

**ATOMET 4701** is a highly compressible, water-atomized low alloy steel powder specially engineered for sinter hardening applications.

- **High strength parts** - without oil quenching, induction hardening or other post-sintering heat treatments (with or without tempering)
- **Microstructure control** - for optimum properties in parts of all sizes.

It is possible to obtain P/M parts with **high strength** and **hardness** with a conventional sintering furnace without post sintering treatment.

**Benefits:**

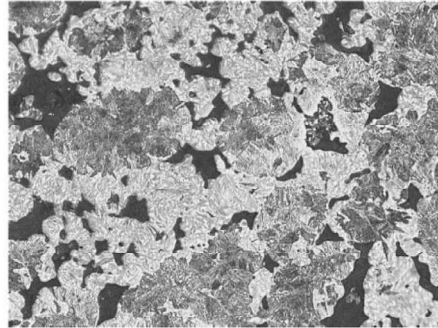
- Lower production costs
- More environmentally friendly
- Elimination of quench distortion
- Large parts with tight tolerances become possible

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## What is sinter hardening?

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- Sinter hardening is a cost-effective process where P/M parts are cooled in production sintering furnace at a rate that transforms the microstructure from austenite into martensite.
- Micrograph illustrates centrally located microstructure in a 540 g part slow cooled at 0.4°C/s. Under controlled conditions, hardness of 30 HRC has been achieved throughout the part.



As Sintered : ATOMET 4701 + 2% Cu + 1.0% C, 540 g piece, sintered 25 minutes à 1120°C, slow cooled at 0.4°C/s

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## How is sinter hardening achieved?

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- **ATOMET 4701** requires cooling rates of 0.4°C to 1.5°C/s, when cooling from 650°C (1200°F) through 400°C (750°F).
- Relative quantities of martensite and bainite may be tailored by adjusting the cooling rate and the added graphite and copper.

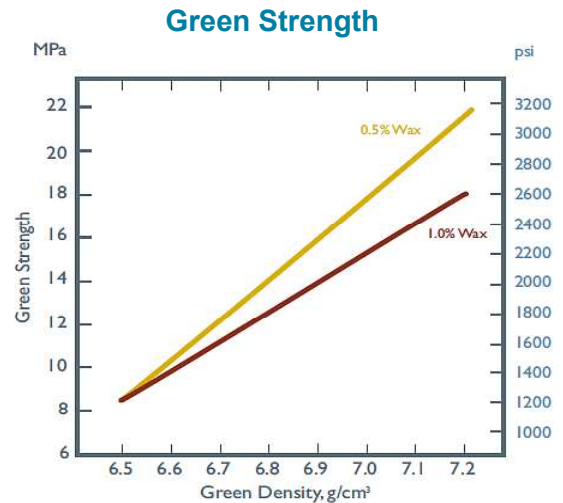
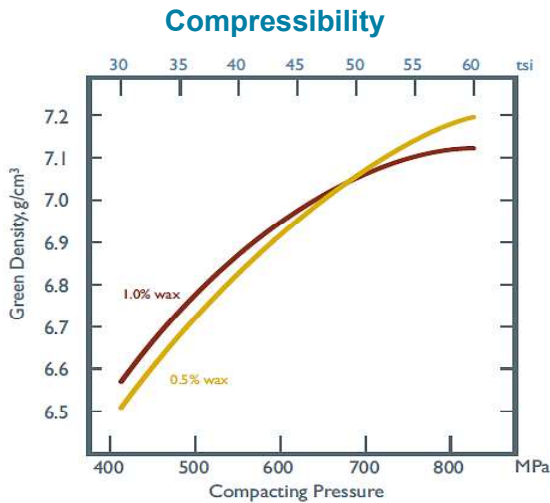
PHYSICAL AND CHEMICAL PROPERTIES

Chemistry, wt%									
C	O	S	P	Mn	Mo	Ni	Si	Cr	Fe
0,01	0,25	0,009	0,012	0,45	1,00	0,90	0,015	0,45	97+

