INFORMATION MANUAL FOR MATERIAL SELECTION OF INDUSTRIAL CUTTING BLADES

WHAT KIND OF STEEL DO I HAVE? HOW DOES IT COMPARE WITH OTHER MATERIAL SELECTION OPTIONS? WHICH MATERIAL SELECTION WILL GIVE THE BEST QUALITY BLADE? THESE ARE THE SAME QUESTIONS OUR FIELD REPRESENTATIVES AND INSIDE SALES TECHNICIANS FREQUENTLY ENCOUNTER. THE PURPOSE OF THIS BOOKLET IS TO PROVIDE INFORMATION THAT ENABLES THE READER TO ANSWER THESE QUESTIONS AND HELP THEM MAKE SOUND MATERIAL SELECTION.

MATERIAL CHOICE IS AN IMPORTANT CONSIDERATION WHEN TRYING TO ACHIEVE THE GOALS OF CONSISTENT AND ACCEPTABLE CUT QUALITY. THE PURCHASE OF KNIVES IS OFTEN BASED UPON PRICE BECAUSE THE DECISION MAKER IS UNAWARE OF THE BENEFITS OF A BETTER MATERIAL, INCLUDING BETTER WEAR RESISTANCE, IMPROVED CUTTING PERFORMANCE, AND BETTER SLIT QUALITY. TWO KNIVES MADE FROM DIFFERENT TYPES OF MATERIAL OFTEN LOOK THE SAME. THE ONLY WAY TO ACCURATELY DIFFERENTIATE BETWEEN THE PERFORMANCE OF TWO BLADES THAT LOOK ALIKE IS TO KNOW THEIR MATERIAL MAKEUP AND ROCKWELL HARDNESS. ONLY THEN CAN YOU SEPARATE FACT FROM FICTION ABOUT WHAT IS BEST FOR YOU.

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STEEL IS IRON ORE THAT HAS HAD THE IMPURITIES BURNED OUT OF IT THROUGH A PROCESS CALLED **SMELTING.** THE MOST BASIC STEEL MANUFACTURED FROM THE SMELTING PROCESS IS AISI 1018 MATERIAL. THIS STEEL, OR VARIATIONS OF IT ARE USED IN THE BODY OF AUTOMOBILES, BASIC JIGS, FIXTURES AND THE LIKE. THE FIRST TWO NUMBERS IN A NUMBERED AISI DESCRIPTION DESIGNATE ALLOY CONTENT. THE SECOND TWO NUMBERS DESIGNATE. CARBON CONTENT. THE TERM **AISI** USED IN THE AISI 1018 DESCRIPTION STANDS FOR **"AMERICAN IRON AND STEEL INSTITUTE".** THIS INSTITUTION NAMES DIFFERENT TYPES OF STEEL AND KEEPS TRACK OF WHERE THAT PARTICULAR STEEL FITS INTO THE FAMILY OF STEELS. THEIR ADDRESS IS:

AMERICAN IRON AND STEEL INSTITUTE
1000 16th ST. N.W.
WASHINGTON D.C., 20036
(202)-452-7100

CARBON IS A NECESSARY COMPONENT IN ANY STEEL FOR IT TO HAVE WHAT IS DESCRIBED IN THE STEEL TRADE AS **"HARDENABILITY".** 1018 STEEL CONTAINS VERY LITTLE CARBON IN ITS CONTENT AND THEREFORE WILL NOT HARDEN TO ANY SIGNIFICANT DEGREE.

ALL KNIFE STEELS HAVE TO BE HARDENED, AFTER MACHINING, TO GIVE THAT PIECE OF STEEL ITS OPTIMUM WEAR CHARACTERISTICS. THIS IS DONE IN A FURNACE THAT HEATS THE STEEL UP TO IT'S HARDENING TEMPERATURE. THIS CAN BE ANYWHERE FROM 1500 TO 2200 DEGREES FAHRENHEIT, DEPENDING ON THE GRADE OF STEEL.

