Fort Wayne Wire Die, Inc.

"Blue Book"

Wire Drawing Reference Guide

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WIRE DIE INDUSTRY LEADER

As a worldwide industry leader, Fort Wayne Wire Die, Inc., has taken great pride for more than 70 years in manufacturing quality, precision-made, wire drawing dies and hard-material components for the wire industry. Having been an ISO 9001:2000 registered company for many years, Fort Wayne Wire Die is committed to ". . . providing total customer satisfaction through the continuous improvement of our products, services and internal processes."

REPEATABILITY IS THE MEASUREMENT OF SUCCESS

Fort Wayne Wire Die's precision manufacturing capabilities are unique within the industry. A disciplined approach throughout the manufacturing process, as well as consistent quality assurance methods, have allowed us to manufacture to the customer's defined specifications each and every time.

GLOBAL ASSISTANCE AVAILABLE NOW

Operating from facilities in the United States, Canada, Germany, China and the Philippines and through representative offices located throughout the world, Fort Wayne Wire Die brings global expertise to service its international customer base.

DAILY TECHNICAL SUPPORT

Through this *Wire Drawing Reference Guide*, Fort Wayne Wire Die will be able to support your need for technical wire drawing information. From wire drawing definitions and equations to diamond and tungsten carbide die specifications, this one source incorporates it all.

- Single Crystal Natural Diamond Dies
- Single Crystal Synthetic Diamond Dies
- Poly-Di® Polycrystalline Diamond Dies
- Tungsten Carbide Dies
- Extrusion Tips and Dies
- Dual-Draw™ Wire Dies
- Multiwire Elongation Sets of Dies
- Shaped Wire Drawing Dies
- Poly-Strand™ Stranding, Bunching and Compacting Dies
- Calibrating / Enameling Dies
- Tubing Dies and Mandrels
- Shaving Dies
- Di-Pro™ Diamond Powder / Compound
- Die Recutting Services
- Die Reconditioning, Inspection and Measurement Equipment
- Ultra-Hard Wear Parts

AMERICAN WIRE GAUGE–INCHES

FULL SIZES	GAUGE	HALF SIZES	COPPER lb/1000 ft*
.580049	6/0		1,017.9020
.516549	5/0		807.2330
.460000	4/0		640.1648
.409642	3/0		507.6738
.364797	2/0		402.6036
.324861	1/0		319.2792
.289297	1		253.1999
	1.5	.273003	225.4810
.257626	2		200.7967
	2.5	.243116	178.8146
.229423	3		159.2390
	3.5	.216501	141.8064
.204307	4		126.2823
	4.5	.192800	112.4576
.181941	5		100.1464
	5.5	.171693	89.1829
.162023	6		79.4197
	6.5	.152897	70.7253
.144285	7		62.9827
	7.5	.136159	56.0877
.128490	8		49.9475
	8.5	.121253	44.4796
.114424	9		39.6102
	9.5	.107979	35.2739
.101897	10		31.4123
	10.5	.096158	27.9735
.090742	11		24.9111
	11.5	.085631	22.1840
.080808	12		19.7554
	12.5	.076257	17.5927
.071962	13		15.6667
	13.5	.067909	13.9516
.064084	14		12.4243
	14.5	.060474	11.0642
.057068	15		9.8529
	15.5	.053854	8.7743
.050821	16		7.8137
	16.5	.047958	6.9583
.045257	17		6.1966
	17.5	.042708	5.5182
.040303	18		4.9141
	18.5	.038033	4.3761
.035891	19		3.8971
	19.5	.033869	3.4704
.031961	20		3.0905
	20.5	.030161	2.7522
.028462	21		2.4509
	21.5	.026859	2.1826
.025347	22		1.9436
	22.5	.023919	1.7309
.022572	23		1.5414
	23.5	.021300	1.3726
.020101	24		1.2224
	24.5	.018969	1.0885
.017900	25		.9694
	25.5	.016892	.8633
.015941	26		.7688
	26.5	.015043	.6846
.014196	27		.6096
	27.5	.013396	.5429
.012641	28		.4835
	28.5	.011929	.4305
.011258	29		.3834
	29.5	.010624	.3414
.010025	30		.3041
	30.5	.009461	.2708
.008928	31		.2411
	31.5	.008425	.2147
.007950	32		.1912
	32.5	.007503	.1703
.007080	33		.1516
	33.5	.006681	.1350
.006305	34		.1203
	34.5	.005950	.1071
.005615	35		.0954
	35.5	.005298	.0849
.005000	36		.0756
	36.5	.004718	.0674
.004453	37		.0600
	37.5	.004202	.0534
.003965	38		.0476
	38.5	.003742	.0424
.003531	39		.0377
	39.5	.003332	.0336
.003145	40		.0299
	40.5	.002967	.0266
.002800	41		.0237
	41.5	.002643	.0211
.002494	42		.0188
	42.5	.002353	.0168
.002221	43		.0149
	43.5	.002096	.0133
.001978	44		.0118
	44.5	.001866	.0105
.001761	45		.0094
	45.5	.001662	.0084
.001568	46		.0074
	46.5	.001480	.0066
.001397	47		.0059
	47.5	.001318	.0053
.001244	48		.0047
	48.5	.001174	.0042
.001108	49		.0037
	49.5	.001045	.0033
.000986	50		.0029
	50.5	.000931	.0026
.000878	51		.0023
	51.5	.000829	.0021
.000782	52		.0019
	52.5	.000738	.0016
.000697	53		.0015
	53.5	.000657	.0013
.000620	54		.0012
	54.5	.000585	.0010
.000552	55		.0009
	55.5	.000521	.0008
.000492	56		.0007
	56.5	.000464	.0007
.000438	57		.0006
	57.5	.000413	.0005
.000390	58		.0005
	58.5	.000368	.0004
.000347	59		.0004
	59.5	.000328	.0003
.000309	60		.0003

*Approximate—density of copper may vary.

AMERICAN WIRE GAUGE–MILLIMETERS

FULL SIZES	GAUGE	HALF SIZES	COPPER g / m*
14.733252	6/0		1,514.8295
13.120340	5/0		1,201.3144
11.684000	4/0		952.6856
10.404902	3/0		755.5141
9.265833	2/0		599.1499
8.251463	1/0		475.1475
7.348140	1		376.8091
	1.5	6.934268	335.5582
6.543707	2		298.8232
	2.5	6.175144	266.1097
5.827340	3		236.9776
	3.5	5.499125	211.0346
5.189396	4		187.9317
	4.5	4.897112	167.3581
4.621291	5		149.0366
	5.5	4.361004	132.7210
4.115378	6		118.1914
	6.5	3.883586	105.2525
3.664850	7		93.7301
	7.5	3.458434	83.4690
3.263643	8		74.3313
	8.5	3.079824	66.1940
2.906358	9		58.9474
	9.5	2.742663	52.4942
2.588187	10		46.7474
	10.5	2.442412	41.6298
2.304847	11		37.0724
	11.5	2.175030	33.0139
2.052525	12		29.3997
	12.5	1.936920	26.1812
1.827827	13		23.3151
	13.5	1.724877	20.7627
1.627727	14		18.4897
	14.5	1.536048	16.4655
1.449532	15		14.6630
	15.5	1.367890	13.0578
1.290846	16		11.6283
	16.5	1.218141	10.3553
1.149531	17		9.2216
	17.5	1.084786	8.2121
1.023687	18		7.3131
	18.5	0.966030	6.5125
0.911620	19		5.7995
	19.5	0.860274	5.1646
0.811821	20		4.5993
	20.5	0.766097	4.0958
0.722947	21		3.6474
	21.5	0.682229	3.2481
0.643803	22		2.8925
	22.5	0.607542	2.5758
0.573323	23		2.2939
	23.5	0.541032	2.0427
0.510559	24		1.8191
	24.5	0.481803	1.6200
0.454666	25		1.4426
	25.5	0.429058	1.2847
0.404892	26		1.1440
	26.5	0.382087	1.0188
0.360567	27		0.9073
	27.5	0.340258	0.8079
0.321094	28		0.7195
	28.5	0.303009	0.6407
0.285942	29		0.5706
	29.5	0.269837	0.5081
0.254639	30		0.4525
	30.5	0.240297	0.4030
0.226763	31		0.3588
	31.5	0.213991	0.3196
0.201938	32		0.2846
	32.5	0.190564	0.2534
0.179831	33		0.2257
	33.5	0.169702	0.2010
0.160144	34		0.1790
	34.5	0.151124	0.1594
0.142612	35		0.1419
	35.5	0.134580	0.1264
0.127000	36		0.1126
	36.5	0.119847	0.1002
0.113097	37		0.0893
	37.5	0.106727	0.0795
0.100716	38		0.0708
	38.5	0.095043	0.0630
0.089690	39		0.0561
	39.5	0.084638	0.0500
0.079871	40		0.0445
	40.5	0.075372	0.0396
0.071127	41		0.0353
	41.5	0.067121	0.0314
0.063341	42		0.0280
	42.5	0.059773	0.0249
0.056406	43		0.0222
	43.5	0.053229	0.0198
0.050231	44		0.0176
	44.5	0.047402	0.0157
0.044732	45		0.0140
	45.5	0.042213	0.0124
0.039835	46		0.0111
	46.5	0.037592	0.0099
0.035474	47		0.0088
	47.5	0.033476	0.0078
0.031591	48		0.0070
	48.5	0.029812	0.0062
0.028132	49		0.0055
	49.5	0.026548	0.0049
0.025053	50		0.0044
	50.5	0.023642	0.0039
0.022310	51		0.0035
	51.5	0.021053	0.0031
0.019868	52		0.0028
	52.5	0.018749	0.0025
0.017693	53		0.0022
	53.5	0.016696	0.0019
0.015756	54		0.0017
	54.5	0.014868	0.0015
0.014031	55		0.0014
	55.5	0.013241	0.0012
0.012495	56		0.0011
	56.5	0.011791	0.0010
0.011127	57		0.0009
	57.5	0.010500	0.0008
0.009909	58		0.0007
	58.5	0.009351	0.0006
0.008824	59		0.0005
	59.5	0.008327	0.0005
0.007858	60		0.0004

*Approximate—density of copper may vary.