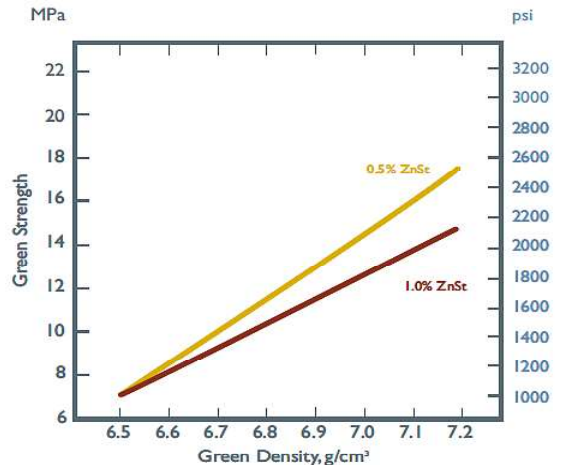
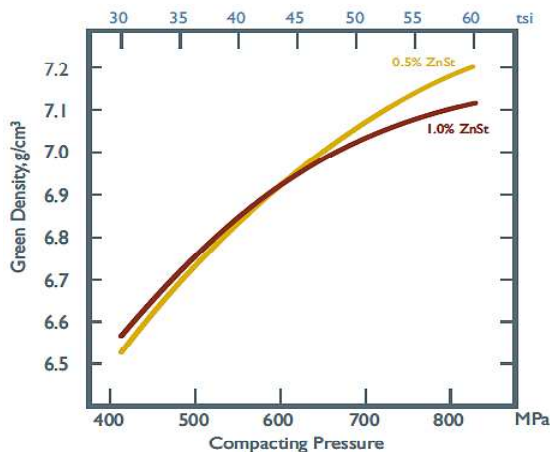
U.S. mesh	Particle Size Analysis, wt%				A.D. g/cm <sup>3</sup>	Flow s/50g	Density* g/cm <sup>3</sup>
	+60	+100	+325	-325			
µm	+250	+150	+45	-45	2.92	26	6.90
	Trace	12	67	21			*@43.5 tsi @600 MPa

COMPACTING PROPERTIES

ATOMET 4701 + Wax



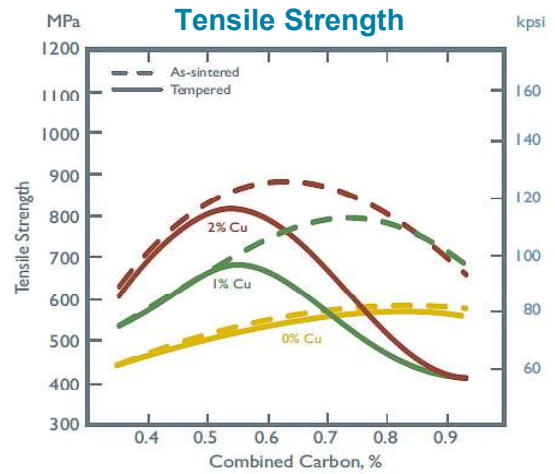
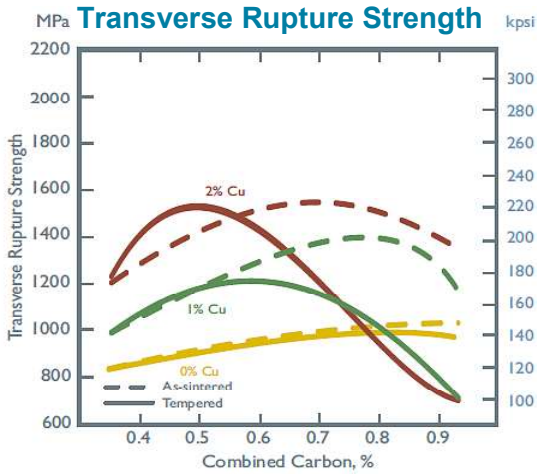
ATOMET 4701 + ZnSt



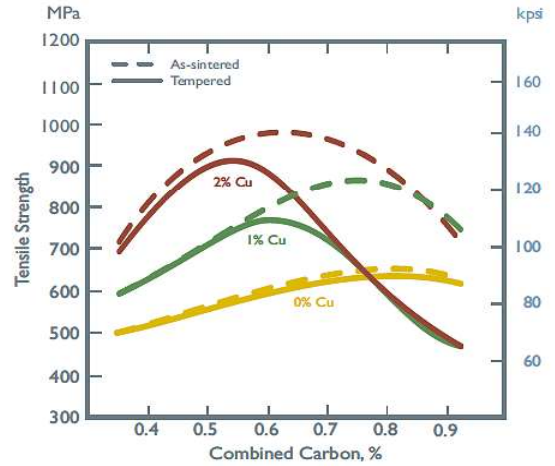
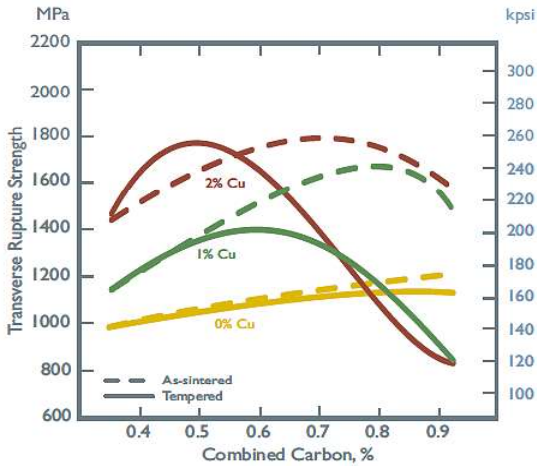
**SINTERED PROPERTIES - Slow Cooled**

Composition: **ATOMET 4701** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).

