ATOMET 4401

ATOMET 4401 is a highly compressible, water-atomized alloy steel containing 0.85% molybdenum, designed for use in high strength, high performance powder metallurgy and powder forging applications.

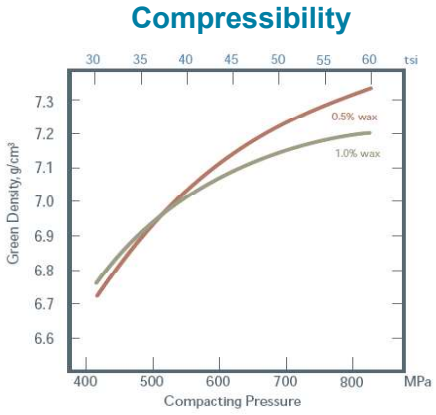
- **Compressibility** - **ATOMET 4401** extends the benefits of prealloyed powders to high-density applications above 7.0 g/cm^3 giving higher strength, higher density PM parts and enhancing compaction capability.
- **Hardenability** - molybdenum enhances heat-treated properties without sacrificing compressibility, thus improving hardness and tensile strength.
- **Consistency** - a stable ore base and ultra modern processing capability, including SPC, assure lot-to-lot consistency and reduced part-to-part variation.
- **Purity and cleanliness** - state-of-the-art clean steel practices and a proprietary powder manufacturing process produce a powder with exceptionally low levels of residuals and inclusions, resulting in improved mechanical and dynamic properties of PM and PF parts.

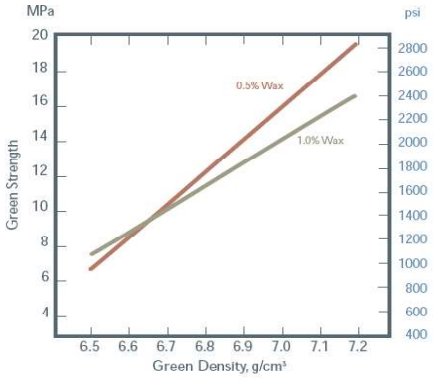
PHYSICAL AND CHEMICAL PROPERTIES

Chemistry, wt%						Particle Size Analysis, wt%				A.D.	Flow	Density*
C	O	S	Mn	Mo	U.S. mesh	+60	+100	+325	-325	g/cm^3	s/50g	g/cm^3
0,003	0,08	0,009	0,15	0,85	um	+250	+150	+45	-45	2.92	26	7,10
						Trace	10	65	25			*@43.5 tsi
												@600 MPa

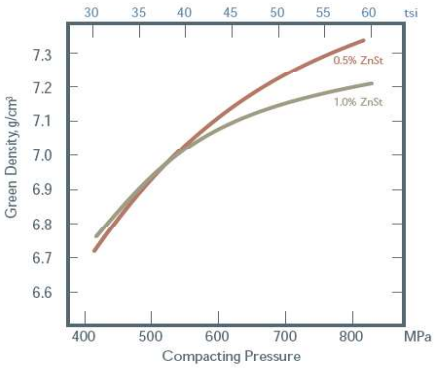
COMPACTING PROPERTIES

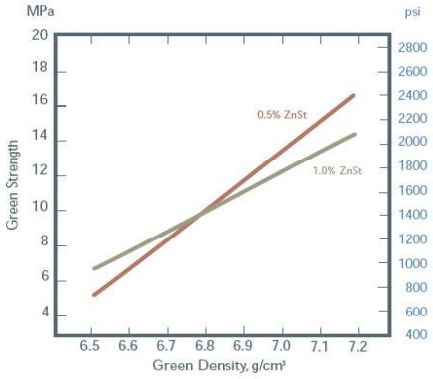
ATOMET 4401 + Wax





ATOMET 4401 + ZnSt





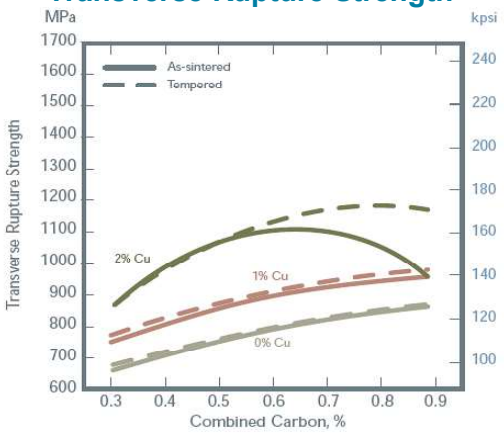
AS-SINTERED PROPERTIES - Copper Steels

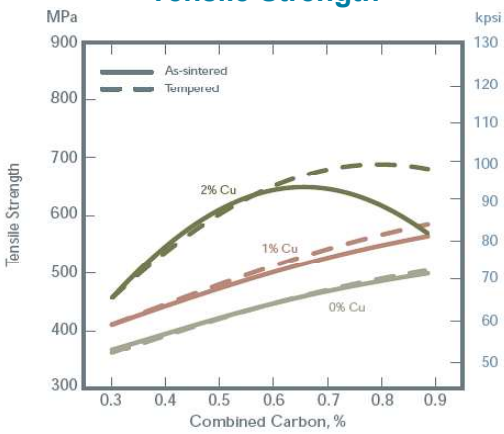
Composition: **ATOMET 4401** + copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Transverse Rupture Strength