SCND STANDARD CASING SIZES

SIZE RANGE (in)	CASING SIZE (in) D X T	SIZE RANGE (mm)	CASING SIZE (mm) D X T
.0163 and smaller	1" or 1 1/8" x 5/16"	0.1 and smaller	25 x 6 or 8
.0164–.041	1" or 1 1/8" x 3/8"	0.101–0.40	25 or 28 x 8
.042 and larger	1" or 1 1/8" x 1/2"	0.401–1.0	25 or 28 x 10
		1.01 and larger	25 or 28 x 12

*Special casing sizes available upon request.

PCD STANDARD CASING SIZES

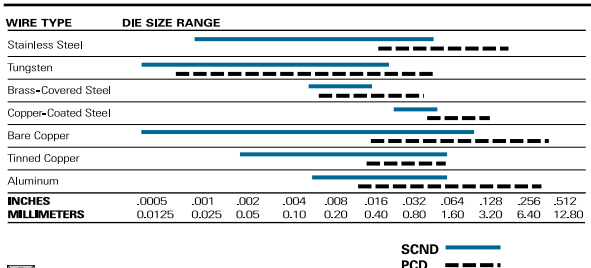
BLANK SIZE	CASING SIZE (in) D X T	CASING SIZE (mm) D X T
D-6 thru D-12	1" or 1 1/8" x 3/8"	25 or 28 x 10
D-15 thru D-24	1" or 1 1/8" x 1/2"	25 or 28 x 12
D-27 thru D-30	1 1/2" x 7/8"	38 x 22
D-33	2" x 1 1/8"	51 x 28
D-36	3" x 2"	76 x 51

*Special casing sizes available upon request.

TYPICAL DIE SPECIFICATIONS FOR VARIOUS WIRE MATERIALS

WIRE MATERIAL	DEGREE OF BLENDING	SINGLE CRYSTAL DIAMOND REDUCTION ANGLE	SINGLE CRYSTAL DIAMOND BEARING LENGTH	POLYCRYSTALLINE DIAMOND REDUCTION ANGLE	POLYCRYSTALLINE DIAMOND BEARING LENGTH
Bare Copper	Well Blended	18° ± 2°	40% ± 10%	18° ± 2°	25% ± 10%
Aluminum	Well Blended	20° ± 2°	25% ± 10%	20° ± 2°	25% ± 10%
Tin or Silver-Plated Copper	Very Well Blended	20° ± 2°	20% ± 10%	20° ± 2°	20% ± 10%
Stainless Steel	Slightly Blended	14° ± 2°	50% ± 10%	15° ± 2°	35% ± 10%
Tungsten	Slightly Blended	14° ± 2°	50% ± 10%	14° ± 2°	30% ± 10%
Brass- or Copper-Covered Steel	Slightly Blended	12° ± 2°	35% ± 10%	12° ± 2°	30% ± 10%

TYPICAL DIE MATERIAL & DIAMETERS BY WIRE TYPE



NEW AND RECUT WIRE DRAWING DIES

INCHES

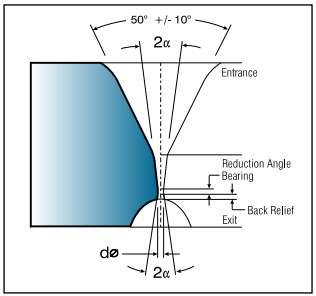
Size Range	Standard Hole Size Tolerance STD102	Standard Ovality Tolerance STD102	Min. "Tightest" Hole Size Tolerance STD301
.0006 or less	.000024	.000020	.000010
.00061-.0008	.000024	.000020	.000012
.00081-.0010	.000028	.000020	.000014
.00101-.0020	.000036	.000020	.000016
.00201-.0030	.000040	.000020	.000020
.00301-.0040	.000050	.000030	.000030
.00401-.0080	.000060	.000040	.000040
.00801-.0100	.000080	.000040	.000040
.01001-.0160	.000080	.000040	.000050
.01601-.0200	.000120	.000080	.000060
.02001-.0300	.000120	.000080	.000080
.03001-.0400	.000160	.000100	.000080
.04001-.0600	.000160	.000100	.000100
.06001-.1500	.000200	.000120	.000120
.1501-.5000	.000500	.000500	.000500

MILLIMETERS

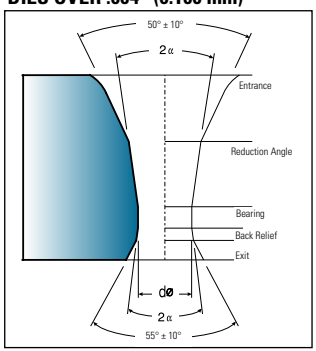
Size Range	Standard Hole Size Tolerance STD102	Standard Ovality Tolerance STD102	Min. "Tightest" Hole Size Tolerance STD301
0.015 or less	0.0006	0.0005	0.00025
0.0151-0.020	0.0006	0.0005	0.0003
0.0201-0.025	0.0007	0.0005	0.00035
0.0251-0.050	0.0009	0.0005	0.0004
0.0501-0.075	0.0010	0.0005	0.0005
0.0751-0.100	0.0012	0.0008	0.0008
0.101-0.200	0.0015	0.0010	0.0010
0.201-0.250	0.0020	0.0010	0.0010
0.251-0.400	0.0020	0.0010	0.0012
0.401-0.500	0.0030	0.0020	0.0015
0.501-0.750	0.0030	0.0020	0.0020
0.751-1.000	0.0040	0.0025	0.0020
1.001-1.500	0.0040	0.0025	0.0025
1.501-3.80	0.0050	0.0030	0.0030
3.801-12.70	0.0127	0.0127	0.0127

DIES UNDER .004" (0.100 mm)

Typical Profile of New Single Crystal Diamond and Polycrystalline Diamond Dies under .004" (0.100 mm)



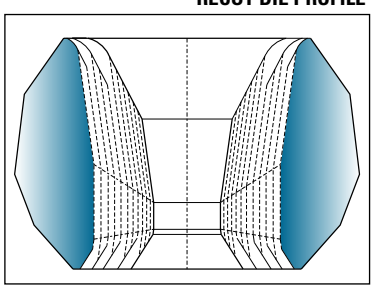
DIES OVER .004" (0.100 mm)



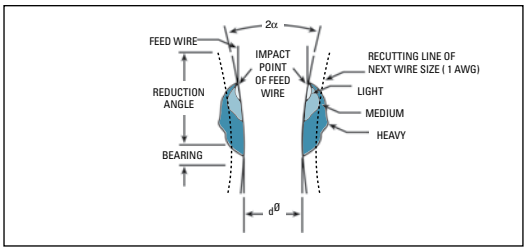
Typical Profile of Single Crystal Diamond and Polycrystalline Diamond Dies over .004" (0.100 mm)

RECUT DIE PROFILE

Typical profile of SCD or PCD die above .004" (0.100 mm) as it is recut to larger sizes, keeping the reduction angle and bearing length percentage constant.



DEGREES OF DIE WEAR

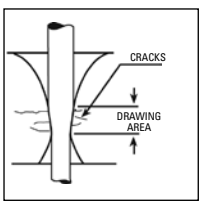


RECUT QUALITY DEFINITIONS

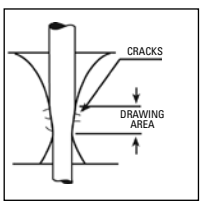
X The recut die may have cracks anywhere in the drawing area, but must be able to draw round wire, without clicks.

XX The recut die may have small cracks or imperfections in the reduction area but not in the bearing.

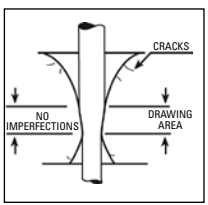
XXX The recut die must have no imperfections in the drawing area of the die.



X QUALITY



XX QUALITY

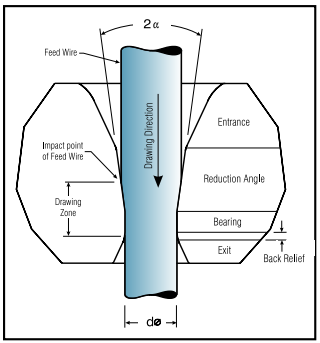


XXX QUALITY

SUGGESTED MICROSCOPE VIEWING RANGES

HOLE SIZE (in)	HOLE SIZE (mm)	MAGNIFICATION
.002 and smaller	0.05 and smaller	120–160X
.00201–.004	0.0501–0.10	90–120X
.00401–.010	0.101–0.25	60–90X
.0101–.090	0.2501–2.30	30–45X
.0901 and larger	2.301 and larger	10–20X

NOMENCLATURE



HOW TO ORDER DIAMOND DIES

To ensure prompt service, please make sure the following information appears on the order.

