1. General

- Technological data
- Finding the Chip Removal Values, Speeds
- Mounting the Tools
- Clamping the Workpieces

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Technical Data

Working area:
X .... 7.87" (200 mm)
Y .... 3.94" (100 mm)
Z .... 7.87" (200 mm)
Milling head swivel .... 90°

Milling table:
Size .... 16.54" x 4.92" (420 x 125 mm)
Number of T-slots 2
Width/distance of T-slots .... .43"/3.54" (11/90 mm)

Distance table - milling head:
Vertically .... .98"-8.86" (25-225 mm)
Horizontally .... 3.15"-11.02" (80-280 mm)

Throat .... 5.51" (140 mm)

Milling spindle:
Tool mounting ANSI B5-50-1978 .... # 30 Taper
Tool clamping .... Quick action system

Drive of milling spindle:
DC motor .... .6 hp 440 W (S1 - 100% ID)
Speed range infinitely variable .... 300-2000 rpm

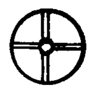
Drive of feed motors:
Step motor - single drive + ball bearing screw
Feed - manual operation .... .20" - 15.75"/min (5-400 mm/min)
Feed - CNC-operation .... .08 - 19.65"/min (2-499 mm/min)
Rapid feed .... 23.62"/min (600 mm/min)
Single step (tip operation) .... 0004" (0.01 mm)
Feed power .... 225 lbs

Weight of milling machine .... 264 lbs (120 kg)
Weight of control unit .... 88 lbs (40 kg)
Size of machine *(width x depth x height)*. 33"/30"/28" (840/750/720 mm)
Size of control unit .... 28"/18"/21" (710/450/540 mm)

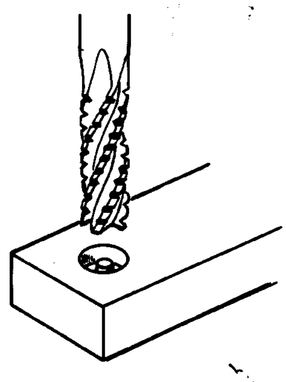
Electrical connection .... 115 Vac

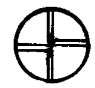
End mills shown are calle "roughing" end mills. Most end mills will have smooth sides. The rough sides act as chip breakers. This is only important for high speed/ high volume milling.

General tips on milling

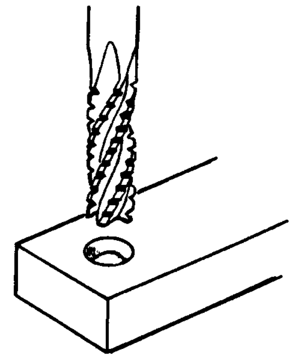


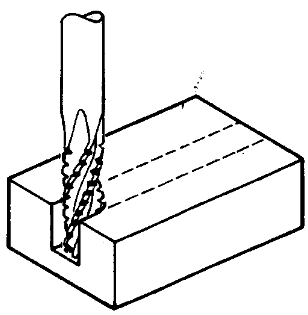
Regular end mill

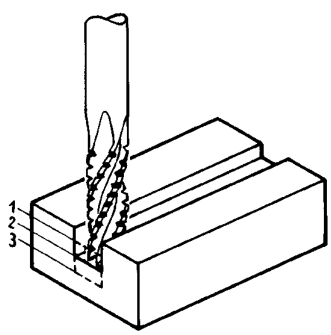




Center cut end mill







Most milling cutters are designed for peripheral work or slot cutting where the cutter is fed in from outside the workpiece edge. They are not designed for feeding into the workpiece from above to make a starting hole. When feeding into a workpiece from above you should always use a center cutting end mill. **Feedrate for this operation should be no more than half that used for normal milling.**

When depth of cut and feedrate are too great the milling cutter may bend, causing a danger of breakage. This is especially true with small diameter end mills and when slotting.

Deep slots should be finished with a series of light cuts with progressively greater depths. Because of the greater force required when slotting, feedrates and speeds should be reduced by 30 % from those used for normal edge milling.

When using end mills of 1/4" diameter or smaller it is a good idea to start with light cuts and conservative feedrates to minimize the hazard of tool breakage. This is especially important when working with an unknown material.