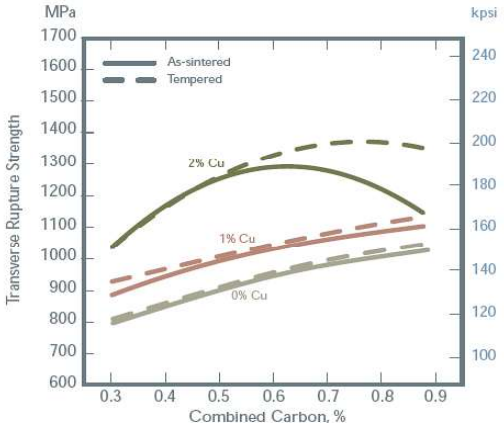
Tensile Strength

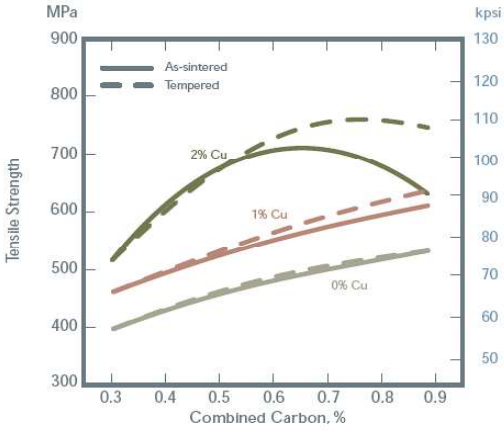
Sintered Density 6.7 g/cm^3



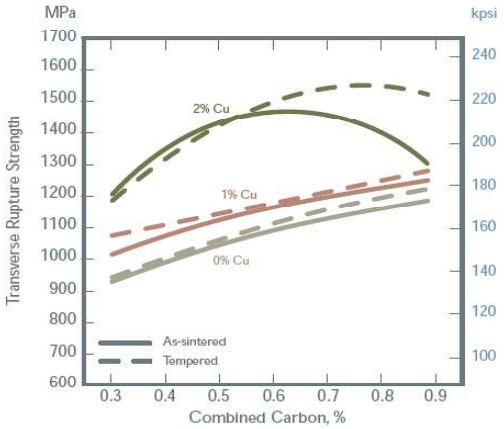


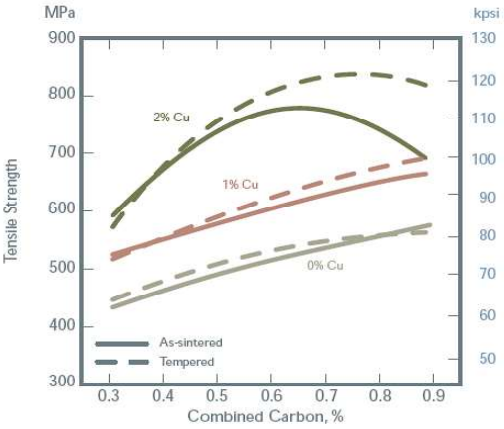
Sintered Density 6.9 g/cm^3





Sintered Density 7.1 g/cm^3





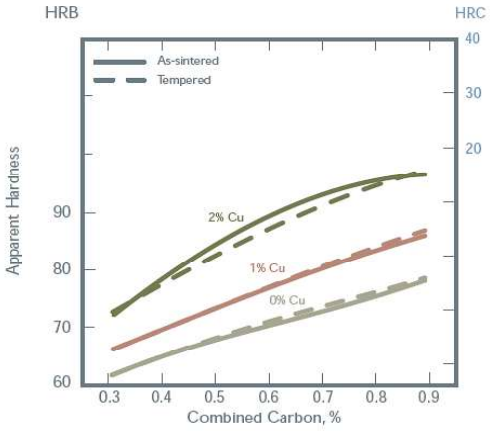
AS-SINTERED PROPERTIES (continued) - Copper Steels

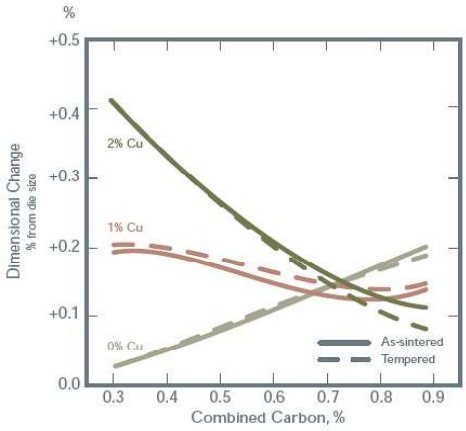
Composition: **ATOMET 4401** + copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Apparent Hardness