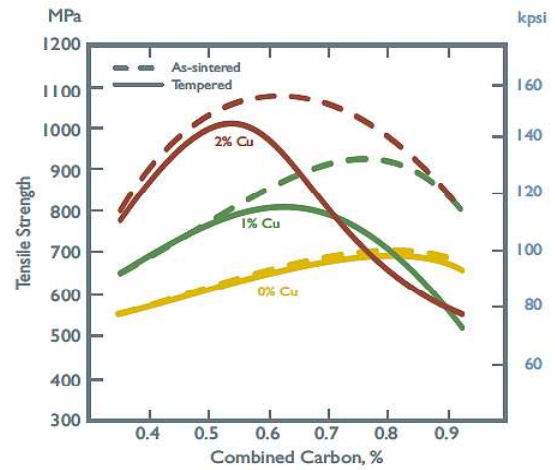
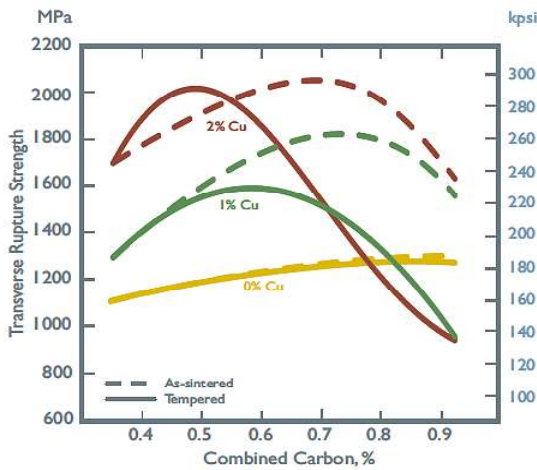
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



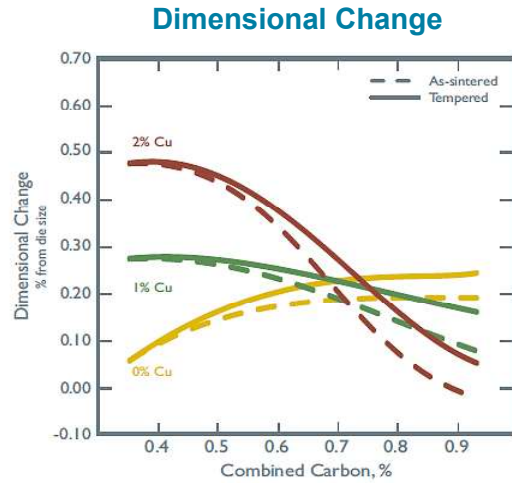
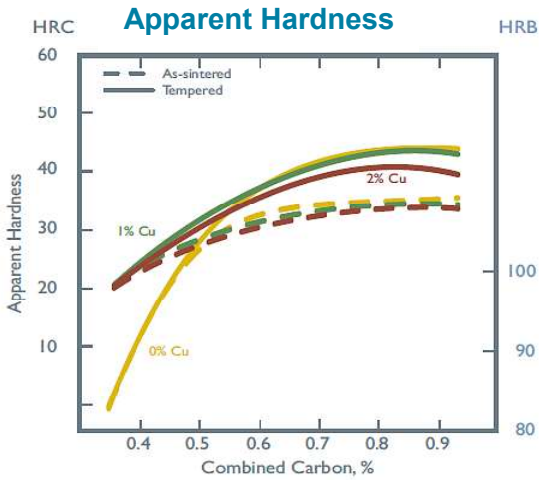
Sintered Density  
 7.1 g/cm<sup>3</sup>



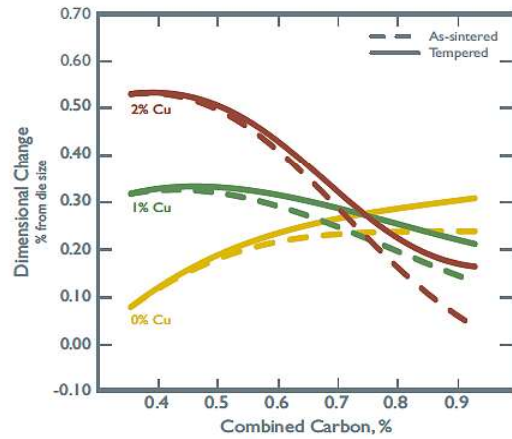
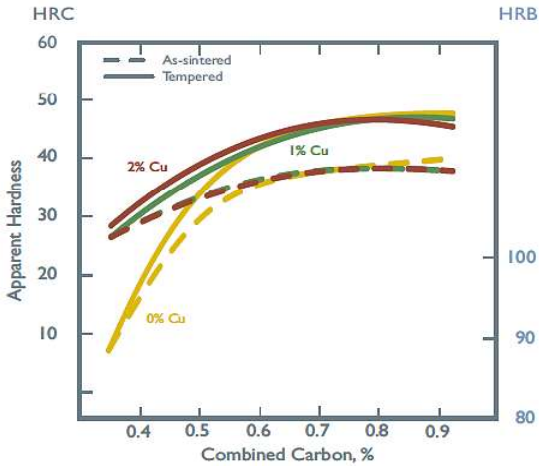
SINTERED PROPERTIES (continued) - Slow Cooled