SINGLE CRYSTAL DIAMOND DIES

1) Casing Dimensions
2) Hole Size
3) Hole Size Tolerance
4) Reduction Angle
5) Bearing Length
6) Quantity per Hole Size
7) Wire Material

RECUT DIAMOND DIES

1) First and Second Requested Hole Size
2) Hole Size Tolerance
3) Reduction Angle
4) Bearing Length
5) Wire Material
6) Recut Quality Level (See pg. 9)

BUNCHING, STRANDING, COMPACTING DIES

1) Entry Angle of Maximum Wires
2) Reduction of Area
3) Hole Size and Tolerance
4) Reduction Angle
5) Bearing Length
6) Quantity per Hole Size
7) Wire Material
8) Casing Dimensions

POLYCRYSTALLINE DIAMOND DIES

1) Blank Number
2) Casing Dimensions
3) Hole Size
4) Hole Size Tolerance
5) Reduction Angle
6) Bearing Length
7) Quantity per Hole Size
8) Wire Material

ELONGATION SETS

1) Hole Size
2) Finished Die Hole Size Tolerance
3) Reduction Angle
4) Bearing Length
5) Wire Material
6) Transmission Diagram
7) Number of Die Positions in Machine
8) % Elongation Between Each Die
9) Diameter of Supply Wire
10) Die Material Type
11) Stamping Instructions
12) Casing Dimensions

TUNGSTEN CARBIDE DIES

1) Nib Number (R-Series)
2) Casing Dimensions
3) Hole Size
4) Hole Size Tolerance
5) Reduction Angle
6) Bearing Length
7) Carbide Grade
8) Back Relief Angle
9) Quantity Per Hole Size
10) Wire Material

ENTRANCE – The entrance zone provides access of the lubrication and wire to the working parts of the die, i.e., the reduction angle and the bearing. The entrance should be designed, particularly in the case of wet drawing, so that a consistent film of lubricant is formed between the die wall and the drawn product.

REDUCTION ANGLE – The deformation of the wire takes place in this area. The reduction angle should be specified by degrees included (2α).

BEARING – The die bearing determines the size of the wire. The bearing length is specified as a percent of the hole diameter.

BACK RELIEF – The back relief is a highly polished area that allows the wire to exit from the bearing smoothly to reduce the generation of metallic fines and minimize shaving due to misalignment.

EXIT – The wire exits the die through this zone. The exit height must be adequate to provide support for the axial mechanical stress produced by the drawing process.

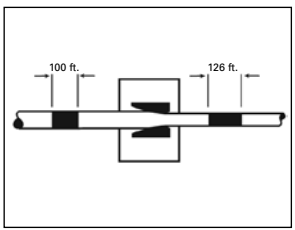
BLEND – The transition between the various zones of the die must be blended in accordance with the purpose for which the die was designed. When dies are designed to draw hard metals, the blending radii should be small. When dies are designed to draw soft nonferrous metals, the blending radii should be larger; however, the transition from the reduction zone to the bearing must not be excessively blended, as this will result in a reduction angle that is smaller than desired for the metal to be drawn.

DRAWING ZONE – The drawing zone is the area that is touched by the wire during normal drawing.

IMPACT POINT – The impact point is the first area in contact with the wire. The wear ring will first develop just below this point.

Wire drawing is a deformation process that involves pulling metal through a die by means of a tensile force applied to the exit side of the die. The wire passes through the die in a general converging flow; its velocity increases as the wire approaches the exit. Because the volume of the wire does not change, the wire elongates as the cross section reduces.

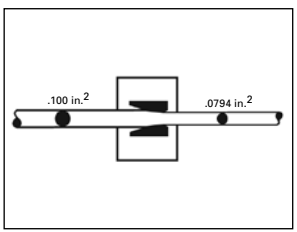
Below are definitions of terms commonly used in the wire drawing industry to describe these occurrences.



ELONGATION (E) is the lengthening of the wire as it is drawn through the die, and is expressed as a percentage of the original length.

Example: Wire length before the die = 100 feet. Wire length after it is drawn through the die = 126 feet.
Elongation = 26%

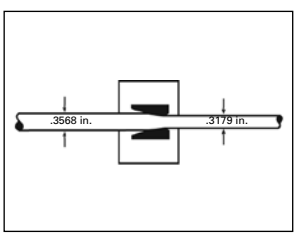
Formula: $E = \frac{100A_r}{100 - A_r}$



REDUCTION OF AREA (A_r) is the reduction of the cross-sectional area of the wire that occurs as the wire is drawn through the die. Reduction of area is expressed as a percentage of the original cross-sectional area.

Example: Cross-sectional area before the die = .100 square inches. Cross-sectional area after it is drawn through the die = .0794 square inches. Reduction of area = 20.7%

Formula: $A_r = \frac{100E}{100+E}$



REDUCTION OF DIAMETER (D_r) is the amount that the wire diameter is reduced as it is drawn through the die. It is expressed as a percentage of the original diameter.

Example: .3568-inch diameter before the die. .3179-inch diameter after it is drawn through the die. Reduction of diameter = 10.9%

Formula: $D_r = 100\left(1 - \sqrt{\frac{A_r}{E}}\right)$

This chart shows the relationship between elongation, reduction of area, reduction of diameter, and the die diameter ratios used in calculating a die sequence.

HOW TO USE: To calculate a die sequence, multiply the die diameter ratio applicable to your wire drawing practice by the finish die hole size to find the next larger die size in the sequence and so forth.

EXAMPLE:	**FACTOR**	**DIE SEQUENCE**
Elongation: 26.0983%		
Reduction of Area: 20.70%	.025347	Finish Die
Reduction of Diameter: 10.94%	.025347 in x 1.12293 = .028462	2nd Die
Finish Hole Size: .025347	.028462 in x 1.12293 = .031961	3rd Die
Die Diameter Ratio: 1.12293	.031961 in x 1.12293 = .035891	4th Die

NOTE: To ensure accuracy in calculating a die sequence, use six decimal places.

AWG	WIRE ELONG. %	RED. OF AREA %	RED. OF DIA. %	DIE DIA. RATIO
	5	4.76	2.43	1.02469
	5.5	5.21	2.67	1.02713
	6	5.66	2.87	1.02956
	6.5	6.10	3.13	1.03198
	7	6.54	3.34	1.03440
	7.5	6.98	3.53	1.03682
	8	7.41	3.76	1.03923
	8.5	7.83	4.02	1.04163
	9	8.26	4.20	1.04403
	9.5	8.68	4.41	1.04642
	10	9.09	4.66	1.04880
	10.5	9.50	4.88	1.05118
	11	9.91	5.08	1.05356
	11.5	10.31	5.32	1.05593
	12	10.71	5.53	1.05830
1/2	12.293	10.95	5.62	1.05968
	12.5	11.11	5.72	1.06066
	13	11.50	5.95	1.06301
	13.5	11.89	6.15	1.06536
	14	12.28	6.34	1.06770
	14.5	12.66	6.56	1.07004
	15	13.04	6.76	1.07238
	15.5	13.42	6.95	1.07470
	16	13.79	7.16	1.07703
	16.5	14.16	7.36	1.07935
	17	14.53	7.55	1.08166
	17.5	14.89	7.76	1.08397
	18	15.25	7.96	1.08627
	18.5	15.61	8.14	1.08857
3/4	18.996	15.96	8.34	1.09085
	19	15.97	8.32	1.09087
	19.5	16.32	8.52	1.09316
	20	16.67	8.70	1.09544
	20.5	17.01	8.91	1.09772
	21	17.36	9.08	1.10000
	21.5	17.70	9.27	1.10227
	22	18.03	9.47	1.10453
	22.5	18.37	9.64	1.10679
	23	18.70	9.83	1.10905
	23.5	19.03	10.01	1.11130
	24	19.35	10.21	1.11355
	24.5	19.68	10.37	1.11579
	25	20.00	10.56	1.11803

AWG	WIRE ELONG. %	RED. OF AREA %	RED. OF DIA. %	DIE DIA. RATIO
	25.5	20.32	10.73	1.12026
	26	20.63	10.92	1.12249
1	26.098	20.70	10.94	1.12293
	26.5	20.95	11.09	1.12472
	27	21.26	11.26	1.12694
	27.5	21.57	11.44	1.12915
	28	21.88	11.60	1.13137
	28.5	22.18	11.78	1.13357
	29	22.48	11.96	1.13578
	29.5	22.78	12.12	1.13798
	30	23.08	12.29	1.14017
	30.5	23.37	12.47	1.14236
	31	23.66	12.64	1.14455
	31.5	23.95	12.80	1.14673
	32	24.24	12.97	1.14891
	32.5	24.53	13.12	1.15108
	33	24.81	13.29	1.15325
	33.5	25.09	13.46	1.15542
1 1/4	33.624	25.16	13.50	1.15595
	34	25.37	13.62	1.15758
	34.5	25.65	13.77	1.15974
	35	25.93	13.93	1.16189
	35.5	26.20	14.09	1.16404
	36	26.47	14.25	1.16619
	36.5	26.74	14.41	1.16833
	37	27.01	14.56	1.17046
	37.5	27.27	14.72	1.17260
	38	27.54	14.87	1.17473
	38.5	27.80	15.02	1.17686
	39	28.06	15.18	1.17898
	39.5	28.32	15.33	1.18110
	40	28.57	15.49	1.18321
	40.5	28.83	15.63	1.18532
	41	29.08	15.78	1.18743
	41.5	29.33	15.93	1.18953
1 1/2	41.6	29.38	15.96	1.18995
	42	29.58	16.08	1.19163
	42.5	29.82	16.24	1.19373
	43	30.07	16.38	1.19582
	43.5	30.31	16.53	1.19791
	44	30.56	16.66	1.20000
	44.5	30.80	16.81	1.20208
	45	31.03	16.96	1.20415

Below are some of the most commonly used equations in the wire drawing industry and examples of their use.