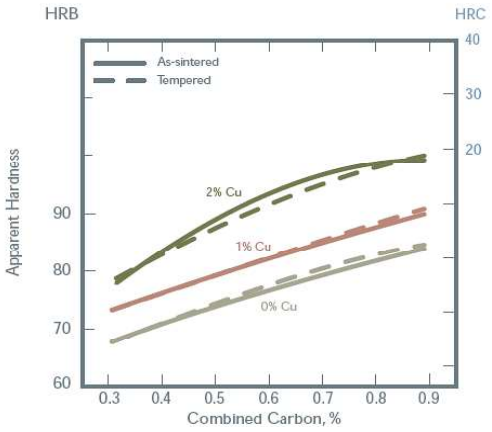
Dimensional Change

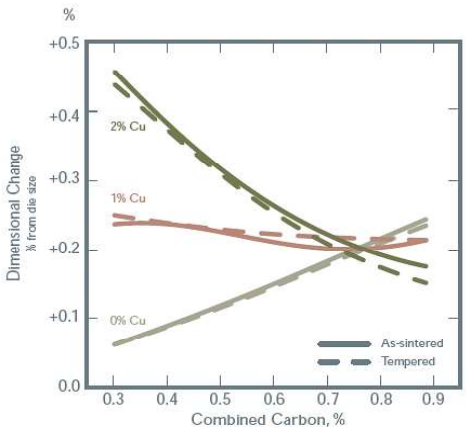
Sintered Density 6.7 g/cm³



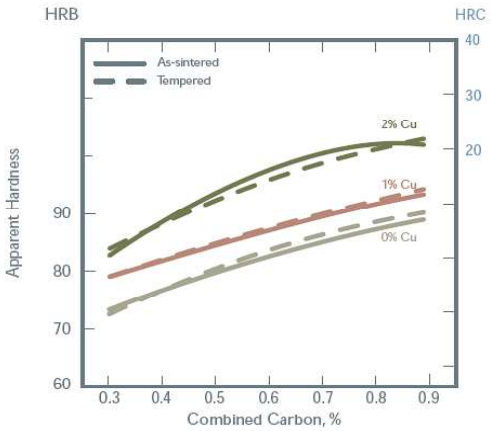


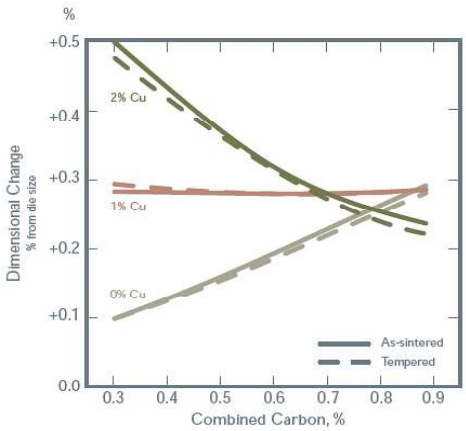
Sintered Density 6.9 g/cm³





Sintered Density 7.1 g/cm³





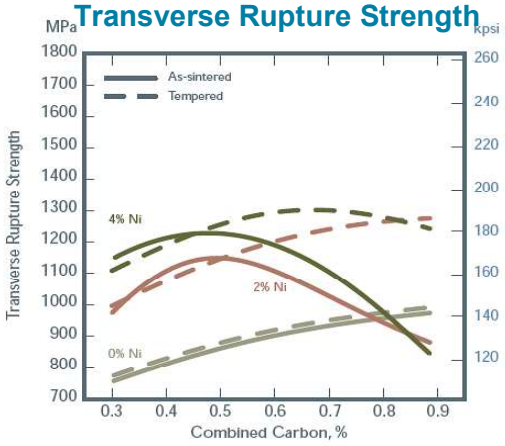
AS-SINTERED PROPERTIES - Nickel-Copper Steels

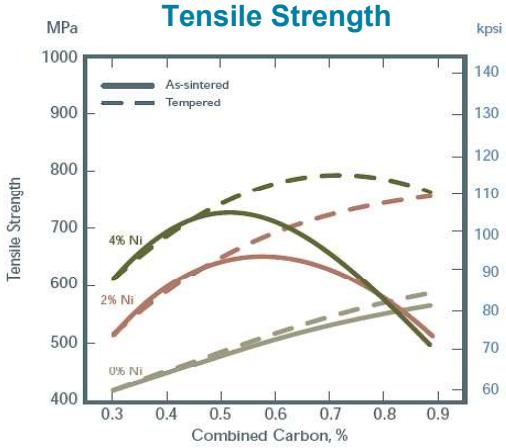
Composition: **ATOMET 4401** + nickel + 1% copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Transverse Rupture Strength

