YC-1½VA & VS-T
OPERATOR MANUAL

TITAN Series

SUPERMAX®

IMPORTANT

Attention is drawn to the requirement of the Health and Safety at Work Act, should always be operated to conform with the appropriate regulations.
Other safety precautions are discussed in the American National Standards Institute Standard entitled Safety Requirements for the Construction, Care, and Use of Drilling, Milling, and Boring Machines (ANSI BLL 8-1974).
To assist machine users in designing point of operation safeguarding for their specific machine applications. the Occupational Safety and Health Administration has published a booklet entitled Concepts and Techniques of Machine Safeguarding (O.S.H.A. Publication Number 1910 212).
General precautions for safe operation.

The general precautions to safety operate this machine are described below to supplement the operation technique and safety precautions explained by our engineer or dealer when the machine is installed. Our products are well designed to ensure the safety of all machine sections.

If the machine is used improperly, however, a serious accident may occur. The basic safety precautions are described below.

(1)Safeguarding for protection at the point of operation can only be designed and constructed when the parameters of the particular operation have been determined. As a result ANSI BLL 8-1974.

(2)The machine should be operated by a trained operator familiar with the machine. Operators not familiar with the machine should be trained before operating the machine.

(3)The operator should not come close to touch or bring an object close to any rotation or moving part.

*Carefully read the manuals listed below to fully understand their contents.
*For safety and correction operation to read this manual before operating this machine is strongly requested!

DO NOT OPERATE
WITHOUT
EYE PROTECTION

DO NOT OPERATE
WITHOUT GUARDS

CAUTION

KEEP HANDS OUT
OF MACHINE

CAUTION

DISCONNECT
POWER BEFORE
SERVICING

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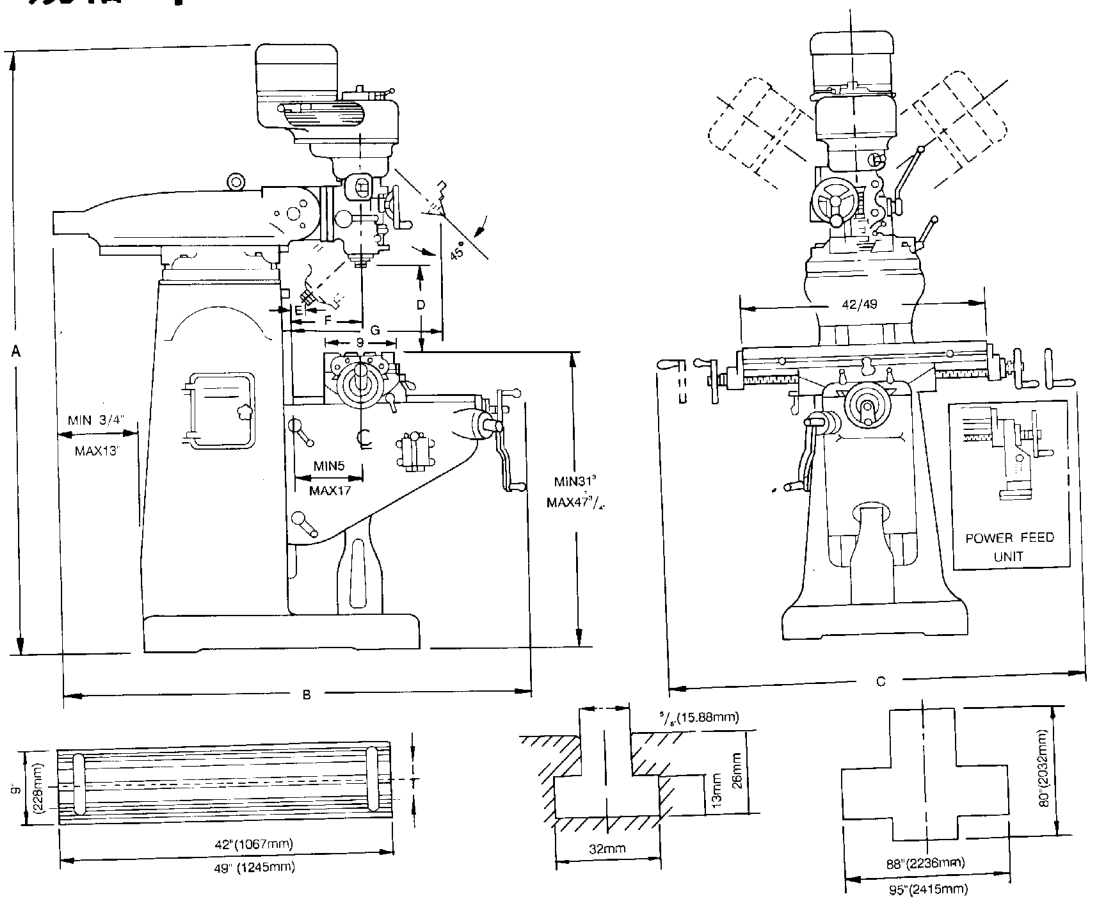
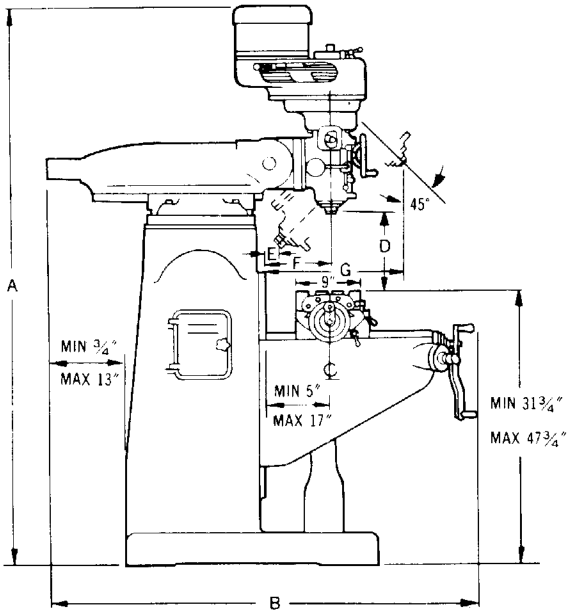
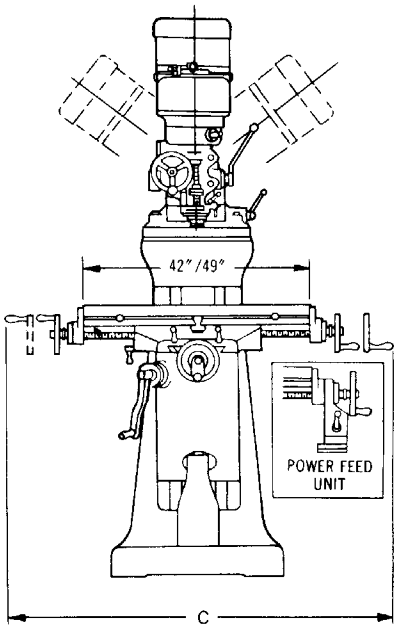


機體規格Specification of basic machine

項目	Item	INCHES(")		METRIC(mm)	
工作台長度	Table length	42	49	1067	1245
工作台左右手動進給行程	Longitudinal traverse(Manual)	29 21/64	34 37/64	745	878
工作台左右自動進給行程	Longitudinal traverse(Power feed)	26 3/16	31 7/16	665	793
工作台前後進給行程	Cross traverse	12		305	
工作台上下進給行程	Vertical traverse	16		406	
工作台T型槽數	Number of Tee slots	3			
T型槽寬度和槽間距離	T-slot Width and Centres	5/8 "at 2½ "		15.88 at 63.5	
伸出臂移動行程	Ram movement	12		305	
主軸轉數(段)	Spindle speeds Number	3			
主軸轉速範圍(轉/每分)	Spindle speeds Range r.p.m.	80～2720 r.p.m.			
主軸一迴轉之上下進給量	Qull feeds , per Rev. of spindle	0017 · 0032 · 0053		04 · 08 · 13	
電動機馬力	Motor H.P.	2			
A.全高	Overall height	80½		2045	
B.全長(前後)	Overall depth	63¾		1620	
C.全寬(左右)	Overall width	87¾	94¾	2230	2408
D.工作台面至主軸端面距離(最小～最大)	Table to spindle gage line(min～max)	0～18⅜		0～466	
E.頭部內傾45°與機身滑動面之距離(最小～最大)	Head 45° inward(min～max)	0～11¼		0～285	
F.頭部正90°與機身滑動面之距離(最小～最大)	Head 90° (min～max)	6¾～19		171～482	
G.頭部外仰45°與機身滑動面之距離(最小～最大)	Head 45° out ward(min～max)	9～21		228～533	
佔地面積	Floor area occupied	88(95)×80		2236×(2415)×2032	
裝箱體積	Case space occupied	55½×58×76		1410×1473×1930	
機械淨重	Net weight	2194 lb	2223 lb	950kg	1010kg
裝箱重置	Gross weight	2972 lb	3001 lb	1350kg	1363kg

1 1/2 VS—T 規格 Specification





規　格 SPECIFICATIONS

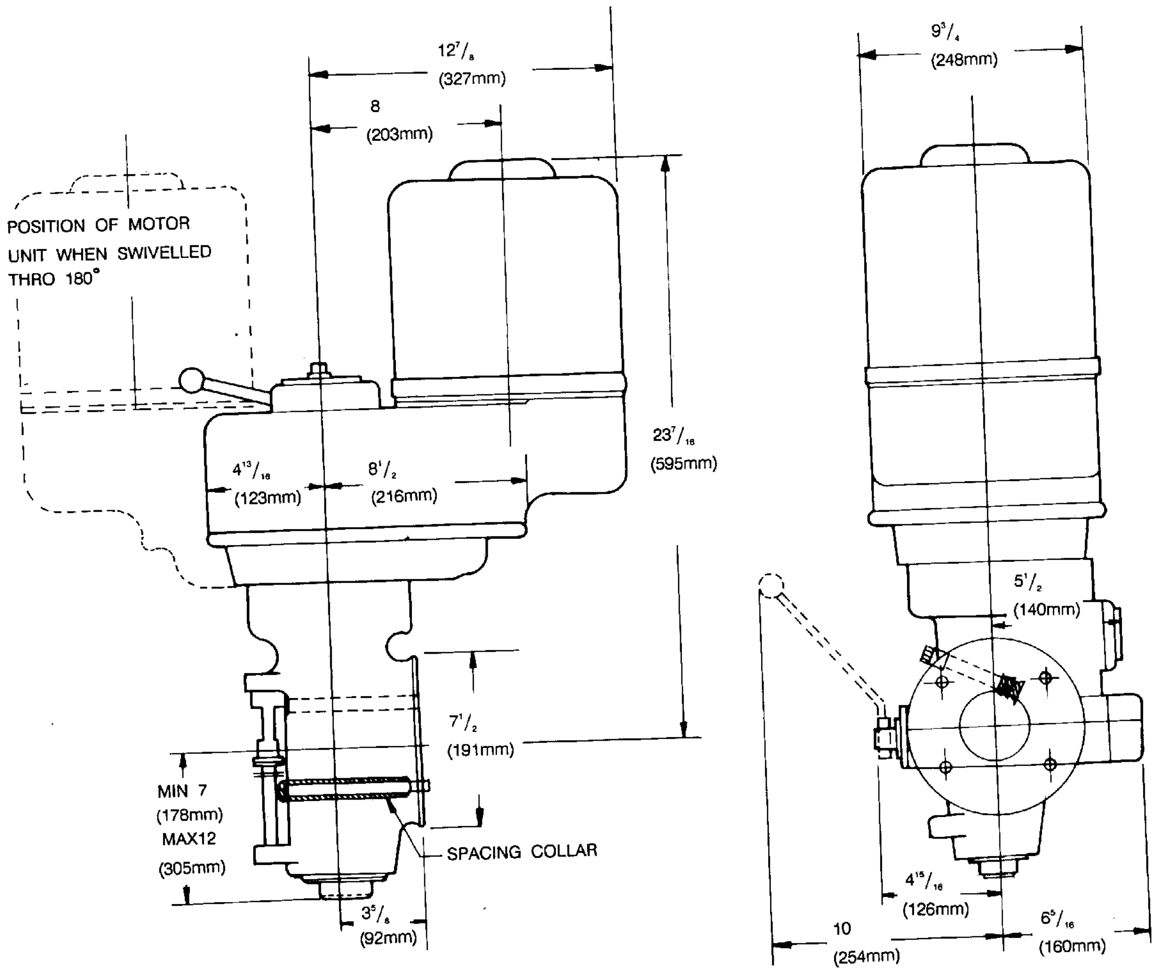
項　目 ITEM		IN		MM	
工作台長度 Table length		42	49	1067	1245
工作台左右進給行程 Longitudinal travel(X)		29 21/64	34 31/64	745	878
工作台左右進給行程(附自動進給裝置) Longitudinal travel (with power feed unit)		26 3/16	31 7/16	665	798
工作台前後進給行程 Cross travel(Y)		12	12	305	305
工作台上下進給行程 Vertical travel of knee(Z)		16	16	406	406
A.全　高 A. Overall height		80 1/2	80 1/2	2045	2045
B,全長(前後) B.Overall depth		63 3/4	63 3/4	1620	1620
C.全寬(左右) C.Overall width		87 3/4	94 3/4	2230	2408
D.工作台面至主軸端面距離(最小～最大) D. Spindle nose to table	min	0	0	0	0
	max	17 9/16	17 9/16	446	446
E.頭部內傾45°與機身滑動面之距離(最小～最大) E. Head 45° inward	min	0	0	0	0
	max	11 1/4	11 1/4	285	285
F.頭部正90°與機身滑動面之距離(最小～最大) F.Head 90°	min	6 3/4	6 3/5	171	171
	max	19	19	482	482
G.頭部外仰45°與機身滑動面之距離(最小～最大) G.Head 45° outward	min	9	9	228	228
	max	21	21	533	533
Net weight:		1912 lb	2032 lb	956kg	1016kg

Spindle speeds—80 135 210 325 660 1115 1750 2720 (R.P.M.) (60Hz)
Power feed per spindle revolution—.0017" .0032" 0053" (.04 .08 .13mm)
Special Accessories: Coolant System
Power Longitudinal Feed

Spindle taper- R-8 or N.S.T. #30
Quill travel- 5" (127mm)
Motor- 2HP

※ We reserve the right to modify and improve our products.

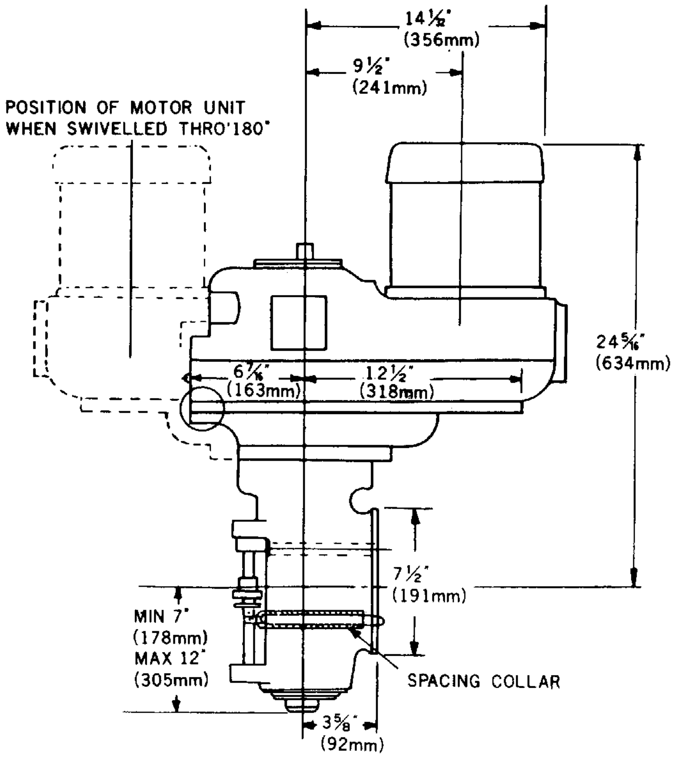
1 ½ VA—T 規格 Specification

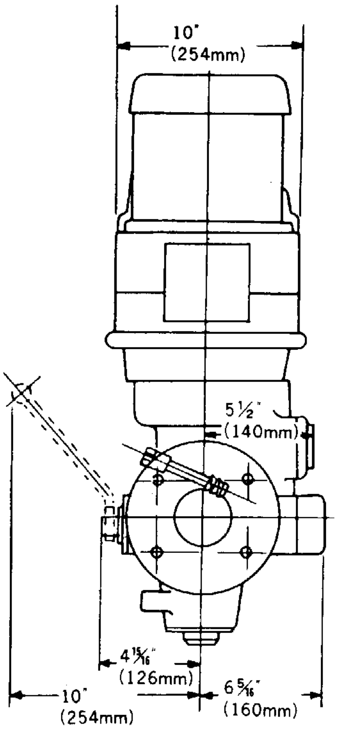


頭部規格 Specification of head

主軸迴轉數（轉／每分）Spindle speeds R.P.M(60 cycles)80,135,210,325,660,1115,1750,2720
主軸一迴轉之自動進給量 Power feed per spmdle revolution .0017" .0032" .0053" (.04 .08 .13mm)
主軸端孔斜度 Spindle taper-R 8 or N. S. T. #30
主軸昇降套之進給行程 Quill travel-5" (127mm)
夾持範圍 Collet capacity1/8" to 3/4"(3mm-19mm)
馬達馬力數 H.P. of Motor. 2
重　量 Weight-183 lbs. (83 kgs.)

1 1/2 VS—T 規格 Specification



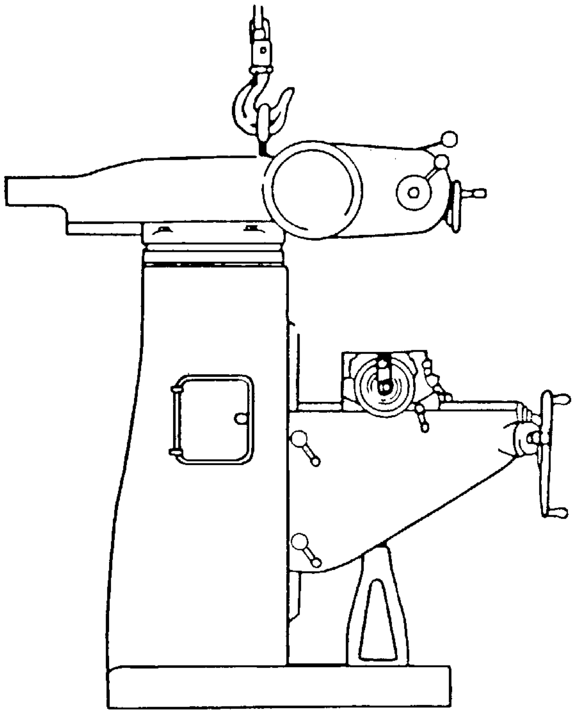


頭部規格 Specification of head

主軸迴轉數(無段)(轉/每分) Spindle speeds R.P.M.(60 cycles)60～4200 (Infinitely variable)
主軸一迴轉之自動進給量 Power feed per spindle revolution .0017" .0032" .0053" (.04 .08 .13mm)
主軸端孔斜度 Spindle taper R 8 or N. S. T. #30
主軸昇降套之進給行程 Quill travel-5" (127mm)
夾持範圍 Collet capacity-1/8" to 3/4" (3mm-19mm)
馬達馬力數 H. P. of Motor -2
重　量 Weight-196 lbs.(89kgs)

本機重量約為 2200 lbs.(997kgs)

This machine weight approximately 2200 lb (997kgs)

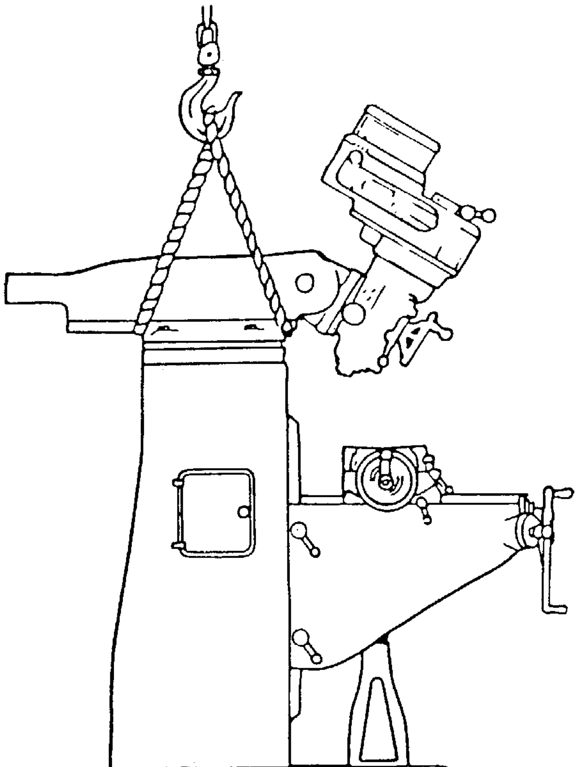


方法 1

如左圖所示：在吊起機器之前，先將頭部迴轉並固定，然後用 5/8" 惠氏螺紋之吊環將其確實鎖牢於伸出臂之螺紋孔內再行吊動。

METHOD 1

Insert 5/8"—11NC eye bolt in tapped hole. Ensure bolt is fully secured before lifting. It is advisable to swivel head before lifting machine.



方法 2

如左圖所示：在吊起機器之前，先將頭部前傾並固定，然後掛上適當的繩索，並在繩與機器接觸處墊上軟布墊，再行吊動。

METHOD 2

Use rope sling as illustrated. Insert pads of soft cloth between rope and machined edges. It is advisable to tilt the head before lifting machine.

1½ VA–T 1½ VS–T 安裝 Installation

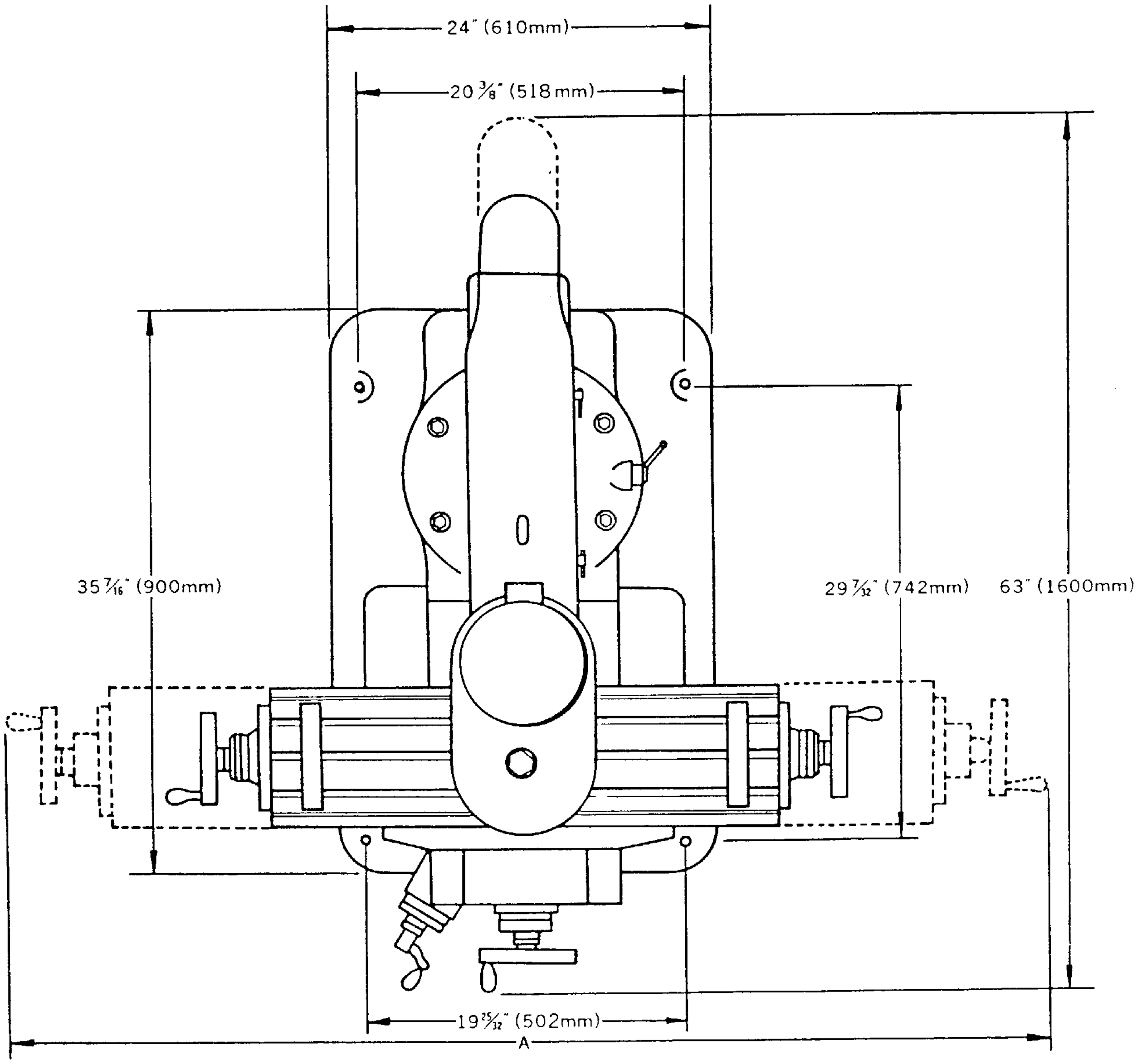
1. 移動任一滑道前先除去防銹劑
1. Remove rust preventative before moving any slideways.

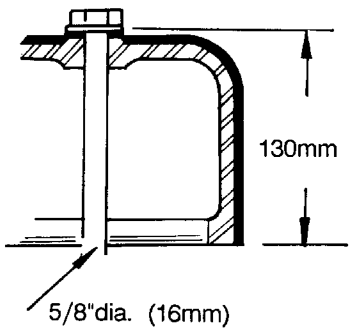
2. 防護層最好以清潔刷沾石腊油除去之，當護層軟化後以清潔破布擦乾淨。
2. The coating is best removed by using paraffin applied with a clean brush. When the coating has softened, remove with clean rags.

3. 以油或黃油潤滑潤滑點，參考此說明書的潤滑部份。
3. Oil or grease all lubrication points. Refer to the lubrication section of this manual P.29 To P.32.

機器之清潔 Cleaning

1 1/2 VA—T 1 1/2 VS—T 安裝 Installation



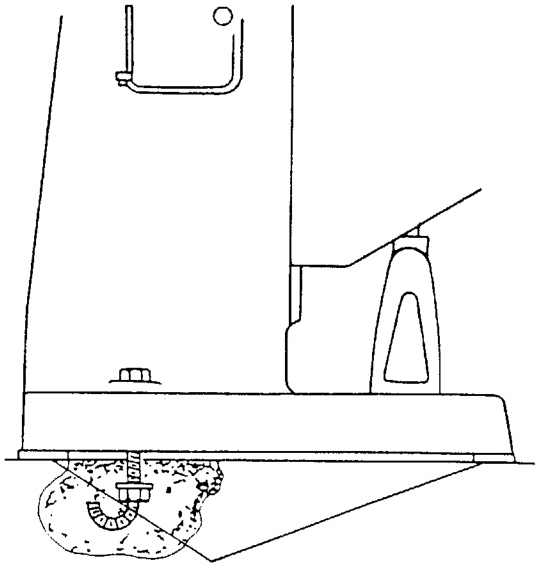


'A'尺寸 'A' DIMENSION

工作台大小 Table size	機器長度 Plain machine
42"	87¾" (2230mm)
49"	94¾" (2408mm)

場地佈置圖 Floor Plan

$1\frac{1}{2}$ VA–T　$1\frac{1}{2}$ VS–T 安裝 Installation



地　基
FOUNDATION

所有銑床應以螺栓鎖於一混凝土地基　本機器應安裝於固體水平地板或防振墊片上以防止任何震動所產生的移動。

Ideally all milling machines should be bolted to a concrete foundation. The machines however should be placed on a solid level floor or anti–vibration pads to prevent any rocking movement.

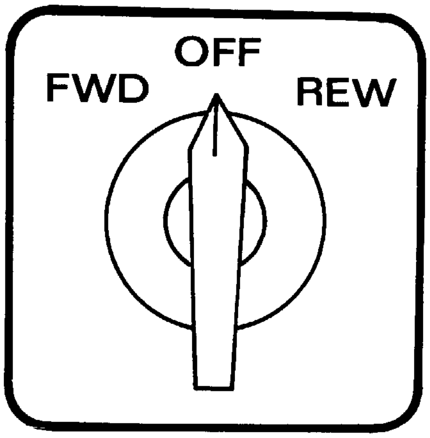
電源供給
POWER SUPPLY

a) 檢查馬達電源之電壓。

b) 確使電源連接符合當地安全規章。注意當未裝控制盤時，頭部開關無過負荷保護作用。

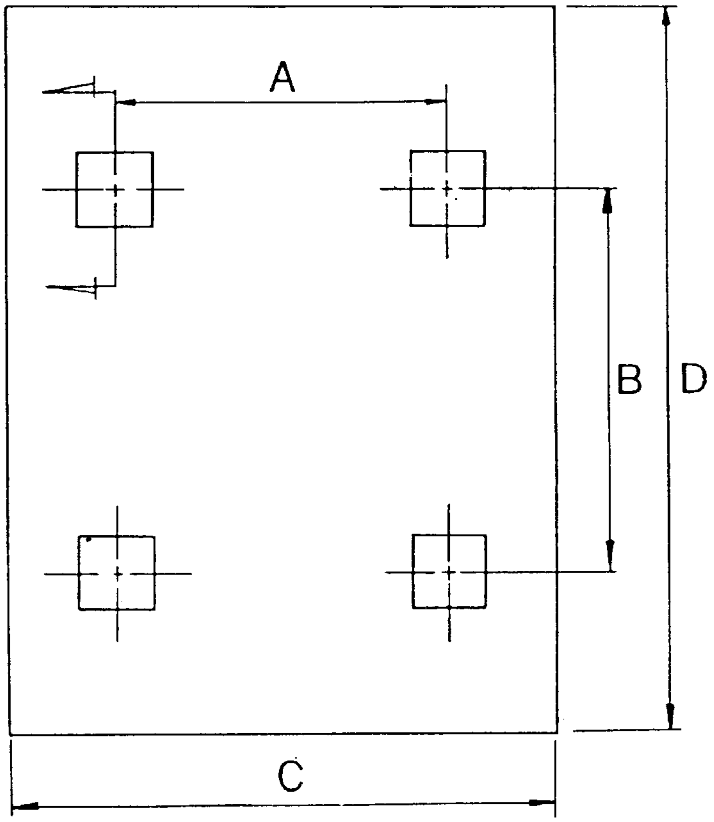
a) Check motor voltages against supply.

b) Ensure that the supply is connected to comply with the local safety regulations. Note: the Head switch has NO overload protection, when a control panel is not fit–ted.



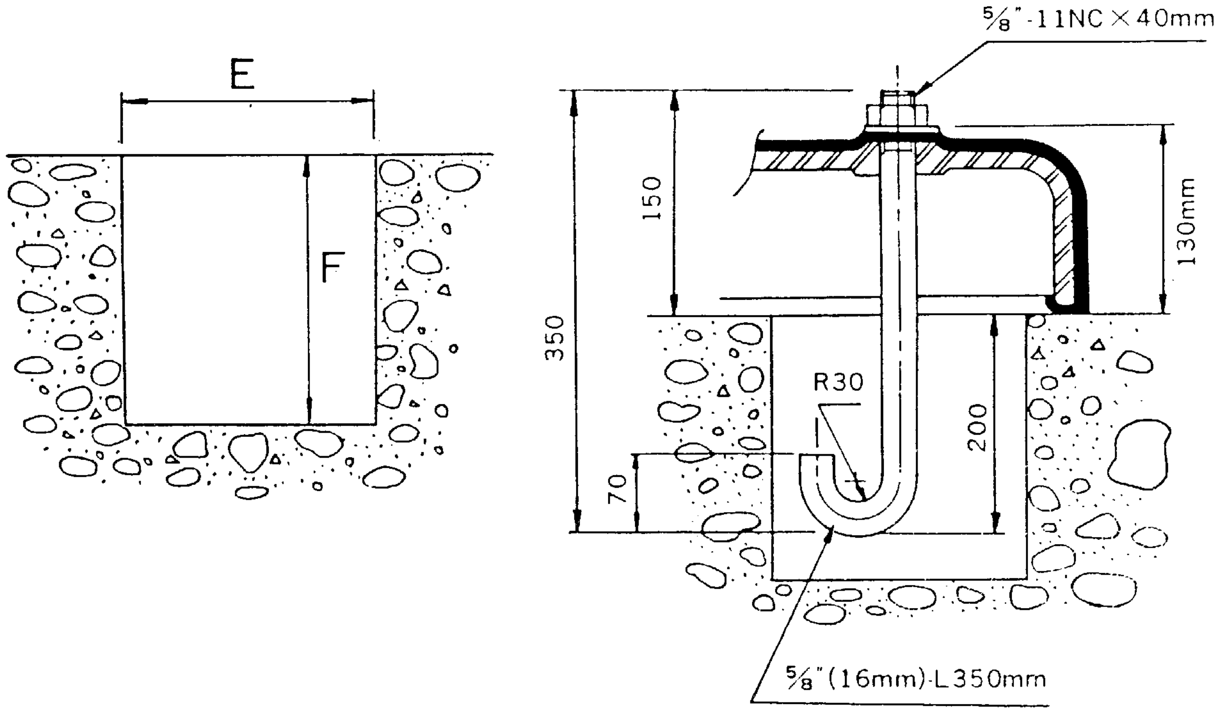
1 1/2 VA—T 1 1/2 VS—T 安裝 Installation

	尺 寸
A	518mm(20⅜")
B	742mm(24 7/32")
C	1020mm(40 5/32")
D	1242mm(48⅞")
E	200mm(7⅞")
F	250mm(9 27/32")

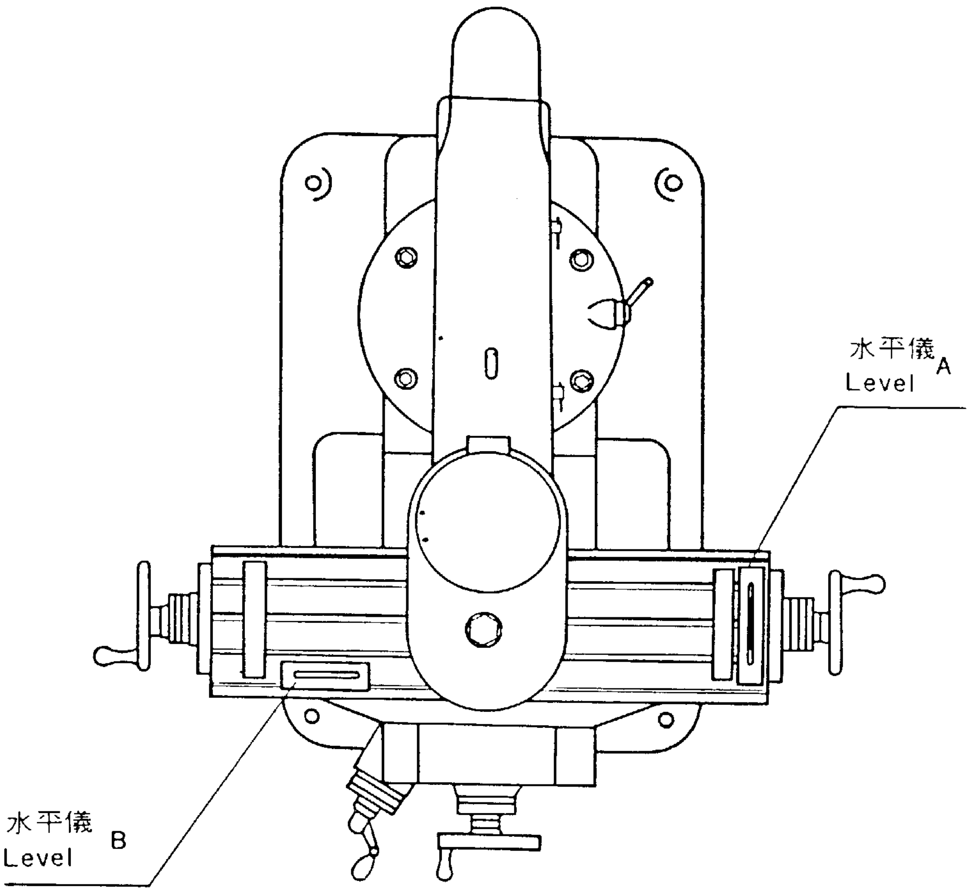


地基平面 Foundation plane

地基構築圖 Foundation Structure



1 1/2 VA–T 1 1/2 VS–T 安裝 Installation

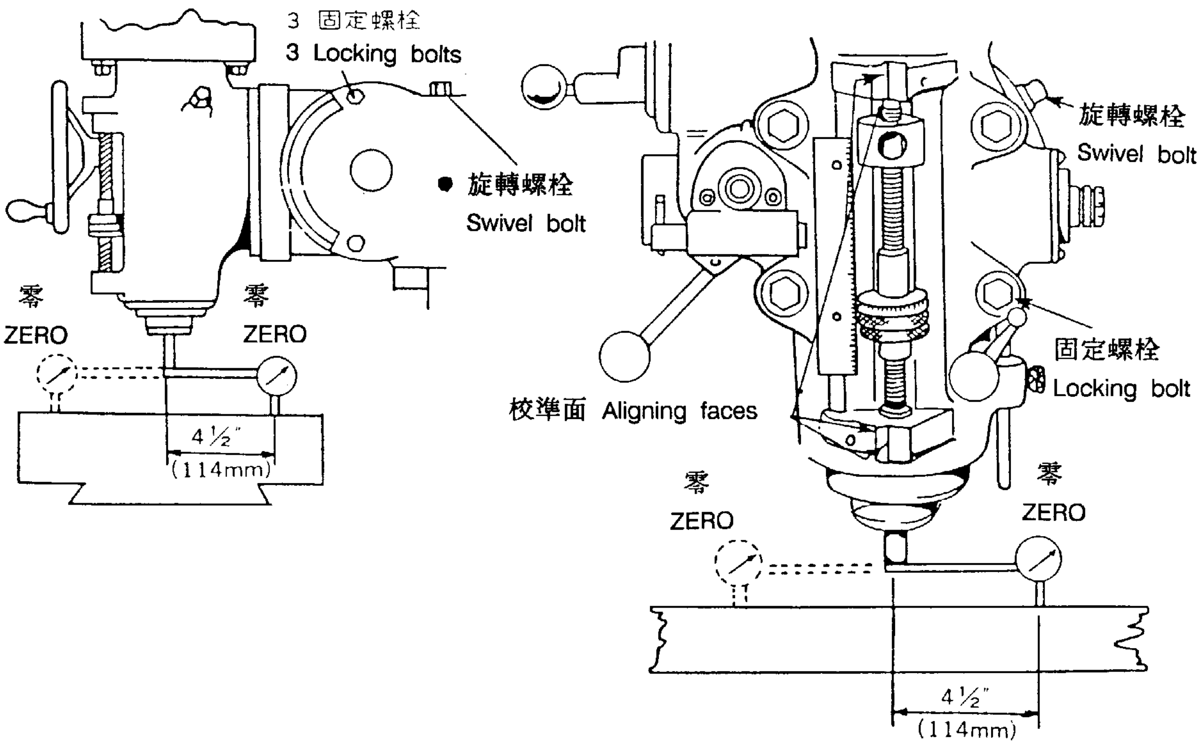


1. 用水平儀放在工作台上，如上圖示。
2. 檢查水平儀 A.B的水平，其允許值 0.06mm/M.
3. 調整時用墊片墊入底床，調整畢鎖緊固定螺栓。

1. Putting levels on the table as illustrated.
2. Check the level A and B. The allowance approximate 0.06mm/M.
3. Putting the shims under the bed if necessary, lock the anchor bolt.

水平校正 Leveling

1 1/2 VA—T 1 1/2 VS—T 安裝 Installation



機器安裝後要校正頭部與工作台的垂直度，有兩個方法：

I. 用一大的 90° 角尺放在工作台上。以此校正頭部的校準面，如上圖示。

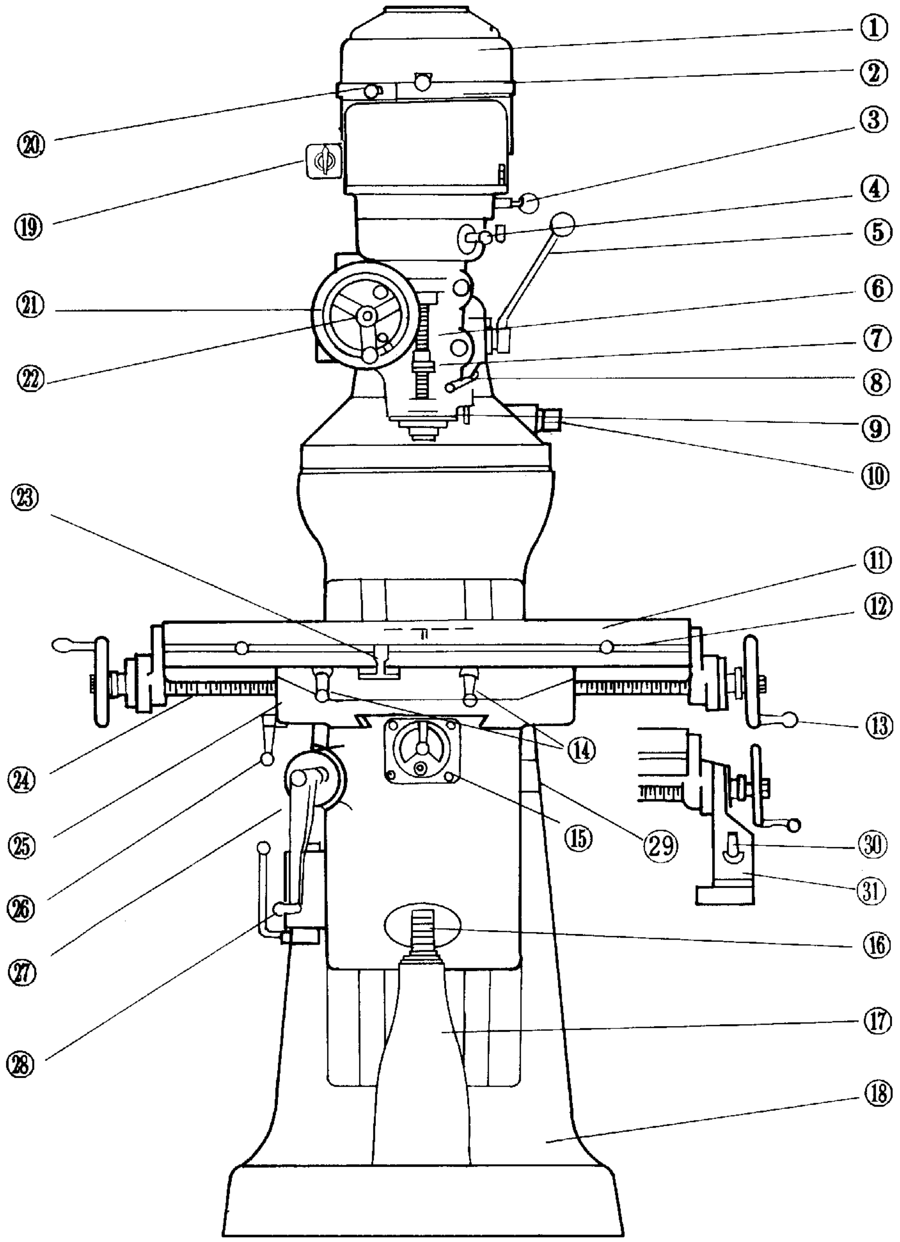
II. 用百分錶裝在主軸端面上，以 4½" 半徑之圓轉動，如上圖示。
校正後每個螺栓需鎖緊。

To set a milling head square to the table two methods are available:

I. Using a large 90° setsquare mounted on the table, align faces with square.

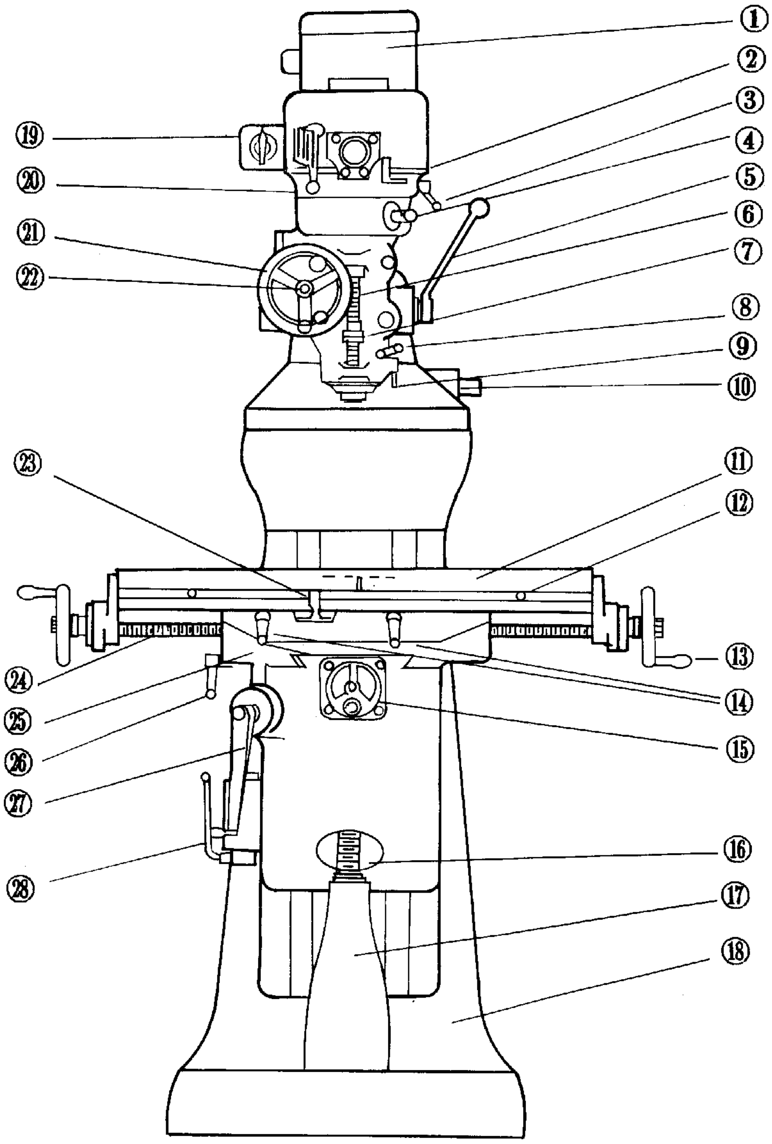
II. An indicator mounted in a spindle nose travelling in a 4½" radius.
It is important that each axis is set separately and locked.

1½ VA–T 機器各部名稱 Legend



代號	名　　　稱	代號	名　　　稱
1	馬達Motor	17	昇降螺桿座Elevating screw housing
2	主軸離合器桿Spindle clutch lever	18	機身Basic
3	後列齒輪選擇柄Back gear selector	19	控制開關Control Switch
4	自動進給驅動柄Auto quill feed engagement	20	主軸剎車及固定桿Spindle brake and lock lever
5	昇降套進給把手Quill feed handle	21	手動微量進給手輪Fine feed handwheel
6	深度控制螺桿Micrometer depth control screw	22	進給方向控制鈕Feed reverse knob
7	深度控制游標刻度環Micrometer depth control	23	橫向進給控制塊Longitudinal feed control
8	昇降套固定桿Quill clamp lever	24	橫向進給螺桿Longitudinal feed screw
9	指示器裝置桿Dial indicator rod	25	鞍　座Saddle
10	伸出臂調整把手Ram adjustment handle	26	鞍座固定把手Saddle lock handle
11	工作台Table	27	昇降座進給把手Elevating feed handle
12	工作台停止檔Table stop	28	給油把手Oil feed lever
13	橫向進給手輪Longitudinal feed handwheel	29	工作台自動進給開關Table power feed switch
14	工作台固定桿Table lock lever	30	工作台自動進給把手Table powerfeed lever
15	縱向進給手輪Cross feed handwheel	31	工作台自動進給附件Table power feed unit
16	昇降座進給螺桿Elevating screw	32	

1 1/2 VS—T 機器各部名稱 Legend



代號	名　稱	代號	名　稱
1	馬達Motor	17	昇降螺桿座Elevating screw housing
2	調速手輪Speed selector handwheel	18	機身Basic
3	高低速選擇把手Spindle range selector	19	控制開關Control Switch
4	自動進給驅動柄Auto quill feed engagement	20	主軸刹車及固定桿Spindle brake and lock lever
5	昇降套進給把手Quill feed handle	21	手動微量進給手輪Finefeed handwheel
6	深度控制螺桿Micrometer depth control screw	22	進給方向控制鈕Feed reverse knob
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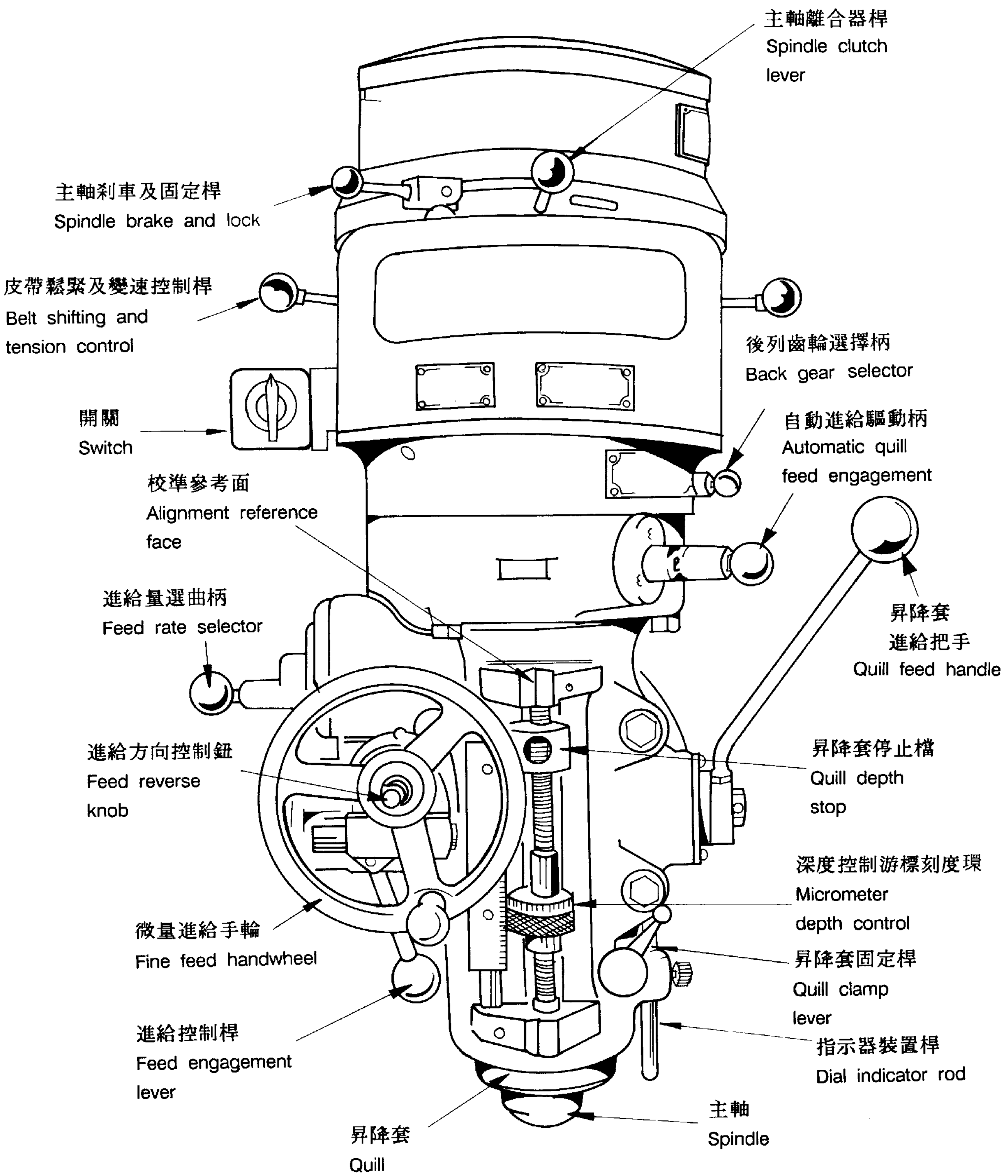
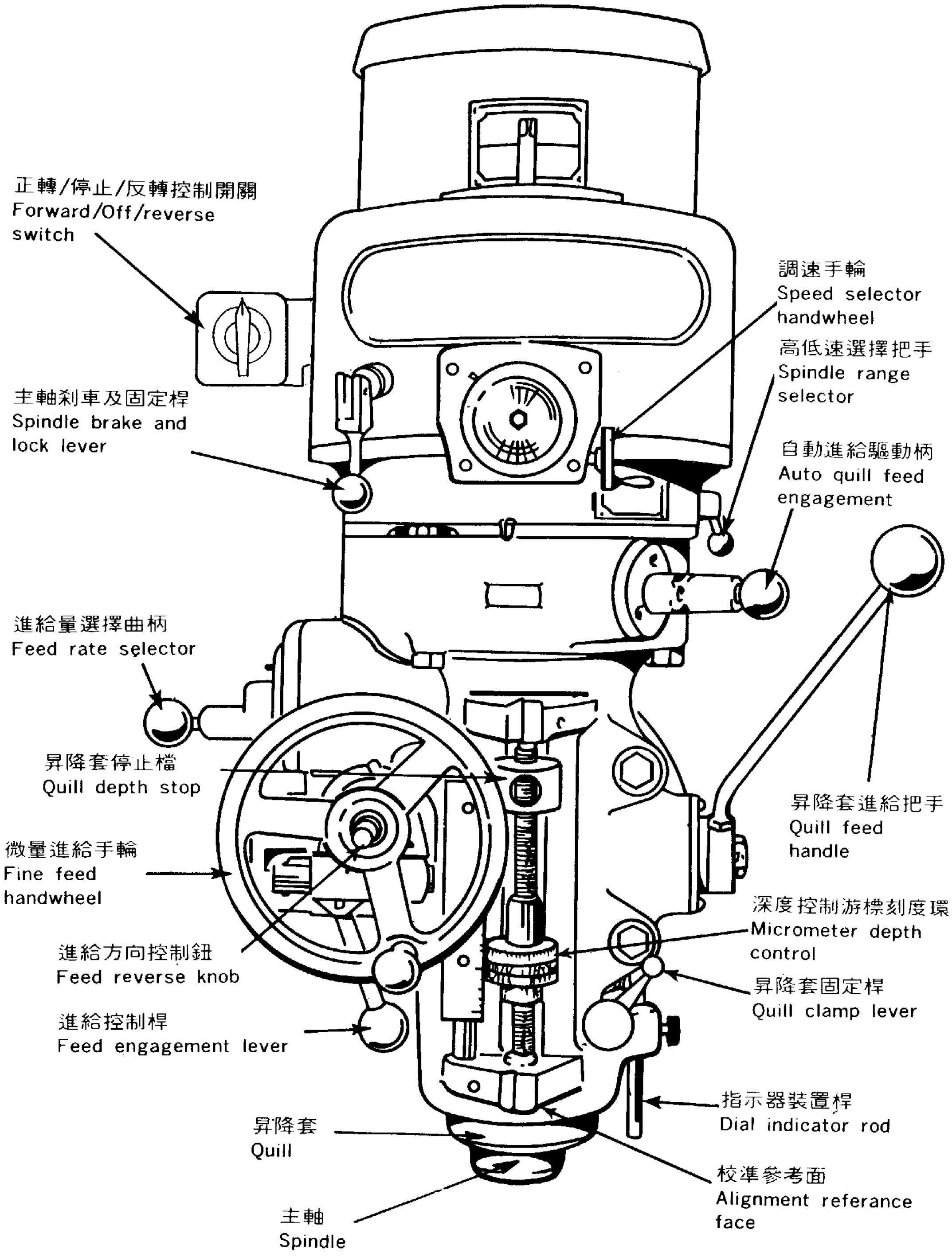
12	工作台停止檔Table stop	28	給油把手Oil feed lever
13	橫向進給手輪Longitudinal feed handwheel	29	
14	工作台固定桿Table lock lever	30	
15	縱向進給手輪Cross feed handwheel	31	
16	昇降座進給螺桿Elevating screw	32	

1 1/2 VA—T 機器各部名稱 Legend



頭部 Head

1½ VS—T 機器各部名稱 Legend

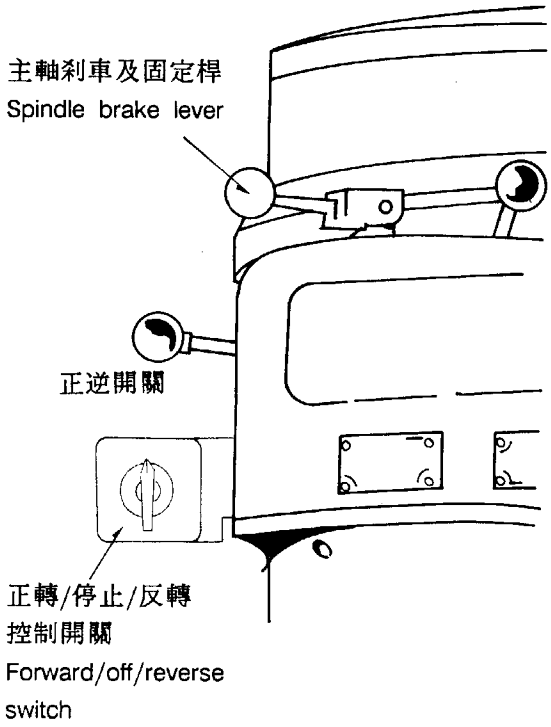


頭部 Head

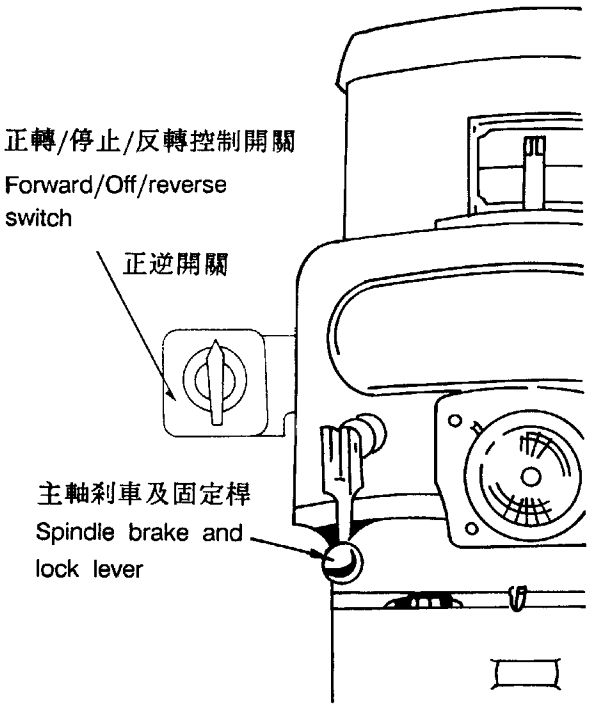
操作 Operation

1. Starting, Stopping

1 1/2 VA—T



1 1/2 VS—T



起動方法

1) 接通電源。
2) 板動頭部左側的開關至所需之轉向(正轉或反轉)。

Starting

1) Connect power.
2) Turn switch to required position (Forward or Reverse).

停車方法

1) 停止進行中的進給。
2) 關掉電源開關。
3) 板動主軸剎車桿，直到主軸完全停止。

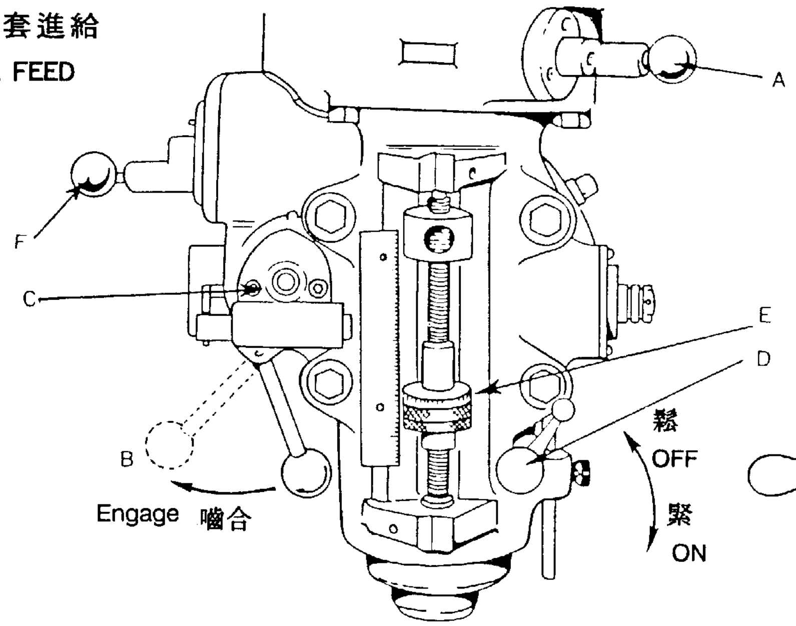
Stopping

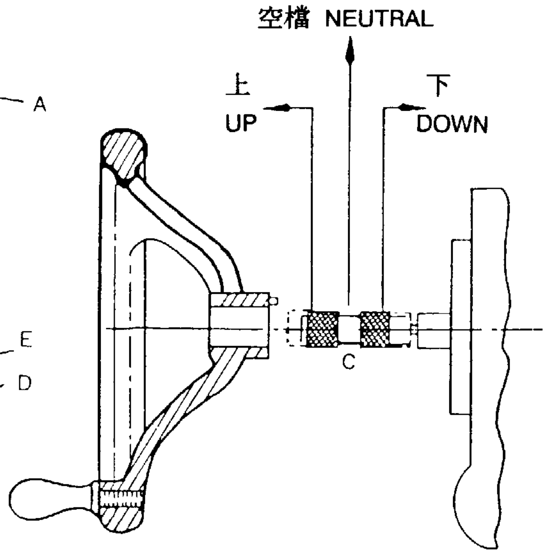
1) Stop feed.
2) Turn switch to "off".
3) Turn spindle brake lever to "brake" till spindle stop.

1½ VA—T 1½VS—T 操作 Operation

2. 昇降套進給

2. QUILL FEED





a) 手動微量進給操作步驟

Ⅰ. 鬆開自動進給驅動柄 'A'

Ⅱ. 將 'C' 置於中央(空檔)位置。

Ⅲ. 板動進給控制桿 'B' 使離合器嚙合。

Ⅳ. 此時昇降套之進給，即可用手輪來控制。

b) 自動進給操作步驟

最大鉆孔徑爲 3/8"(9.5mm) (材料：鋼)

Ⅰ. 放鬆昇降套固定桿 'D'

Ⅱ. 調整游標指示環 'E' 至所需要之深度。

Ⅲ. 板動自動進給驅動柄 'A'。(馬達要停止)

Ⅳ. 由進給量控制柄 'F' 選擇進給量。

Ⅴ. 由進給方向控制鈕 'C' 選定進給方向。

Ⅵ. 板動進給控制桿 'B' 使離合器嚙合。

Ⅶ. 這時昇降套即可行自動進給。

注意：當主軸轉速超過 3000(轉/每分)時，勿使用自動進給。

a) FINE HAND FEED

Ⅰ. Disengage Auto Quill Feed 'A'.

Ⅱ. Locate 'C' in mid (neutral) position.

Ⅲ. Engage Feed Trip Lever 'B'.

Ⅳ. The Quill is now under hand-wheel control.

b) AUTOMATIC FEED

Maximum loading 3/8" (9.5mm) dia. drill in steel.

Ⅰ. Ensure quill lock is off 'D'.

Ⅱ. Set micrometer dial to required depth 'E'.

Ⅲ. Engage auto quill feed 'A'. (when motor has stopped)

Ⅳ. Select feed rate 'F'.

Ⅴ. Select feed direction 'C'.

Ⅵ. Engage feed trip lever 'B'.

Ⅶ. The Quill is now automatic feed.

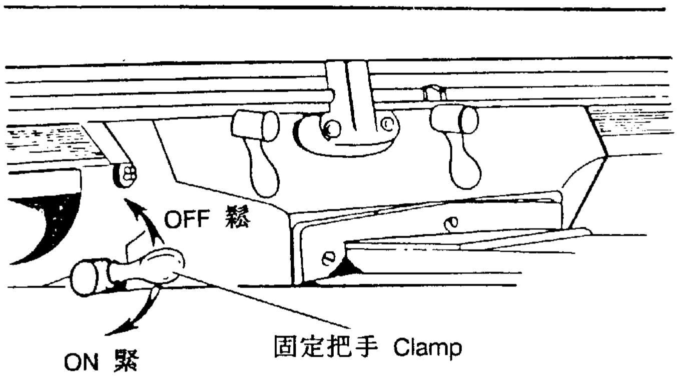
NOTE: Do not engage quill feed 'A' over 3000 R.P.M.

頭部控制 Head Controls

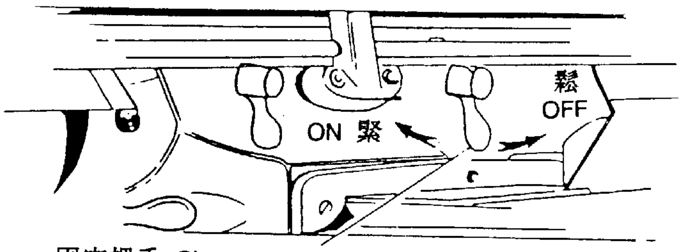
3. 工作台
3. TABLE

1. 固定鞍座與昇降座之滑動。
Clamping the saddle knee slide.

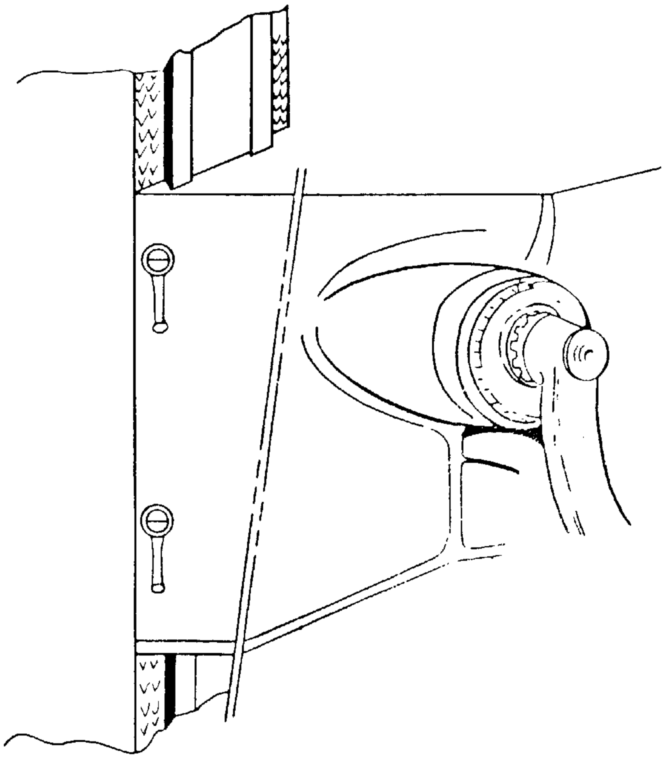
固定時，用適當的壓力即可，用力太大會變形及使得工作台變形。
Moderate pressure is sufficient. Excess pressure will cause distortion and make the table stiff to wind.



2. 固定工作台與鞍座間之滑動。
Clamping the table saddle slide.
固定時，用適當的壓力即可。
Moderate pressure is sufficient.



3. 固定昇降座與機身之滑動。
Clamping the knee column slide.
固定時，用適當的壓力即可。
Moderate pressure is sufficient.



