Graver Rotation Angles Required to Create Parallel Heels on Vee Gravers

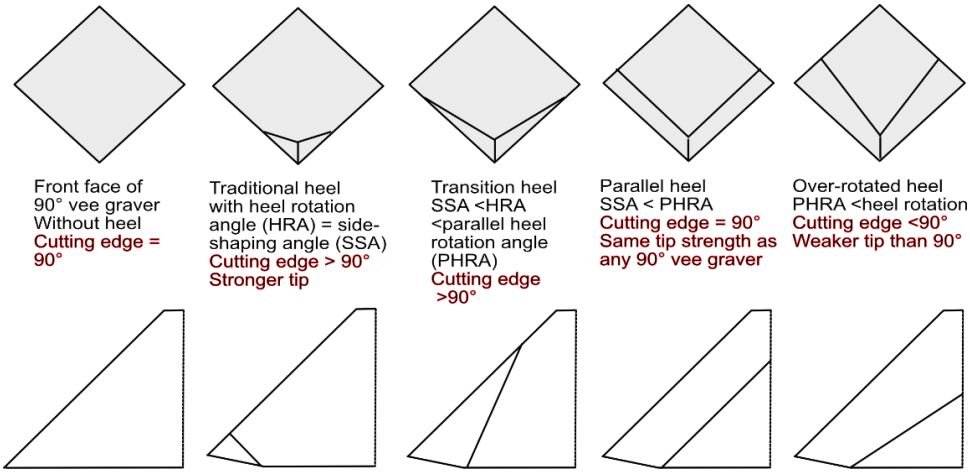
By Allen L. Clapp

A vee graver is shaped by (1) grinding cutting sides on the lower part of the graver at angles that leave the desired included vee angle on the body of the graver between the cutting sides,(2) grinding a face at an angle that will appropriately push up a chip of removed metal in the metal being engraved, and (3) grinding a heel on each side that will effectively produce a lifting heel on the bottom of the cutting surface that will allow control of the depth of the graver.

Heels are the last grind. You could start by grinding the face or grinding the cutting sides, but the heel grinding is last—**and the most important**, because the heel grind can change the angle of the vee graver's cutting edges. If you rotate the graver to the same angle used to shape the sides, you will create a **traditional triangular heel** at the tip of the graver. The cutting vee angle will be the same as that of the initial shaped vee angle. However, the cutting edge will extend only a short way up the sides of the graver and, thus, the graver is not useful for making wide bevel cuts or bright cuts.

In contrast to a traditional heel, a **parallel heel** extends all the way up the side of the graver and is equal in width for the entire distance up the side. Parallel heel gravers are useful for making wide bevel cuts and bright cuts. Because you remove metal at an angle when you grind the face angle, and because you raise the rear of the graver when you grind the heel, you must rotate the graver beyond the angle used to shape the graver for the complete side of the graver to touch the grinding surface and be able to create a parallel heel. Because parallel heels are ground at a greater graver rotation angle than that used to shape the graver body, the resultant cutting vee angle will be less than the initial body angle by an amount equal to twice the difference between the side-shaping angle and the heel rotation angle.

If you grind a heel using the original side-shaping angle as the heel rotation angle, you will produce a **traditional heel**, which is a small triangle. The diagram below shows how heels and resulting cutting angle change with different heel rotation angles on a 90-degree vee graver, but the principle is the same regardless of the vee shape. See the second from left diagram in the group below.



As you rotate the graver beyond the original side-shaping angle, the heel starts to creep up the side (third diagram). If you rotate it enough to lay the entire length of the side cutting surface down on the grinding surface, the heel will be the same length all along the side and you will have **parallel heels** (fourth diagram).