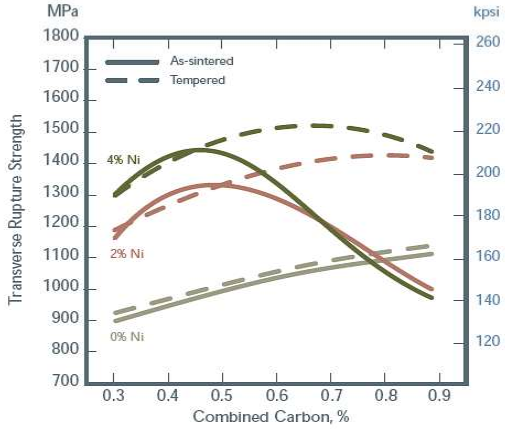
Tensile Strength

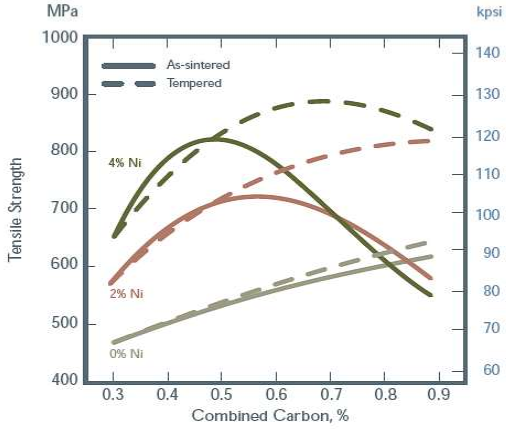
Sintered Density 6.7 g/cm^3



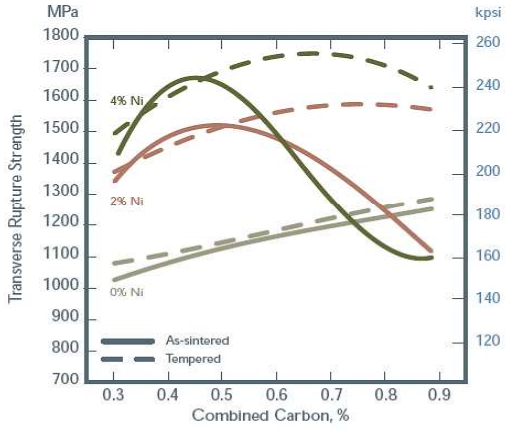


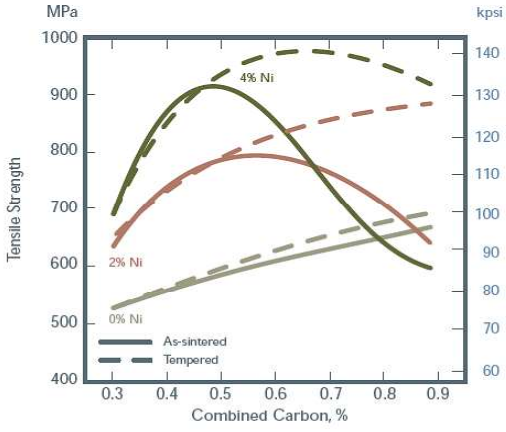
Sintered Density 6.9 g/cm^3





Sintered Density 7.1 g/cm^3





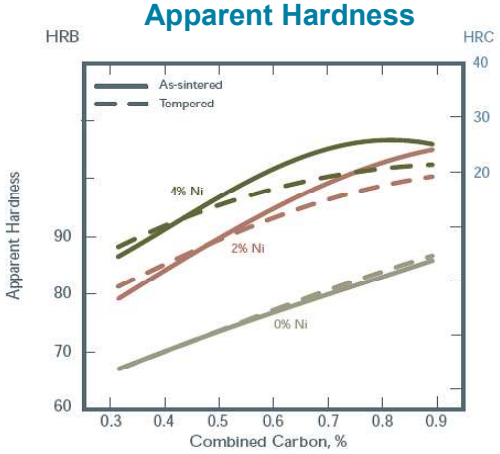
AS-SINTERED PROPERTIES (continued) - Nickel-Copper Steels

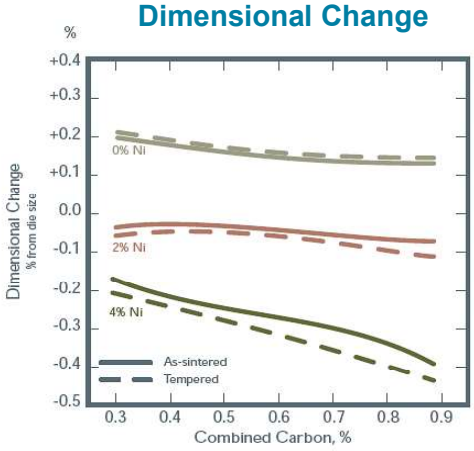
Composition: **ATOMET 4401** + nickel + 1% copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Apparent Hardness