IN DISCUSSING THE DIFFERENT LEVELS OF KNIFE HARDNESS, THE ROCKWELL C SCALE IS GENERALLY USED.

SCALE	TESTING APPLICATION
A	For tungsten carbide and other extremely hard materials. Also for thin, hard sheets.
B	For materials of medium hardness such as low and medium carbon steels in the annealed condition.
C	For materials harder than Rockwell B-100.
D	Where somewhat lighter load is desired than on C scale, as on case hardened pieces.
E	For very soft materials such as bearing metals.

* Robert E. Green, Machinery's Handbook, 24th Edition. Industrial Press, NY, NY

COMPARATIVE HARDNESS SCALES FOR STEEL

Rockwell C Scale Hardness #	Diamond Pyramid Hardness Number Vickers	Brinell Hardness Number 10 mm Ball 3000 kgf Load			Rockwell Hardness Number		Rockwell Superficial Hardness Number Superficial Diam Penetrators		
		Standard Ball	Hultgren Ball	Tungsten Carbide Ball	A-Scale 60-kgf Load Diam Penetrator	D-Scale 60-kgf Load Diam Penetrator	15-N Scale 15-kgf Load	30-N Scale 30-kgf Load	45-N Scale 45-kgf Load
68	940	…	…	…	85.6	76.9	93.2	84.4	75.4
67	900	…	…	…	85.0	76.1	92.9	83.6	74.2
66	865	…	…	…	84.5	75.4	92.5	82.2	73.3
65	832	…	…	739	83.9	74.5	92.2	81.9	72.0
64	800	…	…	722	83.4	73.8	91.8	81.1	71.0
63	772	…	…	705	82.8	73.0	91.4	80.1	69.9
62	746	…	…	688	82.3	72.2	91.1	79.3	68.8
61	720	…	…	670	81.8	71.5	90.7	78.4	67.7
60	697	…	613	654	81.2	70.7	90.2	77.5	66.6
59	674	…	599	634	80.7	69.9	89.8	76.6	65.5
58	653	…	587	615	80.1	69.2	89.3	75.7	64.3
57	633	…	575	595	79.6	68.5	88.9	74.8	63.2
56	613	…	561	577	79.0	67.7	88.3	73.9	62.0
55	595	…	546	560	78.5	66.9	87.9	73.0	60.9
54	577	…	534	543	78.0	66.1	87.4	72.0	59.8
53	560	…	519	525	77.4	65.4	86.9	71.2	58.6
52	544	500	508	512	76.8	64.6	86.4	70.2	57.4
51	528	487	494	496	76.3	63.8	85.9	69.4	56.1
50	513	475	481	481	75.9	63.1	85.5	68.5	55.0
49	498	464	469	469	75.2	62.1	85.0	67.6	53.8
48	484	451	455	455	74.7	61.4	84.5	66.7	52.5
47	471	442	443	443	74.1	60.8	83.9	65.8	51.4
46	458	432	432	432	73.6	60.0	83.5	64.8	50.3
45	446	421	421	421	73.1	59.2	83.0	64.0	49.0
44	434	409	409	409	72.5	58.5	82.5	63.1	47.8
43	423	400	400	400	72.0	57.7	82.0	62.2	46.7
42	412	390	390	390	71.5	56.9	81.5	61.3	45.5
41	402	381	381	381	70.9	56.2	80.9	60.4	44.3
40	392	371	371	371	70.4	55.4	80.4	58.5	43.1
39	382	362	362	362	69.9	54.6	79.9	58.6	41.9
38	372	353	353	353	69.4	53.8	79.4	57.7	40.8
37	363	344	344	344	68.9	53.1	78.8	56.8	39.6
36	354	336	336	336	68.4	52.3	78.3	55.9	38.4
35	345	327	327	327	67.9	51.5	77.7	55.0	37.2
34	336	319	319	319	67.4	50.8	77.2	54.2	36.1
33	327	311	311	311	66.8	50.0	76.6	53.3	34.9
32	318	301	301	301	66.3	49.2	76.1	52.1	33.7
31	310	294	294	294	65.8	48.4	75.6	51.3	32.5
30	302	286	286	286	65.3	47.7	75.0	50.4	31.3
29	294	279	279	279	64.7	47.0	74.5	49.5	30.1
28	286	271	271	271	64.3	46.1	73.9	48.6	28.9
27	279	264	264	264	63.8	45.2	73.3	47.7	27.8
26	272	258	258	258	63.3	44.6	72.8	46.8	26.7
25	266	253	253	253	62.8	43.8	72.2	45.9	25.5
24	260	247	247	247	62.4	43.1	71.6	45.0	24.3
23	254	243	243	243	62.0	42.1	71.0	44.0	23.1
22	248	237	237	237	61.5	41.6	70.5	43.2	22.0
21	243	231	231	231	61.0	40.9	69.9	42.3	20.7
20	238	226	226	226	60.5	40.1	69.4	41.5	19.6