4. 轉塔之旋轉

4. SWIVEL TURRET

a) 用固定板手，放鬆四個螺栓，

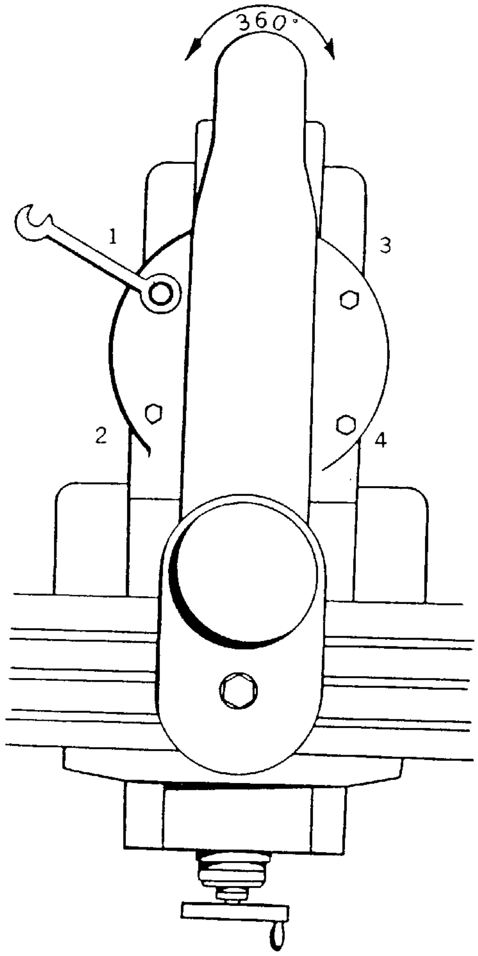
b) 旋轉至所需要的角度。

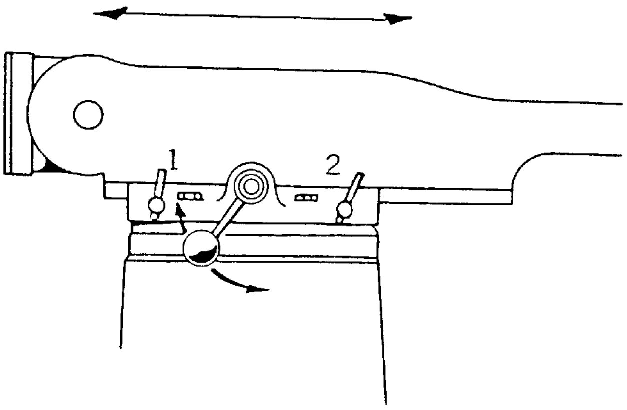
c) 鎖緊四個螺栓。

a) Use spanner and unlock the 4 bolts.

b) Index to the required setting.

c) Lock the 4 bolts.





5. 伸出臂之移動

5. MOVE RAM SLIDE

a) 放鬆兩支固定把手桿。

b) 轉動控制把手至所需要之位置。

c) 固定（先固定後面的把手桿）。

a) Loosen two lock levers.

b) Turn the handle to move the slide to the desired position.

c) Tighten, tightening the rear lock lever first.

1 1/2 VA—T 操作 Operation

1. 皮帶箱旋轉

1. SWIVEL BELT HOUSING

Ⅰ. 放鬆三固定螺帽 'A' (完全地放鬆以避免束縛力存在)。

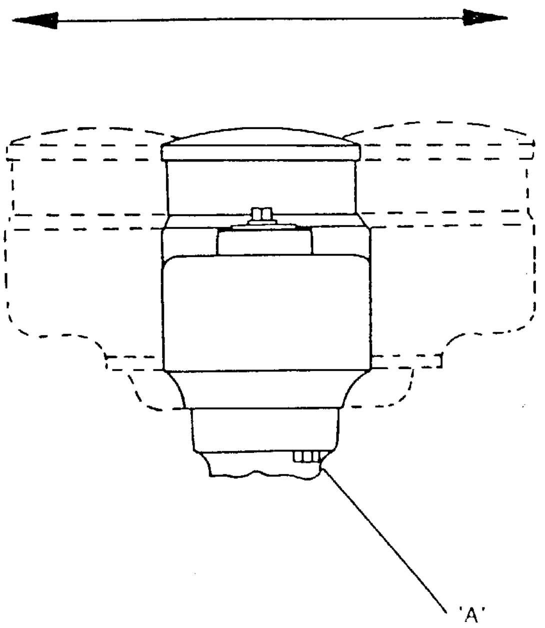
Ⅱ. 旋轉至所需要之角度。

Ⅲ. 鎖緊三固定螺帽最後鎖緊前先轉動主軸使栓槽正確對準。

Ⅰ. Slacken three Locking Nuts 'A'. (Retain sufficiently to stop binding)

Ⅱ. Swivel to required angular setting.

Ⅲ. Tighten three Locking Nuts; be–fore finally securing, run spindle to give correct spline alignment.

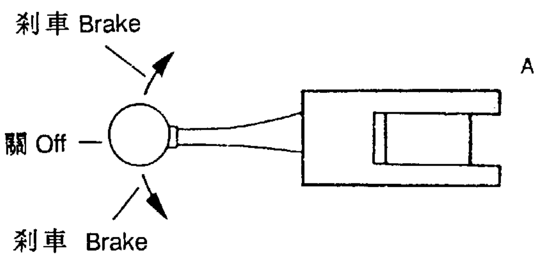


注意：鎖固定螺帽時，若三個不均勻會使昇降套產生剛性變化而造成昇降套內栓槽不正，使進給困難，此現象在操作昇降套進給時可感覺出來。

NOTE: Incorrect spline alignment can be caused by unequal tightening of the locking nuts 'A' causing varying stiffness of the quill feed which can be felt through the sensitive feed handle.

2. 主軸剎車

SPINDLE BRAKE



3. 昇降套快速手動進給

3. QUILL SENSITIVE HAND FEED

Ⅰ. 置手柄於輪轂上。

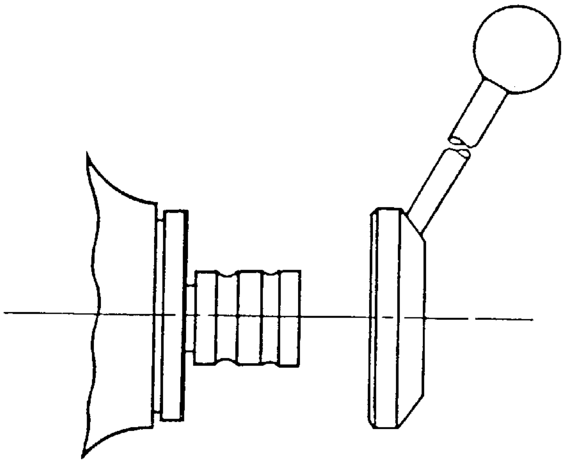
Ⅱ. 選擇最適當之位置。

Ⅲ. 推動手柄直至定位銷嚙合。

Ⅰ. Place the handle on the boss.

Ⅱ. Select the most suitable position.

Ⅲ. Push home until the locating pin engages.



4. 主軸速度（變速前停止馬達）

4. SPINDLE SPEEDS

(Stop motor before changing speed).

80	135	210	325	後列齒輪傳動 BACK GEAR
660	1115	1750	2720	直接傳動 DIRECT

5. 速度變換 CHANGE SPEED

a) 同範圍內之變速

Ⅰ. 關掉電源。

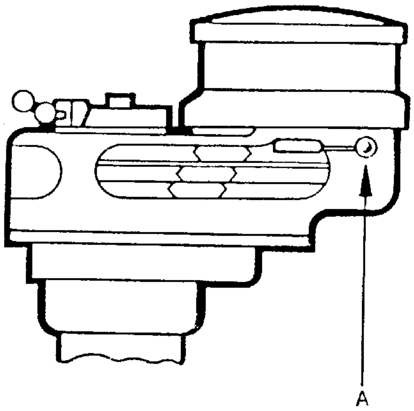
Ⅱ. 放鬆 2 馬達固定桿 'A'。

Ⅲ. 向前移動馬達。

Ⅳ. 將皮帶置入合適之皮帶輪溝內。

Ⅴ. 將馬達推向後方，使 V 形皮帶接緊。

Ⅵ. 鎖緊 2 馬達固定桿。



a) Change Speed Within Range

Ⅰ. Isolate machine

Ⅱ. Slacken 2 motor lock levers 'A'

Ⅲ. Slide motor forward.

Ⅳ. Position belt on appropriate pulleys.

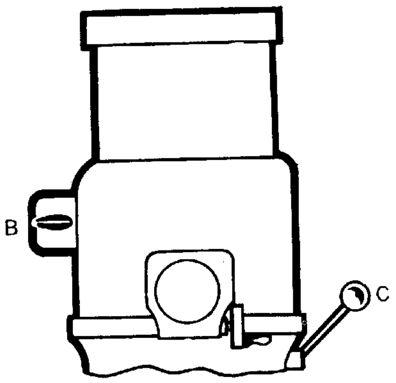
Ⅴ. Slide motor to the rear to tension vee belt.

Ⅵ. Tighten 2 motor locking levers

1 1/2 VS—T 操作 Operation

b) 變更速度範圍。

b) Change Range.



1. 從直接變至後列齒輪驅動：

Ⅰ. 開關 'B' 扭至 off 。

Ⅱ. 移動 'C' 桿經空擋至低速檔。（這時主軸轉向相反）

Ⅲ. 開關 'B' 扭至低速。

1. FROM DIRECT TO BACK GEAR DRIVE:

Ⅰ. Switch 'B' to OFF.

Ⅱ. Move lever 'C' through neutral to LOW. (This reverses the spindle rotation).

Ⅲ. Switch 'B' to LOW.

主軸在運轉中勿變換把手 'C' 之位置！
DO NOT CHANGE RANGE WHILE THE SPINDLE IS RUNNING

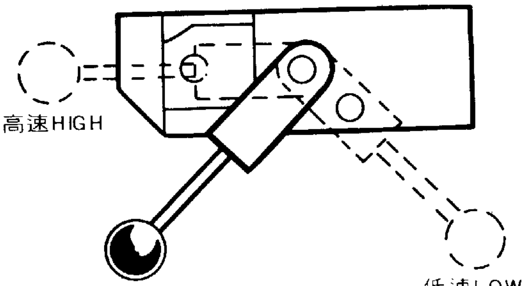
2. 從後列齒輪變至直接驅動：

Ⅰ. 開關 'B' 扭至 off 。

Ⅱ. 移動 'C' 桿經空擋至高速檔。

Ⅲ. 用手轉動主軸直至感覺離合器嚙合爲止。

Ⅳ. 開關 'B' 扭至高速。



2. FROM BACK GEAR TO DIRECT DRIVE:

Ⅰ. Switch 'B' to OFF 。

Ⅱ. Move lever 'C' through neutral to HIGH.

Ⅲ. Rotate spindle by hand until the clutches are felt to engage.

Ⅳ. Switch 'B' to HIGH.

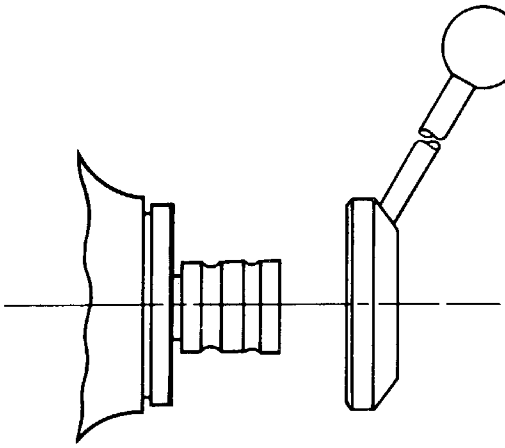
3. 昇降套快速手動進給

3. QUILL SENSITIVE HAND FEED

I. 置手柄於輪轂上。

II. 選擇適當之位置。

III. 推動手柄直至定位銷嚙合。



I. Place the handle on the boss.

II. Select the most suitable position.

III. Push home until the locating pin engages.

主軸速度（在主軸運轉時才可變速）

4. SPINDLE SPEED (Change only when spindle is running)

a) 範圍內之速度

I. 啓動主軸。

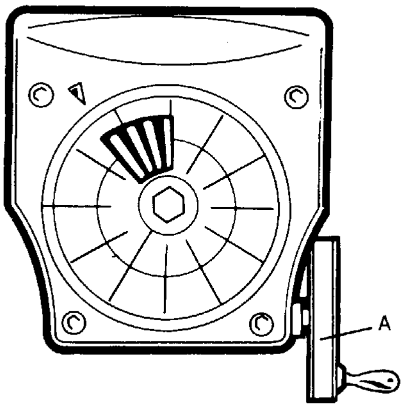
II. 轉動手輪 'A' 至選定所需速度。

b) Change Speed Within Range

I. Start spindle.

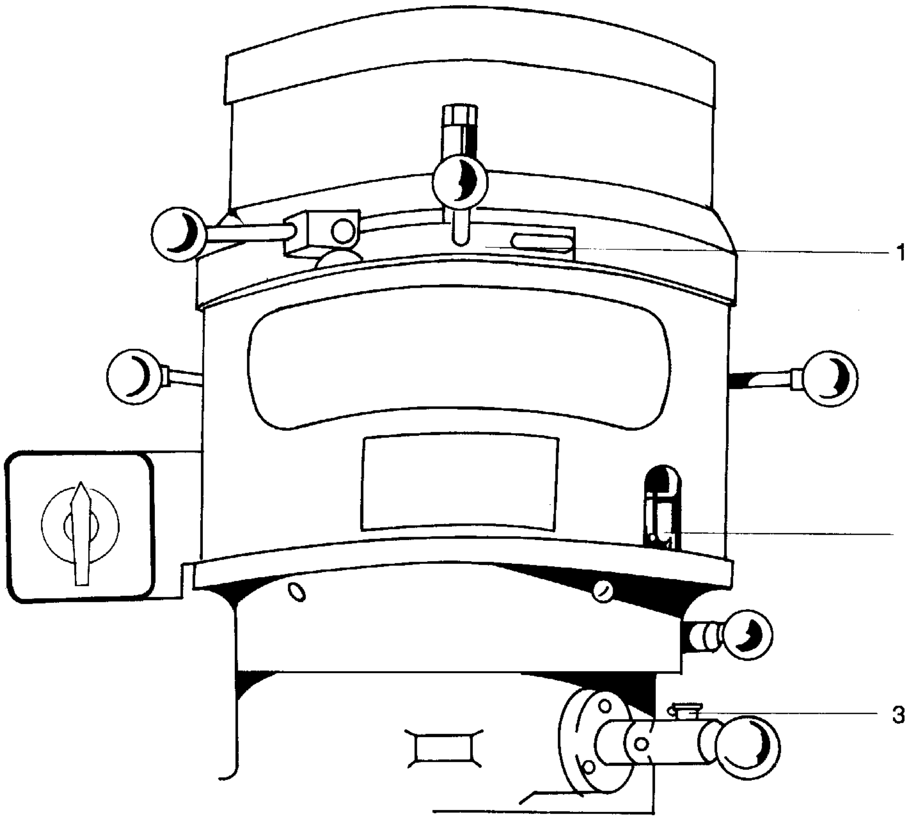
II. Turn handwheel 'A' to select required speed.

Change only when spindle is running.



主軸停止時不可變速
DO NOT CHANGE SPEED
WHILST SPINDLE HAS STOPPED

1 1/2 VA—T 潤滑 Lubrication

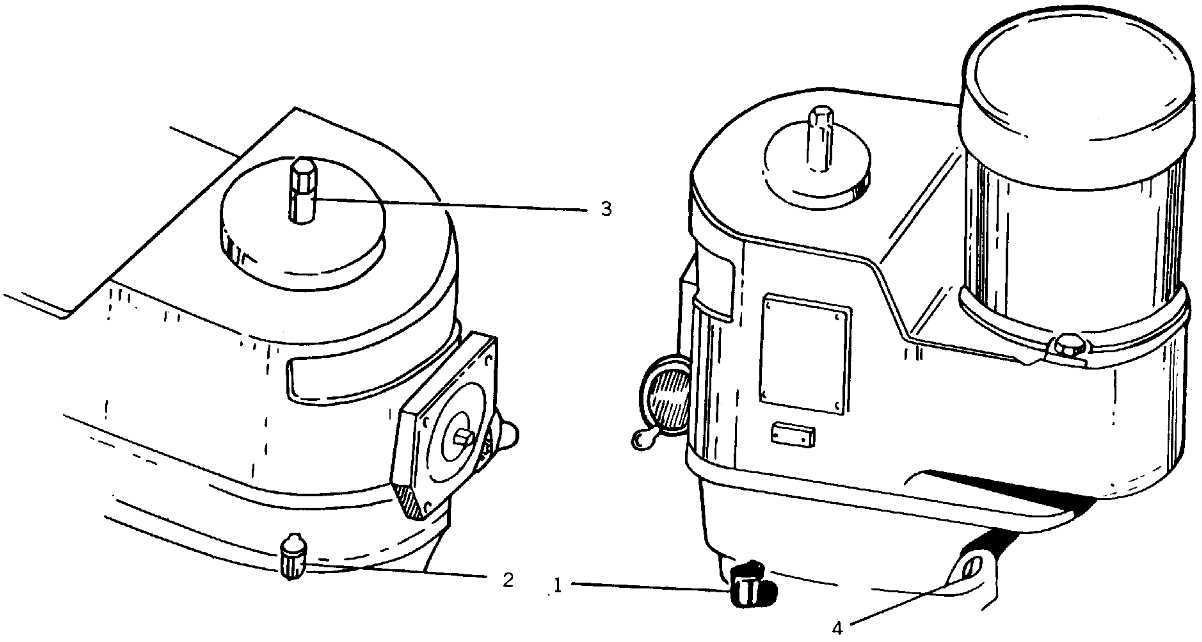


註：'3' 昇降套軸承潤滑錯誤，會導致昇降套太緊，且使得昇降套緊束於座內。

NOTE: Failure to lubricate "Quill bearings" at 3 can result in tight quills and partial seizure of quill in housing.

週 期 FREQUENCY	潤 滑 LUBRICATE	潤 滑 劑 LUBRICANT	數 量 QUANTITY	代號 AT.
每週兩次 Twice Weekly	皮帶輪凸輪 Pulley Cam	中國石油 R53 Vactra Heavy-Medium S.A.E. 10 or 10W Light	5 滴 5 Drops	1
每週兩次 Twice Weekly	主軸軸承 / 昇降套進給 Spindle Bearing/Quill feed	中國石油 R53 Vactra Heavy-Medium S.A.E. 10 or 10W Light	加 滿 Top-Up	2
每週兩次 Twice Weekly	昇降套軸承 Quill Bearings	中國石油 R53 Vactra Heavy-Medium S.A.E. 10 or 10W Light	加 滿 Top-Up	3

1 1/2 VS—T 潤滑 Lubrication



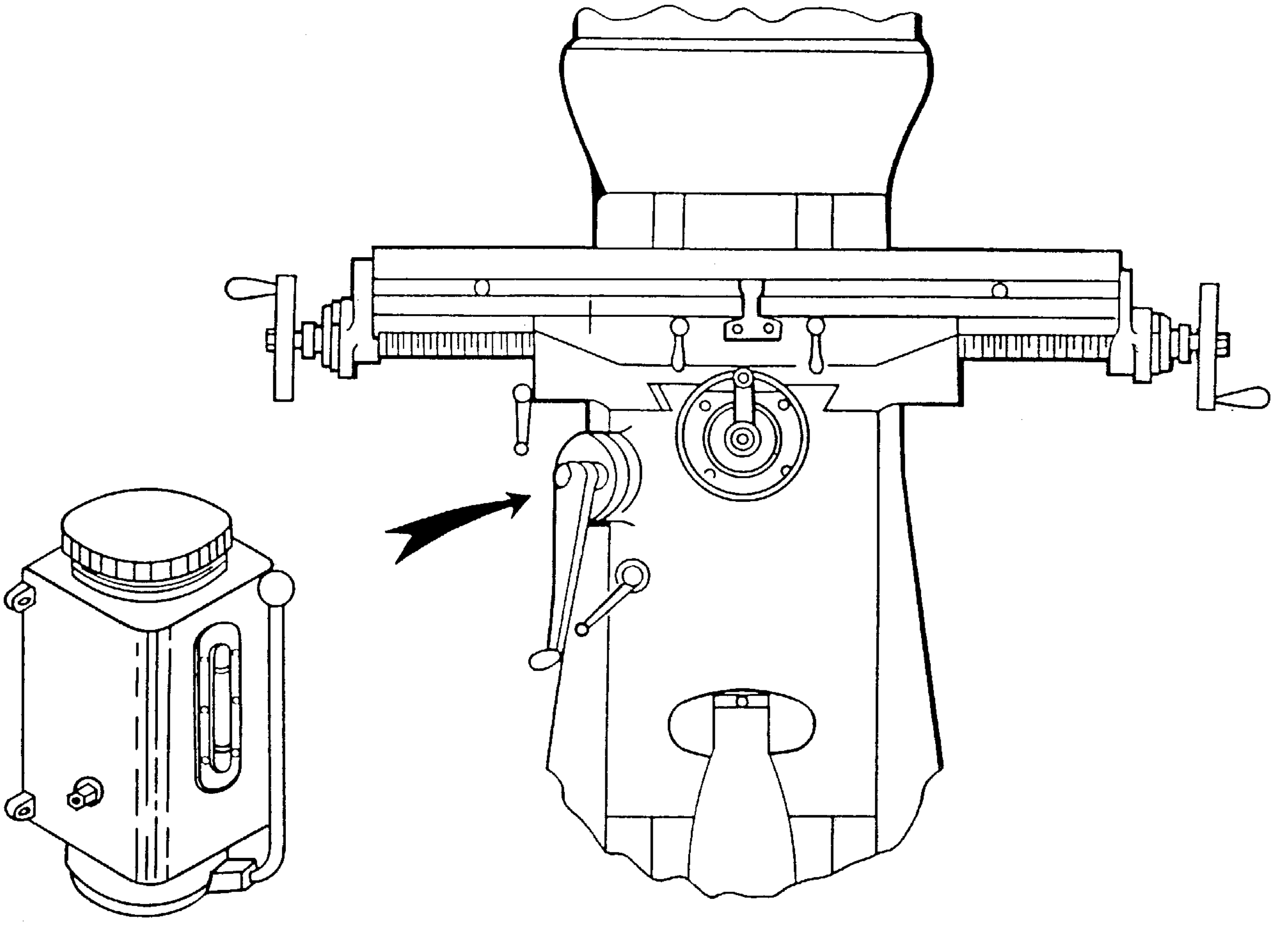
週 期 FREQUENCY	潤 滑 LUBRICATE	潤 滑 劑 LUBRICANT	數 量 QUANTITY	潤滑代號 LUB. AT.
每天兩次 Twice Daily	昇降套軸承 Quill bearings	中國石油 R53 Vactra Heavy Medium S.A.E. 10 or 10W Light	5-10 滴 5-10 drops	1
每天兩次 (當操作進給時) Twice Daily (When feed is in use)	主軸向下進給 Spindle Down Feed	中國石油 R53 Vactra Heavy Medium S.A.E. 10 or 10W light	加 滿 Top-up	2
每週一次 Weekly	拉桿栓軸(將昇降套降下 2") Drawbar splines(move quill down 2")	中國石油 R53 Vactra Heavy Medium S.A.E. 10 or 10W Light	5 滴 5 drops	3

註：錯誤潤滑 1 "昇降套軸承" 會使昇降套太緊且使昇降套部份束縛於座內。

NOTE : Failure to lubricate "Quill bearings" at 1 can result in tight quills and partial seizure of quill in housing.

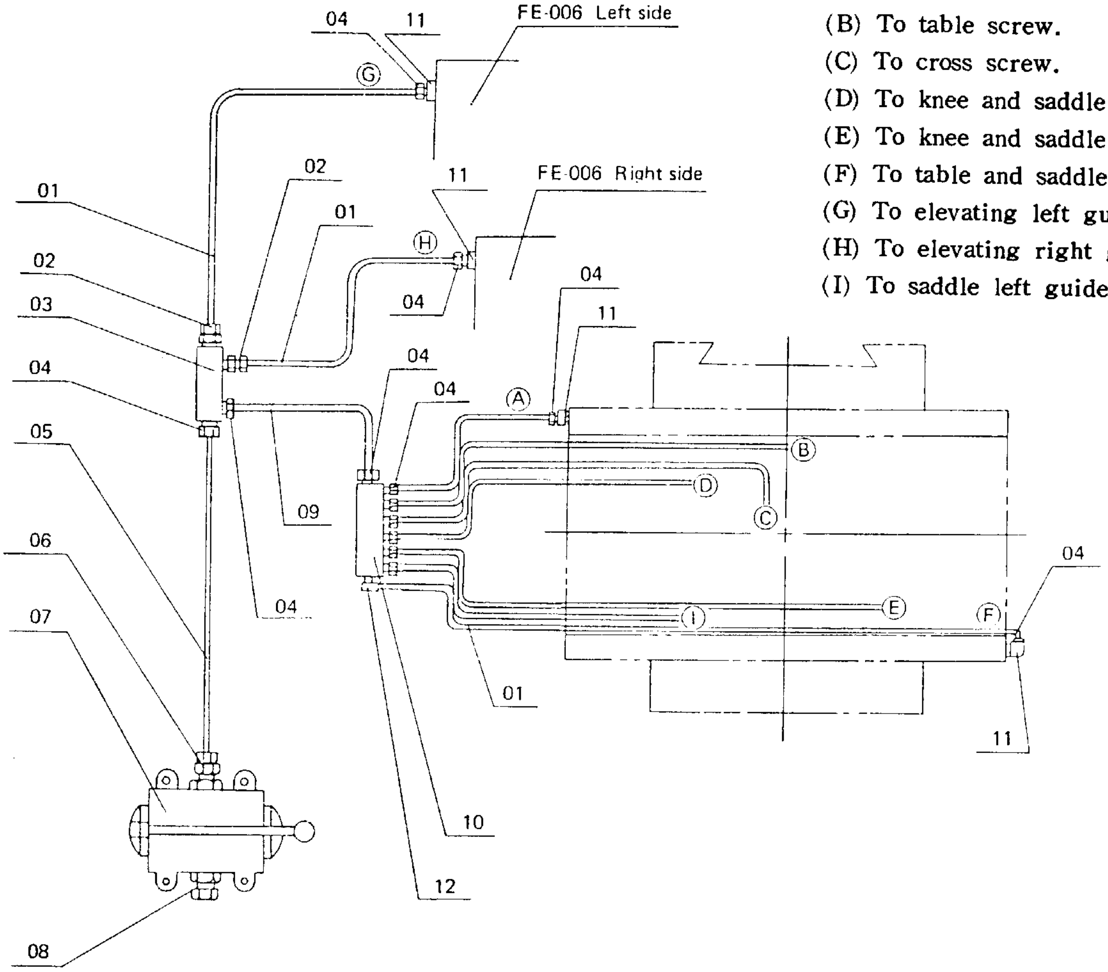
週 期 FREQUENCY	潤 滑 LUBRICATE	潤 滑 劑 LUBRICANT	數 量 QUANTITY	潤滑代號 LUB. AT.
每二個月一次 (正常使用下) Every 2 months (of normal use)	後列齒輪 Back gear	黃 油 Grease	相當於一茶匙 Equivalent of 1 teaspoonful	4. 註：加黃油前將齒輪桿退向 'LO' 處並保持主軸停止。 NOTE:Before greasing put gear lever back to 'LO' & keep spindle stationary.

$1\frac{1}{2}$ VA—T $1\frac{1}{2}$ VS—T 潤滑 Lubrication



週 期 FREQUENCY	潤 滑 LUBRICATE	潤 滑 劑 LUBRICANT	數 量 QUANTITY
每天注滿潤滑泵 Centraliced Lub. Pump Daily 每週檢查油面高 Check Level Weekly	導螺桿 Lead Screw	Shell cornea Oil 41 Mobil X 2 Socony Gargoyle Vactra No.2	一泵浦 One Pump
	鞍座一工作台滑道 Saddle-Table Ways	"Sunoco" Waylube #80 Mobil X 2	一泵浦 One Pump
	鞍座-昇降座滑道 Saddle-Knee Ways	"Sunoco" Waylube #80 Mobil X 2	一泵浦 One Pump
	昇降座機身滑道 Knee Column Ways	"Sunoco" Waylube #80 Mobil X 2	一泵浦 One Pump
每週兩次 Twice Weekly	升降螺桿 Elevating Screw	Shell Carnea Oil 41 Mobil X 2 Socony Gargoyle Vactra No.2	油槍打 5 次 5 Shots(Oil Gun)

1½ VA—T 1½VS—T LUBRICATION SYSTEM



(A) To table and saddle rear guideway.
(B) To table screw.
(C) To cross screw.
(D) To knee and saddle left guideway.
(E) To knee and saddle right guideway.
(F) To table and saddle front guideway.
(G) To elevating left guideway.
(H) To elevating right guideway.
(I) To saddle left guideway.

ITEM NO	PART NO.	PART NAME	QTY
01	062040000	Aluminum pipe (ϕ4)	9
02	041004000 050004000 111001003	Pipe lock nut(PAN—4) Pipe joint(PB—4) Flow regulator(PSS—3)	2 2 2
03	071040408	Oil distributor	1
04	040004000 050004000	Pipe lock nut(PA—4) Pipe joint(PB—4)	13 13
05	045040200	Flexible hose(ϕ4x200MM)	1
06	040004000 050004000 039040818	Pipe lock nut(PA—4) Pipe joint(PB—4) Check valve(PDV—4)	1 1 1
07	013008000	Plunger pump(LT—8)	1
08	085008002	Oil plug(PG—1)	1
09	045040300	Flexible hose(ϕ4x300MM)	1
10	FE—033B	Oil distributor	1
11	FE—031	L type universal connector	4
12	FE—033 041004000 050004000	L type universal connector Pipe lock nut(PAN—4) Pipe joint(PB—4)	1 1 1

預 防 保 養 Preventive Maintenance

爲了確保機器之精密與增加使用壽命，我們提供下列預防保養表給操作者。

For securing the accuracy and life of the machine, we offer the following preventive maintenance charts.

週 期 Frequency	項 目 Item
每 日 Daily	1. 操作前必須依照潤滑說明把各部位加油。 It is necessary to oil each lubrication point before operation. 2. 檢查手動油泵的油量，不足須補充。 Check the level of the oil lubricator and fill if necessary. 3. 操作完畢，所有固定桿應放鬆，工作台面須清除乾淨並潤滑少許的油，以保護工作台面。 It is necessary to release the clamps, clean and lubricate the table after operation.
每 月 Monthly	1. 檢查各部調整楔之鬆緊情形，並作適當的調整。 Check all the gibs and adjust if necessary. 2. 檢查所有螺桿與螺帽間之間隙，並作適當的調整。 Check all the backlash between screws and nuts, and adjust if necessary.
每 季 Quarterly	1. 根據精度檢查表核對各部精度，(看本説明書53頁到55頁並作調整)。 Check and adjust the machine accuracy. (manual P.53 to P.55).

$1\frac{1}{2}$ VA–T $1\frac{1}{2}$ VS–T 保養 Maintenance

敝公司眞誠的向您建議：

當您欲保養機械前，爲了您的安全，請關掉機器之電源，且爲了迅速之保養請閱讀此手册之相關部份。

May We Suggest That.

Before attempting any maintenance in the interests of safety to you, isolate the machine electrically and in the interests of efficiency to you, read the relevant section of this manual.

當訂購更換零件時請說明：

- 機器系列號碼。
  註於機身左側門之上方。
- 頭部系列號碼。
  於皮帶箱前方。
- 項目號碼。
- 零件號碼。
- 數量。
- 概述。

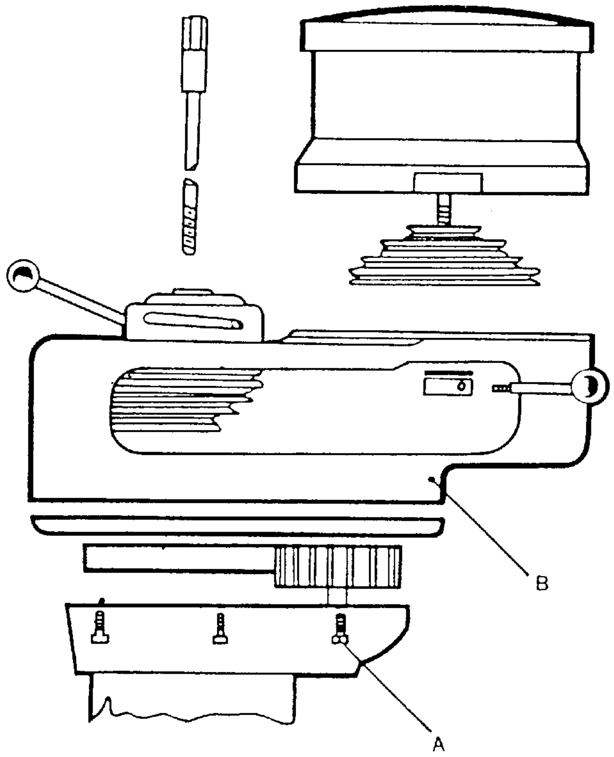
When ordering replacement parts please quote:

- THE MACHINE SERIAL No.
  Situated above the door on the left hand side of the column.
- THE HEAD SERIAL No.
  found on the front of the Belt Housing.
- ITEM NUMBER.
- PART NUMBER.
- QUANTITY.
- DESCRIPTION.

皮帶更換步驟
BELT REPLACEMENT

1. 關掉電源。
2. 取下拉桿。
3. 拆下馬達。
4. 將昇降套降至最下方。
5. 取下六個螺絲 'A'。
6. 取下皮帶箱（輕輕敲動使其脫離連結銷）。
7. 此時即可更換皮帶。

1. Isolate machine.
2. Remove drawbar.
3. Remove motor.
4. Lower quill to full extension.
5. Remove 6 screw 'A'.
6. Remove belt housing 'B', tap to withdraw from dowels.
7. The belts may now be changed.



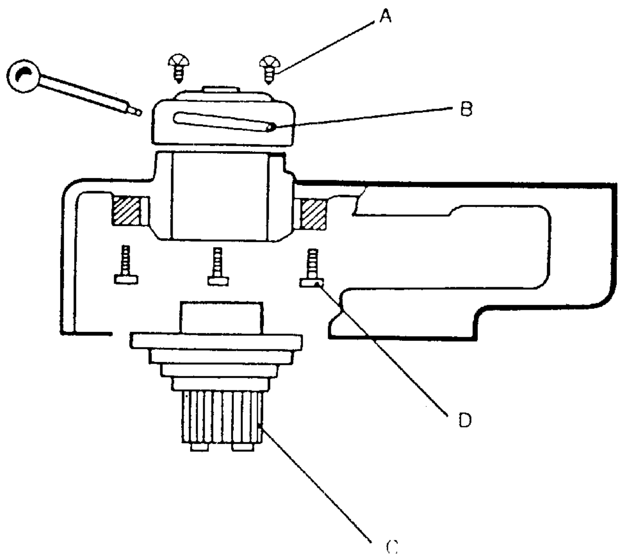
剎車環更換步驟
BRAKE SHOE REPLACEMENT

重覆前頁 1～6 之順序後。

1. 取下四個螺絲 'A'。
2. 取下兩個螺絲 'B'。
3. 從座內推出軸承轂 'C'。
4. 取下三個螺絲 'D'。
5. 更換剎車塊。
6. 更換後鎖緊螺絲 'D'，並用墊圈與螺帽固定。

Repeat the sequence 1. to 6. (Page 35)

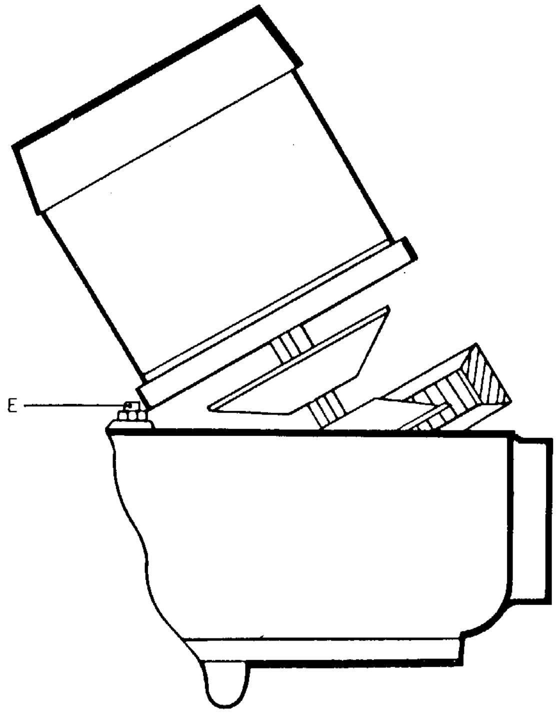
1. Remove 4 screws 'A'.
2. Remove 2 screws 'B'.
3. Push bearing hub 'C' clear of housing.
4. Remove 3 screws 'D'.
5. Replace shoe.
6. Ensure screws 'D' are fully tight–ened and locked with washers and nuts.

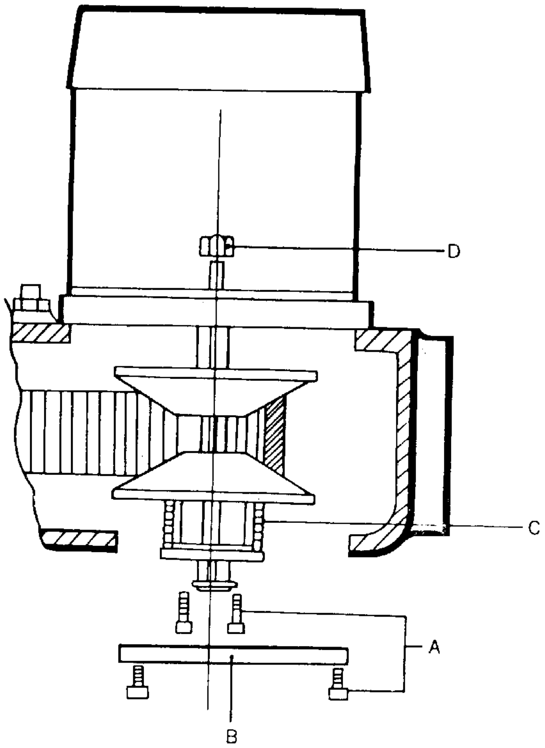


馬達拆卸步驟
MOTOR REMOVAL

1. 轉動頭部調整至最低速。
2. 關掉電源。
3. 取下三個螺絲 'A' 及蓋 'B'。
4. 用兩個螺絲 'A' 壓住彈簧 'C'。
5. 轉動變速器至最高速。
6. 從皮帶箱取下開關。
7. 取下兩個固定螺帽 'D'。
8. 提起馬達，將馬達箱放在螺樁 'E' 上。
9. 放鬆皮帶，並繞過驅動盤，即可取下馬達。

1. Run head to adjust to lowest speed.
2. Isolate machine.
3. Remove 3 screws 'A' & cover 'B'.
4. Using the two screws 'A' compress spring 'C'.
5. Rotate the speed changer to the highest speed.
6. Remove the reversing switch from the belt housing.
7. Remove the two locking nuts 'D'
8. Lift the motor and rest the case on stud 'E'.
9. Ease the belt over the lower drive disc and remove the motor.

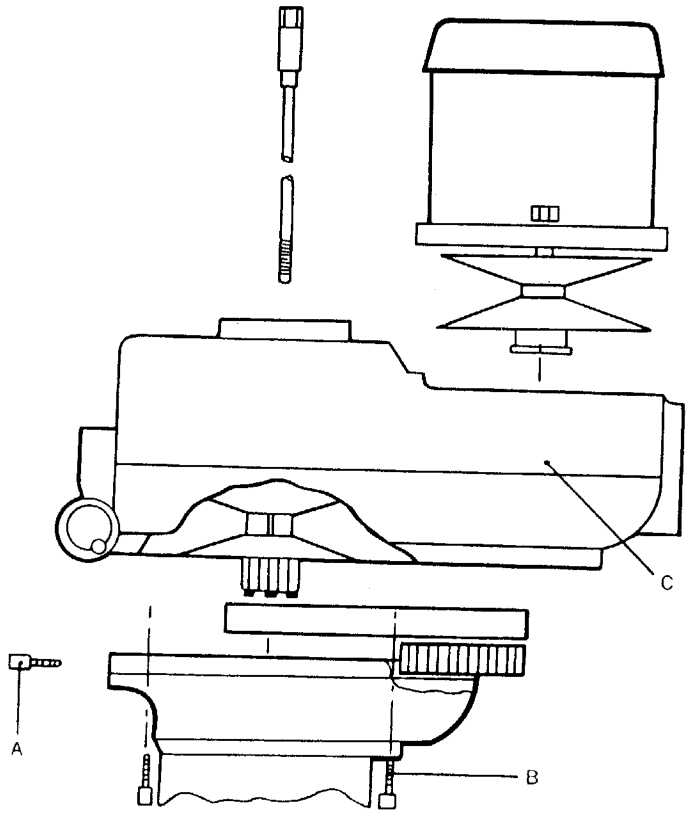




齒型皮帶更換法
TIMING BELT REPLACEMENT

1. 如前頁所述取下馬達。
2. 昇降套降至最低位置。
3. 從變速箱下方取出兩個螺絲 'A'。
4. 取下四個螺絲 'B'。
5. 退出連結銷，使上部份 'C' 分離。
6. 此時即可更換皮帶。

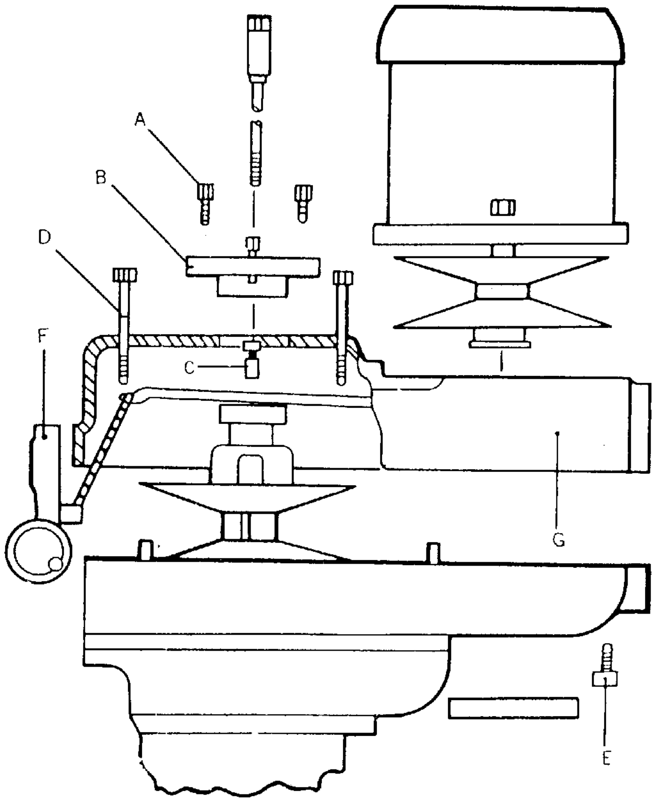
1. Remove the motor.
2. Lower the quill to full extent.
3. Remove the two lower capscrews 'A' from the speed changer housing.
4. Remove the four cap screws 'B'.
5. Remove the top assembly 'C' and tap to clear dowels.
6. Replace the belt.



驅動皮帶更換法
DRIVE BELT REPLACEMENT

1. 如 38頁所述取下馬達。
2. 取下三個螺絲 'A'，鎖進附近之牙孔，退出軸承座 'B'。
3. 取下兩個螺絲及襯套 'C'。
4. 取出四個螺絲 'D' 與一個螺絲 'E'。
5. 取下四個固定變速器之螺絲 'F'。
6. 退出連結銷，並移開頂座 'G'。
7. 此時即可更換皮帶。

1. Remove the motor as described on page 38.
2. Remove the three screws 'A'; insert into the adjacent tapped holes and withdraw bearing housing 'B'.
3. Remove the two screws and the bushes 'C'.
4. Remove four screws 'D' and one screw 'E'.
5. Remove four screws securing the speed changer 'F'.
6. Remove top housing 'G' ;tap to clear the dowels.
7. Replace the belt.

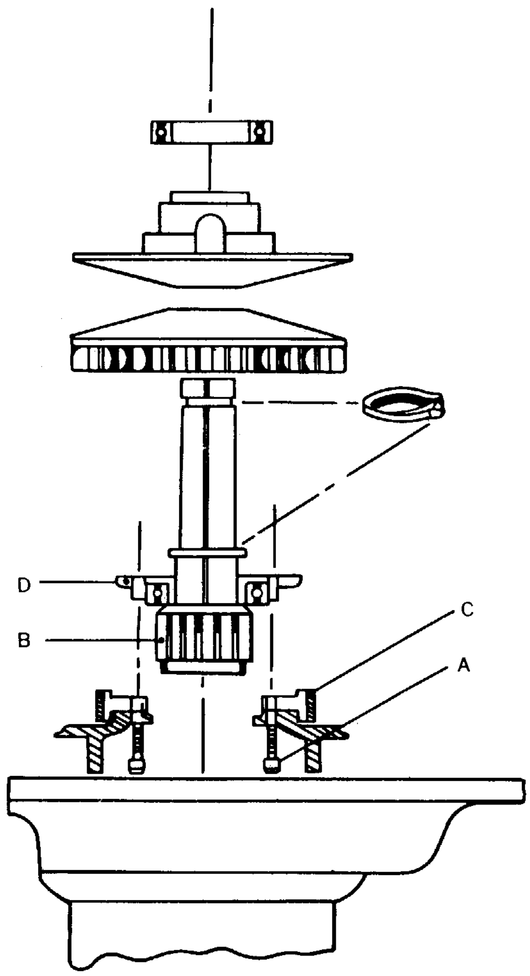


剎車環更換步驟

BRAKE SHOE REPLACEMENT

1. 拆下頂部。
2. 取下兩個螺絲 'A'。
3. 取出離合器轂組件 'B' 和 'D'。
4. 更換剎車環 'C'。

1. Remove the top section.
2. Remove the two screws 'A'.
3. Remove the clutch hub assembly 'B' & 'D'.
4. Replace the brake shoes 'C'.

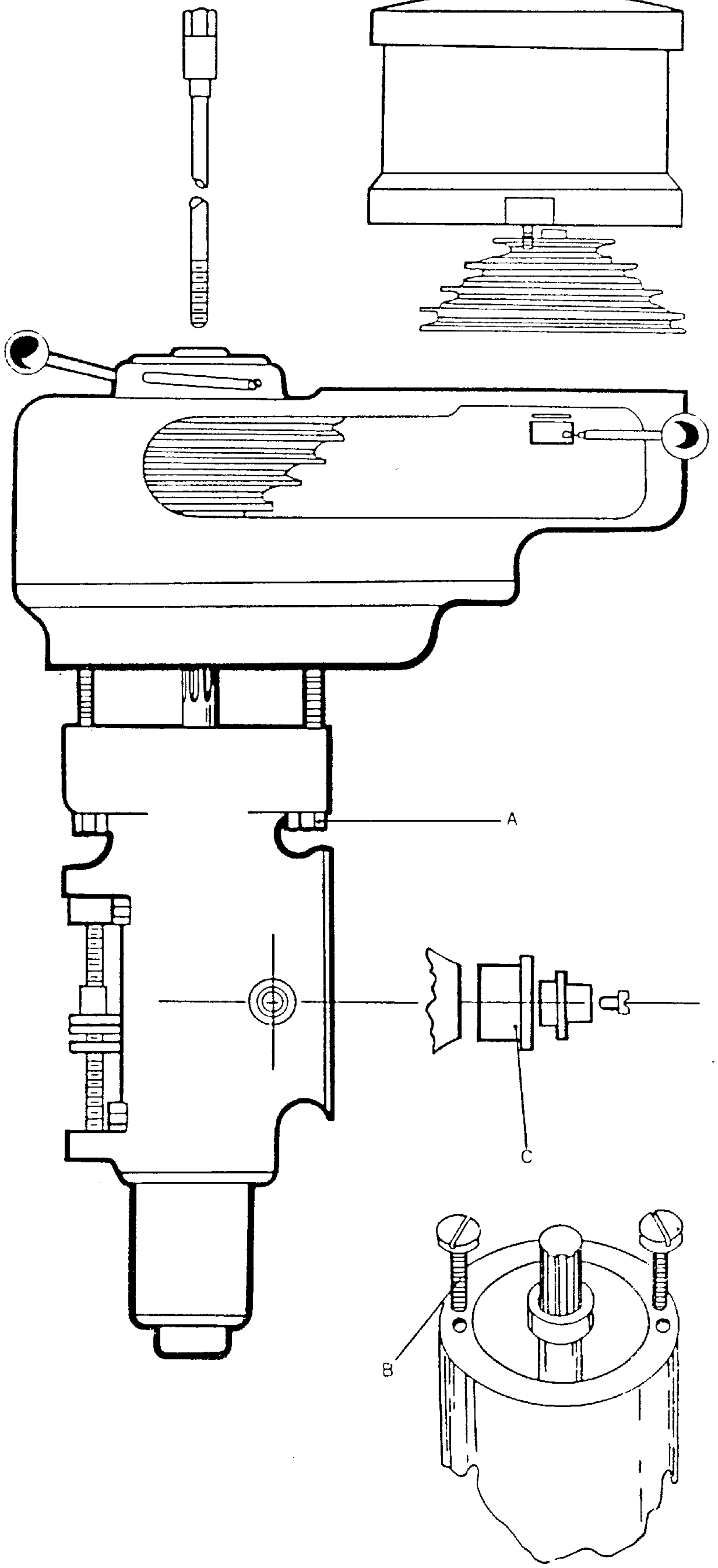


昇降套拆卸法

QUILL REMOVAL

1. 關掉電源。
2. 拆下馬達。
3. 取出拉桿。
4. 昇降套降至最低。
5. 取下三個螺帽 'A' 。
6. 頂部完全地拆出。
7. 取出昇降套頂部兩個螺絲 'B' 。
8. 拆下彈簧座 'C' 。

1. Isolate machine.
2. Remove motor.
3. Remove drawbar.
4. Fully extend quill.
5. Remove 3 nuts 'A'.
6. Remove top section completely.
7. Remove 2 screws 'B' from top of quill.
8. Remove clock spring housing 'C'

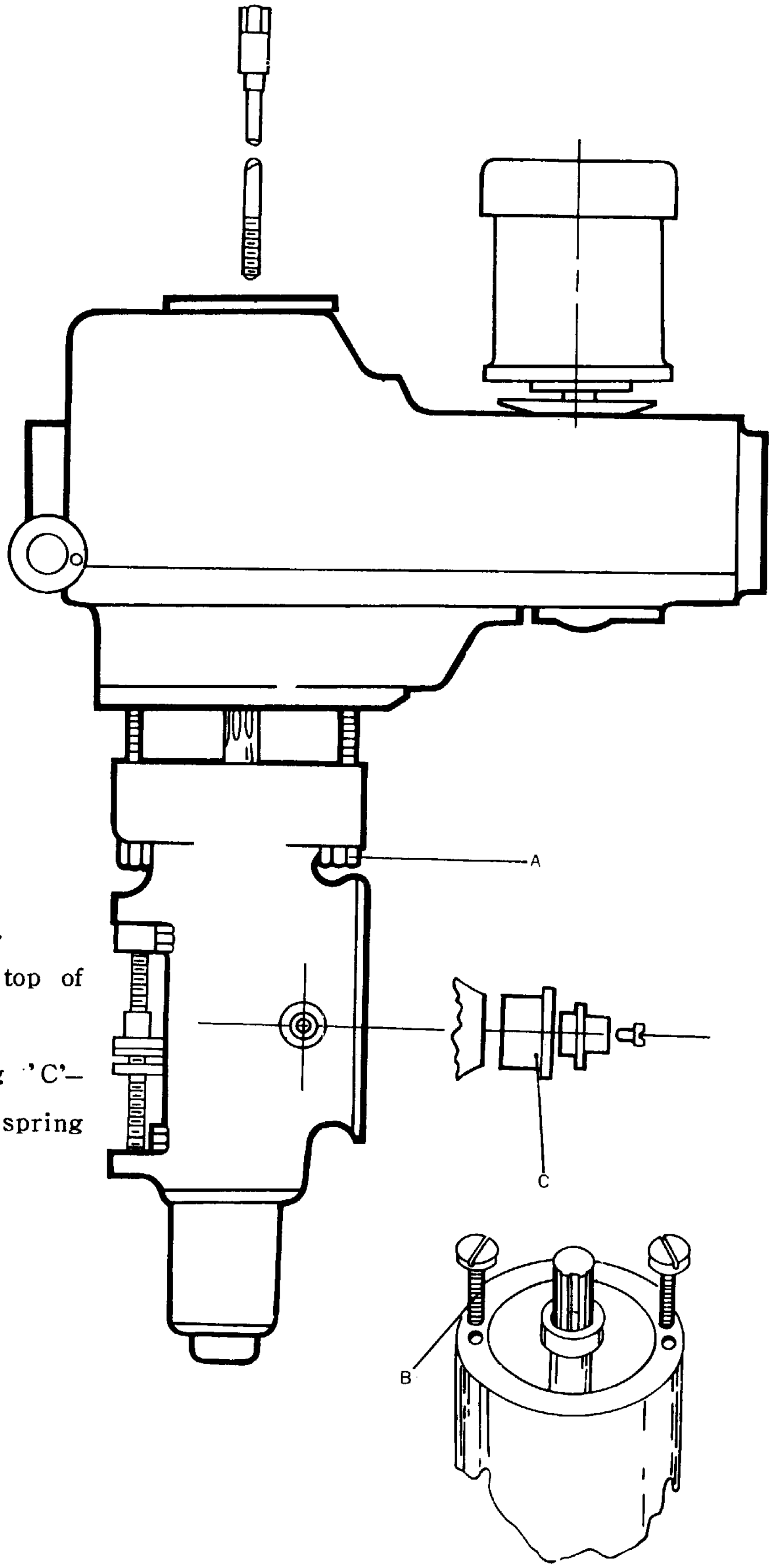


昇降套拆卸法
QUILL REMOVAL

1. 關掉電源。
2. 拆下馬達。
3. 取出拉桿。
4. 昇降套降至最低。
5. 取下三個螺帽 'A'。
6. 頂部完全地拆出。
7. 取出昇降套頂部兩個螺絲 'B'。
8. 拆下彈簧座 'C'。

參看 44 頁更換彈簧說明。

1. Isolate machine.
2. Remove motor.
3. Remove drawbar.
4. Fully extend quill.
5. Remove 3 nuts 'A'.
6. Remove top section completely.
7. Remove 2 screws 'B' from top of quill.
8. Remove clock spring housing 'C'— see instruction on replacing spring page 44.

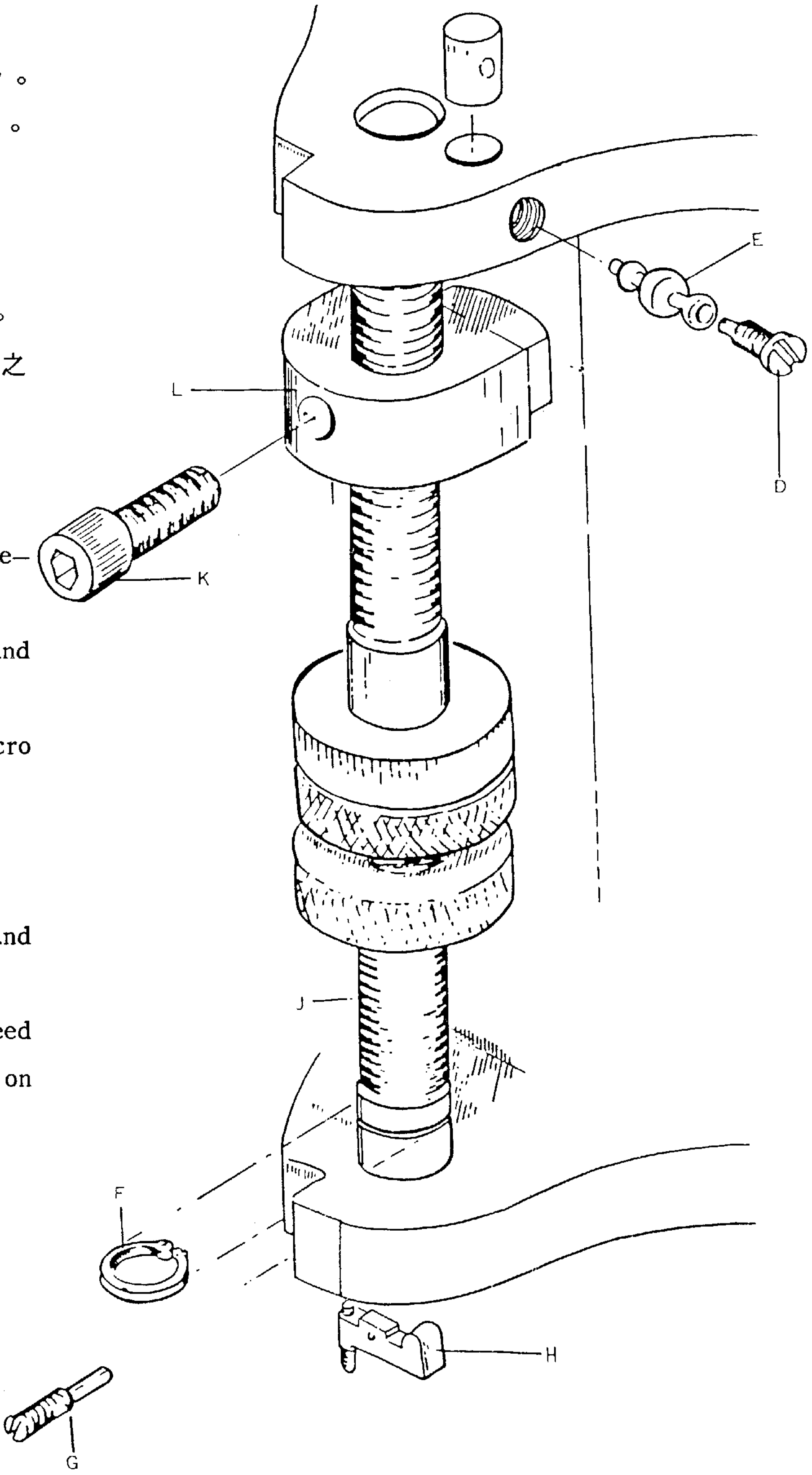


1½ VA—T 1½ VS—T 保養 Maintenance

9. 取下螺絲 'D' 與球形槓桿 'E'。
10. 取下 C 形環 'F'，螺絲 'G' 及臂 'H'。
11. 將螺桿軸 'J' 旋出微動螺帽，並取下。

12. 取下螺絲 'K' 與停止板 'L'。
13. 拆下昇降套。
14. 清潔所有表面，加油，並重新組合。
15. 檢查進給控制桿是否正確，看 45 頁之說明。

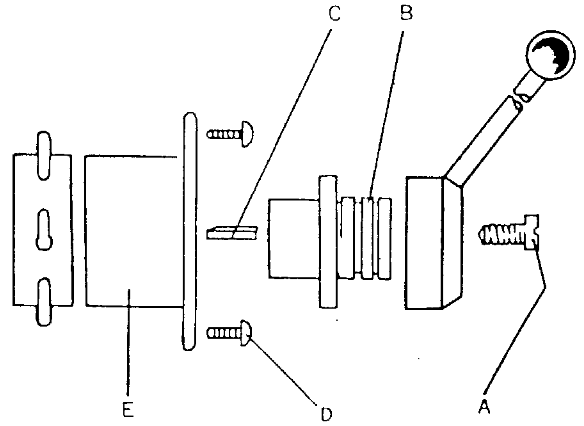
9. Remove screw 'D' and ball reverse lever 'E'.
10. Remove circlip 'F', screw 'G' and arm 'H'.
11. Thread shaft 'J' through micro nuts and remove.
12. Remove screw 'K' and stop 'L'.
13. Remove quill.
14. Clean all areas, oil liberally and reassemble.
15. Check correct operation of feed trip linkage. See instruction on page 45.

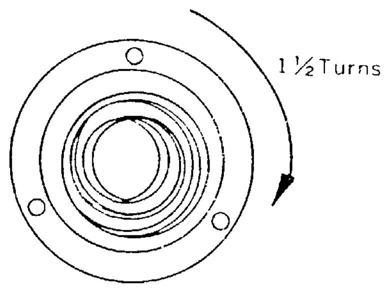


回覆彈簧更換法
BALANCE SPRING REPLACEMENT

1. 移動昇降套於頂部，並固定住。
2. 拆下螺絲'A'，轂'B'及鍵'C'。
3. 拆下螺絲'D'，慢慢轉動座E使彈簧張力得以釋放。
4. 將彈簧之一端從小齒輪軸的釘上提出。
5. 逆時針轉動座'E'（從頭部鑄件來看）。
6. 從座內取出彈簧並更換之。
7. 重新將彈簧組合於座之鑄件上，並應順時針轉動座，直到彈簧進入小齒輪軸之釘上。

1. With quill, at top of movement apply quill lock.
2. Remove screw 'A' ,hub 'B' , and key 'C'.
3. Remove screws 'D', allowing housing to rotate slowly releasing spring tension.
4. Lift end of spring from peg on the pinion shaft.
5. Rotate housing 'E' anti-clockwise from head casting.
6. Remove spring from housing and replace.
7. Refit spring to main housing casting turning housing clockwise until spring locates on peg in pinion shaft.

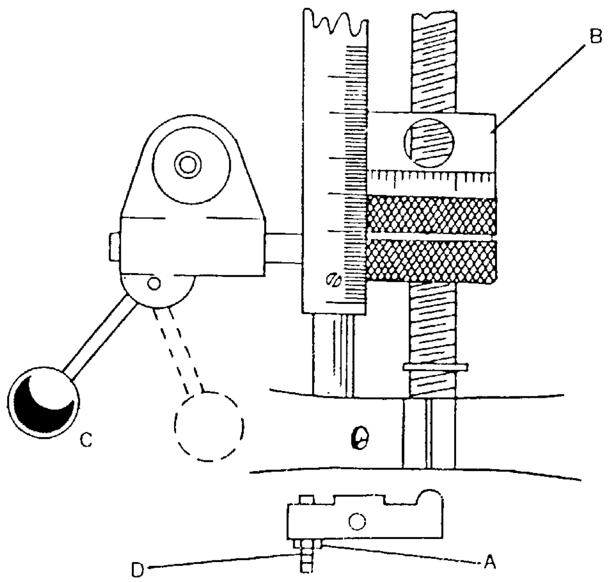




進給控制調整法
FEED TRIP ADJUSTMENT

1. 放鬆固定螺帽 'A' 。
2. 嚙合把手 'C' 。
3. 調整微調螺帽至碰到昇降套停止塊 'B' 。
4. 慢慢轉動調整螺絲 'D' 直到桿 'C' 跳離 。
5. 在此點鎖緊固定螺帽 。
6. 檢查跳動的動作是否正確 。

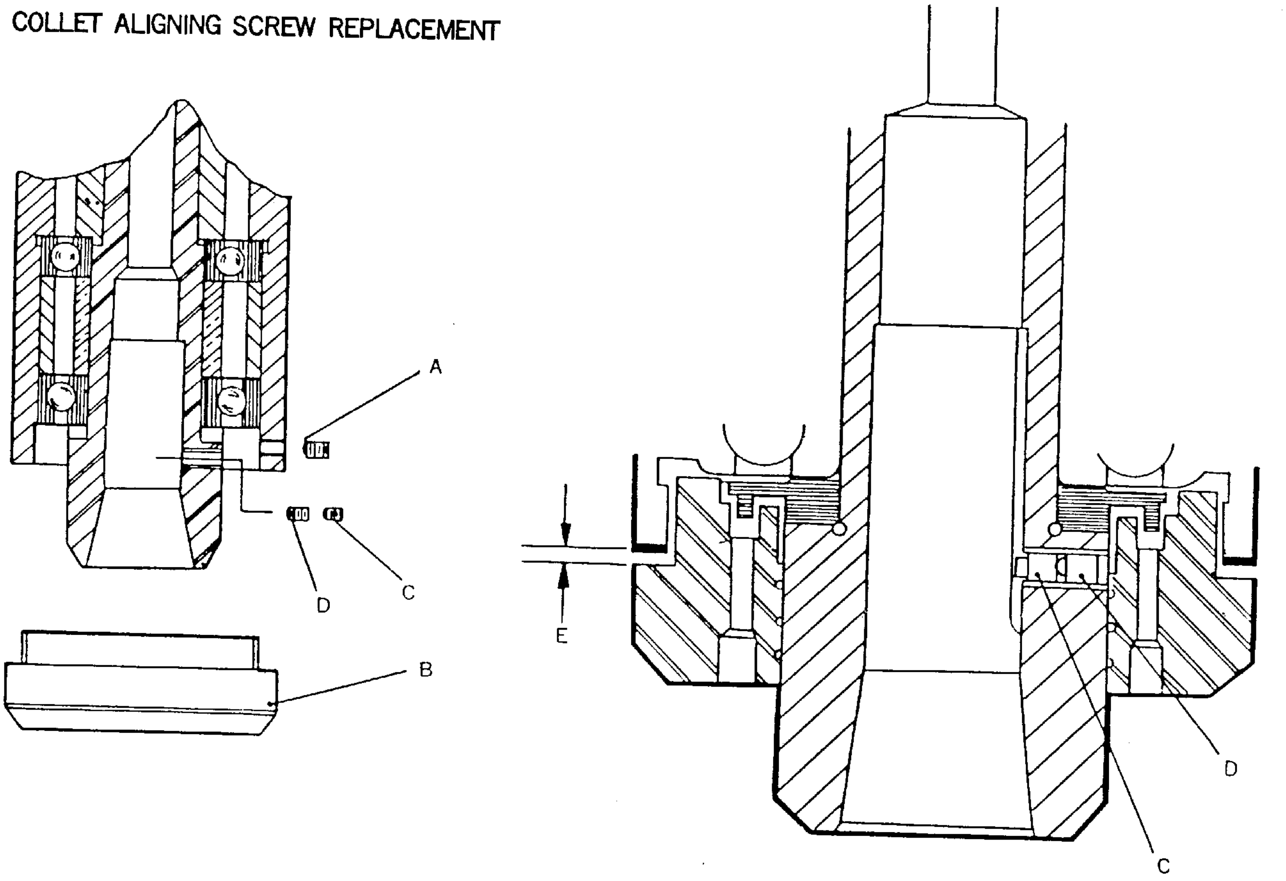
1. Release locknut 'A' 。
2. Engage trip handle 'C'.
3. Adjust micro nuts against quill stop 'B'.
4. Slowly turn adjusting screw 'D' until lever 'C' trips.
5. At this point secure locknut 'A'.
6. Check that smart trip action is obtained.