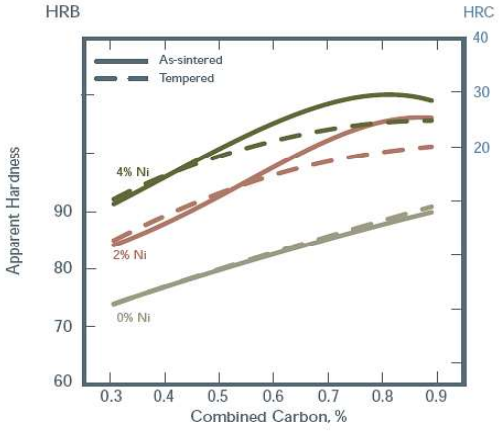
Dimensional Change

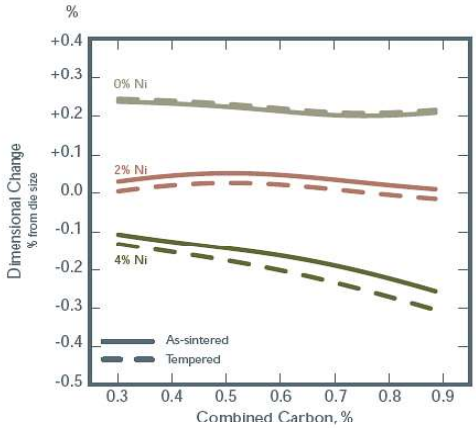
Sintered Density 6.7 g/cm^3



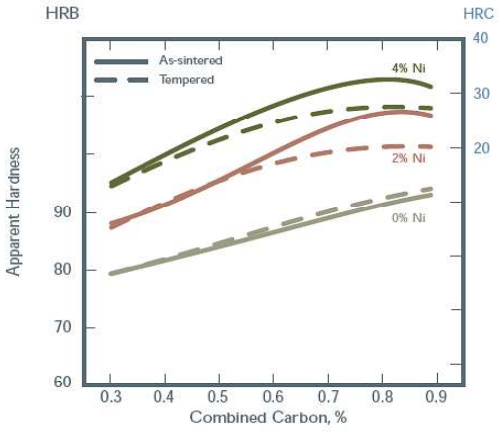


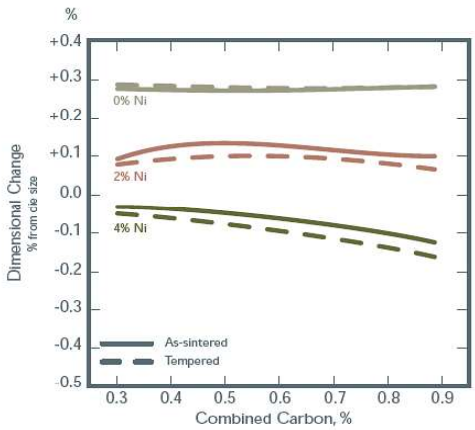
Sintered Density 6.9 g/cm^3





Sintered Density 7.1 g/cm^3





SINTERED PROPERTIES - Copper Steels

Composition: **ATOMET 4401** + copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
g/cm^3	%	%	MPa	kpsi	MPa	kpsi	MPa	kpsi	%	HRC (HRB)	%
6.67	0	0.31	646	94	364	53	284	41	1.5	(61)	0.02
6.88	0	0.31	789	114	399	58	314	46	1.5	(67)	0.05
7.08	0	0.31	933	135	435	63	345	50	1.5	(73)	0.09
6.65	0	0.69	788	114	459	67	361	52	1.0	(71)	0.13
6.86	0	0.69	950	138	494	72	397	58	1.0	(78)	0.17
7.07	0	0.69	1112	161	530	77	433	63	1.0	(84)	0.21
6.64	0	0.89	824	120	484	70	387	56	<1	(76)	0.19
6.85	0	0.89	991	144	525	76	424	61	<1	(83)	0.23
7.06	0	0.89	1158	168	567	82	460	67	1.0	(88)	0.27
6.64	1	0.31	726	105	401	58	324	47	1.2	(63)	0.18
6.85	1	0.31	865	125	459	67	366	53	1.3	(72)	0.22
7.06	1	0.31	1004	146	517	75	408	59	1.4	(78)	0.27
6.65	1	0.50	833	121	454	66	367	53	1.1	(73)	0.16
6.85	1	0.50	969	141	509	74	408	59	1.2	(79)	0.21
7.06	1	0.50	1105	160	564	82	450	65	1.2	(84)	0.26
6.65	1	0.69	900	131	518	75	385	56	1.1	(77)	0.12
6.85	1	0.69	1038	150	570	83	444	64	1.0	(83)	0.19
7.06	1	0.69	1175	170	622	90	502	73	1.0	(89)	0.26
6.65	1	0.89	936	136	548	79	446	65	<1	(85)	0.13
6.85	1	0.89	1083	157	599	87	495	72	<1	(89)	0.20
7.06	1	0.89	1231	179	651	94	543	79	<1	(93)	0.27
6.61	2	0.31	798	116	439	64	337	49	1.3	(69)	0.39
6.82	2	0.31	981	142	505	73	374	54	1.6	(76)	0.43
7.02	2	0.31	1163	169	571	83	410	60	2.0	(81)	0.48
6.65	2	0.69	1065	154	633	92	449	65	<1	(92)	0.15
6.85	2	0.69	1251	181	696	101	483	70	<1	16	0.21
7.06	2	0.69	1438	209	759	110	517	75	<1	20	0.27
6.65	2	0.89	940	136	560	81	453	66	<1	16	0.10
6.86	2	0.89	1113	161	620	90	498	72	<1	19	0.16
7.06	2	0.89	1287	187	679	99	543	79	<1	22	0.22

TEMPERED PROPERTIES - Copper Steels

Composition: **ATOMET 4401** + copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.
Tempered 1 hour in air at 205ºC.

