CRUCIBLE

DATA SHEET

CRUCIBLE CPM® Rex M4 HC(HS)

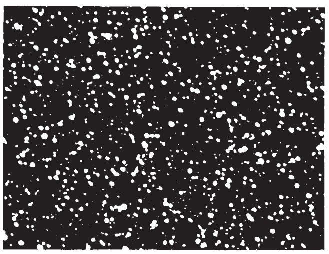
Issue #1

CPM REX M4 HC(HS) is a high vanadium special purpose high speed steel exhibiting better wear resistance and toughness than M2 or M3 in cold work punches, die inserts and cutting applications involving high speed and light cuts.

The high carbon (HC) modification to standard M4 is designed to provide optimum hardening response in larger cross-section tools or in vacuum or atmosphere heat treating.

The high sulfur (HS) modification is standard for larger diameter bars, providing enhanced machinability and grindability.

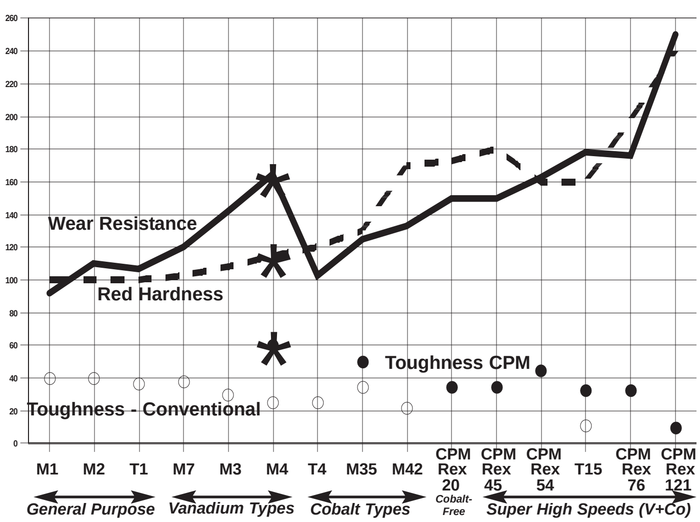
The CPM process produces very homogeneous, high quality steel characterized by superior dimensional stability, grindability, and toughness compared to steels produced by conventional processes.



CPM Steel

Conventional Steel

HIGH SPEED COMPARAGRAPH



Typical Applications

Broaches	Milling Cutters
Gear Hobs	Rolls
Shaper Cutters	Punches
Shaving Cutters	Dies

Note: These are some typical applications. Your specific application should not be undertaken without independent study and evaluation for suitability.

Carbon	**1.42%**
Chromium	**4.00%**
Vanadium	**4.00%**
Tungsten	**5.50%**
Molybdenum	**5.25%**
Manganese	**0.30% (0.70%)**
Sulfur*	**0.06% (0.22%)**

*The addition of 0.20-0.25% sulfur in larger diameter rounds (e.g. 2-9/16" and over) provides a uniform dispersion of small sulfides throughout the structure, resulting in machinability and grindability benefits with no deleterious effect on toughness.

Physical Properties

Elastic Modulus	31 X 10^6 psi	(214 GPa)
Specific Gravity	7.97	
Density	0.288 lbs./in^3	(7.970 g/cm^3)

Thermal Conductivity		BTU/hr-ft-°F	W/m-°K	cal/cm-s-°C
at 72°F	22C°	10.98	18.99	4.54 X 10^{-2}
212°F	100°C	12.03	20.82	4.97 X 10^{-2}
392°F	200°C	13.26	22.95	5.48 X 10^{-2}
572°F	300°C	13.85	23.96	5.72 X 10^{-2}
752°F	400°C	14.28	24.71	5.90 X 10^{-2}
932°F	500°C	14.78	25.58	6.11 X 10^{-2}
1004°F	540°C	15.07	26.09	6.23 X 10^{-2}

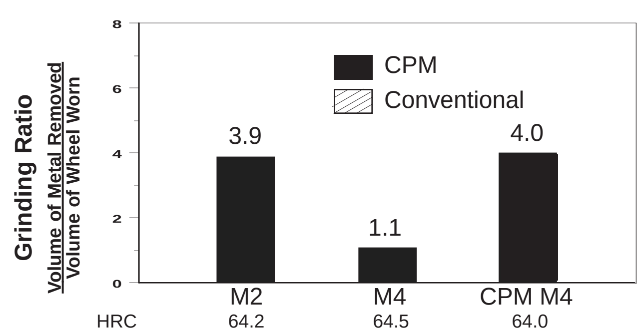
Coefficient of Thermal Expansion

°F	°C	in/in/°F	mm/mm/°C
100 - 500	(40 - 260)	6.40X10^{-6}	(11.5X10^{-6})
100 - 800	(40 - 425)	6.58X10^{-6}	(11.8X10^{-6})
100 - 1000	(40 - 540)	6.72X10^{-6}	(12.1X10^{-6})

Annealed Hardness: BHN 223/255

Machinability: In the annealed condition, the machinability of CPM Rex M4 HC(HS) is approximately 45% of W1 tool steel (1% C) with additional improvement of about 30% for the high sulfur (HS) modification.

