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Machine tool pocket reference guide

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THE ACADEMY

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Contents

Note: Programming examples are for Renishaw macros for Fanuc like CNCs

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M-codes

Typical NC M-codes for milling machines

M00	Program stop
M01	Optional stop
M02	Program end
M03	Spindle CW rotation
M04	Spindle CCW rotation
M05	Spindle stop
M06	Automatic tool change
M07	Through tool coolant
M08	Coolant on
M09	Coolant off
M13	Spindle CW & coolant on
M14	Spindle CCW & coolant on
M19	Main-spindle orientation
M30	Program end & rewind
M54	Parts count
M98	Sub-program call
M99	End of sub-program

*** M-codes may vary from machine to machine**

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M-codes

Typical NC M-codes for lathes

M00	Program stop
M01	Optional stop
M02	Program end
M03	Main-spindle forward
M04	Main-spindle reverse
M05	Main-spindle stop
M07	Through tool coolant
M08	Coolant on
M09	Coolant off
M10	Parts catcher advance
M11	Parts catcher retract
M13	Spindle CW & coolant on
M14	Spindle CCW & coolant off
M17	Machine lock act
M18	Machine lock cancel
M19	Main-spindle orientation
M30	Program end & rewind
M31	Interlock by-pass (SPDL & T/S)
M40	Gear change neutral
M41	Gear change low
M42	Gear change middle
M43	Gear change high
M50	Bar feeder command
M54	Parts count
M65	Main-SPDL & coolant off
M68	Main-chuck clamp
M69	Main-chuck unclamp

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Typical G-code addresses for lathes

G00	Rapid linear positioning
G01	Linear feed interpolation
G02	CW circular interpolation
G03	CCW circular interpolation
G04	Dwell
G07	Hypothetical axis interpolation, sine curve
G09	Exact stop
G10	Offset value setting
G20	Input inches
G21	Input in millimeters
G22	Stored stroke limit on
G23	Stored stroke limit off
G27	Reference point return check
G28	Return to reference point
G29	Return from reference point
G30	Return to 2nd, 3rd & 4th reference point
G31	Skip cutting
G33	Thread cutting
G34	Variable lead thread cutting
G36	Automatic tool compensation X
G37	Automatic tool compensation Z
G40	Tool nose radius compensation cancel
G41	Tool nose radius compensation left
G42	Tool nose radius compensation right
G50	Maximum spindle speed set
G65	User macro simple call
G66	User macro modal call
G67	User macro modal call cancel
G68	Mirror image for double turrets on
G69	Mirror image for double turrets off
G70	Finishing cycle

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Typical G-code addresses for lathes

G71	Stock removal, turning
G72	Stock removal, facing
G73	Repeat pattern
G74	Peck drilling, Z axis
G75	Grooving, X axis
G76	Thread cutting cycle
G90	Cutting cycle stock removal
G92	Thread cutting cycle
G94	Cutting cycle face
G96	Constant surface speed control
G97	Constant surface speed control cancel
G98	Feed per minute
G99	Feed per revolution

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Typical G-code addresses for mills

G01	Linear interpolation
G02	Circular interpolation/ helical interpolation CW
G03	Circular interpolation/ helical interpolation CCW
G04	Dwell, Exact stop
G05	High speed cycle machining
G07.1	(G107) Cylindrical interpolation
G09	Exact stop
G10	Data setting
G11	Data setting mode cancel
G12.1	(G112) Polar coordinate interpolation mode
G13.1	(G113) Polar coordinate interpolation cancel mode
G15	Polar coordinate command cancel
G16	Polar coordinates command
G17	XpYp plane selection Xp : X axis or its parallel axis
G18	ZpXp plane selection
G19	YpZp plane selection
G20	Input inch
G21	Input in mm
G22	Stored stroke check function on
G23	Stored stroke check function off
G27	Reference position return check
G28	Return to reference position
G29	Return from reference position
G30	2nd, 3rd and 4th reference position return
G30.	1 Floating reference point return
G31	Skip function
G33	01 Thread cutting
G37	Automatic tool length measurement
G39	Corner offset circular interpolation

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Typical G-code addresses for mills

G40	Cutter compensation cancel
G41	Cutter compensation left
G42	Cutter compensation right
G43	Tool length compensation + direction
G44	Tool length compensation - direction
G45	Tool offset increase
G46	Tool offset decrease
G47	Tool offset double increase
G48	Tool offset double decrease
G49	Tool length compensation cancel
G50	Scaling cancel
G51	Scaling
G50.1	Programmable mirror image cancel
G51.1	Programmable mirror image
G52	Local coordinate system setting
G53	Machine coordinate system selection
G54	Workpiece coordinate system 1 selection
G54.1	Additional workpiece coordinate system selection
G55	Workpiece coordinate system 2 selection
G56	Workpiece coordinate system 3 selection
G57	Workpiece coordinate system 4 selection
G58	Workpiece coordinate system 5 selection
G59	Workpiece coordinate system 6 selection
G60	00 Single direction positioning
G61	Exact stop mode

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Typical G-code addresses for mills

G62	Automatic corner override
G63	Tapping mode
G64	Cutting mode
G65	Macro call
G66	Macro modal call
G67	Macro modal call cancel
G68	Coordinate rotation
G69	Coordinate rotation cancel
G73	Peck drilling cycle
G74	Counter tapping cycle
G76	Fine boring cycle
G80	Canned cycle cancel/external operation function cancel
G81	Drilling cycle, spot boring cycle or external operation function
G82	Drilling cycle or counter boring cycle
G83	Peck drilling cycle
G84	Tapping cycle
G85	Boring cycle
G86	Boring cycle
G87	Back boring cycle
G88	Boring cycle
G89	Boring cycle
G90	Absolute command
G91	Increment command
G92	Setting for work coordinate system or clamp at maximum spindle
G94	Feed per minute
G95	Feed per rotation
G96	Constant surface speed control
G97	Constant surface speed control cancel
G98	Return to initial point in canned cycle
G99	Return to R point in canned cycle