Note: The values in this table shown in bold type correspond to those shown in American Society for Testing and Materials Specification E140-67.

STEEL ENGINEERS, OR METALLURGISTS, DEVELOP VARIOUS FORMULATIONS OF STEEL BASED UPON THEIR INTENDED USE. **ALLOYS** ARE INCLUDED IN STEEL FORMULAS TO GIVE STEEL DIFFERENT PHYSICAL CHARACTERISTICS BASED UPON ITS INTENDED APPLICATION. SOME EXAMPLES OF THE DIFFERENT ALLOYING ELEMENTS ARE LISTED BELOW.

1. **CARBON** IS THE PRINCIPLE HARDENING AGENT IN STEEL.

2. **MANGANESE** CONTRIBUTES TO STRENGTH AND ALSO HARDNESS.

3. **PHOSPHORUS** INCREASES A STEEL'S MACHINABILITY AND RESISTANCE TO CORROSION.

4. **MOLYBDENUM** GIVES STEEL CORROSION RESISTANCE, AND MAKES IT LESS BRITTLE AT A HIGH HARDNESS.

ALL STEELS FIT INTO 3 BASIC CATEGORIES BASED UPON THEIR DIFFERENT FORMULAS. THEY ARE LISTED BELOW.

1. **PLAIN CARBON GRADE STEELS** - THESE STEELS CONTAIN NO ALLOYING ELEMENTS. THESE STEELS WILL HARDEN, BUT WILL EXHIBIT NO IMPROVED ALLOYING CHARACTERISTICS. (EXAMPLES - 1050, 1075,1080)

2. **ALLOY GRADE MATERIAL** - THESE STEELS ATTAIN A HARDNESS AND DISPLAY SOME IMPROVED PERFORMANCE CHARACTERISTICS BECAUSE OF THE ADDITIONAL ALLOYS CONTAINED IN THEIR FORMULA. (EXAMPLES - 52100, 4142, 4150)

3. **TOOL STEELS** - THESE STEELS ATTAIN A HARDNESS AND DISPLAY IMPROVED PERFORMANCE CHARACTERISTICS SUCH AS WEAR, TOUGHNESS, AND STRENGTH. THE **AISI** HAVE ASSIGNED THEM A DIFFERENT TITLE DESIGNATION THAT NO LONGER CONTAINS FOUR OR MORE NUMBERS. THIS SETS THEM APART AS A **TOOL STEEL**. EXAMPLES (0-1, D-2, M-2).

THE CHART ON THE FOLLOWING PAGE LISTS DIFFERENT TYPES OF STEEL AND THEIR COMPOSITION. THESE ELEMENTS ENABLE THE INDIVIDUAL STEEL TO ACQUIRE IMPROVED PERFORMANCE CHARACTERISTICS. 1018 IS NOT A KNIFE STEEL, BUT IS LISTED AS A REFERENCE FOR COMPARISON PURPOSES.