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional change
g/cm^3	%	%	MPa	kpsi	MPa	kpsi	MPa	kpsi	%	HRC (HRB)	%
6.67	0	0.31	660	96	358	52	304	44	1.6	(61)	0.02
6.88	0	0.31	800	116	401	58	338	49	1.7	(67)	0.06
7.08	0	0.31	940	136	444	64	373	54	1.8	(73)	0.09
6.65	0	0.69	790	115	457	66	364	53	1.2	(71)	0.13
6.86	0	0.69	961	139	498	72	402	58	1.1	(79)	0.17
7.07	0	0.69	1133	164	539	78	440	64	1.0	(85)	0.20
6.64	0	0.89	825	120	493	71	396	57	<1	(76)	0.18
6.85	0	0.89	1009	146	524	76	431	63	<1	(83)	0.22
7.06	0	0.89	1193	173	556	81	467	68	<1	(89)	0.27
6.64	1	0.31	732	106	397	58	319	46	1.6	(63)	0.19
6.85	1	0.31	893	130	453	66	361	52	1.7	(72)	0.24
7.06	1	0.31	1053	153	508	74	403	58	1.8	(78)	0.28
6.65	1	0.50	847	123	465	67	374	54	1.2	(74)	0.17
6.85	1	0.50	983	143	521	76	419	61	1.3	(79)	0.22
7.06	1	0.50	1119	162	578	84	464	67	1.4	(84)	0.27
6.65	1	0.69	914	133	524	76	415	60	1.0	(77)	0.13
6.85	1	0.69	1051	153	579	84	459	67	1.0	(83)	0.20
7.06	1	0.69	1189	172	634	92	503	73	1.1	(89)	0.26
6.65	1	0.89	957	139	568	82	439	64	1.3	(86)	0.13
6.85	1	0.89	1108	161	624	90	497	72	1.1	(90)	0.20
7.06	1	0.89	1259	183	679	98	554	80	<1	(94)	0.27
6.61	2	0.31	814	118	443	64	339	49	1.1	(69)	0.39
6.82	2	0.31	980	142	500	73	382	55	1.4	(76)	0.43
7.02	2	0.31	1145	166	558	81	424	62	1.7	(82)	0.46
6.65	2	0.69	1133	164	655	95	484	70	<1	(90)	0.14
6.85	2	0.69	1323	192	734	106	539	78	<1	(94)	0.20
7.06	2	0.69	1514	220	81	118	594	86	<1	18	0.26
6.65	2	0.89	1144	166	667	97	530	77	<1	17	0.07
6.86	2	0.89	1327	193	734	106	592	82	<1	20	0.14
7.06	2	0.89	1510	219	802	116	594	86	<1	23	0.21

SINTERED PROPERTIES - Copper - Nickel Steels

Composition: **ATOMET 4401** + nickel + 1% copper + graphite + 0.75% ZnSt.
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.

Sintered Density	Added Nickel	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
g/cm^3	%	%	%	MPa	kpsi	MPa	kpsi	MPa	kpsi	%	HRC (HRB)	%
6.64	0	1	0.31	726	105	401	58	324	47	1.2	(63)	0.18
6.85	0	1	0.31	865	125	459	67	366	53	1.3	(72)	0.22
7.06	0	1	0.31	1004	146	517	75	408	59	1.4	(78)	0.27
6.65	0	1	0.5	833	121	454	66	367	53	1.1	(73)	0.16
6.85	0	1	0.5	969	141	509	74	408	59	1.2	(79)	0.21
7.06	0	1	0.5	1105	160	564	82	450	65	1.2	(84)	0.26
6.65	0	1	0.69	900	131	518	75	385	56	1.1	(77)	0.12
6.85	0	1	0.69	1038	150	570	83	444	64	1.0	(83)	0.19
7.06	0	1	0.69	1175	170	622	90	502	73	1.0	(89)	0.26
6.65	0	1	0.89	936	136	548	79	446	65	<1	(85)	0.13
6.85	0	1	0.89	1083	157	599	87	495	72	<1	(89)	0.20
7.06	0	1	0.89	1231	179	651	94	543	79	<1	(93)	0.27
6.68	2	1	0.31	968	140	511	74	365	53	1.3	(78)	-0.04
6.88	2	1	0.31	1157	168	570	83	396	57	1.5	(83)	0.02
7.08	2	1	0.31	1346	195	629	91	428	62	1.7	(88)	0.09
6.67	2	1	0.5	1130	164	629	91	432	63	2.1	(89)	-0.03
6.88	2	1	0.5	1321	192	701	102	481	70	2.2	(93)	0.05
7.08	2	1	0.5	1513	219	773	112	529	77	2.2	16	0.13
6.68	2	1	0.69	1018	148	617	90	479	69	<1	19	-0.05
6.88	2	1	0.69	1196	174	686	100	527	77	<1	22	0.03
7.08	2	1	0.69	1375	199	755	110	576	84	<1	25	0.11
6.68	2	1	0.89	880	128	498	72	396	57	<1	25	-0.07
6.88	2	1	0.89	996	144	567	82	449	65	<1	26	0.01
7.08	2	1	0.89	1111	161	636	92	502	73	<1	27	0.10
6.7	4	1	0.31	1155	168	614	89	424	62	1.3	(86)	-0.18
6.9	4	1	0.31	1308	190	654	95	444	64	1.6	(91)	-0.10
7.1	4	1	0.31	1461	212	695	101	464	67	1.9	16	-0.03
6.71	4	1	0.5	1238	180	725	105	514	74	<1	17	-0.24
6.91	4	1	0.5	1450	210	818	119	546	79	1.2	22	-0.15
7.11	4	1	0.5	1662	241	911	132	578	84	1.5	25	-0.05
6.72	4	1	0.69	1124	163	658	96	512	74	<1	26	-0.29
6.91	4	1	0.69	1220	177	703	102	533	77	<1	30	-0.18
7.11	4	1	0.69	1315	191	748	109	555	81	<1	33	-0.08
6.73	4	1	0.89	863	125	502	73	411	60	<1	27	-0.38
6.92	4	1	0.89	992	144	554	80	429	62	<1	30	-0.25
7.12	4	1	0.89	1121	163	606	88	446	65	<1	33	-0.12