1 1/2 VA—T 1 1/2 VS—T 保養 Maintenance

筒夾校準螺絲更換法 (R–8 Spindle Taper)

COLLET ALIGNING SCREW REPLACEMENT



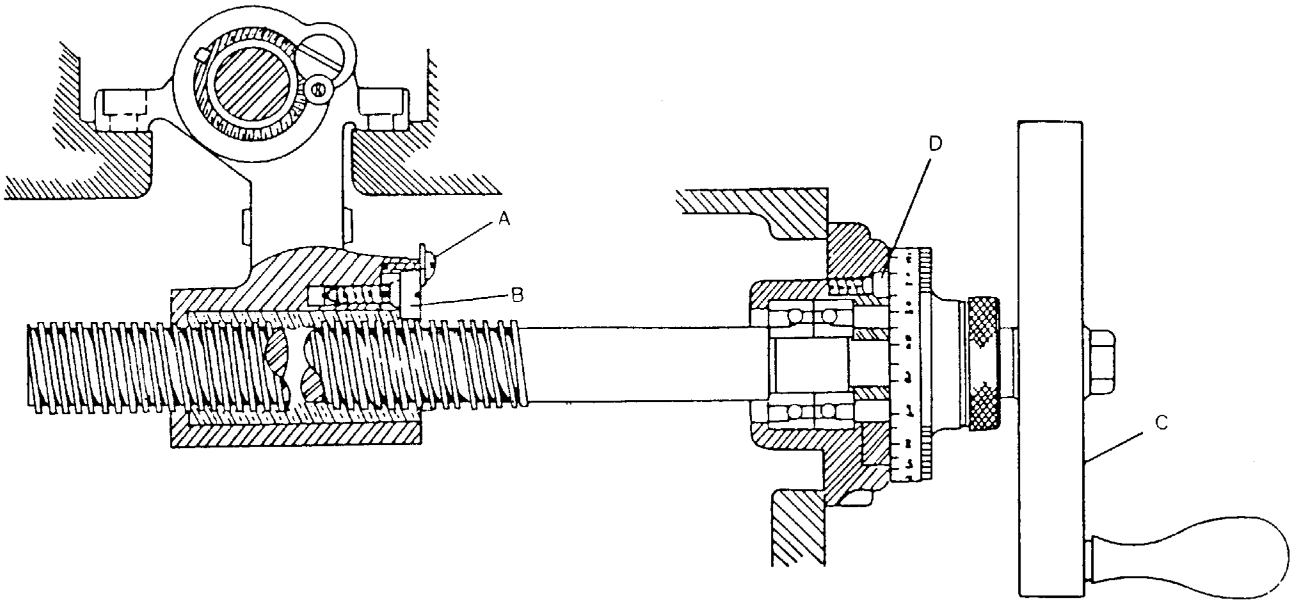
1. 用氈筆在昇降套和主軸端蓋 'B' 劃一參考線。
2. 拆下固定螺絲 'A'。
3. 取下端蓋 'B'。
4. 取下固定螺絲 'C' 與筒夾校準螺絲 'D'。
5. 更換 'D' 套入 R-8 筒夾，並檢查，勿使螺絲末端碰到導槽之底部。
6. 更換固定螺絲 'C'。
7. 重新裝上 'B'，檢查參考線是否對準。
8. 裝上固定螺絲 'A'。

注意：不可鎖太緊免造成變型。

9. 檢查間隙 'E'(0.003" = 0.8mm)。

1. Use felt pen,mark reference line on quill and nose cap 'B'.
2. Remove set screw 'A'.
3. Unscrew nose cap 'B'.
4. Remove lock scew 'C' and collet aligning screw 'D'.
5. Replace 'D' ;insert R-8 collet and check that the dog on the end of the screw does not foul on the bottom of the guide slot.
6. Replace lock screw 'C'.
7. Replace nose cap 'B' ;check felt pen markings for correct alignment.
8. Replace set screw 'A'.
   Caution: do not overtighten as this will cause distortion.
9. Check gap 'E'.(0.003" = .08mm)

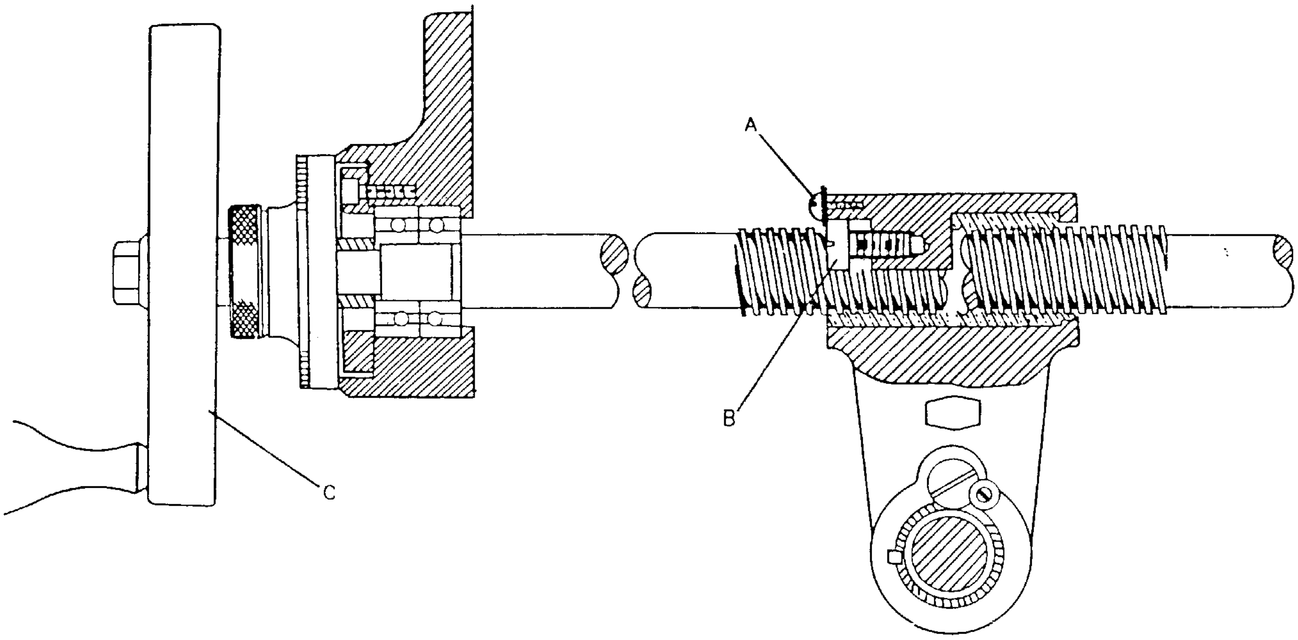
前後進給螺桿間隙調整法
CROSS SCREW BACKLASH ADJUSTMENT



1. 轉動曲柄使鞍座位於中間位置。
2. 旋出四個螺絲 'D'。
3. 將鞍座拉向前，以露出螺絲 'A' 與 'B'。
4. 螺絲 'A' 旋出 1/2 轉。
5. 慢慢轉動手輪 'C'，並鎖緊螺絲 'B' 直到產生間隙 0.004" 或 0.005" 爲止。
6. 將固定螺絲 'A' 鎖於 'B' 上。
7. 最後將鞍座移到昇降座之前方，重新組合四個螺絲 'D'。

1. Crank the saddle to Mid position.
2. Withdraw 4 screws 'D'.
3. Pull the saddle forward to expose screws 'A' & 'B'.
4. Withdraw screw 'A', 1/2 a turn.
5. Whilst slowly turning handle 'C' tighten screw 'B' until 0.004" or 0.005" is obtained.
6. Lock screw 'A' onto 'B'.
7. Finally crank the saddle to the front of the knee and replace 4 screws 'D'.

左右進給螺桿間隙調整法
TABLE SCREW BACKLASH ADJUSTMENT



1. 將工作台移至左方。
2. 螺絲 'A' 旋出 1/2 轉。
3. 慢慢旋轉手輪 'C'，並鎖緊螺絲 'B' 直至產生間隙 0.004" 或 0.005" 爲止。
4. 最後將固定螺絲 'A' 鎖在 'B' 上。

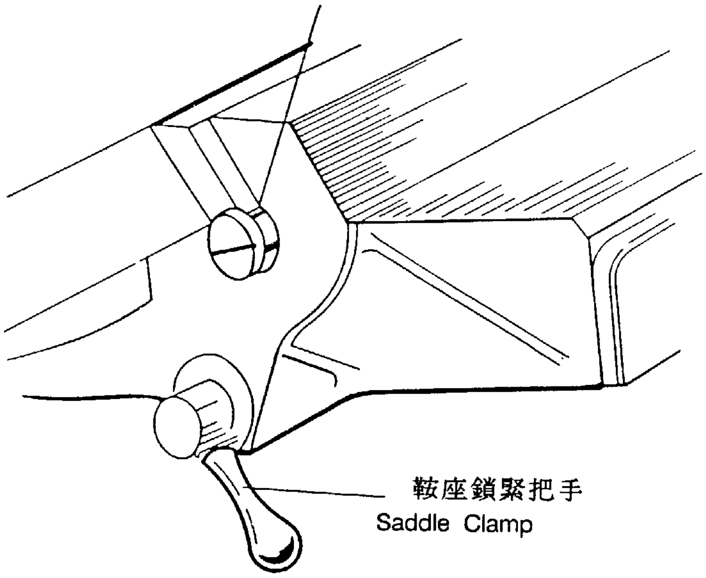
1. Crank the table to the left.
2. Withdraw screw 'A' 1/2 a turn.
3. Tighten screw 'B' whilst slowly turning handle 'C' until 0.004" or 0.005" is obtained.
4. Finally lock screw 'A' on to 'B'.

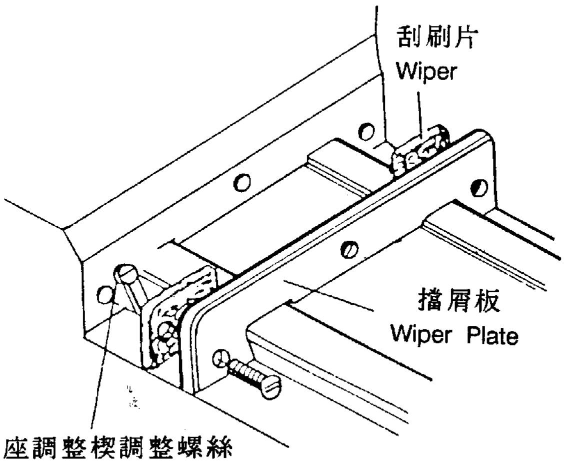
a) 工作台鞍座滑道

1. 清除所有的切削屑。
2. 移動工作台時，順時針轉動工作台調整楔調整螺絲，直到感覺輕微阻力即可。

a) Table Saddle Ways

1. Remove all swarf from area.
2. Turn the table gib screw clockwise while moving the table until slight drag is felt.





b) 鞍座、昇降座滑道

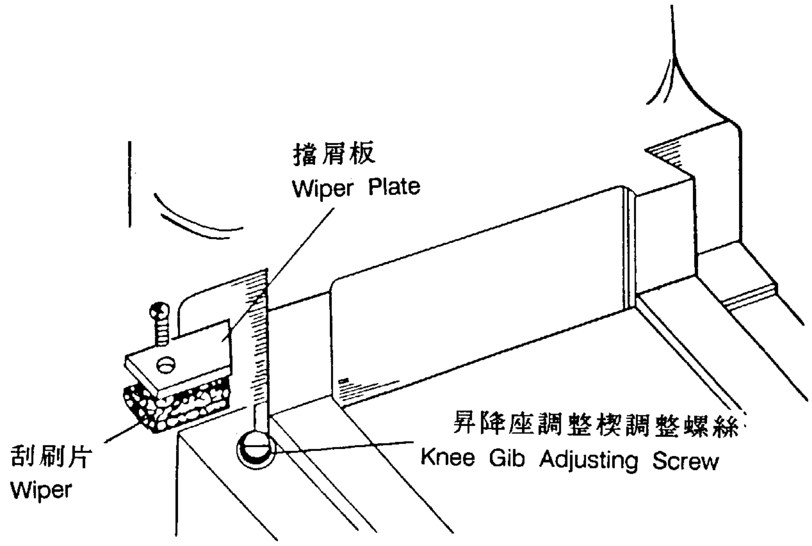
1. 清除所有切削屑。
2. 拆下擋屑板和刮刷片。
3. 移動鞍座時，順時針轉動調整楔螺絲，直至感覺輕微阻力爲止。
4. 重新裝上擋屑板與刮刷片。

b) Saddle Knee Ways

1. Remove all swarf from area.
2. Remove chip wiper guards and wiper.
3. Turn gib adjusting screw clockwise while moving the saddle until slight drag is felt.
4. Ensure chip wiper plate and wiper are re—placed.

C) 昇降座機身滑道

C) Knee Column Ways



1. 清除所有切削屑。
2. 拆下擋屑板。
3. 拆下刮刷片。
4. 移動昇降座時，順時針轉動調整楔螺絲直至感覺輕微阻力爲止。
5. 重新裝上擋屑板與刮刷片。

1. Remove all swarf from area.
2. Remove chip wiper plate.
3. Remove wiper.
4. Turn gib adjusting screw clock—wise while moving knee until slight drag is felt.
5. Ensure wiper plate and wiper are replaced.

1 1/2 VA—T 1 1/2 VS—T 故障排除 Trouble—Shooting

The following chart contains some typical probable troubles of operation, along with the possible cause(s) and remedies for each:

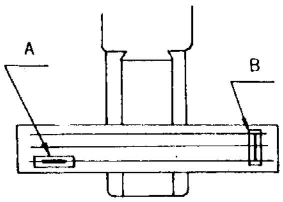
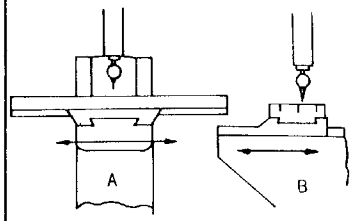
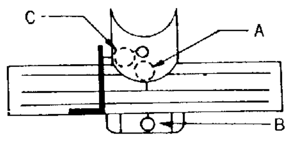
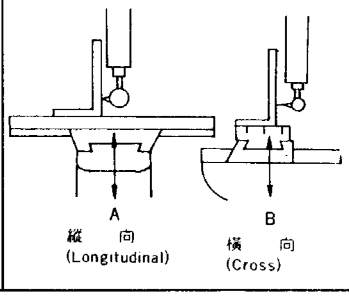
TROUBLE	POSSIBLE CAUSES	REMEDY
Spindle feed stuck	Quill clamp lever not released	Release clamp lever
Spindle brake does not stop spindle	Brake shoes worn out or broken	Replace brake shoes
Spindle not turning	1. Poor contact on the switch 2. Drive belt too slack 3. Poor motor	1. Check the switch 2. Adjust or replace 3. Repair or renew
Incorrect rotation direction of spindle	The switch knob indicated at wrong position	Change to correct position
Table travel feels rough or sticky	1. Gib strip too tight 2. Improper backlash between nut and screws 3. The lubricant not to lubrication point	1. Release gib 2. Adjust backlash 3. Check lubrication
Vibration when machining	1. Machine unstable 2. Unsuitable cutting condition	1. Reclamp 2. Select proper cutting speed according to materials and cutter

1 1/2 VA—T 1 1/2VS—T 故障排除 Trouble—Shooting

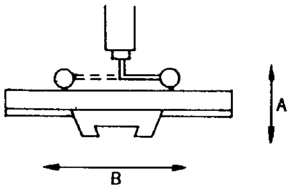
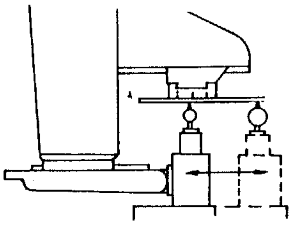
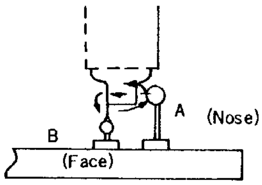
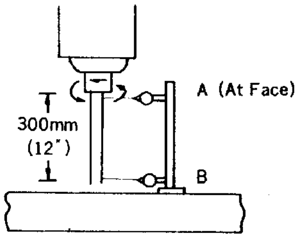
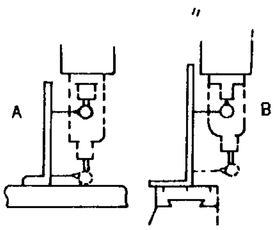
下表所列的是關於在操作時可能發生的故障，及其可能的原因與處理方法。
The following chart contains some typical probable troubles of operation, along with the possible cause(s) and remedies for each.

故障TROUBLE	可能的原因POSSIBLE CAUSES	處理方法REMEDY
主軸進給不順 Spindle feed un-normal	昇降套固定桿未放鬆 Quill clamp lever unrelease.	放鬆固定桿 Release clamp lever.
主軸刹車失靈 Spindle brake brake-down.	刹車環磨損 Brake shoe worn out	更 換 Replace
主軸不轉 Spindle unrotate.	1. 開關接觸不良 Poor contact on the switch. 2. 皮帶太鬆 Drive belt too slack. 3. 馬達出毛病 Poor motor.	1. 檢查電源開關 Check the switch. 2. 調整或更換 Adjust or replace. 3. 修理或更新 Repair or renew.
轉向錯誤 Incorrect rotation.	電源開關扭轉位置不對 The switch knob indicated at wrong position.	轉變開關指示位置 Change to correct position
工作台上下、前後、左右進給不順。 Table vertical, cross, Longitudinal feed unsmooth.	1. 調整楔太緊 Gib strip too tight. 2. 螺帽與螺桿間隙不當 Unproper backlash between nut and screws. 3. 潤滑油未到達潤滑面 The lubricant not to lubrication point.	放鬆調整楔 Release 調整間隙 Adjust 檢查潤滑油路 Check lubrication.
切削時震動 Vibrative when machining.	1. 機械不穩固 Machine unstable. 2. 切削條件不適當 unsuitable cutting condition	重新固定機械 Reclamp 依材質和銑刀大小選適當切削速度 Select proper cutting speed according to materials and cutter.

1½ VA—T 1½VS—T 檢驗規格表 Inspection Chart

番號	檢 查 項 目	圖 示	容 許 差	測 定 值
No	Inspection Items	IIlustrations	Tolerances	Measurements
1	工作台面水平 Plane of Surface Even Level.		Approx.Level 0.06mm/m 0.06mm/m	A. B.
2	工作台移動平行度。 Surface Parallel to its Movements.		A. 0.02mm/500mm (.0008"/20") B. 0.02mm/300mm (.0008"/12")	A. B.
3	T槽側面與縱向移動的平行度。 與橫向移動的垂直度。 T-slots,Front Edge Parallel to Longitudinal Travel, Perpendicular to Cross Travel.		0.02mm/300mm (.0008"/12")	T槽 A.T-Slote 縱向 B.Front C.Cross 橫向
4	昇降座上、下移動與工作台的垂直度。 Vertical Movement of Knee Square to Table Surface.		0.02mm/300mm (.0008"/12")	A. B.

1 1/2 VA—T 1 1/2VS—T 檢驗規格表 Inspection Chart

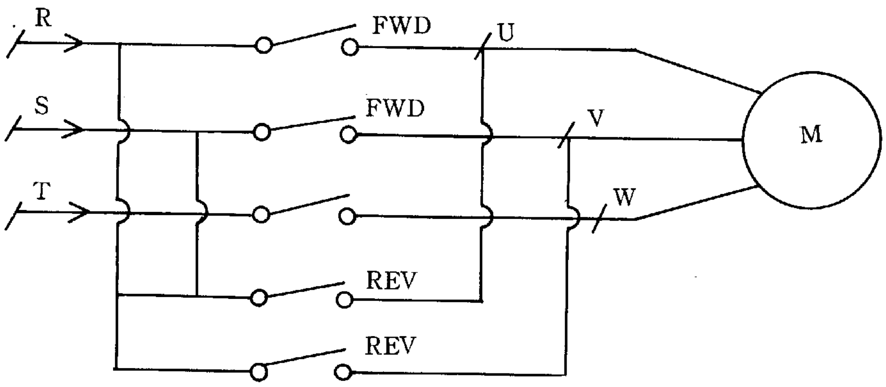
番號	檢 查 項 目	圖 示	容 許 差	測 定 值
No	Inspection Items	IIlustrations	Tolerances	Measurements
5	工作台面與主軸的直角度。 Spindle Perpendicular to top of table		0.02mm/300mm (.0008"/12")	A. ______ B. ______
6	伸出臂與工作台面平行度。 Ram Slide Parallel With Table Top.		0.02mm/300mm (.0008"/12")	______
7	主軸、主軸端面振幅。 Spindle Nose and Face True.		A.0.01mm (.0004') MAX. B.0.01mm (.0004") MAX.	A. ______ B. ______
8	主軸孔偏轉。 Spindle Bore Runout.		A.0.01mm (.0004") MAX. B.0.02mm (.0008") MAX.	A. ______ B. ______
9	昇降套上、下與工作台垂直度。 Quill Travel Square to Table Surface.		A. 0.02mm/300mm (.0008"/12') B. 0.02mm/300mm (.0008"/12")	A. ______ B. ______

1½ VA–T 1½VS–T 檢驗規格表 Inspection Chart

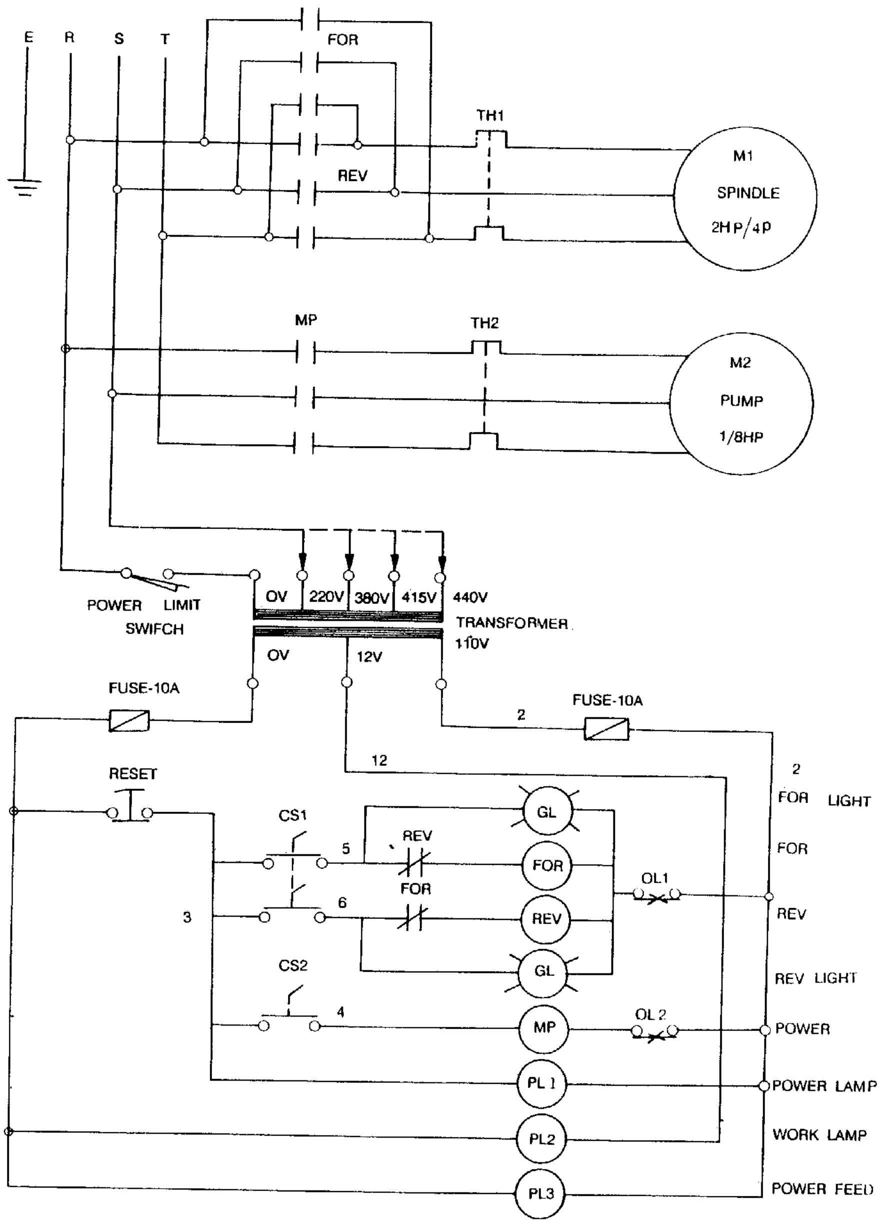
No		項 目 Items
10	在刻度環讀出齒隙。 Backlash-Read on Dials.	允許最大值0.127mm(0.005")MAX. 0.127mm(0.005") 測定讀數： Test Readings: A.縱向導螺桿 A. Long. Lead Screw A.________ B.橫向導螺桿 B.Cross Lead Screw B.________
11	導螺桿： Leadscrews:	最大誤差 Maximum Error: 0.02mm/300mm 0.02mm Per 300mm 或0.0008"/12" or 0.0008" Per 12" 0.04mm或0.0016"總工作長度 0.04mm or 0.0016" Total Overall A.縱向：在300mm(12") A.Longitudinal:At300mm(12")______ 總工作長度 Overall______ B.橫向：在300mm(12") B.Transverse: At 300mm(12")______ 總工作長度 Overall______
12	手動操作 Manual	1) 楔的調整 1) Gibs Adjusted ______ 2) 昇降套昇降的鬆緊度 2) Quill Tight ______ 3) 主軸的齒隙 3) Spindle Backlash ______ 4) 所有移動體移動時的平穩性 4) All Movements Smooth ______ 5) 刀具夾頭裝置情形 5) Collet Fit ______
13	動態試驗 Power	速度 SPEEDS 低LOW HIGH高 1) 自動進給的動作 1) Powerfeed Kickouts ____ ____ 2) 所有移動體移動時的平穩性 2) All Movements Smooth ____ ____ 3) 震 動 3) Vibration ____ ____ 4) 噪音（最大73DB） 4) Sound(73DB Max.) ____ ____ 5) 切削試驗 5) Test Cuts ____ ____ A.面銑 A. Face ____ ____ B.側銑 B. Side ____ ____
14	外 觀 Visual	1) 表面處理 1) Finishes ________ A.噴漆部份 A. Paint ________ B.噴漆部份 B. Machined ________ C.電鍍部份 C. Chrome ________ D.塑膠部份 D. Plastic ________ E.染黑部份 E. Black Oxide ________ 2) 防銹處埋 2) Rustproofing ________
15	電氣方面 Electrical	馬達電壓 Voltage for which Motors ______伏特 Volts 接 頭 connected ________ 頭 部 Head ________ 自動進給附件 Powerfeed ________ 冷卻油泵 Coolant Pump ________

電氣回路圖 Electricity Circuit Diagram

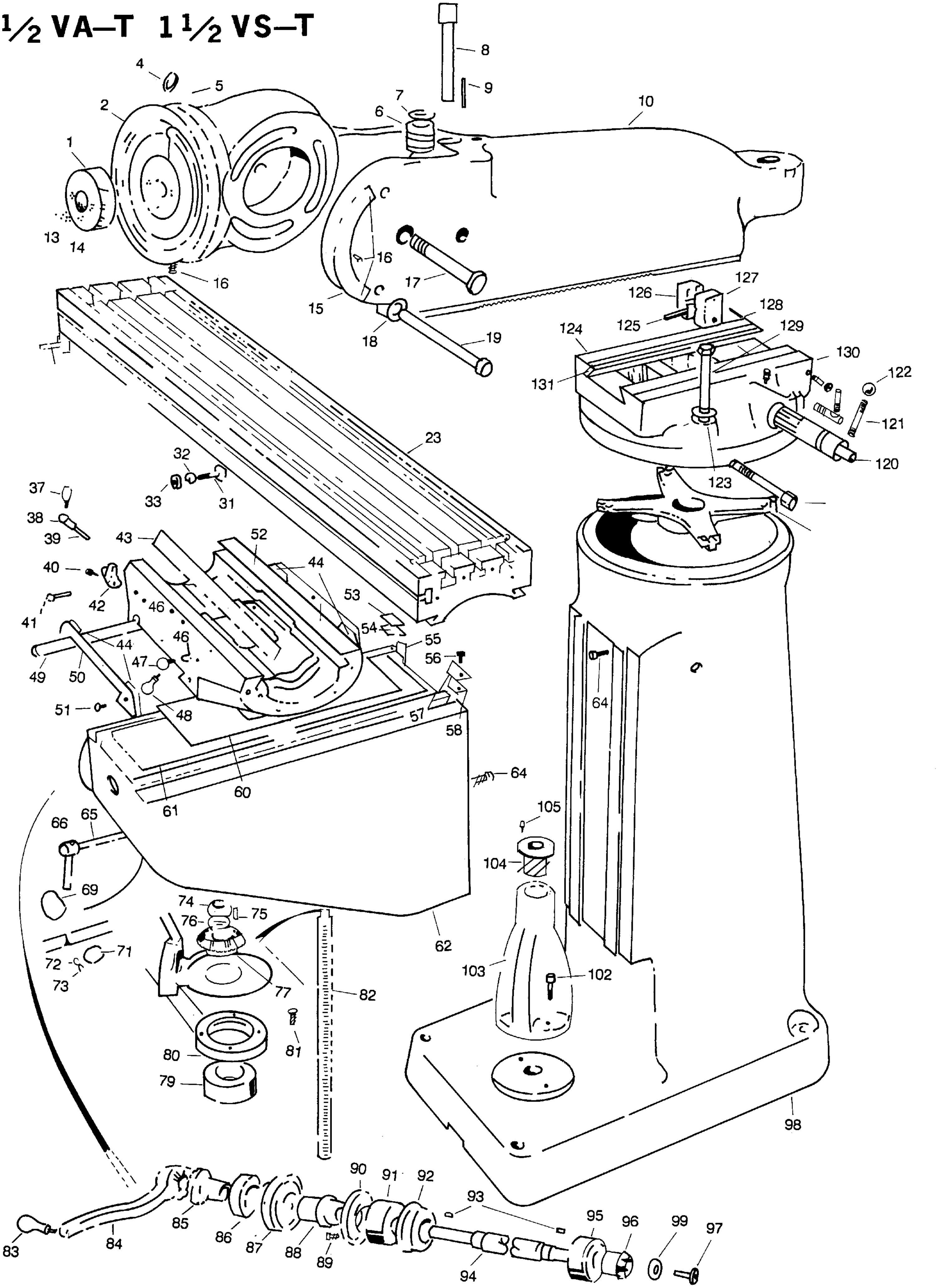
STANDARD



OPTIONAL(CONTROLBOX)



1 1/2 VA—T 1 1/2 VS—T

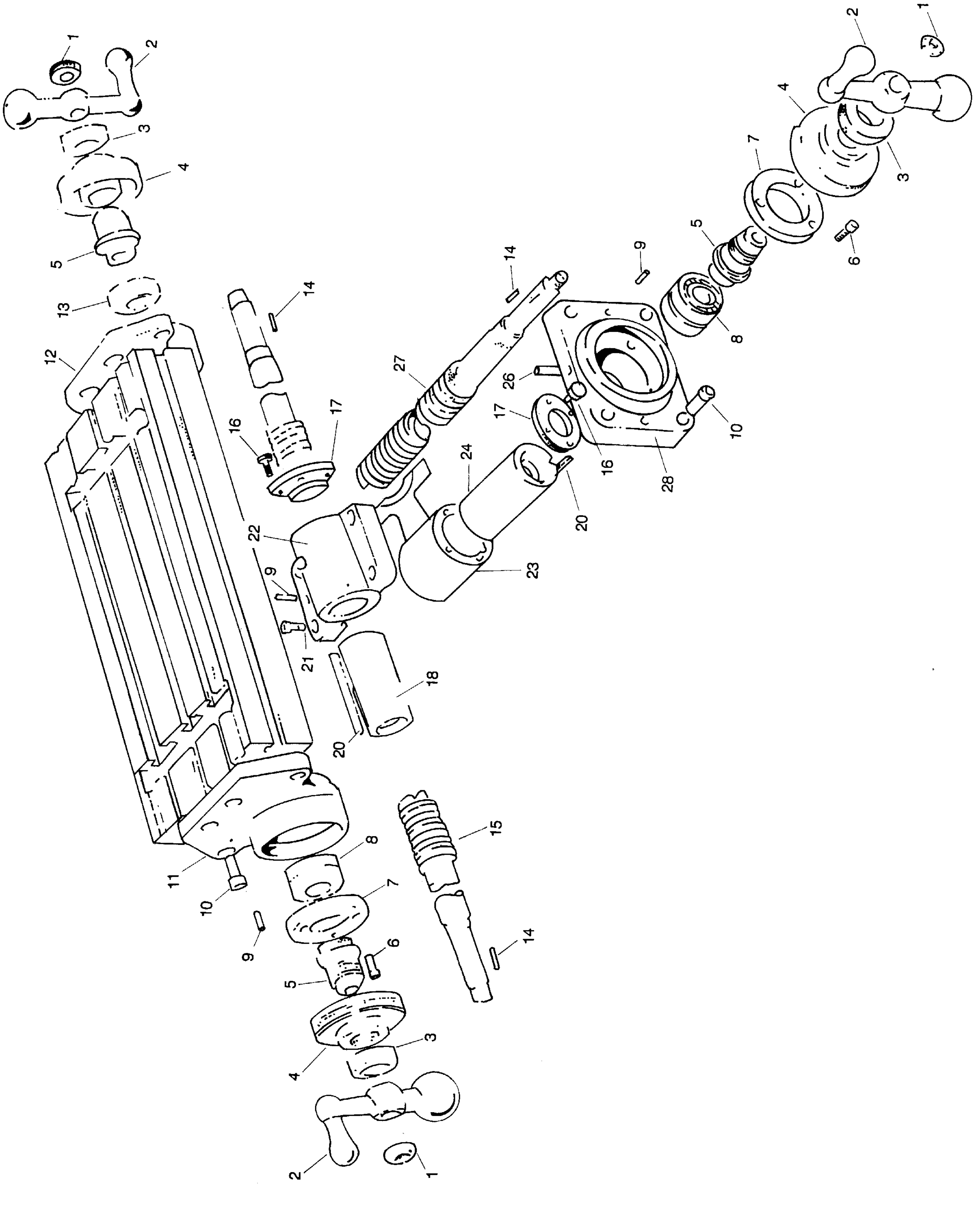


機身組件 Basic Machine Assembly

BASIC MACHINE

ITEM NO.	PARTS NO.	DESCRIPTION
1	5033	Quill Housing ADJ.Gear
2	5019	Ram Adapter
4	5027	Nut
6	5020	Vertical Adjusting Worm
7	5022	Worm Thrust Washer(2 Req.)
8	5021	Vertical Adjusting Worm Shaft
9	5023	Worm Key
10	5018	Ram
13	5035	Socket Cap Screw(2 Req.)
14	5034	Roll Dowel Pin
15	5043	Angle Plate
16	5032	Round HD Drive Screw(5 Req.)
17	5026	Adapter Pivot Pin
18	5029	Chamfered & Hardened Washer (7 Req.)
19	5028	Adapter Locking Bolt(3 Req.)
23	2001	Table 42" or 48"
31	2031	Stop Piece T-Bolt(3 Req.)
32	2030	Table Stop Piece(2 Req.)
33	2032	Hex Nut(3 Req.)
37	3031	Table Lock Bolt Handle
38	3030	Saddle Lock Bolt
39	3032	Saddle Lock Plunger
40	3036	Socket HD Cap Screw(2 Req.)
41	3028	Gib Adjusting Screw(3 Req.)
42	3035	Table Stop Bracket
43	3026	Saddle/Table Gib
44	3037	Felt Wipers(4 Req.)
46	3029	Table Lock Plunger
47	3030	Table Lock Bolt
48	3031	Table Lock Bolt Handle
49	3027	Saddle/Knee Gib
50	3037-2	Saddle Knee Wiper Plate(4 Req.)
51	3038	Oval Head Screw(8 Req.)
52	3001	Saddle
53	4028-2	Left Hand Column Wiper Holder
54	4028-1	Knee Wiper Felt
55	4038	Knee/Column Gib
56	4029	Allen Cap Screw(2 Req.)
57	4028-2	Right Hand Column Wiper Holder
58	4028	Knee Wiper Felt
60	3040	Chip Guards-Upper
61	3039	Chip Guards-Lower
62	4001	Knee 12" Adjusting Worm
64	1001-1	Stop Screw
65	4048	Knee Lock Shaft Assembly
69	4001-1	Knee Lock Plunger
71	4045	Knee Binder Plug(Plastic)
72	4049	Dog Point Set Screw
73	4049	Set Screw
74	4023	Jam Nut
75	4020	Key
76	4022	Washer
77	4019	Bevel Gear
79	4040	Sealed Ball Bearing
80	4039	Bearing Retainer Ring
81	4041	Socket Head Cap Screw
82	4021	Elevating Screw Assembly
83	4003	Handle
84	4002	Elevating Crank
85	4013	Gearshaft Clutch Insert
86	2016	Dial Lock Nut
87	4010	Dial with 100 Graduations
88	4011	Dial Holder
89	4009	Socket Head Cap Screw
90	2011	Bearing Retaining Ring
91	4007	Grease Sealed Bearing
92	4006	Bearing Cap
93	4015	Key
94	4017	Elevating Shaft for 12" Knee
95	4016	Grease Sealed Bearing
96	4014	Bevel Pinion
97	4042	Set Screw
98	1001	Column
99	4017-1	Washer
102	4027	Socket Head Cap Screw
103	4026	Pedestal
104	4024	Elevating Screw Nut
105	4025	Socket Head Cap Screw
118	5003	Spider
119	5009-1	Ram Lock Stud
120	5012	Ram Pinion
121	5013	Ram Pinion Handle
122	5014	Plastic Ball
123	5005	Chamfered X Hardened Washer
124	5001	Turret
125	5002-3	Ram Clamp Bar
126	5002-1	Ram Clamp Untapped
127	5002-2	Ram Clamp Tapped
128	5002-4	Split Pin
129	5004	Locking Bolt
130	5015	Ram Pinion Screw
131	5002	Ram/Turret Gib

1½ VA—T 1½ VS—T



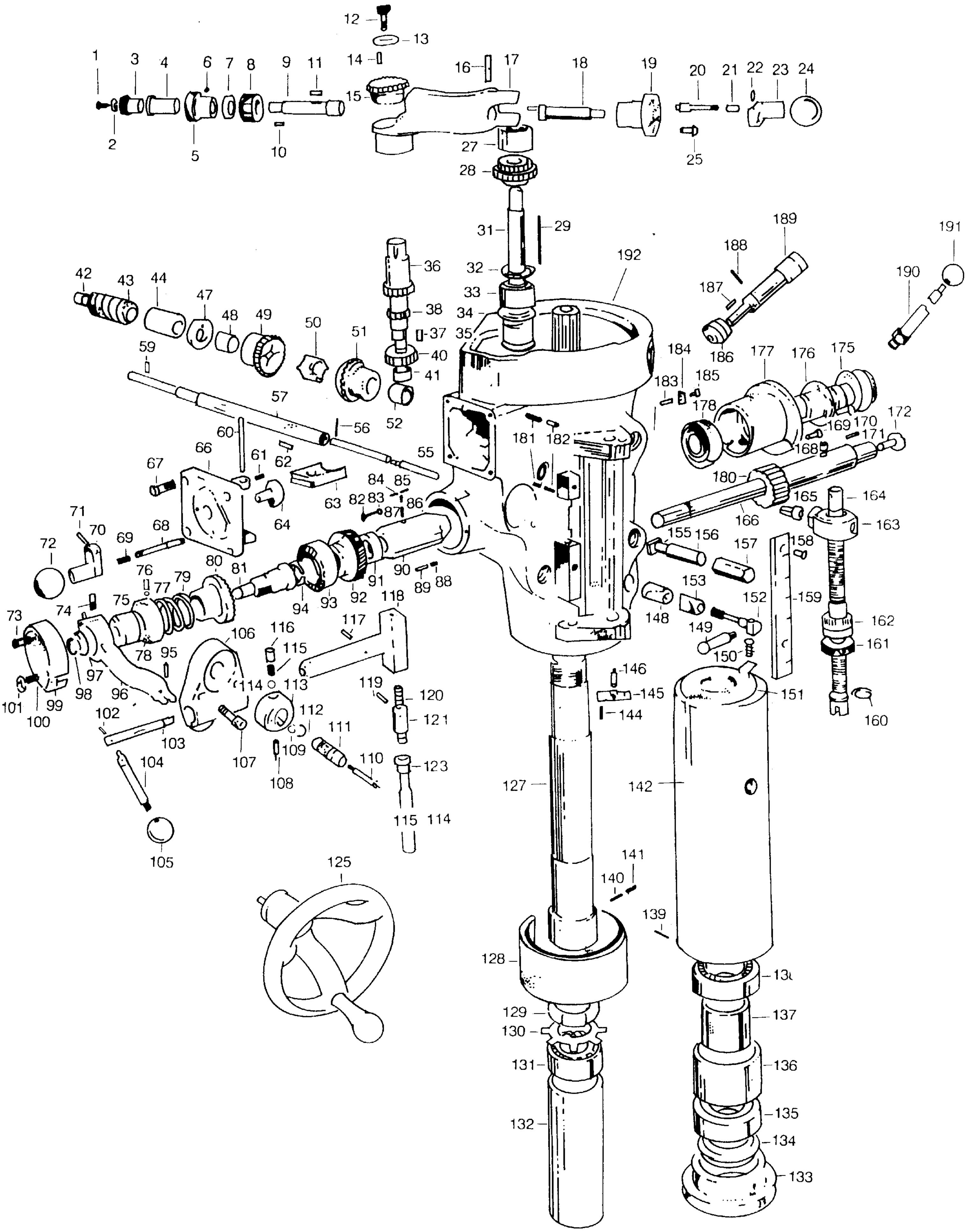
螺桿組件Leadscrew Assembly

 $1\frac{1}{2}$ VA—T

LEADSCREW ASSEMBLY

ITEM NO.	PARTS NO.	DESCRIPTION
1	2004	Jam Nut(3 Req.)
2	2018	Ball Crank Handle(3 Req.)
3	2004	Dial Lock Nut(3 Req.)
4	2012	Dial with 200 Graduations(3 Req.)
5	2014	Dial Holder(3 Req.)
6	2036	Socket Cap Screw(6 Req.)
7	2011	Bearing Retainer Ring(2 Req.)
8	2008	Grease Sealed Ball Bearings(2 Req.)
9	2027	Roll Pin(10 Req.)
10	2026	Socket Cap Screw(12 Req.)
11	2006	Left Bearing Bracket
12	2006	Right Bearing Bracket
13	2008	Grease Seal Ball Bearing
14	2003	Key(3 Req.)
15	2002	Longitudinal Feed Screw 42" or 48"
16	3021	Socket Cap Screw(8 Req.)
17	3019	Cross Feed Nut Retaining Plate(2 Rcq.)
18	3020	Longitudinal Feed Nut
20	3041	Key(2 Req.)
21	3024	Socket Cap Scre(8 Req.)
22	3023	Longitudinal Feed Nut Bracket
23	3022	Cross Feed Nut Bracket
24	3020	Cross Feed Nut
26	3005-1	Stop Screw
27	3002	Cross Feed Screw for 12" Knee
28	3005	Cross Feed Bearing Bracket

1½ VA—T 1½ VS—T

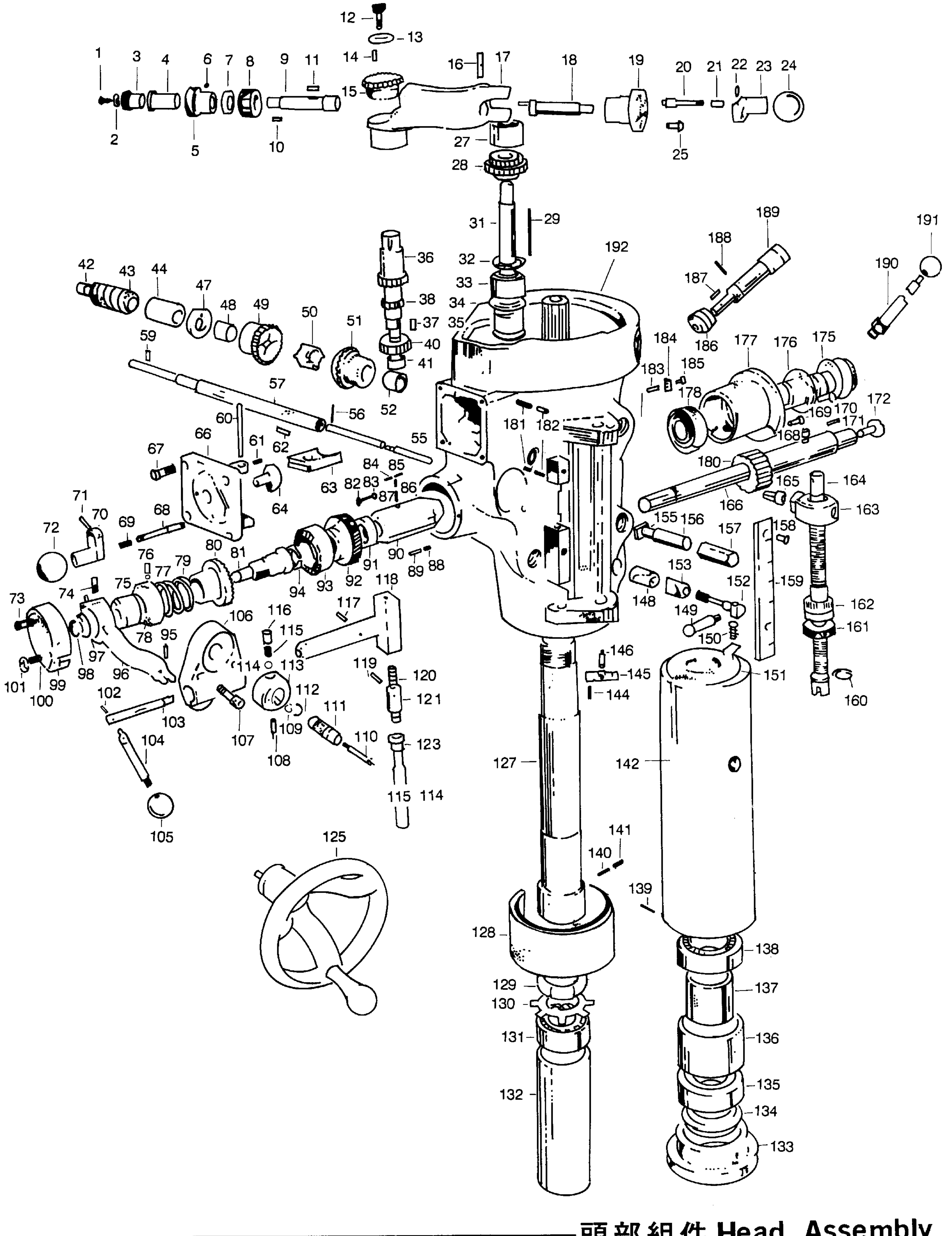


頭部組件 Head Assembly

$1\frac{1}{2}$# HEAD

ITEM NO.	PARTS NO.	DESCRIPTION
1	6141	RD.HD.Screw
2	6140	Bevel Pinion Washer
3	6139	Feed Bevel Pinion
4	6138	Feed Worm Gear Shaft Sleeve
5	6137	Worm Cradle Bushing
6	6123	Setscrew
7	6136	Worm Gear Spacer(4 Req.)
8	6134	Feed Drive Worm Gear
9	6133	Feed Drive Worm Gear Shaft
10	6142	Worm Shaft Key
11	6135	Key
12	6150	Locknut
13	6149	Washer
14	6147	Cluster Gear Key
15	6148	Feed Reverse Bevel Gear
16	6122	Feed Engage Pin
17	6121	Worm Gear Cradle
18	6126	Worm Gear Cradle Throw-out
19	6125	Shift Sleeve
20	6169	Gearshift Plunger
21	6170	Compression Spring
22	6128	Roll Pin
23	6168	Shift Crank
24	6131	Black Plastic Ball
25	6132	Cap Screw(3 Req.)
27	6157	Cluster Gear Shaft Upper Bearing
28	6153	Cluster Gears Assembly
29	6160	Cluster Gear Key
31	6151	Cluster Gear Shaft
32	6158	Snap Ring
33	6156	Bevel Gear Bearing
34	6159	Bevel Gear Thrust Spacer
35	6151	Feed Reverse Bevel Pinion
36	6143	Feed Driving Gear
37	6145	Key
38	6143	Cluster Gear Input Shaft
40	6144	Feed Drive Gear
41	6252	Needle Bearing
42	6227	Bushing
43	6225	Worm
44	6224	Feed Worm Shaft Bushing
47	6223	Feed Worm Shaft Thrusher
48	6220	Bushing
49	6220	Feed Reverse Bevel Gear
50	6222	Feed Reverse Clutch
51	6220	Feed Reverse Bevel Gear
52	6220	Bushing
55	6216	Reverse Clutch Rod
56	6217	Roll Pin
57	6209	Feed Worm Shaft
59	6226	Pin
60	6163	Feed Shift Rod
61	6164	KP.Set Screw
62	6230	Key
63	6162	Feed Gear Shift Fork
64	6166	Cluster Gear Shift Crank
66	6161	Cluster Gear Cover
67	6165	Cap Screw(4 Req.)
68	6169	Gear Shift Plunger
69	6170	Compression Spring
70	6168	Shift Crank
71	6167	Roll Pin
72	6171	Black Plastic Ball
73	6206	Cap Screw(2 Req.)
74	6202	Clutch Ring Pin(2 Req.)
75	6200	Clutch Ring
76	6199	Socket Set Screw
77	6199-1	Brass Plug
78	6198	Overload Clutch Locknut
79	6197	Safety Clutch Spring
80	6194	Overload Clutch
81	6195	Overload Clutch Sleeve
82	6190	Single Spring Washer(3 Req.)
83	6189	Round Head Screw(3 Req.)
84	6228	Mock-it Lockscrew
85	6228	Socket Set Screw
86	6246	Lockscrew
87	6246-1	Socket Set Screw
88	6191	Compression Spring
89	6193	Overload Clutch Lever Spring Plunger
90	6186	Quill Pinion Shaft Bushing
91	6190	Pinion Shaft Worm Gear Spacer
92	6187	Overload Clutch Worm Gear
93	6188	Overload Clutch Ring
94	6188-1	Snap Ring
95	6236-1	Dowel Pin
96	6203	Overload Clutch Trip Lever
97	6201	Overload Clutch Washer
98	6195-1	Snap Ring
99	6205	Clutch Arm Cover
100	6207	Socket Set Screw
101	6208	Chem Blacked Locknut
103	6239	Cam Rod
104	6234	Trip Handle
105	6233	Black Plastic Ball
106	6231	Feed Trip Bracket
107	6232	Cap Screw(2 Req.)
108	6219	Socket Set Screw
109	6229	Key
110	6214	Feed Reverse Knob Stud
111	6213	Reverse Knob
112	6215	Snap Ring
113	6218	Handwheel Clutch
114	6255	Steel Ball

1 1/2 VA–T 1 1/2 VS–T



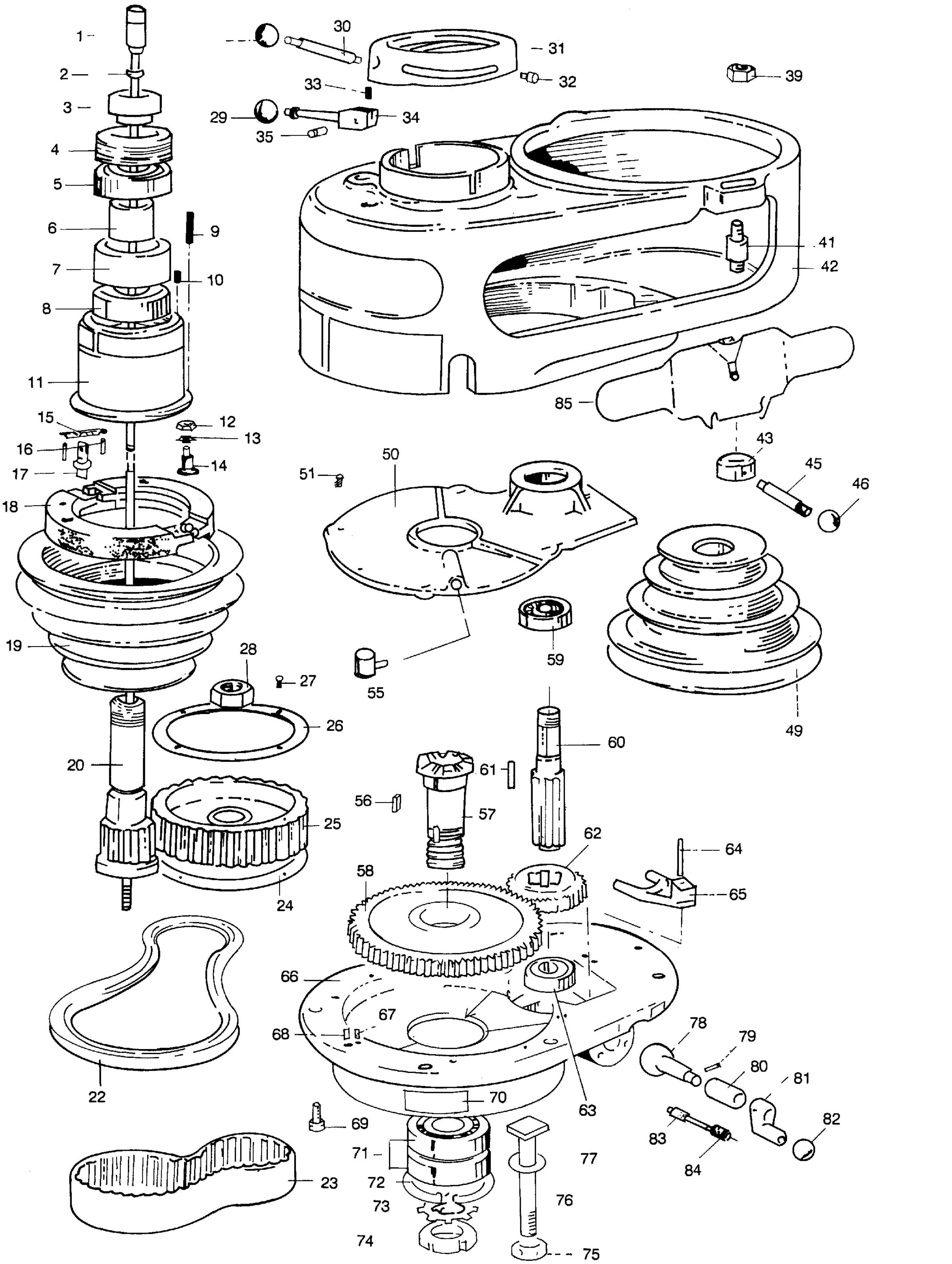
頭部組件 Head Assembly

1 1/2# HEAD (CONTINUED)

ITEM NO.	PARTS NO.	DESCRIPTION
115	6219-2	Compression Spring
116	6219-1	Handwheel Clutch Spring Screw
117	6237	Roll Pin
118	6236	Cam Rod Sleeve Assy.
119	6241	Roll Pin
120	6242	Compression Spring
121	6240	Trip Plunger
123	6118-1	Trip Plunger Bushing
124	6118	Feed Trip Plunger
125	6210	Handwheel
127	6084	Spindle
128	6086	Quill Skirt
129	6090	Locknut
130	6091	Lockwasher
131	6092	Bearing
132	6094	Sleeve
133	6098	Nose-piece
134	6097	Spindle Dirt Shield
135	6093	Bearing
136	6095	(Bearing Spacer-Large)
137	6096	(Bearing Spacer-Small)
138	6093	Bearing
140	6253	Special Socket Set Screw
141	6254	Collet Alignment Screw
142	6085	Quill
144	6113	Socket Set Screw
145	6111	Feed Trip Lever
146	6112	Trip Lever Pin
148	6116	Quill Lock Sleeve
149	6119	Lock Handle
151	6088	Felt Washer
152	6117	Quick Lock Bolt
153	6116	Quill Lock Sleeve Tapped
155	5036	T-Bolt Assy.
156	6120	Lower Clamping Bolt Spacer (2 Req.)
157	5038	Locknut

ITEM NO.	PARTS NO.	DESCRIPTION
158	6244	Chem Blacked RD.HD. Screws (2 Req.)
159	6243	Micrometer Scale
160	6115	Snap Ring
161	6108	Quill Micro-stop Nut
162	6107	Micrometer Nut
163	6105	Quill Stop Knob
164	6104	Quill Stop Micro-screw
165	6106	Screw
166	6172	Quill Pinion Shaft
168	6185	Spring Pin
169	6180-	1 RD.Head Screw(2 Req.)
170	6179	Roll Pin
171	6184	Key
172	6183	Pinion Shaft Hub Screw
173	6176	Steel Ball
174	6175	Compression Spring
175	6178	Rack Feed Handle Hub
176	6182	Pinion Shaft Hub Sleeve
177	6180	Spring Cover
178	6181	Clock Spring(Clock Spring Assy.)
180	6172	Quill Pinion
181	6246-	1 Socket Set Screw
182	6246	Lockscrew
183	6110	Reverse Trip Ball Lever
184	6109	Feed Reverse Trip Plunger
185	6114	Reverse Trip Ball Lever Screw
186	5039	Worm Gear
187	5041	Key
188	5042	Sooket Set Screw
189	5040	ADJ Worm Shaft
190	6174	Pinion Shaft Hub Handle
191	6173	Black Plastic Ball Handles
192	6101	Quill Housing

1 1/2 VA—T

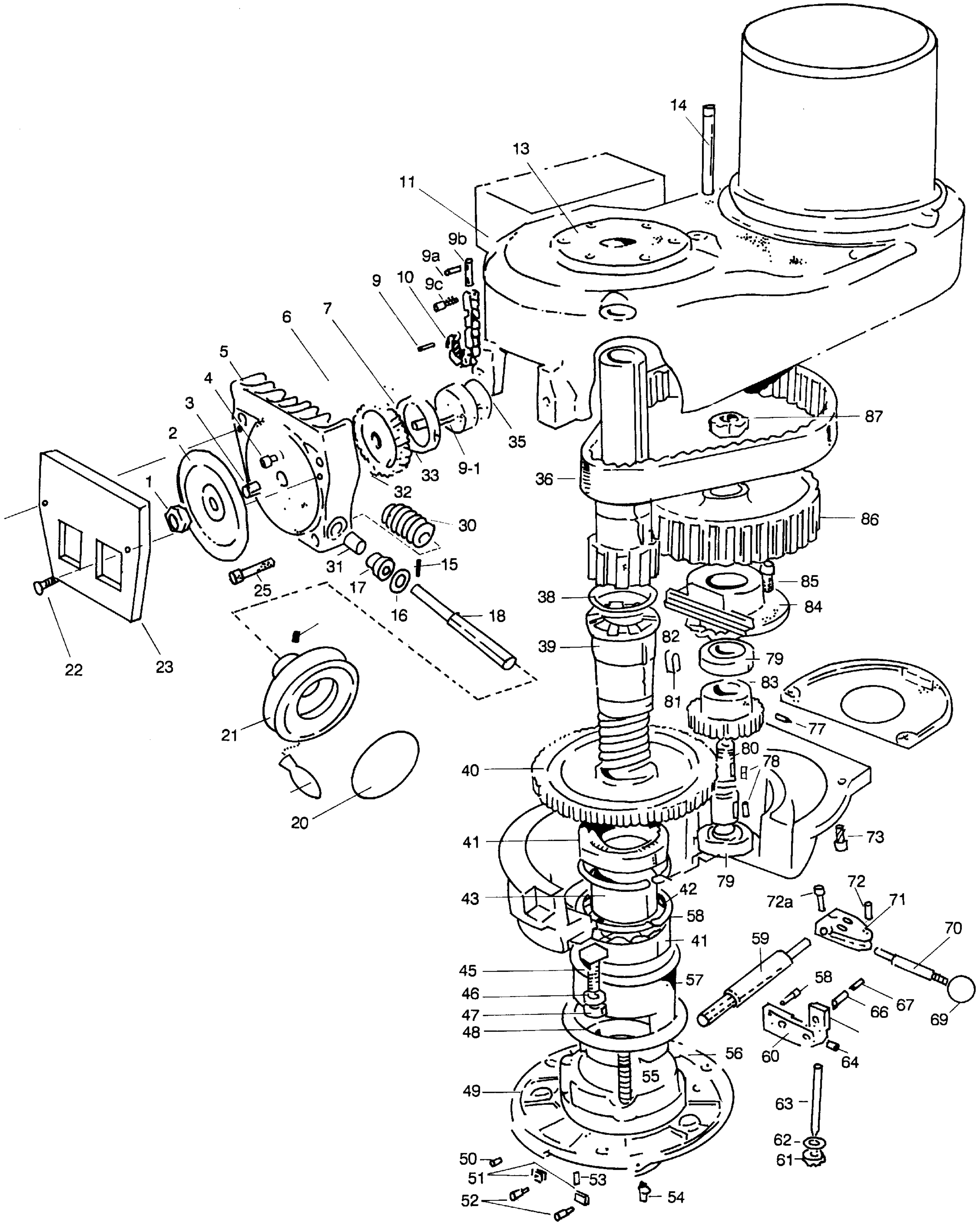


頭部頂座 Head Top Housing

HEAD TOP HOUSING

ITEM NO.	PARTS NO.	DESCRIPTION
1	6031	Drawbar for R.8 Collet
2	6032	Drawbar Washer
3	6041	Upper Bearing Locknut
4	6042	Bearing Sleeve Locknut
5	6043	Ball Bearing
6	6044	Upper Bearing Spacer(small)
7	6045	Upper Bearing Spacer(large)
8	6043	Ball Bearing
9	6049	Compression Spring(4 Req.)
10	6049	Socket Set Screw(2 Req.)
11	6047	Spindle Pulley Bearing Sleeve
12	6019	Jam Nut
13	6022	External Lock Washer
14	6018	Brake Ring Screw(3 Req.)
15	6024	Spring(2 Req.)
16	6025	Machine Screw(4 Req.)
17	6020	Brake Lock Stud
18	6014	Brake Assembly
19	6048	Spindle Pulley
20	6040	Spindle Pulley Hub
22	6034	'V' Belt
23	6035	Timing Belt
24	6072	Timing Belt Pulley Flange
25	6071	Timing Belt Pulley
26	6072	Timing Belt Pulley Flange
27	6073	Flat Head Screw
28	6070	Hex Jam Nut
29	6038	Black Plastic Ball Handle (2 Req.)
30	6037	Spindle Clutch Lever
31	6036	Cam Ring
32	6039	Cam Ring Pin(2 Req.)
33	6023	Socket Set Screw
34	6016	Brake Lock Handle
35	6021	Brake Lock Pin
39	6008	Hex Jam Nut(2 Req.)
41	6002	Motor Mounting Studs(2 Req.)
42	6013	Belt Housing
43	6003	Motor Locknut(2 Req.)
45	6006	Motor Locknut Handle(2 Req.)
46	6007	Black Plastic Ball(2 Req.)
49	6009	Motor Pulley
50	6078	Gear Housing Cover
51	6080	Round HD Screw(5 Req.)
55	6079	Oil Cup
56	6075-1	Bull Gear Key
57	6075	Splined Gear Hub
58	6074	Spindle Bull Gear A[illegible]mbly
59	6056	Bearing
60	6068	Countershaft
61	6069	Key
62	6067	Countershaft Gear
63	6056	Bearing
64	6066	Dowel Pin
65	6065	Back Gear Shifter Fork
66	6050	Gear Housing
67	6051	Dowel Pin(2 Req.)
68	6052	Roll Pins(2 Req.)
69	6057	Socket Cap Screw(6 Req.)
71	6053	Ball Bearing
72	6054	Snap Ring
73	6077	Lockwasher
74	6076	Bearing Locknut
75	6083	Hex Nut Hardened (3 Req.)
76	6081	Vertical Tee Bolt(3 Req.)
77	6082	Vertical Bolt Washer(3 Req.)
78	6060	Back Gear Shift Crank
79	6167	Roll Pin
80	6058	Back Gear Shift Bushing
81	6168	Shift Crank
82	6171	Black Plastic Ball 1" Dia
83	6169	Gearshift Plunger
84	6170	Compression Spring
85	6026	Belt Guard Assembly

1 1/2 VS—T

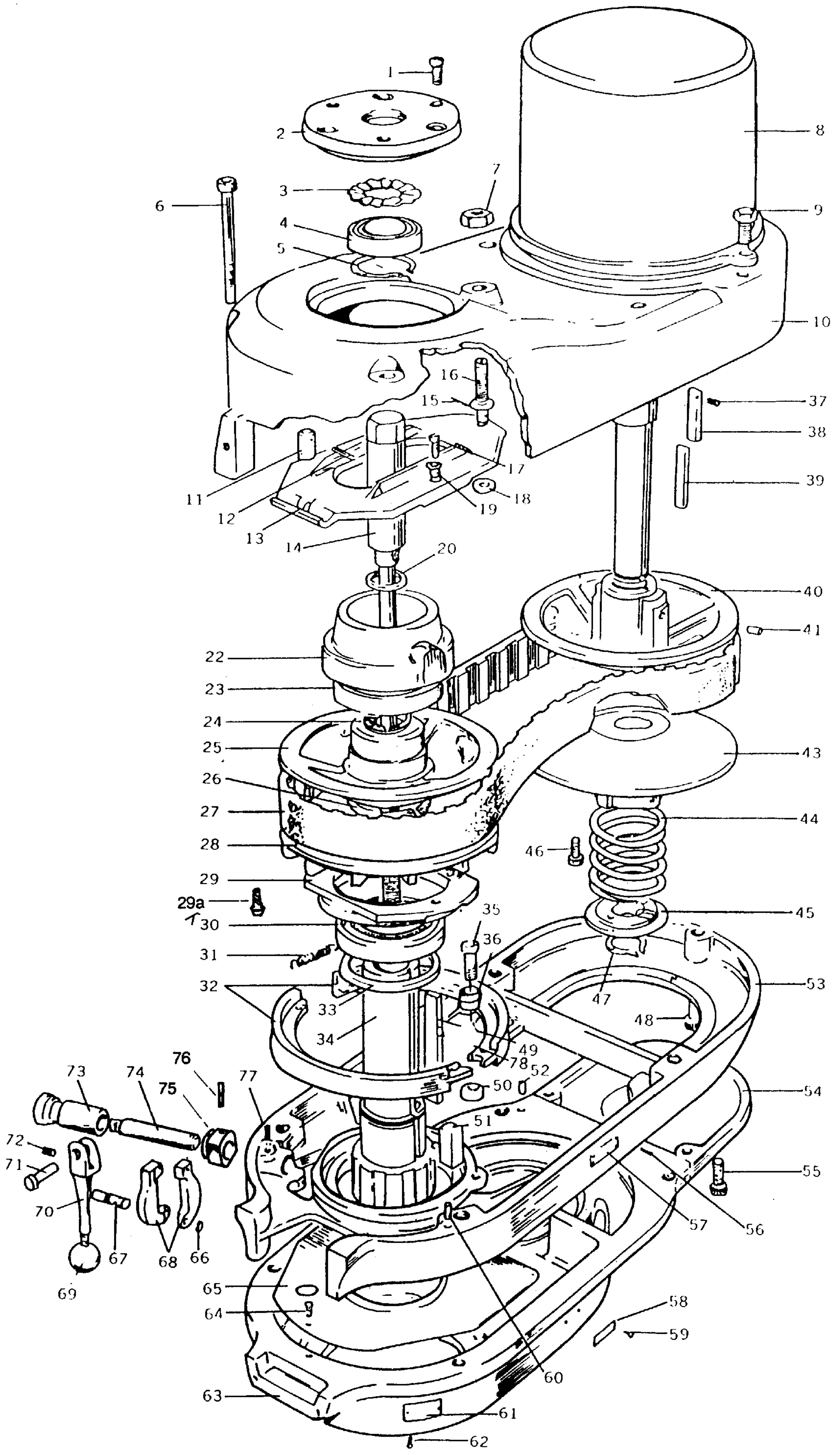


Head Top Housing

HEAD TOP HOUSING

ITEM NO.	PART NO.	DESCRIPTION
1	7101	Hex Cap Nut
2	7102	Vari-Speed Dial
3	7103	Bronze Bearing
4	7104	Full Dog Socket Set Screw
5	7105	Speed Changer Housing
6	7106	Speed Changer Chip Shield
7	7107	Machine Screws(2 Req.)
9	7108	Roll Pin
9-1	7109	Roll Pin
9a	7110	Roll Pin
9b	7111	Speed Change Stud
9c	7112	Cotter Pin
10	7113	Speed Changer Chain
11	7114	Drum Switch
13	7115	Top Bearing Cap
14	7116	Soc HD Cap Screw(2 Req.)
15	7117	Roll Pin
16	7118	Spring
17	7119	Bearing
18	71120	Speed Change Shaft
19	71121	Handle
20	71122	Caution Plate
21	71123	Speed Change Handwheel
22	71124	Flat Hd.Cap Screw(2 Req.)
23	71125	Plastic Face Plate
24	71126	Set Screw
25	71127	Socket HD Cap Screw(4 Req.)
30	71128	Worm Gear
31	71129	Bearing
33	71130	Speed Changer Spur Gear
35	71131	Speed Change Chain Drum
36	71132	Belt
38	71133	Timing Pulley Clutch Sleeve
39	71134	Splined Gear Hub
40	71135	Spindle Bull Gear Assembly
41	71136	Ball Bearing(2 Req.)
42	71137	Snap Ring(2 Req.)
43	71138	Bull Gear Bearing Spacer
45	71139	Vert.Tee Bolts(3 Req.)
46	71140	Steel Washer(3 Req.)

ITEM NO.	PART NO.	DESCRIPTION
47	71141	Hex Jam Nut-Finished HDN.(3 Req.)
48	71142	Ball Bearing Gear Sleeve Washer
49	71143	Fixed Clutch Bracket
50	71144	Socket Set Screw
51	71145	Guide for Clutch Bracket
52	71146	Flat HD Socket Cap Screw(2 Req.)
53	71147	Dowel Pin
54	71148	Oil Cup
55	71149	Compression Spring(3 Req.)
56	71150	Bearing Locknut
57	71160	Bearing Sleeve
58	71161	Wave Spring Washer
59	71162	Bull Gear Shift Pinion
60	71163	HI-LOW Detent Plate
61	71164	Hex Nut(3 Req.)
62	71165	Lock Washer(3 Req.)
63	71166	Studs(3 Req.)
64	71167	Socket Set Screw
65	71168	Adjustable Plate
66	71169	HI-LOW Detent Plunger
67	71170	Spring
68	71171	Socket Cap Screw(2 Req.)
69	71172	Bakelite Ball Handle
70	71173	HI-LOW Shift Crank
71	71174	HI-LOW Pinion Block
72	71175	Roll Pin(.Req.)
72a	71176	Socket HD Cap Screw(2 Req.)
73	71177	Socket Cap Screw(4 Req.)
77	71178	Socket Set Screw
78	71179	KEY(2 Req.)
79	71180	Ball Bearing(2 Req.)
80	71181	Ball Gera Pinion Counter Shaft
81	71182	Key
82	71183	Wave Spring Washer
83	71184	Bull Gear Pinion
84	71185	Bull Gear Pinion Bearing Cap
85	71186	Socket HD Cap Screw(2 Req.)
86	71187	Timing Belt Pulley
87	71188	Jam Nut



頭部頂座Head Top Housing

HEAD TOP HOUSING

ITEM NO.	PART NO.	DESCRIPTION
1	7201	Socket Cap Screw(3 Req.)
3	7203	Spring Washer
4	7204	Ball Bearing
5	7205	Snap Ring No.
6	7206	Socket HD Cap Screw(2 Req.)
7	7207	Hex Jam Nut
8	7208	Motor 2HP (complete unit)230/460 3/60
9	7209	Hex HD Screw(2 Req.)
10	7210	Belt Housing
13	7211	Speed Change Plate
14	7212	Drawbar
15	7213	Cutter Pin
16	7214	Speed Change Plate Pivot Stud
17	7215	Socket HD Cap Screw(2 Req.)
18	7216	Washer
19	7217	Pivot Sleeve(2 Req.)
20	7218	Draw Bar Washer
22	7219	Spindle Pulley Bearing Sliding Housing
23	7220	Ball Bearing
24	7221	Plastic Lnsert(2 Req.)
25	7222	Adjustable-Driven Varidisc
26	7223	Snap Ring No.
27	7224	Belt
28	7225	Stationary Driven Varidisc
29	7226	Brake Bearing Cap
29a	7227	Socket HD Cap Screw(2 Req.)
30	7228	Ball Bearing
31	7229	Brake Spring(2 Req.)
32	7230	Brake Shoe Assembly(2 Req.)
33	7231	Spindle Pulley Spacer
34	7232	Spindle Pulley Hub
35	7233	Hex HD.Screw
36	7234	Brake Shoe Pivot Sleeve
37	7235	Roll Dowel Pin
38	7236	Drive Key
39	7237	Key for ADJ Varidisc Motor Shaft

ITEM NO.	PART NO.	DESCRIPTION
40	7238	Stationary Motor Varidisc
41	7239	Socket Set Screw
42	7240	Plastic Insert(2 Req.)
43	7241	Adjustable Motor Varidisc Assembly
44	7242	Spring for Varidisc Motor Shaft
45	7243	Adjustable Varidisc Spring Collar
46	7244	Socket HD Cap Screw(2 Req.)
47	7245	Ret.Ring
48	7246	Socket Cap Screw
49	7247	Plastic Key
51	7248	Key
52	7249	Taper Pin
53	7250	Belt Housing Base
54	7251	Motor Pulley Cover
55	7255	Socket Cap Screw
58	7256	HI-LOW Range Nameplate
59	7257	Drive Screw(4 Req.)
60	7258	Taper Pin(2 Req.)
61	7259	Quill Feed Nameplate
62	7260	Rivets(4 Req.)
63	7261	Gear Housing
64	7262	Round HD.Machine Screw(3 Req.)
65	7263	Gear Housing Plate
66	7264	Snap Ring
67	7265	Breake Finger Pivot Stud
68	7266	Brake Operating Finger
69	7267	Bakelite Ball Handle
70	7268	Brake Lock Handle
71	7269	Brake Lock Pin
72	7270	Socket Set Screw
73	7271	Sleeve for Brake Lock Shaft
74	7272	Brake Lock Shaft
75	7273	Brake Lock Cam
76	7274	Roll Pin
77	7275	Socket Set Screw

YC-1½VA & VS-T
OPERATOR MANUAL

TITAN Series

SUPERMAX®

DRO 200M™

REFERENCE MANUAL

ACU-RITE®

Readout Parameter Access Code

An access code must be entered before machine-related parameters can be set or changed. This prevents inadvertent adjustments to the setup parameters.