LEGEND

d=Smaller Exit Diameter
D=Larger Entrance Diameter
A_r=Total Reduction of Area %
E=Elongation %
fpm=Feet Per Minute
Vd=Velocity of Wire Exiting Die
VD=Velocity of Wire Entering Die
A_{re}=Even Reduction of Area %
n=Number of Dies in a Set

ENTRANCE DIAMETER (D)

Formula: $\frac{d}{(1-(A_r/100))^{1/2}}$

Example: d=.0179 A_r=84.3%

$D=\frac{.0179}{(1-(84.3/100))^{1/2}}$

D=.0452

EXIT DIAMETER (d)

Formula: $d=D(\sqrt{1-(A_r/100)})$

Example: A_r=84.3% D=.0452

$d=.0452\ (\sqrt{1-(84.3/100)})$

D=.0179

ELONGATION % (E)

Formula: $E=100\left[\left(\frac{D}{d}\right)2-1\right]$

Example: D=.0452 d=.0179

$E=100\left[\left(\frac{.0452}{.0179}\right)2-1\right]$

E=537.6%

TOTAL REDUCTION OF AREA % (A_r)

Formula: $A_r=100\left[1-\left(\frac{d}{D}\right)2\right]$

Example: D=.0452 d=.0179

$A_r=100\left[1-\left(\frac{.0179}{.0452}\right)2\right]$

A_r=84.3%

EVEN REDUCTION OF AREA (A_{re})

Formula: $A_{re}=100\left[1-\sqrt[n]{\left(\frac{d}{D}\right)2}\right]$

Example: d=.0179 D=.0452 n=9

$A_{re}=100\left[1-\sqrt[9]{\left(\frac{.0179}{.0452}\right)2}\right]$

A_{re}=18.6%

VELOCITY OF WIRE ENTERING DIE (VD)

Formula: $VD=Vd\left(\frac{d}{D}\right)2$

Example: d=.0179 D=.0452 Vd=1000 fpm

$VD=1000\left(\frac{.0179}{.0452}\right)2$

VD=156.8 fpm

VELOCITY OF WIRE EXITING DIE (Vd)

Formula: $Vd=\frac{VD}{1-(A_r/100)}$

Example: VD=156.8 fpm A_r=84.3%

$Vd=\frac{156.8}{1-(84.3/100)}$

Vd=1000 fpm

NUMBER OF DIES IN A SET WITH EVEN REDUCTION (n)

Formula: $n=\frac{Log[1-(A_r/100)]}{Log[1-(A_{re}/100)]}$

Example: A_r=84.3% A_{re}=18.6%

$n=\frac{Log[1-(84.3/100)]}{Log[1-(18.6/100)]}$

n=9

WIRE DRAWING EQUATIONS

LEGEND

d=Wire Diameter (in or mm)
W=Weight/Length (lb/ft or g/m)
DN=Density (lb/in^3 or g/mm^3)
WP=Weight Produced (lb/h or kg/h)
Vf=Final Wire Speed (ft/min or m/s)
K=Units Factor

CROSS SECTION OF ROUND WIRE

Formula: $Area=\frac{\pi d^2}{4}=.7854 \times d^2$

Example: The area for a .035" diameter wire:
Area=.7854 x .035^2=.000962 in^2

WEIGHT/LENGTH RELATIONSHIP

Formula: W=K x d^2 x DN
For lb/ft, K=9.425 For g/m, K=785.4

Example: The weight per foot of .090" bare copper wire is:
W=9.425 x .090^2 x .321=.0245 lb/ft

PRODUCTION RATE

Formula: WP=Vf x d^2 x DN x K
For lb/h, K=565.5 For kg/h, K=2827

Example: Production rate for an .090" diameter bare copper wire drawn at a finishing speed of 1000 ft/minute:

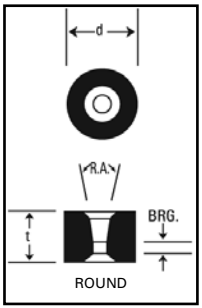
WP=1000 x .090^2 x .321 x 565.5=1470 lb/h

DENSITY

Electrolytic Copper	DN=.321 lb/in^3	DN=0.00889 g/mm^3
Tungsten	DN=.697 lb/in^3	DN=0.0193 g/mm^3
Stainless Steel	DN=.283 lb/in^3	DN=0.00783 g/mm^3

POLYCRYSTALLINE DIAMOND CORE DIMENSIONS

ADDMA NO.	MFG. NO.	GRAIN SIZE CLASS	NIB FEATURE	THERMAL STABILITY IN AIR	CORE DIM. in d	t
D-6	5010	F	1	1200°C	.122	.039
D-12	5815	F	2	630°C	.055	.059
D-12	5015	F	1	1200°C	.122	.059
D-12	5235	M	2	630°C	.055	.059
D-15	5823	F	2	630°C	.150	.088
D-15	5025	F	1	1200°C	.205	.098
D-15	5223	M	2	630°C	.150	.088
D-15	5430	C	2	630°C	.150	.088
D-18	5829	F	2	630°C	.150	.112
D-18	5035	F	1	1200°C	.205	.138
D-18	5229	M	2	630°C	.150	.112
D-18	5435	C	2	630°C	.150	.112
D-21	5840	F	2	630°C	.268	.152
D-21	5240	M	2	630°C	.268	.152
D-21	5530	C	2	630°C	.268	.152
D-24	5853	F	2	630°C	.268	.202
D-24	5253	M	2	630°C	.268	.202
D-24	5225	M	2	630°C	.500	.275
D-24	5535	C	2	630°C	.268	.202
D-24	5725	C	2	630°C	.500	.275
D-27	5208	M	2	630°C	.500	.343
D-27	5730	C	2	630°C	.500	.343
D-30	5211	M	2	630°C	.500	.457
D-30	5735	C	2	630°C	.500	.457
D-30	5913	M	2	630°C	.717	.531
D-33	5915	M	2	630°C	.717	.610
D-33	5917	M	2	630°C	.717	.689
D-36	5918	M	2	630°C	.717	.728



Average Grain Size Designation
U=Ultra Fine (0-2µ)
F=Fine (3-10µ)
M=Medium (11-29µ)
C=Coarse (30µ & larger)

Nib features:
1. Core is round, self-supported, metal-absent and thermally stable to 1200°C.
2. Diamond core is round, metal-filled, has a tungsten carbide support ring and is thermally stable to 630°C.

MAXIMUM RECOMMENDED HOLE SIZE RANGE**

BEARING PERCENTAGE (BRG.)		10%					30%					50%				
REDUCTION ANGLE (R.A.)		8	12	16	20	24	8	12	16	20	24	8	12	16	20	24
D-6	5010	.016	.023	.030	.037	.043	.014	.019	.024	.028	.031	.013	.017	.020	.022	.025
D-12	5815	.027	.032	.032	.032	.032	.024	.032	.032	.032	.032	.021	.028	.032	.032	.032
D-12	5015	.027	.039	.051	.062	.072	.024	.033	.040	.047	.053	.021	.028	.034	.038	.042
D-12	5235	.027	.032	.032	.032	.032	.024	.032	.032	.032	.032	.021	.028	.032	.032	.032
D-15	5823	.045	.065	.084	.102	.112	.039	.054	.067	.078	.087	.035	.047	.056	.063	.069
D-15	5025	.050	.073	.094	.114	.133	.044	.061	.075	.087	.098	.039	.052	.062	.070	.077
D-15	5223	.045	.065	.084	.102	.112	.039	.054	.067	.078	.087	.035	.047	.056	.063	.069
D-15	5430	.045	.065	.084	.102	.112	.039	.054	.067	.078	.087	.035	.047	.056	.063	.069
D-18	5829	.057	.082	.107	.109	.109	.050	.069	.085	.099	.109	.045	.059	.070	.080	.087
D-18	5035	.070	.102	.131	.153	.153	.062	.085	.105	.122	.137	.055	.073	.087	.098	.108
D-18	5229	.057	.082	.107	.109	.109	.050	.069	.085	.099	.109	.045	.059	.070	.080	.087
D-18	5435	.057	.082	.107	.109	.109	.050	.069	.085	.099	.109	.045	.059	.070	.080	.087
D-21	5840	.077	.112	.145	.176	.204	.068	.093	.115	.134	.151	.061	.080	.096	.108	.119
D-21	5240	.077	.112	.145	.176	.204	.068	.093	.115	.134	.151	.061	.080	.096	.108	.119
D-21	5530	.077	.112	.145	.176	.204	.068	.093	.115	.134	.151	.061	.080	.096	.108	.119
D-24	5853	.103	.149	.193	.199	.199	.090	.124	.153	.178	.199	.080	.107	.127	.144	.158
D-24	5253	.103	.149	.193	.199	.199	.090	.124	.153	.178	.199	.080	.107	.127	.144	.158
D-24	5225	.140	.203	.262	.318	.372	.123	.169	.208	.243	.272	.109	.145	.173	.196	.215
D-24	5535	.103	.149	.193	.199	.199	.090	.124	.153	.178	.199	.080	.107	.127	.144	.158
D-24	5725	.140	.203	.262	.318	.372	.123	.169	.208	.243	.272	.109	.145	.173	.196	.215
D-27	5208	.174	.253	.327	.378	.378	.153	.211	.260	.302	.339	.136	.181	.216	.244	.268
D-27	5730	.174	.253	.327	.378	.378	.153	.211	.260	.302	.339	.136	.181	.216	.244	.268
D-30	5211	.232	.337	.366	.366	.366	.204	.281	.346	.366	.366	.182	.241	.287	.325	.357
D-30	5735	.232	.337	.366	.366	.366	.204	.281	.346	.366	.366	.182	.241	.287	.325	.357
D-30	5913	.270	.392	.507	.540	.540	.237	.327	.403	.469	.527	.212	.280	.335	.379	.415
D-33	5915	.317	.461	.540	.540	.540	.279	.384	.474	.540	.540	.249	.330	.393	.445	.489
D-33	5917	.365	.530	.540	.540	.540	.321	.442	.540	.540	.540	.286	.379	.452	.512	.540
D-36	5918	.389	.540	.540	.540	.540	.342	.471	.540	.540	.540	.305	.404	.482	.540	.540

**The above chart designates the maximum recommended hole size for the various polycrystalline cores depending on a given reduction angle and bearing length.