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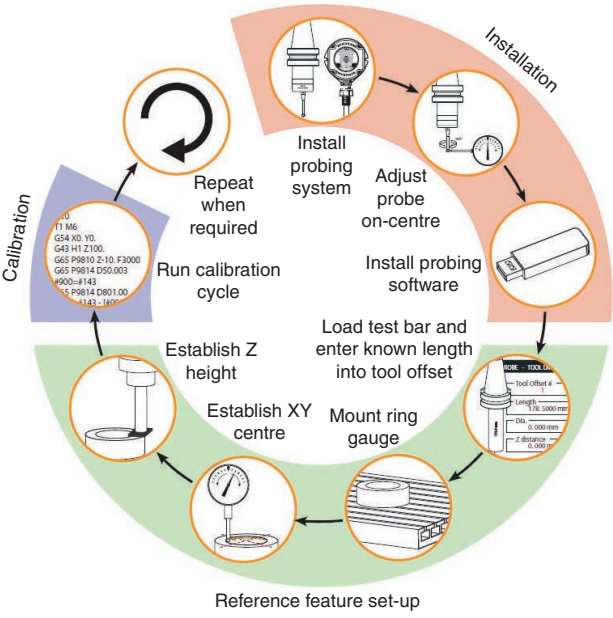
Calibration methods

Although a variety of probe calibration methods are available, the routines remain similar for each; it is actually the reference features that are chosen and set up differently.

The most widely applicable method is explained here: in the case of machines with rotary axes (5-axis machines) it is essential that this method is followed. There are alternative methods for 3-axis machines.



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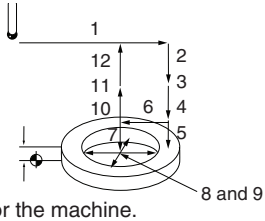
Spindle probe calibration

This example describes how to carry out full calibration of the probe of an internal feature using macros O9801, O9802 and O9804, using a 50.001 mm (1.9685 in) diameter ring gauge, with a known centre position and top face height value.

The approximate probe length must be stored in the tool offset register before running this program. Set the exact X, Y and Z feature positons in a work offset (example using G54).

Full calibration in an internal feature



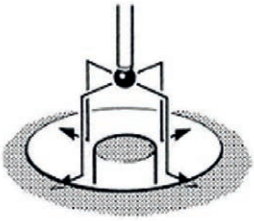
O0006

G90G80G40G0 Prepatory codes for the machine.

1. G54X35.Y0 Move off centre of feature for height setting.
2. G43H1Z100. Activate offset 1, go to 100 mm (3.94 in) above.
3. G65P9832 Spin the probe on (includes M19), or M19 for spindle orientation.
4. G65P98010Z30.F3000 Protected positioning move above reference surface.
5. G65P9801Z20.006T1 Calibrate the probe length. Surface at 20.006 mm (7.876 in)
6. G65P9810X0Y0 Protected positioning move to centre.
7. G65P9810Z5. Protected positioning move into hole.
8. G65P9802D50. Calibrate in a 50 mm (1.97 in) diameter bored hole to establish the X, Y stylus offset.
9. G65P9804D50.001 Calibrate in a 50.001 mm (1.9685 in) diameter ring gauge to establish the ball radius values, including the vector directions.
10. G65P9810Z100.F3000 Protected positioning move retract to 100 mm (3.94 in).
11. G65P9833 Spin the probe off (when applicable).
12. G28Z100. Reference return. H00 Cancel offset (when applicable) M30 End of program.

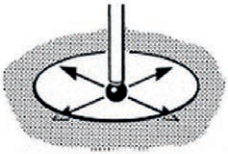
Inspection Plus software

Bore / Boss



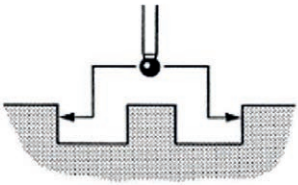
G65 P9814 D50. Z-10. R-5. S4

G65 P9814 D50. Z-10. S4

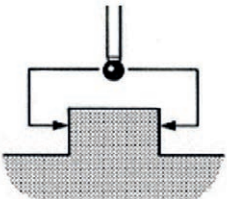


G65 P9814 D50. S4

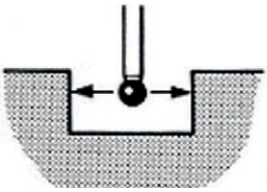
Web / Pocket



G65 P9812 X50. Z-10. R-5. S4



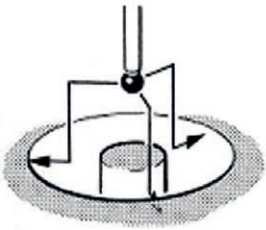
G65 P9812 X50. Z-10. S4

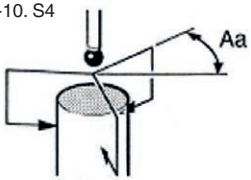


G65 P9812 X50. S4

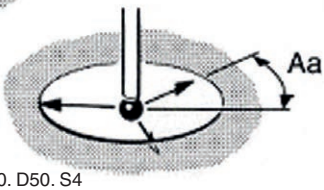
3 Point Bore / Boss

G65 P9823 A0. B120. C-120. D50. Z-10. S4





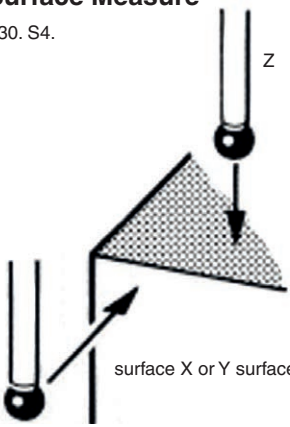
G65 P9823 A0. B120. C-120. D50. Z-10. R-5. S4



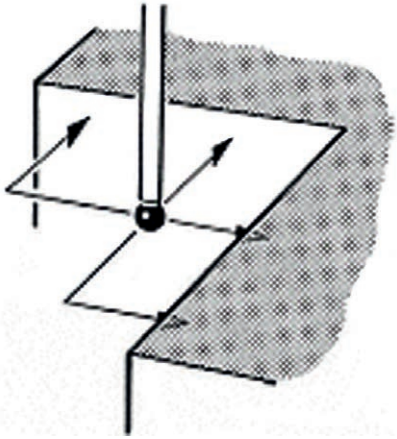
G65 P9823 A0. B120. C-120. D50. S4

X / Y / Z Surface Measure

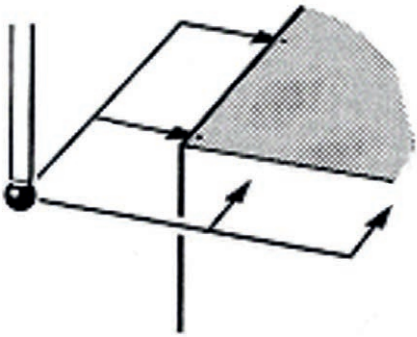
G65 P9811 X30. S4.