IMPORTANT
The access code is 8891

Refer to the Setup section. Begin by pressing the SETUP key. When "SETUP" is displayed, press the 8, 8, 9, 1, and ENTER keys. The readout is now ready for machine parameter setting operations.

IMPORTANT
Supervisors may wish to remove this page from the Reference manual after initially setting up the readout system. Retain in a safe place for future use.

Warranty

ACU-RITE Products and accessories are warranted against defects in material and workmanship for a period of three years from the date of purchase. ACU-RITE will, at its option and expense, repair or replace any part of the ACU-RITE product that fails to meet this warranty. This warranty covers both materials and factory labor. In addition, authorized ACU-RITE service representatives will provide service labor (field service) for a period of one year at no charge. Notice of the claimed defect must be received by ACU-RITE within the warranty period.

This warranty applies only to products and accessories installed and operated in accordance with this reference manual. ACU-RITE shall have no obligation, with respect to any defect or other condition caused in whole or part by the customer's incorrect use, improper maintenance, modification of the equipment, or by the repair or maintenance of the product by any person except those deemed qualified by ACU-RITE.

Responsibility for loss of operation or diminished performance due to conditions beyond ACU-RITE's control cannot be accepted by ACU-RITE.

The foregoing warranty obligations are in lieu of all expressed or implied warranties. ACU-RITE INCORPORATED shall not be liable under any circumstances for consequential damages.

30 Day Red Carpet Warranty

All ACU-RITE products are covered by a 30-day Red Carpet Warranty. If in the first 30 days this product fails for any reason, repack it in the original packing materials and contact your Authorized ACU-RITE Distributor for return procedures.

This symbol alerts you to the fact that important information concerning the installation and operation of this readout has been included in this manual.

Keep these instructions in a secure place for future reference.

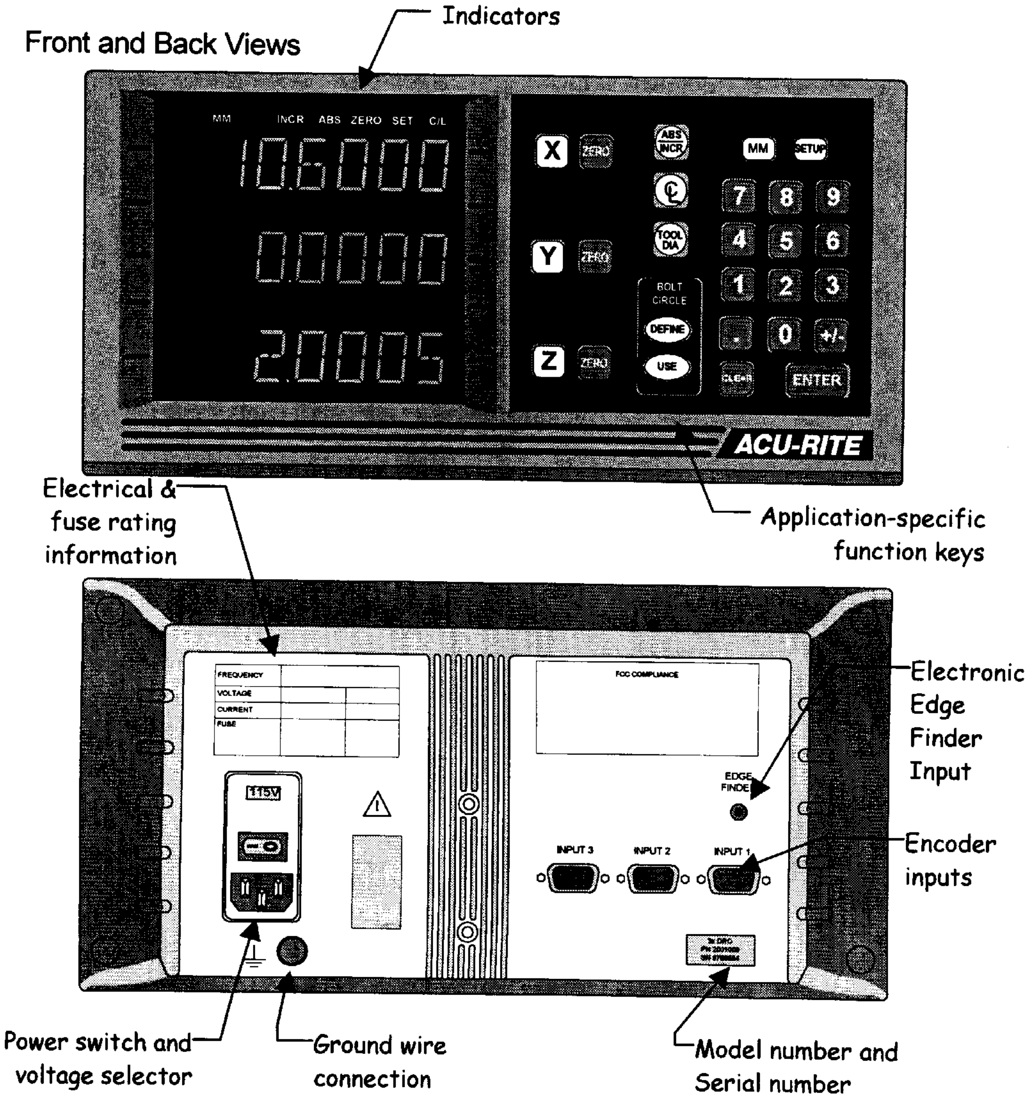
Introduction

ACU-RITE's DRO 200 readout series provides application-specific features required for you to obtain the most productivity from your manual machine tools.

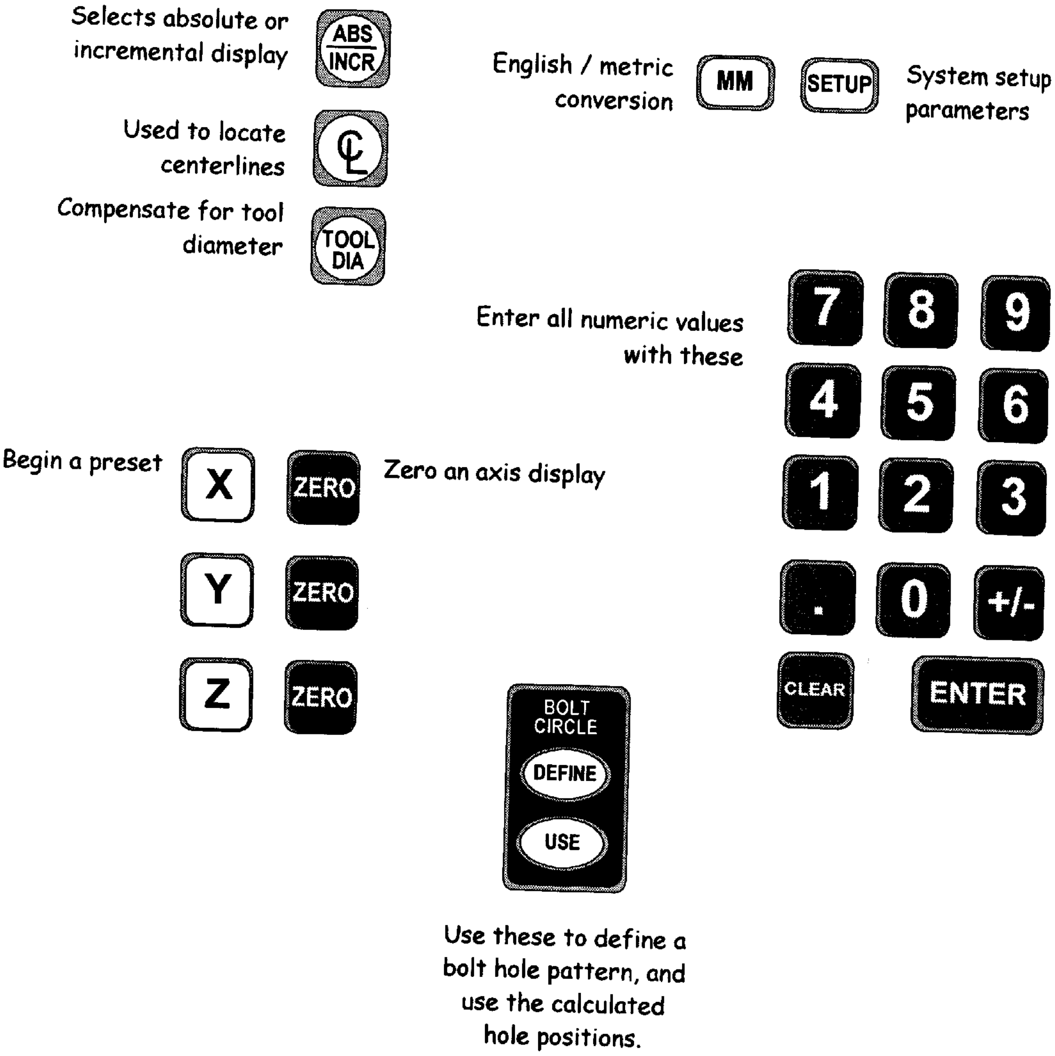
The DRO 200M is designed specifically for milling and drilling applications. Special features include an easy to use bolt hole routine, centerline locating, and quick tool offsetting.

A Tour of the Readout

Front and Back Views

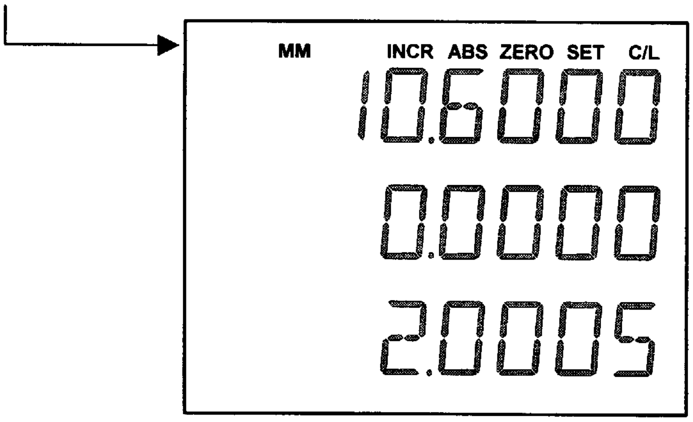


Keypad


Selects absolute or incremental display
ABS INCR
Used to locate centerlines
Compensate for tool diameter
TOOL DIA
English / metric conversion
MM
SETUP
System setup parameters
Enter all numeric values with these
7
8
9
4
5
6
1
2
3
.
0
+/-
CLEAR
ENTER
Begin a preset
X
ZERO
Zero an axis display
Y
ZERO
Z
ZERO
BOLT CIRCLE
DEFINE
USE
Use these to define a bolt hole pattern, and use the calculated hole positions.

Displays

At the top of the display window is a row of indicators. These tell you the current state of the readout.



ZERO

Appears when setting an absolute zero.

SET

Lets you know when you are setting a preset or an absolute zero.

C/L

Tells you when the centerline function is active.

MM

Appears when you're positioning in metric, dark when you're positioning in inches.

INCR ABS

These tell you if the position display is incremental or absolute. They also refer to the type of preset.

In addition to the lighted indicators along the top of the display, the top axis display will scroll longer messages that will help you step through some of the procedures.

Power-On Position Recovery

Position-Trac

Certain ACU-RITE encoders, such as the ENC 150, contain closely spaced reference marks that enable the display to show the correct position after a power interruption. The readout will indicate when power has been lost, and will prompt you to move each axis until a reference mark is located. By traversing the reference marks once in each axis, you will re-establish the display position relative to the last known zero. The most you will ever have to move an axis is about one inch. You must move in a positive count direction. A flashing decimal point will indicate that the last position has not been recalled.

If you use an encoder without Position-Trac, the procedure for recovering your position is slightly different. Reference marks on these encoders are about 8" apart. You must find a convenient reference mark and then use the same mark every time.

1. Move near the desired reference mark.
2. Press and hold the ABS/INCR key until the decimal point starts to flash.
3. Move slowly past the reference mark until the readout recalls its position. You must move in a positive count direction.

Readout Operations

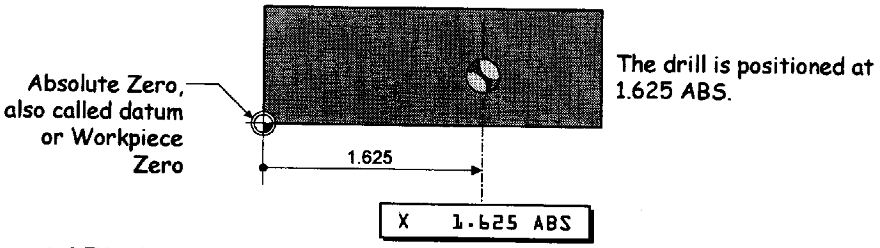
Clear Key

Use the CLEAR key to erase digits that you entered by mistake, or to take you back if you've pressed a wrong function key.

Absolute and Incremental Displays

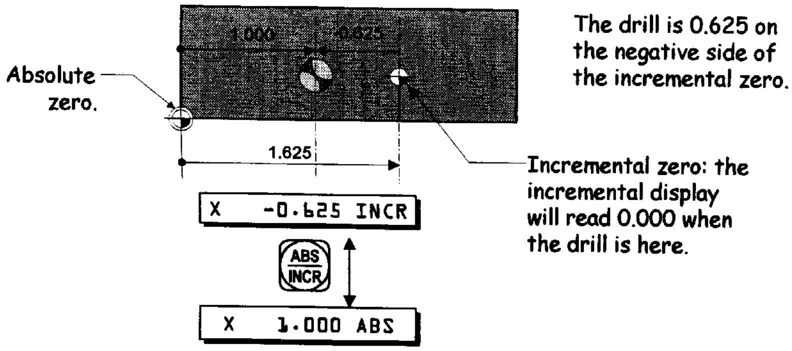
Absolute Display

Shows the distance from your current position to *absolute zero.*



Incremental Display

Shows the distance from your current position to *incremental zero.* An incremental zero is set when you preset a dimension, or when you zero the incremental display.



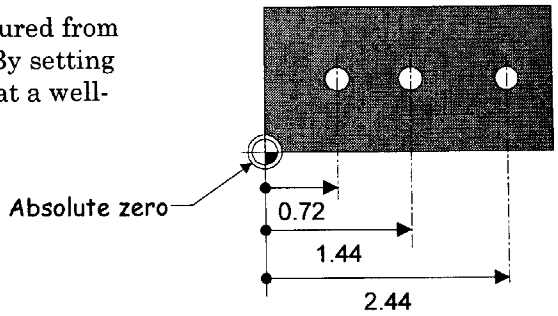
Automatic Display Switching

Sometimes the readout will switch from one display to the other automatically. When you enter a preset, for example, the display switches to the incremental display so that you can move to zero. Whenever the readout does an automatic display switch, INCR will appear briefly in the display.

Zeroing the Displays

Absolute Zero

On many prints, dimensions are measured from one or two surfaces of the workpiece. By setting the readout's absolute display to zero at a well-chosen surface, you can enter the part's dimensions directly from the print, using absolute presets.

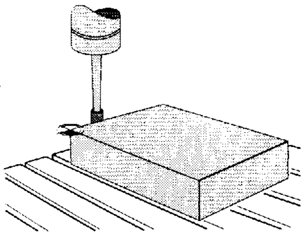


Setting Absolute Zero at the Current Position

1. Move to desired location.
2. Make sure that the absolute position is displayed. [ABS/INCR] ABS
3. Zero the appropriate axis. [ZERO] [ENTER] Shortcut [ZERO] [ZERO]

Setting Absolute Zero Using an Electronic Edge Finder

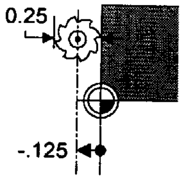
1. Install the edge finder into the spindle and connect it to the readout.
2. Make sure that the absolute position is displayed. [ABS/INCR] ABS
3. Press the [ZERO] key for the appropriate axis. [ZERO] ABS ZERO SET
4. Move slowly until the edge finder touches the edge of the workpiece. The absolute position display will automatically be set to zero at the workpiece edge.



You don't have to worry about overtraveling because the edge finder probe shaft is flexible. The readout will zero on contact.

Setting Absolute Zero with a Tool

1. Touch the tool to the edge of the workpiece.



You will have better results if you mill a new edge.

2. Make sure that the absolute position is displayed. ABS/INCR ABS

3. Press the ZERO key for the appropriate axis. ZERO ABS ZERO SET

4. Enter the position of the tool center.

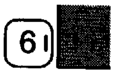
+/- . 1 2 5 ENTER

Setting Absolute Zero Using a Tool Offset

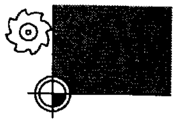
1. Enter the tool's diameter. TOOL DIA . 2 5 ENTER

2. Make sure that the absolute position is displayed. ABS/INCR ABS

3. Identify the right edge of the tool.



4. Touch the tool to the X=0 edge of the workpiece and press the ZERO key for the appropriate axis.



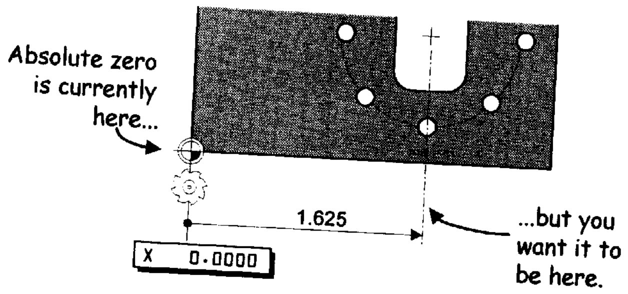
ZERO ENTER

Shortcut

ZERO ZERO

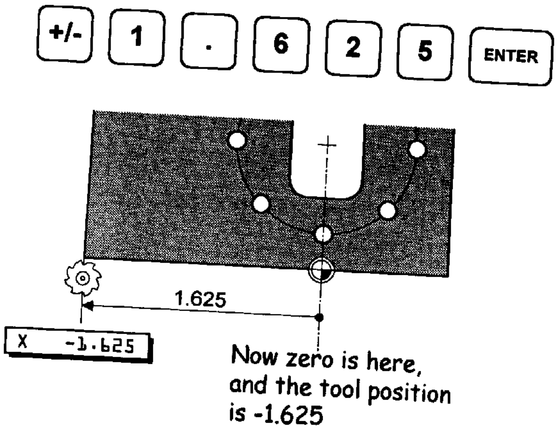
Moving the Absolute Zero

Sometimes you may need to move the absolute zero from its original position on the workpiece to a different position.



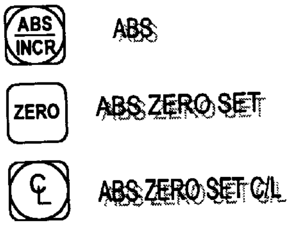
1. Move the tool to absolute zero.

2. Press the ZERO key of the appropriate axis and enter the *new* tool position, from the new absolute zero.

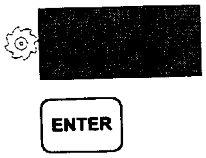


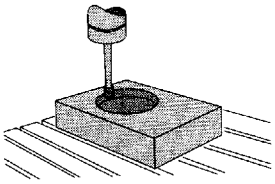
Zeroing at a Center Line

Begin setting absolute zero in the usual way and then tell the readout that you want to use the centerline feature.

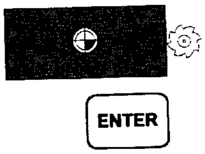


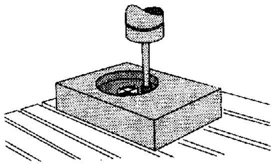
Touch the first edge...





...then the second edge.





The absolute zero is placed mid-way between the two edges.

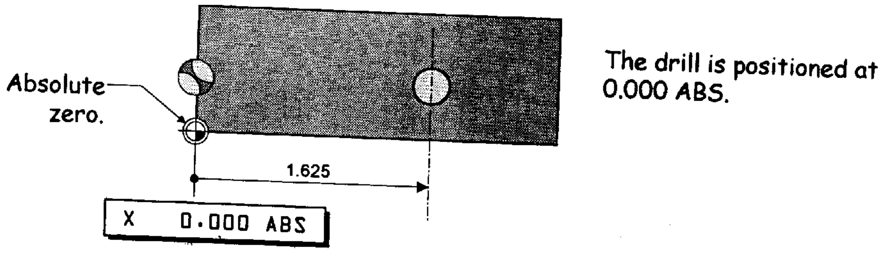
Incremental Zero

From the incremental display, press the ZERO key. This sets the incremental display to zero at the current tool position.

Presetting

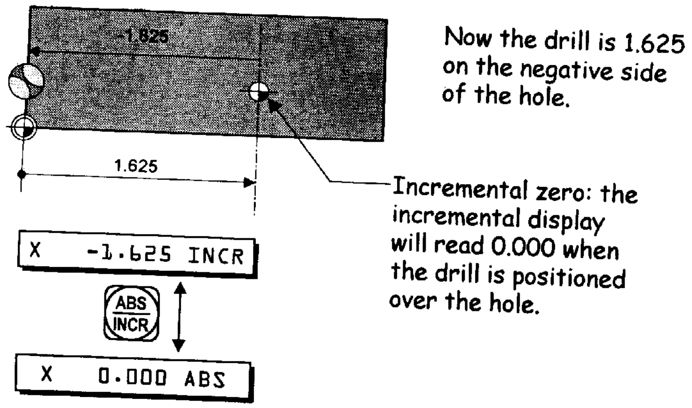
When you preset a dimension, the readout places an incremental zero at the location you specify. Then the display automatically switches to the incremental display so that you can move to zero.

Begin a preset by pressing an axis key (X for example). The information of the previous preset will appear. The display will show you if the preset is absolute or incremental. Use the ABS/INCR key to toggle between them.



Preset the absolute location of the hole.

X 1 . 6 2 5 ENTER

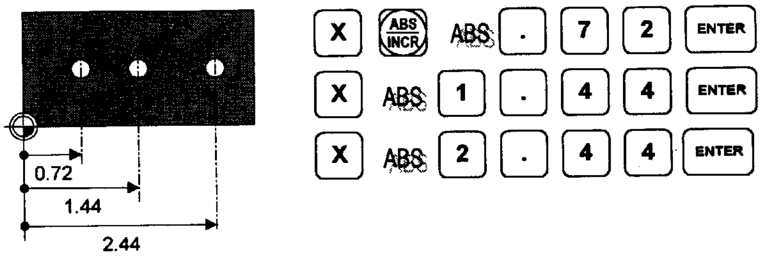


Absolute and Incremental Presets

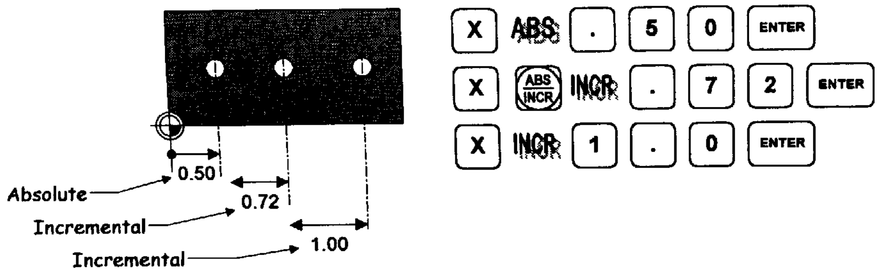
To maintain the best tolerance and to minimize the chance for errors, use

- absolute presets for absolute dimensions
- incremental presets for incremental dimensions.

When you enter an absolute preset, it **does not matter** where the tool position is. The DRO 200M calculates the desired location automatically.



When you enter an incremental preset, the tool **must** be positioned at the location you are dimensioning from.



Center-line Presets

You can set a preset at the center of a workpiece, or in the center of a hole.

[X] [℄]

Move to the first edge...

[ENTER]

X 0.000 INCR

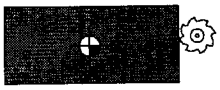
Sets an incremental zero at the tool location.

...then to the second edge

X 2.250 INCR

[ENTER]

Calculates the center, and sets an incremental zero in the middle.

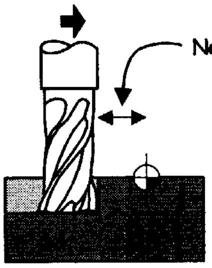


X 1.125 INCR

Near Zero Warning

When you are moving to zero, the readout can "warn" you when you are getting close. This allows you to machine faster and avoid overshooting your desired location.

You can set the near zero range in Setup.



Centerlines

You will normally use the centerline function when you are doing a preset, to put an incremental zero at a centerline, or when you want to set the absolute zero at a centerline. Refer to page 12 for presetting to a centerline, and page 9 for setting absolute zero on a centerline.

At any other time, using the centerline function will divide the current position in half and display the result in the incremental display.

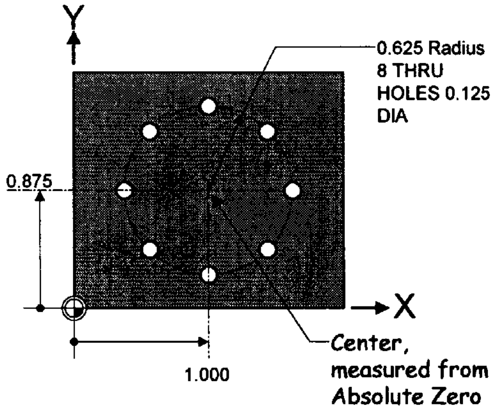
Divides the X axis display in half.

Bolt Hole Patterns

Calculating hole locations in a bolt hole pattern is a two-step process: *defining* the bolt hole pattern and *using* the results.

Defining the Bolt Hole Pattern

Press the (DEFINE) key. The readout will prompt you to enter information about the bolt hole pattern.



Number of holes: [8] [ENTER]

The maximum number of holes is 99.

Circle center, X-axis: [1] [.] [0] [0] [ENTER]

Circle center, Y-axis: [.] [8] [7] [5] [ENTER]

Circle radius: [.] [6] [2] [5] [ENTER]

Always enter the center of the circle as a dimension from absolute zero.

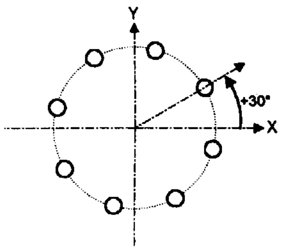
Starting angle of the first hole: [ENTER]

Ending angle of the last hole: [ENTER]

For a full circle with the first hole at the 3 o'clock position, like the example above, both the *start angle* and *end angle* can be left blank.

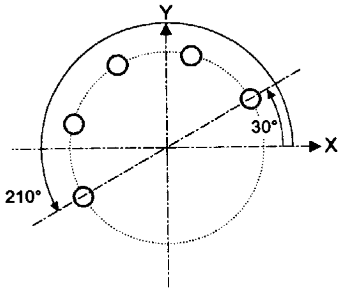
You can review the bolt hole pattern definition by pressing (DEFINE) and cycling through the parameters with the [ENTER] key.

If the bolt hole pattern is rotated from the 3 o'clock position, enter the *start angle*.



This 8-hole bolt hole pattern starts at 30°. Leave the *end angle* blank for a full (360°) pattern.

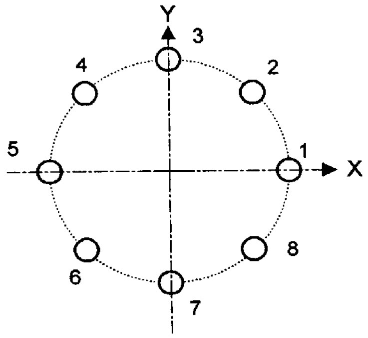
For partial bolt hole patterns, you need to enter an *end angle*.



This 5-hole bolt hole pattern starts at 30°, and ends at 210°.

Using the Result

After you have defined the bolt hole pattern, press the (USE) key to use the results. Each time you press (USE), the readout displays the hole number briefly, then presets the X and Y location for that hole. All you have to do is move to zero and drill the hole.



The readout will remember the hole pattern until you change it. This means that you can return to any of the holes at any time—just press (USE).

If you need to go to a specific hole, just enter its number after the (USE) key.

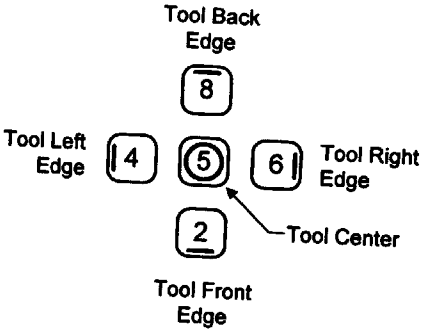
(USE) [5] [ENTER]

Tool Offset

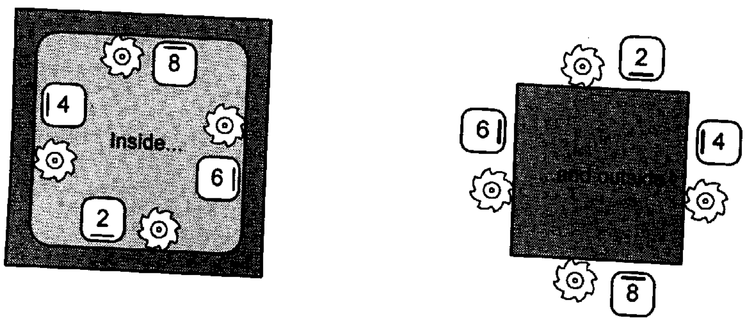
If you enter the diameter of the cutting tool you are using, you don't have to add or subtract the tool's radius when you enter a preset. Just select which edge of the tool you want to compensate for, and the DRO 200M automatically adds or subtracts the tool's radius.

Defining the Offset Direction

The symbols on the number keys indicate the offset directions—they represent a top view of the tool and the part edge.



Whenever the readout is displaying an absolute or incremental position, the number keys can be used for tool offset compensation. Just press the key corresponding to the edge of the tool whose position you want to display.



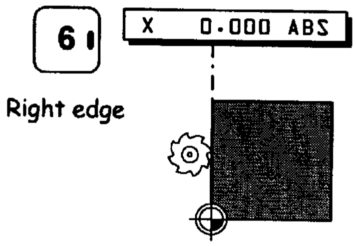
Using Tool Offsets

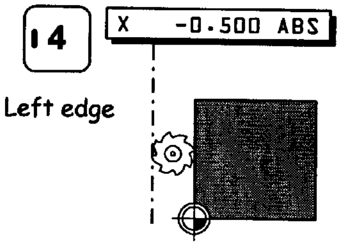
First enter the tool diameter.

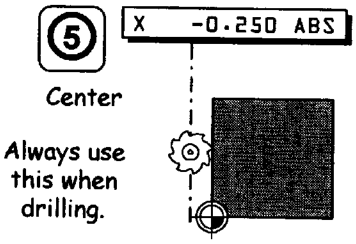
[TOOL DIA] [.] [5] [0] [0] [ENTER]

Then select the edge you want to use for the axis you want to move.

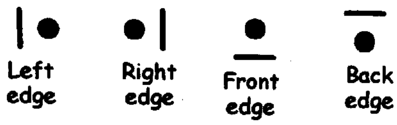
If the right edge is at absolute zero-







While you are moving, the readout display will indicate if a tool is being compensated for.



To check your tool compensation *before* you move, press [TOOL DIA]. Press it again to return to the position display.

Setup

The SETUP key lets you change the system parameters. Some of these parameters are job related, meaning that they may change from job to job. Others are machine related and should be set as part of the installation. The machine-related parameters can be accessed by pressing:

SETUP [ ] Access Code [ ] ENTER

Use the X key to move from one parameter to the next. After the last parameter, the X key ends the setup process and saves any changes. Use the CLEAR key to move back to a previous parameter.

Some parameters have choices. Use the Y key to cycle through the available choices.

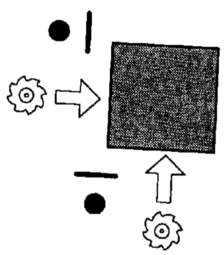
At any time during setup, pressing the SETUP key will end the setup process and save the changes.

Machine-Related Setup Parameters

Count Direction

This determines which way is positive. Move each axis in the positive count direction. The display will show a 1 or a 2 depending on count direction. You can also change the count direction by pressing the Y key.

Tool Offset Direction



Move each axis in the direction that will make the tool edge contact a workpiece as shown here. The display will show a 1 or a 2 depending on offset direction. You can also change directions by pressing the Y key.

Encoder Resolution

Move each encoder until the readout senses and displays the resolution. You won't have to move more than two inches. For encoders without Position-Trac, you need to enter the scale resolution. You can press the Y key to select from common choices, or you can use the keypad to enter the resolution directly.

Job Setup Parameters

Display Resolution

The display resolution will be the same as the encoder resolution. If the job tolerance is coarser than the encoder resolution (±0.005 for example), you can adjust the display resolution so you won't be tempted to waste time by machining to a finer resolution. Use the [Y] key to cycle through all the possible choices. The choices available depend upon the resolutions of the scales.

Scale Factor

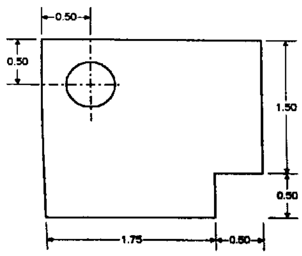
You can define a scale factor for each axis. The typical scale factor is 1.000, which means that the displayed dimensions are the actual part dimensions. A scale factor less than 1 causes the part to be smaller than the print dimensions; a scale factor greater than 1 causes the part to be larger.

For a scale factor that allows for 3% material shrinkage, use this formula:

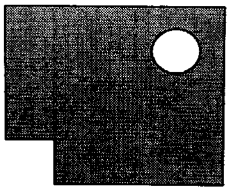
$$\text{ScaleFactor} = \frac{1}{1-.03} = \frac{1}{.97} = 1.0309$$

Enter the factor by pressing [1] [.] [0] [3] [0] [9] [ENTER]

Additionally, a scale factor of −1.00 will produce a mirror image of the part. You can both mirror *and* scale a part at the same time.



Print



Resulting part with
X scale factor = -1
Y scale factor = +1

Near Zero Warning

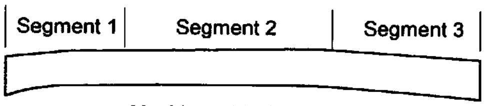
Each axis has its own near zero range. You can activate or deactivate the near zero warning feature by pressing the [Y] key. When the warning is activated, you can enter the range. Refer to page 13.

Bolt Circle Definition

You can define the size of a bolt hole circle either by its radius or by its diameter. Use the [Y] key to toggle between radius and diameter.

Linear Error Compensation

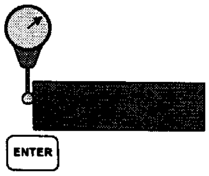
The DRO 200M includes a linear error compensation feature that enables you to compensate for machine tool inaccuracies.

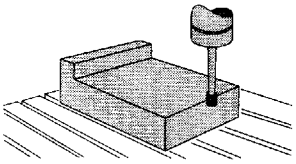


Machine table front view (slightly exaggerated)

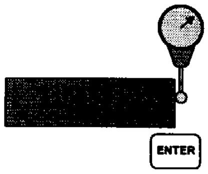
You can have up to three different compensation segments per axis. You will need either a dial indicator or an edge finder, along with a measurement standard.

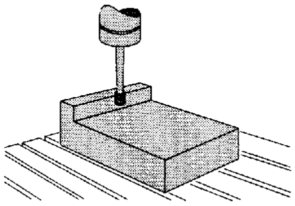
1. Enter the number of intervals you will use. If you do not want to use any error correction, enter 0. Press [X] to start the first interval.
2. Position the standard in the center of the first segment.
3. Press [Y]
4. Enter one edge of the standard.



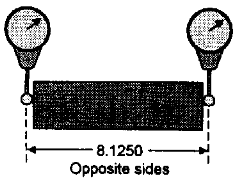


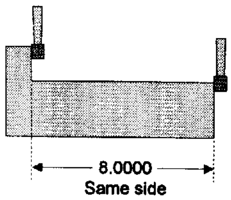
5. Enter the other edge of the standard.





6. Enter the actual size of the standard, including the probe diameter if necessary.





If the display shows all dashes, refer to "Display Overflow Errors" on page 30.

7. Press [X] for the next segment or, if all segments are done, the next axis.

Edge Finder Diameter

Enter the diameter of your electronic edge finder. You can use the [MM] key to select between English and metric units, depending on your edge finder.

Installation

IMPORTANT

Before installing the DRO 200M readout, record the serial number on the warranty card and return it to ACU-RITE INCORPORATED. The serial number label is located on the back of the readout.

Selecting a Location

Selecting a location for the readout is an important consideration for proper installation. Keep the following points in mind when selecting a safe and convenient location:

- The readout should be within reach of the operator for easy access to the keypad.
- The readout should be approximately at eye level.
- Avoid moving components or tools and minimize coolant splash or spray.
- The operating environment must be within the temperature range of 0° to 40°C (32° to 104°F) with a non-condensing relative humidity of 25% to 85%.

Proper Mounting

ACU-RITE has developed special mounting kits for the readout, which address the most common mounting requirements. Mounting kits include:

- Column and base machine mountings
- Hardware and mounting instructions

These kits are available from your factory authorized ACU-RITE Distributor or OEM/OEI.

If you fabricate a support device for the readout, it should be large enough and strong enough to accommodate the readout. It must also be stiff enough to minimize any vibration induced by machinery on the shop floor.

Connecting the Encoders

Insert the connector from each encoder into the mating connector on the back of the readout. Fasten it with a small screwdriver.

Encoder input 1 will be displayed in the readout's top display, input 2 in the next display, and input 3, if any, in the bottom display.

Provide enough slack in the encoder cables to allow for full travel of all machine axes. Check that machine movements will not pinch the cables. Use the cable tie-down hardware kits supplied with the encoders to fasten the cables neatly to the machine.

Connecting a Ground Wire

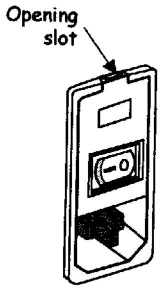
Connect a ground wire from the terminal on the back of the readout to the machine. The machine should also be connected to a solid earth ground. If not, be sure that the readout is.

Checking Voltage and Connecting Power

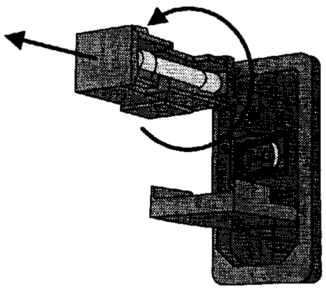
> ⚠ **CAUTION**
>
> Connecting the readout to a power source outside of the acceptable range, or making an inappropriate setting with the voltage selector, may damage the readout, the encoders, or both.

Check that the voltage available at the power source is within specification before connecting it to the readout. If required, set the voltage selector to match the line voltage.

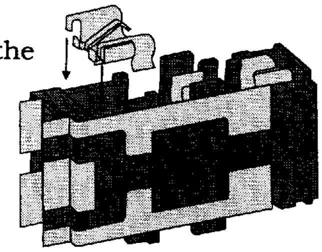
1. Remove the caution label from the input module, and use a thin-blade screwdriver in the slot at the top of the power-input module to open the module cover.



2. Pull the selection block out.



3. Remove the fuse, move the shorting bar to the other side, install the correct fuse, and push the block back into place.



4. Close and snap the cover shut.

The voltage setting will show through the window in the voltage selector cover. Connect the readout to the power source using the power cord supplied.

Readout Specifications

Characteristic	Specification
Operating conditions	0° to 40°C (32° to 104°F) 25% to 85% relative humidity (non-condensing)
Storage conditions	-40° to 60°C (-40° to 140°F) 25% to 95% relative humidity (non-condensing)
Input requirements	
Voltage:	115VAC or 230VAC (+/-20%), single phase
Frequency:	47-63 Hz
Current:	300ma @115V, 150ma @230V
Fuse	115V operation: ½ A, 250V, 3AG, Slo-blo 230V operation: ¼ A, 250V, 3AG, Slo-blo
Encoder input	Position signals: channels A & B TTL square wave signal in quadrature (90° nominal phase relationship) Maximum input rate: 50 kHz Reference signal: TTL square wave
Edge finder input	Compatible with ACU-RITE electronic edge finder
Size	12.5"W x 5.125"D x 6.5H"
Weight	7.5 lbs.
Mounting	Bottom: two ¼ -20 threaded inserts
FCC compliance	Class A

Troubleshooting

This section is intended to provide you with some basic troubleshooting assistance with your readout system. If you cannot correct the problem after following these instructions, contact your authorized ACU-RITE distributor or OEM/OEI for repair or replacement procedures.

No Operation

> **NOTICE**
>
> If you turn power off, you must wait at least 5 seconds before turning it back on, or the readout may not power up. This is because the power supply, in order to withstand brief power outages and brownouts, requires several seconds to reset itself.

If the readout display will not operate, check the following conditions:

- ***Check AC power source.*** If the readout cannot be powered up, confirm that line voltage is present at the source and that the line voltage meets the required specifications.

- ***Check power cord.*** Remove the power cord at the electrical input module on the back of the readout. Determine if line voltage is present at this end of the cord.

- ***Check fuse.*** With the power cord removed, use a thin straight-blade screwdriver to remove the cover of the electrical input module. Refer to page 24. Slide out the fuse holder and check the fuse. If necessary, replace it. Replace the input module cover by snapping it back into place, and reconnect the power cord.

> ⚠ **CAUTION**
>
> Replace fuses only with the specified type. Using incorrect fuses can present a safety hazard. The readout may also be permanently damaged. Refer to the Readout Specification chart on page 25 for the correct fuse.

Incorrect Operation

If system positioning does not seem to be repeatable, the problem could be with the machine tool or with the readout system.

- ***Check the machine tool.*** Check that the table is not locked. Ensure that the knee, ram, head bolts, turret-to-column bolts, and head-to-knuckle bolts are properly secured. Check the gib adjustments. Tram the head. Check spindle run-out.

- ***Check linear encoders.*** Check each encoder and reading head for proper installation. Ensure that the mounting brackets are secure.

If the system seems to be displaying incorrect positions, check the following items.

- ***Verify presets.*** Make sure the numbers you enter are correct.

- ***Verify tool.*** Check that the correct tool number is being used. Make sure the tool diameter has been entered correctly. Measure the tool diameter to check for tool wear.

- ***Verify the scale factor.*** Ensure that the correct scale factor is being used.

- ***Verify linear error compensation.*** Make sure that the factors used for linear error compensation are correct.

Power-On Self Test

There are four tests performed when power is applied to the readout. You will not notice these tests unless a problem is found, in which case a message will scroll across the display.

Keypad—a key was detected stuck down. The message will display what *row* (x) and *column* (y) the stuck key is in:

KEY STUCK – RxCy – PRESS CLEAR

Parameter memory—some of the system setup parameters are not valid. You may be able to check and reset these settings, but it's possible they will be lost again. The readout should be serviced as soon as possible.

MEMORY FAILURE [1] – PRESS CLEAR

> ⚠ **CAUTION**
>
> Some working settings are not valid. Proceed with caution.

Working memory—the memory used by the readout for calculations is faulty. While it may be possible to use the readout, it's position display and other information will not be reliable.

MEMORY FAILURE [2] – PRESS CLEAR

> ⚠ **CAUTION**
>
> The readout cannot be relied on for correct operation if any memory failure is indicated. The readout should be serviced immediately.

Program memory—the memory used to store the software is faulty. While it may be possible to operate the readout, some functions will not work properly and wrong information can be displayed.

MEMORY FAILURE [3] – PRESS CLEAR

> ⚠ **CAUTION**
>
> The readout cannot be relied on for correct operation if any memory failure is indicated. The readout should be serviced immediately.

Internal Testing

Several internal tests may be performed to ensure that the readout is functioning properly. Tests are available for the internal memory, the keypad, and the display. In addition, the testing procedure reports the software version of the readout.

Begin the internal testing by holding down the [.] key for about 2 seconds. The software version will appear in the X-axis display

Keypad test. Begin by pressing the [X] key, then press each key (except the [X] key) in turn to verify that it is functioning properly. When a key is pressed, the X-axis activates a "plus sign" indicator and increments a count. When you release the key, the plus sign disappears.

Display test. Begin by pressing the [X] key. All indicators in all displays will light. Visually check each portion of each display to ensure that they are functioning properly.

Press [X] again to test the display electronics. All decimal points on all displays will light momentarily, then each segment of all displays will light in turn. Press [X] again, and each digit of all displays will light, one digit at a time, starting with the leftmost digit and moving to the right.

Exit the diagnostics by pressing the [X] key.

Other Errors

The readout includes built-in test and error-checking circuitry. This circuitry identifies errors that occur, and reports the problem to the operator. Errors are reported by scrolling messages in the X-axis display.

Loss of power is indicated by the "Power was off" message. Loss of power means that power to the readout has been interrupted. Since power to the encoders has also been interrupted, positioning information may no longer be accurate. Press the [CLEAR] key to clear the error message. All display measurements will be zeroed. Refer to page 4 for information about position recovery.

Counting errors are indicated by the "Scale miscount" message, telling you in which axis the miscount occurred. Counting errors result from distorted electrical signals from an encoder. These signals can be a result of an encoder malfunction, misalignment, mounting problems, or electrical interference. Press the [CLEAR] key to clear the error message. The axis display (for both absolute and incremental measurements) will be zeroed. Follow these steps to determine if your difficulties are associated with the readout or with the encoder.

- Ensure that the linear encoder connectors are correctly seated.
- Swap linear encoder cables at the readout to see if the problem still appears in the same display.
- If the problem remains in the same display, the readout is in error.

- If the problem follows the connection change, the linear encoder may be in error. Refer to the Checking the Linear Encoders section of your encoder reference manual.

Display overflow errors are indicated by dashes in all digits in an axis display. A numeric overflow occurs when the intended measurement is too large for the eight-digit display. Clear the error by returning the machine table into an area where measurements can again be displayed, selecting a lower display resolution, setting a new preset, or zeroing the display.

This error may also occur when using the automatic compensation routine while setting the LEC parameter. An error indicates that the calculated compensation factor was outside the acceptable range of -9999 to +9999, and usually is the result of incorrectly entering data. Clear the error and return to the beginning of the linear error compensation routine. Refer to page 20.

Data Logging

The readout collects information about itself while it is being used. This information is stored in memory for review at a later time.

Press and hold the [.] key until the software version is displayed. Then press the [SETUP] and [MM] keys simultaneously. Use the [X] key to cycle through the following information.

Power on time—displayed in decimal hours.

Scale travel distance—the travel distance in feet for each axis is scrolled one after the other.

Last 3 errors—the most recent three errors are remembered and messages for the errors are scrolled one after the other.

ACU-RITE Readout Systems are manufactured in the USA

ACU-RITE IS AN
ISO 9001
CERTIFIED
MANUFACTURER

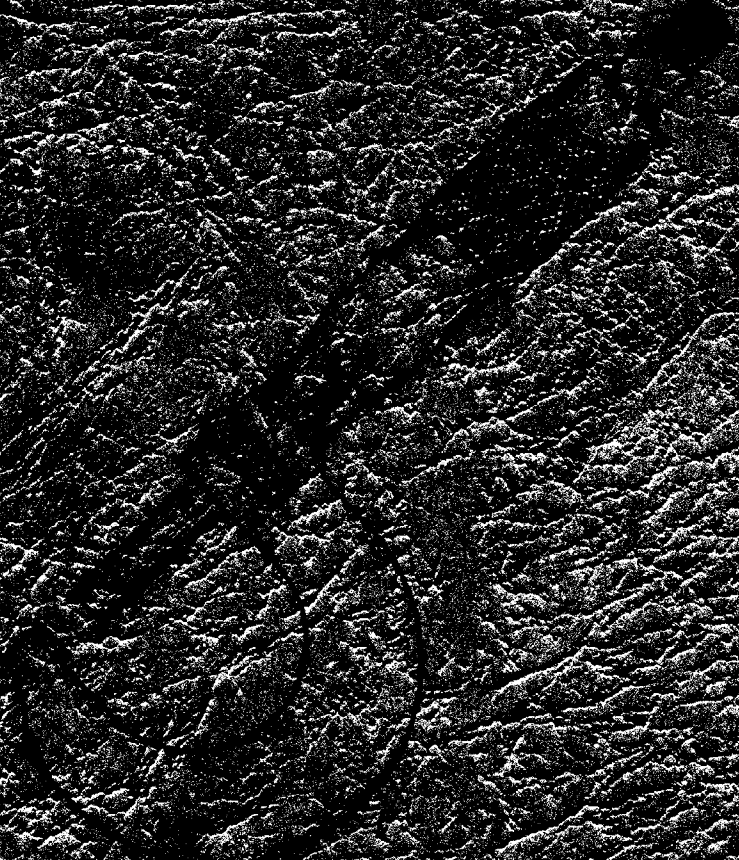
ACU-RITE®

ACU-RITE INCORPORATED
ONE PRECISION WAY
MASON INDUSTRIAL PARK
JAMESTOWN, NEW YORK 14701

2001-704 EDITION C

PRINTED IN USA

Measurement



Suggested Unit Course in

MEASUREMENT

Machine Shop Series

DELMAR PUBLISHERS, Inc.
Albany, New York

MACHINE SHOP SERIES

This series of texts covers six major occupational areas of Machine Shop Practice: (1) *Measurement*, (2) *Bench Work*, (3) *Drill Press*, (4) *Lathe*, (5) *Milling Machine*, and (6) *Shaper Work*.

The instructional material in each book is written in simple trade terminology and illustrated through the generous use of line drawings. The range of technical information (*Why-to-do*) and fundamental process units (*How-to-do*) provides basic instruction for beginning students, apprentices and home workshop enthusiasts; and advanced reference material for skilled craftsmen, engineers, supervisory personnel and teachers.

MACHINE SHOP MEASUREMENT

A beginner's text and workbook which covers basic mathematical principles of linear, circular, and angular measurement from the standpoint of related mathematics and machine shop practice.

65 pages (7¾ x 10¼); 109 line drawings

BENCH WORK

A basic text which describes the theory of *Bench Work* and the operations performed with measuring, layout and bench tools.

88 pages (7¾ x 10¼); 159 line drawings; formulas; tables

DRILL PRESS WORK

An introductory text dealing with the theory and operation of drill presses; uses of accessories and holding devices; cutting speeds and feeds; drilling, reaming, countersinking, counterboring and tapping.

42 pages (7¾ x 10¼); 48 line drawings; 6 tables

LATHE WORK

A comprehensive text covering the related technical information and fundamental processes which are basic for *Lathe Work* held between centers and in a chuck. A partial list of topics includes: centering, mounting work; grinding tool bits; facing, straight turning; speeds and feeds; turning shoulders, chamfering, knurling, thread cutting, angle and taper turning; mandrel and chuck work; drilling, boring, reaming and tapping.

164 pages (7¾ x 10¼); 197 line drawings; formulas; tables

MILLING MACHINE WORK

An exhaustive study of modern milling machines and accessories. The instructional units cover in minute detail the theory and practice of basic and advanced milling machine operations, with emphasis on dividing head work.

298 pages (7¾ x 10¼); over 300 illustrations including phantom and cut-away sections

SHAPER WORK

A new and complete treatise on modern types of crank and hydraulic shapers. The text covers all the basic and advanced operations and related technical information required to do *Shaper Work*.

326 pages (7¾ x 10¼); 582 illustrations including phantom and cut-away sections

PREFACE

The production of interchangeable parts, which is the keystone of our present day manufacturing system, depends largely on the skill of the individual machine operator and of the all-around craftsman in operating machine tools and using measuring instruments so that each machine part is held within certain prescribed limits of accuracy.

Over a period of years careful analyses were made to determine essential occupational areas of training for machine shop practice. As a result of these studies, the following six main divisions of the trade were defined and a series of texts were prepared to cover them: (1) *Measurement*, (2) *Bench Work*, (3) *Drill Press*, (4) *Lathe*, (5) *Milling Machine*, and (6) *Shaper Work*.

Further study revealed that each operation in machine shop practice involves the teaching and learning of basic trade theory and fundamental processes. Following this line of reasoning, two types of instructional units are included in each monograph: (1) *Trade Theory Series* and (2) *Fundamental Process Series*. A brief description of each type follows.

Trade Theory Series

The basic trade theory and related technical information, such as principles governing machine shop operations, the derivation and application of formulas, and descriptions of machine tools and accessories, are covered in the *Trade Theory Series*. This technical information furnishes the student with background trade knowledge necessary to perform machine shop operations skillfully. The *Trade Theory* units which are directly related to the *Fundamental Process* units may be used as text or reference material for class, laboratory or home study.

Fundamental Process Series

The term *Fundamental Process* covers those manipulative processes which involve the use of hand and machine tools and are common to machine or bench work. The manipulative phases of an operation are described in common trade terminology and are well illustrated with line drawings. As the *Fundamental Process* units provide reference material for the actual performance of operations, they may be used as supplementary text material for the teaching of fundamental processes either in a school or an industrial plant.

The selected series of instructional units in each text includes those fundamental operations which are common for a specific division of the trade and which apply under all conditions. Throughout the series the units are arranged in the natural order of dependence of one operation on the next; i.e., in a sequence which conforms to the logical order of teaching and learning difficulty. However, this arrangement may be changed to meet exacting industrial and educational training course requirements without altering the effectiveness of any one of the suggested unit courses.

Sincere appreciation is expressed to the Bureau of Industrial and Technical Education, The New York State Education Department for permission to reproduce this instructional material.

The Editor

Albany, New York

MEASUREMENT

TABLE OF CONTENTS

SECTION I

Units of Instruction in Measurement for Machine Shop Practice

SECTION II

Units of Instruction in Machine Shop Mathematics Related to Measurement

* Key to unit numbers
- 1 First year or beginner level
- M - Unit course in measurement
- T Trade theory series
- P Fundamental process series
- BP Basic principle series
- A Assignment series
- -3 Sequence of units of instruction

Examples:
- 1M-T3 First year course in Measurement, Trade Theory unit number three
- 1M-BP3 First year course in Measurement, Basic Principle unit number three

SECTION I

Units of Instruction in

MACHINE SHOP MEASUREMENT

MACHINE SHOP MEASUREMENT

SECTION I

Machine Shop Practice | Unit 1M-T1 | Trade Theory Series

DESCRIPTION OF MEASURING TOOLS

OBJECTIVES OF UNIT

1. To acquaint the learner with the common fraction and decimal fraction systems of measuring.

2. To explain the application of the steel rule, outside caliper, inside caliper, micrometer caliper, and the steel square in measuring.

3. To explain the construction, reading, and use of the micrometer caliper.

INTRODUCTORY INFORMATION

The measuring of material and machined work involves the use of a number of measuring tools to secure sizes of length, width, thickness, and diameter. One or more of these factors may be involved when determining the size of material or a piece of work.

The English system of linear measure, of which the yard is the unit of length, is the standard used in American industry. In machine shop work, the more commonly used unit is the inch, the thirty-sixth part of a yard. The inch may be divided into smaller parts by means of either common or decimal fractional divisions.

The fractional divisions of an inch are found by dividing the inch into equal parts; the more common of which are: halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. When smaller units of measurement are required, the decimal system is used in which the inch is divided into tenths, hundredths, thousandths, and ten-thousandths of an inch (Figure 1).

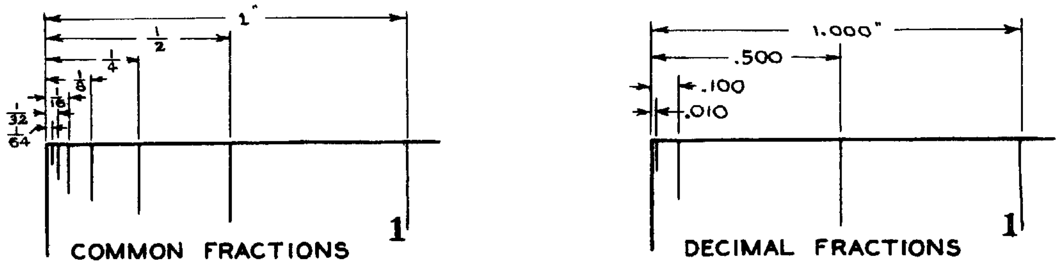


FIG. 1 TWO SYSTEMS OF DIVIDING THE INCH

In machine shop it is common practice to use fractions of an inch expressed in decimals, called decimal equivalents of an inch; i.e. 1/8" is expressed as .125" (one hundred twenty-five thousandths of an inch), or 1/4" as .250" (two hundred fifty thousandths of an inch), etc.

DESCRIPTION OF MEASURING TOOLS

THE STEEL RULE

The steel rule is used for measuring either common fractions up to sixty-fourths of an inch, or decimal fractions up to one-hundredths of an inch. These rules are made in various lengths, widths, thicknesses, and methods of graduation. Two types are illustrated below. The first type (Fig. 2) is the more common machinist's rule--with graduations of one-eighth inch on one edge and sixteenths on the other.. Turning the scale over, thirty-seconds are on the top edge and sixty-fourths on the other.

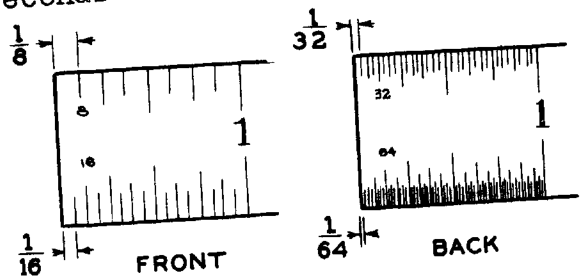


FIG. 2 MACHINIST'S STEEL RULE

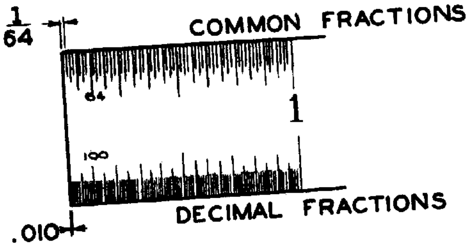


FIG. 3 COMBINATION STEEL RULE

On another type of scale (Fig. 3), divisions of common fractions in sixty-fourths of an inch are on the top edge, and decimal fractions in one-hundredths of an inch are on the bottom edge. One-hundredths of an inch are the smallest divisions found on machinist's rules.

The steel rule may be used for two purposes: setting or securing dimensions and measurements, and as a straight edge (Fig. 4). With practice it can be read accurately and is one of the most valuable shop tools.

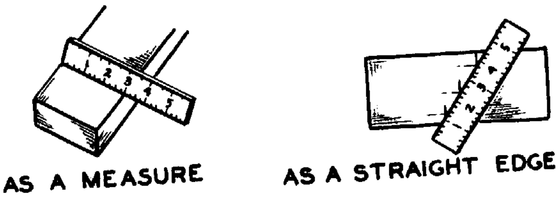


FIG. 4 TWO USES OF STEEL RULE

OUTSIDE AND INSIDE CALIPERS

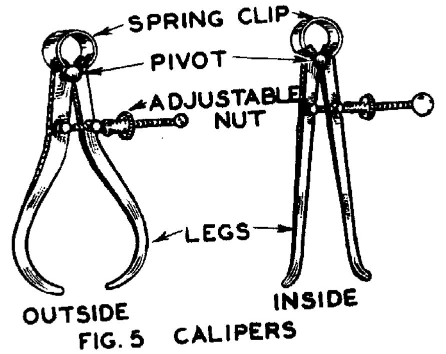


FIG. 5 CALIPERS

The two tools most commonly used to transfer measurements from the work to the scale or from the scale to the work are the outside and inside calipers.

As their names imply, they are constructed to take external or internal measurements and are built on that basis (Fig. 5).

DESCRIPTION OF MEASURING TOOLS

The legs of the calipers are attached to a pivot at the upper end. This end is held together above the pivot by a spring clamp. The clamp tends to hold the legs firmly against the adjusting nut and on the pivot. The working tips of the legs should be kept in line to preserve the accuracy of the tool (Fig. 5).

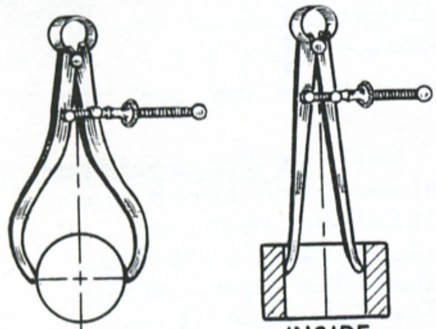


FIG. 6 MEASURING WITH CALIPERS

The accurate use of calipers depends upon the "feel" which is developed through use. They should never be forced over or into the work. Likewise, they should always be used square with the axis of the work and the surface being measured (Fig. 6).

The caliper can be used in two ways to make a measurement. They can be set over the object (as illustrated) and then tested on a steel measuring rule, or they can be set from the rule and the measurement transferred to the work.

Calipers are made in a variety of sizes depending upon the size of opening: 2", 3", 4", 5", 6", etc.

THE MICROMETER CALIPER

The smallest measurement which can be made with the use of the caliper and steel rule are, in the case of common fractions, 64ths of an inch; in decimal fractions, hundredths of an inch. To measure finer than these (thousandths and ten-thousandths of an inch), a micrometer caliper is used.

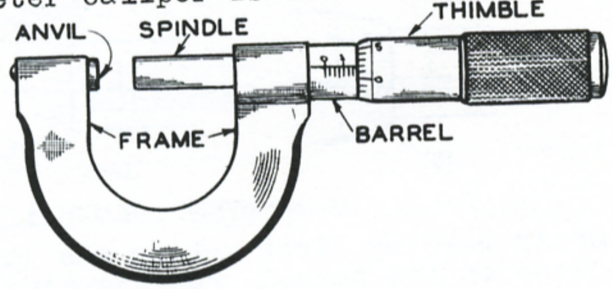


FIG. 7 PARTS OF THE MICROMETER CALIPER

If a dimension in common fractions is to be measured with the micrometer, it must be converted to its decimal equivalent.

The principal parts of the micrometer are: the anvil, frame, barrel, spindle and screw, and thimble (Fig. 7). The micrometer caliper operates on a screw which is free to move in the threaded portion inside the barrel.

DESCRIPTION OF MEASURING TOOLS

The legs of the calipers are attached to a pivot at the upper end. This end is held together above the pivot by a spring clamp. The clamp tends to hold the legs firmly against the adjusting nut and on the pivot. The working tips of the legs should be kept in line to preserve the accuracy of the tool (Fig. 5).

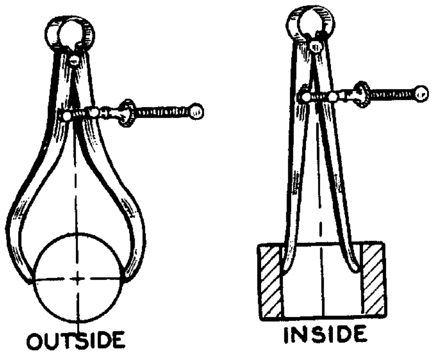


FIG. 6 MEASURING WITH CALIPERS

The accurate use of calipers depends upon the "feel" which is developed through use. They should never be forced over or into the work. Likewise, they should always be used square with the axis of the work and the surface being measured (Fig. 6).

The caliper can be used in two ways to make a measurement. They can be set over the object (as illustrated) and then tested on a steel measuring rule, or they can be set from the rule and the measurement transferred to the work.

Calipers are made in a variety of sizes depending upon the size of opening: 2", 3", 4", 5", 6", etc.

THE MICROMETER CALIPER

The smallest measurement which can be made with the use of the caliper and steel rule are, in the case of common fractions, 64ths of an inch; in decimal fractions, hundredths of an inch. To measure finer than these (thousandths and ten-thousandths of an inch), a micrometer caliper is used.

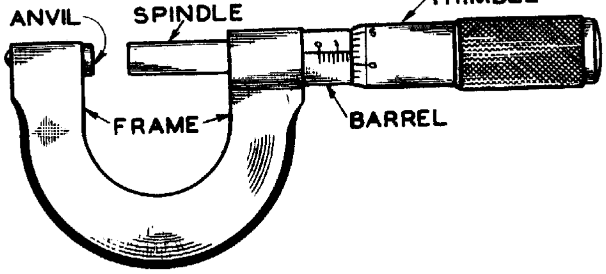


FIG. 7 PARTS OF THE MICROMETER CALIPER

If a dimension in common fractions is to be measured with the micrometer, it must be converted to its decimal equivalent.

The principal parts of the micrometer are: the anvil, frame, barrel, spindle and screw, and thimble (Fig. 7). The micrometer caliper operates on a screw which is free to move in the threaded portion inside the barrel.

DESCRIPTION OF MEASURING TOOLS

The movement of the screw provides an opening between the anvil and the end of the spindle where the work is measured. The size is indicated by the graduation on the barrel and the thimble.

The lines on the barrel marked 1,2,3,4, etc., indicate measurements of .100", .200", .300", .400", etc., respectively. (Fig. 8).

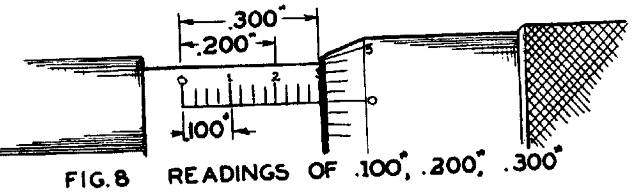


FIG.8 READINGS OF .100", .200", .300"

Each of the sections between the tenth inch divisions (between 1,2, 3,4, etc.) is divided into four equal parts of .025" each (Fig. 9A)

One complete revolution of the thimble from its zero to zero, moves it one of these .025" divisions as in Figure 9B.

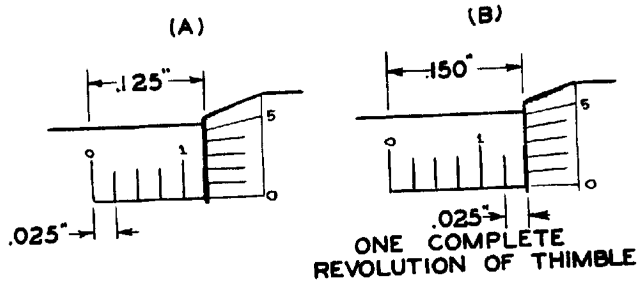


FIG. 9 DIVISIONS OF .025"

The bevel edge of the thimble, in turn, is divided into twenty-five equal parts. Each of these parts represents one twenty-fifth of the distance the thimble travels along the barrel in moving from one of the .025" divisions to another. Thus each division on the thimble represents a thousandth (.001") of an inch. These divisions are marked for convenience at every five spaces by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the spindle (having made one revolution) has moved .025".

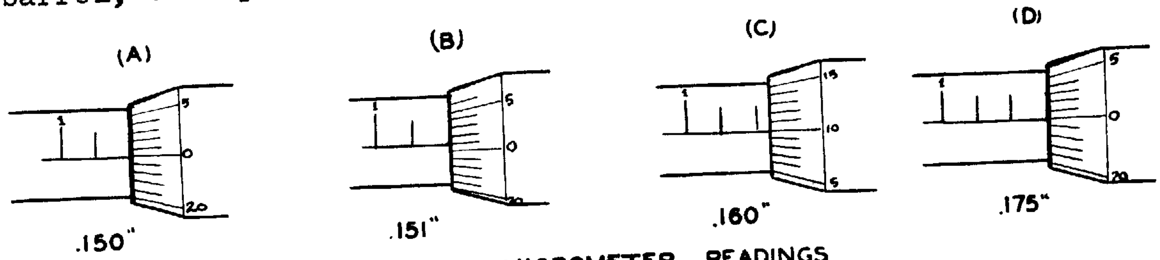


FIG. 10 MICROMETER READINGS

The micrometer is read by first noting the last visible figure on the horizontal line on the barrel, representing tenths of an inch. Add to this the amount represented by the visible graduations beyond this figure (by multiplying the number of them by 25), and the number of divisions on the bevel edge of the thimble that coincides with the line of the graduation. The sum, of the tenths of an inch, plus the number of divisions beyond the last tenth of an inch graduation multiplied by 25, and the divisions on the bevel edge of the thimble, is the reading (Figures 10-A,B,C, and D).

