A. Finkl & Sons Co.

DATA SHEET

FX-XTRA®

Forging Die Steel

Cleanest . . . Toughest . . . Most Machinable

FX-XTRA

General Characteristics

An alloy of Ni-Cr-Mo offered in a wide range of heat treated conditions for *versatile service* in the forging industry.

FX Temper 2

The most popular, FX Temper 2 (38-42 HRC) is a remarkably strong die steel with balanced wear and fracture toughness characteristics.

FX Temper 3

The more ductile, FX Temper 3 (33-37 HRC) is for die blocks, rams, shafts, die holders, v-guides, sow blocks and other general industrial uses favoring fracture toughness over abrasion demands.

FX Temper 1 and FX Temper H

Higher hardness FX Temper 1 (43-46 HRC) or FX Temper H (47-50 HRC) is for applications where higher die temperatures and cavity pressures, or wear-prone components demand more abrasion resistance.

The balanced chemistry of FX-XTRA offers a wide range of mechanical properties suitable for a variety of industrial applications. A. Finkl & Sons Co. Sales and Technical personnel are available to help you achieve your performance goals.

Finkl Standard Hardness Ranges

Finkl Std.	BHN	HRC
XH	495-534	51-54
H	444-477	47-50
T1	401-429	43-46
T2	352-388	38-42
T3	311-341	33-37
T4	277-302	29-32
Annealed	229 approx	20 approx.

Nominal Chemistry* (Wt. %)

0.50%	CARBON
0.85%	MANGANESE
0.25%	SILICON
0.90%	NICKEL
1.15%	CHROMIUM
0.50%	MOLYBDENUM
0.05%	VANADIUM
12.5	Ideal Diameter (DI)**

* Plus patented microalloying additions

** For more information on this topic, please refer to the **Finkl Die Handbooks**.

Machinability

Machinability at all hardness levels is enhanced through patented micro-alloying additions, but where maximum machinability is desired, a fully annealed condition (approximately 229 BHN) is available.

Recommended Applications

- Hammer Dies and Hammer Rams
- Press Dies and Coining Dies
- Sow Blocks and Knockout Pins
- Punches and Inserts
- Headers and Insert Die Holders
- Gripper Dies and Hammer Guides
- Gripper Die Inserts and Piston Heads
- Guide Pins and Hammer Keys
- Extrusion Press-Backup Tools
- Gear Applications

* Covered under one or more of the following U.S. Patents: 5,496,516; 5,180,444; 5,827,376; 6,398,885

Right is reserved to change chemistry at any time to improve product.

PRODUCT WARRANTY

The material herein merely constitute instructions furnished gratuitously for your consideration. These instructions are intended as suggestions only and do not purport to be complete or to replace or to constitute normal shop practices. A. Finkl & Sons Co. makes no representation or warranty of any kind, express or implied, with respect to the matters covered herein, whether as to merchantability, fitness for a particular purpose, reproducibility of properties and results set out herein, or any other matter.

EXCLUSION OF WARRANTIES. THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR ANY PURPOSE ARE EXCLUDED.