Composition: **ATOMET 4701** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
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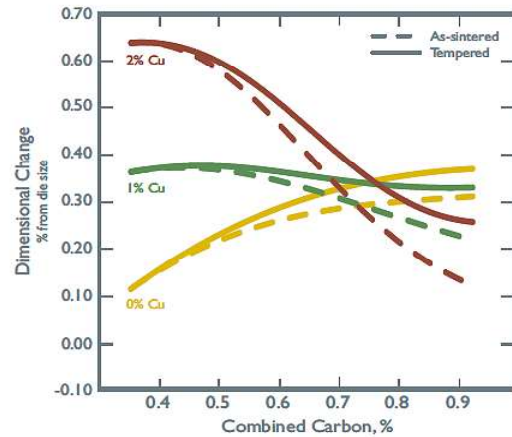
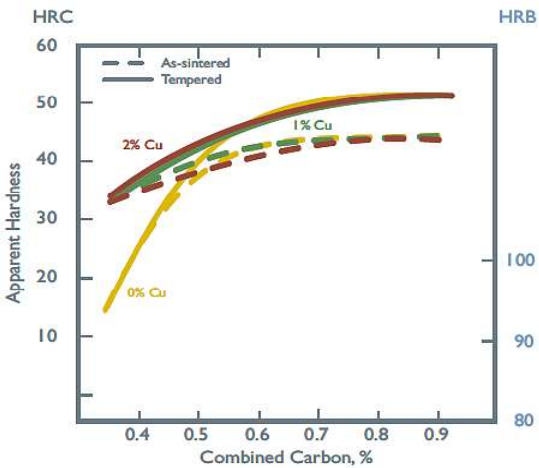
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



Sintered Density  
 7.1 g/cm<sup>3</sup>



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**AS-SINTERED PROPERTIES** - Copper Steels, Slow cooled
 

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Composition: **ATOMET 4701** + copper + carbon + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
			MPa	kpsi	MPa	kpsi	MPa	kpsi			
6.69	0	0.31	834	121	421	61	331	48	1.1	(71)	-0.04
6.89	0	0.31	966	140	483	70	372	54	1.4	(78)	0.00
7.13	0	0.31	1138	165	538	78	414	60	1.4	(84)	0.06
6.68	0	0.49	917	133	490	71	400	58	<1	(80)	0.03
6.89	0	0.49	1076	156	552	80	428	62	1.0	(85)	0.05
7.12	0	0.49	1221	177	607	88	576	69	1.0	(91)	0.12
6.67	0	0.69	931	135	552	80	469	68	<1	(86)	0.10
6.86	0	0.69	1083	157	628	91	524	76	<1	(90)	0.14
7.09	0	0.69	1248	181	669	97	559	81	<1	(95)	0.19
6.66	0	0.88	952	138	545	79	476	69	<1	(88)	0.17
6.86	0	0.88	1103	160	621	90	531	77	<1	(93)	0.21
7.06	0	0.88	1234	179	634	92	566	82	<1	(96)	0.27
6.65	1	0.35	938	136	510	74	393	57	<1	(79)	0.13
6.86	1	0.35	1090	158	586	85	428	62	1.0	(85)	0.16
7.11	1	0.35	1297	188	641	93	483	70	1.0	(91)	0.24
6.65	1	0.50	1131	164	662	96	524	76	<1	17	0.15
6.85	1	0.50	1324	192	766	111	586	85	<1	22	0.20
7.09	1	0.50	1559	226	772	112	586	85	<1	25	0.27
6.66	1	0.71	1110	161	600	87	566	82	<1	31	0.10
6.86	1	0.71	1234	179	669	97	607	88	<1	34	0.15
7.07	1	0.71	1476	214	759	110	648	94	<1	41	0.23
6.67	1	0.92	683	99	407	59	-	-	<1	37	0.06
6.87	1	0.92	848	123	455	66	-	-	<1	40	0.12
7.06	1	0.92	897	130	503	73	-	-	<1	44	0.19
6.59	2	0.33	1110	161	579	84	407	59	<1	(88)	0.40
6.79	2	0.33	1310	190	662	96	497	72	<1	(91)	0.43
6.95	2	0.33	1510	219	752	109	538	78	1.0	19	0.51
6.61	2	0.51	1393	202	766	111	572	83	<1	23	0.31
6.81	2	0.51	1607	233	890	129	655	95	<1	28	0.35
7.03	2	0.51	1883	273	979	142	738	107	<1	34	0.42
6.65	2	0.71	1000	145	579	84	483	70	<1	35	0.11
6.85	2	0.71	1221	177	628	91	607	88	<1	38	0.17
7.04	2	0.71	1276	185	697	101	641	93	<1	42	0.24
6.68	2	0.92	662	96	407	59	-	-	<1	35	-0.02
6.87	2	0.92	800	116	462	67	-	-	<1	39	0.07
7.06	2	0.92	869	126	552	80	-	-	<1	43	0.12