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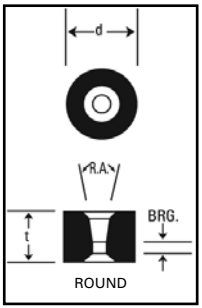
POLYCRYSTALLINE DIAMOND CORE DIMENSIONS

ADDMA NO.	MFG. NO.	GRAIN SIZE CLASS	NIB FEATURE	THERMAL STABILITY IN AIR	CORE DIM. mm d	t
D-6	5010	F	1	1200°C	3.1	1.0
D-12	5815	F	2	630°C	1.4	1.5
D-12	5015	F	1	1200°C	3.1	1.5
D-12	5235	M	2	630°C	1.4	1.5
D-15	5823	F	2	630°C	3.8	2.24
D-15	5025	F	1	1200°C	5.2	2.5
D-15	5223	M	2	630°C	3.8	2.24
D-15	5430	C	2	630°C	3.8	2.24
D-18	5829	F	2	630°C	3.8	2.84
D-18	5035	F	1	1200°C	5.2	3.5
D-18	5229	M	2	630°C	3.8	2.84
D-18	5435	C	2	630°C	3.8	2.84
D-21	5840	F	2	630°C	6.8	3.86
D-21	5240	M	2	630°C	6.8	3.86
D-21	5530	C	2	630°C	6.8	3.86
D-24	5853	F	2	630°C	6.8	5.13
D-24	5253	M	2	630°C	6.8	5.13
D-24	5225	M	2	630°C	12.7	6.98
D-24	5535	C	2	630°C	6.8	5.13
D-24	5725	C	2	630°C	12.7	6.98
D-27	5208	M	2	630°C	12.7	8.7
D-27	5730	C	2	630°C	12.7	8.7
D-30	5211	M	2	630°C	12.7	11.6
D-30	5735	C	2	630°C	12.7	11.6
D-30	5913	M	2	630°C	18.2	13.5
D-33	5915	M	2	630°C	18.2	15.5
D-33	5917	M	2	630°C	18.2	17.5
D-36	5918	M	2	630°C	18.2	18.5



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MAXIMUM RECOMMENDED HOLE SIZE RANGE**

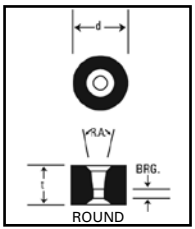
BEARING PERCENTAGE (BRG.)		10%					30%					50%				
REDUCTION ANGLE (R.A.)		8	12	16	20	24	8	12	16	20	24	8	12	16	20	24
D-6	5010	0.41	0.59	0.76	0.93	1.08	0.36	0.49	0.61	0.71	0.79	0.32	0.42	0.50	0.57	0.63
D-12	5815	0.69	0.81	0.81	0.81	0.81	0.60	0.81	0.81	0.81	0.81	0.54	0.71	0.81	0.81	0.81
D-12	5015	0.69	1.00	1.29	1.56	1.83	0.60	0.83	1.02	1.19	1.34	0.54	0.71	0.85	0.96	1.06
D-12	5235	0.69	0.81	0.81	0.81	0.81	0.60	0.81	0.81	0.81	0.81	0.54	0.71	0.81	0.81	0.81
D-15	5823	1.14	1.65	2.14	2.60	2.84	1.00	1.38	1.70	1.98	2.22	0.89	1.18	1.41	1.60	1.75
D-15	5025	1.27	1.84	2.38	2.90	3.38	1.12	1.54	1.90	2.21	2.48	1.00	1.32	1.57	1.78	1.95
D-15	5223	1.14	1.65	2.14	2.60	2.84	1.00	1.38	1.70	1.98	2.22	0.89	1.18	1.41	1.60	1.75
D-15	5430	1.14	1.65	2.14	2.60	2.84	1.00	1.38	1.70	1.98	2.22	0.89	1.18	1.41	1.60	1.75
D-18	5829	1.44	2.09	2.71	2.78	2.78	1.27	1.75	2.15	2.51	2.78	1.13	1.50	1.79	2.02	2.22
D-18	5035	1.78	2.58	3.34	3.88	3.88	1.56	2.15	2.65	3.09	3.47	1.39	1.85	2.20	2.49	2.74
D-18	5229	1.44	2.09	2.71	2.78	2.78	1.27	1.75	2.15	2.51	2.78	1.13	1.50	1.79	2.02	2.22
D-18	5435	1.44	2.09	2.71	2.78	2.78	1.27	1.75	2.15	2.51	2.78	1.13	1.50	1.79	2.02	2.22
D-21	5840	1.96	2.85	3.68	4.47	5.18	1.72	2.37	2.93	3.41	3.82	1.54	2.04	2.43	2.75	3.02
D-21	5240	1.96	2.85	3.68	4.47	5.18	1.72	2.37	2.93	3.41	3.82	1.54	2.04	2.43	2.75	3.02
D-21	5530	1.96	2.85	3.68	4.47	5.18	1.72	2.37	2.93	3.41	3.82	1.54	2.04	2.43	2.75	3.02
D-24	5853	2.60	3.78	4.89	5.04	5.04	2.29	3.15	3.89	4.53	5.04	2.04	2.70	3.23	3.66	4.01
D-24	5253	2.60	3.78	4.89	5.04	5.04	2.29	3.15	3.89	4.53	5.04	2.04	2.70	3.23	3.66	4.01
D-24	5225	3.54	5.15	6.66	8.09	9.45	3.11	4.29	5.29	6.16	6.92	2.78	3.68	4.39	4.97	5.46
D-24	5535	2.60	3.78	4.89	5.04	5.04	2.29	3.15	3.89	4.53	5.04	2.04	2.70	3.23	3.66	4.01
D-24	5725	3.54	5.15	6.66	8.09	9.45	3.11	4.29	5.29	6.16	6.92	2.78	3.68	4.39	4.97	5.46
D-27	5208	4.41	6.41	8.30	9.61	9.61	3.88	5.35	6.60	7.68	8.62	3.46	4.59	5.48	6.20	6.80
D-27	5730	4.41	6.41	8.30	9.61	9.61	3.88	5.35	6.60	7.68	8.62	3.46	4.59	5.48	6.20	6.80
D-30	5211	5.89	8.55	9.29	9.29	9.29	5.18	7.13	8.80	9.29	9.29	4.62	6.12	7.30	8.26	9.07
D-30	5735	5.89	8.55	9.29	9.29	9.29	5.18	7.13	8.80	9.29	9.29	4.62	6.12	7.30	8.26	9.07
D-30	5913	6.85	9.95	12.88	13.71	13.71	6.02	8.30	10.24	11.91	13.38	5.38	7.12	8.50	9.62	10.55
D-33	5915	8.06	11.71	13.71	13.71	13.71	7.09	9.76	12.04	13.71	13.71	6.32	8.37	9.99	11.31	12.41
D-33	5917	9.26	13.46	13.71	13.71	13.71	8.15	11.22	13.71	13.71	13.71	7.27	9.62	11.49	13.01	13.71
D-36	5918	9.87	13.71	13.71	13.71	13.71	8.68	11.96	13.71	13.71	13.71	7.74	10.25	12.24	13.71	13.71

**The above chart designates the maximum recommended hole size for the various polycrystalline cores depending on a given reduction angle and bearing length.

Compax is a registered trademark of Diamond Innovations, U.S.A.

POLYCRYSTALLINE DIAMOND CORE DIMENSIONS

ADDMA NO.	MFG. NO.	GRAIN SIZE CLASS U 0–2μ	F 3–10μ	M 11–29μ	NIB FEATURE	THERMAL STABILITY IN AIR	CORE DIM. in d	t
D-6	WD705	F	M	C, E	1	700°C	.098	.039
D-6	WD805	F	M	C, E	2	1000°C	.098	.039
D-12	WD710	F	M	C, E	1	700°C	.126	.059
D-12	WD810	F	M	C, E	2	1000°C	.126	.059
D-12	WD910	F	S, M	C, E	3	700°C	.059	.059
D-15	WD715	F	M	C, E	1	700°C	.205	.098
D-15	WD815	F	M	C, E	2	1000°C	.205	.098
D-15	WD915	F	S, M	C, E	3	700°C	.157	.091
D-18	WD720	F	M	C, E	1	700°C	.205	.138
D-18	WD820	F	M	C, E	2	1000°C	.205	.138
D-18	WD920	F	S, M	C, E	3	700°C	.157	.114
D-21	WD925	-	S, M	C, E	3	700°C	.276	.157
D-24	WD930	-	S, M	C, E	3	700°C	.276	.209
D-27	WD940	-	M	C, E	3	700°C	.354	.295
D-27	WD945	-	M	C, E	3	700°C	.512	.354
D-30	WD950	-	M	C, E	3	700°C	.512	.472
D-33	WD960	-	-	C, E	3	650°C	.630	.630
D-36	WD970	-	-	E	3	650°C	.748	.748
D-36	WD975	-	-	E	3	650°C	.984	.787
D-36	WD980	-	-	E	3	650°C	1.181	.866
D-36	WD990	-	-	E	3	650°C	1.575	.984
D-36	WD995	-	-	E	3	650°C	1.772	1.063



Nib Features:

1. WD700 Series diamond core is self-supported, metal-filled and thermally stable to 700°C.
2. WD800 Series is thermally stable to 1000°C, metal-absent and is self-supported.
3. WD900 Series diamond core is round, metal-filled, has a tungsten carbide support ring and is thermally stable to 650°C or 700°C.

Product designations should include manufacturer's number and grain size, i.e., WD705F, WD915C.
Readily available die blanks are shown in bold print. Please check availability of other products.