DESCRIPTION OF MEASURING TOOLS

The ability to measure to a thousandth of an inch with micrometers makes them an accurate tool with which to work. If they are dropped and the screw which moves the spindle is damaged, their accuracy may be permanently affected. Likewise, continually sliding work between the anvil and spindle may wear the surfaces, tending to affect their accuracy (Fig. 11).

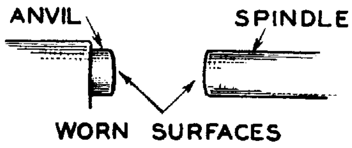


FIG. 11 WEAR ON SPINDLE AND ANVIL

THE STEEL SQUARE

The steel square is used to measure an angle of ninety degrees (90°). Surfaces at 90° to each other are said to be "square" with each other (Fig. 12).

FIG. 12 MEASURING RIGHT ANGLES

The steel square is made of high grade tool steel, hardened, tempered, and ground to a fine degree of accuracy. The right angle, or perpendicular as it is also called, may be found on either the inside or outside of the square (Fig. 13).

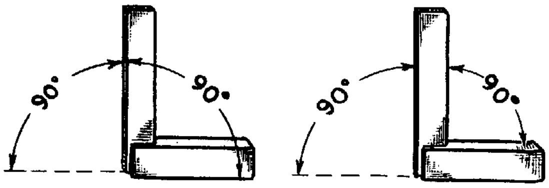


FIG. 13 THE STEEL SQUARE

NOTE: Care must be taken not to damage the square as any change in the position of the surfaces will destroy its accuracy.

SELECTED REFERENCES

Henry Ford Trade School ------------------------------ Shop Theory

Burghardt ----------------- Part I ------- Machine Tool Operation

MEASUREMENT

HOW TO USE MEASURING TOOLS

OBJECTIVES OF UNIT

1. To point out general practices in the application of the most commonly used measuring tools.

2. To show how to measure with the steel rule, outside caliper, inside caliper, micrometer caliper, and steel square.

INTRODUCTORY INFORMATION

To become proficient in the use of measuring tools, a beginner must develop judgment and a sense of "feel" which will enable him to measure accurately and skillfully.

The steel rule, when used alone or in combination with the setting of calipers, is employed to obtain "scale" dimensions which are only approximate. For measurements that require greater accuracy (to within one thousandth of an inch or finer), the micrometer caliper is used either alone or in combination with inside calipers and other special measuring tools.

A good mechanic is known by the manner in which he cares for his tools. Abuse and careless handling of measuring tools destroys their usefulness.

TOOLS AND EQUIPMENT

Steel Rule
Outside Caliper
Inside Caliper

Micrometer Caliper
Steel Square

PROCEDURE

STEEL RULE

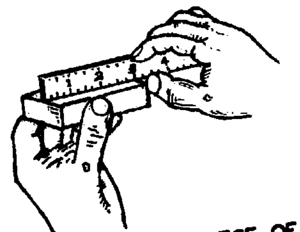


FIG. 1 MEASURING A PIECE OF STO[CK]

1. To measure a piece of stock, place the rule flat across the surface or distance to be measured; holding or steadying the work with the left hand.

2. With rule held in the right hand and guided by the thumb nail, extend the rule until its end is even with the left hand edge of the work (Fig. 1).

HOW TO USE MEASURING TOOLS

3. Read the graduations on the rule from left to right by noting which line on the rule coincides closest with the right hand edge of the stock (Fig. 2).

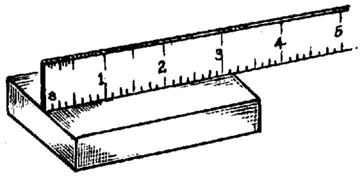


FIG. 2 READING A STEEL RULE

NOTE: Select that edge of the rule which is graduated in fractional divisions of an inch in which the desired dimension is wanted; i.e. eighths, sixteenths, thirty-seconds, and sixty-fourths (Fig. 3).

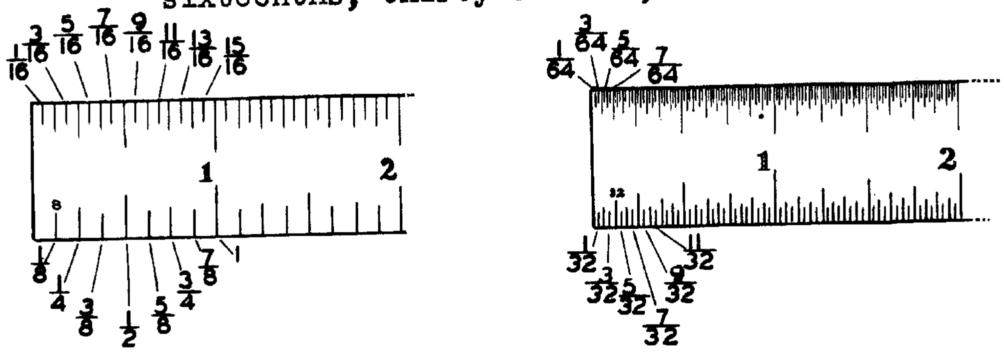


FIG. 3 GRADUATIONS ON A STEEL RULE

OUTSIDE CALIPERS

1. To measure a piece of work with the outside calipers, hold the calipers in the right hand and, with the thumb and forefinger, grasp the knurled adjusting nut (Fig. 4).

2. Turn the adjusting nut with the thumb and forefinger until the caliper will just slide over the work by its own weight.

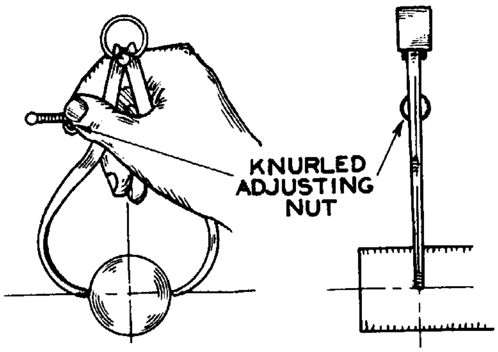


FIG. 4 TAKING A MEASUREMENT WITH AN OUTSIDE CALIPER

NOTE: At all times keep the calipers square with the work to be measured. A piece of round stock is calipered as shown in Figure 4.

3. Remove the caliper from the work, being careful not to disturb the setting.

HOW TO USE MEASURING TOOLS

4. To measure the distance between the caliper legs with the aid of a steel rule, hold the rule in the left hand with the second finger at the bottom and behind the rule.

5. Place one of the legs at the end of the rule, and the other leg on the graduated face of the rule in line with the first leg, and read the measurement.

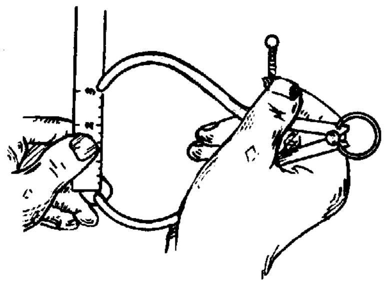


FIG. 5 SETTING AN OUTSIDE CALIPER

NOTE: The caliper may be used to check a given size by first setting it to the desired dimension from a steel rule (Fig. 5). Then use the caliper as a gage in selecting a piece of the required size.

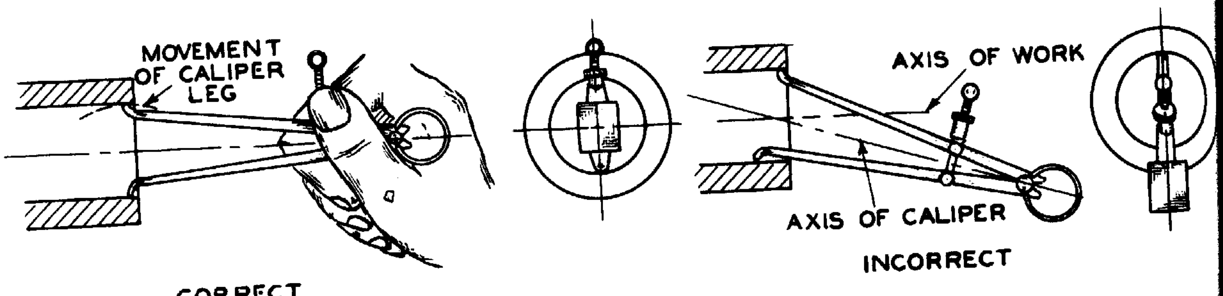
INSIDE CALIPERS

1. To take an inside measurement, hold the caliper in the right hand with the thumb and forefinger grasping the knurled adjusting nut (Fig. 6).

2. Rest one leg of the inside caliper slightly inside of the edge of the space to be measured. Turn the adjusting nut until the caliper is felt striking the high point of the arc on entering the space to be measured (Fig. 6).

NOTE: Make sure that the tips of the caliper legs are square with the largest portion of the diameter being measured.

With the calipers held in this position, test to see whether they can be moved sideways. If necessary, readjust so that no side motion can be felt.



CORRECT

FIG. 6 CORRECT AND INCORRECT USE OF CALIPER

HOW TO USE MEASURING TOOLS

3. To measure the distance over the caliper legs with the aid of a steel rule, place one end of the steel rule against a vertical surface. Hold the caliper leg against the vertical surface, keeping the ends level at the same time. Read the dimension from the rule (Fig. 7).

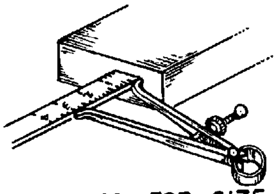


FIG. 7 CHECKING FOR SIZE

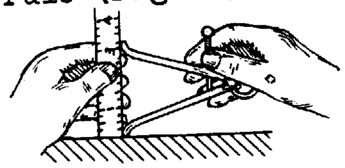


FIG. 8 SETTING AN INSIDE CALIPER

NOTE: An inside caliper may be used to check a given size by first setting it to the desired dimension from the steel rule (Fig. 8), and then using the caliper as a gage to check the internal measurement.

MICROMETER CALIPER

A. TO MEASURE A PIECE OF WORK WITH THE MICROMETER WHEN THE WORK IS HELD IN THE HAND

1. The frame of the micrometer is held in the palm of the right hand by the little finger (or the third finger, whichever is more convenient), allowing the thumb and forefinger to be free to revolve the thimble for the adjustment (Fig. 9).

2. Place the work between the anvil and the spindle. Turn the thimble until its movement has brought the spindle and the anvil in contact. (Fig. 9).

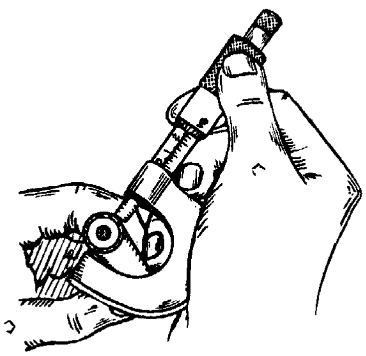
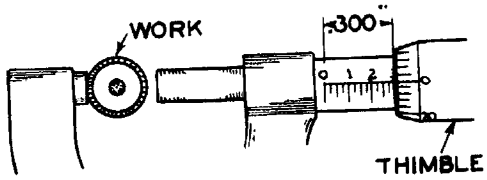


FIG. 9 MEASURING STOCK

NOTE: The beginner must develop a sense of "feel" in adjusting the micrometer to the work. Avoid the tendency to cramp the micrometer by using too much pressure.



READING .300

FIG. 10 START TURNING THIMBLE

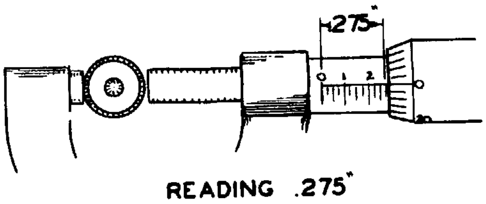
3. The measurement is taken from the graduations on the barrel and thimble by:

   a first noting the last figure visible on the graduations of the horizontal line along the barrel, which represent the tenths of an inch (Fig. 11);

HOW TO USE MEASURING TOOLS

3. b adding the number of twenty-five thousandth inch (.025") spaces beyond this figure, (Fig. 11) and then;

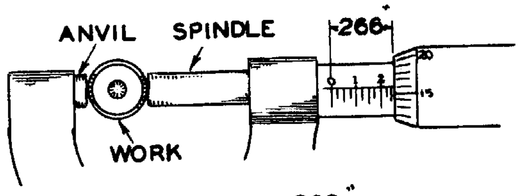
c adding the number of the division on the beveled edge of the thimble that coincides with the line of the graduations on the barrel (Fig. 12).



READING .275"

FIG. 11 THIMBLE TURNED ONE REVOLUTION

The sum of these expressed in thousandths gives the measurement. The steps in securing this measurement are illustrated in Figures 10, 11, and, for the final reading, Figure 12.



READING .266"

FIG. 12 FINAL READING ANVIL, WORK, AND SPINDLE IN CONTACT

NOTE: After the measurement has been determined, open the micrometer screw before removing it from the work. This practice prevents wear on the ends of the spindle and anvil, which impairs the accuracy of the tool.

B. TO MEASURE WITH THE MICROMETER CALIPER WHEN WORK IS MOUNTED IN A MACHINE.

1. Grasp the frame of the micrometer near the anvil with the thumb and forefinger of the left hand. The frame is steadied with the second and third fingers of the right hand while the thumb and forefinger are used to rotate the thimble (Fig. 13).

2. Open the micrometer and place it over the work to be measured. Turn the thimble until its movement has brought the spindle and anvil in light contact with the work (Fig. 13).

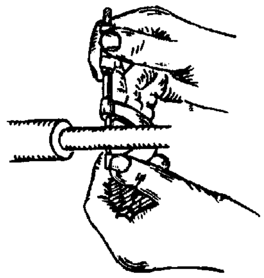


FIG. 13 MEASURING WORK MOUNTED IN A MACHINE

3. Read the micrometer as indicated in the preceding section.

NOTE: The reading is taken while the micrometer is held on the work. Always open the micrometer before removing from the part being measured.

CAUTION: The micrometer should never be used to measure rotating work or while the machine is running. Personal injury may result or the tool may be damaged.

HOW TO USE MEASURING TOOLS

C. TO TRANSFER A MEASUREMENT ON THE INSIDE CALIPERS TO THE MICROMETER CALIPERS.

1. Set the calipers to the space being measured.

2. Lay the calipers in the left hand with the tips of the caliper legs extending beyond the fingers (Fig.14).

3. Hold the micrometer in the right hand so that the thimble may be adjusted with the thumb and forefinger (Fig.14).

4. Rotate the thimble until the tips of the caliper legs can be felt in light contact with the anvil and the end of the spindle.

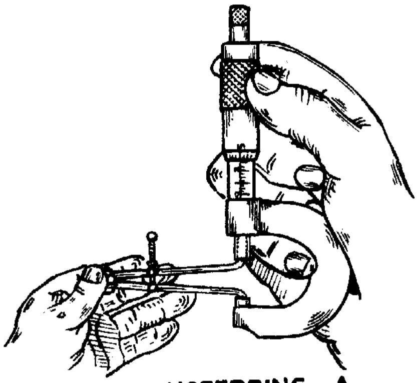


FIG.14 TRANSFERRING A MEASUREMENT

5. By placing the tip of one leg on the micrometer anvil, a fine adjustment of the setting is made by swinging an arc with the other leg until contact is felt at the high point of the arc (Fig. 15A).

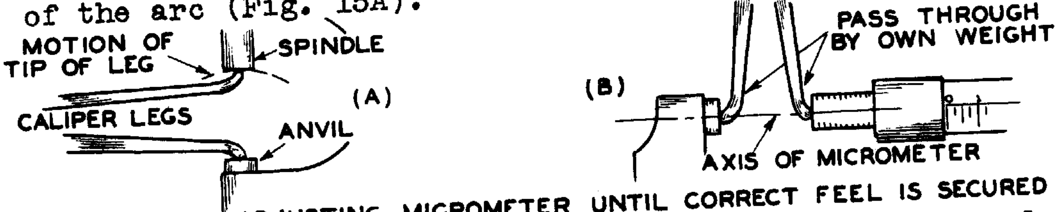


FIG. 15 ADJUSTING MICROMETER UNTIL CORRECT FEEL IS SECURED

The tips of the caliper legs must also be held parallel to the axis of the micrometer spindle; and when accurately set, should pass between the end of the spindle by their own weight (Fig. 15B).

NOTE: When reading the micrometer, remove the thumb and forefinger from the thimble so that the setting is not disturbed.

NOTE: An inside caliper may be used as a gage to check an internal measurement by first setting the inside caliper to a micrometer caliper reading.

THE STEEL SQUARE

1. Remove all burrs from the surface of the work to be checked. Wipe work clean of chips, oil, and dirt.

2. Wipe the square clean, and draw the edges to be used over the palm of the hand to insure absolute freedom from small particles.

HOW TO USE MEASURING TOOLS

3. Face the source of light so that it will shine on the work.

4. Hold the work with the left hand; grasp the beam of the square with the right hand. Place the inside of the square against a finished surface of the work, so that the beam is in full contact with one side and a slight space remains between the blade and the other surface of the work. (Fig. 16 - Position A).

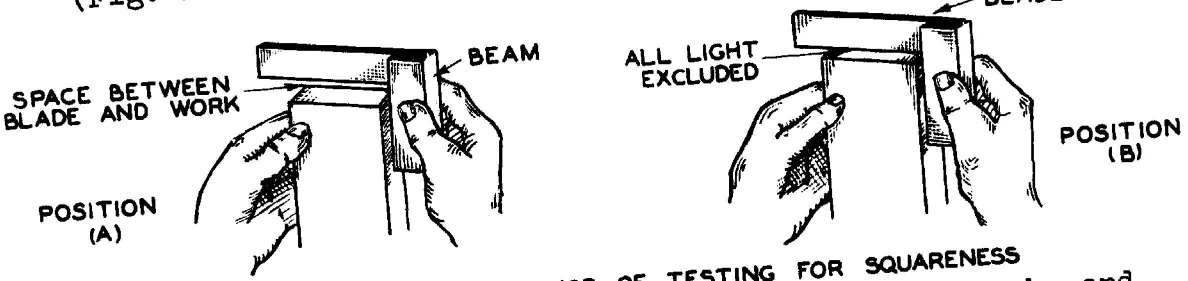


FIG. 16 CORRECT METHOD OF TESTING FOR SQUARENESS

5. Lower the blade carefully to the surface of the work, and note where the blade first comes in contact with the surface. If the angle is square, all light will be excluded (Fig. 16 - Position B).

NOTE: If the angle is not square, light will be seen at either end of the blade (Fig. 17).

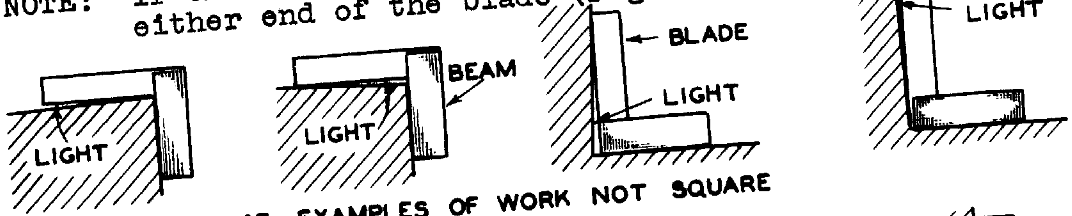


FIG.17 EXAMPLES OF WORK NOT SQUARE

NOTE: The error resulting from burred edges, when attempting to check the squareness of work, is shown in Fig.18.

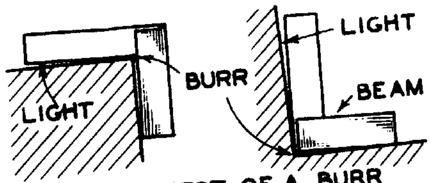


FIG. 18 EFFECT OF A BURR

NOTE: The method of checking an inside right angle with the outside edges of the square is illustrated in Figure 19, Positions (A) and (B).

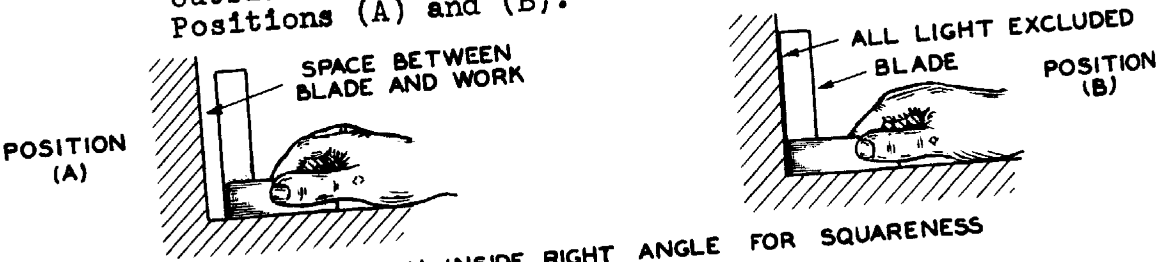


FIG. 19 TESTING AN INSIDE RIGHT ANGLE FOR SQUARENESS

MEASUREMENT

DESCRIPTION OF LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To describe the various tools commonly used in layout work.

2. To point out the application of simple layout tools.

INTRODUCTORY INFORMATION

Layout tools are made in a variety of designs to aid the machinist in transferring information and dimensions from the drawing to the surfaces of the job. (Fig. 1). The general uses of these tools are to scribe lines involving circles, arcs, angles and straight lines which indicate intersections and the outlines of the shape of the work. They are also used to indicate centers of holes to be machined.

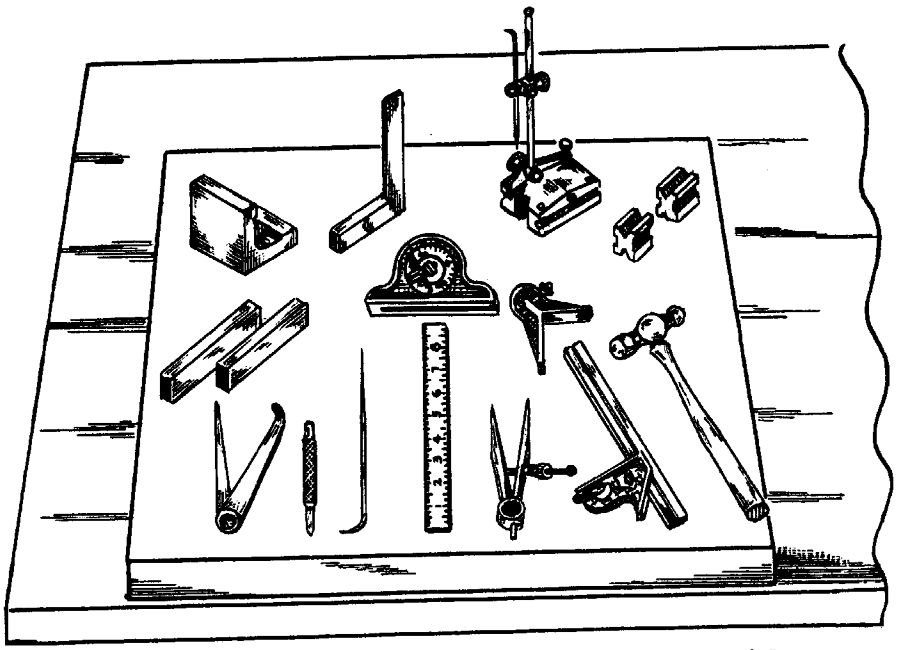


FIG. 1 BENCH PLATE AND COMMON LAYOUT TOOLS

Straight, sharp and keen-edged tools are essential for accuracy since a clean but distinctly scribed layout guides the workman more closely to desired sizes and shapes of the finished article. Therefore, it is important that the workman keep his tools in the best condition and use them only for the purpose for which they are intended.

DESCRIPTION OF LAYOUT TOOLS

BENCH PLATE

The bench plate is a cast iron plate carefully machined to a flat surface. (Fig. 2). Bench plates vary in size. An average size for the work bench is about 18" square by 1-1/2" thick. It is used as a base upon which to work. The work may lie directly on the bench plate, be clamped to an angle plate, or held on "V" blocks while being marked or scribed. The bench plate is used for ordinary layout work where great accuracy is not required.

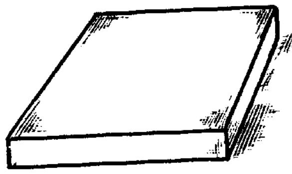
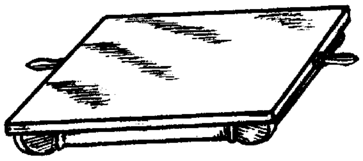


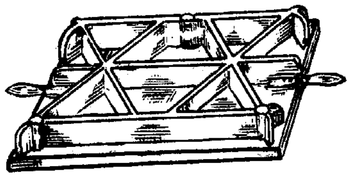
FIG. 2 BENCH PLATE

SURFACE PLATE

The surface plate is used where a finer degree of accuracy is required. This plate is an expensive piece of equipment and must be used with care. It is made of a special grade of close grained cast iron and is well ribbed on the under side to prevent warping of the surface (Fig. 3).

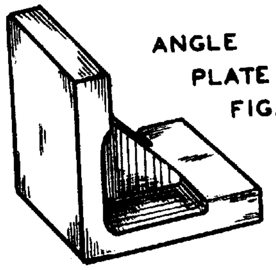


SURFACE PLATES FIG. 3



After being carefully machined, the plate is hand scraped to a flat smooth surface. Besides being used for precision layout work, it is also used for checking accurate work such as gages, jigs, fixtures, etc.

ANGLE PLATE



ANGLE PLATE FIG. 4

The angle plate is an "L" shaped piece of cast iron or steel carefully machined to an angle of 90 degrees. (Fig. 4). The angle plate is used when the work must be held at right angles to the bench or surface plate. The work is clamped in this position on the angle plate while being laid out or checked.

DESCRIPTION OF LAYOUT TOOLS

"V" BLOCKS

"V" blocks are made of either cast iron or steel in various sizes to accommodate a wide range of work. (Fig. 5). They are machined with a "V" shaped slot of 90° on top and bottom. The sides usually are grooved to receive the clamp yoke which is used to hold the work securely in place while being laid out or drilled.

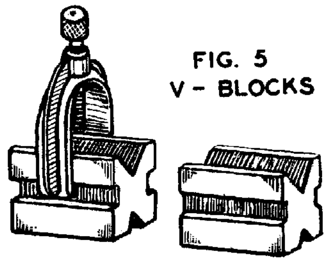


FIG. 5
V - BLOCKS

PARALLELS

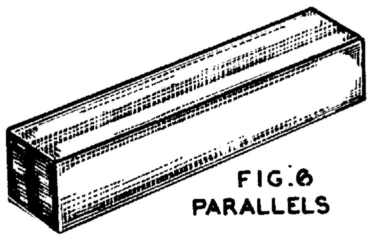


FIG.6
PARALLELS

Parallels are bars of steel or cast iron, square or rectangular in shape and carefully machined for accuracy. (Fig. 6). They are made in pairs of various sizes and lengths depending upon the nature of the work for which they are to be used.

Precision layout work requires hardened and ground parallels. For ordinary work, cold drawn steel, or planed cast iron bars are commonly used.

Parallels may be used for mounting work parallel to the surface of a bench plate, surface plate, or other surface. They may also be used for leveling work on a flat surface when projections on the work prevent setting the job directly upon the plate.

THE COMBINATION SET

The combination set (Fig.7) is a tool consisting of four parts:

1. The stock (square). One side is 90°, the other 45°.
2. The protractor head.
3. The center head.
4. The steel rule or blade which fits any of the three heads.

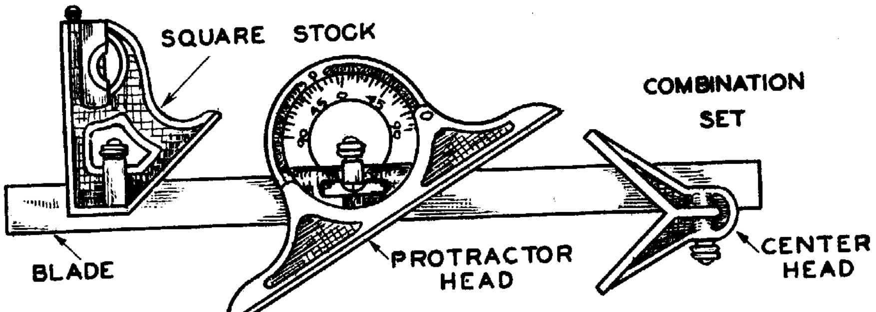


FIG. 7

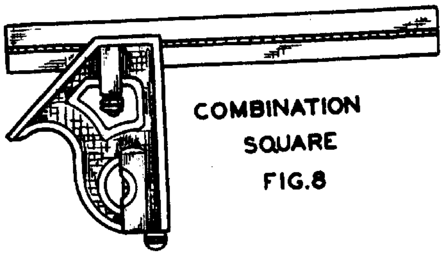
DESCRIPTION OF LAYOUT TOOLS

The combination set is one of the most useful and convenient tools for layout work.

1. The stock can be moved along the steel blade and clamped in any position desired. (Fig.8). It is used as a square for checking angles of 90°, as a depth gage, for scribing lines at right angles to a surface, or for angles of 45°.

By setting the end of the steel rule flush with the stock, it may be used as a height gage directly or in combination with a surface gage.

A spirit level is mounted in the stock. A scriber is held in the lower end by a friction bushing. The scriber may be drawn out when needed.



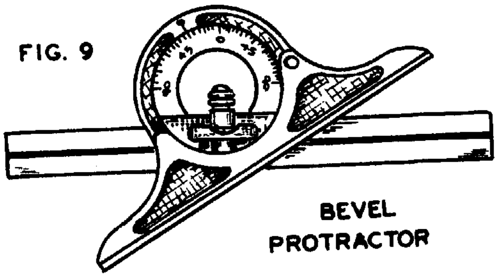
COMBINATION SQUARE FIG.8

2. The protractor head is provided with a swivel or turret to which the steel rule is clamped. (Fig.9). The revolving turret is graduated in degrees from 0 to 180. On some standard makes, it is graduated in degrees from 0 to 90 in either direction.

It can be accurately adjusted to show any angle and is clamped in position with a knurled nut.

The protractor is used for laying out lines at any given angle and for measuring angles.

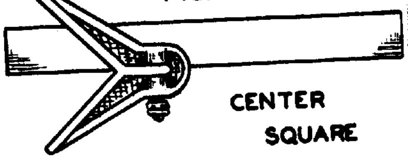
FIG. 9



BEVEL PROTRACTOR

3. The center head forms a center square when clamped to the steel rule. (Fig.10). The sides of the center head are placed on the outer surface of round jobs and the center is found by scribing lines along the edge of the rule.

FIG. 10



CENTER SQUARE

STEEL RULE

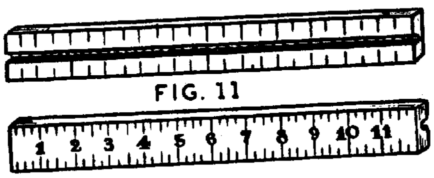


FIG. 11

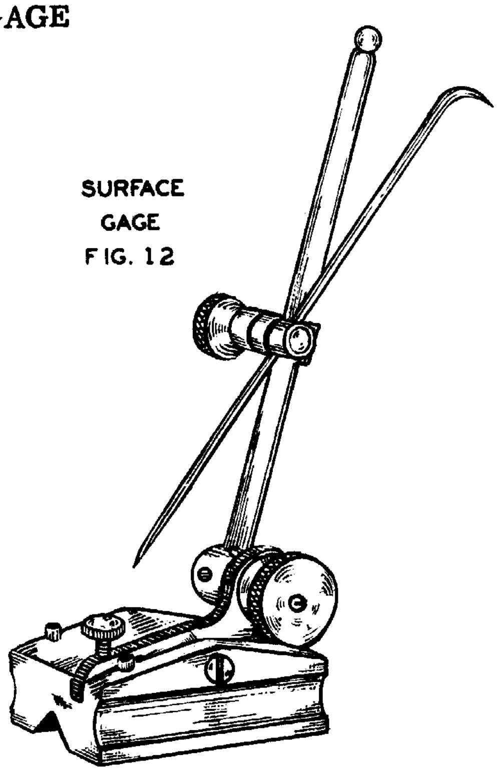
4. The steel blade or rule, which is part of the combination set, may be fitted to either the square stock, the center head, or the protractor head. (Fig. 11). It may be set at any desired position and clamped. It is sometimes used separately for measuring or used as a straight edge.

DESCRIPTION OF LAYOUT TOOLS

THE SURFACE GAGE

The surface gage is an instrument used for scribing lines at a given height from some face of the work or for the construction of lines around several surfaces of the job. (Fig.12). The gage consists of a heavy base and a spindle pivoted upright, to which is attached a scriber held by a clamp. The scriber may be turned through a complete revolution.

SURFACE GAGE
FIG. 12



By resting both the surface gage and the work upon a plane surface, it is possible to set the point of the scriber at a given height, either by use of a scale or some other standard, and draw lines at this height on all faces of the work or on any number of pieces when duplicate parts are being made.

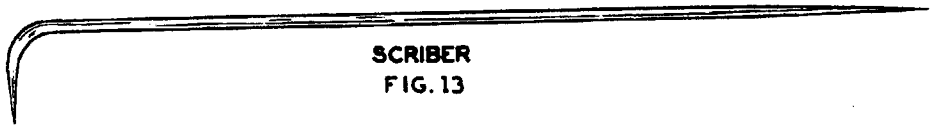
The use of the surface gage is not restricted to the scribing of horizontal lines, but may also be used on other surfaces from which it can be conveniently guided or held.

It can be used as a height gage and also for leveling work on a machine vise or plate.

The bent end on the scriber permits lines to be drawn on horizontal surfaces, while a groove in the base of the gage makes it possible to mark out desired distances from the outside of a circular piece.

THE SCRIBER

The scriber is a piece of tool steel, usually drill rod, about 1/8" in diameter, 8" to 12" long, tapered at both ends to a needle



SCRIBER
FIG. 13

point. (Fig.13). One end is bent to be used in reaching through holes, etc. The scriber is hardened and tempered. It is used to scribe or mark lines on metal surfaces which have been prepared with chalk or blue vitriol.

DESCRIPTION OF LAYOUT TOOLS

DIVIDERS

Dividers have two straight legs, both tapered to a needle point and adjusted for opening by screw and knurled nut (Fig.14).

They are used for scribing circles and radii; and in combination with the steel rule or other standard, to measure distances between points, or to transfer distances taken directly from the steel rule.

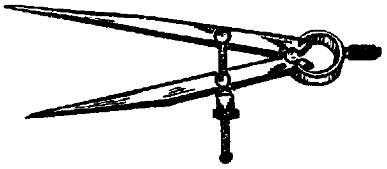


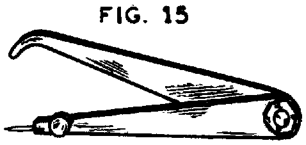
FIG. 14 DIVIDERS

HERMAPHRODITE CALIPERS

The hermaphrodite calipers are made with two legs; one blunt and bent at the end, the other with scriber point. (Fig.15). The scriber point is usually adjustable so that it can be adjusted for length when the bent leg is resting on an outer edge.

It is used for locating centers of round pieces, centers of bosses, etc. It may also be used to scribe a line or locate a point parallel with a surface or shoulder.

FIG. 15



HERMAPHRODITE CALIPERS

PRICK PUNCH

The prick punch is made of tool steel, usually from 4" to 6" long, and is hardened and tempered. It is knurled to give a good finger grip. One end is tapered to a point that is ground to an angle of about 30°. The prick punch is used for making small indentations along scribed lines, for marking the location of points, and centers for divider points.

CENTER PUNCH

The center punch is similar in design to the prick punch, excep that the tapered point is ground to an angle of about 90°. (Fig.16

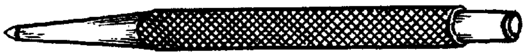


FIG. 16 CENTER PUNCH

The center punch is used for making indentations along scribed lines, for marking the location of points and the centers of holes to be drilled.

SELECTED REFERENCES

Burghardt ------------------ Part I -------- Machine Tool Operation

Henry Ford Trade School -------------------------------- Shop Theory

MEASUREMENT

HOW TO USE LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To point out how to care for layout tools.
2. To show how to use layout tools.

INTRODUCTORY INFORMATION

The more commonly used layout tools are: the scriber; the combination set consisting of the protractor head, center head, square, and the steel blade; hermaphrodite calipers; the center and prick punches; the spring dividers; and the surface gage.

Care should be taken in the use of these tools so that sharpened and pointed edges are kept in good condition to prevent impairing the accuracy, which is essential to a good layout job. Tools which have pointed ends should only be used for the purpose for which they are intended and not on hardened surfaces.

TOOLS AND EQUIPMENT

Scriber
Steel rule
Oil stone
Combination set
Hermaphrodite caliper
Spring dividers

Center punch
Prick punch
Machinist's hammer
Surface plate
Surface gage

PROCEDURE

SCRIBER

1. Inspect the point of the scriber to make sure that it is sharp. If the point is dull, sharpen it on an oil stone by rotating the scriber between the thumb and forefinger while moving it back and forth. (Fig. 1).

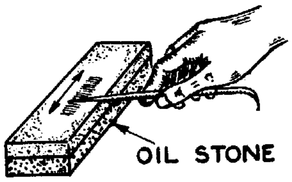


FIG. 1 SHARPENING A SCRIBER

2. Wipe the surfaces of the work to be scribed clean and free of oil, dirt, and chips.

HOW TO USE LAYOUT TOOLS

3. Place the steel rule flat on the work in position for scribing. Grasp the scriber in the right hand as a pencil is gripped. (Fig.2).

4. Hold the rule firmly by exerting pressure with the tips of the fingers of the left hand (Fig.2).

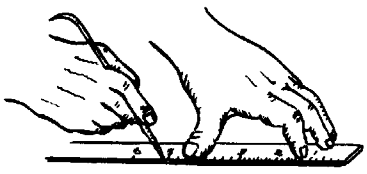


FIG. 2 SCRIBING A LINE

5. Set the point of the scriber as close to the edge of the rule as possible by tipping the top of the scriber outward (Fig.3).

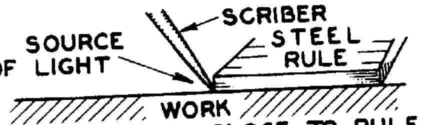


FIG. 3 SCRIBING CLOSE TO RULE

6. Scribe the line by exerting pressure on the scriber and drawing it along the edge of the rule, inclining the top of the scriber slightly in the direction in which it is to be moved. (Fig.4).

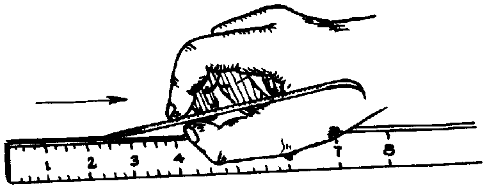


FIG. 4 INCLINING SCRIBER

NOTE: Make sure that the light shines on the portion of the work being scribed.

COMBINATION SET

A. CENTER HEAD

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt.

2. Extend the blade, through the V-opening a length equal to the diameter of the work to be centered. Clamp the blade in position by tightening the knurled nut.

3. Place the V-opening against the diameter of the work to be centered.

4. Scribe a line along the inner edge of the blade (Fig. 5).

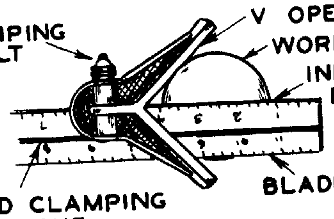


FIG. 5 SCRIBING A CENTER LINE USING A CENTER HEAD

HOW TO USE LAYOUT TOOLS

B. COMBINATION SQUARE

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt (Fig.6).

2. Extend the blade through the slot at the required length and clamp in position by tightening the knurled nut.

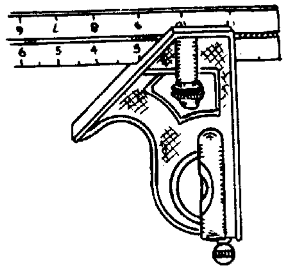


FIG. 6 COMBINATION SQUARE

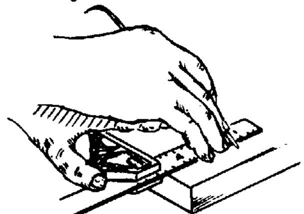


FIG. 7 USING COMBINATION SQUARE FOR LAYING OUT LINES

3. Place the head of the square against the side of the work to be scribed, and scribe lines from either side or the end of the square according to the requirements of the job at hand. (Fig.7).

C. PROTRACTOR

1. Insert the blade through the slot in the swivel turret so that the rounded groove in the blade engages with the clamping bolt.

2. Extend the blade to the required length and tighten (Fig.8).

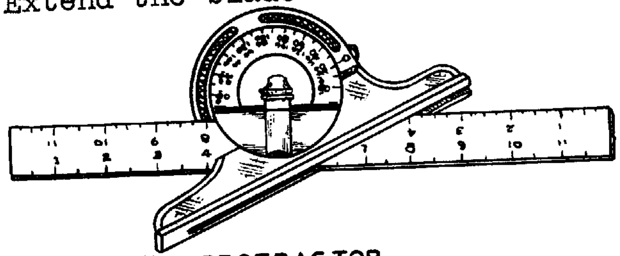


FIG.8 BEVEL PROTRACTOR

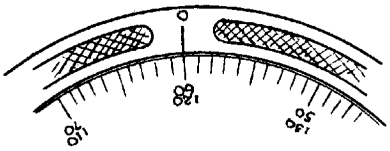


FIG.9 READING PROTRACTOR

3. Loosen the clamping screw on the body of the protractor and swing the revolving turret to the desired angle. This angle is read at the index line on the body and the graduations on the turret. (Fig.9) Tighten the clamping screw.

4. Place the base of the protractor against the side of the work and scribe lines as desired. (Fig.10).

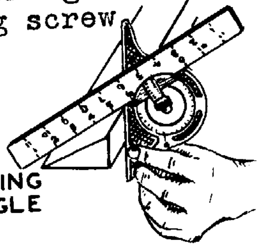


FIG. 10 MEASURING AN ANGLE

HERMAPHRODITE CALIPERS

1. Inspect the scriber leg of the caliper to make sure that the point is sharpened. If the point is dull, sharpen on oil stone.

HOW TO USE LAYOUT TOOLS

2. Adjust the length of the scriber leg so that it is even with the inside edge of the rounded caliper leg when it is to be used to scribe lines from the outside edge of the work. (Fig. 11).

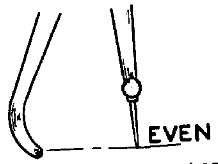


FIG. 11 ADJUSTING LENGTH OF SCRIBER LEG

3. When scribing lines with the caliper reversed, set the scriber point to the full length of the caliper leg. (Fig.12).

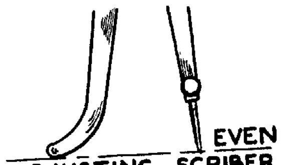


FIG. 12 ADJUSTING SCRIBER LEG WITH CALIPER REVERSED

4. Case 1

To set the caliper at the desired dimension, loosen the lock nut slightly. Place the caliper leg against the end of the steel rule and adjust the scriber leg to the required graduation on the steel rule. Tighten the clamp nut. (Fig.13-Case 1).

FIG. 13 SETTING HERMAPHRODITE CALIPERS

Case 2

To set the caliper at the desired dimension with the legs reversed, place the end of the steel rule against a straight surface and set the end of the caliper even with the end of the rule. Adjust the scriber leg so that the point of the scriber coincides with the required graduation on the rule (Fig.13-Case 2). Tighten the clamping nut.

5. Grasp the top of the caliper with the thumb and forefinger of the right hand. Place the curved tip of the caliper against the surface from which the line is being located, keeping the tip of the caliper leg square with the surface from which it is guided and in contact with the surface. Scribe the line by exerting a slight pressure on the scriber and drawing the caliper along the surface being scribed. (Fig.14).

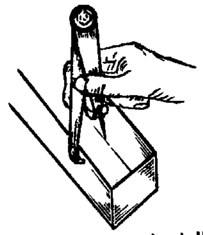


FIG. 14 SCRIBING A LINE

HOW TO USE LAYOUT TOOLS

CENTER PUNCH AND PRICK PUNCH

1. Inspect the point of the punch to make sure that it is sharp.

   NOTE: The point of the prick punch is usually sharpened to an angle of 30°, while the center punch is usually ground to an angle of 90° (Fig.15).

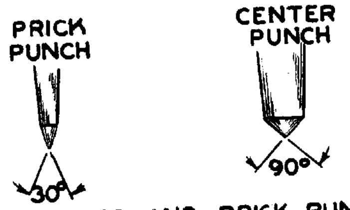


FIG. 15 CENTER AND PRICK PUNCH

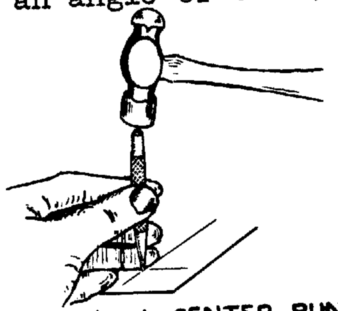


FIG. 16 USING A CENTER PUNCH

2. Grasp the punch in the left hand and punch directly on the line or intersection of lines to be marked. (Fig.16).

   NOTE: With a little practice, the beginner can feel the point of the punch when it strikes the scribed line or meets the intersection.

3. Hold the punch in a vertical position and tap it lightly with a machinist's hammer. Repeat blow if indentation is not deep enough.

   NOTE: Tap the prick punch lighter than the center punch. The prick punch is used for making light indentations, as for the point of the divider. The center punch is used to make heavier indentations such as the starting point for a drill.

DIVIDERS

1. Inspect the points of the dividers to make sure they are sharp.

2. To set the dividers, hold them in the left hand and place the point of one leg in a graduation on the steel rule. By turning the knurled adjusting nut with the thumb and forefinger of the right hand, adjust the divider until the point of the other leg rests on the graduation of the steel rule, which gives the required measurement. (Fig.17).

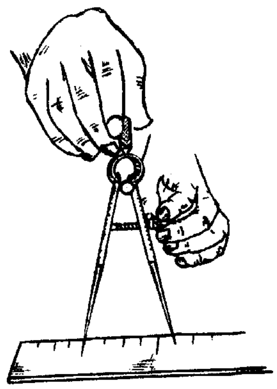


FIG. 17 SETTING DIVIDERS

3. To scribe an arc or circle with the dividers, grasp the knurled thumb attachment on the top of the dividers with the thumb and forefinger of the right hand.

HOW TO USE LAYOUT TOOLS

4. Place the point of the pivoting leg on the punched mark. With pressure exerted on both legs, swing in a clockwise direction and scribe the desired arc or circle. (Fig. 18).

   NOTE: By inclining the dividers in the direction in which they are being rotated, the tendency to slip is avoided.

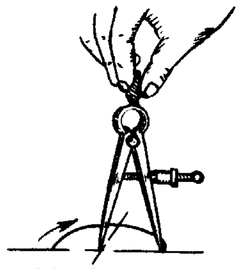


FIG. 18 SCRIBING A CIRCLE

SURFACE GAGE

1. Clean the surfaces of the surface plate, the base of the surface gage, and the work.

2. Decide on the best position in which to set the spindle and scriber of the surface gage.

   NOTE: The surface gage will be more rigid if the scriber is clamped close to the spindle and as near the base as possible.

3. To set the surface gage to a given dimension, adjust the position of the spindle by loosening the swivel bolt lock nut and adjusting the spindle to a convenient position. Clamp in position. (The position of the spindle depends on the nature of the job. Ordinarily, it can be set in a vertical position but may be tilted as the job demands).

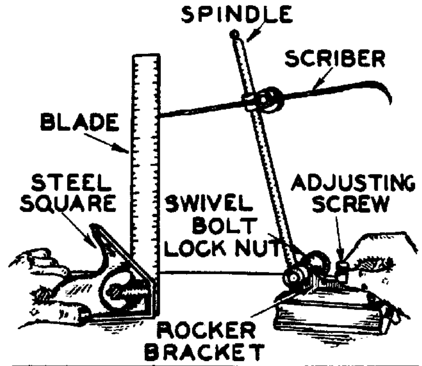


FIG. 19 ADJUSTING SURFACE GAGE

   Then, set the scriber at approximately the given dimension by loosening the scriber clamp nut and adjusting it for its position on the spindle and its extension from the swiveling head. Clamp in position (Fig.19).

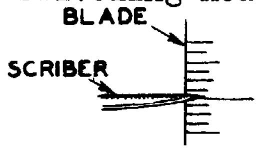


FIG. 20 ADJUSTING SCRIBER TO DESIRED DIMENSION

   To make the final adjustment, turn the small adjusting screw at the rear of the rocker bracket so that the scriber is elevated or depressed to the given dimension.

4. To scribe lines, grasp the surface gage at the base and move it along the surface plate with the scriber point bearing against the surface to be laid out.

MEASUREMENT

DESCRIPTION OF LAYOUT WORK

OBJECTIVES OF UNIT

1. To define the meaning of layout as it applies to machine shop practice.
2. To indicate the kinds of work where laying out is required and the necessity for laying out work prior to machining.
3. To describe the materials used for preparing surfaces for marking.

INTRODUCTORY INFORMATION

Laying out is the planning of the work on the surface of the job prior to machining. It is the scribing of lines which are used to indicate the boundaries, centers, and other locations which guide the workman in making the job to given dimensions.

Through layout, the machinist is able to analyze the sequence of operations and thereby plan his work in more efficient and orderly steps.

The accuracy of the finished job depends largely upon the care taken in the original layout. The nature of the job determines the kind of tools to be used.

NECESSITY FOR LAYOUT

Laying out is frequently used on work that is to be machined on shaper, planer, milling machine, or drill press. Much layout work is done on castings. This requires skill and judgment on the part of the workman to see that the job is properly machined. Quite often a casting is uneven or scant in places and, therefore, needs some calculation and judgment in layout.

Machined parts and finished surfaces can be laid out more readily and to a finer degree of accuracy than rough castings or unfinished work, since it is possible to set up the work on a surface plate or angle plate before scribing lines and locations.

In layout work, some "base" line or finished surface is selected from which to begin to make measurements. This serves as a starting point from which to lay out dimensions and as a location from which to check, should the work be shifted during the layout process.

DESCRIPTION OF LAYOUT WORK

MARKING MATERIALS

When scribing lines on metal surfaces, it is necessary to prepare the surface with a marking material so that the lines and markings are more legible. Several materials are used for this purpose.

1. Chalk is used for rough castings or unfinished steel that has an oxidized surface. Chalk rubbed on the surface before marking will make the scribed lines and markings much plainer.

2. A soapstone pencil is also very useful in marking the surface of rough castings.

3. Blue vitriol is generally used in preparing a finished surface for layout. The blue vitriol solution contains copper sulphate, water, and sulphuric acid. As much copper sulphate as will dissolve is added to four ounces of water and then ten drops of sulphuric acid are added to the solution.

CAUTION: To prevent personal injury when mixing the solution, add the acid to the water. Never add water to acid.

This solution gives a reddish-brown color against which the lines will show.

CAUTION: Care should be exercised in the use of blue vitriol solution so that none is spilled on the bench, surface plate, tools, or machinery. This solution is likely to rust or damage the tools and impair their accuracy. Blue vitriol spilled on clothing will cause the fabric to rot.

4. Coloring by heat is sometimes used on jobs where the tempe of the metal is not to be considered. Heating the metal to a blue will give a satisfactory coloring through which scribed lines are plainly visible.

SELECTED REFERENCES

Burghardt ------------------ Part I -------- Machine Tool Operatio

Henry Ford Trade School ------------------------------- Shop Theor

Machinery's Handbook

MEASUREMENT

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

OBJECTIVES OF UNIT

1. To explain the method of preparing a surface prior to laying out.
2. To explain how to lay out work on rough castings.
3. To explain how to lay out work on flat surfaces of a squared piece.
4. To explain how to lay out work on the bench, surface, or angle plate.

INTRODUCTORY INFORMATION

Practically all layout work is done on a bench plate or surface plate. The bench plate is generally used for rough and approximate layout; while the surface plate is used for precision work as well as checking the accuracy of tools and finished jobs. Each job of layout is a problem in itself involving judgment on the part of the workman according to the requirements peculiar to the job at hand.

TOOLS AND EQUIPMENT

Bench Plate
Surface plate
Parallel bars
Angle plate
Surface gauge
Combination square set
Scriber
Center punch and hammer
Dividers

Hermaphrodite Calipers
Clamps
Solid steel square
Steel rule
Marking materials
  a. Chalk
  b. Copper sulphate
    (Blue Vitriol)
Swab for copper solution

PROCEDURE

A. LAYOUT WORK ON ROUGH CASTINGS

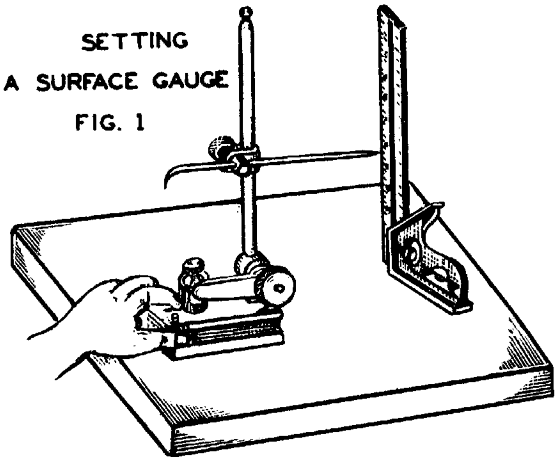
1. Check casting with the blueprint or drawing to determine starting point and also to ascertain the amount of material to be removed.

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

NOTE: Remove all rough projections and fins from surfaces upon which lines are to be scribed as well as those upon which the work rests.

SETTING A SURFACE GAUGE

FIG. 1

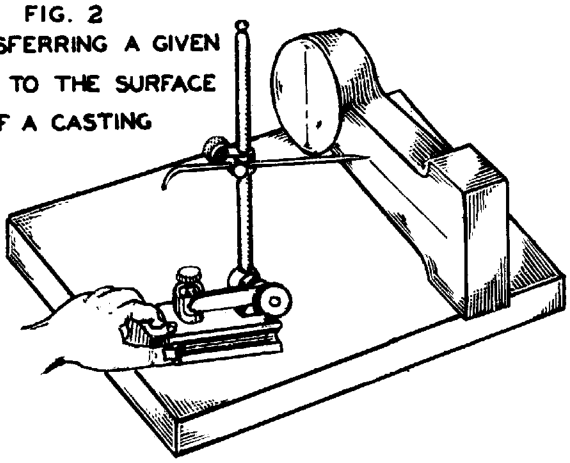


2. Level the casting on the bench plate, using a square, or surface gage.

3. Rub chalk over surface upon which lines are to be scribed.

4. Refer to the drawing or blueprint for dimensions and determine the distance from the base of the bench plate to the first line to be scribed.

FIG. 2
TRANSFERRING A GIVEN HEIGHT TO THE SURFACE OF A CASTING



Horizontal lines may be scribed by use of the surface gage resting on the bench plate.

The surface gage should be set to the desired height with the aid of the steel rule, combination square or other gage. (Fig.1). Transfer the given height to the surface of the casting by sliding the surface gage along the bench plate with the scriber in contact with the casting (Fig. 2).

5. Vertical lines are next laid out by using the combination square or solid steel square and scriber. Intersections and centers are then marked off on the horizontal lines from the first vertical line by use of the dividers. The subsequent vertical lines are marked with the dividers, square, and scriber. (Fig.3). Angular lines may be laid out by using the bevel protractor. (Fig. 4).

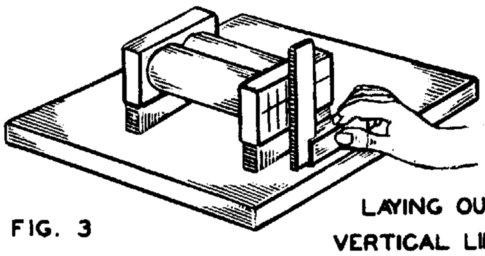


FIG. 3 LAYING OUT VERTICAL LINES

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

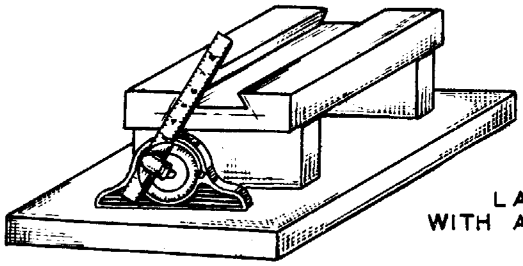
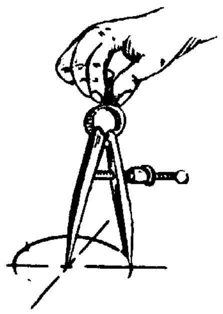
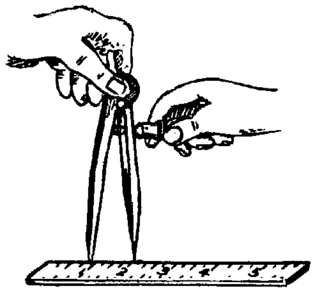


FIG. 4
LAYING OUT ANGULAR LINES WITH A BEVEL PROTRACTOR



SCRIBING A CIRCLE
FIG. 5

6. Light indentations are made at points of intersection with a prick punch. Using these marks as centers, circles are scribed with dividers to the diameter of the hole to be drilled and prick punched around the circle to guide the workman. After the circles are scribed, make a deeper indentation at the center so that the drill will start centrally.
7. Check layout with the blueprint for errors.



SETTING DIVIDERS
FIG. 6

B. LAYOUT WORK ON FLAT SURFACES OF A SQUARED PIECE

1. Remove all burrs.

2. Clean or polish surface to be laid out before applying copper sulphate (Blue Vitriol). Surface must be kept free of grease or oil.

   CAUTION: Copper sulphate is a poisonous substance and should be handled with care.

3. Using a swab or clean piece of cloth, apply copper sulphate (blue vitriol) solution to the prepared surface and rub it until a copper coating appears.

   NOTE: Blue vitriol solution has a corrosive action and should be kept away from tools and polished surfaces.

4. Refer to drawing or blueprint for dimensions and determine the distance from the squared edges to the first line to be scribed.

5. Set the hermaphrodite calipers by placing the blunt leg on the end of the scale and the pointed leg to the graduation at the desired distance. (Fig. 7).

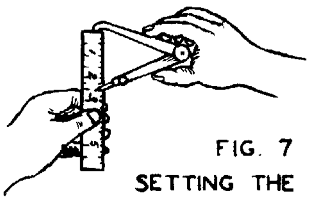
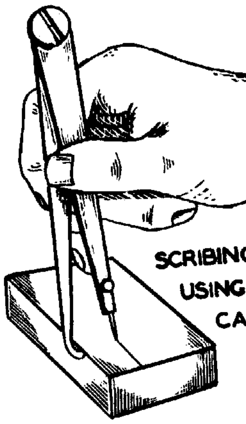


FIG. 7
SETTING THE HERMAPHRODITE CALIPER

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

6. By setting the blunt leg against the squared edge of the piece, scribe a line parallel to the edge with the scriber point of the caliper (Fig. 8). Repeat the process for other parallel lines.



SCRIBING PARALLEL LINES USING A HERMAPHRODITE CALIPER
FIG. 8

7. Parallel lines may also be scribed by using the combination square. Set the blade of the square at the desired dimension and scribe lines at each end as shown in Figure 9. Connect these lines with the steel rule or combination square placed on edge.

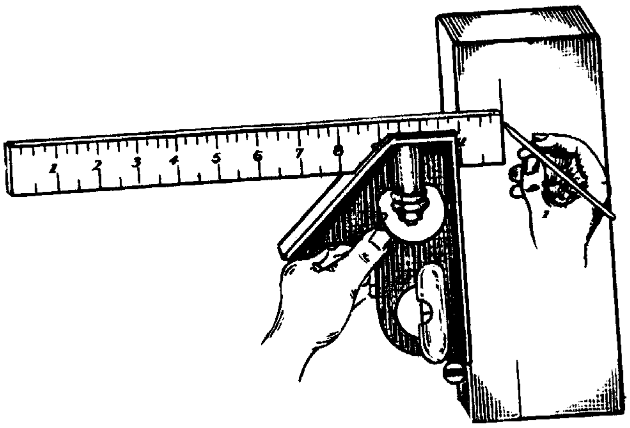


FIG. 9
SCRIBING PARALLEL LINES USING A COMBINATION SQUARE

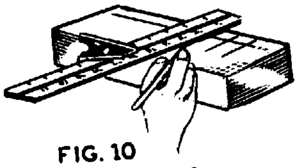


FIG. 10
SCRIBING LINES AT RIGHT ANGLES

8. Lines are drawn at right angles by using the combination square or st square. The blade is held at righ angles to the work and the lines a scribed along the edge of the blad (Fig. 10).

9. Distances may be laid off along an of the lines by using the dividers or the steel scale and scriber.

10. Angular lines may be laid out by using the bevel protractor.

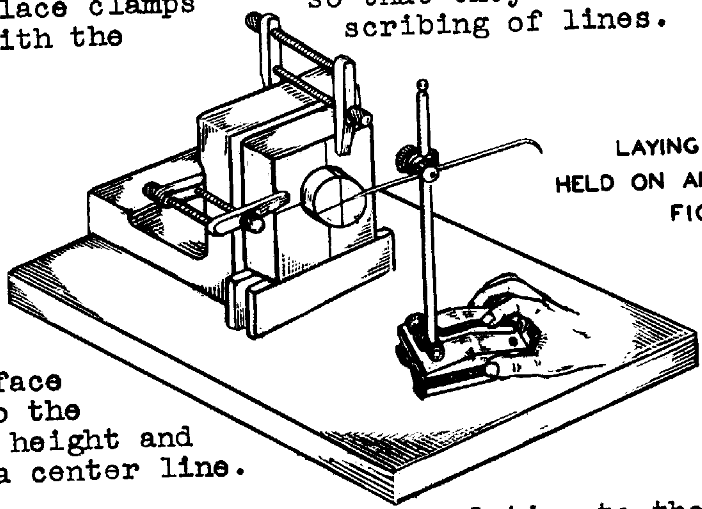
11. Check layout with the blueprint for errors.

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

C. LAY OUT WORK ON THE ANGLE PLATE

1. Check work with the blueprint or drawing to determine the locations of lines to be scribed.
2. Select an angle plate of a size suitable for the job at hand.
3. Remove all burrs from surfaces of the work.
4. Prepare the surfaces for marking:
   a) If rough casting, use chalk.
   b) If machined surface, use copper sulphate.
5. Clean bench plate, angle plate, parallel bars, and work.
6. Set the angle plate and parallel bars on a bench or surface plate.
7. Place the machined surface of work against the angle plate and rest the lower edge on parallel bars prior to clamping. Secure the work with clamps. (Fig. 11)

NOTE: Place clamps so that they do not interfere with the scribing of lines.



LAYING OUT WORK HELD ON AN ANGLE PLATE
FIG. 11

8. Set surface gauge to the desired height and scribe a center line.
9. Scribe other parallel lines in relation to the center line.
10. Turn angle plate on end to scribe lines at right angles to other lines.
11. Repeat steps 8 and 9.
12. Remove work from angle plate and center punch intersections.
13. Check layout with blueprint for errors.

SECTION II

Units of Instruction in

MACHINE SHOP MATHEMATICS

SECTION II

Units of Instruction in

MACHINE SHOP MATHEMATICS

MACHINE SHOP MEASUREMENT

SECTION II

Machine Shop Mathematics Unit 1M-BP1 Basic Principle Series

INTRODUCTION TO THE UNITS OF MEASURE

A. THE UNITS OF MEASURE ARE STANDARDIZED FOR EACH TRADE.

1. THE BASIC UNITS OF MEASURE

The basic units of measure, such as length, weight, capacity, temperature, etc., are determined in Washington, D. C. by the properly authorized Federal organization to do such work, the Bureau of Standards.

These units are in accord with those used throughout the world, and the United States standards are set up to be in agreement with them.

The measuring tools of industry are periodically sent to this bureau and there the Bureau of Standards furnishes the inquirer the information to show how closely that measuring tool (used within some factory as a standard) agrees with the universally accepted standard.

2. THE STANDARDS OF MEASURE WITHIN THE VARIOUS TRADES

For almost every industry, there is a committee on standardization of some sort which determines the units, specifications, forms, and practices for that industry.

To secure a closer working agreement between those different industries, one great body has been formed, the greatest of its kind, representative of every great industrial organization in this country, the American Standards Association. This body passes on the standards set throughout this country and secures the cooperation of other similar organizations throughout the world to establish and maintain standards of measure, specification, and practice.

MEASUREMENT

CONCEPTS OF UNITS OF MEASURE

1. List several examples of the necessity for a general agreement on measurement and the units of measure for:

   a. The assembly of unit parts in a single manufacturing plant.

   b. The production of parts and assemblies throughout a whole country for a single industry or by closely related industries.

2. Name one or two of the units of measure used in determining:

   a. Length

   b. Surface

   c. Weight

   d. Volume

   e. Temperature

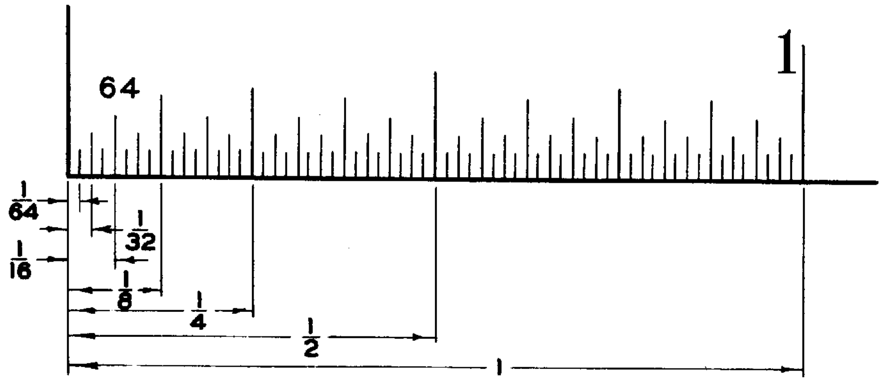
MEASUREMENT

THE UNITS OF LINEAR MEASURE

TABLE OF LINEAR MEASURE

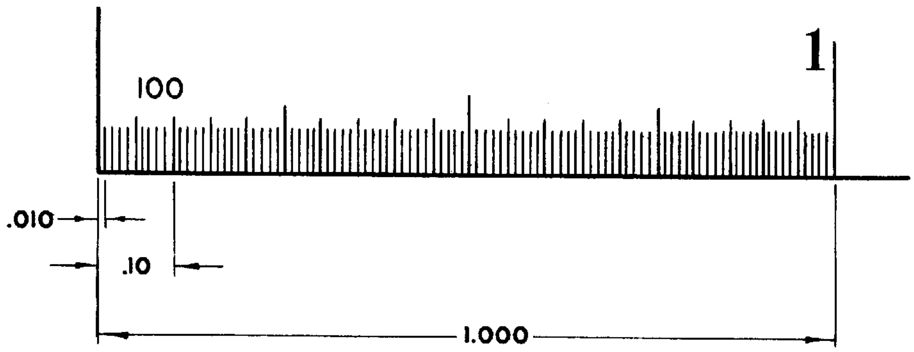
unit	=	1 inch
12 inches	=	1 foot
3 feet	=	1 yard

The divisions of the inch, binary system.



The divisions of the inch, decimal system. Divisions of the inch with the denominator of the fraction a power of ten.

1.	=	1.000	=	one
$\frac{1}{10}$	=	.10	=	one-tenth
$\frac{1}{100}$	=	.010	=	one-hundredth
$\frac{1}{1000}$	=	.0010	=	one-thousandth
$\frac{1}{10000}$	=	.00010	=	one ten thousandth



MEASUREMENT

APPLICATION OF LINEAR MEASURE

A. USE OF SCALE IN TAKING LINEAR MEASUREMENTS

1. With the steel scale, construct straight lines of the following lengths:

a. 2-1/4 inches

b. 3-3/4 inches

c. 4-1/2 inches

d. 1-1/8 inches

e. 2-5/8 inches

f. 4-3/8 inches

g. 5-7/8 inches

h. 2-1/16 inches

i. 4-5/16 inches

j. 5-9/16 inches

k. 3-15/16 inches

l. 5-7/32 inches

m. 1-19/32 inches

n. 2-1/64 inches

o. 1-9/64 inches

p. 3-3/64 inches

q. 4-47/64 inches

r. 1-7/10 inches

s. 2-9/10 inches

t. 3-7/100 inches

u. 5-29/100 inches

v. 4-31/32 inches

LINEAR MEASURE

2. Measure these lines to the nearest quarter of an inch.

a.

b.

c.

d.