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**TEMPERED PROPERTIES** - Copper Steels, Slow cooled
 

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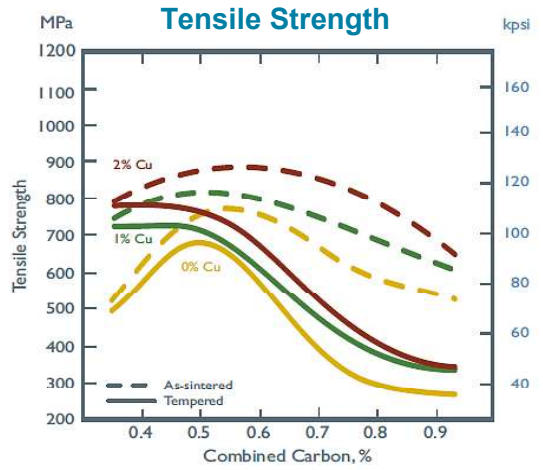
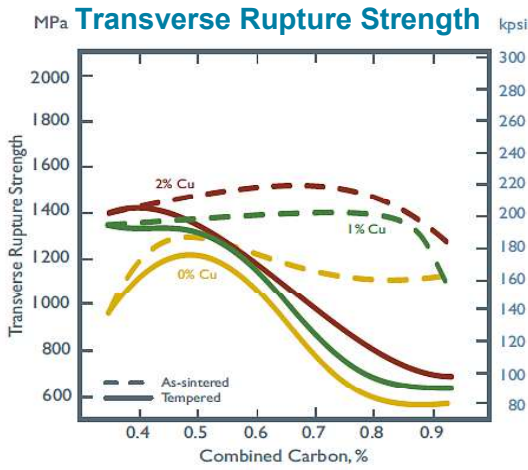
Composition: **ATOMET 4701** + copper + carbon + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).  
 Tempered 60 minutes at 200°C (390°F).

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
			MPa	kpsi	MPa	kpsi	MPa	kpsi			
6.69	0	0.31	834	121	421	61	331	48	1.1	(71)	-0.04
6.89	0	0.31	966	140	483	70	372	54	1.4	(78)	0.00
7.13	0	0.31	1138	165	538	78	414	60	1.4	(84)	0.06
6.68	0	0.49	917	133	490	71	400	58	<1	(80)	0.03
6.89	0	0.49	1076	156	552	80	428	62	1.0	(85)	0.05
7.12	0	0.49	1221	177	607	88	576	69	1.0	(91)	0.12
6.67	0	0.69	931	135	552	80	469	68	<1	(86)	0.10
6.86	0	0.69	1083	157	628	91	524	76	<1	(90)	0.14
7.09	0	0.69	1248	181	669	97	559	81	<1	(95)	0.19
6.66	0	0.88	952	138	545	79	476	69	<1	(88)	0.17
6.86	0	0.88	1103	160	621	90	531	77	<1	(93)	0.21
7.06	0	0.88	1234	179	634	92	566	82	<1	(96)	0.27
6.65	1	0.35	938	136	510	74	393	57	<1	(79)	0.13
6.86	1	0.35	1090	158	586	85	428	62	1.0	(85)	0.16
7.11	1	0.35	1297	188	641	93	483	70	1.0	(91)	0.24
6.65	1	0.50	1131	164	662	96	524	76	<1	17	0.15
6.85	1	0.50	1324	192	766	111	586	85	<1	22	0.20
7.09	1	0.50	1559	226	772	112	586	85	<1	25	0.27
6.66	1	0.71	1110	161	600	87	566	82	<1	31	0.10
6.86	1	0.71	1234	179	669	97	607	88	<1	34	0.15
7.07	1	0.71	1476	214	759	110	648	94	<1	41	0.23
6.67	1	0.92	683	99	407	59	-	-	<1	37	0.06
6.87	1	0.92	848	123	455	66	-	-	<1	40	0.12
7.06	1	0.92	897	130	503	73	-	-	<1	44	0.19
6.59	2	0.33	1110	161	579	84	407	59	<1	(88)	0.40
6.79	2	0.33	1310	190	662	96	497	72	<1	(91)	0.43
6.95	2	0.33	1510	219	752	109	538	78	1.0	19	0.51
6.61	2	0.51	1393	202	766	111	572	83	<1	23	0.31
6.81	2	0.51	1607	233	890	129	655	95	<1	28	0.35
7.03	2	0.51	1883	273	979	142	738	107	<1	34	0.42
6.65	2	0.71	1000	145	579	84	483	70	<1	35	0.11
6.85	2	0.71	1221	177	628	91	607	88	<1	38	0.17
7.04	2	0.71	1276	185	697	101	641	93	<1	42	0.24
6.68	2	0.92	662	96	407	59	-	-	<1	35	-0.02
6.87	2	0.92	800	116	462	67	-	-	<1	39	0.07
7.06	2	0.92	869	126	552	80	-	-	<1	43	0.12