Internal / External Corner

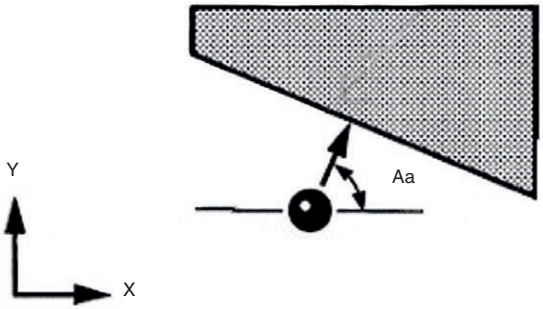


Example
G65 P9815 X0 Y0 120. J20. S6.

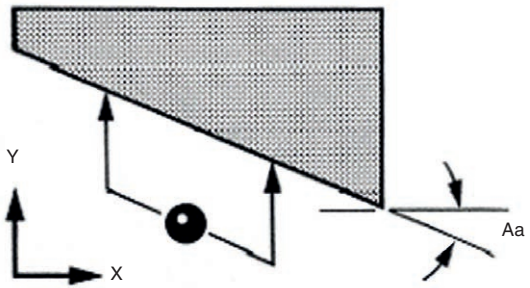


Example
G65 P9815 X0 Y0 120. J20. S6.

Angled Surface



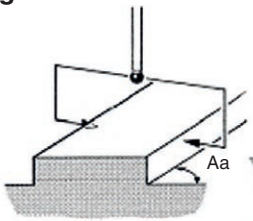
Example
G65 P9821 A60. D30.



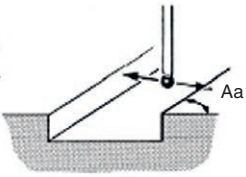
Example
G65 P9843 Y50. D30. A-30

Inspection Plus software

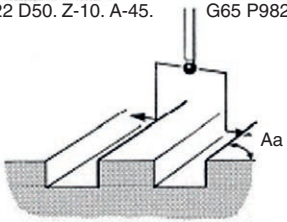
Angled Web / Pocket



G65 P9822 D50. Z-10. A-45.

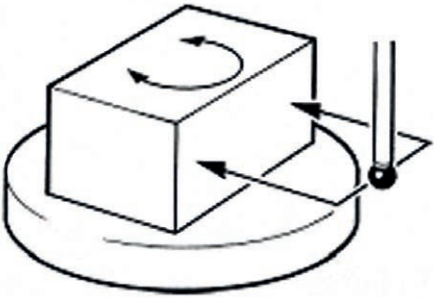


G65 P9822 D50. A-45.



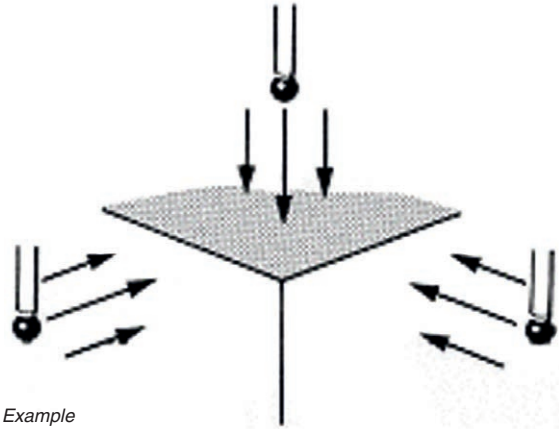
G65 P9822 D50. A-45. R-5.

4th Axis Measure Cycle



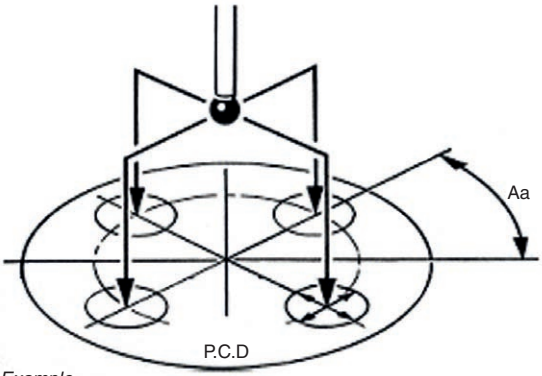
Example
G65 P9817 X100. Z50. S1.

Stock Allowance



Example
G65 P9820 Z0 120. 120 130. J30 140. J40. S6

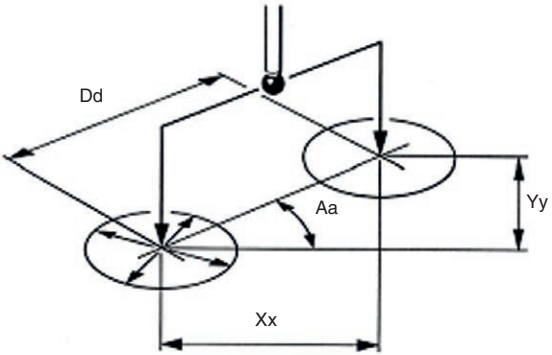
Bore / Boss on P.C.D. Cycle



Example
G65 P9819 C200. D25. K-10. B4. A45.

Inspection Plus software

Feature-to-Feature



Example
G65 P9810 X0 Y0 F5000.

G65 P9814 D20.