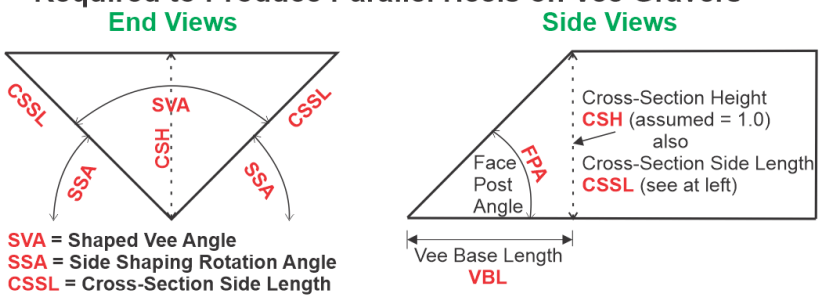
If the graver heel rotation is less than that required to produce a parallel heel, the cutting vee angle will be greater than the original shape angle, and the tip will be stronger as a result. Wider vee angles produce stronger graver tips.

If the graver heel rotation angle is greater than that required to produce a parallel heel, the cutting vee angle will be less than the original shape angle and the tip will be weaker.

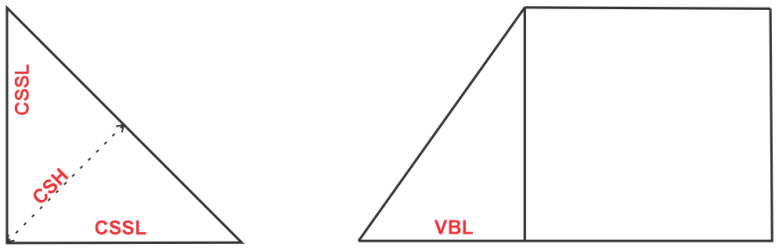
It should be clear that, the higher the heel lift angle, the farther the top end of the side cutting surface will be above the grinding surface, and the greater will be the extra rotation beyond the original shaping angle required to lay the complete side down on the grinding surface to grind a parallel flat. Similarly, as you lower the face angle, the top of the side cutting surfaces will be ground further back from the point and, thus, the top of the side cutting surfaces will be a greater distance above the grinding surface and require a greater heel rotation angle to lay the entire side down flat on the grinding surface.

The rotation of the graver required when cutting parallel heels is a function of the face angle, the heel lift angle, and the side-shaping angle. If any of these angles change, so must the required heel rotation angle.

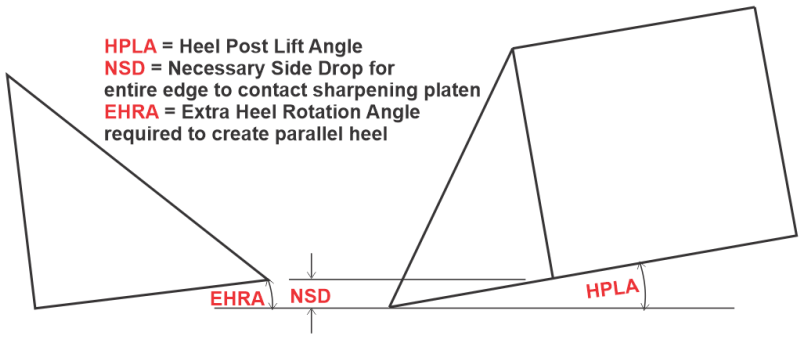
Diagrams For Calculations of Graver Rotation Angles Required to Produce Parallel Heels on Vee Gravers



Graver Rotated at 0 Degrees (i.e., Upright)