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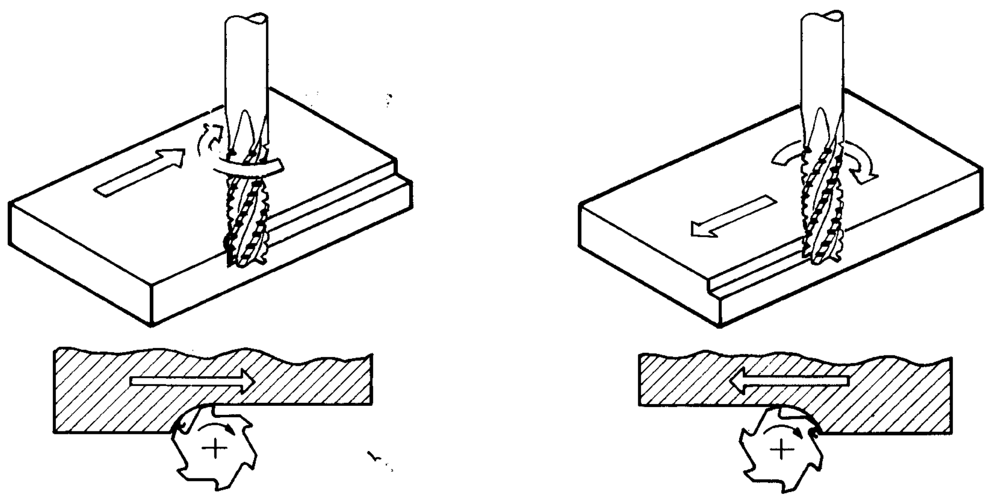
Climb Milling (downcut milling) vs. Conventional Milling (up-milling)



For many years it was common practice to do up-milling (known as conventional milling) in which the cutting direction goes against the direction of feed. This was popular because most older machines were not fitted with ballscrews and backlash eliminating devices. On more modern NC-machines many people prefer downcut or "climb" milling, where the cutting direction is the same as the feed direction. In climb milling the cutter enters the workpiece with a full chip load that thins out toward the end of the cut. This tends to dissipate heat into the chips rather than the workpiece, and also tends to push the piece into the table creating a greater load. Generally, it makes little difference which method is used on the F1-CNC, except with very small cutters or this sections where conventional up-milling may be preferred.

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Calculations used in milling

1. Cutting speed:

V = .262 x D x RPM where

v = cutting speed in ft/min.

D = cutter diameter in inches

The optimum cutting speed depends on the tool and material being cut. Some suggested speeds with HSS:

Aluminium (2011,2024,7075)	-	450-500 ft/min
Free machining brass	-	250-300 ft/min
Plastics	-	300-400 ft/min
Low carbon steel	-	115 ft/min
Med. carbon & alloy steel	-	80 ft/min

2. Spindle speed:

$$RPM = \frac{3.82 \times V}{D} \quad \text{where}$$

V = desired cutting speed in ft/min

D = cutter diameter in inches

3. Feed per tooth:

$$f_t = \frac{fm}{n \times RPM} \quad \text{where}$$

f_t = feed per tooth

f_n = feedrate in inches/min

n = number of teeth on cutter

Some suggested feeds per tooth, taken from various reference manuals (3/8-3/4" dia. cutters):

Aluminium	-	.003"-.004"
Free machining brass	-	.001"-.002"
Plastics	-	.003"-.004"
Steel	-	.001"-.002"

These feeds are suggested optimum rates. However, they may not be attainable with small diameter cutters because of their limited strength. The higher the feedrate the more force is exerted against the cutter, causing it to bend. With small end mills it is better to start slow and gradually increase feeds till you find a safe limit.

4. Cutting horsepower at spindle:

HP = d x D x fm x P where

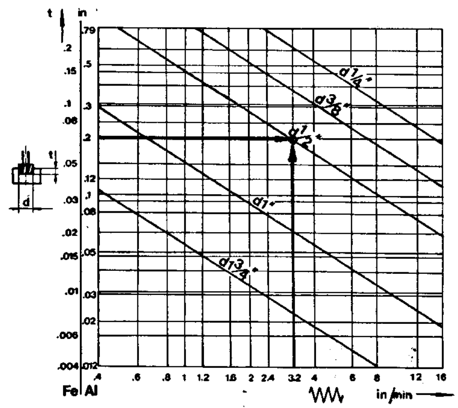
HP = required horsepower
d = depth of cut in inches
D = cutter diameter
fm = feed per minute
P = unit power factor. $HP/In^3/min$

The power required to cut various types of material is often expressed as a Unit Power Factor, in terms of horsepower, required to remove material at the rate of one cubic inch per minute. Unit power factors for milling some common material are:

Aluminium alloys	- .32-.40
Brass	- .64-.80
Low carbon steel	- 1.1-1.4
Medium carbon & alloy steel	- 1.5-2.0
Cast iron	- .6-1.4

Unit power factor can vary depending on the hardness of the material. There are also many other factors which can effect the power and performance in machining operations. Among these are cutter sharpness, lubricants, various material properties, machine drive efficiency, motor torque characteristics, and machine rigidity to mention a few.
While it may be impossible to find the perfect combination without trial and error experiments, the above formulas and figures can be used for estimating starting values.