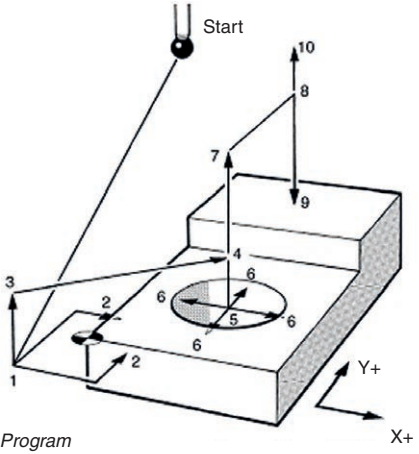
G65 P9834

G65 P9810 X50.

G65 P9814 D20.

G65 P9834 X50.

Inspection Plus software



Example Program

```
%
G80 G90 G40 G00
T01
M06
G54X0Y0
G43H1Z100.0
1.    G65P9810 X-10.0 Y-10. Z-5.0 F1000 (protected move)
2.    G65 P9816 X0.0 Y0.0120.J20. S1. (corner measure)
3.    G65 P9810Z10.0
4.    G65 P9810X50.0 Y40.0
5.    G65 P9810Z-5.0
6.    G65 P9814 D40.0 T10 M20 H0.2 (bore measure)
7.    G65 P9810 Z20.0
8.    G65 P9810 Y90.
9.    G65 P9811Z5.0 S2. (Z measure)
10.   G65 P9810Z50.0
G00 G28 Z100.0
M30.
```

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Tool setting calibration

Manually position the reference tool to approximately 10 mm (0.4 in) above the stylus and approximately on the centre-line of the stylus.

When the program is run, all macro variable data is set and the probe is fully calibrated.

The reference tool makes the following measurements:

1. Z measure on top of the stylus (four touches).
2. Measure 3 sides of the stylus, depends on setting in 09750.
3. Return to 10 mm (0.4 in) above the stylus and on-centre.

G65 P9855 T1 D12.7 R10

Rotating tool setting software

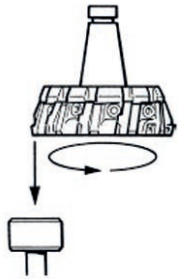
Tool length / diameter setting

The tool is manually positioned over the stylus within 10 mm of the surface. The following examle program is then executed.

Tool length setting

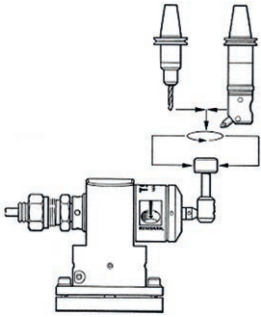
G65 P9856 T1.

Rotating length setting



G65 P9856 T1. D80.

Rotating length and diameter setting



G65 P9856 D80. B3.0.

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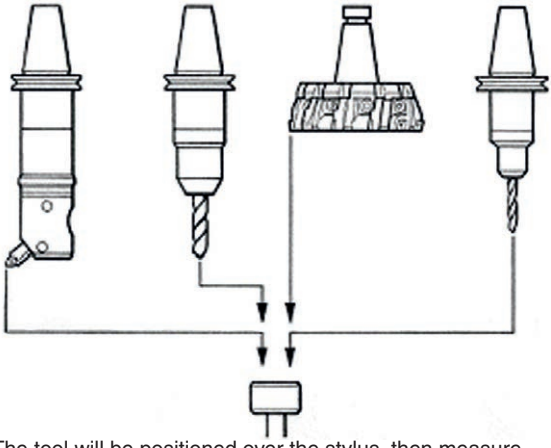
Rotating tool setting software

Automatic tool measurement



The tool will be positioned over the stylus, then measure the length and diameter before returning to the home position and updating the relevant offsets.

Example
1. G65 P9857 B3. T1. D20.
(automatically measures length offset No. 1 and diameter offset No. 1 for a 20 diameter tool).

Broken tool detection

After machining, the tool is positioned by the program over the stylus before running the following cycle to check the length or diameter offset.

Example
1. G65 P9858 B1. T1. H0.2
(tool breakage tolerance ± 0.2 mm).

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Inspection Plus legend

Bb	Angle tolerance of the surface, e.g. 30 degrees ± 1 degree inputs A30. B1.
Ee	Experience value. Specify the number of a spare tool offset where an adjustment value to the measured size is stored.
Ff	Percent feedback when updating a tool offset. Enter a value between O and 1 (0% and 100%). Default = 100%. Also: Feedrate in the protected positioning macro (O9810). *Example*: F15 sets a feedrate of 15 mm/min. (F.6 sets a feedrate of 0.6 in/min.)
Hh	Tolerance value of a feature dimension being measured. *Example*: for dimension 50.0 mm + 0.4 mm -0 mm, the nominal tolerance is 50.2 mm with H.2.
Ii	See the relevant measuring cycles and specific macro calls.
Jj	See the relevant measuring cycles and specific macro calls.
Kk	See the relevant measuring cycles and specific macro calls.
Mm	True position tolerance of a feature. A cylindrical zone about the theoretical positon. *Example*: M.1 sets a true position tolerance of 0.1 mm.
Qq	Probe overtravel distance for use when the default values are unsuitable. The probe will then travel beyond expected position when it searches for a surface. Default = 4 mm in the Z-axis, and 10 mm in the X and Y axes.
Rr	An incremental dimension that is used in external features, e.g. bosses and webs, to give a radial clearance from the nominal target surface prior to a Z-axis move. Default = 5 mm. *Example*: R10. sets a radial clearance of 10 mm.
R-r	Similar to Rr, except that the clearance is applied in the opposite direction to force an internal boss or web cycle. Default = 5 mm. *Example*: R-10. sets a radial clearance of -10 mm.
Ss	Work offset number which will be set. The work offset number will be updated. S1 to S6 (G54 to G59) AS0 (external work offset). S101 to S148 (G54.1 P1 to G54.1 P48) additional offsets option.

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Inspection Plus legend (cont.)

