8	45.2	34.7	42.9	34.7	42.9	34.7	34.7	34.7	134.8
	New Sample Cycle 1	1438.6	4701.8	9859.6	2.1793	1.9455	1.9950	1.9950	2.0863	26.9	49.0	61.6	61.6	34.7	7.1	37.3	7.1	37.3	7.1	37.3	151.0
	New Sample Cycle 1	1438.6	4701.8	9614	1.9455	1.9455	1.8690	1.9264	1.9264	38.2	33.7	36.5	40.8	37.3	7.1	37.3	7.1	37.3	7.1	37.3	134.8
	<b>Avg</b>	<b>1438.6</b>	<b>4631.6</b>	<b>9675.4</b>	<b>2.0352</b>	<b>2.0910</b>	<b>1.9024</b>	<b>1.9278</b>	<b>1.9891</b>	<b>31.4</b>	<b>31.4</b>	<b>39.6</b>	<b>48.2</b>	<b>37.7</b>	<b>19.7</b>	<b>37.7</b>	<b>19.7</b>	<b>37.7</b>	<b>19.7</b>	<b>37.7</b>	<b>139.2</b>
CF_22%	New Sample1 Cycle 2	1438.6	4947.4	10105.3	1.9528	2.0316	1.8573	1.8758	1.9294	24.8	39.2	41.3	50.5	39.0	25.7	39.0	25.7	39.0	25.7	39.0	129.7
	New Sample1 Cycle 2	1438.6	5017.5	10189.3	2.0177	2.1748	1.8172	1.9796	1.9973	25.9	29.3	32.1	44.2	32.9	18.3	32.9	18.3	32.9	18.3	32.9	119.1
	New Sample1 Cycle 2	1438.6	5017.5	10175.4	2.1273	2.1664	1.9580	1.9751	2.0567	32.5	29.1	47.2	61.3	42.5	32.2	42.5	32.2	42.5	32.2	42.5	128.0
	New Sample1 Cycle 2	1438.6	5017.5	10175.4	1.9270	1.9437	1.9270	1.8363	1.9085	42.0	31.8	43.2	37.2	38.6	11.4	38.6	11.4	38.6	11.4	38.6	139.2
	<b>Avg</b>	<b>1438.6</b>	<b>5000.0</b>	<b>10161</b>	<b>2.0062</b>	<b>2.0791</b>	<b>1.8899</b>	<b>1.9167</b>	<b>1.9730</b>	<b>31.3</b>	<b>32.4</b>	<b>41.0</b>	<b>48.3</b>	<b>38.2</b>	<b>21.9</b>	<b>38.2</b>	<b>21.9</b>	<b>38.2</b>	<b>21.9</b>	<b>38.2</b>	<b>132.3</b>
CF_22%	-	-	-	<b>0.2003</b>	<b>0.2311</b>	<b>0.1408</b>	<b>0.1434</b>	<b>0.1482</b>	<b>17.2</b>	<b>10.1</b>	<b>15.1</b>	<b>24.1</b>	<b>9.7</b>	<b>20.8</b>	<b>9.7</b>	<b>20.8</b>	<b>9.7</b>	<b>20.8</b>	<b>9.7</b>	<b>20.8</b>	<b>11.2</b>
	New Sample1 Cycle 3	1438.6	4947.4	10105.3	1.9589	2.0502	1.8603	1.8896	1.9397	26.9	33.9	43.7	33.6	33.6	16.8	33.6	16.8	33.6	16.8	33.6	127.8
	New Sample1 Cycle 3	1438.6	5017.5	10175.4	2.0189	2.1761	1.8208	1.9751	1.9977	27.1	30.3	33.9	45.8	34.3	18.7	34.3	18.7	34.3	18.7	34.3	119.7
	New Sample1 Cycle 3	1438.6	5017.5	10175.4	2.3308	2.3518	2.1503	2.1816	2.2536	33.0	26.3	51.9	59.3	42.6	33.0	42.6	33.0	42.6	33.0	42.6	126.8
	New Sample1 Cycle 3	1438.6	5017.5	10175.4	1.9362	1.9530	1.9506	1.8447	1.9161	36.3	38.3	35.7	45.5	39.0	9.8	39.0	9.8	39.0	9.8	39.0	138.8