The following charts can also be used as a guide to starting feeds and speeds for the F1-CNC. To truly optimize programs you will have to experiment a little with your own tools and material.



Procedure

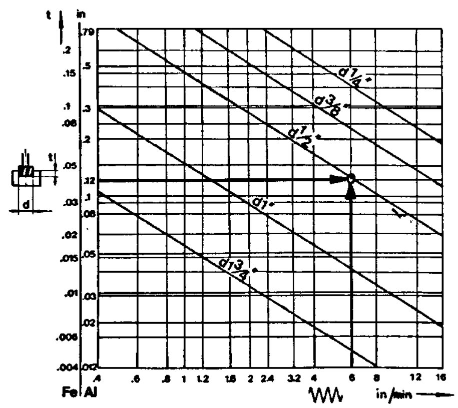
The technological data are written into the tool specification sheet.

Finding the feed rate and the depth of cut:

Material: aluminium

① Depth of cut (t = .2″)	② Dia. of milling cutter (d= 1/2″)

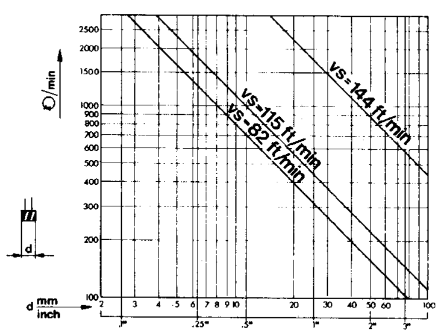
→ F = 3.2 in/min



You can also proceed in a different way:

① Feed rate F =6 in/min	② Dia. of milling cutter (1/2″)

→ Depth of cut .12″



Finding the speed of rotations:

$\boxed{d}$ Diameter of milling cutter

↓

$\boxed{V_s}$ Correct cutting speed for the specific material

↓

$\boxed{S}$ Spindle speed

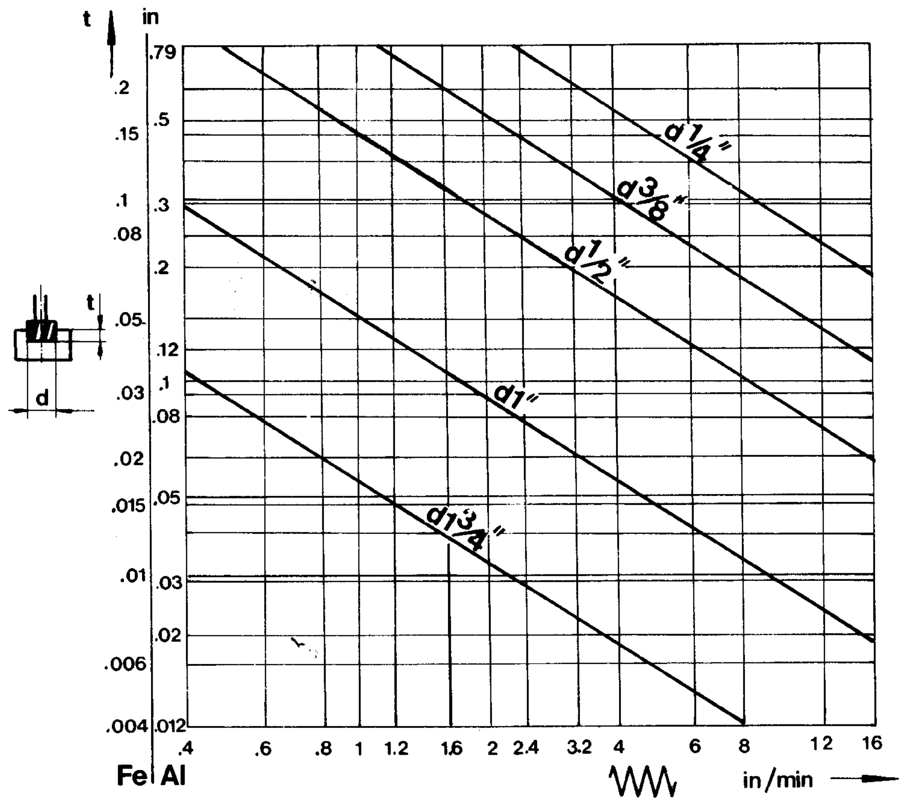
The same procedure applies for drilling.