3. Measure these lines to the nearest eighth of an inch.

a.

b.

c.

d.

4. Measure these lines to the nearest sixteenth of an inch.

a.

b.

c.

d.

5. Measure these lines to the nearest thirty-second of an inch.

a.

b.

c.

d.

6. Measure these lines to the nearest sixty-fourth of an inch.

a.

b.

c.

d.

LINEAR MEASURE

7. Measure these lines to the nearest tenth of an inch.

a.

b.

c.

d.

e.

f.

g.

h.

i.

j.

8. Measure these lines to the nearest one hundredth of an inch.

a.

b.

c.

d.

e.

f.

g.

h.

i.

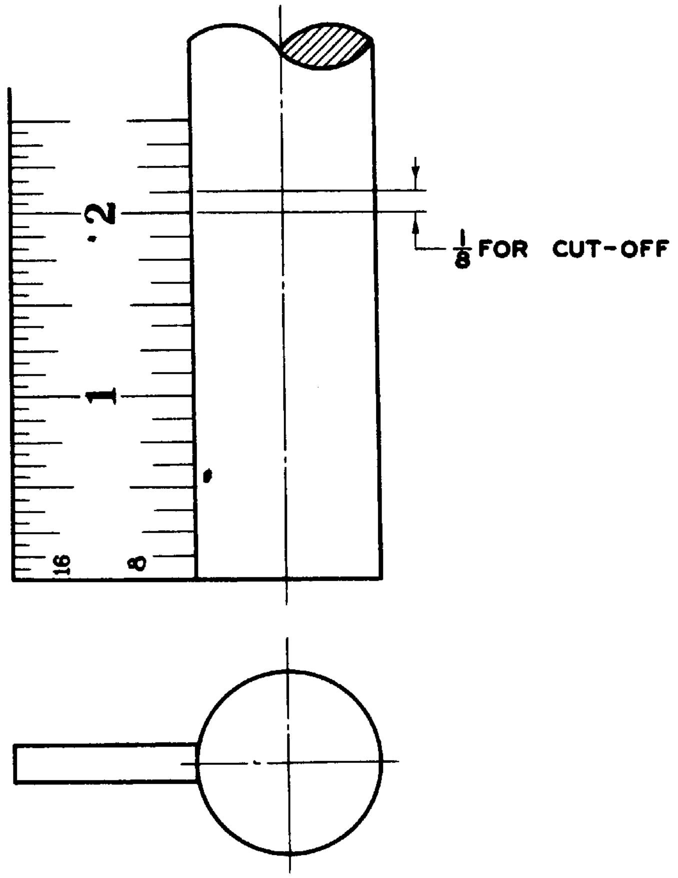
j.

k.

LINEAR MEASURE

B. PRACTICAL APPLICATION OF LINEAR MEASURE

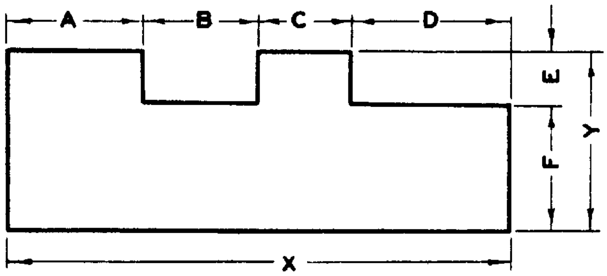
Allowances For Cutting Off Stock



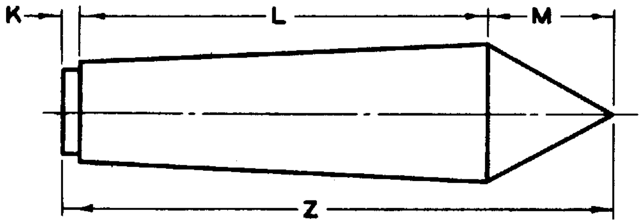
1. How much stock is required for 4 pieces of C. R. S. $2\frac{1}{4}$" long, if 1/8" must be allowed for each piece for cutting off?

LINEAR MEASURE

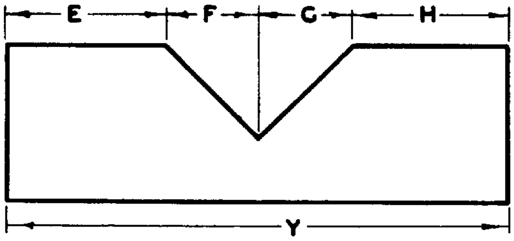
2. In this milled block, measure lengths A, B, C, and D and check the sum of these against the overall dimension X. Do the same for dimensions E, F, and Y.



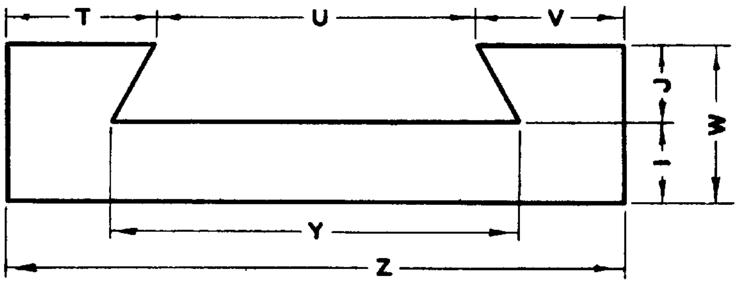
3. On the lathe center, measure the length K, L, and M, and check the sum of their lengths against the overall dimension Z.



4. Measure dimensions E, F, G, H, and the overall length Y of this V-block; and check.



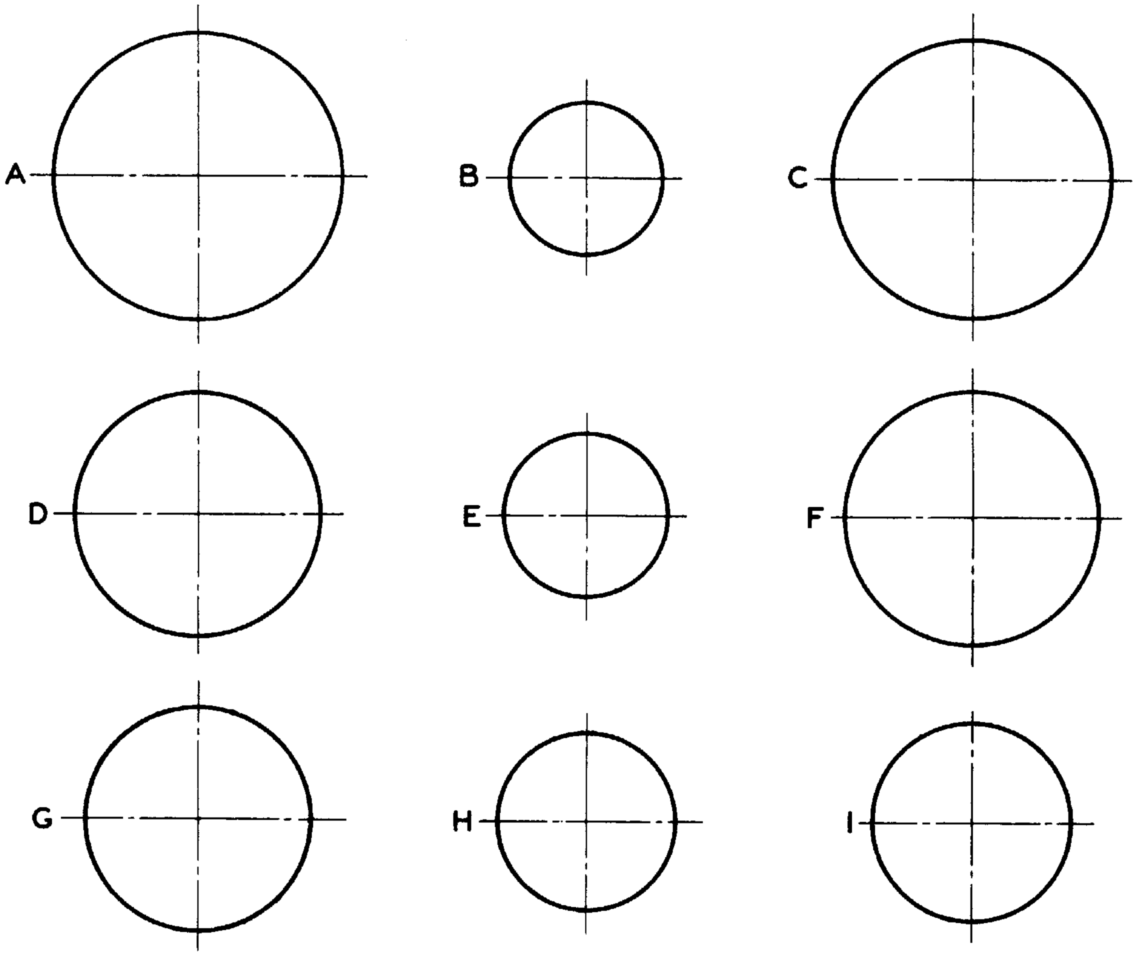
5. Measure dimensions T, U, and V, and check with the overall length Z of the lathe slide. Do the same for I and J and check with the overall length W.



LINEAR MEASURE

C. APPLICATION OF TRANSFERRED MEASUREMENT

1. The circles below represent the sizes of holes to be drilled. Measure the diameters with an inside caliper, transfer the measurement to a scale, and record the size drill to use.

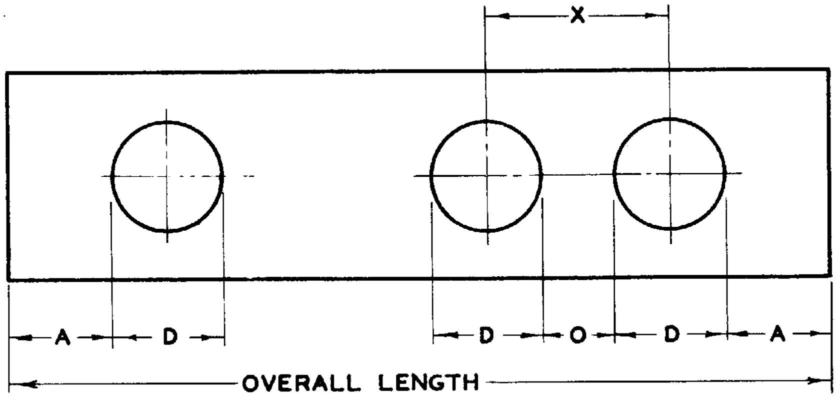


Diameter A ________ What size drill should be used? ________.
Diameter B ________ What size drill should be used? ________.
Diameter C ________ What size drill should be used? ________.
Diameter D ________ What size drill should be used? ________.
Diameter E ________ What size drill should be used? ________.
Diameter F ________ What size drill should be used? ________.
Diameter G ________ What size drill should be used? ________.
Diameter H ________ What size drill should be used? ________.
Diameter I ________ What size drill should be used? ________.

COMPUTED MEASURE

When a measurement is transferred from one measuring device to another, or an overall length is divided into a number of equal parts, the measurement is obtained indirectly.

1. The overall length of a piece of metal is 30". If 1/4" is allowed on each end, how many 1" holes can be bored leaving 1/2" between them? What is the distance from center to center of each hole?



2. On the bending jig illustrated above, find the missing dimensions and place these in the indicated place on the table.

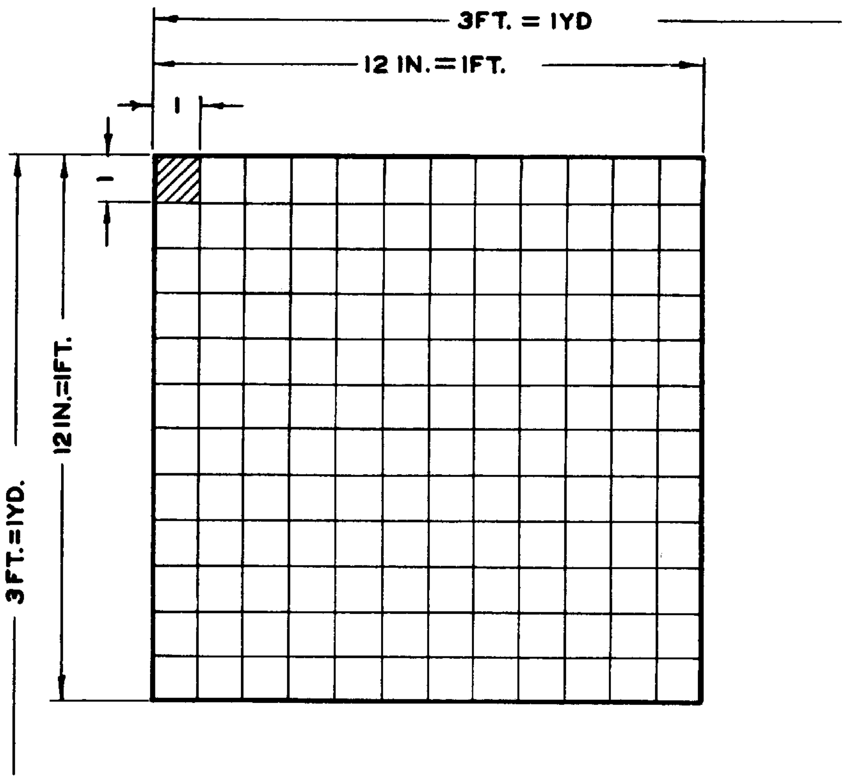
Overall length	(A) End spaces	No. of holes	(X) Center to center	(D) Diameter of circle	(O) Space between
1'4-7/8"	7/16		$1\frac{1}{4}$"	1"	$\frac{1}{4}$"
2' 0"		12	$1\frac{1}{4}$"		3/8
	7/8"	16		1/8"	$\frac{1}{2}$"
	1-1/16	17	2-9/16	2"	

MEASUREMENT

THE UNITS OF AREA

A. TABLE OF SQUARE MEASURE

unit	=	1 square inch
144 square in.	=	1 square foot
9 square ft.	=	1 square yard



B. SIMPLE SURFACE FORMULAS

The area of a rectangle is equal to length times width.

$$A = lw$$

The area of a square is equal to the square of one side.

$$A = s \times s \quad \text{or} \quad A = s^2$$

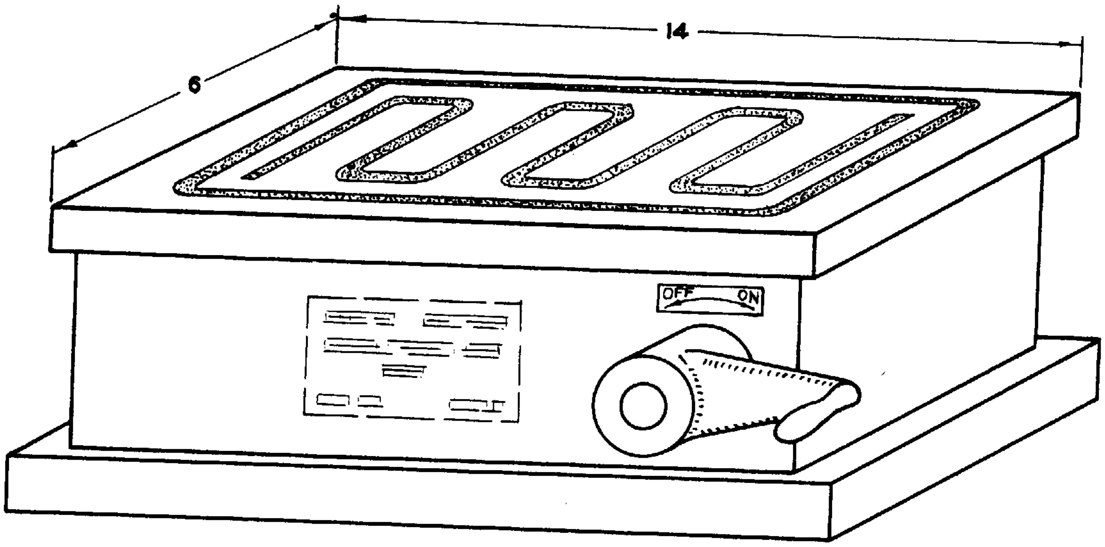
MEASUREMENT

APPLICATION OF SURFACE MEASURE

1. The top of a magnetic chuck for a surface grinder is 6" wide and 14" long.

    a. How many square inches are there on the surface of the chuck?

    b. How many pieces 2" x 2" can be placed over the entire area of the chuck face?

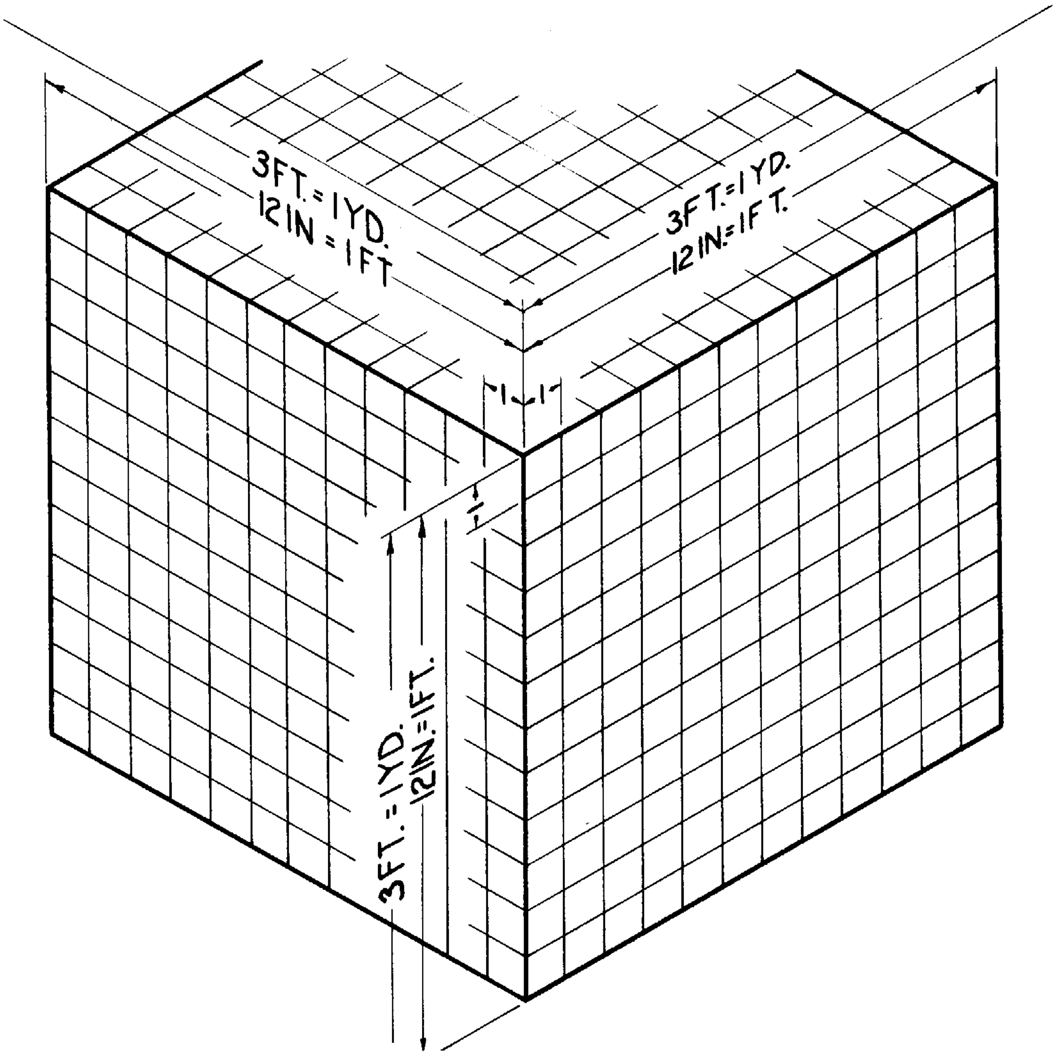


MEASUREMENT

THE UNITS OF VOLUME

A. TABLE OF CUBIC MEASURE

unit	=	1 cubic inch
1728 cubic inch	=	1 cubic foot
27 cubic feet	=	1 cubic yard



B. SIMPLE VOLUME FORMULAS

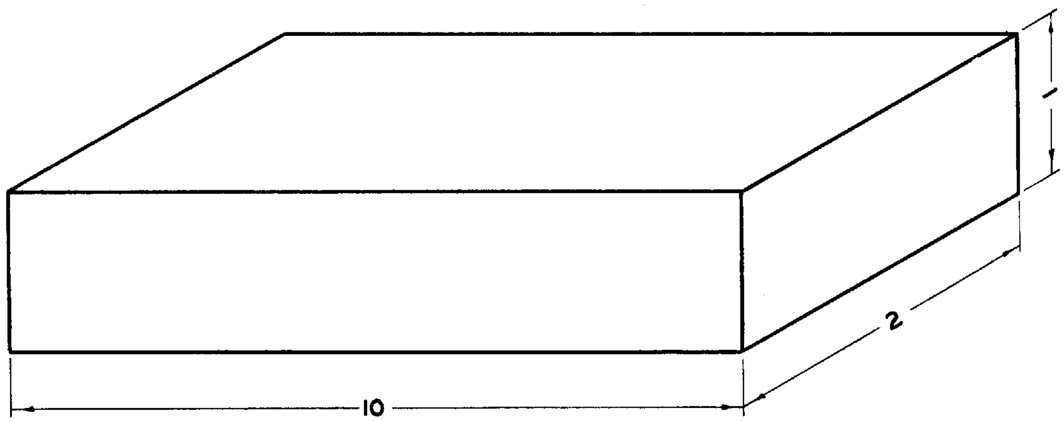
The volume of a rectangular solid equals the length times the width times the thickness. $V = lwh$.

The volume of a cylinder equals π times the square of the radius times the height. $\pi = 3.14$ $V = \pi r^2 h$

MEASUREMENT

APPLICATION OF VOLUME MEASURE

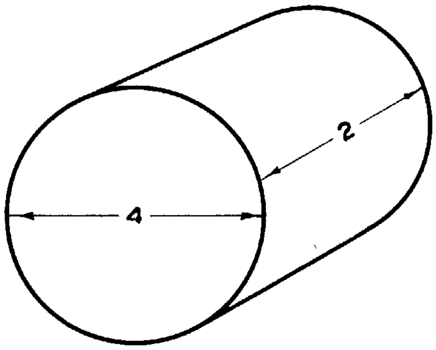
1. Twelve bars of 1" x 2" flat cold rolled steel are to be cut 10" long.



(a) How many cubic inches are there in each piece of stock?

(b) What is the weight of each piece when cold rolled steel weighs .28#/cu. in.

(c) What is the cost of the twelve bars of cold rolled steel at eight cents per pound.



2. Two bronze discs are to be machined from 4" diameter stock, 2" thick.

(a) How many cubic inches of metal are there in each disc?

(b) What is the weight of each disc if bronze weighs .28#/cu.in.?

(c) What is the cost of the two discs at forty cents per pound?

MEASUREMENT

THE UNITS OF ANGULAR MEASURE

A. ANGULAR MEASUREMENT

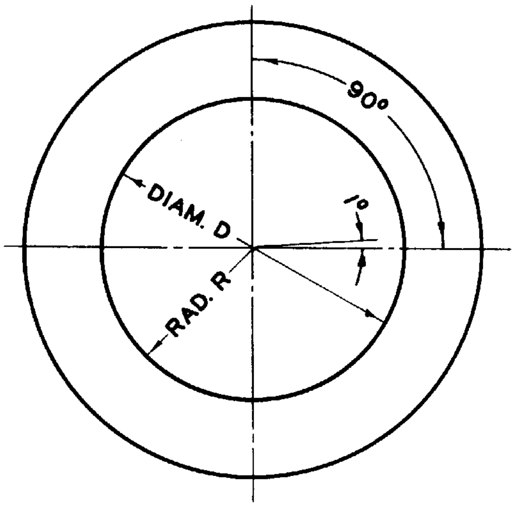


Table of Angular Measure

60 seconds	=	1 minute
60 minutes	=	1 degree
90 degrees	=	1 quadrant
360 degrees	=	1 circumference

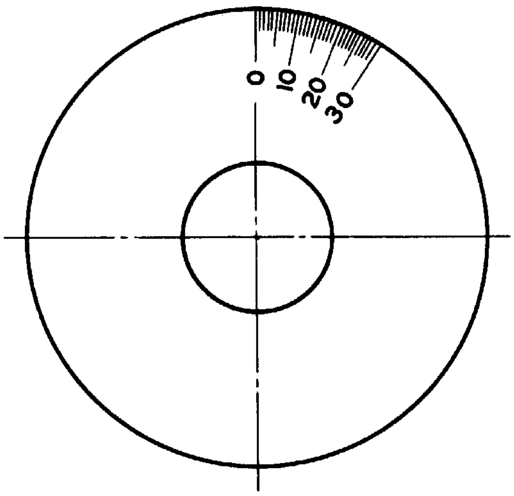
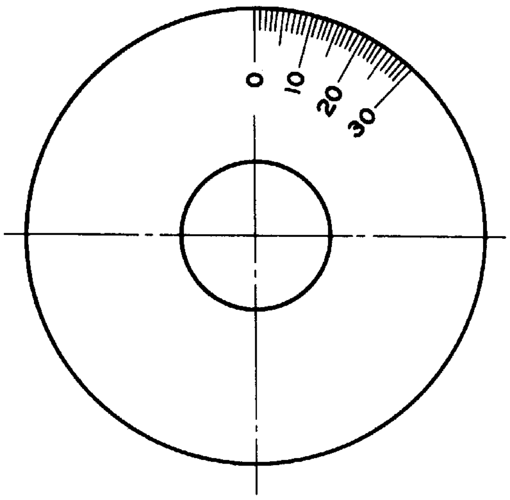


Illustration shows 1° between each space.

Angular Measure is obtained by measuring with a protractor.

B. LINEAR MEASURE ON A CIRCULAR FORM

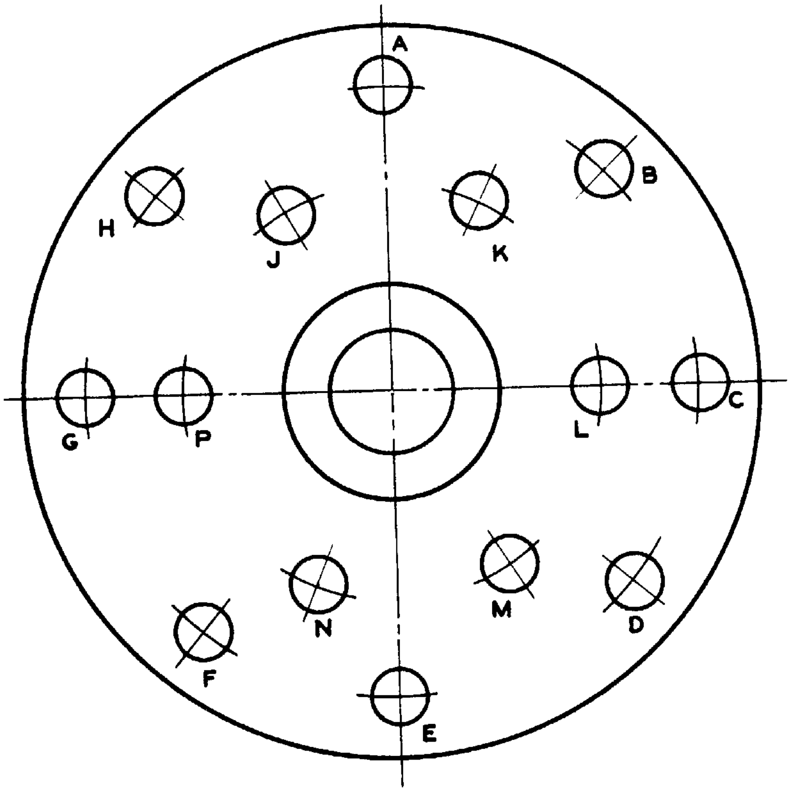
Illustration shows .001 movement between each space for .250 lead screw.



MEASUREMENT

APPLICATION OF ANGULAR MEASURE

Use a protractor to measure the angle to the nearest degree between the following holes on the face plate shown in the accompanying sketch.



1. Hole A to Hole B includes an angle of ______ degrees.
2. " B " " L " " " " ______ " .
3. " C " " E " " " " ______ " .
4. " L " " M " " " " ______ " .
5. " E " " J " " " " ______ " .
6. " F " " H " " " " ______ " .
7. " P " " A " " " " ______ " .
8. " B " " P " " " " ______ " .
9. " L " " P " " " " ______ " .
10. " G " " L " " " " ______

MEASUREMENT

MEASURE OF CIRCULAR LENGTH AND AREA

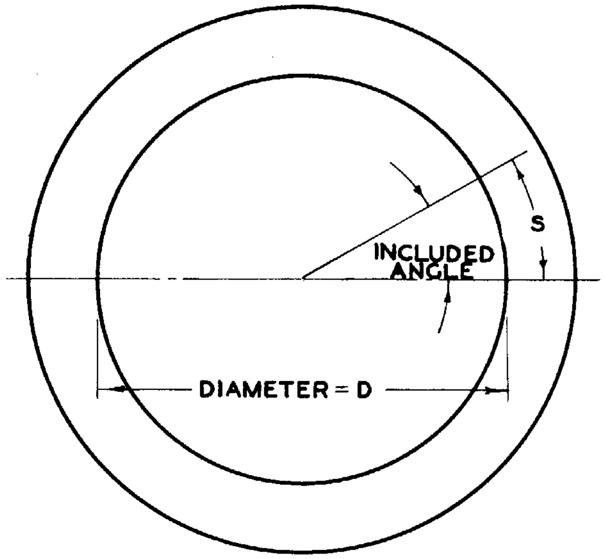
A. MEASURE OF CIRCULAR LENGTH

Circumference = π x Diameter

$$C = \pi D$$

For a portion of the circumference,

$$S = \frac{\text{No. of degrees in the included angle}}{360^\circ} \times \pi D$$

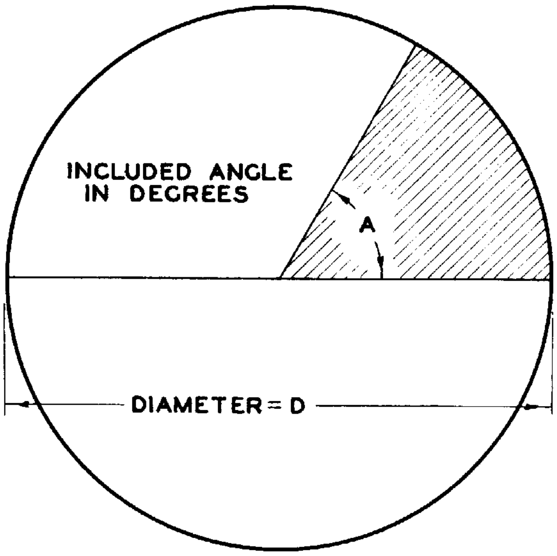


B. MEASURE OF CIRCULAR AREA

$$\text{Area} = \frac{\pi D^2}{4}$$

Portion of Area, as indicated =

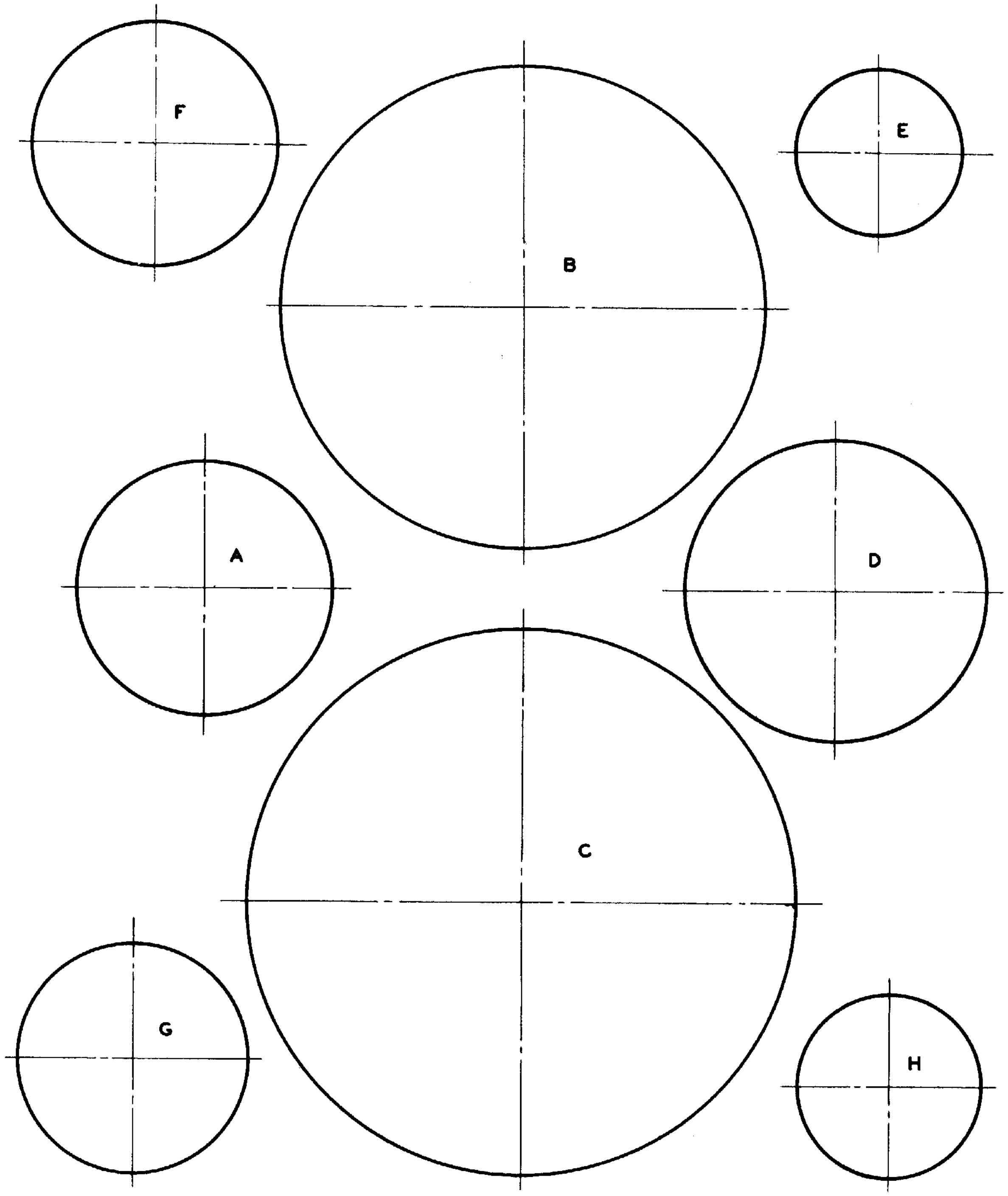
$$\frac{\text{No. of degrees in the included angle}}{360^\circ} \times \frac{\pi D^2}{4}$$



MEASUREMENT

APPLICATION OF CIRCULAR MEASURE

1. Measure the diameter of each of the following circles and compute their circumferences.



MEASUREMENT

COMPARISON OF METRIC AND ENGLISH UNITS OF MEASURE

A. UNITS OF LENGTH

		Metric		English
One Millimeter	=	.001 meters	equals	.03937 inches
One Centimeter	=	.01 "	"	.3937 "
One Decimeter	=	.10 "	"	3.937 "
One Meter	=	1.0 "	"	39.37 "
One Kilometer	=	1,000 meters	=	.6214 miles

B. UNITS OF AREA

		Metric		English
One Sq. Millimeter	=	.000001 sq. meters	=	.00155 sq. in.
One Sq. Centimeter	=	.0001 sq. meters	=	.155 sq. in.
One Sq. Decimeter	=	.01 sq. meters	=	15.50 sq. in.
One Sq. Meter	=	1.0 unit	=	1550. sq. in.
One Hectare	=	10,000 sq. meters	=	2.471 acres

C. UNITS OF CUBIC MEASURE

One Milliliter = .001 liter = 1 cubic centimeter

Unit = one liter = 1,000 cubic centimeters = 1.057 qts.

D. UNITS OF WEIGHT

		Metric		English
Unit	=	1 gram	=	.03527 ounces
1,000 grams	=	1 kilogram	=	2.205 pounds

MEASUREMENT

PROBLEMS IN CONVERTING ENGLISH AND METRIC UNITS OF MEASURE

1. How many millimeters are there in 4 inches?

2. How many millimeters are there in $10\frac{1}{4}$ inches?

3. How many inches are there in 27 millimeters?

4. How many inches are there in 340 millimeters?

5. How many centimeters are there in 8 inches?

6. How many centimeters are there in 36 inches?

7. How many inches are there in 100 centimeters?

8. How many square centimeters are there in 5 square inches?

9. How many square inches are there in 80 square centimeters?

10. How many grams are there in 16 ounces?

11. How many ounces are there in 1000 grams?

12. How many pounds are there in 12 kilograms?

13. How many kilograms are there in 8 pounds?

MEASUREMENT

DEGREE OF ACCURACY

A. CONDITIONS WHICH AFFECT THE DEGREE OF ACCURACY

In a large number of machine shop operations, extreme accuracy is not required. As the production cost of a machine depends to a large degree on direct labor, it is important that the parts be made as economically as possible. If extreme accuracy is required by the designer when it is not needed, unnecessary costs are added.

To achieve extreme accuracy, rough machining, finish machining, grinding, and lapping are often required. For these operations, the degree of accuracy varies.

For rough machining, plus or minus 1/32" may be specified and this would be measured by a scale. For the second machining plus or minus 1/64" may be specified and measured by micrometers. For the grinding operation plus or minus .0002" may be given and again measured by a micrometer which should have .0001" graduations. For measuring the products during the lapping operation and also in its finished state, gage blocks and indicators would be used. (Comparison method). That this procedure is costly can be clearly seen. In determining the degree of accuracy for a part, great care must be exercised. If, for instance, a drill produces a slightly larger hole than is required for the corresponding tap, no harm would be done.

Should a drill cut larger by the amount allowed for reaming, no material would remain for this operation and spoilage may result. For milling machine and lathe operations the advance of the tool into the work or the work into the cutter is controlled by the graduated dial. A fair degree of accuracy may be expected of screws which transmit movement; but due to wear they should not be depended upon.

Lathes, milling machines, shapers, etc. are designed and built with such a degree of accuracy that tolerances of better than plus or minus .001" are obtainable if care and skill are employed. When measuring for extreme accuracy, care must be taken or the results will be misleading. If a micrometer is set too tightly, as much as .0005" can be forced. When reading a vernier scale, excessive pressure against the sliding jaw must be prevented as the deflection of the material and slight clearances in the bearing surfaces of the sliding jaw may cause wrong readings.

DEGREE OF ACCURACY

Often a magnifying glass is used for measuring to a graduated line as the width of the line itself is approximately .006. The temperature of the work to be measured should be about room temperature of 72 degrees, as higher temperatureswill expand, lower temperatures contract the work.

B. THE FACTORS WHICH DETERMINE THE DEGREE OF ACCURACY

1. Possible Limits.

   Measure can be determined under the best conditions to the accuracy of the wave-length of light. For most commercial uses, the limit of accuracy required will be to the fourth decimal place.

2. Specified.

   Specified tolerances are definitely a part of all engineering drawings. These are a function of many design and construction requirements.

   The American Standards Association has standardized tolerances and classes of fit for cylindrical fits, screw threads, and surface finish.

   Tolerances (specified deviations) originate in the design, and indicate the limits of accuracy desired.

3. Limitations of the measuring instrument.

   Possible exactness of measurements is limited to the tool used.

   a. The ordinary pocket scale has a limit of 1/64" and 1/100".

   b. The micrometer and caliper indicate measure to .001", with a vernier attachment, to .0001".

   c. Precision Gage blocks measure, (if ordinary) to .000008 of an inch, to .000002 of one inch (if of the finest grade). These blocks may be used in combination of ordinary and fine.

DEGREE OF ACCURACY

The figures (except those for precision gage blocks) represent the graduation on the scale on which the measure is indicated. The precision gage blocks are fixed and piled together in series to make the required dimension.

d. Tool-maker's microscope.

4. **Errors in Measurement**

a. **Measuring tool**

(1) Manufactured accuracy
(2) Wear
(3) Temperature (in 4th place work)

b. **Human Element**

(1) Eyesight (light available to read properly)
(ability to interpret 4th place correctly)
(2) Touch (ability to "feel" measure on measuring tools)

c. Possibility of securing mechanical duplication depends on:

(1) Variation in material
(2) Kind of machine, its rigidity, tightness of bearings, of bed, and fixture.
(3) Wear and support of tools

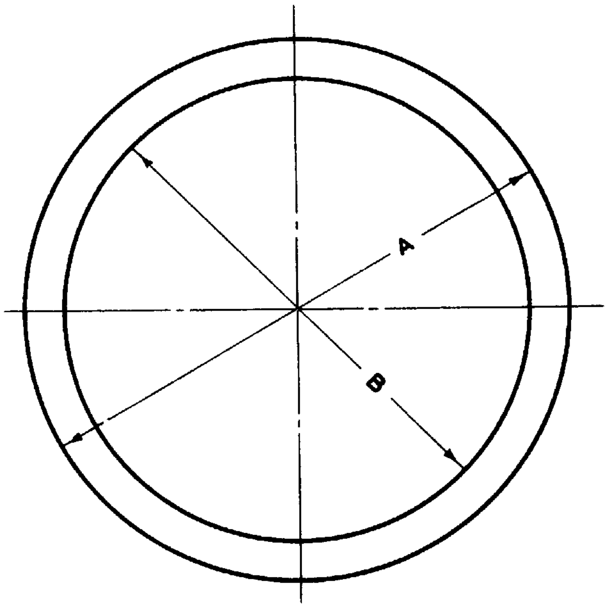
d. Development of judgment in working to practical limits of accuracy.

The character of the manufactured part and the nature of fit to mating members in an assembly determine the degree of accuracy required in production.

MEASUREMENT

DEGREE OF ACCURACY

A. PROBLEMS INVOLVING DEPTH OF CUT



On the piece to be turned, if the existing diameter A is measured and the finished diameter B is known, what is the depth of the cut?

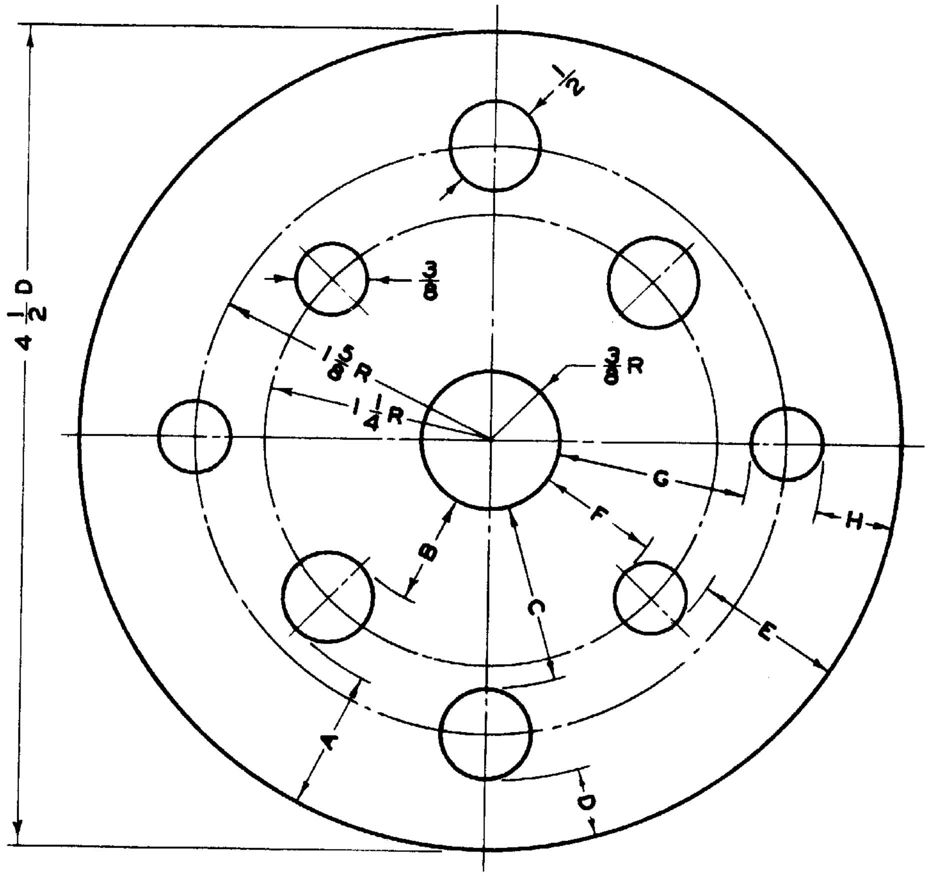
1.	A	is	1.875	B	is	to	be	1.00"	requiring	____"	to	be	removed	.
2.	"	"	1.350	"	"	"	"	1.100	"	____"	"	"	"	.
3.	"	"	1.375	"	"	"	"	1.300	"	____"	"	"	"	.
4.	"	"	2.125	"	"	"	"	1.875	"	____"	"	"	"	.
5.	"	"	3.000	"	"	"	"	1.600	"	____"	"	"	"	.
6.	"	"	2.831	"	"	"	"	1.750	"	____"	"	"	"	.
7.	"	"	3.875	"	"	"	"	3.500	"	____"	"	"	"	.
8.	"	"	1.380	"	"	"	"	1.275	"	____"	"	"	"	.
9.	"	"	2.736	"	"	"	"	1.254	"	____"	"	"	"	.
10.	"	"	1.937	"	"	"	"	1.854	"	____"	"	"	"	.

DEGREE OF ACCURACY

B. PROBLEMS INVOLVING ALLOWANCES FOR REAMING

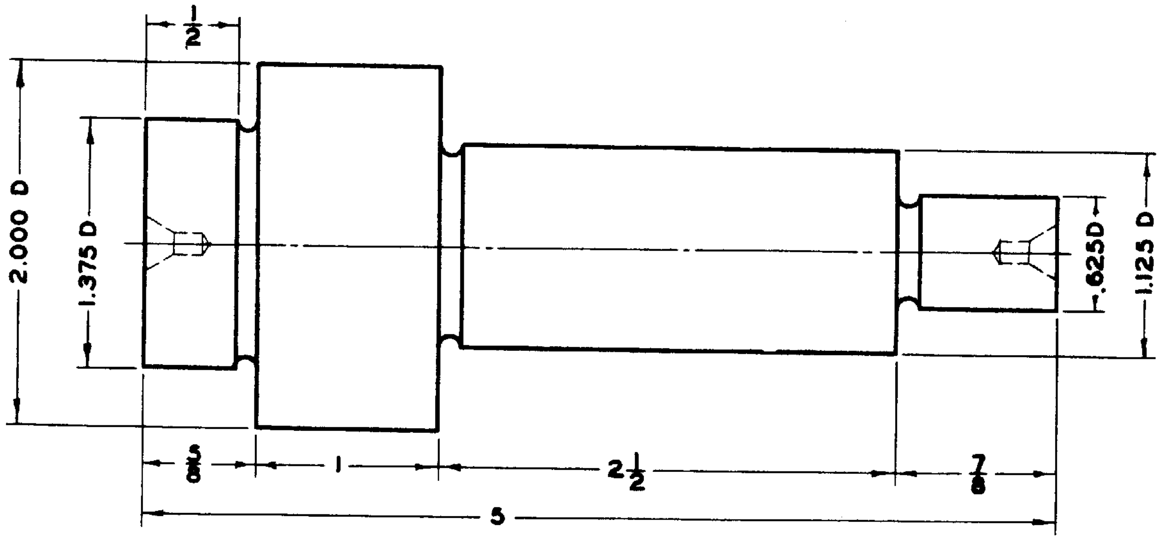
1. Find the distances A, B, C, D, E, F, G, and H, if on all 3/8" and 1/2" holes 1/64" is allowed for reaming.

2. What are the respective distances after reaming?



DEGREE OF ACCURACY

C. PROBLEMS INVOLVING ALLOWANCES FOR TURNING AND GRINDING



The above spindle must be rough turned, annealed, finish turned, hardened and tempered, and ground.

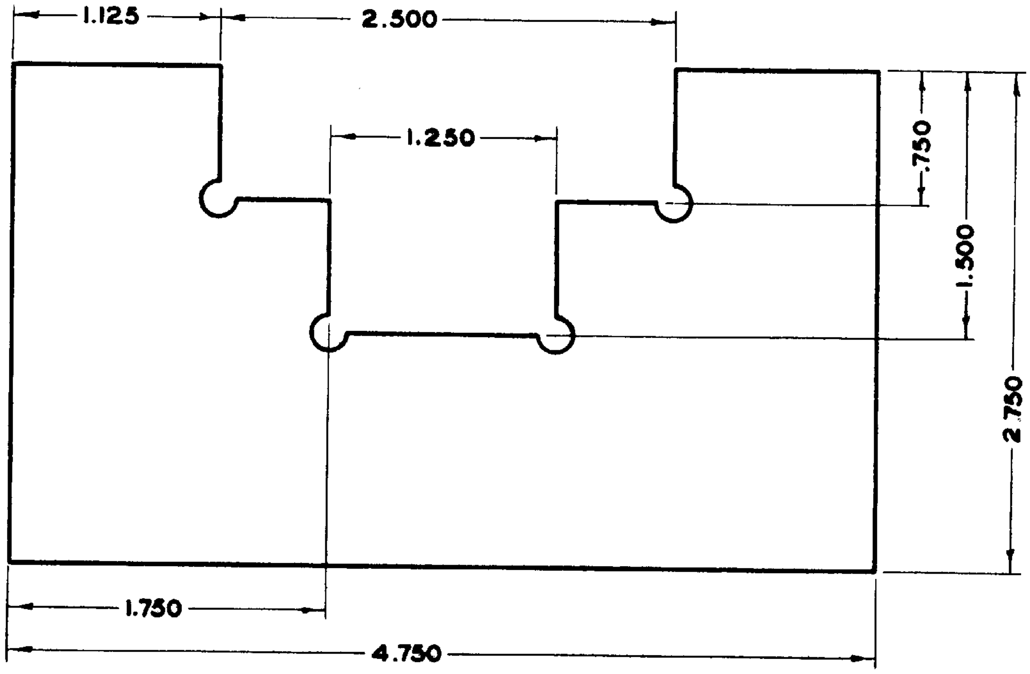
1. Rough turn the piece allowing 1/16" for finish machining on all diameters and 1/32" on all faces. Finish turn to allow .012 for grinding on all diameters and .008 on all faces.

   a. Find the corresponding dimensions for rough machining.

   b. Find the corresponding dimensions for finish machining.

DEGREE OF ACCURACY

D. PROBLEMS INVOLVING ALLOWANCES FOR MILLING AND GRINDING



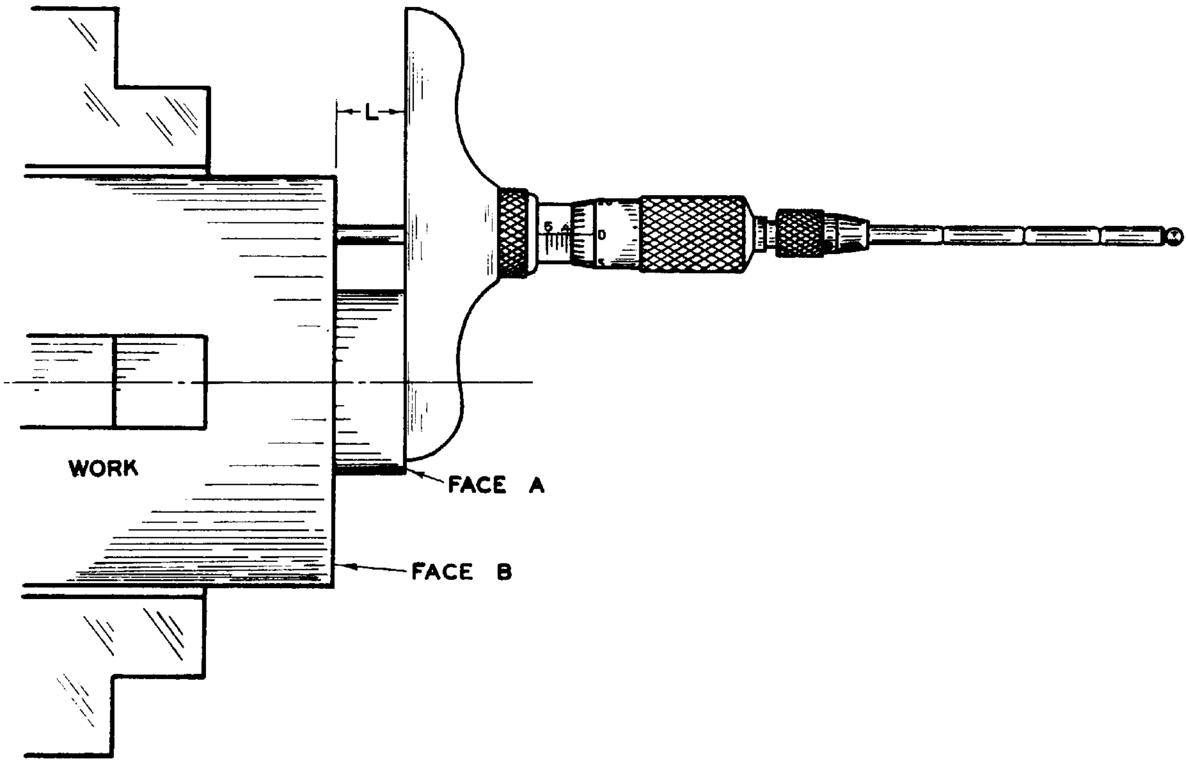
1. On the turbine gage above, the part must be rough machined, annealed, finish machined, hardened and tempered, and ground.

   a. Find the dimensions to which the piece must be roughly machined, allowing 1/32" for finish machining.

   b. Find the dimensions to which the piece must be finish machined before grinding, allowing .008" for grinding.

DEGREE OF ACCURACY

E. APPLICATION OF MEASUREMENT INVOLVING LIMITS

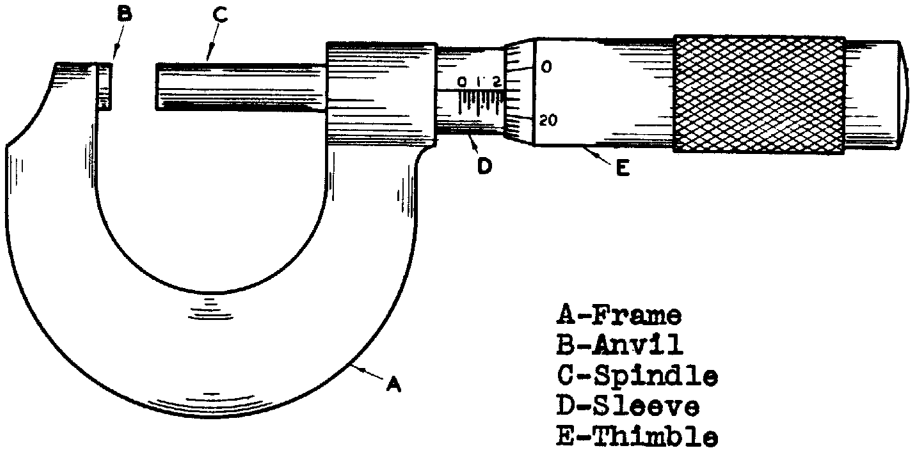


1. Dimension L must be .375 $^{+.001}_{-.001}$ How much material must be removed on faces A or B if the micrometer reads:

.372	______	.362	______
.374	______	.370	______
.380	______	.376	______
.386	______	.351	______
.398	______	.350	______

MEASUREMENT

READING A MICROMETER



A-Frame
B-Anvil
C-Spindle
D-Sleeve
E-Thimble

The spindle C is attached to the thimble E on the inside. The part of the spindle which is concealed within the sleeve and thimble is threaded to fit a nut in the frame A. The frame being held stationary, the thimble E is revolved by the thumb and finger, and the spindle C being attached to the thimble, revolves with it and moves thru the nut in the frame, approaching or receding from the anvil B.

The article to be measured is placed between the anvil B and the spindle C. The measurement of the opening between the anvil and the spindle is shown by the lines and figures on the sleeve D and the thimble E.

The pitch of the screw threads on the concealed part of the spindle is 40 to an inch. One complete revolution of the spindle therefore moves it longitudinally one fortieth (or twenty-five thousandths) of an inch. The sleeve D is marked with 40 lines to the inch, corresponding to the number of threads on the spindle. When the micrometer is closed, the beveled edge of the thimble coincides with the line 0 on the sleeve, and the 0 line on the thimble agrees with the horizontal line on the sleeve.

READING A MICROMETER

Open the micrometer by revolving the thimble one full revolution, or until the 0 line on the thimble again coincides with the horizontal line on the sleeve; the distance between the anvil B and the spindle C is then 1/40 (or .025) of an inch, and the beveled edge of the thimble will coincide with the second vertical line on the sleeve. Each vertical line on the sleeve indicates a distance of 1/40 of an inch. Every fourth line is made longer than the others, and is numbered 0, 1, 2, 3, etc. Each numbered line indicates a distance of four times 1/40 of an inch, or one tenth.

The beveled edge of the thimble is marked in twenty-five divisions, and every fifth line is numbered, from 0 to 25. Rotating the thimble from one of these marks to the next moves the spindle longitudinally 1/25 of forty thousandths, or one thousandths of an inch. Rotating it two divisions indicates two thousandths, etc. Twenty-five divisions will indicate a complete revolution, .025 or 1/40 of an inch.

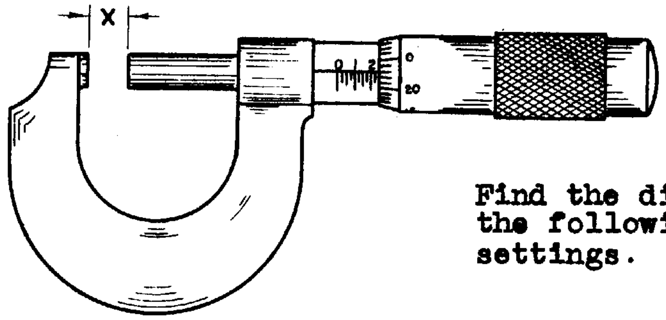
To read the micrometer, therefore, multiply the number of vertical divisions visible on the sleeve by 25, and add the number of divisions on the bevel sleeve. For example, as the tool is represented in the illustration, there are nine divisions visible on the sleeve. Multiply this number by 25, and add the number of divisions shown on the bevel of the thimble (23). The micrometer is open two hundred and forty-eight thousandths. (9 x 25 = 225; 225 + 23 = 248).

(Courtesy of L. S. Starrett Company)

MEASUREMENT

PROBLEMS IN READING A MICROMETER

A. DIRECT MEASURE



Find the distance "x" for the following micrometer settings.

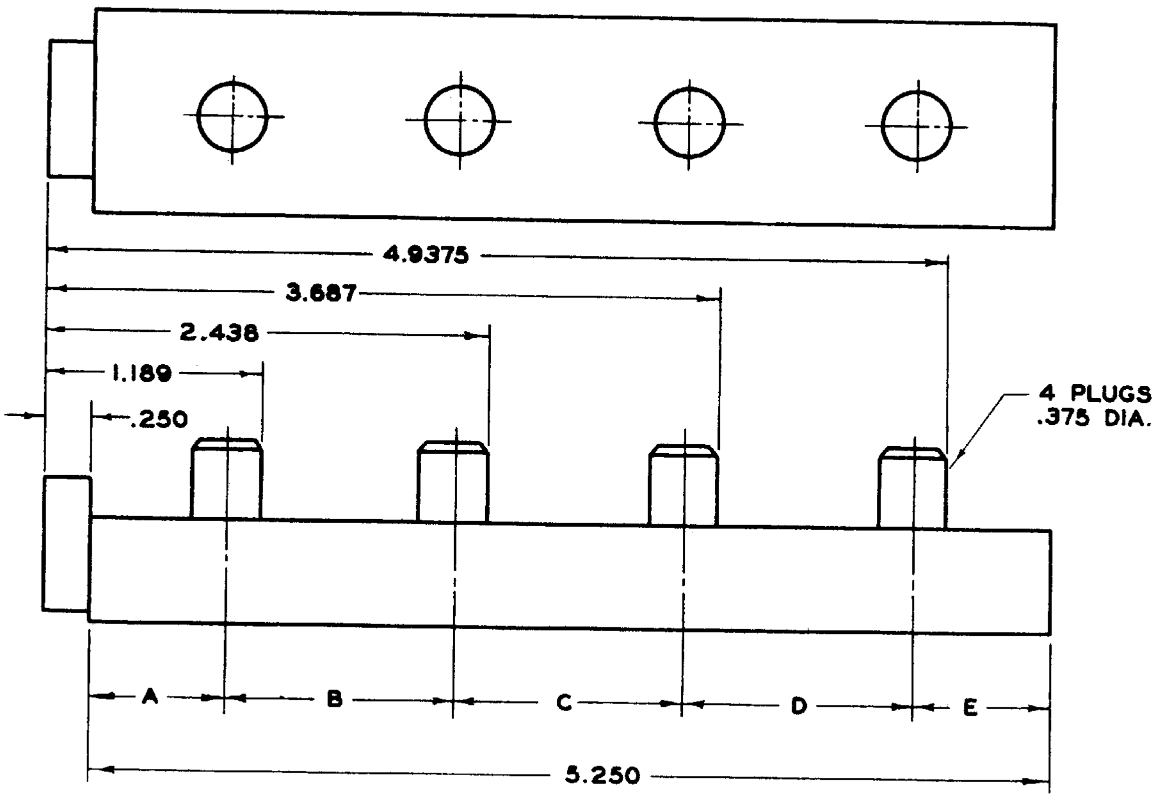
NOTE: Where possible, secure a micrometer, set at the indicated positions, and note the reading in each instance.

Reading on sleeve is between	Nearest line on thimble	Reading
.000 and .025	6	
.075 and .100	14	
.125 and .150	24	
.250 and .275	5	
.325 and .350	15	
.450 and .475	23	
.400 and .425	4	
.575 and .600	16	
.525 and .550	22	
.675 and .700	3	
.600 and .625	17	
.700 and .725	21	
.775 and .800	2	
.825 and .850	18	
.900 and .925	20	
.975 and 1.000	1	
.800 and .825	19	
.800 and .825	7	
.750 and .775	13	
.625 and .650	8	

PROBLEMS IN READING A MICROMETER

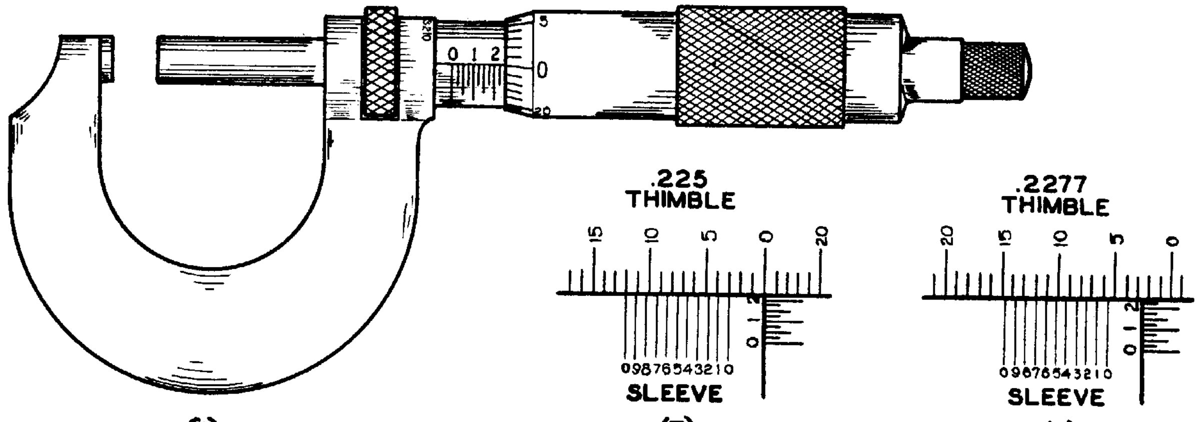
B. COMPUTED MEASURE

1. Find distances A, B, C, D and E.



MEASUREMENT

READING A MICROMETER GRADUATED IN TEN-THOUSANDTHS OF AN INCH



(A) (B) (C)

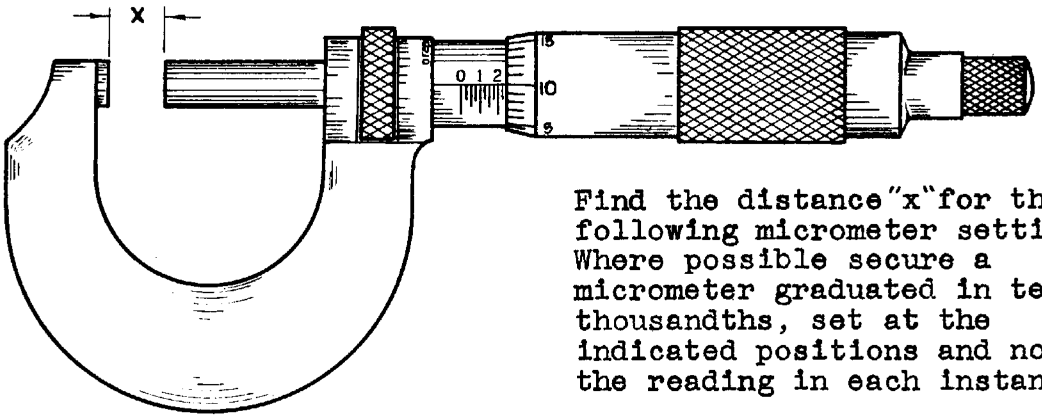
Readings in ten thousandths of an inch are obtained by the use of a vernier, so named from Pierre Vernier, who invented the device in 1631. As applied to a micrometer, this consists of ten divisions on the adjustable sleeve, which occupy the same space as nine divisions on the thimble. The difference between the width of one of the ten spaces on the sleeve and one of the nine spaces on the thimble is, therefore, one tenth of a space on the thimble. In the illustration B, the third line from 0 on the thimble coincides with the first line on the sleeve.

The next two lines on thimble and sleeve do not coincide by one tenth of a space on thimble; the next two marked 5 and 2, are two tenths apart, and so on. In opening the tool, by turning the thimble to the left, each space on the thimble represents an opening of one thousandth of an inch. If, therefore, the thimble be turned so that the lines marked 5 and 2 coincide, the caliper will be opened two tenths of one thousandth or two ten-thousandths. Turning the thimble further, until the line 10 coincides with the line 7 on the sleeve, as in the illustration C, the caliper has been opened seven ten-thousandths, and the reading of the tool is .2277.

To read a ten-thousandths micrometer, first note the thousandths as in the ordinary micrometer, then observe the line on the sleeve which coincides with a line on the thimble. If it is the second line, marked 1, add one ten-thousandth; if the third, marked 2, add two ten-thousandths, etc.

MEASUREMENT

PROBLEMS IN READING A MICROMETER GRADUATED IN TEN-THOUSANDTHS OF AN INCH



Find the distance "x" for the following micrometer settings. Where possible secure a micrometer graduated in ten-thousandths, set at the indicated positions and note the reading in each instance.

Reading on sleeve is between	Reading on thimble between	Vernier line	Reading
.000 and .025	7 and 8	2	
.075 and .100	15 and 16	3	
.125 and .150	23 and 24	5	
.250 and .275	6 and 7	7	
.325 and .350	16 and 17	9	
.450 and .475	24 and 25	2	
.400 and .425	5 and 6	4	
.575 and .600	17 and 18	6	
.525 and .550	23 and 24	8	
.675 and .700	4 and 5	1	
.600 and .625	18 and 19	5	
.700 and .725	22 and 23	9	
.775 and .800	3 and 4	2	
.825 and .850	19 and 20	6	
.900 and .925	21 and 22	3	
.975 and 1.000	2 and 3	7	
.800 and .825	20 and 21	1	
.800 and .825	8 and 9	9	

Suggested Unit Course in

MEASUREMENT

Machine Shop Series

DELMAR PUBLISHERS, Inc.
Albany, New York

Suggested Unit Course in

BENCH WORK

Machine Shop Series

DELMAR Publications
INDUSTRIAL • TECHNICAL

DELMAR PUBLISHERS, Inc.
Albany, New York

MACHINE SHOP SERIES

This series of texts covers six major occupational areas of Machine Shop Practice: (1) *Measurement*, (2) *Bench Work*, (3) *Drill Press*, (4) *Lathe*, (5) *Milling Machine*, and (6) *Shaper Work*.

The instructional material in each book is written in simple trade terminology and illustrated through the generous use of line drawings. The range of technical information (*Why-to-do*) and fundamental process units (*How-to-do*) provides basic instruction for beginning students, apprentices and home workshop enthusiasts; and advanced reference material for skilled craftsmen, engineers, supervisory personnel and teachers.

MACHINE SHOP MEASUREMENT

A beginner's text and workbook which covers basic mathematical principles of linear, circular, and angular measurement from the standpoint of related mathematics and machine shop practice.

65 pages (7¾ x 10¼); 109 line drawings

BENCH WORK

A basic text which describes the theory of *Bench Work* and the operations performed with measuring, layout and bench tools.