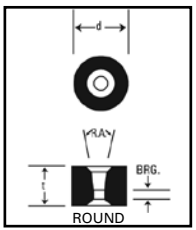
MAXIMUM RECOMMENDED HOLE SIZE RANGE**

BEARING PERCENTAGE (BRG.)		10%					30%						50%				
REDUCTION ANGLE (R.A.)		8	12	16	20	24	8	12	16	20	24	8	12	16	20	24
D-6	WD705	.016	.023	.030	.037	.043	.014	.019	.024	.028	.031	.013	.017	.020	.022	.025
D-6	WD805	.016	.023	.030	.037	.043	.014	.019	.024	.028	.031	.013	.017	.020	.022	.025
D-12	WD710	.027	.039	.051	.062	.072	.024	.033	.040	.047	.053	.021	.028	.034	.038	.042
D-12	WD810	.027	.039	.051	.062	.072	.024	.033	.040	.047	.053	.021	.028	.034	.038	.042
D-12	WD910	.027	.035	.035	.035	.035	.024	.033	.035	.035	.035	.021	.028	.034	.035	.035
D-15	WD715	.050	.073	.094	.114	.133	.044	.061	.075	.087	.098	.039	.052	.062	.070	.077
D-15	WD815	.050	.073	.094	.114	.133	.044	.061	.075	.087	.098	.039	.052	.062	.070	.077
D-15	WD915	.046	.067	.086	.105	.118	.040	.056	.069	.080	.090	.036	.048	.057	.065	.071
D-18	WD720	.070	.102	.131	.153	.153	.062	.085	.105	.122	.137	.055	.073	.087	.098	.108
D-18	WD820	.070	.102	.131	.153	.153	.062	.085	.105	.122	.137	.055	.073	.087	.098	.108
D-18	WD920	.058	.084	.109	.116	.116	.051	.070	.087	.101	.113	.046	.060	.072	.081	.089
D-21	WD925	.080	.116	.150	.183	.210	.070	.097	.119	.139	.156	.063	.083	.099	.112	.123
D-24	WD930	.106	.154	.199	.205	.205	.093	.128	.158	.184	.205	.083	.110	.131	.149	.163
D-27	WD940	.150	.218	.261	.261	.261	.132	.182	.224	.261	.261	.118	.156	.186	.210	.231
D-27	WD945	.190	.261	.338	.387	.387	.158	.218	.269	.313	.351	.141	.187	.223	.253	.277
D-30	WD950	.240	.348	.374	.374	.374	.211	.291	.358	.374	.374	.188	.249	.297	.337	.369
D-33	WD960	.329	.467	.467	.467	.467	.289	.399	.467	.467	.467	.258	.342	.408	.462	.467
D-36	WD970	.400	.566	.566	.566	.566	.352	.485	.566	.566	.566	.314	.416	.497	.562	.566
D-36	WD975	.424	.616	.765	.765	.765	.373	.514	.634	.738	.765	.333	.441	.526	.596	.653
D-36	WD980	.472	.685	.887	.930	.930	.415	.571	.705	.820	.921	.370	.490	.585	.662	.726
D-36	WD990	.543	.789	1.021	1.240	1.261	.478	.658	.811	.944	1.060	.426	.564	.673	.762	.836
D-36	WD995	.591	.858	1.110	1.348	1.426	.519	.715	.882	1.027	1.153	.463	.613	.732	.829	.909

**The above chart designates the maximum recommended hole size for the various polycrystalline cores depending on a given reduction angle and bearing length.

POLYCRYSTALLINE DIAMOND CORE DIMENSIONS

ADDMA NO.	MFG. NO.	GRAIN SIZE CLASS U 0–2μ	F 3–10μ	M 11–29μ	NIB FEATURE	THERMAL STABILITY IN AIR	CORE DIM. mm d	t
D-6	WD705	F	M	C, E	1	700°C	2.5	1.0
D-6	WD805	F	M	C, E	2	1000°C	2.5	1.0
D-12	WD710	F	M	C, E	1	700°C	3.2	1.5
D-12	WD810	F	M	C, E	2	1000°C	3.5	1.5
D-12	WD910	F	S, M	C, E	3	700°C	1.5	1.5
D-15	WD715	F	M	C, E	1	700°C	5.2	2.5
D-15	WD815	F	M	C, E	2	1000°C	5.2	2.5
D-15	WD915	F	S, M	C, E	3	700°C	4.0	2.3
D-18	WD720	F	M	C, E	1	700°C	5.2	3.5
D-18	WD820	F	M	C, E	2	1000°C	5.2	3.5
D-18	WD920	F	S, M	C, E	3	700°C	4.0	2.9
D-21	WD925	-	S, M	C, E	3	700°C	7.0	4.0
D-24	WD930	-	S, M	C, E	3	700°C	7.0	5.3
D-27	WD940	-	M	C, E	3	700°C	9.0	7.5
D-27	WD945	-	M	C, E	3	700°C	13.0	9.0
D-30	WD950	-	M	C, E	3	700°C	13.0	12.0
D-33	WD960	-	-	C, E	3	650°C	16.0	16.0
D-36	WD970	-	-	E	3	650°C	19.0	19.0
D-36	WD975	-	-	E	3	650°C	25.0	20.0
D-36	WD980	-	-	E	3	650°C	30.0	22.0
D-36	WD990	-	-	E	3	650°C	40.0	25.0
D-36	WD995	-	-	E	3	650°C	45.0	27.0



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Product designations should include manufacturer's number and grain size, i.e., WD705F, WD915C.
Readily available die blanks are shown in bold print. Please check availability of other products.

MAXIMUM RECOMMENDED HOLE SIZE RANGE**

BEARING PERCENTAGE (BRG.)		10%					30%						50%				
REDUCTION ANGLE (R.A.)		8	12	16	20	24	8	12	16	20	24	8	12	16	20	24
D-6	WD705	0.41	0.59	0.76	0.93	1.08	0.36	0.49	0.61	0.71	0.79	0.32	0.42	0.50	0.57	0.63
D-6	WD805	0.41	0.59	0.76	0.93	1.08	0.36	0.49	0.61	0.71	0.79	0.32	0.42	0.50	0.57	0.63
D-12	WD710	0.69	1.00	1.29	1.56	1.83	0.60	0.83	1.02	1.19	1.34	0.54	0.71	0.85	0.96	1.06
D-12	WD810	0.69	1.00	1.29	1.56	1.83	0.60	0.83	1.02	1.19	1.34	0.54	0.71	0.85	0.96	1.06
D-12	WD910	0.69	0.89	0.89	0.89	0.89	0.60	0.83	0.89	0.89	0.89	0.54	0.71	0.85	0.89	0.89
D-15	WD715	1.27	1.84	2.38	2.90	3.38	1.12	1.54	1.90	2.21	2.48	1.00	1.32	1.57	1.78	1.95
D-15	WD815	1.27	1.84	2.38	2.90	3.38	1.12	1.54	1.90	2.21	2.48	1.00	1.32	1.57	1.78	1.95
D-15	WD915	1.17	1.70	2.19	2.67	3.00	1.03	1.41	1.74	2.03	2.28	0.92	1.21	1.45	1.64	1.80
D-18	WD720	1.78	2.58	3.34	3.88	3.88	1.56	2.15	2.65	3.09	3.47	1.39	1.85	2.20	2.49	2.74
D-18	WD820	1.78	2.58	3.34	3.88	3.88	1.56	2.15	2.65	3.09	3.47	1.39	1.85	2.20	2.49	2.74
D-18	WD920	1.47	2.14	2.77	2.94	2.94	1.29	1.78	2.20	2.56	2.87	1.15	1.53	1.83	2.07	2.27
D-21	WD925	2.03	2.95	3.82	4.63	5.34	1.79	2.46	3.03	3.53	3.96	1.59	2.11	2.52	2.85	3.13
D-24	WD930	2.69	3.91	5.06	5.19	5.19	2.37	3.26	4.02	4.68	5.19	2.11	2.79	3.34	3.78	4.14
D-27	WD940	3.81	5.53	6.63	6.63	6.63	3.35	4.61	5.69	6.62	6.63	2.99	3.95	4.72	5.34	5.86
D-27	WD945	4.57	6.64	8.58	9.83	9.83	4.02	5.53	6.83	7.94	8.92	3.58	4.74	5.66	6.41	7.03
D-30	WD950	6.09	8.85	9.50	9.50	9.50	5.36	7.38	9.10	9.50	9.50	4.78	6.33	7.55	8.55	9.38
D-33	WD960	8.36	11.86	11.86	11.86	11.86	7.35	10.13	11.86	11.86	11.86	6.56	8.68	10.37	11.74	11.86
D-36	WD970	10.17	14.38	14.38	14.38	14.38	8.94	12.32	14.38	14.38	14.38	7.98	10.57	12.61	14.28	14.38
D-36	WD975	10.77	15.65	19.42	19.42	19.42	9.47	13.05	16.10	18.73	19.42	8.45	11.19	13.36	15.13	16.59
D-36	WD980	11.98	17.41	22.52	23.62	23.62	10.54	14.51	17.90	20.83	23.39	9.40	12.45	14.86	16.82	18.45
D-36	WD990	13.79	20.04	25.92	31.49	32.03	12.13	16.71	20.61	23.98	26.93	10.82	14.33	17.10	19.36	21.24
D-36	WD995	15.00	21.79	28.19	34.24	36.23	13.19	18.17	22.41	26.08	29.28	11.77	15.58	18.60	21.06	23.10

**The above chart designates the maximum recommended hole size for the various polycrystalline cores depending on a given reduction angle and bearing length.

ACCURATE AND CONSISTENT INSULATION APPLICATION

Provide us with your specifications, and we'll provide you with long-lasting, custom-made extrusion tips and dies to help your extrusion process run efficiently and economically.

SUPERIOR EXTRUSION TIP CONCENTRICITY

Fort Wayne Wire Die guarantees that all our precision natural diamond and polycrystalline diamond extrusion tips are concentric within .0002 in (0.005 mm) total indicator reading.