PS: Downcut milling - Conventional Milling

The specific knowledge is presupposed. However, with the F1-CNC the differences may be neglected.

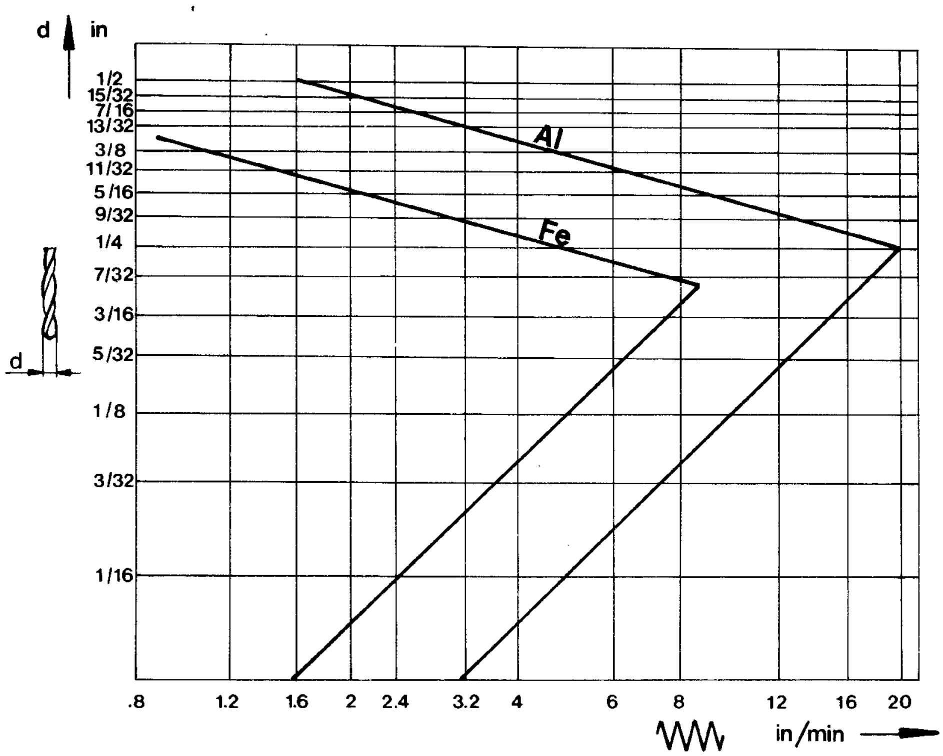
Milling

Depth of cut · Cutter diameter · Feed

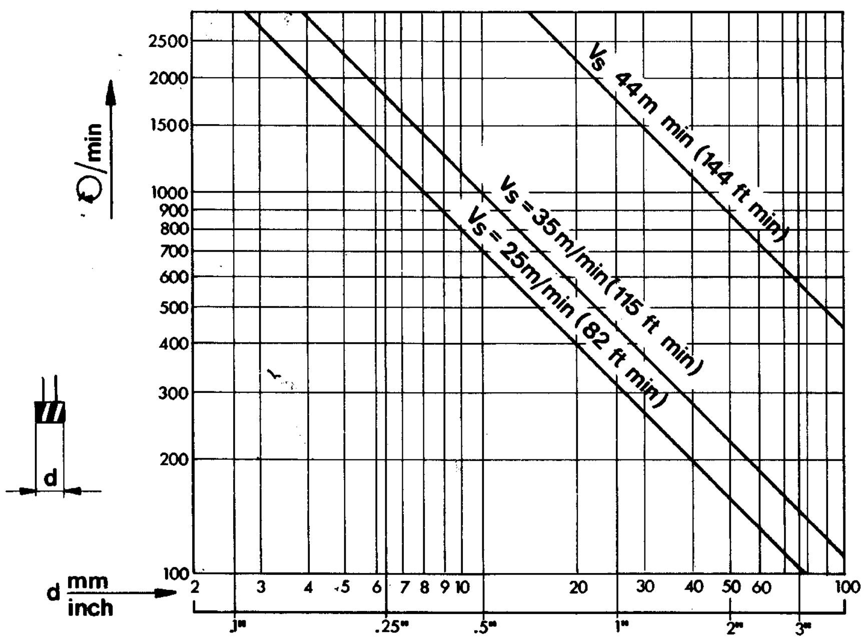


Drilling

Diameter of drill bit · Feed



Speed (of rotation) — Cutting speed — Feed



Attention:

When plunging in with cutter, halve feed values of mill chart.