88 pages (7¾ x 10¼); 159 line drawings; formulas; tables

DRILL PRESS WORK

An introductory text dealing with the theory and operation of drill presses; uses of accessories and holding devices; cutting speeds and feeds; drilling, reaming, countersinking, counterboring and tapping.

42 pages (7¾ x 10¼); 48 line drawings; 6 tables

LATHE WORK

A comprehensive text covering the related technical information and fundamental processes which are basic for *Lathe Work* held between centers and in a chuck. A partial list of topics includes: centering, mounting work; grinding tool bits; facing, straight turning; speeds and feeds; turning shoulders, chamfering, knurling, thread cutting, angle and taper turning; mandrel and chuck work; drilling, boring, reaming and tapping.

164 pages (7¾ x 10¼); 197 line drawings; formulas; tables

MILLING MACHINE WORK

An exhaustive study of modern milling machines and accessories. The instructional units cover in minute detail the theory and practice of basic and advanced milling machine operations, with emphasis on dividing head work.

298 pages (7¾ x 10¼); over 300 illustrations including phantom and cut-away sections

SHAPER WORK

A new and complete treatise on modern types of crank and hydraulic shapers. The text covers all the basic and advanced operations and related technical information required to do *Shaper Work*.

326 pages (7¾ x 10¼); 582 illustrations including phantom and cut-away sections

PREFACE

The production of interchangeable parts, which is the keystone of our present day manufacturing system, depends largely on the skill of the individual machine operator and of the all-around craftsman in operating machine tools and using measuring instruments so that each machine part is held within certain prescribed limits of accuracy.

Over a period of years careful analyses were made to determine essential occupational areas of training for machine shop practice. As a result of these studies, the following six main divisions of the trade were defined and a series of texts were prepared to cover them: (*1*) *Measurement*, (2) *Bench Work*, (*3*) *Drill Press*, (*4*) *Lathe*, (5) *Milling Machine*, and (*6*) *Shaper Work*.

Further study revealed that each operation in machine shop practice involves the teaching and learning of basic trade theory and fundamental processes. Following this line of reasoning, two types of instructional units are included in each monograph: (1) *Trade Theory Series* and (2) *Fundamental Process Series*. A brief description of each type follows.

Trade Theory Series

The basic trade theory and related technical information, such as principles governing machine shop operations, the derivation and application of formulas, and descriptions of machine tools and accessories, are covered in the *Trade Theory Series*. This technical information furnishes the student with background trade knowledge necessary to perform machine shop operations skillfully. The *Trade Theory* units which are directly related to the *Fundamental Process* units may be used as text or reference material for class, laboratory or home study.

Fundamental Process Series

The term *Fundamental Process* covers those manipulative processes which involve the use of hand and machine tools and are common to machine or bench work. The manipulative phases of an operation are described in common trade terminology and are well illustrated with line drawings. As the *Fundamental Process* units provide reference material for the actual performance of operations, they may be used as supplementary text material for the teaching of fundamental processes either in a school or an industrial plant.

The selected series of instructional units in each text includes those fundamental operations which are common for a specific division of the trade and which apply under all conditions. Throughout the series the units are arranged in the natural order of dependence of one operation on the next; i.e., in a sequence which conforms to the logical order of teaching and learning difficulty. However, this arrangement may be changed to meet exacting industrial and educational training course requirements without altering the effectiveness of any one of the suggested unit courses.

Sincere appreciation is expressed to the Bureau of Industrial and Technical Education, The New York State Education Department for permission to reproduce this instructional material.

The Editor

Albany, New York

BENCH WORK

TABLE OF CONTENTS

Units of Instruction in Bench Work for Machine Shop Practice

* Key to unit numbers
1- First year or beginner level
{-T Trade Theory Series
{-P Fundamental Process Series
13 Sequence of units of instruction
Example:
1-T13 First Year Machine Shop Practice, Trade Theory unit number thirteen

Units of Instruction in

BENCH WORK

DESCRIPTION OF MEASURING TOOLS

OBJECTIVES OF UNIT

1. To acquaint the learner with the common fraction and decimal fraction systems of measuring.

2. To explain the application of the steel rule, outside caliper, inside caliper, micrometer caliper, and the steel square in measuring.

3. To explain the construction, reading, and use of the micrometer caliper.

INTRODUCTORY INFORMATION

The measuring of material and machined work involves the use of a number of measuring tools to secure sizes of length, width, thickness, and diameter. One or more of these factors may be involved when determining the size of material or a piece of work.

The English system of linear measure, of which the yard is the unit of length, is the standard used in American industry. In machine shop work, the more commonly used unit is the inch, the thirty-sixth part of a yard. The inch may be divided into smaller parts by means of either common or decimal fractional divisions.

The fractional divisions of an inch are found by dividing the inch into equal parts; the more common of which are: halves, quarters, eighths, sixteenths, thirty-seconds, and sixty-fourths. When smaller units of measurement are required, the decimal system is used in which the inch is divided into tenths, hundredths, thousandths, and ten-thousandths of an inch (Figure 1).

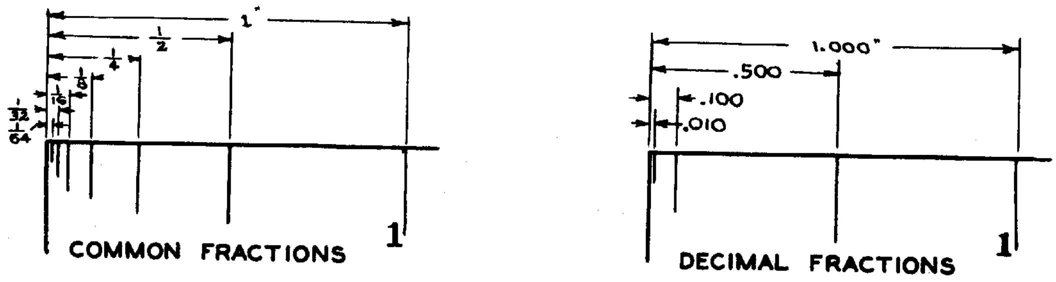


FIG. 1 TWO SYSTEMS OF DIVIDING THE INCH

In machine shop it is common practice to use fractions of an inch expressed in decimals, called decimal equivalents of an inch; i.e. 1/8" is expressed as .125" (one hundred twenty-five thousandths of an inch), or 1/4" as .250" (two hundred fifty thousandths of an inch), etc.

The legs of the calipers are attached to a pivot at the upper end. This end is held together above the pivot by a spring clamp. The clamp tends to hold the legs firmly against the adjusting nut and on the pivot. The working tips of the legs should be kept in line to preserve the accuracy of the tool (Fig. 5).

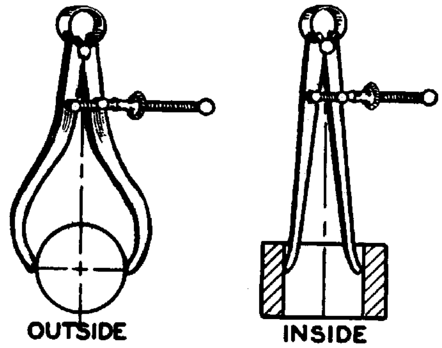


FIG. 6 MEASURING WITH CALIPERS

The accurate use of calipers depends upon the "feel" which is developed through use. They should never be forced over or into the work. Likewise, they should always be used square with the axis of the work and the surface being measured (Fig. 6).

The caliper can be used in two ways to make a measurement. They can be set over the object (as illustrated) and then tested on a steel measuring rule, or they can be set from the rule and the measurement transferred to the work.

Calipers are made in a variety of sizes depending upon the size of opening: 2", 3", 4", 5", 6", etc.

THE MICROMETER CALIPER

The smallest measurement which can be made with the use of the caliper and steel rule are, in the case of common fractions, 64ths of an inch; in decimal fractions, hundredths of an inch. To measure finer than these (thousandths and ten-thousandths of an inch), a micrometer caliper is used.

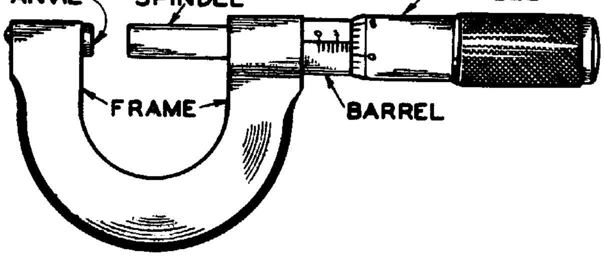


FIG. 7 PARTS OF THE MICROMETER CALIPER

If a dimension in common fractions is to be measured with the micrometer, it must be converted to its decimal equivalent.

The principal parts of the micrometer are: the anvil, frame, barrel, spindle and screw, and thimble (Fig. 7). The micrometer caliper operates on a screw which is free to move in the threaded portion inside the barrel.

The movement of the screw provides an opening between the anvil and the end of the spindle where the work is measured. The size is indicated by the graduation on the barrel and the thimble.

The lines on the barrel marked 1,2,3,4, etc., indicate measurements of .100", .200", .300", .400", etc., respectively. (Fig. 8).

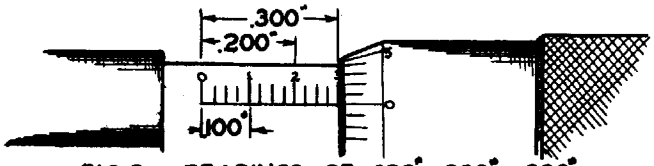


FIG.8 READINGS OF .100", .200", .300"

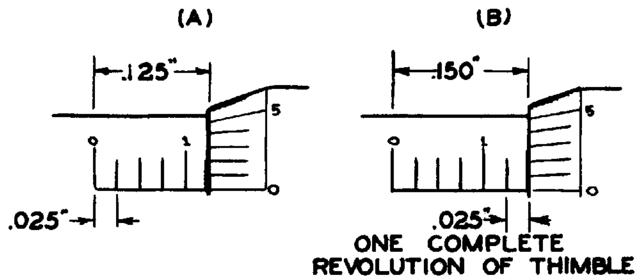


FIG. 9 DIVISIONS OF .025"

Each of the sections between the tenth inch divisions (between 1,2, 3,4, etc.) is divided into four equal parts of .025" each (Fig. 9A)

One complete revolution of the thimble from its zero to zero, moves it one of these .025" divisions as in Figure 9B.

The bevel edge of the thimble, in turn, is divided into twenty-five equal parts. Each of these parts represents one twenty-fifth of the distance the thimble travels along the barrel in moving from one of the .025" divisions to another. Thus each division on the thimble represents a thousandth (.001") of an inch. These divisions are marked for convenience at every five spaces by 0, 5, 10, 15, and 20. When 25 of these graduations have passed the horizontal line on the barrel, the spindle (having made one revolution) has moved .025".

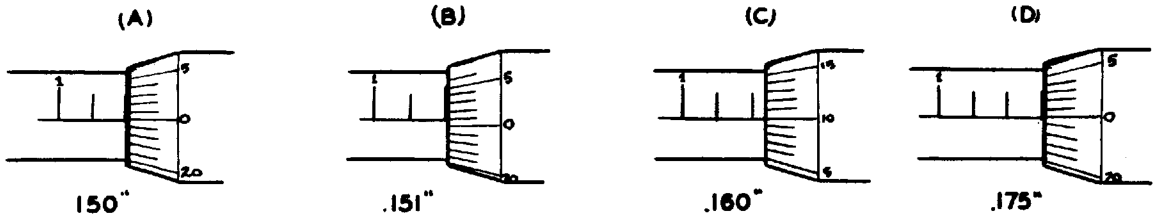


FIG. 10 MICROMETER READINGS

The micrometer is read by first noting the last visible figure on the horizontal line on the barrel, representing tenths of an inch. Add to this the amount represented by the visible graduations beyond this figure (by multiplying the number of them by 25), and the number of divisions on the bevel edge of the thimble that coincides with the line of the graduation. The sum, of the tenths of an inch, plus the number of divisions beyond the last tenth of an inch graduation multiplied by 25, and the divisions on the bevel edge of the thimble, is the reading (Figures 10-A,B,C, and D).

The ability to measure to a thousandth of an inch with micrometers makes them an accurate tool with which to work. If they are dropped and the screw which moves the spindle is damaged, their accuracy may be permanently affected. Likewise, continually sliding work between the anvil and spindle may wear the surfaces, tending to affect their accuracy (Fig. 11).

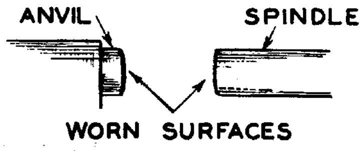


FIG. 11 WEAR ON SPINDLE AND ANVIL

THE STEEL SQUARE

FIG. 12 MEASURING RIGHT ANGLES

The steel square is used to measure an angle of ninety degrees (90°). Surfaces at 90° to each other are said to be "square" with each other (Fig. 12).

The steel square is made of high grade tool steel, hardened, tempered, and ground to a fine degree of accuracy. The right angle, or perpendicular as it is also called, may be found on either the inside or outside of the square (Fig. 13).

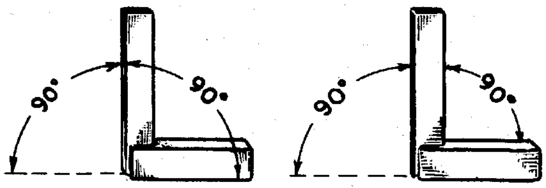


FIG. 13 THE STEEL SQUARE

NOTE: Care must be taken not to damage the square as any change in the position of the surfaces will destroy its accuracy.

SELECTED REFERENCES

Henry Ford Trade School ------------------------------ Shop Theory

Burghardt ----------------- Part I ------- Machine Tool Operation

HOW TO USE MEASURING TOOLS

OBJECTIVES OF UNIT

1. To point out general practices in the application of the most commonly used measuring tools.

2. To show how to measure with the steel rule, outside caliper, inside caliper, micrometer caliper, and steel square.

INTRODUCTORY INFORMATION

To become proficient in the use of measuring tools, a beginner must develop judgment and a sense of "feel" which will enable him to measure accurately and skillfully.

The steel rule, when used alone or in combination with the setting of calipers, is employed to obtain "scale" dimensions which are only approximate. For measurements that require greater accuracy (to within one thousandth of an inch or finer), the micrometer caliper is used either alone or in combination with inside calipers and other special measuring tools.

A good mechanic is known by the manner in which he cares for his tools. Abuse and careless handling of measuring tools destroys their usefulness.

TOOLS AND EQUIPMENT

Steel Rule
Outside Caliper
Inside Caliper
Micrometer Caliper
Steel Square

PROCEDURE

STEEL RULE

1. To measure a piece of stock, place the rule flat across the surface or distance to be measured; holding or steadying the work with the left hand.

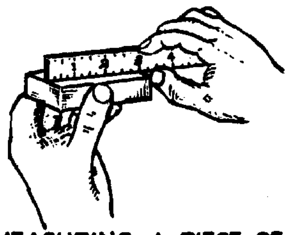


FIG. 1 MEASURING A PIECE OF STOCK

2. With rule held in the right hand and guided by the thumb nail, extend the rule until its end is even with the left hand edge of the work (Fig. 1).

3. Read the graduations on the rule from left to right by noting which line on the rule coincides closest with the right hand edge of the stock (Fig. 2).

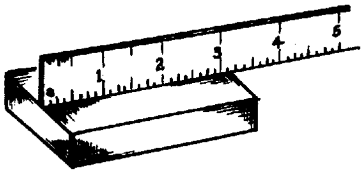


FIG. 2 READING A STEEL RULE

NOTE: Select that edge of the rule which is graduated in fractional divisions of an inch in which the desired dimension is wanted; i.e. eighths, sixteenths, thirty-seconds, and sixty-fourths (Fig. 3).

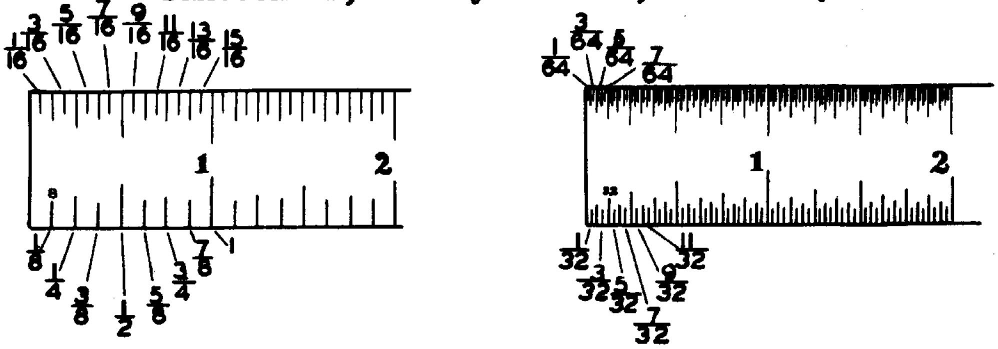


FIG. 3 GRADUATIONS ON A STEEL RULE

OUTSIDE CALIPERS

1. To measure a piece of work with the outside calipers, hold the calipers in the right hand and, with the thumb and forefinger, grasp the knurled adjusting nut (Fig. 4).

2. Turn the adjusting nut with the thumb and forefinger until the caliper will just slide over the work by its own weight.

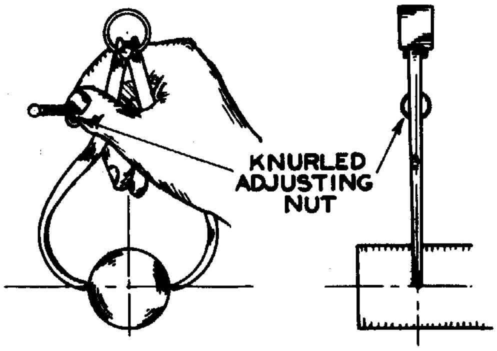


FIG.4 TAKING A MEASUREMENT WITH AN OUTSIDE CALIPER

NOTE: At all times keep the calipers square with the work to be measured. A piece of round stock is calipered as shown in Figure 4.

3. Remove the caliper from the work, being careful not to disturb the setting.

4. To measure the distance between the caliper legs with the aid of a steel rule, hold the rule in the left hand with the second finger at the bottom and behind the rule.

5. Place one of the legs at the end of the rule, and the other leg on the graduated face of the rule in line with the first leg, and read the measurement.

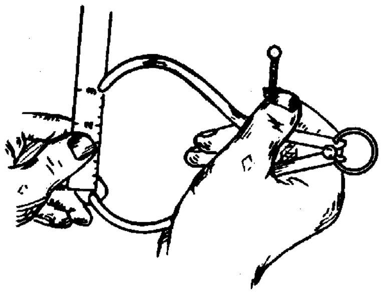


FIG. 5 SETTING AN OUTSIDE CALIPER

NOTE: The caliper may be used to check a given size by first setting it to the desired dimension from a steel rule (Fig. 5). Then use the caliper as a gage in selecting a piece of the required size.

INSIDE CALIPERS

1. To take an inside measurement, hold the caliper in the right hand with the thumb and forefinger grasping the knurled adjusting nut (Fig. 6).

2. Rest one leg of the inside caliper slightly inside of the edge of the space to be measured. Turn the adjusting nut until the caliper is felt striking the high point of the arc on entering the space to be measured (Fig. 6).

NOTE: Make sure that the tips of the caliper legs are square with the largest portion of the diameter being measured.

With the calipers held in this position, test to see whether they can be moved sideways. If necessary, readjust so that no side motion can be felt.

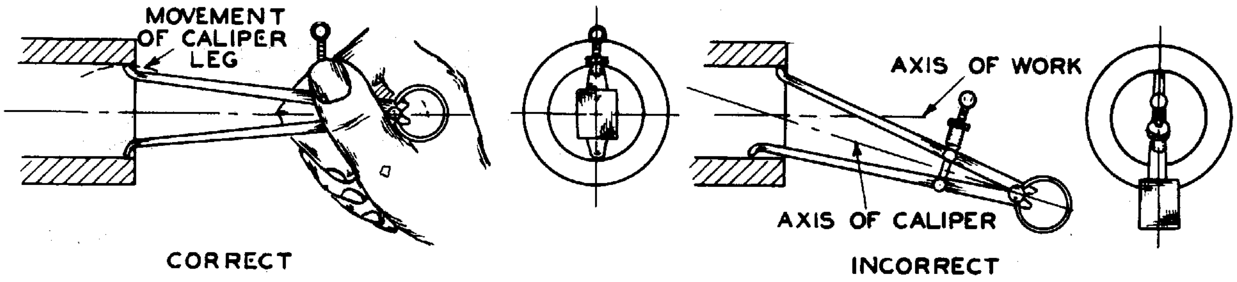


FIG. 6 CORRECT AND INCORRECT USE OF CALIPER

3. To measure the distance over the caliper legs with the aid of a steel rule, place one end of the steel rule against a vertical surface. Hold the caliper leg against the vertical surface, keeping the ends level at the same time. Read the dimension from the rule (Fig. 7).

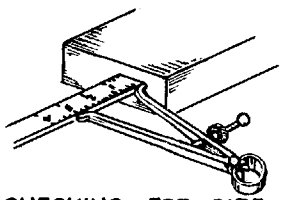


FIG. 7 CHECKING FOR SIZE

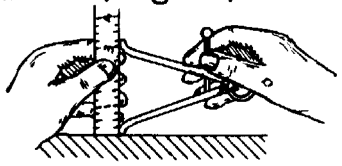


FIG. 8 SETTING AN INSIDE CALIPER

NOTE: An inside caliper may be used to check a given size by first setting it to the desired dimension from the steel rule (Fig. 8), and then using the caliper as a gage to check the internal measurement.

MICROMETER CALIPER

A. TO MEASURE A PIECE OF WORK WITH THE MICROMETER WHEN THE WORK IS HELD IN THE HAND

1. The frame of the micrometer is held in the palm of the right hand by the little finger (or the third finger, whichever is more convenient), allowing the thumb and forefinger to be free to revolve the thimble for the adjustment (Fig. 9).

2. Place the work between the anvil and the spindle. Turn the thimble until its movement has brought the spindle and the anvil in contact. (Fig. 9).

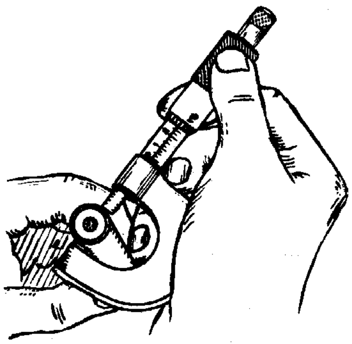


FIG. 9 MEASURING STOCK

NOTE: The beginner must develop a sense of "feel" in adjusting the micrometer to the work. Avoid the tendency to cramp the micrometer by using too much pressure.

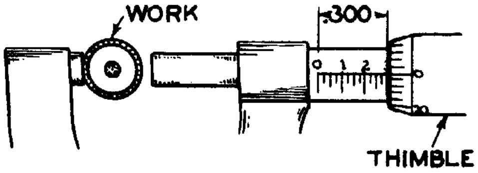


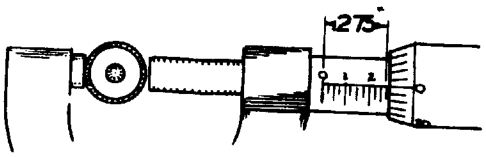
FIG. 10 START TURNING THIMBLE

3. The measurement is taken from the graduations on the barrel and thimble by:

   a first noting the last figure visible on the graduations of the horizontal line along the barrel, which represent the tenths of an inch (Fig. 11);

3. b adding the number of twenty-five thousandth inch (.025") spaces beyond this figure, (Fig. 11) and then;

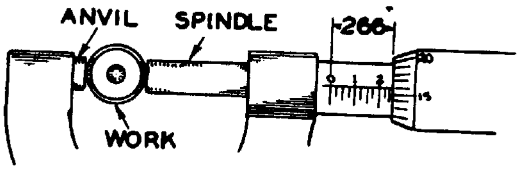
c adding the number of the division on the beveled edge of the thimble that coincides with the line of the graduations on the barrel (Fig. 12).



READING .275"

FIG. 11 THIMBLE TURNED ONE REVOLUTION

The sum of these expressed in thousandths gives the measurement. The steps in securing this measurement are illustrated in Figures 10, 11, and, for the final reading, Figure 12.



READING .266"

FIG. 12 FINAL READING
ANVIL, WORK, AND SPINDLE IN CONTACT

NOTE: After the measurement has been determined, open the micrometer screw before removing it from the work. This practice prevents wear on the ends of the spindle and anvil, which impairs the accuracy of the tool.

B. TO MEASURE WITH THE MICROMETER CALIPER WHEN WORK IS MOUNTED IN A MACHINE

1. Grasp the frame of the micrometer near the anvil with the thumb and forefinger of the left hand. The frame is steadied with the second and third fingers of the right hand while the thumb and forefinger are used to rotate the thimble (Fig. 13).

2. Open the micrometer and place it over the work to be measured. Turn the thimble until its movement has brought the spindle and anvil in light contact with the work (Fig. 13).

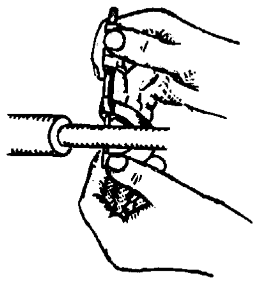


FIG. 13 MEASURING WORK MOUNTED IN A MACHINE

3. Read the micrometer as indicated in the preceding section.

NOTE: The reading is taken while the micrometer is held on the work. Always open the micrometer before removing from the part being measured.

CAUTION: The micrometer should never be used to measure rotating work or while the machine is running. Personal injury may result or the tool may be damaged.

C. TO TRANSFER A MEASUREMENT ON THE INSIDE CALIPERS TO THE MICROMETER CALIPERS

1. Set the calipers to the space being measured.

2. Lay the calipers in the left hand with the tips of the caliper legs extending beyond the fingers (Fig.14).

3. Hold the micrometer in the right hand so that the thimble may be adjusted with the thumb and forefinger (Fig.14).

4. Rotate the thimble until the tips of the caliper legs can be felt in light contact with the anvil and the end of the spindle.

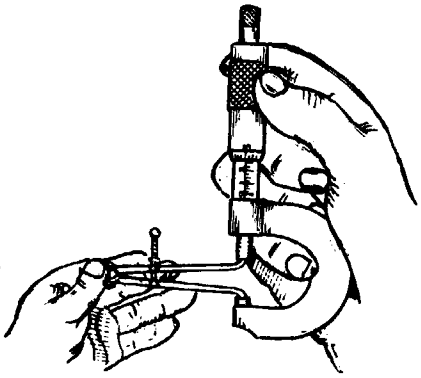


FIG.14 TRANSFERRING A MEASUREMENT

5. By placing the tip of one leg on the micrometer anvil, a fine adjustment of the setting is made by swinging an arc with the other leg until contact is felt at the high point of the arc (Fig. 15A).

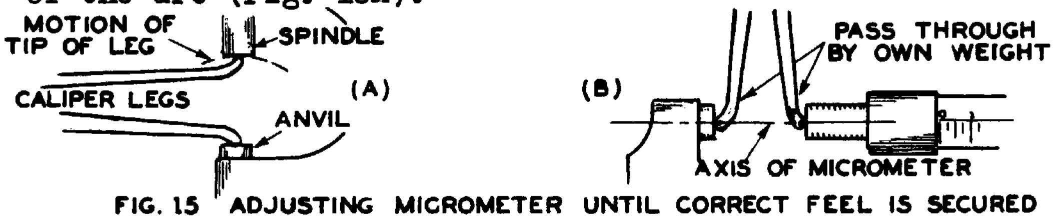


FIG. 15 ADJUSTING MICROMETER UNTIL CORRECT FEEL IS SECURED

The tips of the caliper legs must also be held parallel to the axis of the micrometer spindle; and when accurately set, should pass between the end of the spindle by their own weight (Fig. 15B).

NOTE: When reading the micrometer, remove the thumb and forefinger from the thimble so that the setting is not disturbed.

NOTE: An inside caliper may be used as a gage to check an internal measurement by first setting the inside caliper to a micrometer caliper reading.

THE STEEL SQUARE

1. Remove all burrs from the surface of the work to be checked. Wipe work clean of chips, oil, and dirt.

2. Wipe the square clean, and draw the edges to be used over the palm of the hand to insure absolute freedom from small particles.

3. Face the source of light so that it will shine on the work.

4. Hold the work with the left hand; grasp the beam of the square with the right hand. Place the inside of the square against a finished surface of the work, so that the beam is in full contact with one side and a slight space remains between the blade and the other surface of the work. (Fig. 16 - Position A).

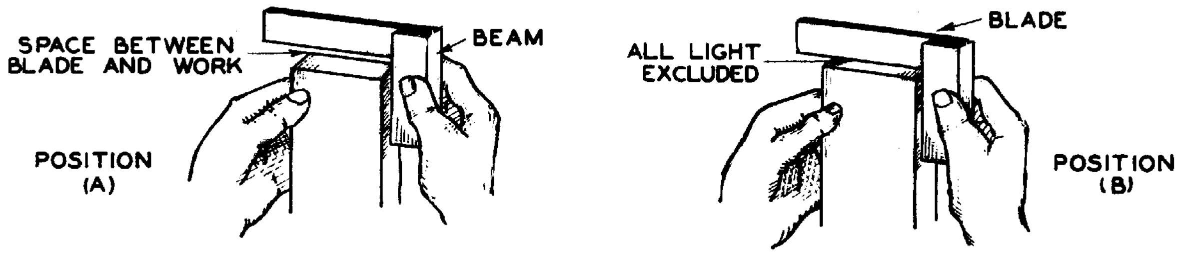


FIG. 16 CORRECT METHOD OF TESTING FOR SQUARENESS

5. Lower the blade carefully to the surface of the work, and note where the blade first comes in contact with the surface. If the angle is square, all light will be excluded (Fig. 16 - Position B).

NOTE: If the angle is not square, light will be seen at either end of the blade (Fig. 17).

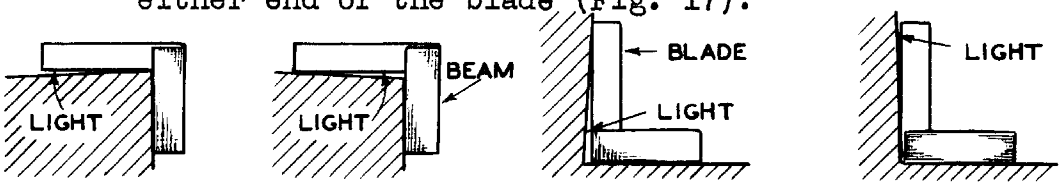


FIG.17 EXAMPLES OF WORK NOT SQUARE

NOTE: The error resulting from burred edges, when attempting to check the squareness of work, is shown in Fig.18.

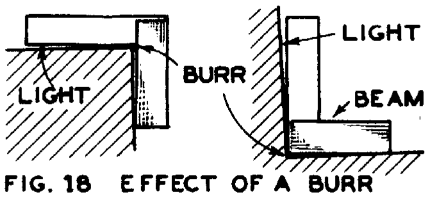


FIG. 18 EFFECT OF A BURR

NOTE: The method of checking an inside right angle with the outside edges of the square is illustrated in Figure 19, Positions (A) and (B).

FIG. 19 TESTING AN INSIDE RIGHT ANGLE FOR SQUARENESS

DESCRIPTION OF BENCH TOOLS

OBJECTIVES OF UNIT

1. To develop an appreciation of good tools.

2. To describe some of the commonly used bench tools.

INTRODUCTORY INFORMATION

A good mechanic is judged by the quality and condition of his tools. In order to gain an appreciation of the best grade of tools, the beginner should become familiar with the construction and materials used in making them. With proper use and care, tools will last longer, give better service, and will be the least expensive over a long period of time.

Some of the more commonly used bench tools are: screwdrivers, hammers and mallets, bench vises, wrenches, "C" clamps and parallel clamps. Other bench tools, such as hand hack saws, chisels, and files, are described in Units 1-T4, 1-T9, and 1-T11, respectively.

SCREW DRIVERS

Screw drivers are used primarily for tightening or loosening slotted screws. The sizes and shapes of screw drivers vary in construction and design depending upon their use. For example, jeweler's screw drivers are used for fine precision work and heavy square shanked machinist's screw drivers are used when it is necessary to apply added force with a wrench.

The screw driver generally consists of three parts: the handle, the clamp or ferrule, and the blade (Fig. 1). The handle is made to fit the grasp of the hand and is composed of wood, metal, or plastic materials.

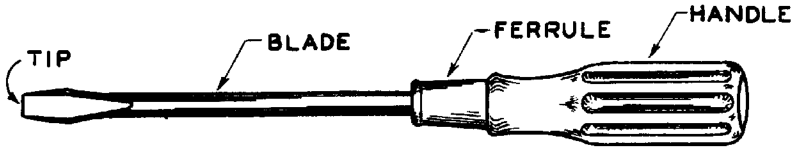


FIG.1 STANDARD BLADE SCREW DRIVER

The blade is generally made of a good grade of steel, forged, machined to shape, hardened and tempered. Smaller screw driver blades are made of round stock; larger blades are square in cross section to take the grip of a wrench. The shank end of the blade is tanged to prevent turning in the handle. The ferrule fits over the end of the handle and serves to protect the handle and clamp it tighter to the blade.

Before using a screw driver, the tip of the blade should be put in good repair. The sides should be straight and parallel, and the bottom square with the edges (Fig. 2).

A worn screw driver with edges rounded or broken may burr or damage the screw slot. A screw driver in poor condition is the mark of a poor workman.

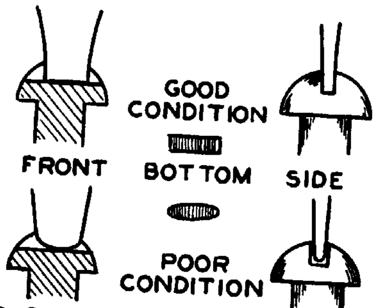


FIG. 2 SCREW DRIVER TIPS

HAMMERS

Hammers are generally made in two types; those with hard heads made of good quality steel forgings; and those with soft heads of lead, copper, babbitt, rubber, and rawhide.

Forged heads come in many different shapes depending upon their use, and in a range of weights from 6 oz. to 2-1/2 pounds. The most common hammer is the machinist's ball peen hammer (Fig. 3). The soft headed hammers will yield under a blow and will not damage harder pieces.

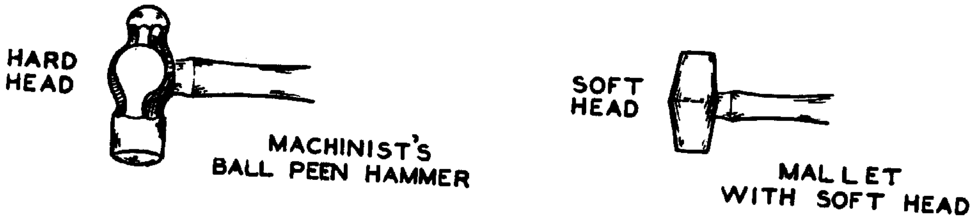


FIG. 3 TWO COMMON TYPES OF HAMMERS

The handle of the hammer is generally made of a good quality wood stock tapered at the head to prevent the head from slipping down the handle. The head and the handle are forced together by means of a wedge driven into the opening that received the handle.

THE BENCH VISE

The bench vise is used only for clamping work between its jaws. The outside jaw is moved by turning the hand lever (handles), causing the clamp screw to turn, moving the jaw assembly (Fig. 4).

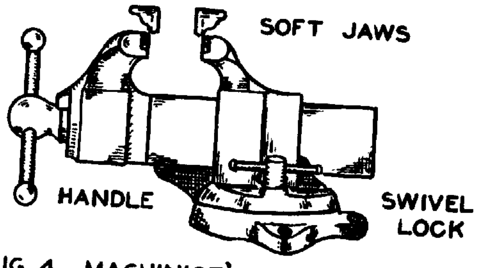


FIG. 4 MACHINIST'S BENCH VISE

On many vises, the immovable jaw is fixed to a swivel base that may be rotated on its axis to secure a better position of the work, if it is at an angle to the normal position of the vise.

Finished work is protected in a vise by means of soft jaws put on over the regular jaws (Fig. 4).

WRENCHES

Wrenches come in many different types, some of which are illustrated below (Fig. 5). They are generally composed of a high quality steel forging; the best alloyed with chromium and vanadium.

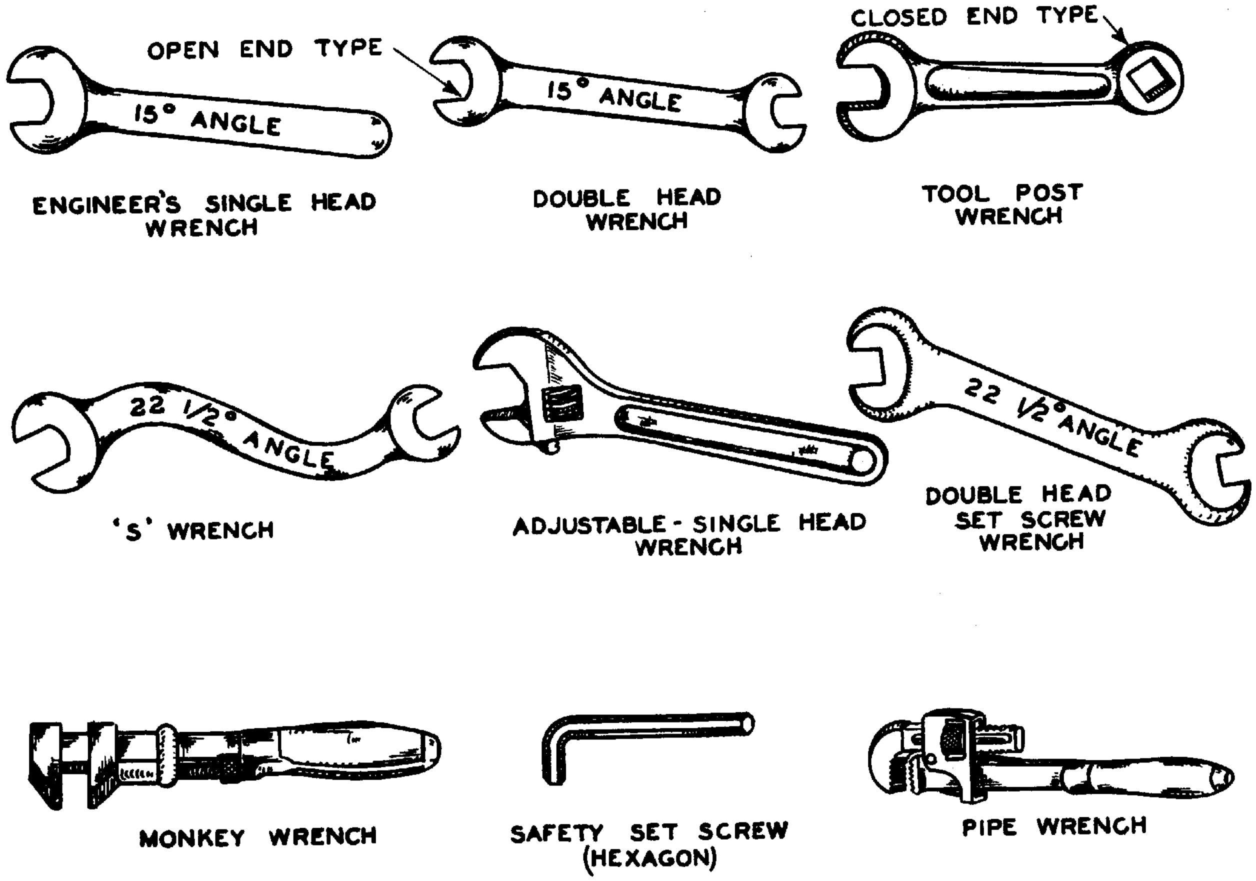


FIG. 5 .TYPES OF WRENCHES

The open end and closed end type of wrenches are preferable to the adjustable or monkey wrench except in cases where the correct sizes are not available. Almost any forged wrench of high grade steel will break a bolt head or screw fastening before it fails.

CLAMPS

In bench work, two principal types of clamps are used: the "C" Clamp, and the Parallel Clamp.

The "C" clamps have one screw member, the end of which has a swivel head. In clamping, the head advances (but does not rotate) as the screw turns (Fig. 6). This prevents the work from being marred.

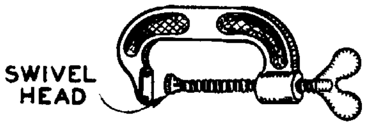


FIG. 6 "C" CLAMP

The parallel clamps have two screw members. The screw near the work tends to hold the jaws together. The screw on the outside pushes the jaws apart. The leverage formed clamps the work when the jaws are parallel. (Figure 7-A)

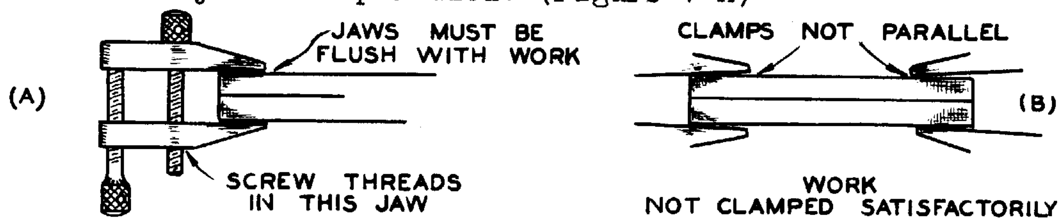


FIG. 7 PARALLEL CLAMP

To get good results the jaws must be parallel so that the full surface of the jaws covers the work. If the jaws pinch the work (Figure 7-B), the work will slip and the clamp will be of no value.

SELECTED REFERENCES

Henry Ford Trade School ---------------------------- Shop Theory

Burghardt ------------ Machine Tool Operation -------- Part I

HOW TO USE BENCH TOOLS

OBJECTIVES OF UNIT

1. To point out to the student general practices in the application of force to bench tools.

2. To show how to use: screw drivers, hammers, the bench vise, wrenches and clamps.

INTRODUCTORY INFORMATION

One of the characteristics of a good workman is the way he uses and cares for his small tools. To care for them by keeping them in their proper place, to sharpen and repair them when they become worn or broken, and to use them for their own particular use, is to prolong their life, speed the completion of a job, and make the reputation of the workman a better one.

In **general, judgment should be used in carefully applying force to small tools.** If they are used carelessly, and a force which cannot be easily controlled is applied to them, injury to the hands or fingers may result. Likewise, if excessive force is applied to screw members, boltheads may break off, threads may strip or break off in tapped holes---causing trouble and unnecessary expense.

TOOLS AND EQUIPMENT

Screw drivers
Hammers
Bench Vise with soft jaws
Open and closed end wrenches
Adjustable and Monkey Wrenches
Parallel and "C" Clamps

PROCEDURE

SCREW DRIVERS

1. Inspect the tip of the screw driver blade. If it is not in good condition, it should be repaired by grinding the tip (Figure 1). Clean dirt and chips out of the screw slot.

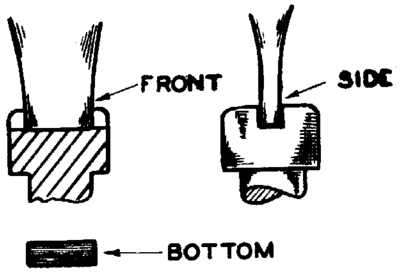


FIG. 1 GOOD SCREWDRIVER TIP

2. Grasp the handle of the screw driver with the right hand. With the left hand, guide the tip of the blade into the screw slot. Use the left hand during the operation to keep the tip of the blade in the screw slot.

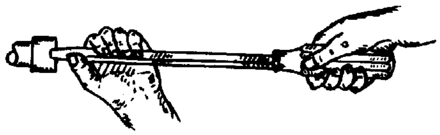


FIG. 2 HOLDING A SCREW DRIVER

3. Unfasten or tighten the screw with sufficient pressure on the screw driver to keep the tip seated in the slot (Fig. 2).

NOTE: In placing a screw in a tapped hole, it should be brushed clean and a light oil applied to permit easy insertion and removal.

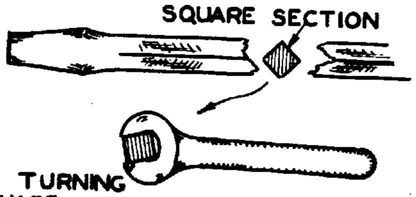


FIG.3 TURNING A SQUARE SHANK SCREW DRIVER WITH AN OPEN END WRENCH

4. For tightening large screws, select a square shanked screw driver and use a wrench that fits the square section of the blade (Fig.3). Turn the screw driver with the wrench. Keep the pressure on the handle to keep the tip in the slot.

NOTE: If the handle of the screw driver is struck with a hammer or hard object, the handle will split, destroying its use.

NOTE: Using the screw driver for a wedge, chisel, or pry-bar will bend the screw driver putting it out of shape and use.

HAMMERS

1. Inspect the hammer to make sure that the head is securely fastened to the handle. To fasten the handle when it is loose, drive the wedge farther into the handle (Fig. 4). If the handle is split, it should be replaced.

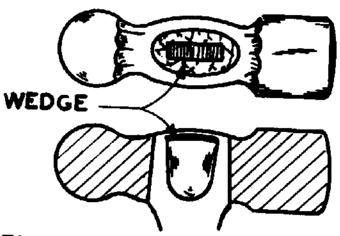


FIG.4 HANDLE SECURELY FASTENED TO HEAD

2. Grasp the hammer near the end of the handle firmly but not rigidly. Start striking with light blows to get the job started in the right direction.

3. Watch the point of action while striking the hammer, not the head of the hammer (Figure 5). By using this method, better work can be done.

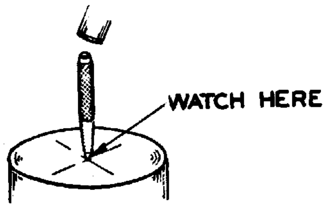


FIG. 5

THE BENCH VISE

1. Clean the vise frequently -- at least daily. Oil the clamp screw occasionally.

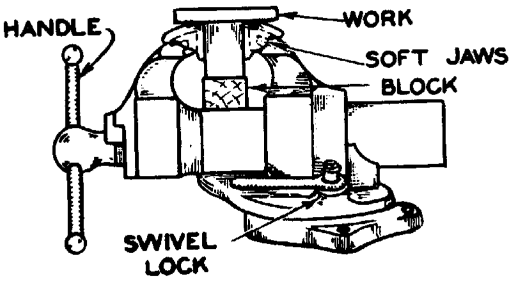


FIG. 6 BENCH VISE

2. Place a pair of soft jaws on the jaws of the vise if finished work is being clamped. Put a block below the work to prevent it from slipping down in the vise (Figure 6).

3. Tighten the work by rotating the handle. Care should be taken that thin sections are not cracked or circular pieces bulged out of round.

NOTE: It is poor practice to strike the handle of the vise with a hammer to tighten.

WRENCHES

ADJUSTABLE OR MONKEY WRENCH

1. Place the wrench on the part to be moved with the jaws in the direction in which the work is to be turned (Figure 7).

2. Adjust the jaws until they fit tightly. If the job does not start easily, it may be loosened by striking the handle with the heel of the hand.

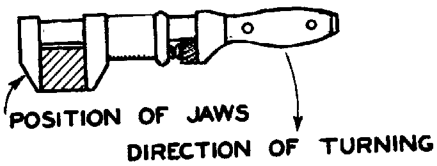


FIG. 7 MONKEY WRENCH

NOTE: Too much leverage (or length) on the wrench will break off small fastenings. Use right size wrench for job.

OPEN AND CLOSED END TYPE WRENCHES

1. Select a wrench that fits the work closely (Figure 8).

CAUTION: If the wrench slips on the work due to the loose fit between the work and the jaws, injured hands or fingers may result and the screw head will be damaged.

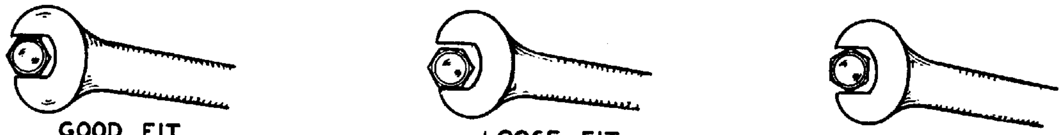


FIG. 8 OPEN END WRENCHES

2. Place the wrench in such a position that the best leverage can be secured. Pull or push on the end of the wrench. Use both hands if the wrench is large and added force is needed to loosen or tighten the job.
3. If the work is in a tight place, (Figure 9) turn the wrench over after each turn to loosen or tighten the nut or bolt.

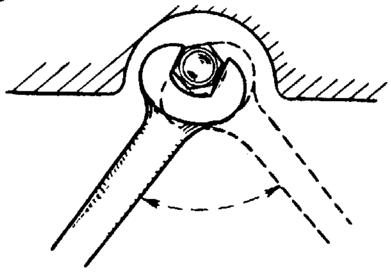


FIG. 9 TURNING WRENCH TO FIT A NUT

PARALLEL AND "C" CLAMPS

Parallel Clamps

1. Clean the surfaces being clamped free of dirt or burrs.

2. Open the clamps by rotating the holding screws. Place the clamps on the work.

3. Adjust the clamps until they are open a slight amount in the direction of the work (Figure 10-A).

FIG. 10 ADJUSTING A PARALLEL CLAMP

4. Rotate the back clamp screw until jaws are closed. When the jaws are correctly closed over the work, they rest fully on the work (Figure 10-B).

"C" Clamps

1. Clean the work free of burrs and dirt.

2. Put a drop of oil in the swivel head occasionally.

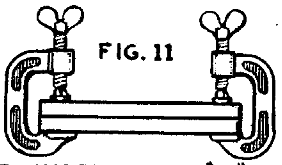


FIG. 11 HOLDING WORK WITH "C" CLAMPS

3. Place the clamps on the work in line with the force being applied (Figure 11). Tighten clamps alternately if more than one clamp is being used.

DESCRIPTION OF IRON AND STEEL STOCK

OBJECTIVES OF UNIT

1. To acquaint the beginner with some of the iron and steel materials used in machine shop.

2. To explain the purpose for which these materials are intended.

3. To describe the shapes of commonly used bar stock.

4. To describe the outward appearance and markings for recognizing various kinds of materials.

INTRODUCTORY INFORMATION

Iron and steel are the more commonly used materials in the construction of tools and machinery. A variety of materials having different characteristics are available. Each one has the qualities suited to the purpose for which it is intended.

Each of these materials is composed of certain elements which give it properties of strength, toughness, malleability, or which enable it to be hardened and tempered.

Iron and steel bars have characteristic external appearances which make them easy to identify. These bars may be identified by manufacturer's labels, stamped markings or painted colors to indicate the kind of material.

SHAPES OF BAR STOCK

Bar stock may be obtained in many shapes, the more common of which are illustrated below.

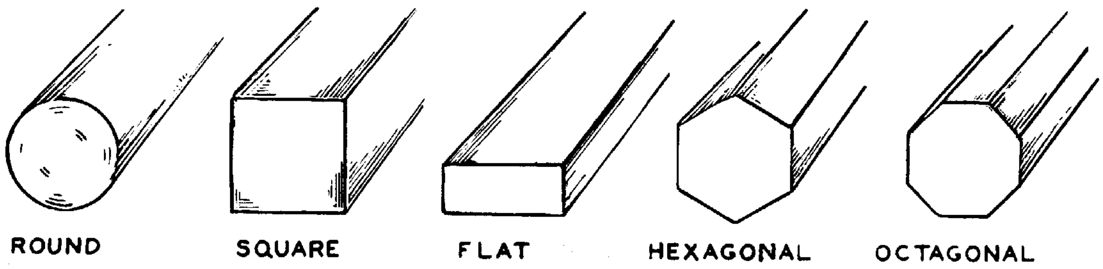


FIG. 1 SHAPES OF BAR STOCK

KINDS OF MATERIAL

CAST IRON

Cast iron is made by pouring molten iron into sand molds of desired shapes. It has a rough, pitted surface which is dull gray in appearance. The outer surface or scale is hard and is difficult to machine. The interior of the metal is dull-gray, granular in appearance and cuts easily when the outer scale is removed.

This material may also be obtained in round, square and flat bars as well as being cast into desired shapes from patterns.

Cast iron is relatively inexpensive. It is used for machine parts where weight and mass are more desirable than a high degree of strength.

MACHINE STEEL

Machine steel is one of the cheaper grades of steel. It contains a very low per cent of carbon. This material can be easily forged but does not machine smoothly. It is tough and strong.

Machine steel bars can be recognized by their dull, dark outer surface. The rough oxidized scale is caused by the hot rolling process employed in the making of the bars.

This steel is used in forged machine parts and such other articles which do not require hardened surfaces or cutting edges.

COLD ROLLED STEEL

Cold rolled steel is of a low carbon content. Since it is a soft grade of steel, it can be easily machined to a smooth finish.

This material can be recognized by its smooth, dull gray surface. The bars are made by passing the material through highly finished rolls under great pressure while cold. This method gives the characteristic smooth finish of cold rolled steel and produces bars which are very close to size.

Cold rolled steel is used for parts of machinery and tools which do not require cutting edges, hardness or great strength. This steel can be hardened on the surfaces by case hardening or pack hardening methods.

KINDS OF MATERIAL

CARBON STEEL

Carbon steel or tool steel is produced by adding carbon to wrought iron or soft grade steels. The carbon content normally ranges from .50% to approximately 1.50%. Carbon is the element which gives tool steel the property which enables it to be hardened.

Tool steel bars are recognized by their markings, such as the manufacturer's labels, stamped symbols, or colored paint which denote the grade and kind of steel.

It is used for all kinds of tools which require strength or which have cutting edges; and parts of machinery which are subject to wear and, therefore, require hardening.

DRILL ROD

Drill rod is made of high grade carbon tool steel. It has the same characteristics and properties for hardening as tool steels of the same carbon content. It is produced in shorter lengths than other tool steel bars and is accurately ground to standard sizes.

Drill rod is easily recognized by its brightly finished ground surface.

It is used for a great variety of small cutting tools, punches and other articles which require strength and hardness.

NOTE: Drill rod is also available in high speed steel, which is an alloy steel used for cutting tools that will cut metal at high speed without losing their hardness or temper. High speed steel is more expensive than ordinary carbon tool steel and requires different heat treatment.

SELECTED REFERENCES

Machinery's Handbook

Palmer -- Tool Steel Simplified

Keller ------------------------- Lectures on Steel and its Treatment

Encyclopedia Britannica

HOW TO SELECT STOCK

OBJECTIVES OF UNIT

1. To explain how to select the kind of material specified.
2. To tell how to select the proper size and shape of stock.
3. To show how to measure the stock.
4. To explain how to test kinds of steel.
5. To explain how to care for materials in the machine shop.

INTRODUCTORY INFORMATION

In selecting the material for a job, the machinist must be able to recognize the stock that has been specified on the job sheet for the part or tool to be made. This involves selecting the proper kind, shape and size of material. The specifications allow 1/16" to 1/8" over the finished size of the part for removing the scale from unfinished bars.

The kinds of material are identified by their outward appearances or by painted colors or markings. When there are no markings to identify it, the kind of stock may be determined by either a spark test or a hardening test.

Good practice demands that the material be cut from the unmarked end of the shortest bar available.

TOOLS AND EQUIPMENT

Stock Rack with materials
Steel Rule
Grinding Wheel

PROCEDURE

1. Refer to the job sheet and note the kind, size and shape of material specified.
2. Select the kind of material from stock rack in accordance with the specifications by noting the external appearance or markings on the material.

3. Select the size and shape of stock which corresponds to the specifications on the job sheet by measuring it across an end section with the steel rule. The sizes of the various shapes of bar stock are measured as indicated by the dimensions shown in Figure 1.

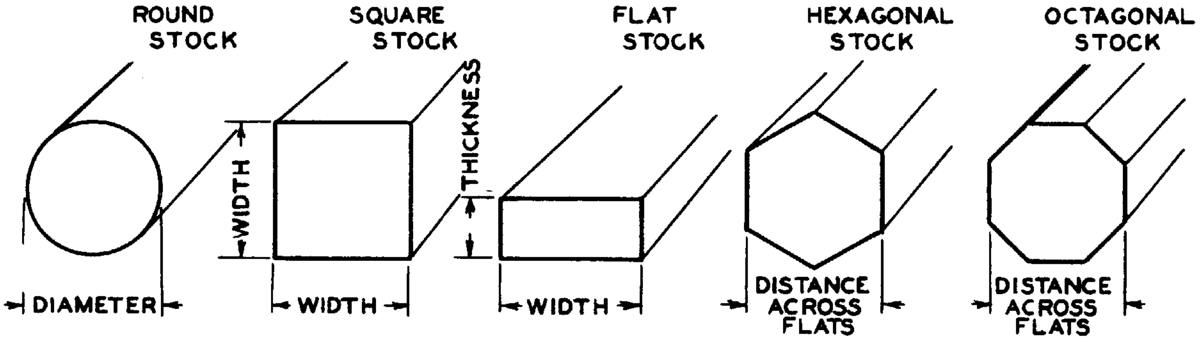


FIG. 1 DIMENSIONS USED IN MEASURING BAR STOCK

4. Use the shortest length of the selected material available and cut the required amount from the unmarked end of the bar.

NOTE: In the event that the material is not marked or cannot be identified by its external appearance, it may be spark tested in order to ascertain the kind of material.

To spark test a piece of material, tough it lightly against the face of a revolving grinding wheel and note the color and shape of the resulting spark as indicated in Figure 2.

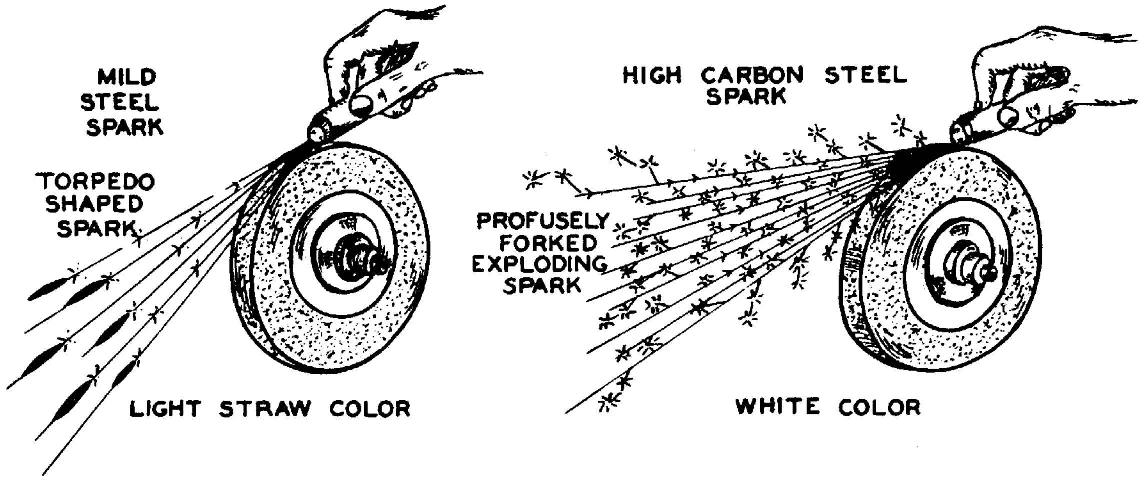


FIG. 2 SPARK TESTING STEEL BY NOTING COLOR AND SHAPE OF SPARK

5. After cutting the piece from the bar of stock, return the remaining piece to the proper rack or bin from which it was taken.

THE HAND HACK SAW

OBJECTIVES OF UNIT

1. To briefly describe two types of hack saw frames commonly used.

2. To explain the characteristics of hand hack saw blades.

3. To consider what factors determine the proper blade to use.

4. To discuss cutting speeds and pressure to apply.

INTRODUCTORY INFORMATION

One of the most abused cutting tools is the hand hack saw. This is undoubtedly due to the fact that the materials, their shapes, thicknesses, and the angle or straightness of the cut vary in each instance. Then too the amount of research the individual worker does in regard to the proper use of the hand tools is limited. An understanding of the correct use is necessary to efficiently cut metal.

There are four factors to be considered about the hack saw blade:

1. The type of frame to be used;

2. The composition, heat treatment, dimensions, pitch and set of the saw teeth;

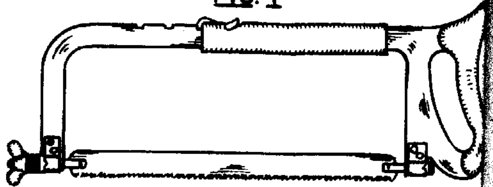
3. The size, shape and composition of the material to be cut; and

4. The actual performance of the cutting operation (which is covered in the Fundamental Process Unit 1-P4).

HACK SAW FRAMES

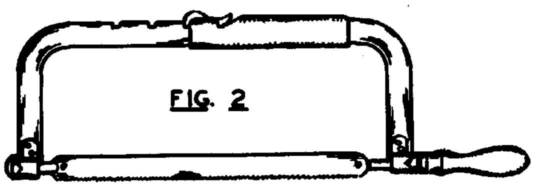
The two types of frames commonly used are the Pistol Grip (Fig. 1) and the Straight Handle (Fig. 2). Either type may be purchased with an adjustable frame to accommodate 8,10, and 12 inch blades; or with the solid steel frame to hold a blade of definite length for the job at hand.

FIG. 1



PISTOL GRIP HACK SAW FRAME

HACK SAW FRAMES



STRAIGHT HANDLE HACK SAW FRAME

The saws are mounted on pins in sliding studs on each end of the frame. The sliding studs provide a means of setting the saw blade to cut with the frame in any one of four positions.

With the straight handle type, the tension is applied to the blade by turning the threaded handle. The desired tension is obtained in the Pistol Grip saw by turning a wing nut.

The selection of the hack saw is a matter of personal choice. The most important consideration is the selection of the proper blade.

HACK SAW BLADES

Hack saw blades are made of .90% to 1.10% carbon tool steel, tungsten alloy steels, and High Speed steel. Steels containing .90% carbon will harden to give maximum cutting speed without being too brittle. Tungsten (1.25%) adds ductile strength to overcome a little of the brittleness. Manganese in the hardening process eases the penetration through the saw teeth to the back.

Blades are hardened and classified as "all hard" or flexible. Flexible blades differ from "all hard" in that only the teeth are hardened. The common lengths of saws vary from 8" to 12". The length is the center to center distance of the holes in the blade. The thickness of the hand hack saw blades is approximately .025". The width of the blade is from 7/16" to 1/2".

The teeth per inch (called pitch) is the most important factor to be considered relative to the material to be cut. (Fig. 3). Blades are made with teeth ranging from 14 to 32 pitch.

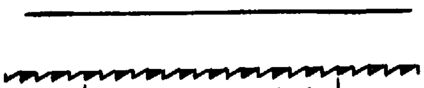
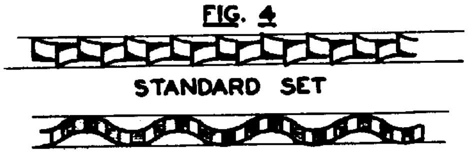


FIG. 3 PITCH OF HACK SAW BLADES



"SET" OF HACK SAW BLADES

The teeth have a standard set (regular alternate) to them which means that one tooth has been moved to the right and the next to the left, an amount sufficient to provide freedom for the cutting blade. (Fig.4) A double alternate set, called "Wave Set" (pairs of teeth are set) is used in fine tooth saws.

HACK SAW BLADES

The following pitch hack saw blades are recommended:

14 Pitch

For Large Sections and Mild Materials

18 Pitch

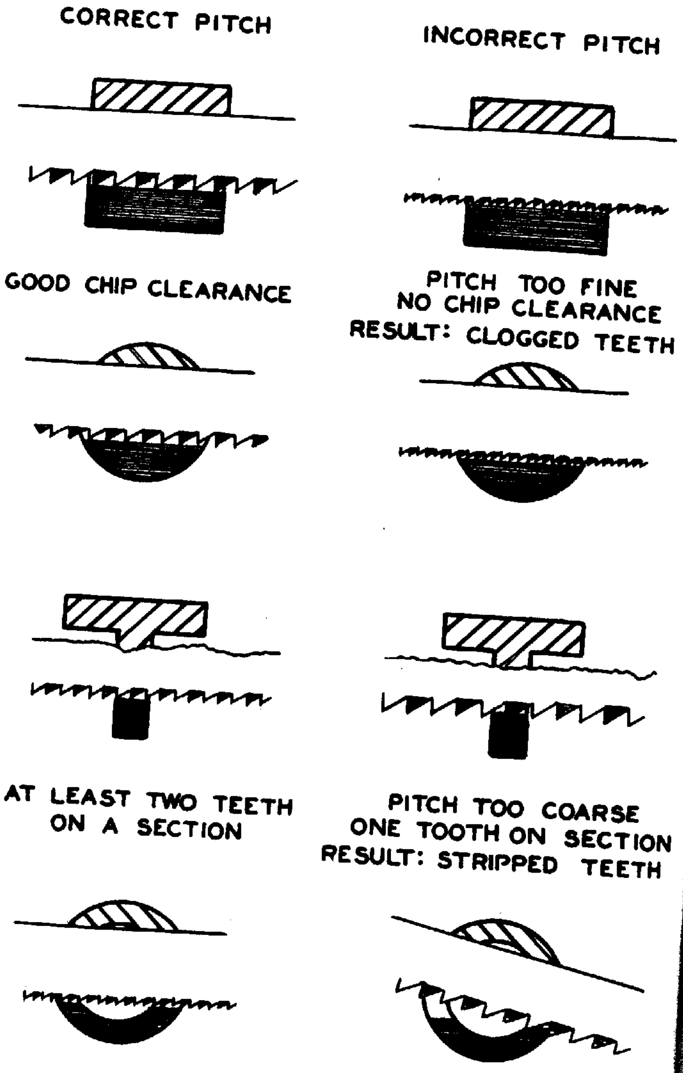
For Tool Steel, High Carbon, and High Speed Steels

24 Pitch

For Angle Iron, Brass, Copper, Iron Pipe, BX and Electrical Conduit

32 Pitch

For Thin Tubing and Sheet Metals



As a general rule, when selecting a blade for tubing or thin materials, choose one on which two or more teeth will be in contact with the sawed surface.

CUTTING SPEEDS AND PRESSURE

The ease with which a piece of metal may be cut depends on the speed and the pressure applied to the saw. Manufacturers recommend a cutting speed of 40 to 50 strokes a minute. This permits the operator to saw without tiring and also gives him a chance to relieve the pressure on the return stroke.

Hack saw blades are thin and, if they travel too fast, the heat generated will draw the temper making the blade soft and useless.

Enough pressure should be applied when cutting to prevent the blade from slipping or sliding. This slipping causes the cutting teeth to become glazed, thereby ruining the saw.

SELECTED REFERENCES

Burghardt ----------------- Part I --------- Machine Tool Operation

Henry Ford Trade School -------------------------------- Shop Theory

L. S. Starrett ---------------------------- Hack Saws and Their Use

HOW TO USE THE HAND HACK SAW

OBJECTIVES OF UNIT

1. To explain how to mount a hack saw blade.
2. To show how to hold the hand hack saw.
3. To show how to mount work to be held in the vise.
4. To explain how to make straight and angular cuts.

INTRODUCTORY INFORMATION

The hand hack saw is used to cut bar stock, tubing, thick sheet stock, webs on drilled sections, and a variety of other shapes.

Normally, it is considered good practice to saw small size bar stock with the hand hack saw, leaving the larger sizes to be cut on the power saw. The proper use of this tool requires judgment on the part of the workman in selecting and mounting the blade and cutting the stock.

TOOLS AND EQUIPMENT

Hack Saw Frame with suitable blade
Bench Vise
Soft Jaws
Steel Rule
File

PROCEDURE

1. Select saw blade for job at hand.
2. Assemble blade in frame so that teeth point in direction away from operator.
3. Strain blade well in frame to prevent saw from buckling and drifting.

   NOTE: Use judgment when tightening the frame to prevent: breaking the blade, shearing the pins, or bending the frame. Excess strain will cause the blade to cant.

4. Clamp work in vise so as to provide as much of a bearing surface as possible in order to engage the greatest number of teeth.

   NOTE: The use of soft removable jaws will prevent marring a finished surface.

NOTE: Place work so the saw will cut about 1/4" away from the vise jaws in order to prevent work from springing.

5. Indicate the starting point by nicking the surface with a file to break any sharp corner which might tend to strip the teeth. This mark will also aid the beginner to start the saw at the proper place.

6. Grasp the handle of the frame securely with the right hand. The thumb should be on top with the remaining fingers closed around the handle. The front end of the frame is held by the left hand to help guide the saw and give added pressure when sawing. (Figure 1)

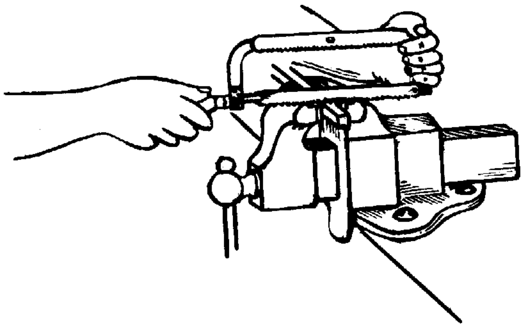


FIG. 1 SAWING WITH A HAND HACK SAW

7. The body should be in the correct position with the left foot forward and pointed toward the bench. The right foot to the right and in back of the left foot placed to give balance when sawing.