TEMPERED PROPERTIES - Copper - Nickel Steels

Composition: **ATOMET 4401** + nickel + 1% copper + graphite + 0.75% ZnSt
Sintered in a 90% nitrogen-based atmosphere at 1120ºC (2050ºF) for 25 minutes.
Tempered 1 hour in air at 205ºC.

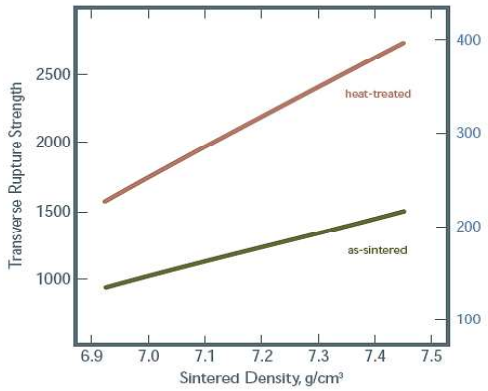
Sintered Density	Added Nickel	Added Copper	Combined Carbon	Transverse Rupture Strength		Tensile Strength		Yield Strength		Elongation	Apparent Hardness	Dimensional Change
g/cm^3	%	%	%	MPa	kpsi	MPa	kpsi	MPa	kpsi	%	HRC (HRB)	%
6.64	0	1	0.31	732	106	397	58	319	46	1.6	(63)	0.19
6.85	0	1	0.31	893	129	453	66	361	52	1.7	(72)	0.24
7.06	0	1	0.31	1053	153	508	74	403	58	1.8	(78)	0.28
6.65	0	1	0.50	847	123	465	67	374	54	1.2	(74)	0.17
6.85	0	1	0.50	983	143	521	76	419	61	1.3	(79)	0.22
7.06	0	1	0.50	1119	162	578	84	464	67	1.4	(84)	0.27
6.65	0	1	0.69	914	133	524	76	415	60	1.0	(77)	0.13
6.85	0	1	0.69	1051	152	579	84	459	67	1.0	(83)	0.20
7.06	0	1	0.69	1189	172	634	92	503	73	1.1	(89)	0.26
6.65	0	1	0.89	957	139	568	82	439	64	1.3	(86)	0.13
6.85	0	1	0.89	1108	161	624	90	497	72	1.1	(90)	0.20
7.06	0	1	0.89	1259	183	679	98	554	80	<1	(94)	0.27
6.68	2	1	0.31	979	142	517	75	370	54	1.4	(80)	-0.06
6.88	2	1	0.31	1171	170	583	85	407	59	1.5	(84)	0.00
7.08	2	1	0.31	1363	198	648	94	444	64	1.6	(87)	0.07
6.67	2	1	0.50	1144	166	633	92	465	67	1.5	(90)	-0.06
6.88	2	1	0.50	1335	194	704	102	506	73	1.4	(93)	0.02
7.08	2	1	0.50	1527	221	775	112	546	79	1.4	16	0.10
6.68	2	1	0.69	1213	176	707	103	501	73	<1	(95)	-0.09
6.88	2	1	0.69	1385	201	775	112	549	80	<1	18	0.00
7.08	2	1	0.69	1556	226	842	122	597	87	<1	20	0.08
6.68	2	1	0.89	1271	184	743	108	492	71	<1	21	-0.12
6.88	2	1	0.89	1424	206	808	117	544	79	<1	21	-0.03
7.08	2	1	0.89	1576	229	874	127	595	86	<1	22	0.06
6.70	4	1	0.31	1118	162	621	90	465	67	1.3	(88)	-0.21
6.90	4	1	0.31	1321	192	662	96	486	70	1.6	(92)	-0.13
7.10	4	1	0.31	1525	221	703	102	506	73	1.9	(95)	-0.05
6.71	4	1	0.50	1267	184	736	107	509	74	<1	(95)	-0.28
6.91	4	1	0.50	1478	214	832	121	546	79	1.1	19	-0.18
7.11	4	1	0.50	1688	245	927	135	583	85	1.3	23	-0.08
6.72	4	1	0.69	1322	192	797	116	496	72	1.0	21	-0.34
6.91	4	1	0.69	1561	226	884	128	527	76	1.1	25	-0.22
7.11	4	1	0.69	1799	261	972	141	558	81	1.2	29	-0.11
6.73	4	1	0.89	1279	186	765	111	410	59	<1	23	-0.42
6.92	4	1	0.89	1471	213	843	122	461	67	1.0	26	-0.29
7.12	4	1	0.89	1662	241	922	134	512	74	1.1	29	-0.15