STEEL COMPOSITION CHART

MASS EFFECT DATA
(SINGLE HEAT RESULTS)

AISI Type	IDENTIFYING ELEMENTS, NOMINAL % OF CONTENT								
(*)	C	Mn	Si	Cr	Ni	V	W	Mo	Co
1018	0.175	0.750							
4140	0.405	0.875	0.275	0.950				0.20	
4142	0.425	0.875	0.275	0.950				0.20	
52100	1.040	0.350	0.275	0.450					
L6	0.700	0.525	0.500 MAX	0.900	1.625	0.250		0.50	
01	0.925	1.200	0.300	0.500		0.300	0.500		
S7	0.500	0.550	0.600	3.250		0.250		1.55	
A2	1.000	0.700	0.300	5.125		0.325		1.15	
D2	1.500	0.400	0.450	12.00		0.800		0.95	
D3	2.175	0.400	0.350	12.25		1.000			
440C (SS)	1.075	1.00 MAX	1.00 MAX	17.00				.75 MAX	
316 (SS)	0.08	2.00	0.75	17.00	12.00			2.50	
M2	0.830	0.275	0.325	4.125		1.850	6.400	5.00	
M4	1.325	0.275	0.325	4.250	0.300 MAX	4.125	5.875	4.875	
M42	1.100			3.875		1.150	1.500	9.50	8.25
T1	0.725	0.250	0.300	4.125	0.300 MAX	1.100	18.00		
CPM10V	2.450	0.500	0.900	5.250		9.750		1.30	
CPMM4	1.400	0.300	0.550	4.000		4.000	5.500	5.25	
Vanad10	2.900	0.500	1.000	8.000		9.800		1.50	
ASP23	1.280			4.200		3.100	6.400	5.00	

(*) C CARBON
Mn MANGANESE
Si SILICON
Cr CHROMIUM
Ni NICKEL

(*) V VANADIUM
W TUNGSTEN
Mo MOLYBDENUM
Co COBALT

MACHINE KNIFE MANUFACTURERS USE MOST OF THE ABOVE STEEL TYPES IN THE MANUFACTURE OF INDUSTRIAL CUTTING BLADES. MATERIAL SELECTION DEPENDS ON WHAT THE CUSTOMER DESIRES WITHIN GIVEN PRICE AND PERFORMANCE PARAMETERS.

CARBIDE, CERAMIC AND POWDERED METAL

CARBIDE AND POWDERED METAL HAVE BECOME IMPORTANT INDUSTRIAL BLADE MATERIALS. CARBIDE IS A COMPOSITION OF TWO ELEMENTS, TUNGSTEN, AND A BINDER MATERIAL TO GIVE THE FINAL MIX STRENGTH. THIS BINDER MATERIAL IS USUALLY COBALT. THESE INGREDIENTS ARE MIXED TOGETHER AND HEATED IN A FURNACE AT TEMPERATURES OF FROM 2500 TO 2900 DEGREES F. THIS PROCESS IS CALLED **SINTERING**. BECAUSE OF ITS HIGH HARDNESS, CARBIDE IS TESTED ON THE **ROCKWELL A** SCALE.

TUNGSTEN CARBIDE GRADE SPECIFICATIONS CHART

Carolina Grade	Cobalt Binder %	C Code	ISO Code	Rockwell Scale A	Hardness Scale C	Minimum Transverse Rupture PSI	Compressive Strength PSI
CD-20	3	C-4	K-01	91.8-92.8	79.8-81.5	180,000	660,000
CD-24X	5	C-3	K-10, M-10	91.5-92.5	79.0-81.0	240,000	680,000
CD-30	6	C-2, C-9	K-20, M-20	90.5-92.0	77.0-80.0	260,000	690,000
CD-35F	9			90.2-91.2	76.5-79.5	300,000	700,000
CD-35	9	C-10	G-10	89.8-90.8	75.6-77.6	275,000	682,000
CD-36	10			89.5-90.5	75.0-77.0	280,000	675,000
CD-337	11	G-20	88.0-89.0	72.0-74.0		420,000	650,000
CD-38	12			88.8-89.8	73.5-75.5	320,000	650,000
CD-18	12			89.0-90.0	74.0-76.0	340,000	660,000
CD-40	3	C-11	G-25	88.5-89.5	73.0-75.0	340,000	639,000
CD-45	14	C-12		88.0-89.0	72.0-74.0	360,000	600,000
CD-50	15	C-13	G-30	87.5-88.5	71.0-73.0	375,000	554,000
CD-53	16	C-13	G-35	87.0-88.0	71.0-72.0	375,000	525,000
CD-55	17			86.0-87.0	69.0-71.0	375,000	500,000
CD-60	20	C-14	G-40	83.0-84.5	63.0-66.0	380,000	483,000
CD-70	25	C-15	G-50, G-55	81.5-83.0	61.0-63.0	370,000	454,000