Graver Rotated at Side Shaping Angle and Laying Flat



Graver Rotated at Side Shaping Angle and Lifted at Heel Post Lift Angle

Graver Rotation Angles to Produce Parallel Heels for Vee-Shaped Gravers--Page 1

Calculated by Allen Clapp

45 Degree Face Angles — Vee Base Length VBL** = **1.000**

Graver Shaped Vee Angle SVA (°)	Side Shape Angle SSA (°)	10 Degree Heel Post Angle (HPLA)	12.5 Degree Heel Post Angle (HPLA)	15 Degree Heel Post Angle (HPLA)	17.5 Degree Heel Post Angle (HPLA)	20 Degree Heel Post Angle (HPLA)	22.5 Degree Heel Post Angle (HPLA)	25 Degree Heel Post Angle (HPLA)	27.5 Degree Heel Post Angle (HPLA)	30 Degree Heel Post Angle (HPLA)
60	60	68.65	70.80	72.95	75.09	77.23	79.35	81.47	83.57	85.66
65	57.5	65.92	68.02	70.11	72.19	74.27	76.33	78.38	80.42	82.44
70	55	63.18	65.21	67.24	69.26	71.27	73.27	75.25	77.22	79.18
75	52.5	60.42	62.39	64.35	66.30	68.24	70.17	72.09	73.99	75.87
80	50	57.64	59.54	61.44	63.32	65.19	67.05	68.89	70.72	72.52
85	47.5	54.86	56.68	58.50	60.31	62.11	63.89	65.65	67.40	69.13
90	45	52.05	53.80	55.55	57.28	59.00	60.70	62.39	64.06	65.70
95	42.5	49.24	50.91	52.57	54.22	55.86	57.48	59.09	60.68	62.24
100	40	46.41	48.00	49.58	51.14	52.70	54.24	55.76	57.27	58.75
105	37.5	43.57	45.07	46.57	48.05	49.52	50.97	52.41	53.83	55.22
110	35	40.72	42.13	43.54	44.93	46.31	47.68	49.03	50.36	51.67
115	32.5	37.85	39.18	40.49	41.80	43.09	44.37	45.62	46.86	48.08
120	30	34.98	36.21	37.44	38.65	39.85	41.03	42.20	43.35	44.48
125	27.5	32.10	33.24	34.36	35.48	36.59	37.68	38.75	39.81	40.85
130	25	29.21	30.25	31.28	32.30	33.31	34.31	35.29	36.25	37.20
	FCA =	55.00	57.50	60.00	62.50	65.00	67.50	70.00	72.50	75.00

FCA (Face contact angle) = face angle + heel angle; very high heels may need lower face angles to work properly.

*CSSL is a function of the graver cross section height CSH and Shaped Vee Angle SVA; CSH assumed = 1.

**VBL is a function of the graver cross section height CSH and the Face Angle FA; CSH assumed = 1

50 Degree Face Angles — Vee Base Length VBL** = **0.839**

Graver Shaped Vee Angle SVA (°)	Side Shape Angle SSA (°)	10 Degree Heel Post Angle (HPLA)	12.5 Degree Heel Post Angle (HPLA)	15 Degree Heel Post Angle (HPLA)	17.5 Degree Heel Post Angle (HPLA)	20 Degree Heel Post Angle (HPLA)	22.5 Degree Heel Post Angle (HPLA)	25 Degree Heel Post Angle (HPLA)	27.5 Degree Heel Post Angle (HPLA)	30 Degree Heel Post Angle (HPLA)
60	60	67.2	69.0	70.8	72.6	74.4	76.1	77.9	79.6	81.3
65	57.5	64.6	66.3	68.1	69.8	71.5	73.2	74.9	76.6	78.2
70	55	61.9	63.6	65.2	66.9	68.6	70.3	71.9	73.5	75.1
75	52.5	59.1	60.8	62.4	64.0	65.7	67.3	68.8	70.4	71.9
80	50	56.4	58.0	59.6	61.1	62.7	64.2	65.8	67.3	68.7
85	47.5	53.7	55.2	56.7	58.2	59.7	61.2	62.7	64.1	65.5
90	45	50.9	52.4	53.8	55.3	56.7	58.1	59.5	60.9	62.3
95	42.5	48.1	49.5	50.9	52.3	53.7	55.0	56.4	57.7	59.0
100	40	45.4	46.7	48.0	49.3	50.6	51.9	53.2	54.4	55.6
105	37.5	42.6	43.8	45.1	46.3	47.6	48.8	50.0	51.1	52.3
110	35	39.8	41.0	42.2	43.3	44.5	45.6	46.7	47.8	48.9
115	32.5	37.0	38.1	39.2	40.3	41.4	42.4	43.5	44.5	45.5
120	30	34.2	35.2	36.2	37.2	38.3	39.2	40.2	41.2	42.1
125	27.5	31.4	32.3	33.3	34.2	35.1	36.0	36.9	37.8	38.7
130	25	28.5	29.4	30.3	31.1	32.0	32.8	33.6	34.4	35.2
	FCA =	60.00	62.50	65.00	67.50	70.00	72.50	75.00	77.50	80.00

*These values match Apex Sharpening System Instruction Sheet values within 0.5 degrees.