Tt	Tool offset number to be updated.
Uu	Upper tolerance limit. If this value is exceeded there is no tool offset or work offset updated and the cycle is stopped with an alarm. This tolerance is applied to both size and position where applicable. *Example*: U2. to set the upper tolerance limit to 2 mm.
Vv	Null band. This is the tolerance zone where no tool offset adjustment occurs. Default = 0. *Example*: V.5. for a tolerance zone of ± 0.5 mm.
Ww	Print data 1. = increment the featuer number only. 2. = Increment the component number, and reset the feature number. *Example*: W1.

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Tool settings legend

Bb	Cycle type. 1 length. 2 Diameter only. 3 = Length + Diameter.
Dd	Cutter diameter or reference tool diameter (omit for non-rotating operation).
D+d	Right handed cutting tools.
D-d	“Left-handed cutting tools. e.g. S80. = 80 mm right-handed cutting tool.”
Kk	Experience value for length.
Ee	Tool radius offset number to be updated. A type offsets only.
Rr	Overtravel distance, and radial clearance when moving down the side of the stylus (4.0 mm default).
Tt	Tool offset number.
Qq	Probe overtravel distance (4.0 mm default).
Zz	Position for diameter measurement.
Mm	Broken too flag.
Hh	Tolerance is set to the ±h value programmed.
Ii	Size adjustments to compensate for cutting conditions. A positive value sets the tool radius small by the stated amount, e.g. I = .01 sets the cutter radius small by 0.01.

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
	0.437	11.1		0.5118	13
7/16	0.4375	11.1125	33/64	0.5156	13.0969
	0.4409	11.2		0.5157	13.1
	0.4449	11.3		0.5197	13.2
	0.4488	11.4		0.5236	13.3
	0.4528	11.5		0.5276	13.4
29/64	0.4531	11.5094	17/32	0.5313	13.4938
	0.4567	11.6		0.5315	13.5
	0.4606	11.7		0.5315	13.6
	0.4646	11.8		0.5394	13.7
	0.4685	11.9		0.5433	13.8
15/32	0.4688	11.9063	35/64	0.5469	13.8906
	0.4724	12		0.5472	13.9
	0.4764	12.1		0.5512	14
	0.4803	12.2		0.561	14.25
	0.4843	12.3	9/16	0.5625	14.2875
31/64	0.4844	12.3031		0.5709	14.5
	0.4882	12.4	37/64	0.5781	14.6844
	0.4921	12.5		0.5807	14.75
	0.4961	12.6		0.5906	15
1/2	0.5	12.7	19/32	0.5938	15.0813
	0.5039	12.8		0.6004	15.25
	0.5079	12.9	39/64	0.6094	15.4781

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
	0.6102	15.5	3/4	0.75	19.05
	0.6201	15.75		0.7579	19.25
5/8	0.625	15.875	49/64	0.7656	19.4469
	0.6299	16		0.7677	19.5
	0.6398	16.25		0.7776	19.75
41/64	0.6406	16.2719	25/32	0.7813	19.8438
	0.6496	16.5		0.7874	20
21/32	0.6563	16.6688	51/64	0.7969	20.2406
	0.6594	16.75		0.7972	20.25
	0.6693	17		0.8071	20.5
43/64	0.6719	17.0656	13/16	0.8125	20.6375
	0.6791	17.25		0.8169	20.75
11/16	0.6875	17.4625		0.8268	21
	0.689	17.5	53/64	0.8281	21.0344
	0.6988	17.75		0.8366	21.25
45/64	0.7031	17.8594	27/32	0.8438	21.4313
	0.7087	18		0.8465	21.5
	0.7185	18.25		0.8563	21.75
23/32	0.7188	18.2563	55/64	0.8594	21.8281
	0.7283	18.5		0.8661	22
47/64	0.7344	18.6531	7/8	0.875	22.225
	0.7832	18.75		0.8858	22.5
	0.748	19	57/64	0.89063	22.6219

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
	0.9055	22.75		1.1417	29
	0.9055	23		1.1614	29.5
29/32	0.90625	23.0188		1.1811	30
	0.9154	23.25		1.2205	31
59/64	0.92188	23.4156	1 1/4	1.25	31.75
	0.9252	23.5		1.2598	32
	0.935	23.75		1.2992	33
15/16	0.9375	23.8125		1.3386	34
	0.9449	24		1.378	35
61/64	0.95313	24.2094		1.4173	36
	0.9547	24.25		1.4567	37
	0.9646	24.5		1.4961	38
31/32	0.96875	24.6063	1 1/2	1.5	38.1
	0.9843	25		1.5354	39
63/64	0.98438	25.0031		1.5748	40
1	1	25.4		1.6142	41
	1.0039	25.5		1.6535	42
	1.0236	26		1.6929	43
	1.0433	26.5		1.7323	44
	1.063	27	1 3/4	1.75	44.45
	1.0827	27.5		1.7717	45
	1.1024	28		1.811	46
	1.122	28.5		1.8504	47

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
	1.8898	48		0.0276	0.7
	1.9291	49		0.0295	0.75
	1.9685	50	1/32	0.0313	0.7938
2	2	50.8		0.0315	0.8
2 1/4	2.25	57.15		0.0335	0.85
2 1/2	2.5	63.5		0.0354	0.9
2 3/4	2.75	69.85		0.0374	0.95
3	3	76.2		0.0394	1
3 1/2	3.5	88.9		0.0413	1.05
4	4	101.6		0.0433	1.1
4 1/2	4.5	114.3		0.0453	1.15
5	5	127	3/64	0.0469	1.1906
6	6	152.4		0.0472	1.2
	0.0039	0.1		0.0492	1.25
	0.0079	0.2		0.0512	1.3
	0.0118	0.3		0.0532	1.35
1/64	0.0156	0.3969		0.0551	1.4
	0.0157	0.4		0.0571	1.45
	0.0177	0.45		0.0591	1.5
	0.0197	0.5		0.061	1.55
	0.0217	0.55	1/16	0.0625	1.5875
	0.0236	0.6		0.063	1.6
	0.0256	0.65		0.065	1.65