George Schneider, Jr., Principles of Tungsten Carbide Engineering, 2nd Edition.
Materials Park, Ohio

RULES OF THUMB WHEN DISCUSSING CARBIDE

- The finer the grain size, the higher the hardness.
- The lower the cobalt content, the higher the hardness.
- The higher the hardness, the greater the abrasive wear resistance.
- The lower the cobalt content, the lower the strength.
- The finer the grain size, the lower the strength.

DEFINED TERMS:

1. **BINDER** % - THE AMOUNT OF COBALT BINDER BLENDED WITH THE TUNGSTEN IN EACH GRADE OF CARBIDE.
2. **C CODE -** CARBIDE'S VERSION OF THE AISI CODE.
3. **ISO CODE -** THE CODE RECOGNIZED INTERNATIONALLY IN DESCRIBING DIFFERENT TYPES OF CARBIDE.
4. **MINIMUM TRANSVERSE RUPTURE PSI -** A STANDARD TEST DEVELOPED BY THE INDUSTRY TO DETERMINE A CARBIDE GRADE'S RESISTANCE TO MECHANICAL SHOCK, OR IMPACT.
5. **COMPRESSIVE STRENGTH PSI -** A STANDARD INDUSTRY TEST TO INFORM THE CUSTOMER ABOUT COMPRESSIVE QUALITIES OF EACH GRADE.

TEST RUN COMPARISONS BETWEEN CARBIDE AND 52100 STEEL BOTTOM KNIVES, HAVE SHOWN UP TO A TENFOLD INCREASE IN PRODUCTION WHEN USING CARBIDE OVER STEEL. THIS MEANS IF YOU WERE CHANGING EVERY 3 WEEKS WITH 52100 KNIVES, YOU SHOULD ONLY CHANGE EVERY 30 WEEKS WITH CARBIDE. IN PAPER CONVERTING WE RECOMMEND A GRADE OF C-13. THIS HAS A 15% COBALT BINDER. COMPARATIVE TESTS HAVE SHOWN IT TO BE THE BEST CHOICE WHEN CONSIDERING RUN TIME AND COST.

CERAMIC

CERAMIC CUTTING TOOLS HAVE ALSO COME INTO USE IN THE PAST 20 YEARS. THEY ORIGINALLY GAINED ACCEPTANCE IN THE AEROSPACE AND MACHINE TOOL INDUSTRIES BECAUSE OF THEIR ABILITY TO MAINTAIN GOOD HARDNESS AND WEAR PROPERTIES AT VERY HIGH TEMPERATURES. FROM THESE AREAS CERAMICS HAVE BRANCHED OUT INTO OTHER INDUSTRIAL AREAS INCLUDING THE CONVERTING PROCESS. THEIR HIGH HARDNESS HAS GAINED THEM ACCEPTANCE IN SOME AREAS OF PAPER CONVERTING. HOWEVER, BECAUSE OF THE HIGH HARDNESS, CERAMICS ARE MORE BRITTLE THAN CARBIDES. THIS MAY RESULT IN EXCESSIVE AND PREMATURE CHIPPING OF THE CUTTING EDGE, SHORTENING THE RUN TIME OF THE KNIFE AS WELL AS REDUCING ITS NORMAL LIFE SPAN AS A USEFUL TOOL.