FX-XTRA Mechanical Properties

FX-XTRA TENSILE PROPERTIES

1" Laboratory Test Bars, Longitudinal Capability Testing

Tested Block Hardness Category	Test Temperature		Hardness at Test Temp.	Tensile Strength		Yield Strength		Elongation in 2"	Reduction Area .505"
	˚F	˚C	BHN	ksi	MPa	ksi	MPa	%	%
Temper H 444-477 BHN	80	27	444	218	1503	202	1393	12.5	41
	300	149	414	207	1428	178	1228	12.0	39
	600	316	392	196	1352	160	1103	15.0	38
	800	427	330	165	1138	142	979	16.0	55
Temper 1 401-429 BHN	80	27	411	205	1414	187	1290	12.7	34
	300	149	392	196	1352	166	1145	12.5	35
	600	316	365	183	1262	150	1034	13.0	36
	800	427	311	156	1076	133	917	15.2	55
	900	482	277	137	945	123	848	17.0	61
	1000	538	217	109	752	95	655	24.0	66
Temper 2 352-388 BHN	80	27	352	174	1200	146	1007	15.5	50
	300	149	321	157	1083	128	883	15.8	48
	600	316	302	147	1014	119	821	17.2	47
	700	371	288	144	993	113	779	16.5	56
	800	427	262	130	897	105	724	18.2	64
	900	482	235	113	779	97	669	20.5	71
	1000	538	197	94	648	78	538	23.8	78
	1100	593	107	52	359	39	269	22.8	64
Temper 3 311-341 BHN	80	27	311	151	1041	130	897	18.2	50
	300	149	285	140	966	112	772	17.5	49
	400	204	277	136	938	102	703	19.0	48
	500	260	277	136	938	103	710	22.0	43
	600	316	268	134	924	95	655	21.8	49
	700	371	241	121	834	89	614	22.0	55
	800	427	215	108	745	82	566	24.2	63
	900	482	187	93	641	78	538	28.0	75
	1000	538	150	75	517	67	462	36.8	84
	1100	593	110	55	379	46	317	54.0	86

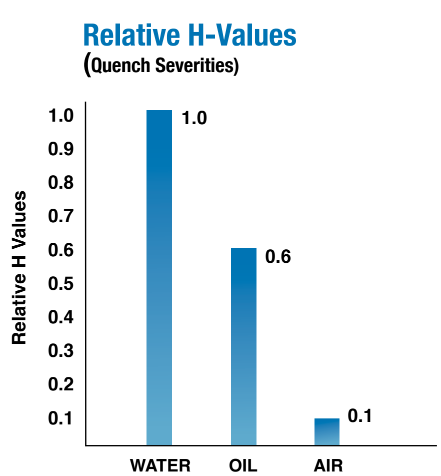
Mechanical Properties for Commercial-Sized Die Blocks

Mechanical properties developed from laboratory-sized test bars, as in the above table, are useful for comparing properties to other grades of steel from similar-sized test bars. *Full-sized blocks, however, experience a "mass-effect"* during the quenching process that reduces the effectiveness of the quench. The extent of the hardness and strength loss is determined by the cross-section size and test-depth below the quench surface. Properties of full-sized blocks should be viewed with this factor taken into account.

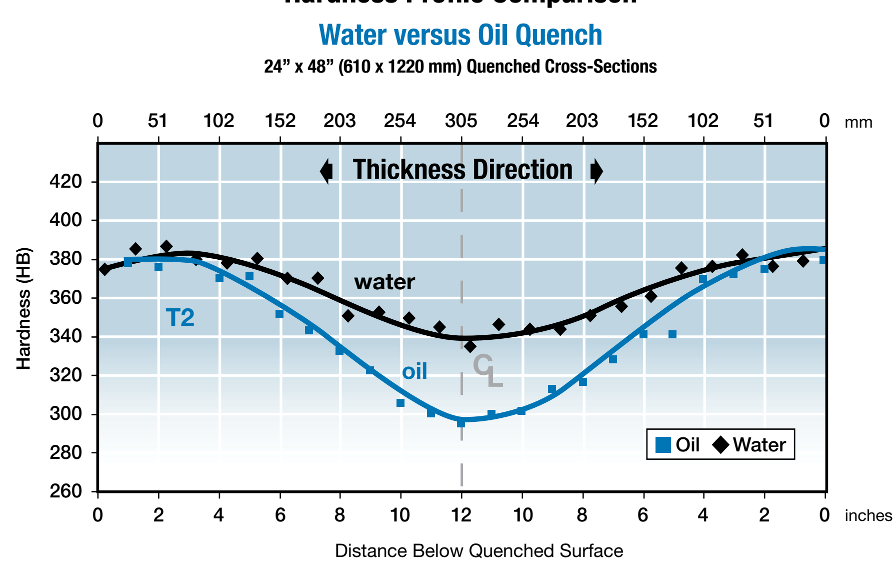
The Water Quench Advantage

Quench Severity

Employing a ***Cold Water Quench*** rather than a less effective oil or polymer quench achieves the highest possible H-value (Heat extraction rate during the quench) and the best possible microstructure and hardness throughout a cross-section.