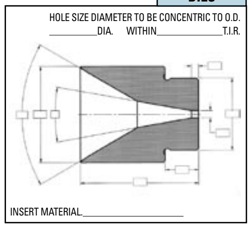
HOW TO ORDER EXTRUSION TIPS AND DIES

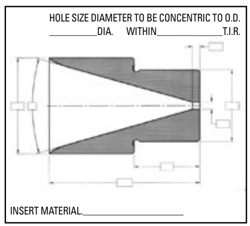
Provide us with an engineering drawing or use the drawings provided here to communicate the dimensions you require. If you do not have a drawing, follow these steps:

1. Use the drawings provided here as a master. Copy the drawings, and enlarge them for worksheets or orders.
2. Find the drawing that represents the extrusion tip or die best suited for your application.
3. Locate each dimension guideline. Determine whether a length, width, diameter or angle measurement is needed.
4. Based on new specifications or measurements of existing tooling, enter an exact measurement in the box corresponding to each dimension requested. If the hole size is to be concentric with the outside diameter, please specify dimensions of that outside diameter.
5. Indicate the extrusion tip or die insert material in the appropriate box using the following definitions:

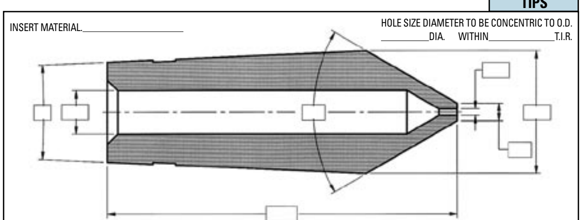
   SCND – Single Crystal Natural Diamond
   PCD – Polycrystalline Diamond
   TC – Tungsten Carbide
   TS – Tool Steel

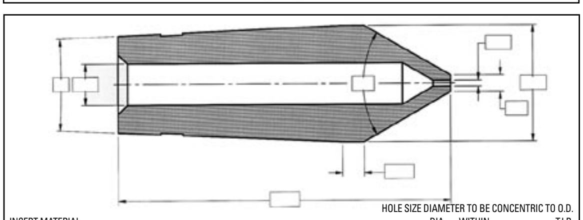
DIES

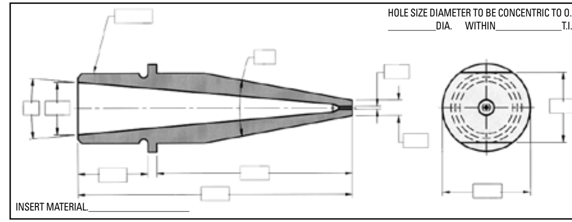


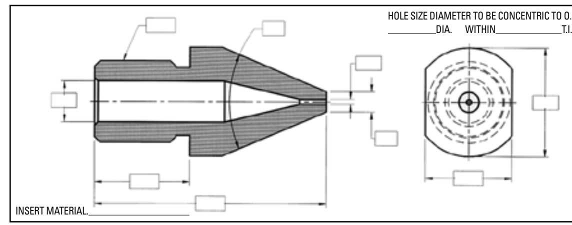


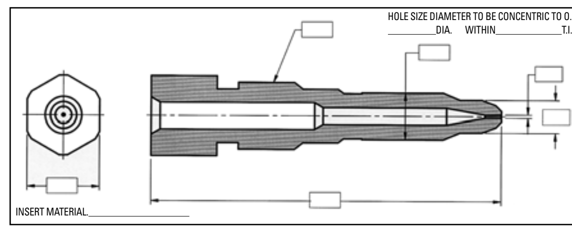
TIPS

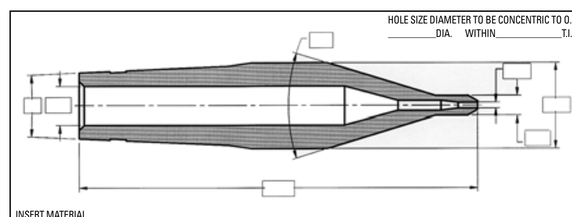












HOLE SIZES

SCND: .012 in (0.30 mm) to .036 in (0.90 mm)	**PCD:** .012 in (0.30 mm) to .093 in (2.36 mm)
TC: .020 in (0.50 mm) to .500 in (12.5 mm)	**TS:** up to 1.0 in (25 mm)

DIE MATERIAL SELECTION TABLE

Material Characteristics	Die Material SCND	PCD	WC
Surface Finish	***	*	**
Resistance to Galling	***	*	**
Ease of Polishing / Recutting	**	*	***
Particle Pull Out	***	*	**
Toughness / Impact Strength	*	***	***
Generation of Micro-Fines (< 1 um)	***	*	**
Abrasive Wear Resistance	**	***	*
Corrosive Wear Resistance (Low C-steel)	**	**	***
Die Pull (Resistance to Drawing Forces)	***	*	**
Purchase Price	*	**	***
Uniformity of Wear / Roundness	**	***	*

* = Good ** = Better *** = Best
SCND = Single Crystal Natural Diamond, PCD = Polycrystalline Diamond, WC = Tungsten Carbide

RELATIVE DIE LIFE BY MATERIAL DRAWN

Wire Type	Die Material SCND	PCD	WC
Copper	50-100X	150-400X	1
Brass or Zinc Plated High-Carbon Steel	2-5X	5-20X	1
Stainless Steel Ni-Chrome Alloys	5-10X	10-20X	1
Aluminum	10-20X	60-100X	1

PHYSICAL AND MECHANICAL PROPERTIES OF DIE MATERIALS

Properties	SCND	PCD	WC
Hardness (Knoop, x10³ MPa)	80 – 120	60 – 80	17-18
Transverse Rupture Strength (MPa)	300	1800	1800
Compression Strength (MPa)	2200-8750	7340	6100
Young's Modulus (x10³ MPa)	11900	8800	6300
Thermal Conductivity Coefficient (kJ/s.m².K)	71 - 92	12.5 - 21	7.1 – 13.7

MATCHED ELONGATION DIE SETS

A matched elongation set is a set of dies that has been engineered to optimize the performance of your drawing machine taking the machine elongation and accumulation of slip into account. They are recommended for multiwire drawing machines or ultrafine single wire machines and offer several advantages during the drawing process.

Eliminate wirebreaks / Reduce downtime / Improve wire surface finish
Reduce capstan wear / Reduce fine generation/die "packing"

Fort Wayne Wire Die has developed proprietary software to aid in the calculation of precision-made die sets with correct tolerances that have been matched to the wire drawing machine elongation and are controlled to a tolerance of ± 0.5% elongation. We calculate each individual die size to minimize slip on the capstans and improve the surface finish of the wire.

Each die is performance tested to check for the correct wire elongation and die pull. The dies are then certified, stamped with set numbers and shipped to the customer as a set. When die sets are made to hole size tolerances alone, big variations in elongation can result, as seen below.

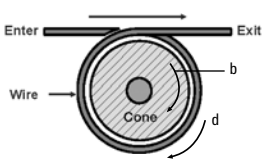
THE EFFECT OF HOLE SIZE TOLERANCE ON ELONGATION

Example: Hole Size Tolerance +/- .000020 in (+/- 0.0005 mm)
Target Elongation: 26.0% Elongation Tolerance +/- 0.5%

	Size (in)	Size (mm)		Size (in)	Size (mm)		Elongation
Minimum	.00440	0.1118	Maximum	.00396	0.1005	results in	23.6% (-2.4%)
Nominal	.00442	0.1123	Nominal	.00394	0.1000	results in	26.0%
Maximum	.00444	0.1128	Minimum	.00392	0.0995	results in	28.4% (+2.4%)

TYPES OF DIES USED

Matched elongation sets can utilize both single crystal natural diamond (SCND) and polycrystalline diamond (PCD) dies or a combination of both. SCND dies will produce the best wire surface finish and are typically used for sizes smaller than .016 -.024" (0.4-0.6 mm) and for finish dies.



$$\% \text{ Slip} = \frac{\text{Roll Speed (b)} - \text{Wire Speed (d)}}{\text{Roll Speed (b)}}$$

SLIP

On a wire drawing machine, slip is the difference between the circumferential speed of the drawing cone and the surface speed of the wire.

The cone or roll is driven "faster" than the wire which slides over them.

Too much slip results in grooves on the rolls, bad surface finish on the wire, excessive fine generation and cross-over wire breaks. Too little slip causes tension wire breaks. Slip should be minimized but must always be positive. Slip accumulates from the finish die backwards through the machine.

NIB NUMBER	REDUCTION ANGLE	GRADE	MAX. HOLE SIZE	NIB O.D.	NIB HEIGHT	CASING O.D.	CASING HEIGHT	
R-2	12°	FW6	.128	.325	.330	1 or 1 1/2	9/16 or 3/4	INCHES
R-2	16°	FW6	.128	.325	.330	1 or 1 1/2	9/16 or 3/4	
R-3	12°	FW6	.182	.450	.380	1 or 1 1/2	9/16 or 3/4	
R-4	12°	FW6	.230	.500	.450	1 1/4 or 1 1/2	7/8	
R-4	16°	FW6	.230	.500	.450	1 1/4 or 1 1/2	7/8	
R-5	12°	FW6	.280	.625	.600	1 1/4 or 1 1/2	7/8	
R-5	16°	FW6	.280	.625	.600	1 1/4 or 1 1/2	7/8	
R-5	12°	FW12	.280	.625	.600	1 1/4 or 1 1/2	7/8	
R-5	16°	FW12	.280	.625	.600	1 1/4 or 1 1/2	7/8	
R-6	16°	FW12	.350	.710	.700	1 1/2 or 2	1 1/8	
R-7	16°	FW12	.425	.768	.768	2 or 3	1 3/8	
R-8	16°	FW12	.516	1.000	.820	3	1 3/4	
R-9	16°	FW12	.687	1.187	.820	3	1 3/4	
R-10	16°	FW12	.875	1.500	1.000	3 or 4	2	
R-11	16°	FW12	1.250	1.830	1.250	4	2 1/4	
R-12	16°	FW12	1.500	2.185	1.375	4	2 3/8	
R-14	22°	FW12	1.750	2.560	1.375	6 or 7	2 1/2	
R-15	22°	FW12	2.250	3.000	1.375	6 or 7	2 1/2	
R-16	22°	FW15	2.500	3.500	1.375	6 or 7	2 1/2	
R-17	30°	FW15	3.000	4.000	1.500	9	3	
R-18	Made to Specs	FW15	3.750	5.500	2.125	11	4 1/2	
R-19	Made to Specs	FW15	4.500	6.500	2.125	13	4 1/2	