Service and Maintenance of Machine

Lubrication:

Lubricate guideways of longitudinal, cross and vertical slide daily using oil gun (1 nipple on vertical slide, 2 nipples left side underneath longitudinal slide).

Pressure resistant, corrosion-protective oil with slip-stick reducing characteristics.
2.87"/sec (cSt) reference temperature 40° C.

E.g. CASTROL MAGNA BD 68
This corresponds to the CINCINNATI Specification P47.

Spindle taper for tool mounting

Interior taper of main spindle and tool taper have to be free of grease and dust. They should also be wiped down regularly with a light oil to prevent surface rust.
When not in use toolholders should be removed from the spindle and stored in the proper storage slots.

Safety measures

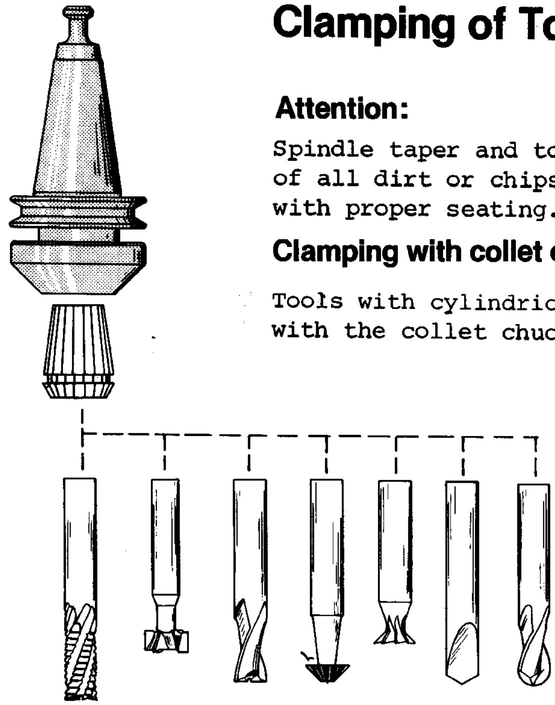
Pay attention to all rules of general shop safety and particularly those for milling. Remember, you are the most important ingredient in safe machining.

Raw material

When using aluminium, choose free machining grades such as 2011, 2017, 2024 or 7075. Generally, the harder tempers will produce finer chips and better finish quality than soft annealled varieties.

Tools

Use of good quality high speed steel cutting tools is recommended on the F1-CNC. Regular end mills, drills, etc. may be used, also special cutters may provide better results on certain non-ferrous materials. In any case, well sharpened cutting tools will give the best results.



Clamping of Tools

Attention:

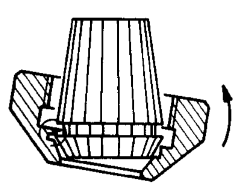
Spindle taper and tool taper must be free of all dirt or chips that would interfere with proper seating.

Clamping with collet chuck

Tools with cylindrical shaft are clamped with the collet chuck.

Note:

- Put collet into nut inclined so that the eccentric ring grips the groove of the collet. Screw nut with collet onto collet chuck.



Clamping of tools

Put tool into collet and tighten nut with cylindrical pin in clockwise direction. For counter-holding of main spindle put cylindrical pin into collet holder.

Taking out the collet:

Unscrew nut. The eccentric ring in the nut presses the collet out when unscrewing.

Maintenance

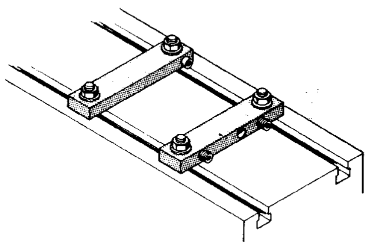
Use oil and clean collet and collet chuck after use. Chips and dirt can damage the tapers and influence the precision.

Collets

You find the clamping capacity in inch and metric engraved on the collets. Diameters smaller or larger than indicated must not be clamped.

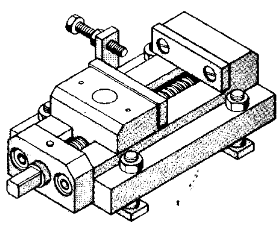
FPC has these items and a small milling vise for the EMCO F1

Clamping Possibilities for Workpieces



Clamping bars

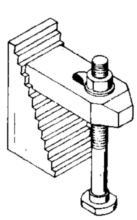
The clamping bars are mounted directly onto the slide depending on the relative workpiece.