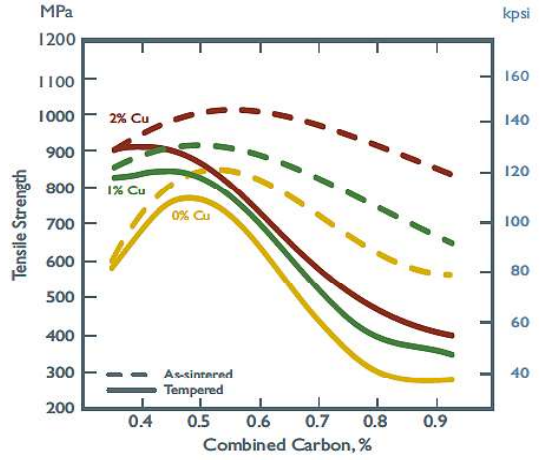
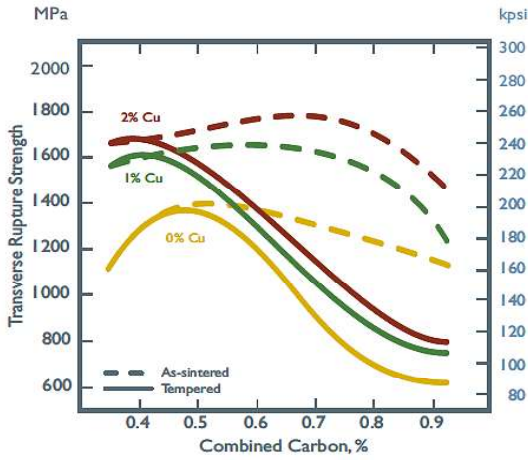
SINTERED PROPERTIES - Fast Cooled

Composition: **ATOMET 4701** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 1.5°C/s from 650 °C (1200°F) to 400°C (750°F).

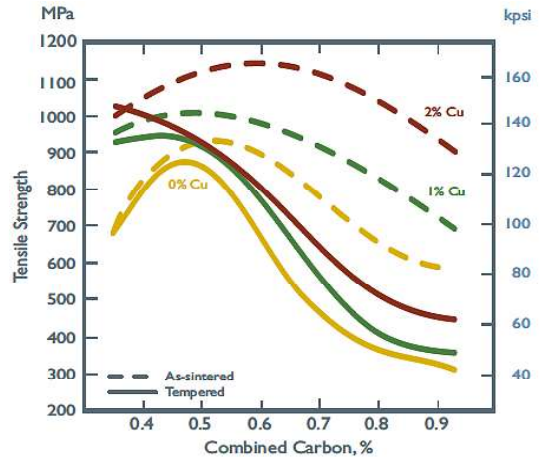
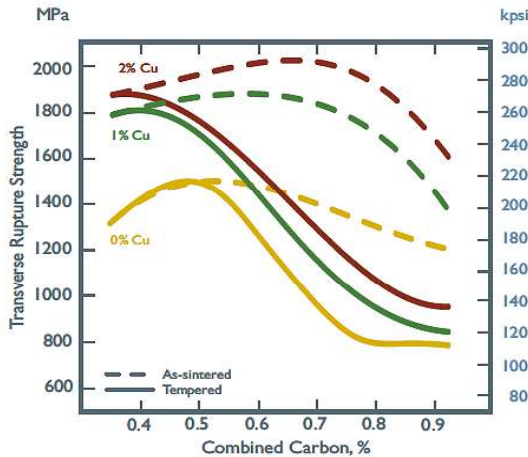
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



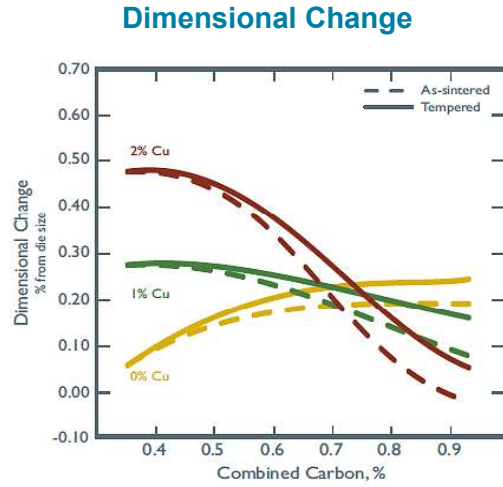
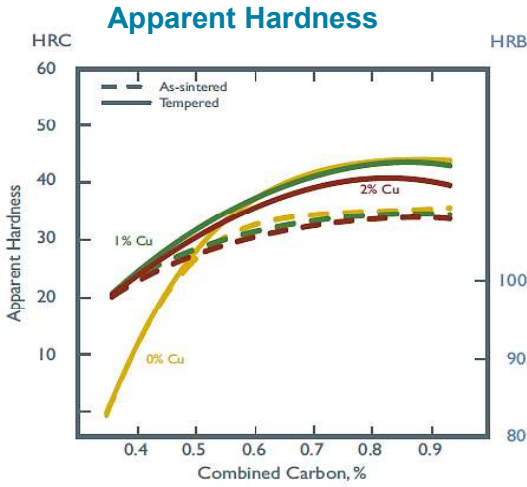
Sintered Density  
 7.1 g/cm<sup>3</sup>