NIB NUMBER	REDUCTION ANGLE	GRADE	MAX. HOLE SIZE	NIB O.D.	NIB HEIGHT	CASING O.D.	CASING HEIGHT	
R-2	12°	FW6	3.25	8.26	8.38	25.4 or 38.1	14.3 or 19.1	MILLIMETERS
R-2	16°	FW6	3.25	8.26	8.38	25.4 or 38.1	14.3 or 19.1	
R-3	12°	FW6	4.62	11.43	9.65	25.4 or 38.1	14.3 or 19.1	
R-4	12°	FW6	5.84	12.70	11.43	31.8 or 38.1	22.2	
R-4	16°	FW6	5.84	12.70	11.43	31.8 or 38.1	22.2	
R-5	12°	FW6	7.11	15.88	15.24	31.8 or 38.1	22.2	
R-5	16°	FW6	7.11	15.88	15.24	31.8 or 38.1	22.2	
R-5	12°	FW12	7.11	15.88	15.24	31.8 or 38.1	22.2	
R-5	16°	FW12	7.11	15.88	15.24	31.8 or 38.1	22.2	
R-6	16°	FW12	8.89	18.03	17.78	38.1 or 50.8	28.6	
R-7	16°	FW12	10.80	19.51	19.51	50.8 or 76.2	34.9	
R-8	16°	FW12	13.11	25.40	20.83	76.2	44.5	
R-9	16°	FW12	17.45	30.15	20.83	76.2	44.5	
R-10	16°	FW12	22.23	38.10	25.40	76.2 or 101.6	50.8	
R-11	16°	FW12	31.75	46.48	31.75	101.6	57.2	
R-12	16°	FW12	38.10	55.50	34.93	101.6	60.3	
R-14	22°	FW12	44.45	65.02	34.93	152.4 or 177.8	63.5	
R-15	22°	FW12	57.15	76.20	34.93	152.4 or 177.8	63.5	
R-16	22°	FW15	63.50	88.90	34.93	152.4 or 177.8	63.5	
R-17	30°	FW15	76.20	101.60	38.10	228.6	76.2	
R-18	Made to Specs	FW15	95.25	139.70	53.98	279.4	114.3	
R-19	Made to Specs	FW15	114.30	165.10	53.98	330.2	114.3	

All back relief angles R-2 through R-6 are 90°; R-7 through R-12 are 30°.

DEFINITION OF MEETING POINT

The use of the meeting point concept enables one to control the length of the bearing in the die.

A meeting point is the hole diameter where the reduction angle and exit angle meet after the die has been ripped to remove the bearing. To finish a die to a required bearing length for a given hole size, the die must first be brought to a meeting point, which is a calculated hole size, based upon the angle of reduction and back relief.

HOW TO USE:

Multiply the bearing length desired by the factor in the column applying to proper back relief. Subtract this product from the finished hole diameter to arrive at the meeting point hole diameter.

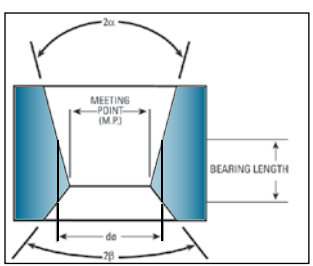
TUNGSTEN CARBIDE FACTOR TABLE

Included Reduction Angle	Back Relief 90° Inc.	Back Relief 30° Inc.
8°	.131	.111
10°	.161	.132
12°	.190	.151
14°	.219	.168
16°	.246	.184
18°	.273	.199
20°	.300	.213
22°	.325	.225
24°	.351	.237
26°	.375	.248
28°	.399	.258
30°	.423	.268

LEGEND: d = Finished Hole Size Diameter
2α = Reduction Angle (inclusive)
L = Percent Bearing
2β = Back Relief Angle (inclusive)

EXAMPLE: Finish Hole Size: .0179
Bearing Length: .00537 (30%)
Reduction Angle: 16°
Back Relief Angle: 90°
Factor From Table: .246
Meeting Point = .0179 – (.00537 x .246)
Meeting Point = .0166

FORMULA: Meeting Point $= d - \left[\left(\frac{2 \times \tan\left(\frac{2\alpha}{2}\right) \times \tan\left(\frac{2\beta}{2}\right)}{\tan\left(\frac{2\alpha}{2}\right) + \tan\left(\frac{2\beta}{2}\right)} \right) \times \left(d \left(\frac{L}{100} \right) \right) \right]$



DI-PRO DIAMOND COMPOUND is an abrasive specially formulated for ripping, polishing and sizing wire drawing dies. A 100% virgin diamond compound, DI-PRO is designed for precision repolishing and sizing of both diamond and tungsten carbide dies. Available in water-soluble, oil-based or grease-based carriers.

DI-PRO-D has been exclusively developed to be used with diamond dies.

DI-PRO-C has been specially formulated to be used with tungsten carbide dies.

Both DI-PRO-D and DI-PRO-C are available in five-gram jars or syringes in the micron size ranges given below.

DRY DIAMOND POWDER (without added carrier) is also available in the micron size ranges given below and is sold by the carat.

GRADE NUMBER	COLOR	MICRON SIZE RANGE
1/10	Gray	0–2/10
1/8	Gray	0–1/4
1/4	Lt. Green	0–1/2
1/2	Pink	0–1
1	Pink	0–2
1 1/4	Pink	1/2–3
3 1/2	Yellow	2–4
4 1/2	Yellow	3–6
6	Orange	4–8
7 1/2	White	5–10
9	Dk. Green	6–12
11 1/2	Dk. Green	8–15
15	Blue	12–22
30	Red	20–40
45	Brown	30–60

Special sizes available upon request.

DI-PRO DIAMOND COMPOUND SELECTION CHART

MATERIAL TYPE	JOB PROCEDURE	MICRON SIZE RANGE	CARRIER TYPE	CLEANING METHOD
Polycrystalline Diamond	Ripping	4–8, 6–12, 12–22, 20–40, 30–60	#30 Water-Based	Water
	Polishing	0–1/4, 0–1/2, 0–2, 2–4, 4–8, 6–12	#22 Oil-Based	Naptha
	Sizing	0–1/4, 0–1/2, 0–2, 2–4	#22 Oil-Based	Naptha
Single Crystal Diamond	Ripping	12–22, 20–40, 30–60	#30 Water-Based	Water
	Polishing	2–4, 3–6, 4–8, 5–10, 6–12	#15 Grease-Based	Naptha
	Sizing	2–4, 3–6, 4–8, 5–10, 6–12	#15 Grease-Based	Naptha
Tungsten Carbide	Ripping	6–12, 12–22	#22 Oil-Based	Naptha
	Polishing	2–4, 4–8, 6–12, 12–22	#22 Oil-Based	Naptha
			#30 Water-Based	Water
	Sizing	0–1/4, 0–2, 2–4, 4–8, 6–12	#22 Oil -Based	Naptha

DI-PRO POWDER SELECTION CHART FOR ULTRASONIC POLISHING MACHINES

MATERIAL TYPE	JOB PROCEDURE	MICRON SIZE RANGE	CLEANING METHOD
Fine Grain	Shaping	8–15	Water
Polycrystalline Diamond	Roughing	1/2–3	Water
	Polishing	0–2/10	Water
Coarse Grain	Shaping	12–22	Water
Polycrystalline Diamond	Roughing	3–6	Water
	Polishing	0–1	Water

HOW TO ORDER DI-PRO

When ordering DI-PRO, please specify the following information:

1. DI-PRO-D or DI-PRO-C
2. Micron Size Range
3. Carrier Type
4. Diamond Compound or Dry Diamond Powder
5. Number of Jars or Number of Carats (if Dry Powder)

SHAPED WIRE DRAWING DIES

Fort Wayne Wire Die produces dies in a wide variety of shapes, including half-round, oval, hexagon, rectangle, triangle, square and flat. Fort Wayne Wire Die will also custom-manufacture specially shaped dies upon request. For uniquely shaped wire requirements, Fort Wayne Wire Die designers can create a series of dies that will gradually deform the wire from round to the desired shape in a sequence of reductions that optimize your drawing machine capabilities.

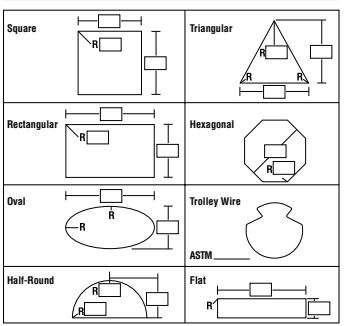
Shaped dies come in Poly-Di® polycrystalline diamond and tungsten carbide. Poly-Di polycrystalline diamond dies maintain high wear resistance and work best with nonferrous metals, such as copper and aluminum. Tungsten carbide dies offer dependable quality, and they are especially useful in steel wire applications or when short runs do not justify the expense of polycrystalline diamond material.

DIMENSIONAL LIMITS

	Tungsten Carbide / Tool Steel	Polycrystalline Diamond
Minimum Height and Width	.020 in / 0.5 mm	.040 in / 1.0 mm
Minimum Corner Radius	.004 in / 0.1 mm	.010 in / 0.25 mm
Minimum Tolerance	.0005 in / 0.0125 mm	.0005 in / 0.0125 mm

*Limits not applicable in all applications.

TYPICAL DIE SHAPES



Special shapes available by request.

ORDERING INFORMATION

To ensure prompt service, please be sure that the following information appears on the quotation request.

1. Finish Profile
2. Material Being Drawn
3. Incoming Wire Size and Shape
4. All Critical Dimensions
5. Corner Radius (R)
6. Reduction Angle
7. Die Nib Size
8. Bearing Length
9. Casing Size

ISO 9001:2000-Registered

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