REPRESSED/RESINTERED PROPERTIES

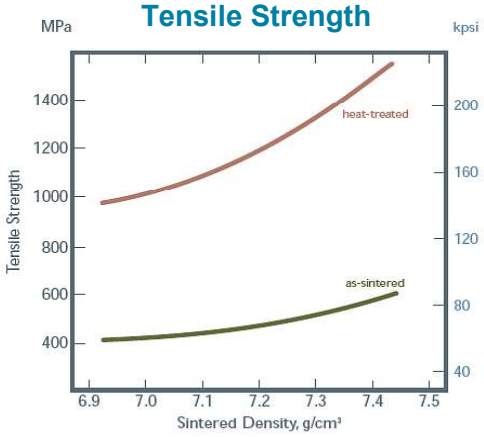
The high compressibility of **ATOMET 4401** allows for added flexibility to conventional press and sinter manufacturing. **ATOMET 4401** may be repressed/ resintered to achieve final densities exceeding 7.4 g/cm^3. These higher densities provide improved mechanical and dynamic properties for demanding applications.

Composition: **ATOMET 4401** + 0.6% graphite + 0.75% ZnSt
First sintering: 725ºC (1340ºF) for 30 minutes in dissociated ammonia.
Second sintering: 1120ºC (2050ºF) for 30 minutes in a rich endo atmosphere
Heat treatment: 15 minutes at 845ºC (1550ºF), oil quenched and tempered 1 hour at 235ºC (445ºF)

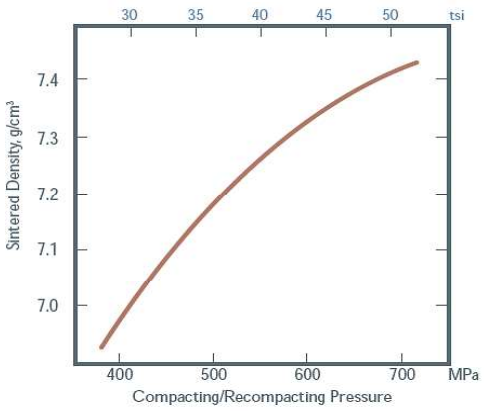
Transverse Rupture Strength



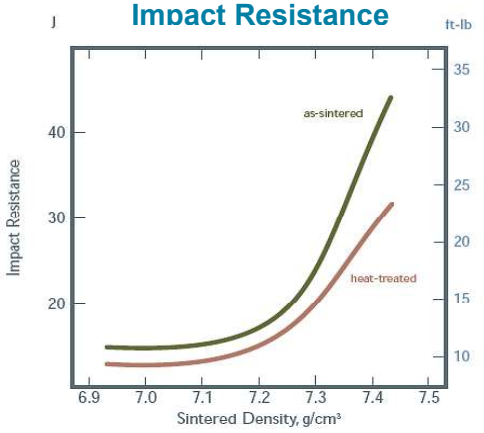
Tensile Strength



Density



Impact Resistance



	Sintered Density g/cm^3	Combined Carbon %	Transverse Rupture Strength MPa	Transverse Rupture Strength kpsi	Tensile Strength MPa	Tensile Strength kpsi	Apparent Hardness HRC (HRB)
As-sintered	7.00	0.54	1030	150	430	62	(78)
	7.20	0.54	1200	175	480	70	(81)
	7.40	0.53	1450	210	570	83	(87)
Heat-treated	7.00	0.54	1720	250	1030	150	40
	7.20	0.54	2210	320	1210	175	45
	7.40	0.53	2620	380	1520	220	50

METALLOGRAPHIC ANALYSIS

ATOMET 4001PF, with an exceptionally low level of non-metallic inclusions, is an ideal choice for fully dense applications which demand exceptional mechanical and dynamic properties.

1. Cleanliness

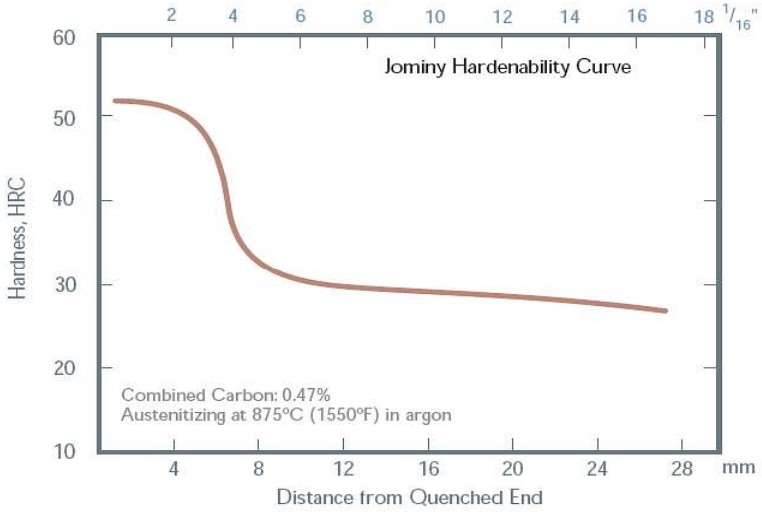
A) Total surface area of inclusions: **0.006%**

B) Inclusions count:

Length µm	Number/ 100 mm^2
30/50	4.0
50/100	0.7
100/150	0.1
>150	0.0

2. Unalloyed Iron: 0.5%

Hardenability at Full Density



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