CF_22%	<b>Avg</b>	<b>1438.6</b>	<b>5000.0</b>	<b>10158</b>	<b>2.0612</b>	<b>2.1328</b>	<b>1.9405</b>	<b>1.9727</b>	<b>2.0268</b>	<b>30.8</b>	<b>32.2</b>	<b>37.9</b>	<b>48.6</b>	<b>37.4</b>	<b>19.6</b>	<b>37.4</b>	<b>19.6</b>	<b>37.4</b>	<b>19.6</b>	<b>37.4</b>	<b>128.3</b>
	-	-	-	<b>0.3946</b>	<b>0.3988</b>	<b>0.3295</b>	<b>0.3368</b>	<b>0.3375</b>	<b>9.4</b>	<b>12.0</b>	<b>22.0</b>	<b>15.6</b>	<b>9.0</b>	<b>23.2</b>	<b>9.0</b>	<b>23.2</b>	<b>9.0</b>	<b>23.2</b>	<b>9.0</b>	<b>23.2</b>	<b>19.1</b>
	New Sample1 Cycle 4	1438.6	4947.4	10105.3	1.9327	2.0073	1.8439	1.8675	1.9128	42.9	46.8	39.0	52.0	45.2	13.0	45.2	13.0	45.2	13.0	45.2	129.0
	New Sample1 Cycle 4	1438.6	5017.5	10175.4	2.0124	2.1457	1.8054	1.9861	1.9874	26.3	26.7	32.2	49.9	33.8	23.6	33.8	23.6	33.8	23.6	33.8	117.7
	New Sample1 Cycle 4	1438.6	5017.5	10175.4	2.1301	2.1528	1.9607	1.9894	2.0583	30.0	32.5	33.9	59.6	39.0	29.6	39.0	29.6	39.0	29.6	39.0	123.5
CF_22%	<b>Avg</b>	<b>1438.6</b>	<b>5000.0</b>	<b>10158</b>	<b>2.0050</b>	<b>2.0571</b>	<b>1.8888</b>	<b>1.9188</b>	<b>1.9662</b>	<b>33.7</b>	<b>35.7</b>	<b>34.0</b>	<b>52.5</b>	<b>38.9</b>	<b>21.0</b>	<b>38.9</b>	<b>21.0</b>	<b>38.9</b>	<b>21.0</b>	<b>38.9</b>	<b>128.0</b>
	-	-	-	<b>0.1974</b>	<b>0.2302</b>	<b>0.1553</b>	<b>0.1572</b>	<b>0.1520</b>	<b>16.6</b>	<b>20.1</b>	<b>8.2</b>	<b>11.2</b>	<b>11.4</b>	<b>16.6</b>	<b>11.4</b>	<b>16.6</b>	<b>11.4</b>	<b>16.6</b>	<b>11.4</b>	<b>16.6</b>	<b>24.0</b>
	New Sample1 Cycle 5	1438.6	4947.4	10105.3	1.9259	2.0387	1.8428	1.8611	1.9171	34.3	34.7	42.5	55.9	41.9	21.6	41.9	21.6	41.9	21.6	41.9	125.2
	New Sample1 Cycle 5	1438.6	5017.5	10175.4	2.0061	2.1715	1.8126	1.9542	1.9861	24.9	31.3	45.0	45.8	36.8	20.9	36.8	20.9	36.8	20.9	36.8	116.1
	New Sample1 Cycle 5	1438.6	5017.5	10175.4	2.1522	2.1452	1.9653	1.9739	2.0541	28.6	37.0	49.5	60.3	43.9	31.7	43.9	31.7	43.9	31.7	43.9	122.5
CF_22%	<b>Avg</b>	<b>1438.6</b>	<b>5000.0</b>	<b>10158</b>	<b>1.9947</b>	<b>2.0702</b>	<b>1.8797</b>	<b>1.8965</b>	<b>1.9603</b>	<b>30.3</b>	<b>37.6</b>	<b>43.6</b>	<b>52.0</b>	<b>40.9</b>	<b>22.1</b>	<b>40.9</b>	<b>22.1</b>	<b>40.9</b>	<b>22.1</b>	<b>40.9</b>	<b>124.6</b>
	-	-	-	<b>0.2178</b>	<b>0.2460</b>	<b>0.1527</b>	<b>0.1771</b>	<b>0.1704</b>	<b>9.4</b>	<b>16.0</b>	<b>12.2</b>	<b>14.5</b>	<b>7.1</b>	<b>17.6</b>	<b>7.1</b>	<b>17.6</b>	<b>7.1</b>	<b>17.6</b>	<b>7.1</b>	<b>17.6</b>	<b>18.6</b>