Grindability: Because of its uniform distribution of fine carbides, the grindability of CPM Rex M4 HC(HS) compares favorably with that of conventional high speed steels . Grinding wheels designed for conventional high speed steels can be used. In special cases, the advice of a grinding wheel manufacturer should be sought.



Crucible Industries LLC

Thermal Treatments

Critical Temperature: 1545°F (840°C)
Forging: 2000-2100°F (1095-1150°) Do not forge below 1700°F (930°C). Slow Cool.
Annealing: Heat to 1600°F (870°C), hold 2 hours, slow cool no faster than 30°F (15°C) per hour to 1000°F (540°C), then furnace cool or cool in still air to room temperature.
Annealed Hardness: About BHN 225/255

Stress Relieving

Annealed Parts: Heat to 1100-1300°F (595°-700°C), hold 2 hours, then furnace cool or cool in still air.
Hardened Parts: Heat to 25-30°F (15°C) below original tempering temperature, hold 2 hours, then furnace cool or cool in still air.
Straightening: Best done warm 400-800°F (200-430°C)

Hardening

Preheat: Heat to 1500-1550°F (820-845°C) Equalize. Second pre-heat stage at 1850-1900°F (1010-1040°C) suggested for vacuum or atmosphere hardening.
Austenitize: 1875-2200°F (1025-1205°C) Hold time at temperature: 5-45 minutes. See table. For cutting tools use 2150-2200°F (1175-1205°C). For cold work applications use 1875-2125°F (1025-1160°C).
Quench: Air or positive pressure quench (2 bar minimum) to below 125°F (50°C), or salt or interrupted oil quench to about 1000°F (540°C), then air cool to below 125°F (50°C). Salt bath treatment, if practical, will ensure maximum attainable toughness for a given hardening treatment. A fast quench rate from hardening temperature to below 1100°F (595°C) is critical to achieve optimum heat treat response. A slower cooling rate below 1000°F (540°C) may be used to minimize distortion.
Temper: Double temper at 1000°F (540°C) minimum. Triple temper recommended when hardening from 2100°F (1150°C) or higher. 2 hours minimum each temper. (See Table) Air cool to room temperature between tempers.
Size Change: +0.15%

Surface Treatments

Because of its high tempering temperatures (>1000°F) CPM M4 HC(HS) is suitable for nitriding, PVD coating or similar surface treatments. CVD coating processes generally exceed the hardening temperature and may result in non-predictable dimensional changes.

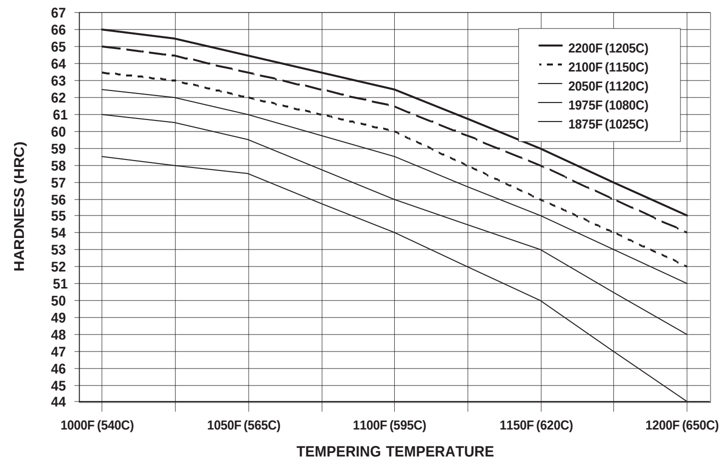
Heat Treat Response

Hardness HRC

Tempering Temperature	Austenitizing Temperature 1875°F (1025°C)	1975°F (1080°C)	2050°F (1120°C)	2100°F (1150°C)	2150°F (1175°C)	2200°F (1205°C)
As Quenched	59.5	62.5	64.5	65	65	63.5
1000°F (540°C)	58.5	61	62.5	63.5	65	66
Optimum for Maximum Toughness and Effective Stress Relieving						
1025°F (550°C)	58	60.5	62	63	64.5	65.5
1050°F (565°C)	57.5	59.5	61	62	63.5	64.5
1100°F (595°C)	54	56	58.5	60	61.5	62.5
1150°F (620°C)	50	53	55	56	58	59
1200°F (650°C)	44	48	51	52	54	55

Results may vary with hardening method and section size. Salt or oil quenching will give maximum response. Vacuum or atmosphere cooling may result in up to 1-2 HRC points lower.

Minimum Time at Aust. Temp.	45 min.	30 min.	20 min.	15 min.	10 min.	5 min.
Minimum Number of Tempers	2	2	2	3	3	3



Toughness

Depending on the hardness requirement, lowering the hardening temperature (underhardening) increases toughness.

Hardening Temperature	Tempering Temperature	Hardness HRC	Charpy C-Notch ft-lb	(J)	Bend Fracture Strength ksi	(MPa)
2200°F (1205°C)	1025°F (550°C)	65.5	20	27	738	5088
2125°F (1165°C)	1050°F (565°C)	63.5	28	38	744	5129

Note: Properties shown throughout this data sheet are typical values. Normal variations in chemistry, size and heat treat conditions may cause deviations from these values.

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