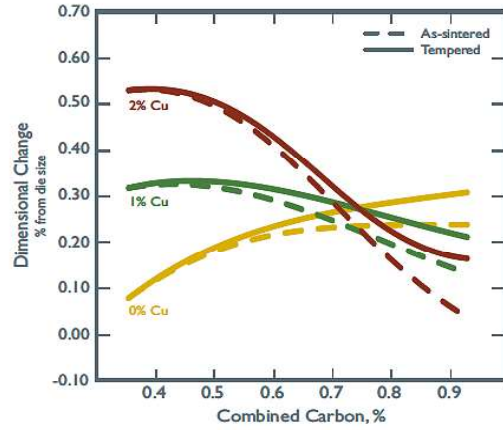
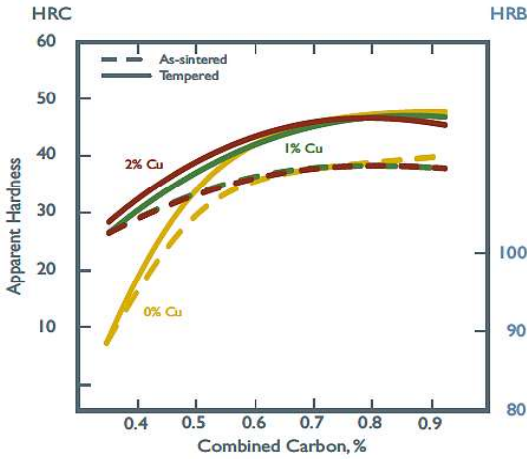
**SINTERED PROPERTIES (continued) - Fast Cooled**

Composition: **ATOMET 4701** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).

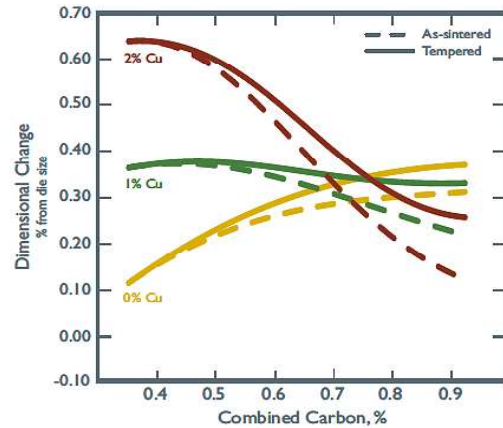
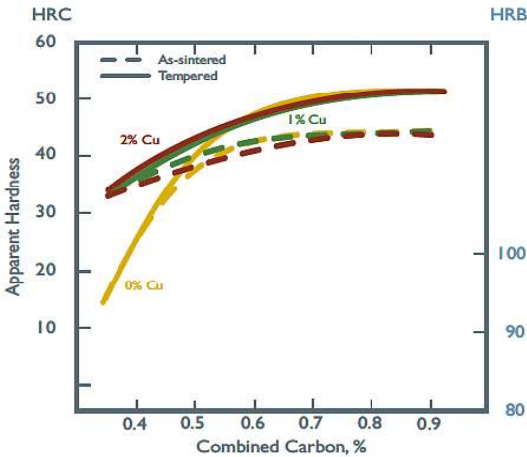
Sintered Density  
6.7 g/cm<sup>3</sup>



Sintered Density  
6.9 g/cm<sup>3</sup>



Sintered Density  
7.1 g/cm<sup>3</sup>





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**AS-SINTERED PROPERTIES (continued) - Copper Steels, fast cooled**