	<b>Avg</b>	<b>1438.6</b>	<b>5000.0</b>	<b>10158</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>	<b>-</b>

## Appendix 2: Physical Properties of Low-Copper and Copper-Free NAO Pads; Aged at Room Temperature for 12 Months

**TABLES 2-1-1** 1st cycle, 2nd cycle, 3<sup>rd</sup> cycle of low copper 18% porosity samples.

Samples	Nat Freq(kHz)			Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility 1X			
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 100 bar
Old Sample Cycle 1	1537.2	5396.8	10596.5	3.8271	3.7303	3.1770	2.8662	3.4002	78.0	80.2	76.5	73.2	77.0	7	102.2
Old Sample Cycle 1	1543.9	5403.5	10596.5	3.3233	3.4403	3.4705	3.4046	3.4097	73.9	81.9	81.4	81.7	79.7	8	111.0
<b>Avg</b>	<b>1540.55</b>	<b>5400.2</b>	<b>10596.5</b>	<b>3.5752</b>	<b>3.5853</b>	<b>3.3238</b>	<b>3.1354</b>	<b>3.4049</b>	<b>76.0</b>	<b>81.1</b>	<b>79.0</b>	<b>77.5</b>	<b>78.4</b>	<b>7.5</b>	<b>106.6</b>
<b>Range</b>	-	-	<b>0.5038</b>	<b>0.2900</b>	<b>0.2935</b>	<b>0.5383</b>	<b>0.0095</b>	<b>4.1</b>	<b>1.7</b>	<b>4.9</b>	<b>8.5</b>	<b>2.8</b>	<b>1.0</b>	<b>8.8</b>	
Old Sample Cycle 2	1508.8	5368.4	10491.2	3.7178	3.5918	3.0334	2.7064	3.2623	83.7	82.2	72.0	64.3	75.6	19.4	100.2
Old Sample Cycle 2	1543.9	5403.5	10701.8	3.2779	3.3229	3.4515	3.2014	3.3134	76.0	83.5	81.6	84.8	81.5	8.8	99.8
<b>Avg</b>	<b>1526.35</b>	<b>5386.0</b>	<b>10596.5</b>	<b>3.4979</b>	<b>3.4574</b>	<b>3.2425</b>	<b>2.9559</b>	<b>3.2879</b>	<b>79.9</b>	<b>82.9</b>	<b>76.8</b>	<b>74.6</b>	<b>78.5</b>	<b>14.1</b>	<b>100.0</b>
<b>Range</b>	-	-	<b>0.4398</b>	<b>0.2689</b>	<b>0.4182</b>	<b>0.4950</b>	<b>0.0511</b>	<b>7.7</b>	<b>1.3</b>	<b>9.6</b>	<b>20.5</b>	<b>5.9</b>	<b>10.6</b>	<b>0.4</b>	
Old Sample Cycle 3	1508.8	5368.4	10491.2	3.7285	3.6553	3.0631	2.7691	3.3040	87.9	86.7	70.9	69.2	78.7	18.7	93.3
Old Sample Cycle 3	1543.9	5403.5	10596.5	3.3275	3.3852	3.5112	3.3162	3.3850	74.5	85.0	85.5	80.1	81.3	11	99.7
<b>Avg</b>	<b>1526.35</b>	<b>5386.0</b>	<b>10543.9</b>	<b>3.5280</b>	<b>3.5202</b>	<b>3.2871</b>	<b>3.0427</b>	<b>3.3445</b>	<b>81.2</b>	<b>85.9</b>	<b>78.2</b>	<b>74.7</b>	<b>80.0</b>	<b>14.9</b>	<b>96.5</b>
<b>Range</b>	-	-	-	0.4010	0.2701	0.4481	0.5471	0.0810	13.4	1.7	14.6	10.9	2.6	7.7	6.4