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
	0.0669	1.7		0.1083	2.75
	0.0689	1.75	7/64	0.1094	2.7781
	0.0709	1.8		0.1102	2.8
	0.0728	1.85		0.1122	2.85
	0.0748	1.9		0.1142	2.9
	0.0768	1.95		0.1161	2.95
5/64	0.0781	1.9844		0.1181	3
	0.0787	2		0.122	3.1
	0.0807	2.05	1/8	0.125	3.175
	0.0827	2.1		0.126	3.2
	0.0846	2.15		0.1299	3.3
	0.0866	2.2		0.1339	3.4
	0.0886	2.25		0.1378	3.5
	0.0906	2.3	9/64	0.1406	3.5719
	0.0925	2.35		0.1417	3.6
3/32	0.0938	2.3813		0.1457	3.7
	0.0945	2.4		0.1496	3.8
	0.0965	2.45		0.1535	3.9
	0.0984	2.5	5/32	0.1563	3.9688
	0.1004	2.55		0.1575	4
	0.1024	2.6		0.1614	4.1
	0.1043	2.65		0.1654	4.2
	0.1063	2.7		0.1693	4.3

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Standard drill sizes

Inches	Decimal	Metric	Inches	Decimal	Metric
11/64	0.1719	4.3656		0.2441	6.2
	0.1732	4.4	1/4	0.25	6.35
	0.1772	4.5		0.252	6.4
	0.1811	4.6		0.2559	6.5
	0.185	4.7		0.2598	6.6
3/16	0.1875	4.7625		0.2638	6.7
	0.189	4.8	17/64	0.2656	6.7469
	0.19296	4.9		0.8677	6.8
	0.1959	5		0.2717	6.9
	0.2008	5.1		0.2756	7
13/64	0.2031	5.1594		0.2795	7.1
	0.2047	5.2	9/32	0.2813	7.1438
	0.2087	5.3		0.2874	7.2
	0.2126	5.4		0.2874	7.3
	0.2165	5.5		0.2913	7.4
7/32	0.2188	5.5563		0.2953	7.5
	0.2205	5.6	19/64	0.2969	7.5406
	0.2244	5.7		0.2992	7.6
	0.2283	5.8		0.3032	7.7
	0.2323	5.9		0.3071	7.8
15/64	0.2344	5.9531		0.311	7.9
	0.2362	6	5/16	0.3125	7.9375
	0.2402	6.1		0.315	8

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Standard drill sizes

Inches	Decimal	Metric
	0.3189	8.1
	0.3228	8.2
	0.3268	8.3
21/64	0.3281	8.3344
	0.3307	8.4
	0.3346	8.5
	0.3386	8.6
	0.3425	8.7
11/32	0.3438	8.7313
	0.3465	8.8
	0.3504	8.9
	0.3543	9
	0.3583	9.1
23/64	0.3594	9.1281
	0.3622	9.2
	0.3661	9.3
	0.3701	9.4
	0.374	9.5
3/8	0.375	9.525
	0.378	9.6
	0.3819	9.7
	0.3858	9.8
	0.3898	9.9

Inches	Decimal	Metric
25/64	0.3906	9.9219
	0.3937	10
	0.3976	10.1
	0.4016	10.2
	0.4055	10.3
13/32	0.4063	10.3188
	0.4095	10.4
	0.4134	10.5
	0.4173	10.6
	0.4213	10.7
27/64	0.4219	10.7156
	0.4252	10.8
	0.4291	10.9
	0.4331	11

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Tapping data

Metric fine screw thread data

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
M3 x 0.35	3.10	2.65	-
M4 x 0.50	4.10	3.50	-
M5 x 0.50	5.10	4.50	-
M6 x 0.75	6.10	5.20	-
M7 x 0.75	7.20	6.20	-
M8 x 1.00	8.20	7.00	-
M10 x 1.25	10.20	8.80	-
M12 x 1.25	12.20	10.80	-
M14 x 1.50	14.25	12.50	-
M16 x 1.50	16.25	14.50	-
M18 x 1.50	18.25	16.50	-
M20 x 1.50	20.25	18.50	-
M22 x 1.50	22.25	20.50	-
M24 x 2.00	24.25	22.00	-
M27 x 2.00	27.25	25.00	-
M30 x 2.00	30.50	28.00	-

Tapping data

Metric coarse screw thread data

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
M1 x 0.25	1.05	0.75	-
M1.1 x 0.25	1.15	0.85	-
M1.2 x 0.25	1.25	0.95	-
M1.4 x 0.30	1.45	1.10	-
M1.6 x 0.35	1.65	1.25	1.45
M1.8 0.35	1.85	1.45	1.65
M2 x 0.40	2.05	1.60	1.80
M2.2 x 0.45	2.25	1.75	2.00
M2.5 x 0.45	2.60	2.05	2.30
M3 x 0.50	3.10	2.50	2.80
M3.5 x 0.60	3.60	2.90	3.20
M4 x 0.70	4.10	3.30	3.70
M4.5 x 0.75	4.60	3.70	4.10
M5 x 0.80	5.10	4.20	4.60
M6 x 1.00	6.10	5.00	5.60
M7 x 1.00	7.20	6.00	6.50
M8 x 1.25	8.20	6.80	7.40
M9 x 1.25	9.20	7.80	8.36
M10 x 1.50	10.20	8.50	9.30
M11 x 1.50	11.20	9.50	-

Tapping data

Metric coarse screw thread data

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
M12 x 1.75	12.20	10.20	11.20
M14 x 2.00	14.25	12.00	13.00
M16 x 2.00	16.25	14.00	15.00
M18 x 2.50	18.25	15.50	16.80
M20 x 2.50	20.25	17.50	18.80
M22 x 2.50	22.25	19.50	-
M24 x 3.00	24.25	21.00	-
M27 x 3.00	27.25	24.00	-

UNC screw thread data

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
No 1 UNC 64	1.95	1.55	1.65
No 2 UNC 56	2.30	1.85	1.95
No 3 UNC 48	2.65	2.10	2.25
No 4 UNC 40	2.95	2.35	2.55
No 5 UNC 40	3.30	2.65	2.85
No 6 UNC 32	3.60	2.85	3.10
No 8 UNC 32	4.30	3.50	3.80

Tapping data

UNC screw thread data (cont.)