Hardness Profile Comparison

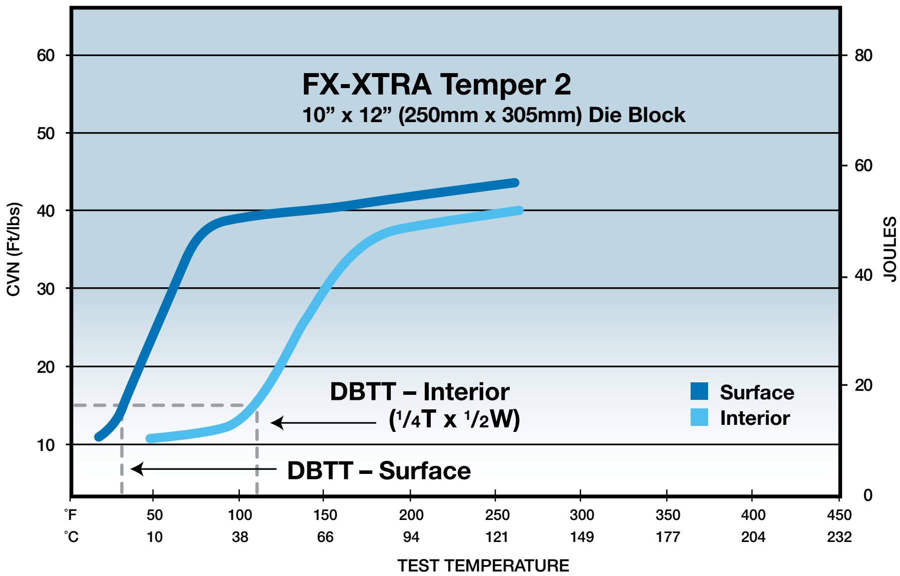


Comparing interior hardness profiles of two large 24-inch thick blocks reveals the advantage of a cold water quench.

FX-XTRA Impact Toughness

Impact Toughness—Ductile-Brittle Transition Temperature (DBTT)

The DBTT is common to all die steels, and is the temperature where the fracture characteristics transition from a brittle, crack-prone condition to a more ductile, crack resistant condition.



One definition of DBTT is where the Charpy V-Notch (CVN) test temperature produces impact-toughness energy of 15 ft-lbs.

The DBTT is influenced by the chemistry, hardness and micro-structure of the steel. Different DBTT temperatures, therefore, may occur between surface and interior locations of die blocks.

Heating beyond the DBTT offers a rapid improvement to impact toughness until the "Upper Energy Shelf" is reached.

Die Preheating

The DBTT for a die block is influenced by the hardness and microstructure. For this reason, the minimum recommended die-preheating temperatures change with block thickness and hardness according to the provided table. [For more information on this topic, please refer to the **Finkl Die Handbooks**.]

Selective Shank Tempering

For high hardness die blocks (T1, TH, TXH) selective tempering is available to reduce hardness *only on the shank side* by approximately one Finkl "Temper Range", or about four Rockwell points. The modified shank hardness gradually transitions to the base hardness at approximately three-inches below the shank surface. This option improves machinability and fracture toughness in the critical shank area.

Recommended FX® Die Steel Minimum Preheating Temperatures ˚F

			Die Block (Thickness)			
		inches / mm	5 / 127	10 / 254	15 / 381	20 / 508
Increased Wear Resistance / Increased Fracture Sensitivity ↑	DIE HARDNESS	XH	300	350	NA	NA
		H	250	300	350	350
		1	200	250	300	300
		2	70	150	200	200
		3	70	70	200	200
		4	70	70	70	200

Conversion:

˚F	70	150	200	250	300	350
˚C	20	65	95	120	150	175

Welding

The *purpose* of welding, e.g., joining, hard facing, or matching the die block hardness, will determine the appropriate welding rod for a particular application. Your selection should be discussed with a welding rod supplier. Beyond the choice of welding rod, there are many variables affecting the success of a weld. One common cause of failure is an embrittled Heat Affected Zone (HAZ). To minimize the risk of this type of failure, a preheating and post-heating procedure should be employed:

- **Preheat: 800˚F (425˚C)**
- **Maintain minimum of 400˚F (200˚C) during welding**
- **Postheat: To avoid softening of the base hardness, heat to a temperature that is 50 ˚F (30 ˚C) below the tempering temperature used to establish the base hardness (see Tempering Table below).**

Heat Treating FX-XTRA

Critical Temperatures at a Rate of 200˚F/hr (110˚C/hr):

Ac3 / Ar3	**1360 / 1340˚F (737 / 727˚C)**
Ac1 / Ar1	**840 / 720˚F (449 / 382˚C)**

Lowering the hardness of FX-XTRA may be achieved by tempering ***above*** the tempering temperature used to establish the existing hardness of the die block. Nominal tempering temperatures employed to establish the standard hardness ranges are:

Tempering Table

Nominal Tempering Temperatures for Water-Quenched Forgings

Temperature	Finkl Std.	BHN	HRC
450˚F (232˚C)	XH	495-534	51-54
880˚F (471˚C)	H	444-477	47-50
1020˚F (549˚C)	T1	401-429	43-46
1120˚F (604˚C)	T2	352-388	38-42
1180˚F (638˚C)	T3	311-341	33-37
1220˚F (660˚C)	T4	277-302	29-32

Sub-Critical Anneal

Softening may be achieved through ***Sub-Critical annealing*** by holding at 1220˚F (660˚C) for an extended period, typically 1.5 hrs/inches (1.5 hrs/25 mm). Expected hardness is approximately 248 BHN maximum.

Full Anneal

Softening with additional refinement to the microstructure may be achieved through a *Full Anneal:*

- **Heat to 1440/1460˚F (780/800˚C) and Hold 1/2 hr/inch (25mm)**
- **Drop to 1220˚F (660˚C) and Hold 4 hrs.**
- **Furnace Cool to 800˚F (425˚C)**
- **Air Cool to ambient temperature**

Expected hardness is approximately 229 BHN

Hardening

Increasing the hardness requires heating to an austenitizing temperature (1550-1600˚F/840-870˚C) followed by a quenching operation. (Some oxidation/decarburization will occur on the block surface unless heating is performed in a vacuum or protective atmosphere furnace.) *Quenching is a high stress operation introducing a risk of cracking, particularly for a machined block with contours, sharp edges, drilled holes or thin-web features.* For such product, employing a quenchant with a lower quench-severity rating will lower the risk of cracking.

- **Heat to 1550/1600˚F (840/870˚C) and Hold 1/2 hr./inch (25mm)**
- **Drop to 1450˚F (790 ˚C) and Hold 2 hrs.**
- **Quench (Oil, Polymer or Molten salt bath)**
- **Immediately temper according to the Tempering Table to the left.**

Physical Properties

Test Temperature	20˚C/68˚F	200˚C/390˚F	400˚C/750˚F
Density	7800 Kg/m³	7750	7700
	0.282 lbs/in³	0.280	0.277
Coefficient of Thermal Expansion	11.9×10^{-6} cm/cm/˚C	12.7×10^{-6}	13.6×10^{-6}
	6.6×10^{-6} in/in/˚F	7.0×10^{-6}	7.5×10^{-6}
Thermal Conductivity	29.0 J/m²/m/s/˚C	29.5	31.0
	202 BTU/ft²/in/hr/˚F	205	216
Modulus of Elasticity	205×10^{3} N/mm²	200×10^{3}	185×10^{3}
	29.7×10^{6} lbs/in²	29.0×10^{6}	26.8×10^{6}
Specific Heat	460 J/Kg ˚C	492	538
	0.110 BTU/lb ˚F	0.118	0.129
Poisson's Ratio	0.3	0.3	0.3

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