Machine vice with stop

Width of jaw: 2.36″

Clamping capacity: 2.36″



Stepped clamping shoe

Height: 2.36″

For clamping a workpiece you need at least two clamping shoes.

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FPC does not have the adapters shown

3-jaw chuck (2× 3 Jaws)

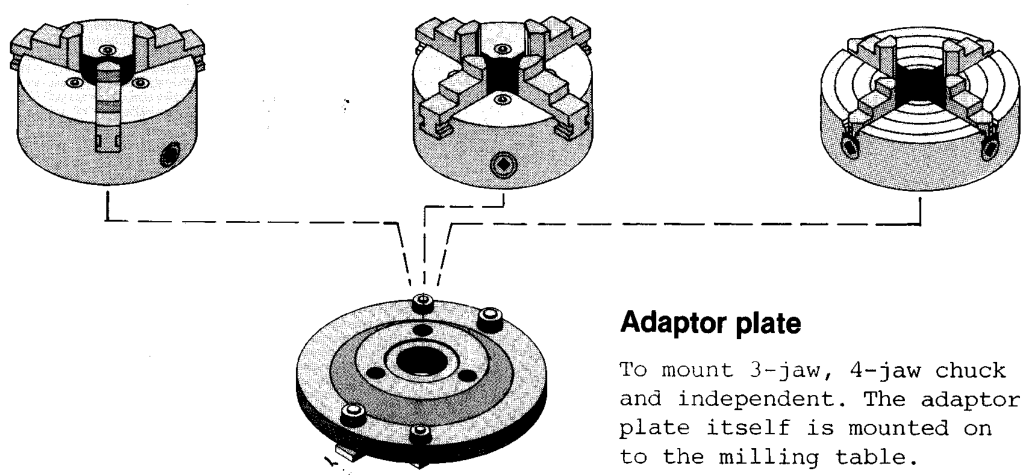
For holding of round, triangular and hexagonal workpieces centrically.

4-jaw chuck (2 × 4 jaws)

For holding of round, square and octogonal workpieces centrically.

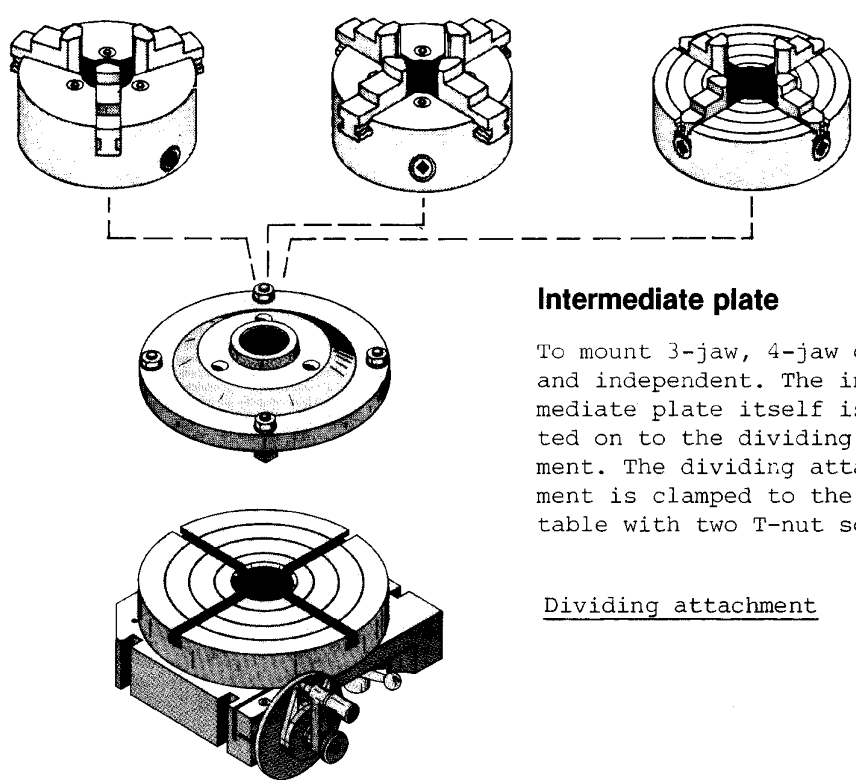
4-jaw independed chuck

For holding of workpieces centrically and eccentrically.



Adaptor plate

To mount 3-jaw, 4-jaw chuck and independent. The adaptor plate itself is mounted on to the milling table.