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
No 10 UNC 24	4.90	3.90	4.30
No 12 UNC 24	5.60	4.50	5.00
1/4 UNC 20	6.50	5.10	5.80
5/16 UNC 18	8.10	6.60	7.30
3/8 UNC 16	9.70	8.00	8.80
7/16 UNC 14	11.30	9.40	10.46
1/2 UNC 13	13.00	10.80	11.90
9/16 UNC 12	14.50	12.20	-
5/8 UNC 11	16.25	13.50	-
3/4 UNC 10	19.25	16.50	-
7/8 UNC 9	22.50	19.50	-
1 UNC 8	25.75	22.25	-
1 1/8 UNC 7	29.00	25.00	-
1 1/4 UNC 7	32.00	28.00	-

Tapping data

UNF screw thread data

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
No 0 UNF 80	1.60	1.25	1.40
No 1 UNF 72	1.95	1.55	1.70
No 2 UNF 64	2.30	1.90	2.00
No 3 UNF 56	2.65	2.15	2.30
No 4 UNF 48	2.95	2.40	2.60
No 5 UNF 44	3.30	2.70	2.90
No 6 UNF 40	3.60	2.95	3.20
No 8 UNF 36	4.30	3.50	3.80
No 10 UNF 32	4.90	4.10	4.50
No 12 UNF 28	5.60	4.70	5.10
1/4 UNF 28	6.50	5.50	5.90
5/16 UNF 24	8.10	6.90	7.50
3/8 UNF 24	9.70	8.50	9.00
7/16 UNF 20	11.30	9.90	10.50
1/2 UNF 20	13.00	11.50	12.20
9/16 UNF 18	14.50	12.90	-
5/8 UNF 18	16.25	14.50	-
3/4 UNF 16	19.25	17.50	-
7/8 UNF 14	22.50	20.40	-
1 UNF 12	25.75	23.25	-

Tapping data

UNF screw thread data (cont.)

Thread size	Clearance drill diameter (mm)	Cutting tap drill diameter (mm)	Forming tap drill diameter (mm)
1 1/8 UNF 12	29.00	26.50	-
1 1/4 UNF 12	32.00	29.50	-
1 3/8 UNF 12	35.50	32.75	-
1 1/2 UNF 12	38.50	36.00	-

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British Standard

British Standard Fine (B.S.F.)			British Standard Whitworth (B.S.W.)		
Nominal dia. of threads	Pitch (T.P.I.)	Tapping drill dia. mm	Nominal dia. of threads	Pitch (T.P.I.)	Tapping drill dia. mm
3/16”	32	4	1/8”	40	2.55
7/32”	28	4.6	3/16”	24	3.7
1/4”	26	5.3	1/4”	20	5.1
9/32”	26	6.1	5/16”	18	6.5
5.16”	22	6.8	3/8”	16	7.9
3/8”	20	8.3	7/16”	14	9.3
7/16”	18	9.7	1/2”	12	10.5
1/2”	16	11.1	9/16”	12	12.1
9/16”	16	12.7	5/8”	11	13.5
5/8”	14	14	11/16”	11	15
11/16”	14	15.5	3/4”	10	16.25
3/4”	12	16.75	7/8”	9	19.25
7/8”	11	19.75	1”	8	22
1”	10	22.75	1.1/8”	7	24.75
1.1/8”	9	25.5	1.1/4”	7	28
1.1/4”	9	28.5	1.1/2”	6	33.5
1.3/8”	8	31.5	1.3/4”	5	39
1.1/2”	8	34.5	2”	4.5	44.5

British Standard

British Standard Brass (BSB)

Nominal dia. of threads	Pitch (T.P.I.)	Tapping drill dia. mm	Nominal dia. of threads	Pitch (T.P.I.)	Tapping drill dia. mm
1/4”	26	5.4	9/16”	26	13
5/16”	26	6.9	5/8”	26	14.7
3/8”	26	8.4	3/4”	26	17.8
7/16”	26	10	7/8”	26	21
1/2”	26	11.5	1”	26	24.2

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Conversion factors

To calculate spindle speed
318 x m/min ÷ Ø = RPM
e.g.: 318 x 150 ÷ 25 = 1908 RPM

To calculate table feed
Fz x Z x RPM = Vf
e.g.: 0.22 x 2 x 1908 = 839.5

Legend
318 = Constant (1000 ÷ n)
m/min = Surface speed
Ø = dia. of cutter/work piece
Fz = Feed per tooth
Z = Number of teeth
Vf = Table feed in mm/min

Length

1 cm	=	0.3937 in	1 inch	=	25.4 mm
1 m	=	3.2808 ft	1 foot	=	0.3048 m
1 km	=	0.6214 mile	1 mile	=	1.6093 km

Weight

1 gram	=	0.0353 oz	1 oz	=	28.35 g
1 kg	=	2.20460 lb	1 lb	=	0.4536 kg
1 tonne	=	0.9842 ton	1 ton	=	1.016 tonne

Area

1 m	=	1.196 yard	1 in	=	645.2 mm
1 hectare	=	2.471 acre	1 yard	=	0.8361 m
			1 acre	=	0.4047 hectare
			1 sq mile	=	259 hectare

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Conversion factors

Capacity

1 cm	=	0.061 in	1 in	=	16.387 cm
1 m	=	1.308 yard	1 yard	=	0.7646 m
1 litre	=	1.761 pints	1 pint	=	0.57 litre
1 liter	=	0.22 gallons	1 gallon	=	4.5461 litre

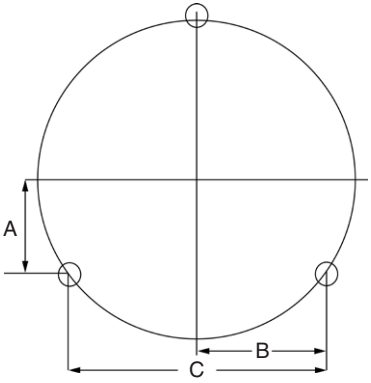
Velocity

1 km/h	=	0.6215 mile/h	1 mile/h	=	1.609 km/h
1 m/s	=	3.2808 ft/s	1 ft/s	=	0.3048 m/s