Graver Rotation ° =((180-**SVA**)/2)+(ASIN((SIN(**HPLA***PI()/180)/TAN(**FA***PI()/180))/(1/COS(0.5***SVA***PI()/180)))*180/PI())

Graver Rotation Angles to Produce Parallel Heels for Vee-Shaped Gravers--Page 2

Calculated by Allen Clapp

		55 Degree Face Angles								
										Vee Base Length VBL** = 0.700
Graver Shaped Vee Angle SVA (°)	Side Shape Angle SSA (°)	10 Degree Heel Post Angle (HPLA)	12.5 Degree Heel Post Angle (HPLA)	15 Degree Heel Post Angle (HPLA)	17.5 Degree Heel Post Angle (HPLA)	20 Degree Heel Post Angle (HPLA)	22.5 Degree Heel Post Angle (HPLA)	25 Degree Heel Post Angle (HPLA)	27.5 Degree Heel Post Angle (HPLA)	30 Degree Heel Post Angle (HPLA)
60	60	66.04	67.54	69.03	70.51	71.97	73.42	74.85	76.26	77.65
65	57.5	63.39	64.84	66.29	67.73	69.15	70.56	71.95	73.32	74.67
70	55	60.72	62.13	63.54	64.93	66.31	67.68	69.03	70.36	71.67
75	52.5	58.04	59.41	60.77	62.12	63.45	64.77	66.08	67.36	68.63
80	50	55.34	56.67	57.98	59.28	60.57	61.85	63.10	64.34	65.56
85	47.5	52.64	53.92	55.18	56.43	57.67	58.89	60.10	61.29	62.46
90	45	49.93	51.15	52.36	53.56	54.75	55.92	57.08	58.22	59.33
95	42.5	47.21	48.38	49.53	50.68	51.81	52.93	54.03	55.12	56.18
100	40	44.48	45.59	46.69	47.78	48.86	49.92	50.97	51.99	53.01
105	37.5	41.74	42.79	43.83	44.86	45.88	46.89	47.88	48.85	49.81
110	35	39.00	39.99	40.97	41.94	42.90	43.84	44.77	45.69	46.58
115	32.5	36.25	37.17	38.09	39.00	39.89	40.78	41.65	42.50	43.34
120	30	33.49	34.35	35.20	36.04	36.88	37.70	38.51	39.30	40.08
125	27.5	30.72	31.51	32.30	33.08	33.85	34.61	35.35	36.09	36.80
130	25	27.95	28.67	29.39	30.11	30.81	31.50	32.18	32.85	33.51
	FCA =	65.00	67.50	70.00	72.50	75.00	77.50	80.00	82.50	85.00

FCA (Face contact angle) = face angle + heel angle; **very high heels may need lower face angles to work properly.**

*CSSL is a function of the graver cross section height CSH and Shaped Vee Angle SVA; CSH assumed = 1.