CATEGORY kg/mm² Mpap m½	VICKERS HARDNESS psi	FRACTURE TOUGHNESS psi x 10^6	BENDING STRENGTH k^1 10^6	MODULUS OF ELASTICITY Cal	THERMAL EXPANSION	THERMAL CONDUCTIVE cm sec pc
Aluminumoxide with Zirconiumoxide	1.700	5.5	90.000	53	8.3	0.060
Aluminum with Titaniumcarbide	2.000	4.5	90.000	59	8.0	0.079
Aluminumoxide with Siliconcarbide Whiskers	2.000	6.8	100.000	58	5.8	0.100
Siliconnitride with Metaloxides	1.600	6.5	115.000	44	2.8	0.069
Titaniumcarbonitride with Tantalum / Niobiumcarbide	1.500	10.0	260.000	59	8.7	0.024
Cemented Tungsten Carbide K20(C2)	1.700	8.5	270.000	90	5.0	0.191
Cemented Tungsten Carbide P30(C5)	1.450	11.0	310.000	80	6.0	0.091

Comparison of typical properties of various cutting materials.

AS YOU CAN SEE FROM THE ABOVE CHART, THE BENDING STRENGTH AS WELL AS THE MODULUS OF ELASTICITY ARE MUCH GREATER WITH CARBIDE THAN THEY ARE WITH CERAMIC. OFTEN THIS ENABLES CARBIDE TO RUN LONGER BECAUSE IT IS MORE FORGIVING THAN CERAMIC WHEN OPERATING IN ENVIRONMENTS THAT ARE LESS THAN LABORATORY CONTROLLED.

POWDERED METAL

THERE ARE SIGNIFICANT DIFFERENCES BETWEEN POWDERED METAL AND CONVENTIONAL STEEL MANUFACTURING. CONVENTIONAL STEELMAKING INVOLVES MELTING THE STEEL IN A LARGE ELECTRIC FURNACE, THEN SLOWLY COOLING IT. A CHARACTERISTIC FEATURE OF SLOW COOLING IS THAT ALLOYING ELEMENTS SEGREGATE NON-UNIFORMLY, RESULTING IN LESS CONSISTENT HARDNESS AND WEAR PATTERN IN THE STEEL AFTER HEAT TREATING. THE HIGHER THE ALLOY CONTENT, THE MORE SERIOUS THE PHYSICAL AND MECHANICAL PROPERTIES OF THE STEEL WILL BE AFFECTED.

IN THE POWDERED METAL PROCESS, THE METAL IS POURED THROUGH A SMALL NOZZLE AND GAS ATOMIZED TO PRODUCE A FINE POWDER. THIS POWDER IS FILTERED THROUGH A SCREEN, POURED INTO STEEL CONTAINERS AND HEATED TO SOLIDIFY THE CONTENTS INTO ONE MASS.

THIS PROCESS IS TECHNICALLY CALLED “PARTICLE METALLURGY”. THIS NAME WAS BESTOWED ON THE PROCESS TO DISTINGUISH IT FROM THE DISSIMILAR “POWDERED METALLURGY” PROCESS USED TO CREATE PRESSED AND SINTERED PARTS SUCH AS GEARS AND PULLEYS. STEEL PRODUCED THROUGH THE PARTICLE METALLURGY PROCESS GAIN INCREASED PERFORMANCE CHARACTERISTICS IN MOST ALL AREAS OF OBJECTIVE EVALUATION. THE CRUCIBLE STEEL CORPORATION INVENTED THE PROCESS AND CAN ANSWER ANY QUESTIONS YOU MAY HAVE. YOU CAN CONTACT THEM AT 1-800--365-1180.

WE HOPE THIS INFORMATION CLARIFIES THE TYPE OF MATERIALS USED IN THE MANUFACTURE OF CUTTING BLADES. UNDERSTANDING THIS WILL HELP YOU MAKE THE BEST SELECTION OF MATERIAL FOR YOUR APPLICATIONS. IF YOU HAVE ANY QUESTIONS CONTACT ONE OF OUR MANUFACTURING FACILITIES FOR FURTHER INFORMATION.

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