Holes in jig boring

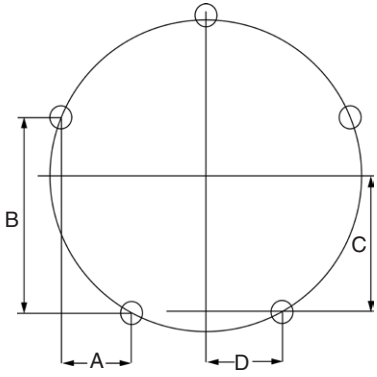
Co-ordinates for locating equally spaced holes in jig boring

Multiply values shown by diameter of pitch circle



3 Hole

A = 0.25000
B = 0.43301
C = 0.86603



5 Hole

A = 0.18164
B = 0.55902
C = 0.40451
D = 0.29389

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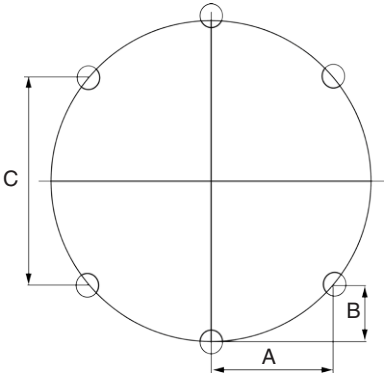
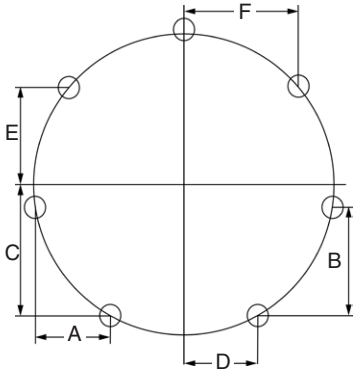
Holes in jig boring

Multiply values shown by diameter of pitch circle



6 Hole

A = 0.43301
B = 0.25000
C = 0.50000



7 Hole

A = 0.27052
B = 0.33922
C = 0.45049
D = 0.21694
E = 0.31175
F = 0.39092

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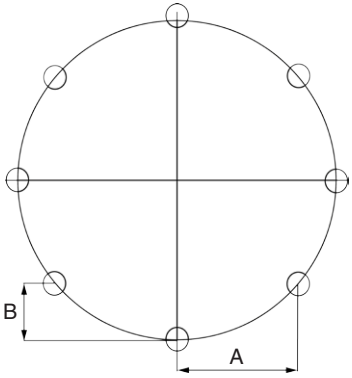
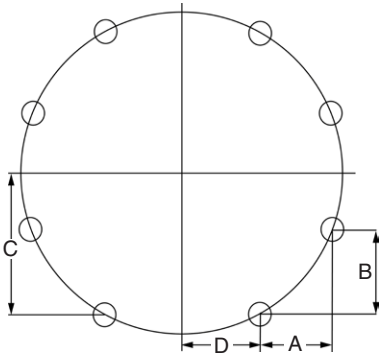
Holes in jig boring

Multiply values shown by diameter of pitch circle



8 Hole

A = 0.35355
B = 0.14645



8 Hole

A = 0.27059
B = 0.27059
C = 0.46194
D = 0.19134

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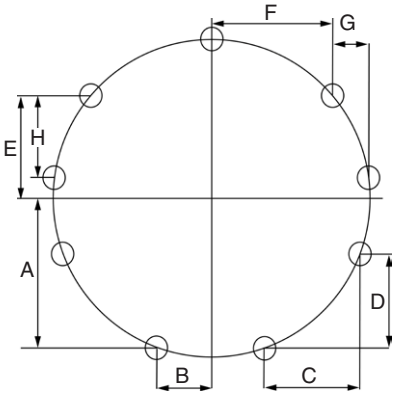
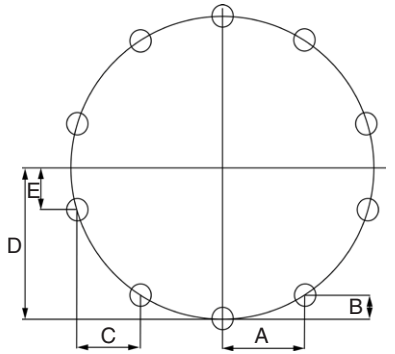
Holes in jig boring

Multiply values shown by diameter of pitch circle



9 Hole

A = 0.46985
B = 0.17101
C = 0.26201
D = 0.21985
E = 0.38302
F = 0.32139
G = 0.17101
H = 0.29620



10 Hole

A = 0.29389
B = 0.09549
C = 0.18165
D = 0.25000
E = 0.15451

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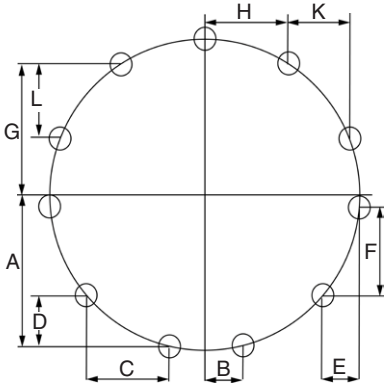
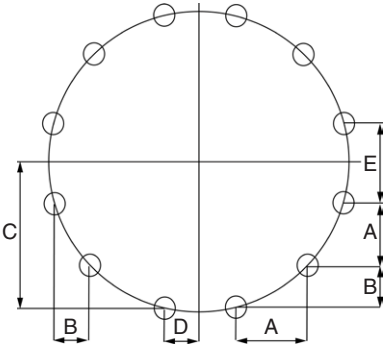
Holes in jig boring

Multiply values shown by diameter of pitch circle



11 Hole

A = 0.47975
B = 0.14087
C = 0.23700
D = 0.15231
E = 0.11704
F = 0.25627
G = 0.42063
H = 0.27032
K = 0.18449
L = 0.21291



12 Hole

A = 0.22415
B = 0.12941
C = 0.48296
D = 0.12941
E = 0.25882

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Notes

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Notes

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