**TABLES 2-1-2** 1st cycle, 2nd cycle, 3rd cycle of low copper 22% porosity samples.

Samples	Nat Freq(kHz)				Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility 1X	
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range
Old Sample Cycle 1	1473.7	5244.4	10421.1	3.1912	3.1260	2.4479	2.7559	2.8802	78.6	69.8	66.6	68.3	70.8	12
Old Sample Cycle 1	1473.7	5244.4	10421.1	3.0023	3.0736	2.8756	2.7966	2.9370	76.2	70.9	65.5	70.7	70.8	10.7
<b>Avg</b>	<b>1473.7</b>	<b>5244.4</b>	<b>10421.1</b>	<b>3.0968</b>	<b>3.0998</b>	<b>2.6617</b>	<b>2.7763</b>	<b>2.9086</b>	<b>77.4</b>	<b>70.4</b>	<b>66.1</b>	<b>69.5</b>	<b>70.8</b>	<b>11.4</b>
<b>Range</b>	-	-	-	<b>0.1889</b>	<b>0.0524</b>	<b>0.4278</b>	<b>0.0407</b>	<b>0.0568</b>	<b>2.4</b>	<b>1.1</b>	<b>1.1</b>	<b>2.4</b>	<b>0.0</b>	<b>1.3</b>
Old Sample Cycle 2	1403.5	5157.9	9964.9	3.1502	3.0921	2.6098	2.6754	2.8819	82.5	83.4	67.0	67.5	75.1	16.4
Old Sample Cycle 2	1403.5	5157.9	9964.9	2.8697	2.9789	2.9358	2.7885	2.8932	80.5	83.4	68.0	68.5	75.1	15.4
<b>Avg</b>	<b>1403.5</b>	<b>5157.9</b>	<b>9964.9</b>	<b>3.0100</b>	<b>3.0355</b>	<b>2.7728</b>	<b>2.7319</b>	<b>2.8875</b>	<b>81.5</b>	<b>83.4</b>	<b>67.5</b>	<b>68.0</b>	<b>75.1</b>	<b>15.9</b>
<b>Range</b>	-	-	-	<b>0.2805</b>	<b>0.1131</b>	<b>0.3260</b>	<b>0.1131</b>	<b>0.0114</b>	<b>2.0</b>	<b>0.0</b>	<b>1.0</b>	<b>1.0</b>	<b>0.0</b>	<b>1.0</b>
Old Sample Cycle 3	1403.5	5157.9	9514	3.0450	2.9926	2.5998	2.6140	2.8124	84.2	83.6	61.3	69.9	74.8	22.9
Old Sample Cycle 3	1403.5	5157.9	9514	3.0116	2.9819	2.9533	2.6377	2.8961	82.8	83.2	63.4	69.6	74.8	19.8
<b>Avg</b>	<b>1403.5</b>	<b>5157.9</b>	<b>9514</b>	<b>3.0273</b>	<b>2.9872</b>	<b>2.7766</b>	<b>2.6259</b>	<b>2.8542</b>	<b>83.5</b>	<b>83.4</b>	<b>62.4</b>	<b>69.8</b>	<b>74.8</b>	<b>21.4</b>
<b>Range</b>	-	-	-	<b>0.0314</b>	<b>0.0107</b>	<b>0.3534</b>	<b>0.0237</b>	<b>0.0838</b>	<b>1.4</b>	<b>0.4</b>	<b>2.1</b>	<b>0.3</b>	<b>0.0</b>	<b>3.1</b>