Intermediate plate

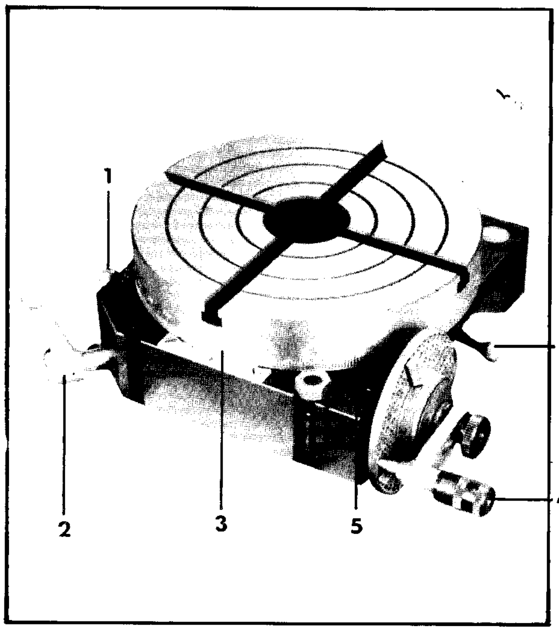
To mount 3-jaw, 4-jaw chuck and independent. The intermediate plate itself is mounted on to the dividing atachment. The dividing attachment is clamped to the milling table with two T-nut screws.

Dividing attachment

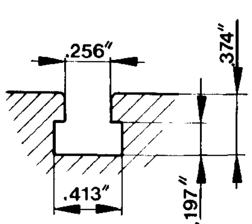
The Dividing Attachment

Operating tips

FPC does not have the dividing head shown. A small PRC unit is available from Harbor Freight for about 100$. Larger American European made units suitable for the Bridgeport can cost as much as 5-6,000$



T-slots of the dividing attachment



TECHNICAL DATA

Diameter of rotary table: 6"

Worm reduction: 1:40

T-slots according to factory standard

Number of holes in dividing plates:
27,33,34,36,38,39,40,42

OPERATING ELEMENTS

Clamping levers for rotary table (1):

Clamping levers are loosened during the dividing operation itself, but must be clamped before every machining operation.

Indexing pin with handle (2):

During direct dividing from 15^{o} to 15^{o}, the pin rests into the parameter notches of the rotary table. During indirect dividing (worm dividing) or free dividing by means of the graduated scale, the indexing pin must be pulled out and swivelled to the left.

The graduated scale (3) is for controlling the divisions.

Crank handle with index plunger (4) moves the worm which is engaged with the wormwheel of the rotary table during indirect dividing.

The shears serve to facilitate adding the number of holes when a fraction of a turn is to be added.

Disengaging and engaging the worm:

The allen head screw (5) is loosened. When the dividing plate is turned counterclockwise, the worm and wormwheel are disengaged. The rotary table can be turned by hand for direct indexing. By turning the dividing plate clockwise, worm and wormwheel are engaged. To facilitate engagement of worm and wormwheel, the rotary table should be moved slightly by hand.
The allen head screw (5) must again be retightened.

Types of Dividing

Indirect dividing:

Indirect dividing offers many more dividing possibilities and is more accurate because of the worm reduction of 1:40.

Indirect dividing method:

If the crank handle is turned 40 times, the rotary table makes 1 revolution (360°). With help of the dividing plates, exact fractions of turns can be executed.

Direct dividing:

Worm and wormwheel are disengaged.

Possibility 1:

Dividing by means of the indexing pin. Dividing possibility from 15° to 15° (i.e., maximum of 24 divisions within 360°).

Possibility 2:

The dividing can be done freely with the aid of the graduated scale on the rotary table.

Note

With indirect dividing the indexing pin is always disengaged. For manufacturing a workpiece the rotary table has to be fixed.

The indexing chart:

1st column: indicates number of divisions per 360°

2nd column: shows the corresponding angle of the division

3rd column: shows the number of 360° crank handle revolutions which are necessary

4th column: shows the number of holes to be added for each index plate

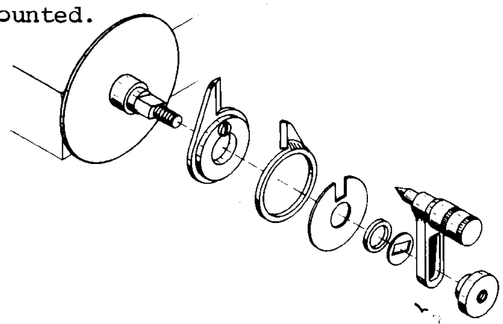
Example of an indirect dividing operation:

Desired division: 13 divisions in 360°

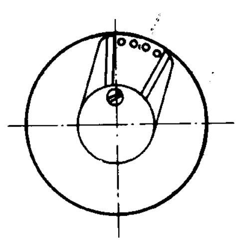
From the indexing table it can be seen that at the desired division 13, 3 full crank turns must be made plus a fraction turn of 3 additionsl holes on the indexing plate 39.