**VBL is a function of the graver cross section height CSH and the Face Angle FA; CSH assumed = 1

		60 Degree Face Angles								
										Vee Base Length VBL** = 0.577
Graver Shaped Vee Angle SVA (°)	Side Shape Angle SSA (°)	10 Degree Heel Post Angle (HPLA)	12.5 Degree Heel Post Angle (HPLA)	15 Degree Heel Post Angle (HPLA)	17.5 Degree Heel Post Angle (HPLA)	20 Degree Heel Post Angle (HPLA)	22.5 Degree Heel Post Angle (HPLA)	25 Degree Heel Post Angle (HPLA)	27.5 Degree Heel Post Angle (HPLA)	30 Degree Heel Post Angle (HPLA)
60	60	64.98	66.21	67.44	68.65	69.85	71.03	72.20	73.35	74.48
65	57.5	62.35	63.55	64.74	65.92	67.09	68.24	69.38	70.49	71.59
70	55	59.71	60.88	62.03	63.18	64.31	65.43	66.53	67.61	68.68
75	52.5	57.06	58.19	59.31	60.42	61.51	62.60	63.66	64.71	65.74
80	50	54.40	55.49	56.57	57.64	58.70	59.74	60.77	61.78	62.78
85	47.5	51.74	52.79	53.83	54.85	55.87	56.88	57.86	58.84	59.79
90	45	49.07	50.07	51.07	52.05	53.03	53.99	54.94	55.87	56.78
95	42.5	46.38	47.34	48.29	49.24	50.17	51.08	51.99	52.88	53.75
100	40	43.69	44.61	45.51	46.41	47.29	48.16	49.02	49.87	50.69
105	37.5	41.00	41.86	42.72	43.57	44.40	45.23	46.04	46.84	47.62
110	35	38.30	39.11	39.92	40.71	41.50	42.28	43.05	43.80	44.53
115	32.5	35.59	36.35	37.11	37.85	38.59	39.32	40.03	40.74	41.42
120	30	32.87	33.58	34.28	34.98	35.67	36.34	37.01	37.66	38.30
125	27.5	30.15	30.81	31.46	32.10	32.73	33.36	33.97	34.57	35.16
130	25	27.43	28.03	28.62	29.21	29.79	30.36	30.92	31.47	32.01
	FCA =	70.00	72.50	75.00	77.50	80.00	82.50	85.00	87.50	90.00

FCA (Face contact angle) = face angle + heel angle; **very high heels may need lower face angles to work properly.**

Graver Rotation ° =((180-**SVA**)/2)+(ASIN((SIN(**HPLA***PI()/180)/TAN(**FA***PI()/180))/(1/COS(0.5***SVA***PI()/180)))*180/PI())

Graver Angle Rotation Required to Produce Parallel Heels on a Vee Graver

EXCEL spreadsheet created by Allen L. Clapp

You can set up your own EXCEL spreadsheet by adding the formulas shown in each of the calculation boxes below and referencing the formulas to the appropriate input boxes.

NOTES:
1. You can change any number in the yellow boxes below and the results will be displayed below the line.
2. The assumed vertical height CSH at the full cross-section = 1

Degree

Inputs:

		Inputs
Shaped Vee Angle	**SVA**	90
Face Angle	**FA**	45
Heel Post Lift Angle	**HPLA**	15

Calculated results:

NOTE: Angles in degrees are converted to radians by multiplying degrees by pi()/180 in formulas

Side Shaping Angle	**SSA**SSA =	45	(180-SVA)/2
Cross-section Side Length	**CSSL**CSSL	1.414214	= (CSH=1)/Cos(0.5*SVA*pi()/180)
Base Vee Length	**BVL**BVL =	1	(CSH=1)/tan(FA*pi()/180
Necessary Side Drop	**NSD**NSD	0.258819	= Sin(HPLA*pi()/180)/Tan(FA*pi()/180)
Extra Heel Rotation Angle		10.54529	**EHRA**EHRA = asin(NSD/CSSL)
Parallel Heel Rotation Angle	**PHRA**PHRA	55.54529	= SSA + EHRA

Abbreviations:

SVA **Shaped Vee Angle** = shaped or trued-up vee angle of graver

FA **Face Angle** = angle of face from axis of graver

HPLA **Heel Post Lift Angle** = the post angle used to add a heel *to each side of the face*

SSA **Side Shaping Angle** = Graver rotation angle used to shape each side

CSSL **Cross-section Side Length** = length of shaped side of cross-section taken normal to the axis of the graver

BVL **Base Vee Length** = length of the baseline of the vee from tip to full cross-section

NSD **Necessary Side Drop** = height of top face corner above wheel when rotated at original side shaping angle

EHRA **Extra Heel Rotation Angle** = extra rotation above SSA required to place entire side on wheel to shape a parallel heel

PHRA **Parallel Heel Rotation Angle** = graver rotation angle required to produce a parallel heel