**TABLES 2-2-1** 1st cycle, 2nd cycle, 3rd cycle of Copper Free 18% porosity samples.

Samples	Nat Freq(kHz)			Modulus @ 100 N (GPa)				Hardness HRR				Compressibility 1x			
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	
Old Sample Cycle 1	1604	560.7	11027.6	3.2342	3.2113	2.9146	3.0842	3.1111	75.2	70.6	74.9	69.5	72.6	5.7	
Old Sample Cycle 1	1614	5614	10842.1	3.2756	3.3051	2.9447	3.0057	3.1328	77.3	78.9	67.7	61.9	71.5	17	
<b>Avg</b>	<b>1609</b>	<b>3087.4</b>	<b>10934.9</b>	<b>3.2549</b>	<b>3.2582</b>	<b>2.9297</b>	<b>3.0450</b>	<b>3.1219</b>	<b>76.3</b>	<b>74.8</b>	<b>71.3</b>	<b>65.7</b>	<b>72.0</b>	<b>11.4</b>	
<b>Range</b>	-	-	<b>0.0413</b>	<b>0.0938</b>	<b>0.0301</b>	<b>0.0785</b>	<b>0.0217</b>	<b>2.1</b>	<b>8.3</b>	<b>7.2</b>	<b>7.6</b>	<b>1.1</b>	<b>11.3</b>	<b>1.6</b>	
Old Sample Cycle 2	1578.9	5508.8	11052.6	3.0842	3.1058	2.8517	2.9494	2.9978	71.9	73.9	79.2	73.8	74.7	7.3	
Old Sample Cycle 2	1578.9	5473.7	10842.1	3.1846	3.1846	2.8355	2.8977	3.0256	74.4	79.1	73.4	62.0	72.2	17.1	
<b>Avg</b>	<b>1578.9</b>	<b>5491.3</b>	<b>10947.4</b>	<b>3.1344</b>	<b>3.1452</b>	<b>2.8436</b>	<b>2.9236</b>	<b>3.0117</b>	<b>73.2</b>	<b>76.5</b>	<b>76.3</b>	<b>67.9</b>	<b>73.5</b>	<b>12.2</b>	
<b>Range</b>	-	-	<b>0.1004</b>	<b>0.0789</b>	<b>0.0161</b>	<b>0.0517</b>	<b>0.0278</b>	<b>2.5</b>	<b>5.2</b>	<b>5.8</b>	<b>11.8</b>	<b>2.5</b>	<b>9.8</b>	<b>2.1</b>	
Old Sample Cycle 3	1578.9	5508.8	11052.6	3.0273	3.0377	2.8395	2.9115	2.9540	74.9	74.8	71.0	68.3	72.3	6.6	
Old Sample Cycle 3	1578.9	5473.7	10912.3	3.2021	3.2021	2.8455	2.9525	3.0506	75.4	73.3	66.4	75.3	72.6	9	
<b>Avg</b>	<b>1578.9</b>	<b>5491.3</b>	<b>10982.5</b>	<b>3.1147</b>	<b>3.1199</b>	<b>2.8425</b>	<b>2.9320</b>	<b>3.0023</b>	<b>75.2</b>	<b>74.1</b>	<b>68.7</b>	<b>71.8</b>	<b>72.4</b>	<b>7.8</b>	
<b>Range</b>	-	-	-	<b>0.1645</b>	<b>0.1749</b>	<b>0.1645</b>	<b>0.0061</b>	<b>0.0410</b>	<b>0.0966</b>	<b>0.5</b>	<b>1.5</b>	<b>4.6</b>	<b>7.0</b>	<b>0.3</b>	<b>2.4</b>
														<b>1.8</b>	