Practical execution:

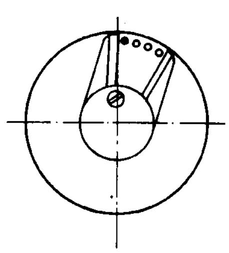
1. The indexing plate with 39 holes is mounted.



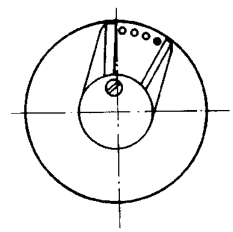
2. in the indexing table one sees that at the division 13, 3 full turns plus 3 holes on the 39 plate have to be added.. Therefore, the shears are fixed so that they include 4 holes.



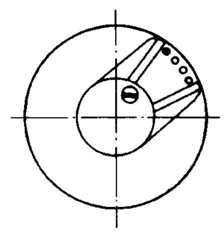
3. The indexing plunger is placed in a hole of the 39 plate (marked black on the drawing) and the left shear arm moved until it touches the pin of the plunger.



4. Execution of the dividing operation: 3 full turns plus the fractional turn of the 3 added holes are made; that means that the plunger is placed in the black hole. One dividing operation is completed.



5. Next dividing operation: The shears are turned until the left arm touches the pin again; the next dividing operation follows as described in 4. above.



NOTE: The shears may not be moved during the dividing operation, otherwise they do not serve their purpose as an orientation aid.

NOTE: If a larger number of holes has to be reached than the maximum opening of the shears allow, you have to set the difference of holes between the shears.

Example

21 divisions per 360° have to be carried through. From the chart one can see that one full turn plus the fractional turn of 38 holes on the disc 42 have to be carried through. 38 holes cannot be set.

Thus: 42-38=4 holes. When dividing you make one additional turn (2 turn alltogether) and turn back the difference of 4 holes (the shears comprise 5 holes).

INDEX TABLE	Formula for the Calculation of the Hole Numbers Required
	z = No. of divisions required for one revolution of the workpiece.
	K = No. of revolutions of handle for a complete revolution of the workpiece.
	n = No. of revolutions of handle for one dividing move: $n = \frac{K}{z}$
	Worm reduction of dividing head 1:40; i. e. K = 40.

Division Desired	Degrees	No. of crank turns req'd	Amount of holes to be added for each index plate							
			27	33	34	36	38	39	40	42
2	180°	20								
	175°	19	12							
	170°	18	24							
	160°	17	21							
	150°	16	18							
	140°	15	15							
	130°	14	12							
	125°	13	24							
3	120°	13	9	11		12		13		14
	110°	12	6							
	100°	11	3							
4	90°	10								
	80°	8	24							
	75°	8	9	11		12		13		14
5	72°	8								
	70°	7	21							
	65°	7	6							
6	60°	6	18	22		24		26		28
	55°	6	3							
7		5								30
	50°	5	15							
8	45°	5								
9	40°	4	12			16				
10	36°	4								
11		3		21						
12	30°	3	9	11		12		13		14
13		3						3		
14		2								36
	25°	2	21							
15	24°	2	18	22		24		26		28
16		2			17	18	19		20	21
17		2			12					
18	20°	2	6			8				
19		2					4			
20	18°	2								
	16°	1	21							
21		1								38
22		1		27						
24	15°	1	18	22		24		26		28
25		1							24	
26		1						21		
27		1	13							
28		1								18
30	12°	1	9	11		12		13		14

Division Desired	Degrees	No. of crank turns req'd	Amount of holes to be added for each index plate							
			27	33	34	36	38	39	40	42
32		1				9			10	
33		1		7						
34		1			6					
35		1								6
36	10°	1	3			4				
38		1					2			
39		1						1		
40	9°	1								
42										40
44				30						
45	8°		24			32				
48						30				35
50									32	
	7°		21			28				
52								30		
54			20							
55				24						
56										30
60	6°		18							
64									25	
65								24		
66				20						
68					20					
70										24
72	5°		15			20				
76							20			
78								20		
80					17	18	19		20	21
84										20
85					16					
88				15						
90	4°		12			16				
95							16			
96						15				
100									16	
120	3°		9	11		12		13		14
180	2°		6			8				
200									8	
240						6				7
270			4							
360	1°		3							
	40′		2							
	30′					2				
	20′		1							

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