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Composition: **ATOMET 4701** + copper + carbon + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 20 minutes.  
 Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
			MPa	kpsi	MPa	kpsi	MPa	kpsi			
6.67	0	0.35	931	135	434	63	386	56	<1	(82)	0.05
6.87	0	0.35	1110	161	579	84	441	64	<1	(88)	0.07
7.11	0	0.35	1290	187	634	92	483	70	<1	(94)	0.11
6.65	0	0.53	1200	174	634	92	586	85	<1	31	0.18
6.85	0	0.53	1290	187	724	105	697	101	<1	37	0.20
7.08	0	0.53	1462	212	786	114	759	110	<1	43	0.25
6.64	0	0.71	703	102	366	53	-	-	<1	41	0.22
6.84	0	0.71	848	123	428	62	-	-	<1	45	0.25
7.06	0	0.71	924	134	428	62	-	-	<1	49	0.32
6.65	0	0.93	559	81	255	37	-	-	<1	43	0.24
6.84	0	0.93	669	97	310	45	-	-	<1	46	0.29
7.03	0	0.93	717	104	296	43	-	-	<1	50	0.35
6.62	1	0.36	1234	179	683	99	572	83	<1	18	0.25
6.83	1	0.36	1517	220	814	118	648	94	<1	25	0.29
7.08	1	0.36	1807	262	897	130	724	105	<1	31	0.36
6.60	1	0.54	1207	175	648	94	586	85	<1	32	0.25
6.83	1	0.54	1372	199	772	112	703	102	<1	37	0.30
7.07	1	0.54	1634	237	862	125	786	114	<1	44	0.37
6.64	1	0.73	793	115	421	61	-	-	<1	41	0.19
6.84	1	0.73	883	128	483	70	-	-	<1	45	0.25
7.05	1	0.73	1069	155	483	70	-	-	<1	49	0.32
6.66	1	0.93	621	90	324	47	-	-	<1	42	0.15
6.85	1	0.93	710	103	338	49	-	-	<1	46	0.20
7.04	1	0.93	807	117	317	46	-	-	<1	49	0.28
6.58	2	0.36	1262	183	724	105	545	79	<1	19	0.46
6.78	2	0.36	1524	221	848	123	628	91	<1	25	0.49
7.03	2	0.36	1841	267	979	142	717	104	<1	32	0.59
6.59	2	0.54	1179	171	697	101	621	90	<1	33	0.40
6.80	2	0.54	1372	199	772	112	641	93	<1	38	0.44
7.02	2	0.54	1621	235	841	122	724	105	<1	43	0.53
6.63	2	0.76	821	119	359	52	-	-	<1	41	0.18
6.78	2	0.76	924	134	462	67	-	-	<1	44	0.22
7.03	2	0.76	1069	155	517	75	-	-	<1	49	0.31
6.66	2	0.93	676	98	324	47	-	-	<1	41	0.05
6.86	2	0.93	793	115	379	55	-	-	<1	44	0.11
7.03	2	0.93	917	133	441	64	-	-	<1	48	0.42

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**TEMPERED PROPERTIES** - Copper Steels, fast cooled
 

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Composition: **ATOMET 4701** + copper + carbon + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based at 1120°C (2050°F) for 20 minutes.  
 Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).  
 Tempered 60 minutes at 200°C (390°F).

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
			MPa	kpsi	MPa	kpsi	MPa	kpsi			
6.68	0	0.35	924	134	441	64	400	58	<1	(81)	0.05
6.88	0	0.35	1131	164	586	85	455	66	<1	(89)	0.07
7.11	0	0.35	1303	189	634	92	517	75	<1	15	0.12
6.65	0	0.53	1241	180	710	103	683	99	<1	29	0.16
6.86	0	0.53	1407	204	841	122	745	108	<1	33	0.19
7.09	0	0.53	1476	214	890	129	834	121	<1	40	0.25
6.65	0	0.71	1097	159	641	93	-	-	<1	33	0.18
6.85	0	0.71	1276	185	738	107	-	-	<1	37	0.22
7.07	0	0.71	1379	200	717	104	-	-	<1	42	0.27
6.65	0	0.93	1117	162	524	76	-	-	<1	34	0.18
6.86	0	0.93	1076	156	552	80	-	-	<1	40	0.23
7.05	0	0.93	1221	177	524	76	-	-	<1	43	0.29
6.62	1	0.36	1207	175	710	103	641	93	<1	17	0.25
6.77	1	0.36	1510	219	848	123	731	106	<1	24	0.30
7.08	1	0.36	1690	245	917	133	800	116	<1	31	0.37
6.63	1	0.54	1317	191	786	114	697	101	<1	28	0.25
6.83	1	0.54	1538	223	883	128	814	118	<1	33	0.30
7.07	1	0.54	1834	266	979	142	890	129	<1	40	0.37
6.65	1	0.73	1338	194	697	101	676	98	<1	32	0.15
6.80	1	0.73	1538	223	786	114	683	99	<1	37	0.20
7.06	1	0.73	1752	254	848	123	779	113	<1	43	0.28
6.67	1	0.93	1076	156	586	85	483	70	<1	33	0.07
6.87	1	0.93	1200	174	676	98	593	86	<1	39	0.12
7.06	1	0.93	1352	196	655	95	566	82	<1	42	0.19
6.58	2	0.36	1207	175	731	106	634	92	<1	17	0.46
6.78	2	0.36	1448	210	848	123	683	99	<1	24	0.50
7.04	2	0.36	1779	258	945	137	828	120	<1	31	0.59
6.60	2	0.54	1352	196	821	119	717	104	<1	27	0.38
6.80	2	0.54	1572	228	952	138	848	123	<1	32	0.43
7.03	2	0.54	1903	276	1076	156	986	143	<1	38	0.50
6.70	2	0.76	1510	219	786	114	669	97	<1	33	0.12
6.80	2	0.76	1621	235	931	135	731	106	<1	37	0.18
7.05	2	0.76	1931	280	1014	147	841	122	<1	42	0.26
6.68	2	0.93	1262	183	628	91	490	71	<1	33	-0.02
6.87	2	0.93	1462	212	745	108	579	84	<1	38	0.03
7.06	2	0.93	1552	225	869	126	648	94	<1	41	0.12

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