**TABLES 2-2-1** 1st cycle, 2nd cycle, 3rd cycle of Copper Free 22% porosity samples.

Samples	Nat Freq(kHz)			Modulus @ 100 N (GPa)				Hardness - HRR				Compressibility 1X				
	Peak 1	Peak 2	Peak 3	Position 1	Position 2	Position 3	Position 4	Avg	Position 1	Position 2	Position 3	Position 4	Avg	Range	@ 100 bar	
Old Sample Cycle 1	1508.8	5112.8	10421.1	2.3841	2.3730	2.2629	2.3511	2.3428	50.5	54.6	54.4	47.9	51.9	6.7	133.7	
Old Sample Cycle 1	1508.8	5052.6	10175.4	2.1392	2.1933	2.2904	2.2732	2.2240	50.7	51.7	57.9	52.1	53.1	7.2	139.7	
<b>Avg</b>	<b>1508.8</b>	<b>5082.7</b>	<b>10298.3</b>	<b>2.2616</b>	<b>2.2831</b>	<b>2.2766</b>	<b>2.3121</b>	<b>2.2834</b>	<b>50.6</b>	<b>53.2</b>	<b>56.2</b>	<b>50.0</b>	<b>52.5</b>	<b>7.0</b>	<b>136.7</b>	
<b>Range</b>	-	-	-	<b>0.2449</b>	<b>0.1797</b>	<b>0.0275</b>	<b>0.0779</b>	<b>0.1188</b>	<b>0.2</b>	<b>2.9</b>	<b>3.5</b>	<b>4.2</b>	<b>1.3</b>	<b>0.5</b>	<b>6.0</b>	
Old Sample Cycle 2	1432.6	5157.9	10421.1	2.3051	2.2843	2.2300	2.2167	2.2590	65.3	60.8	56.2	62.6	61.2	9.1	117.6	
Old Sample Cycle 2	1473.7	5087.7	10315.8	2.1100	2.1504	2.2416	2.3033	2.2013	58.8	53.6	53.9	54.7	55.3	5.2	130.0	
<b>Avg</b>	<b>1453.15</b>	<b>5122.8</b>	<b>10368.5</b>	<b>2.2076</b>	<b>2.2173</b>	<b>2.2358</b>	<b>2.2600</b>	<b>2.2302</b>	<b>62.1</b>	<b>57.2</b>	<b>55.1</b>	<b>58.7</b>	<b>58.2</b>	<b>7.2</b>	<b>123.8</b>	
<b>Range</b>	-	-	-	<b>0.1951</b>	<b>0.1338</b>	<b>0.0116</b>	<b>0.0866</b>	<b>0.0577</b>	<b>6.5</b>	<b>7.2</b>	<b>2.3</b>	<b>7.9</b>	<b>6.0</b>	<b>3.9</b>	<b>12.4</b>	
Old Sample Cycle 3	1438.6	5157.9	10421.1	2.3357	2.3002	2.2588	2.3108	2.3014	71.3	69.8	66.6	72.6	70.1	6	119.6	
Old Sample Cycle 3	1473.7	5087.7	10315.8	2.0953	2.1353	2.2621	2.2826	2.1938	60.2	52.3	53.8	58.6	56.2	7.9	138.4	
<b>Avg</b>	<b>1456.15</b>	<b>5122.8</b>	<b>10368.5</b>	<b>2.2155</b>	<b>2.2177</b>	<b>2.2604</b>	<b>2.2967</b>	<b>2.2476</b>	<b>65.8</b>	<b>61.1</b>	<b>60.2</b>	<b>65.6</b>	<b>63.2</b>	<b>7.0</b>	<b>129.0</b>	
<b>Range</b>	-	-	-	<b>0.2403</b>	<b>0.1650</b>	<b>0.0033</b>	<b>0.0282</b>	<b>0.1075</b>	<b>11.1</b>	<b>17.5</b>	<b>12.8</b>	<b>14.0</b>	<b>13.9</b>	<b>1.9</b>	<b>18.8</b>	

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