8. When sawing, the body should lean forward from the hips on the forward stroke for about two-thirds of the stroke, returning to the original position at the end of the return stroke.

NOTE: When sawing to a given line, place work in the vise so that the line is at right angles to the top of the vise jaws. (Figure 2)

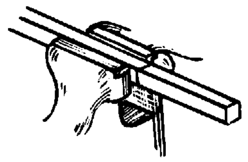


FIG. 2 CUT PERPENDICULAR TO TOP OF VISE JAWS

9. To start the cut, place the front end of the blade on the mark. Apply slight pressure and make the first stroke by pushing the saw straight across the surface of the work. Release the pressure and return saw to starting position.

10. Repeat the process by adding a little pressure on the succeeding strokes. Continue the process at the rate of 40 to 50 strokes a minute for average work.

NOTE: No lubricant is necessary when sawing by hand. However, a little oil applied to the sides of the blade with the finger will aid in taking a deep cut.

NOTE: Care should be taken to prevent either stripping the teeth or breaking the blade. Some of the causes of breakage are:

a. Pitch too coarse for material;

b. Too much pressure applied on the cutting stroke;

c. Work moving in vise; and

d. Cutting off at an angle and then trying to straighten cut by twisting the saw.

NOTE: When a saw has been broken in an unfinished cut, the cut should be resumed in another place on the work because the "set" of a new saw is thicker than that of a used saw. A new blade will break if forced into the old cut.

THE POWER HACK SAW

OBJECTIVES OF UNIT

1. To mention the general types of sawing machines.
2. To describe the function of the power hack saw.
3. To discuss the selection and use of the proper saw blade.
4. To point out the need for use of cutting compound.

INTRODUCTORY INFORMATION

Three general types of power saws are used in machine shops and allied metal work industries. The most commonly and widely used machine is the power hack saw and the type which we shall consider. The metal cutting band saw is a newer type of sawing machine which operates with a horizontally mounted continuous steel band saw. The circular saw or cold saw is a heavy duty type machine used for cutting off large stock.

The function of the power hack saw is to cut off metal bars, castings, and other metal materials used in the machine shop, by means of a hardened steel saw blade which is mechanically operated on the same principle as the hand hack saw.

The power hack saw may be used for sawing materials (except hardened steel) from about one-half inch in size to the capacity of the saw. Metal bars less than one-half inch in size are usually sawed by hand, since the pressure of the power saw blade has a tendency to bend the stock and the saw teeth straddle and break on the narrow section of the work. The wide range of gripping capacity and the ease with which the saw blade may be changed make it a popular type of machine for sawing standard machine shop work. Two bars may be cut at the same time, if quantity production is desired.

Power hack saw machines may be either draw-cut or push-cut types. On a draw-cut machine, the cutting stroke is away from the operator and the pressure is relieved on the return movement. On a push-cut machine the movement is reversed.

SELECTION AND USE OF SAW BLADES

Power saw blades are usually somewhat wider and a trifle thicker than those used for hand sawing. They are made of various kinds of high grade tool and alloy steels, hardened and tempered. The blades are very hard and consequently very brittle.

SELECTION AND USE OF SAW BLADES

In the selection of power hack saw blades it is important that the kind of material, shape and thickness be taken into consideration. In cutting large sections of soft steel, a blade with coarse teeth is recommended (Figure 1-a). For cutting tubing and thin materials a blade with finer teeth should be used in order to have two or more teeth in contact with the section of metal at all times. (Figure 1-b).

In case it becomes necessary to use a regular coarse tooth blade when sawing pipe or tubing, clamp a piece of wood or a piece of bar stock with the work and saw both at the same time, in order to avoid breaking the saw teeth.

The pitch of a saw blade refers to the distance from a point on one tooth to a corresponding point on the next tooth. The size of saw teeth is designated by the number of teeth per inch.

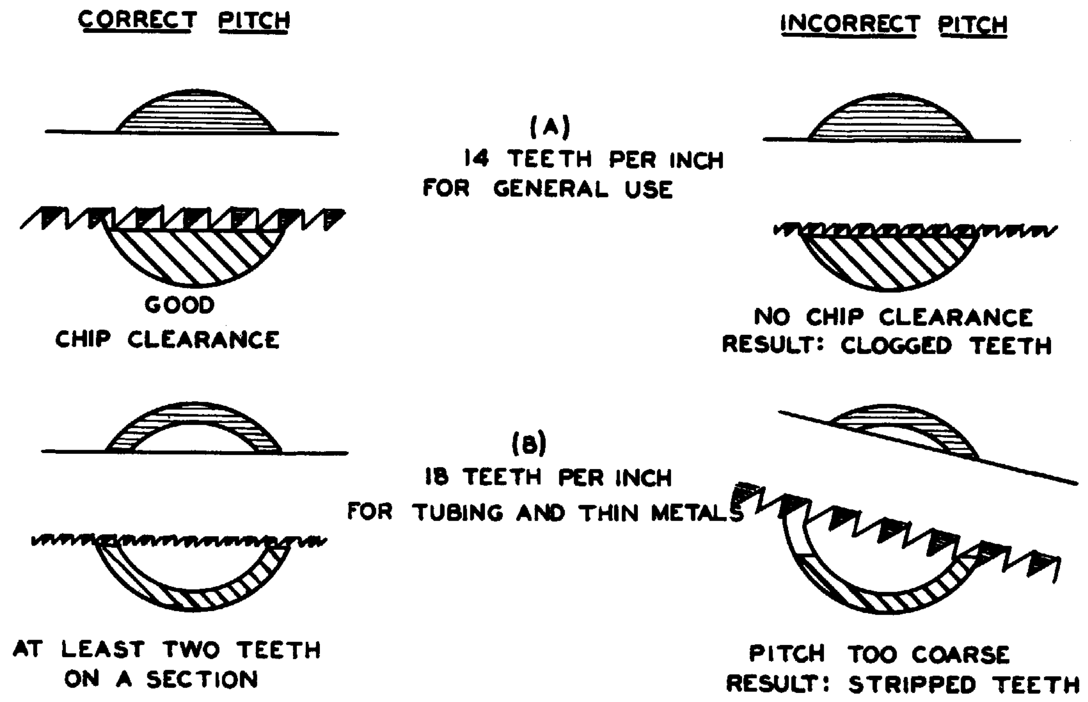


FIG. 1 SELECTING THE CORRECT PITCH FOR LIGHT POWER SAWS

CUTTING COMPOUND

Power saws operating at a high rate of speed require a coolant to carry away the heat from the cutting surface of the teeth. Each tooth is very sharp and consequently cannot conduct the heat away fast enough to prevent the steel in the saw blade from losing its temper.

A steady stream of coolant flowing on the work and blade during the sawing process absorbs the heat due to friction and prevents overheating of the cutting edge, thereby prolonging the life of the saw blade.

The coolant most commonly used is soda-water. This is a mixture of two pounds of sal-soda to three gallons of water. A small quantity of soft soap or lard oil is sometimes added to give body to the mixture.

SELECTED REFERENCES

Burghardt ------------ Machine Tool Operation ----------- Part I

Henry Ford Trade School ---------------------------- Shop Theory

L. S. Starrett Co. --------------------- Hack Saws and Their Use

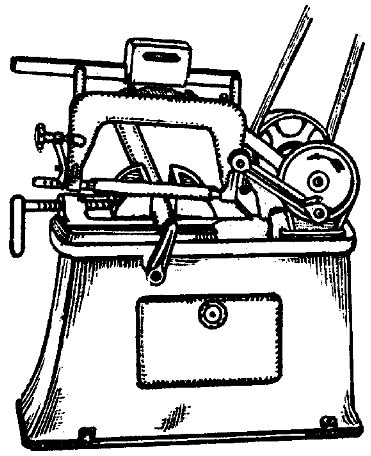
HOW TO OPERATE THE POWER HACK SAW

OBJECTIVES OF UNIT

1. To describe the operation of the power hack saw.
2. To explain how to use the power hack saw.
3. To explain how to mount a saw blade.

INTRODUCTORY INFORMATION

Power hack saws operate on the same principle as hand hack saws. The work is held in a vise, and the blade is secured in a frame which is moved in a forward and backward motion.



POWER HACK SAW
FIG.1

The saw frame is mechanically lifted on the non-cutting stroke, thereby relieving the pressure on the saw blade. The blade is fed into the work by weight or spring pressure on the cutting stroke. An automatic trip stops the machine on completion of the cut.

TOOLS AND EQUIPMENT

Power hack saw
Steel rule
Open end wrench
File

HOW TO OPERATE THE POWER HACK SAW

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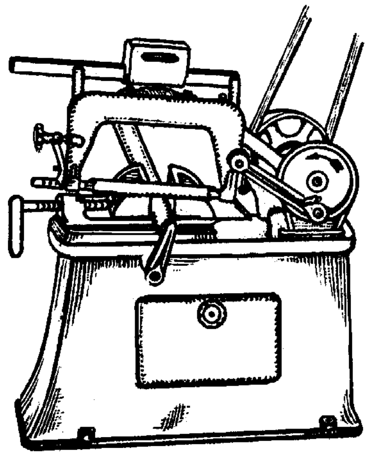

POWER HACK SAW
FIG.1

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TOOLS AND EQUIPMENT

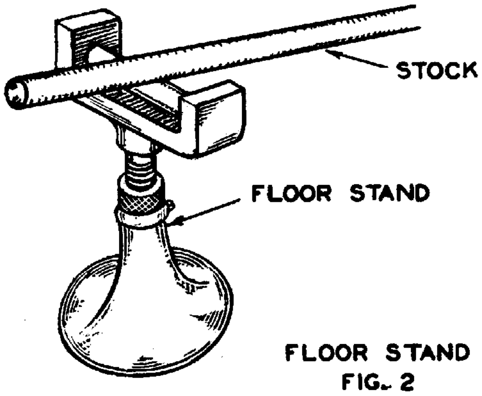
Power hack saw
Steel rule
Open end wrench
File

PROCEDURE

1. Place stock in saw vise. Do not clamp vise jaws.

   NOTE: If long bars are to be sawed, support the overhanging end on a floor stand. (Fig.2)

   NOTE: Thin materials should be held flat in the machine in order to lessen the danger of breaking the saw teeth.



FLOOR STAND
FIG. 2

2. Lower saw nearly to the work.

3. Place steel rule against outer side of saw blade and adjust stock to the required length. Allow about 1/16 inch for the run (slanting out) of the saw.

   NOTE: When the length of stock is laid off prior to placing the work in the machine, mark the location of the cut with the corner of a file. The work is then placed in a vise so that, when the saw is lowered, it rests on the file mark.

4. Lock the work securely in the vise.

5. Lower the saw to the work. Check the weight or pressure. Start the cut.

   NOTE: If the saw frame is allowed to drop, the blade will break. Some saws are equipped with a lowering mechanism which gradually feeds the saw to the work. On others, the saw must be lowered to the work before starting the machine.

   NOTE: As the saw dulls, increase the weight or pressure. Insufficient pressure causes the saw blade to slide over the work without cutting. Too much pressure wears the blade out quickly and will cause the blade to run.

6. Adjust the compound nozzle so that a steady stream of the coolant plays on the saw at its point of contact with the work.

7. USE OF GAUGE OR STOP

   When several pieces of the same length are to be cut, set the gauge to the given length including the usual allowance. The gauge or stop is usually attached to a round bar which passes under the vise and held in place by a set screw. It may be swung down and out of the way when not used.

HOW TO MOUNT A SAW BLADE IN POWER SAW

INTRODUCTORY INFORMATION

Power hack saw machines are constructed as either draw-cut or push-cut types. When operating a draw-cut machine the teeth of the saw blade should point away from the operator, while on a push-cut machine the teeth point toward the operator.

PROCEDURE

1. Select proper type saw blade. (See Unit 1-T5 describing power hack saw blades).

2. Release tension clamp (Figure 3). Adjust for length of saw blade.

3. Insert saw blade in frame so that the teeth point in the direction in which the cutting is to be done.

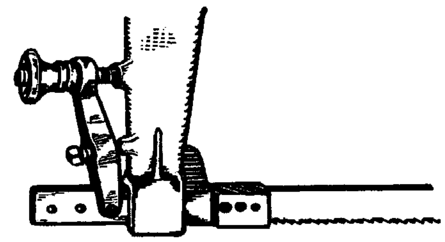


FIG. 3 TENSION CLAMP

4. Tighten the blade rigidly in the frame.

   NOTE: If it becomes necessary to replace a worn or broken blade on a partly sawed job, do not insert the new blade in the same cut as it generally will stick or wedge. Turn the work over and start a new cut.

BURRED EDGES

OBJECTIVES OF UNIT

1. To point out some of the common causes of burrs.
2. To explain why burring is necessary.
3. To show why burrs cause inaccurate work.

INTRODUCTORY INFORMATION

A burr is the turned-up or projecting edge of metal which commonly results from sawing, drilling, punching, and cutting processes in general. (Figs. 1 and 2). Burrs are frequently thrown up through careless handling, dropping, nicking, or when the edge of a piece of metal is subjected to abrasion.

Damaged or spoiled work is often caused by failure to remove burrs before clamping the work in a machine.

Burred edges, nicks, dents, and ragged or sharp corners are usually removed by hand with a medium or fine grade file. This process is termed "burring". The sharp edges on hardened steel pieces can easily be removed with a small oilstone.

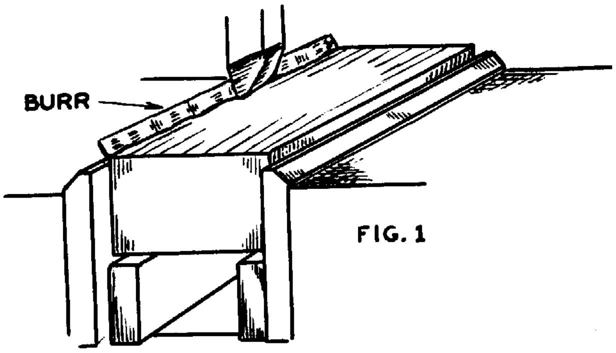
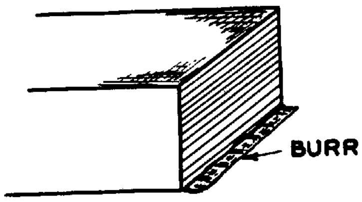


FIG. 1

BURR TURNED OVER BY PLANER TOOL



BURR LEFT BY SAW CUT
FIG. 2

THE NECESSITY FOR BURRING

Burring is done to insure accuracy, fit, safety in handling, and for appearance.

BURRING FOR ACCURACY

One of the frequent causes of inaccurate layout work is either the lack of burring or improper burring. It is impossible to lay out a job to any degree of accuracy, if it rests on a burred edge or on a surface which is not clean. The burred edge of a job resting on parallels or a surface plate would produce the same effect as if a shim were placed under it. (Fig. 3).

Work held in a machine should be free from burrs so that the work rests evenly on parallels, vise, table, or other holding device. A burr under one edge is sufficient to throw the job out

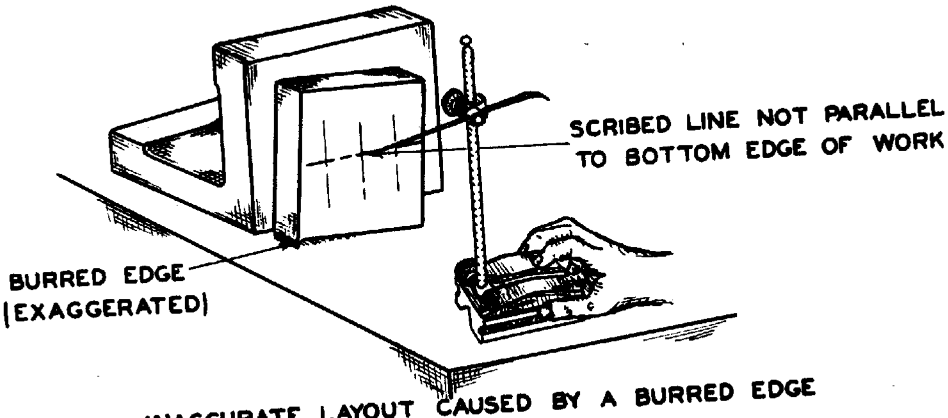


FIG. 3 INACCURATE LAYOUT CAUSED BY A BURRED EDGE

of alignment so that the result is inaccurate, damaged, or spoiled work. (Fig. 3).

Measurements taken over burrs are often a source of trouble. The careful machinist always makes sure that his measurements are taken on a part of the work free from burrs.

Burrs frequently cause a great deal of trouble when fitting parts together. Sharp corners, turned over edges, drilling and tapping burrs, must be removed so that parts may fit accurately.

BURRING FOR SAFETY

Burred tools and sharp corners on machine parts are not safe to handle. Personal injury can be prevented by removing the sharp corners and burrs from work which requires further handling.

BURRING FOR APPEARANCE

The hallmark of a craftsman's job is a properly burred piece of work. The rounding of corners and the removal of sharp corners adds to the finished appearance of a job. Industry frequently demands that work be finished in this manner. On many standard industrial blueprints the following notations may be found: "Round all unnecessary sharp corners", "Break edges".

SELECTED REFERENCES

Burghardt ---------------- Part II ----------Machine Tool Operatio

DESCRIPTION OF LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To describe the various tools commonly used in layout work.

2. To point out the application of simple layout tools.

INTRODUCTORY INFORMATION

Layout tools are made in a variety of designs to aid the machinist in transferring information and dimensions from the drawing to the surfaces of the job. (Fig. 1). The general uses of these tools are to scribe lines involving circles, arcs, angles and straight lines which indicate intersections and the outlines of the shape of the work. They are also used to indicate centers of holes to be machined.

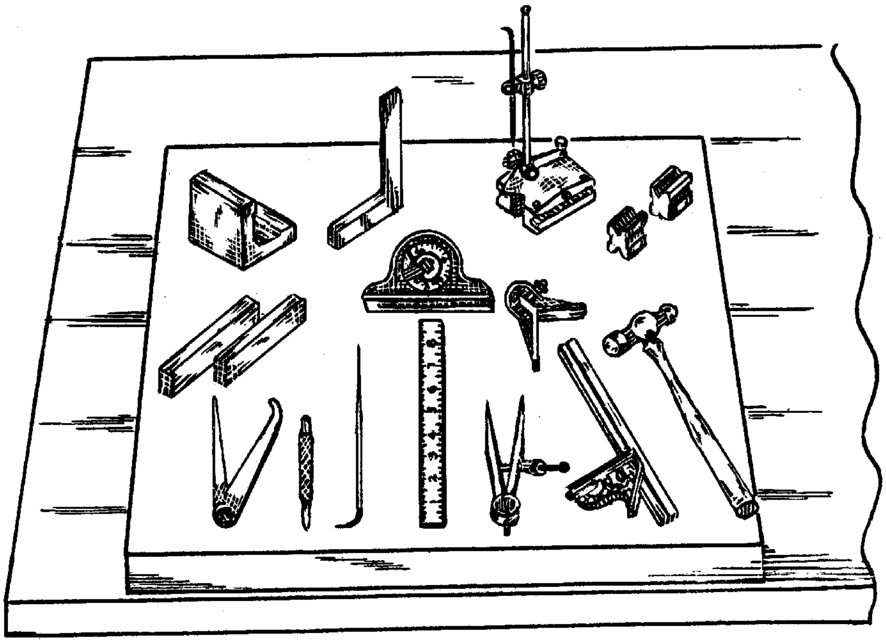


FIG. 1 BENCH PLATE AND COMMON LAYOUT TOOLS

Straight, sharp and keen-edged tools are essential for accuracy since a clean but distinctly scribed layout guides the workman more closely to desired sizes and shapes of the finished article. Therefore, it is important that the workman keep his tools in the best condition and use them only for the purpose for which they are intended.

BENCH PLATE

The bench plate is a cast iron plate carefully machined to a flat surface. (Fig. 2). Bench plates vary in size. An average size for the work bench is about 18" square by 1-1/2" thick. It is used as a base upon which to work. The work may lie directly on the bench plate, be clamped to an angle plate, or held on "V" blocks while being marked or scribed. The bench plate is used for ordinary layout work where great accuracy is not required.

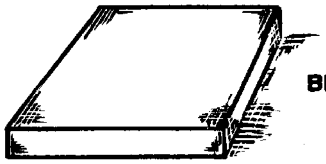
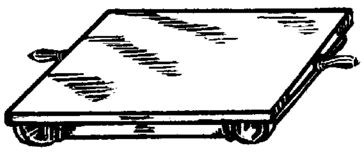


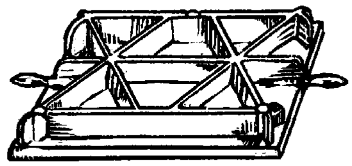
FIG. 2
BENCH PLATE

SURFACE PLATE

The surface plate is used where a finer degree of accuracy is required. This plate is an expensive piece of equipment and must be used with care. It is made of a special grade of close grained cast iron and is well ribbed on the under side to prevent warping of the surface (Fig. 3).

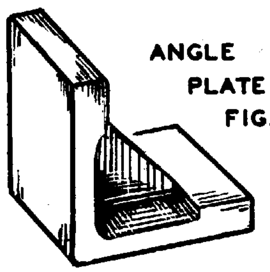


SURFACE PLATES
FIG. 3



After being carefully machined, the plate is hand scraped to a flat smooth surface. Besides being used for precision layout work, it is also used for checking accurate work such as gages, jigs, fixtures, etc.

ANGLE PLATE



ANGLE PLATE
FIG. 4

The angle plate is an "L" shaped piece of cast iron or steel carefully machined to an angle of 90 degrees. (Fig. 4). The angle plate is used when the work must be held at right angles to the bench or surface plate. The work is clamped in this position on the angle plate while being laid out or checked.

"V" BLOCKS

"V" blocks are made of either cast iron or steel in various sizes to accommodate a wide range of work. (Fig. 5). They are machined with a "V" shaped slot of 90° on top and bottom. The sides usually are grooved to receive the clamp yoke which is used to hold the work securely in place while being laid out or drilled.

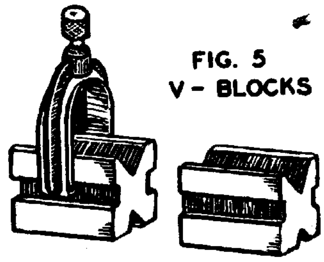


FIG. 5
V - BLOCKS

PARALLELS

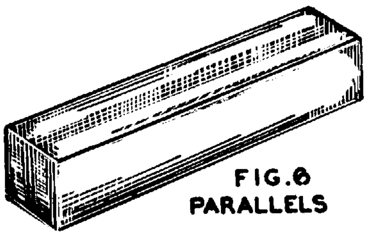


FIG.6
PARALLELS

Parallels are bars of steel or cast iron, square or rectangular in shape and carefully machined for accuracy. (Fig. 6). They are made in pairs of various sizes and lengths depending upon the nature of the work for which they are to be used.

Precision layout work requires hardened and ground parallels. For ordinary work, cold drawn steel, or planed cast iron bars are commonly used.

Parallels may be used for mounting work parallel to the surface of a bench plate, surface plate, or other surface. They may also be used for leveling work on a flat surface when projections on the work prevent setting the job directly upon the plate.

THE COMBINATION SET

The combination set (Fig.7) is a tool consisting of four parts:

1. The stock (square). One side is 90°, the other 45°.
2. The protractor head.
3. The center head.
4. The steel rule or blade which fits any of the three heads.

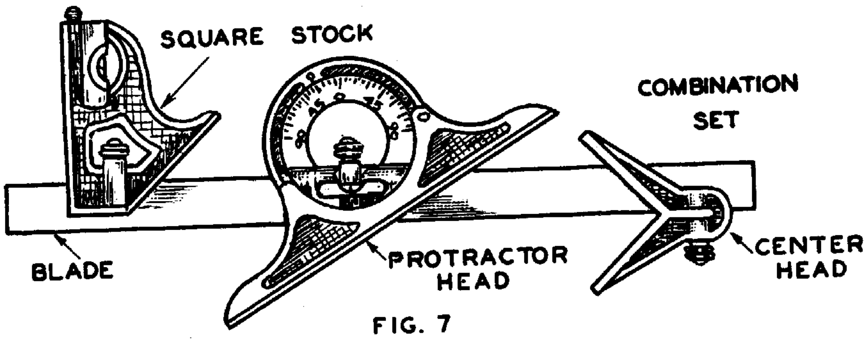


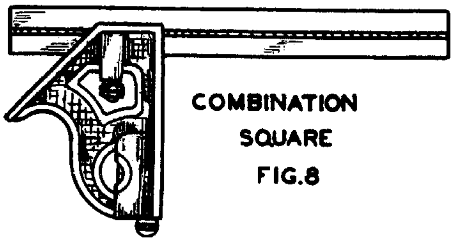
FIG. 7

The combination set is one of the most useful and convenient tools for layout work.

1. The stock can be moved along the steel blade and clamped in any position desired. (Fig.8). It is used as a square for checking angles of 90°, as a depth gage, for scribing lines at right angles to a surface, or for angles of 45°.

By setting the end of the steel rule flush with the stock, it may be used as a height gage directly or in combination with a surface gage.

A spirit level is mounted in the stock. A scriber is held in the lower end by a friction bushing. The scriber may be drawn out when needed.



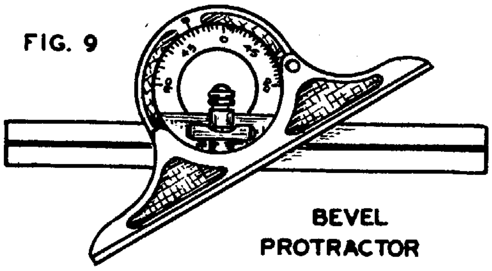
COMBINATION SQUARE FIG.8

2. The protractor head is provided with a swivel or turret to which the steel rule is clamped. (Fig.9). The revolving turret is graduated in degrees from 0 to 180. On some standard makes, it is graduated in degrees from 0 to 90 in either direction.

It can be accurately adjusted to show any angle and is clamped in position with a knurled nut.

The protractor is used for laying out lines at any given angle and for measuring angles.

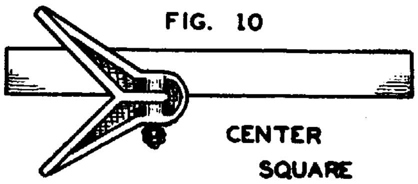
FIG. 9



BEVEL PROTRACTOR

3. The center head forms a center square when clamped to the steel rule. (Fig.10). The sides of the center head are placed on the outer surface of round jobs and the center is found by scribing lines along the edge of the rule.

FIG. 10



CENTER SQUARE

STEEL RULE

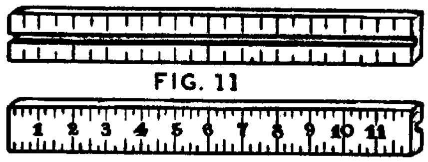
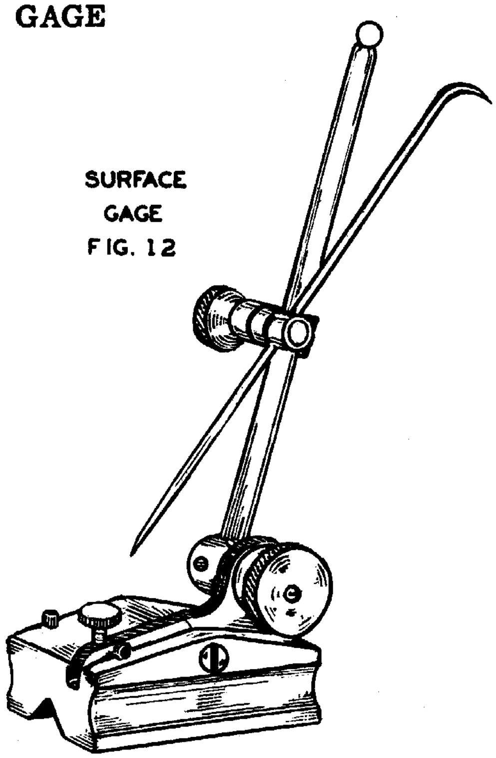


FIG. 11

4. The steel blade or rule, which is part of the combination set, may be fitted to either the square stock, the center head, or the protractor head. (Fig. 11). It may be set at any desired position and clamped. It is sometimes used separately for measuring or used as a straight edge.

THE SURFACE GAGE

The surface gage is an instrument used for scribing lines at a given height from some face of the work or for the construction of lines around several surfaces of the job. (Fig.12). The gage consists of a heavy base and a spindle pivoted upright, to which is attached a scriber held by a clamp. The scriber may be turned through a complete revolution.



SURFACE GAGE FIG. 12

By resting both the surface gage and the work upon a plane surface, it is possible to set the point of the scriber at a given height, either by use of a scale or some other standard, and draw lines at this height on all faces of the work or on any number of pieces when duplicate parts are being made.

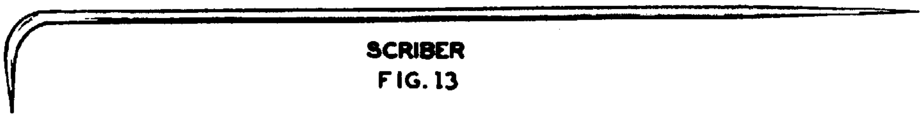
The use of the surface gage is not restricted to the scribing of horizontal lines, but may also be used on other surfaces from which it can be conveniently guided or held.

It can be used as a height gage and also for leveling work on a machine vise or plate.

The bent end on the scriber permits lines to be drawn on horizontal surfaces, while a groove in the base of the gage makes it possible to mark out desired distances from the outside of a circular piece.

THE SCRIBER

The scriber is a piece of tool steel, usually drill rod, about 1/8" in diameter, 8" to 12" long, tapered at both ends to a needle



SCRIBER FIG. 13

point (Fig.13). One end is bent to be used in reaching through holes, etc. The scriber is hardened and tempered. It is used to scribe or mark lines on metal surfaces which have been prepared with chalk or blue vitriol.

DIVIDERS

Dividers have two straight legs, both tapered to a needle point and adjusted for opening by screw and knurled nut (Fig.14).

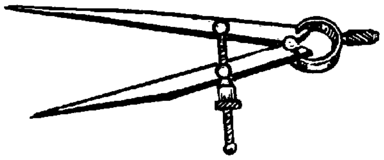


FIG. 14 DIVIDERS

They are used for scribing circles and radii; and in combination with the steel rule or other standard, to measure distances between points, or to transfer distances taken directly from the steel rule.

HERMAPHRODITE CALIPERS

The hermaphrodite calipers are made with two legs; one blunt and bent at the end, the other with scriber point. (Fig.15). The scriber point is usually adjustable so that it can be adjusted for length when the bent leg is resting on an outer edge.

FIG. 15

HERMAPHRODITE CALIPERS

It is used for locating centers of round pieces, centers of bosses, etc. It may also be used to scribe a line or locate a point parallel with a surface or shoulder.

PRICK PUNCH

The prick punch is made of tool steel, usually from 4" to 6" long, and is hardened and tempered. It is knurled to give a good finger grip. One end is tapered to a point that is ground to an angle of about 30°. The prick punch is used for making small indentations along scribed lines, for marking the location of points, and centers for divider points.

CENTER PUNCH

The center punch is similar in design to the prick punch, excep[t] that the tapered point is ground to an angle of about 90°. (Fig.16)

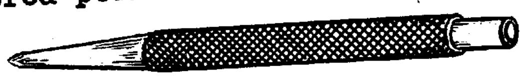


FIG. 16
CENTER PUNCH

The center punch is used for making indentations along scribed lines, for marking the location of points and the centers of holes to be drilled.

SELECTED REFERENCES

Burghardt ----------------- Part I -------- Machine Tool Operation
Henry Ford Trade School ----------------------------- Shop Theory

HOW TO USE LAYOUT TOOLS

OBJECTIVES OF UNIT

1. To point out how to care for layout tools.
2. To show how to use layout tools.

INTRODUCTORY INFORMATION

The more commonly used layout tools are: the scriber; the combination set consisting of the protractor head, center head, square, and the steel blade; hermaphrodite calipers; the center and prick punches; the spring dividers; and the surface gage.

Care should be taken in the use of these tools so that sharpened and pointed edges are kept in good condition to prevent impairing the accuracy, which is essential to a good layout job. Tools which have pointed ends should only be used for the purpose for which they are intended and not on hardened surfaces.

TOOLS AND EQUIPMENT

Scriber
Steel rule
Oil stone
Combination set
Hermaphrodite caliper
Spring dividers
Center punch
Prick punch
Machinist's hammer
Surface plate
Surface gage

PROCEDURE

SCRIBER

1. Inspect the point of the scriber to make sure that it is sharp. If the point is dull, sharpen it on an oil stone by rotating the scriber between the thumb and forefinger while moving it back and forth. (Fig. 1).

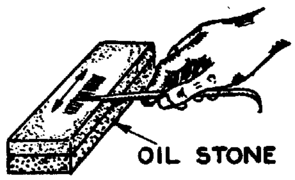


FIG. 1 SHARPENING A SCRIBER

2. Wipe the surfaces of the work to be scribed clean and free of oil, dirt, and chips.

3. Place the steel rule flat on the work in position for scribing. Grasp the scriber in the right hand as a pencil is gripped. (Fig.2).

4. Hold the rule firmly by exerting pressure with the tips of the fingers of the left hand (Fig.2).

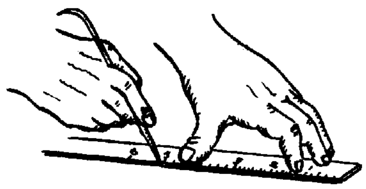


FIG. 2 SCRIBING A LINE

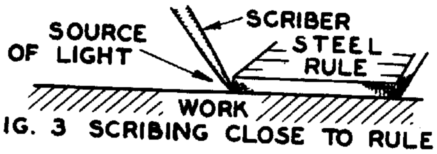


FIG. 3 SCRIBING CLOSE TO RULE

5. Set the point of the scriber as close to the edge of the rule as possible by tipping the top of the scriber outward (Fig.3).

6. Scribe the line by exerting pressure on the scriber and drawing it along the edge of the rule, inclining the top of the scriber slightly in the direction in which it is to be moved. (Fig.4).

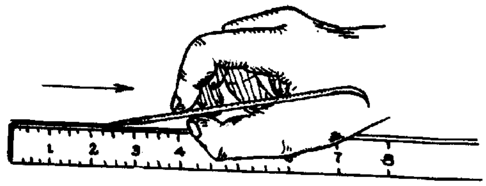


FIG. 4 INCLINING SCRIBER

NOTE: Make sure that the light shines on the portion of the work being scribed.

COMBINATION SET

A. CENTER HEAD

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt.

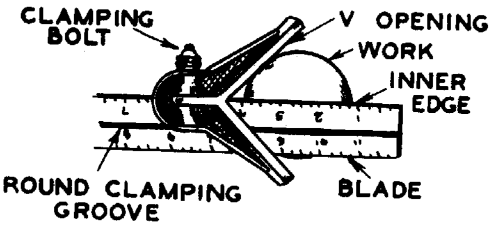


FIG. 5 SCRIBING A CENTER LINE USING A CENTER HEAD

2. Extend the blade through the V-opening a length equal to the diameter of the work to be centered. Clamp the blade in position by tightening the knurled nut.

3. Place the V-opening against the diameter of the work to be centered.

4. Scribe a line along the inner edge of the blade (Fig. 5).

B. COMBINATION SQUARE

1. Insert the blade through the slot in the head so that the round clamping groove in the blade engages with the end of the clamping bolt (Fig.6).

2. Extend the blade through the slot at the required length and clamp in position by tightening the knurled nut.

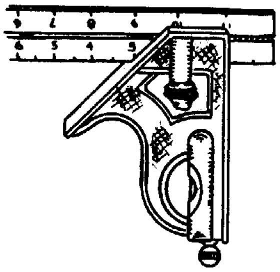


FIG. 6 COMBINATION SQUARE

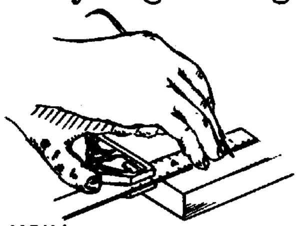


FIG. 7 USING COMBINATION SQUARE FOR LAYING OUT LINES

3. Place the head of the square against the side of the work to be scribed, and scribe lines from either side or the end of the square according to the requirements of the job at hand. (Fig.7).

C. PROTRACTOR

1. Insert the blade through the slot in the swivel turret so that the rounded groove in the blade engages with the clamping bolt.

2. Extend the blade to the required length and tighten (Fig.8).

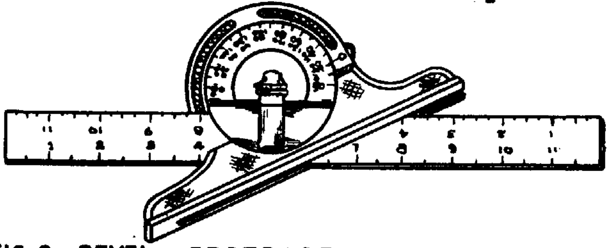


FIG.8 BEVEL PROTRACTOR

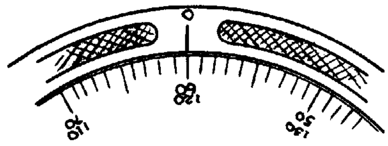


FIG.9 READING PROTRACTOR

3. Loosen the clamping screw on the body of the protractor and swing the revolving turret to the desired angle. This angle is read at the index line on the body and the graduations on the turret. (Fig.9) Tighten the clamping screw.

4. Place the base of the protractor against the side of the work and scribe lines as desired. (Fig.10).

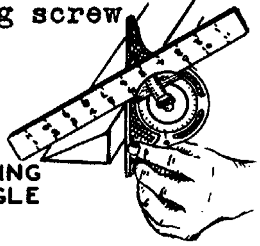


FIG. 10 MEASURING AN ANGLE

HERMAPHRODITE CALIPERS

1. Inspect the scriber leg of the caliper to make sure that the point is sharpened. ,If the point is dull, sharpen on oil stone.

2. Adjust the length of the scriber leg so that it is even with the inside edge of the rounded caliper leg when it is to be used to scribe lines from the outside edge of the work. (Fig. 11).

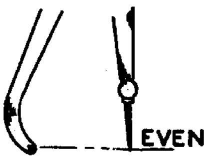


FIG. 11 ADJUSTING LENGTH OF SCRIBER LEG

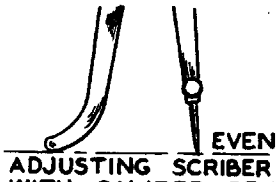


FIG. 12 ADJUSTING SCRIBER LEG WITH CALIPER REVERSED

3. When scribing lines with the caliper reversed, set the scriber point to the full length of the caliper leg. (Fig.12).

4. **CASE 1**

To set the caliper at the desired dimension, loosen the lock nut slightly. Place the caliper leg against the end of the steel rule and adjust the scriber leg to the required graduation on the steel rule. Tighten the clamp nut. (Fig.13-Case 1).

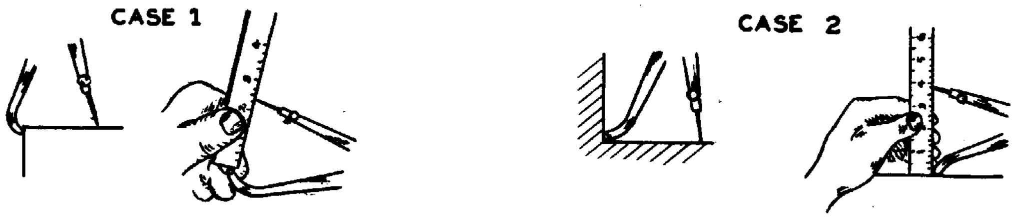


FIG. 13 SETTING HERMAPHRODITE CALIPERS

CASE 2

To set the caliper at the desired dimension with the legs reversed, place the end of the steel rule against a straight surface and set the end of the caliper even with the end of the rule. Adjust the scriber leg so that the point of the scriber coincides with the required graduation on the rule (Fig.13-Case 2). Tighten the clamping nut.

5. Grasp the top of the caliper with the thumb and forefinger of the right hand. Place the curved tip of the caliper against the surface from which the line is being located, keeping the tip of the caliper leg square with the surface from which it is guided and in contact with the surface. Scribe the line by exerting a slight pressure on the scriber and drawing the caliper along the surface being scribed. (Fig.14).

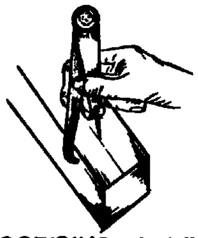


FIG. 14 SCRIBING A LINE

CENTER PUNCH AND PRICK PUNCH

1. Inspect the point of the punch to make sure that it is sharp.

   NOTE: The point of the prick punch is usually sharpened to an angle of 30°, while the center punch is usually ground to an angle of 90° (Fig.15).

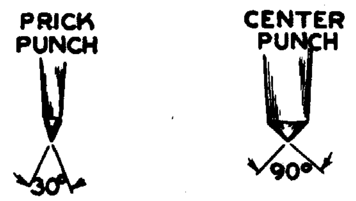


FIG. 15 CENTER AND PRICK PUNCH

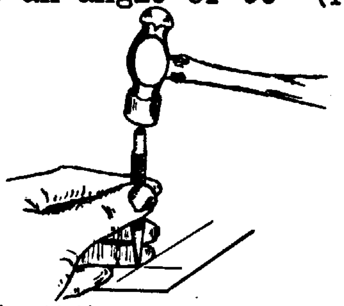


FIG. 16 USING A CENTER PUNCH

2. Grasp the punch in the left hand and punch directly on the line or intersection of lines to be marked. (Fig.16).

   NOTE: With a little practice, the beginner can feel the point of the punch when it strikes the scribed line or meets the intersection.

3. Hold the punch in a vertical position and tap it lightly with a machinist's hammer. Repeat blow if indentation is not deep enough.

   NOTE: Tap the prick punch lighter than the center punch. The prick punch is used for making light indentations, as for the point of the divider. The center punch is used to make heavier indentations such as the starting point for a drill.

DIVIDERS

1. Inspect the points of the dividers to make sure they are sharp.

2. To set the dividers, hold them in the left hand and place the point of one leg in a graduation on the steel rule. By turning the knurled adjusting nut with the thumb and forefinger of the right hand, adjust the divider until the point of the other leg rests on the graduation of the steel rule, which gives the required measurement. (Fig.17).

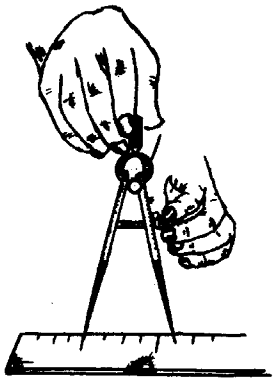


FIG. 17 SETTING DIVIDERS

3. To scribe an arc or circle with the dividers, grasp the knurled thumb attachment on the top of the dividers with the thumb and forefinger of the right hand.

4. Place the point of the pivoting leg on the punched mark. With pressure exerted on both legs, swing in a clockwise direction and scribe the desired arc or circle. (Fig. 18).

NOTE: By inclining the dividers in the direction in which they are being rotated, the tendency to slip is avoided.

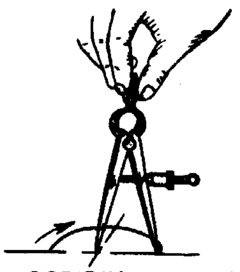


FIG. 18 SCRIBING A CIRCLE

SURFACE GAGE

1. Clean the surfaces of the surface plate, the base of the surface gage, and the work.

2. Decide on the best position in which to set the spindle and scriber of the surface gage.

NOTE: The surface gage will be more rigid if the scriber is clamped close to the spindle and as near the base as possible.

3. To set the surface gage to a given dimension, adjust the position of the spindle by loosening the swivel bolt lock nut and adjusting the spindle to a convenient position. Clamp in position. (The position of the spindle depends on the nature of the job. Ordinarily, it can be set in a vertical position but may be tilted as the job demands).

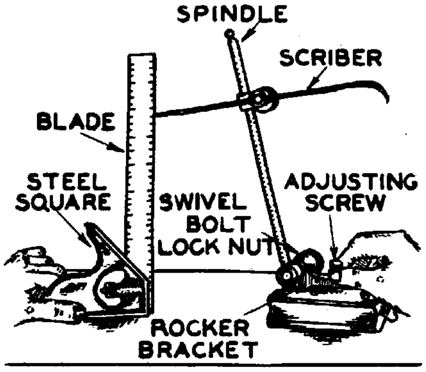


FIG. 19 ADJUSTING SURFACE GAGE

Then, set the scriber at approximately the given dimension by loosening the scriber clamp nut and adjusting it for its position on the spindle and its extension from the swiveling head. Clamp in position (Fig.19).

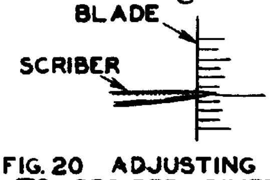


FIG. 20 ADJUSTING SCRIBER TO DESIRED DIMENSION

To make the final adjustment, turn the small adjusting screw at the rear of the rocker bracket so that the scriber is elevated or depressed to the given dimension.

4. To scribe lines, grasp the surface gage at the base and move it along the surface plate with the scriber point bearing against the surface to be laid out.

DESCRIPTION OF LAYOUT WORK

OBJECTIVES OF UNIT

1. To define the meaning of layout as it applies to machine shop practice.

2. To indicate the kinds of work where laying out is required and the necessity for laying out work prior to machining.

3. To describe the materials used for preparing surfaces for marking.

INTRODUCTORY INFORMATION

Laying out is the planning of the work on the surface of the job prior to machining. It is the scribing of lines which are used to indicate the boundaries, centers, and other locations which guide the workman in making the job to given dimensions.

Through layout, the machinist is able to analyze the sequence of operations and thereby plan his work in more efficient and orderly steps.

The accuracy of the finished job depends largely upon the care taken in the original layout. The nature of the job determines the kind of tools to be used.

NECESSITY FOR LAYOUT

Laying out is frequently used on work that is to be machined on shaper, planer, milling machine, or drill press. Much layout work is done on castings. This requires skill and judgment on the part of the workman to see that the job is properly machined. Quite often a casting is uneven or scant in places and, therefore, needs some calculation and judgment in layout.

Machined parts and finished surfaces can be laid out more readily and to a finer degree of accuracy than rough castings or unfinished work, since it is possible to set up the work on a surface plate or angle plate before scribing lines and locations.

In layout work, some "base" line or finished surface is selected from which to begin to make measurements. This serves as a starting point from which to lay out dimensions and as a location from which to check, should the work be shifted during the layout process.

MARKING MATERIALS

When scribing lines on metal surfaces, it is necessary to prepare the surface with a marking material so that the lines and markings are more legible. Several materials are used for this purpose.

1. Chalk is used for rough castings or unfinished steel that has an oxidized surface. Chalk rubbed on the surface before marking will make the scribed lines and markings much plainer.

2. A soapstone pencil is also very useful in marking the surface of rough castings.

3. Blue vitriol is generally used in preparing a finished surface for layout. The blue vitriol solution contains copper sulphate, water, and sulphuric acid. As much copper sulphate as will dissolve is added to four ounces of water and then ten drops of sulphuric acid are added to the solution.

CAUTION: To prevent personal injury when mixing the solution, add the acid to the water. Never add water to acid.

This solution gives a reddish-brown color against which the lines will show.

CAUTION: Care should be exercised in the use of blue vitriol solution so that none is spilled on the bench, surface plate, tools, or machinery. This solution is likely to rust or damage the tools and impair their accuracy. Blue vitriol spilled on clothing will cause the fabric to rot.

4. Coloring by heat is sometimes used on jobs where the temper of the metal is not to be considered. Heating the metal to a blue will give a satisfactory coloring through which scribed lines are plainly visible.

SELECTED REFERENCES

Burghardt ------------------ Part I -------- Machine Tool Operation

Henry Ford Trade School -------------------------------- Shop Theory

Machinery's Handbook

HOW TO LAY OUT WORK ON A BENCH OR SURFACE PLATE

OBJECTIVES OF UNIT

1. To explain the method of preparing a surface prior to laying out.
2. To explain how to lay out work on rough castings.
3. To explain how to lay out work on flat surfaces of a squared piece.
4. To explain how to lay out work on the bench, surface, or angle plate.

INTRODUCTORY INFORMATION

Practically all layout work is done on a bench plate or surface plate. The bench plate is generally used for rough and approximate layout; while the surface plate is used for precision work as well as checking the accuracy of tools and finished jobs. Each job of layout is a problem in itself involving judgment on the part of the workman according to the requirements peculiar to the job at hand.

TOOLS AND EQUIPMENT

Bench Plate
Surface plate
Parallel bars
Angle plate
Surface gauge
Combination square set
Scriber
Center punch and hammer
Dividers
Hermaphrodite Calipers
Clamps
Solid steel square
Steel rule
Marking materials
  a. Chalk
  b. Copper sulphate
    (Blue Vitriol)
Swab for copper solution

PROCEDURE

A. LAYOUT WORK ON ROUGH CASTINGS

1. Check casting with the blueprint or drawing to determine starting point and also to ascertain the amount of material to be removed.

NOTE: Remove all rough projections and fins from surfaces upon which lines are to be scribed as well as those upon which the work rests.

2. Level the casting on the bench plate, using a square, or surface gage.

3. Rub chalk over surface upon which lines are to be scribed

4. Refer to the drawing or blueprint for dimensions and determine the distance from the base of the bench plate to the first line to be scribed.

SETTING A SURFACE GAUGE FIG. 1

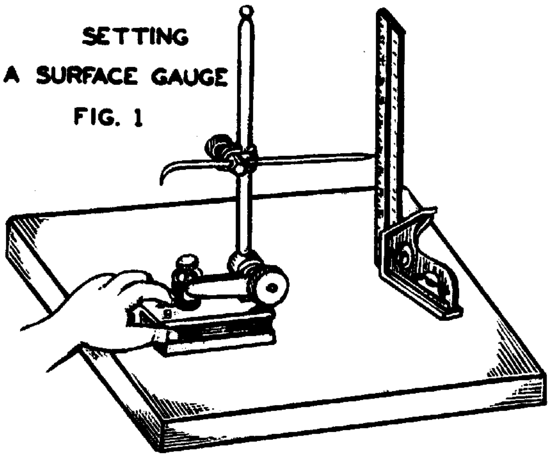
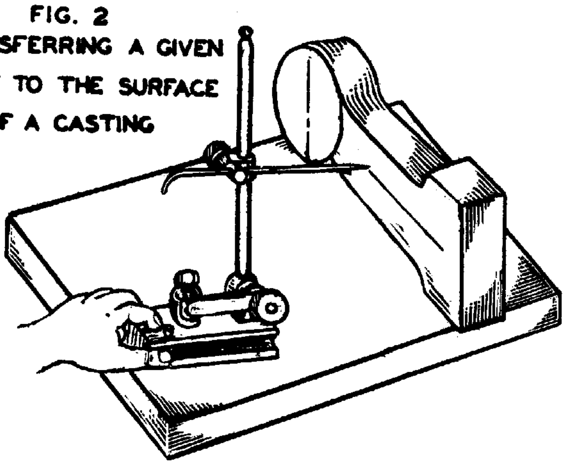


FIG. 2 TRANSFERRING A GIVEN HEIGHT TO THE SURFACE OF A CASTING



Horizontal lines may be scribed by use of the surface gage resting on the bench plate.

The surface gage should be set to the desired height with the aid of the steel rule, combination square or other gage. (Fig.1). Transfer the given height to the surface of the casting by sliding the surface gage along the bench plate with the scriber in contact with the casting (Fig. 2).

5. Vertical lines are next laid out by using the combination square or solid steel square and scriber. Intersections and centers are then marked off on the horizontal lines from the first vertical line by use of the dividers. The subsequent vertical lines are marked with the dividers, square, and scriber. (Fig.3). Angular lines may be laid out by using the bevel protractor. (Fig. 4).

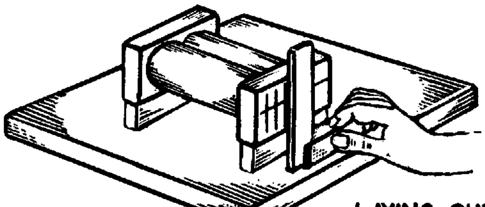


FIG. 3 LAYING OUT VERTICAL LINES

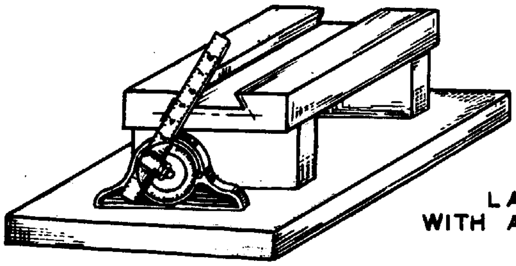
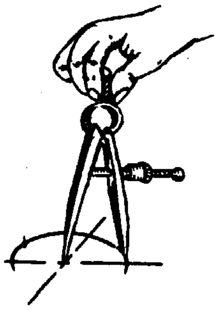
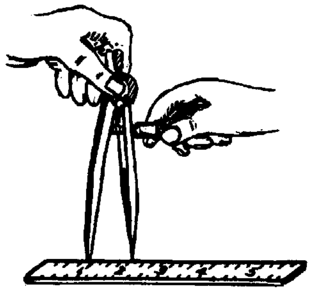


FIG. 4
LAYING OUT ANGULAR LINES
WITH A BEVEL PROTRACTOR



SCRIBING A CIRCLE
FIG. 5

6. Light indentations are made at points of intersection with a prick punch. Using these marks as centers, circles are scribed with dividers to the diameter of the hole to be drilled and prick punched around the circle to guide the workman. After the circles are scribed, make a deeper indentation at the center so that the drill will start centrally.
7. Check layout with the blueprint for errors.



SETTING DIVIDERS
FIG. 6

B. LAYOUT WORK ON FLAT SURFACES OF A SQUARED PIECE

1. Remove all burrs.
2. Clean or polish surface to be laid out before applying copper sulphate (Blue Vitriol). Surface must be kept free of grease or oil.

CAUTION: Copper sulphate is a poisonous substance and should be handled with care.

3. Using a swab or clean piece of cloth, apply copper sulphate (blue vitriol) solution to the prepared surface and rub it until a copper coating appears.

NOTE: Blue vitriol solution has a corrosive action and, therefore, should be kept away from tools and polished surfaces.

4. Refer to drawing or blueprint for dimensions and determine the distance from the squared edges to the first line to be scribed.
5. Set the hermaphrodite calipers by placing the blunt leg on the end of the scale and the pointed leg to the graduation at the desired distance. (Fig. 7).

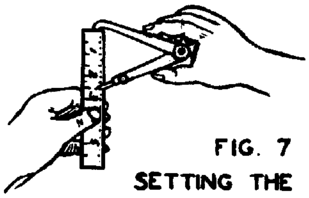
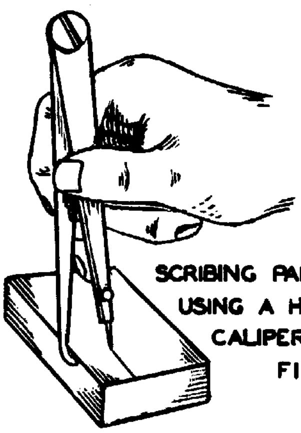


FIG. 7
SETTING THE
HERMAPHRODITE CALIPER

6. By setting the blunt leg against the squared edge of the piece, scribe a line parallel to the edge with the scriber point of the caliper (Fig. 8). Repeat the process for other parallel lines.



SCRIBING PARALLEL LINES USING A HERMAPHRODITE CALIPER
FIG. 8

7. Parallel lines may also be scribed by using the combination square. Set the blade of the square at the desired dimension and scribe lines at each end as shown in Figure 9. Connect these lines with the steel rule or combination square placed on edge.

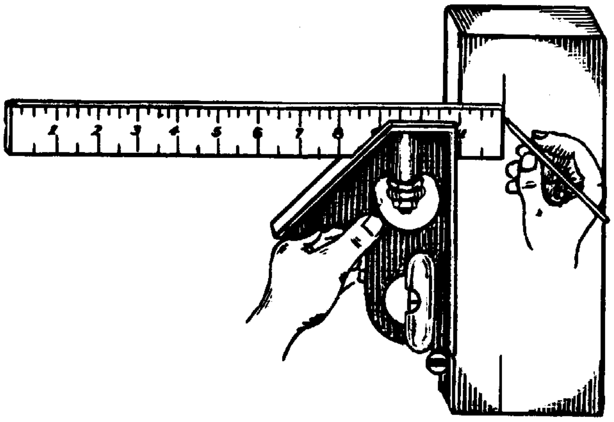


FIG. 9
SCRIBING PARALLEL LINES USING A COMBINATION SQUARE

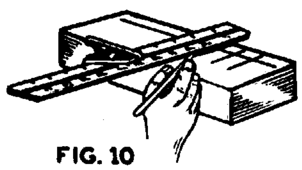


FIG. 10
SCRIBING LINES AT RIGHT ANGLES

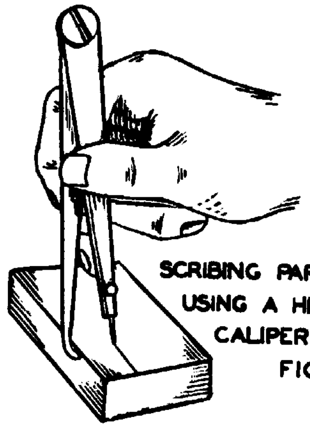
8. Lines are drawn at right angles by using the combination square or steel square. The blade is held at right angles to the work and the lines are scribed along the edge of the blade. (Fig. 10).

9. Distances may be laid off along any of the lines by using the dividers or the steel scale and scriber.

10. Angular lines may be laid out by using the bevel protractor.

11. Check layout with the blueprint for errors.

6. By setting the blunt leg against the squared edge of the piece, scribe a line parallel to the edge with the scriber point of the caliper (Fig. 8). Repeat the process for other parallel lines.



SCRIBING PARALLEL LINES USING A HERMAPHRODITE CALIPER
FIG. 8

7. Parallel lines may also be scribed by using the combination square. Set the blade of the square at the desired dimension and scribe lines at each end as shown in Figure 9. Connect these lines with the steel rule or combination square placed on edge.

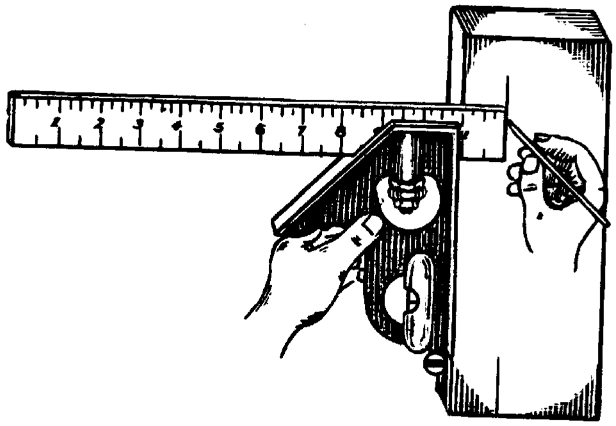


FIG. 9
SCRIBING PARALLEL LINES USING A COMBINATION SQUARE

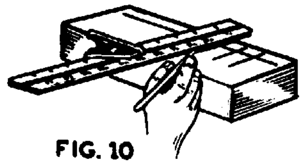


FIG. 10
SCRIBING LINES AT RIGHT ANGLES

8. Lines are drawn at right angles by using the combination square or steel square. The blade is held at right angles to the work and the lines are scribed along the edge of the blade. (Fig. 10).

9. Distances may be laid off along any of the lines by using the dividers or the steel scale and scriber.

10. Angular lines may be laid out by using the bevel protractor.

11. Check layout with the blueprint for errors.

C. LAY OUT WORK ON THE ANGLE PLATE

1. Check work with the blueprint or drawing to determine the locations of lines to be scribed.

2. Select an angle plate of a size suitable for the job at hand.

3. Remove all burrs from surfaces of the work.

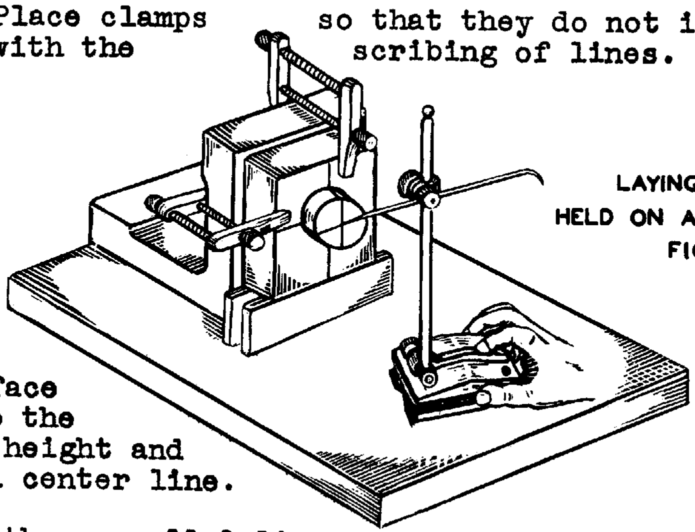
4. Prepare the surfaces for marking:
   a) If rough casting, use chalk.
   b) If machined surface, use copper sulphate.

5. Clean bench plate, angle plate, parallel bars, and work.

6. Set the angle plate and parallel bars on a bench or surface plate.

7. Place the machined surface of work against the angle plate and rest the lower edge on parallel bars prior to clamping. Secure the work with clamps. (Fig. 11)

   NOTE: Place clamps so that they do not interfere with the scribing of lines.



LAYING OUT WORK
HELD ON AN ANGLE PLATE
FIG. 11

8. Set surface gauge to the desired height and scribe a center line.

9. Scribe other parallel lines in relation to the center line.

10. Turn angle plate on end to scribe lines at right angles to other lines.

11. Repeat steps 8 and 9.

12. Remove work from angle plate and center punch intersections.

13. Check layout with blueprint for errors.

DESCRIPTION OF CHISELS

OBJECTIVES OF UNIT

1. To describe the common shapes of chisels.

2. To study the cutting angle and methods of grinding chisels.

3. To explain the care of chisels.

INTRODUCTORY INFORMATION

Mechanics use a variety of chisels to cut and chip or remove metal. When the chisel is used to sever pieces of metal, the cutting action resembles a wedging process; in chipping, the cutting action resembles a combination of wedging and shearing. Chisels are driven either with a hammer or a pneumatic device. The pneumatic chisel is used where a great deal of metal is to be removed.

The chisel is used to do special work or to remove surplus material roughly. Chipping is resorted to in cases where great accuracy is not essential and when it would be too expensive or impractical to set up the work in a machine.

Cold chisels are usually forged from octagonal tool steel containing about .80% carbon. This steel when properly hardened and tempered is tough enough to withstand the impact of the blow delivered, and yet sufficiently hard to maintain its cutting edge.

TYPES OF CHISELS

The cold chisels most commonly used are: flat, cape, diamond point, round nose, and gouge. (Fig. 1).

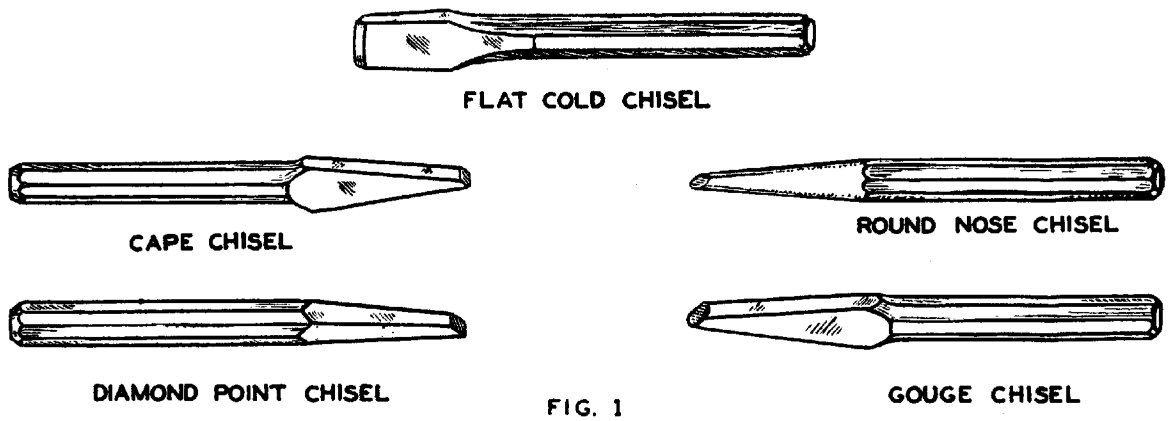
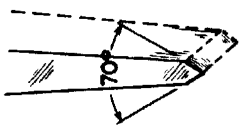


FIG. 1

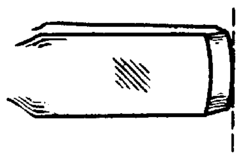
CUTTING ANGLES

The cutting angle of the chisel is determined according to the strength of the material being cut. Chisels used on hard or tough metal require a strong cutting edge (included angle of 70°). (Fig. 2). This angle can be decreased for softer metals where less pressure is needed in the cutting process.



70° INCLUDED ANGLE
FIG. 2

GRINDING



CONVEX CUTTING EDGE
FIG. 3

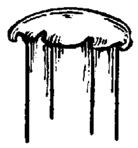
Chisels are ground to have an included angle of from 60 to 70 degrees. The flat chisel will give better results if ground with a slightly convex cutting edge. (Fig.3)

With a convex cutting edge there is less tendency for the corners to dig into the surfaces being chiseled. This method of grinding also centralizes the pressure exerted on the tool. When a blow is delivered to the head of the chisel, the impact is taken up by the center of the tool where it has more material to withstand the strain.

NOTE: If too much pressure is applied while grinding a chisel, the heat generated may draw the temper.

CARE OF CHISELS

The head of a chisel should be dressed if it becomes "mushroomed" while in use. (Fig.4). Always return a chisel to the tool crib in good condition.



"MUSHROOMED" HEAD
FIG. 4

When the point of a chisel does not maintain a sharp cutting edge after a trial on the job, it should be tested for hardness. If found to be soft, it should be rehardened and ground to the proper cutting angle.

Cracks and breaks in chisels are caused by improper forging or heat treating. Cracks indicate that the tool was either forged too cold or heated above the critical range of the steel in the hardening process. Breaks are usually caused by poor tempering.

SELECTED REFERENCES

Burghardt ----------------- Part I -------- Machine Tool Operation
Henry Ford Trade School ------------------------------ Shop Theory

HOW TO CHIP WITH A COLD CHISEL

OBJECTIVES OF UNIT

1. To explain how to remove metal by chipping or chiseling.

INTRODUCTORY INFORMATION

Chipping is the process of removing metal by means of a cold chisel and hammer. Even though the use of the milling machine, planer, and shaper, are more efficient methods of removing metal accurately and rapidly, the use of the chisel is indispensable on many jobs where accuracy is not important and no great amount of metal is to be removed.

TOOLS AND EQUIPMENT

Chipping guard
Goggles
Chisels
Bench vise
Machinist's hammer
Bench stop

PROCEDURE

1. Secure the work firmly in the bench vise or hold against a stop on the bench.

   NOTE: If the work has finished surfaces, use soft jaws in the vise to prevent marring.

2. Grasp the body of the chisel with the thumb and fingers of the left hand clasped around it, so that the head end extends slightly above the hand (Fig. 1)

   CAUTION: The thumb and forefinger should be relaxed so as to take up the shock of the hammer blow.

   CAUTION: Make sure that the chisel head is not "mushroomed", as the particles may break off and cause a personal injury.

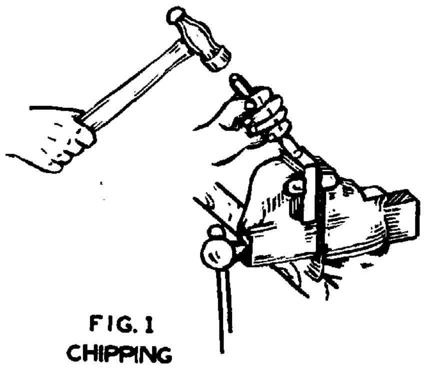
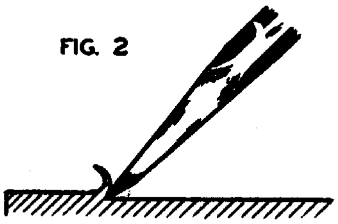


FIG. 1
CHIPPING
WITH A COLD CHISEL

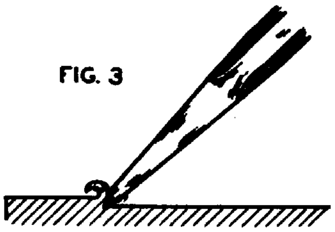
3. Place the cutting edge of the chisel on the surface of the job where the cut is to be made. Hold the chisel at the proper cutting angle as shown in Figure 3.

FIG. 2



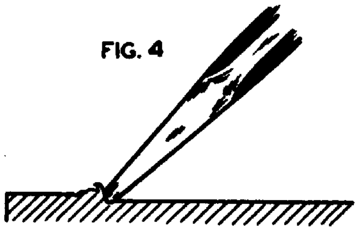
CUTTING ANGLE TOO SHARP

FIG. 3



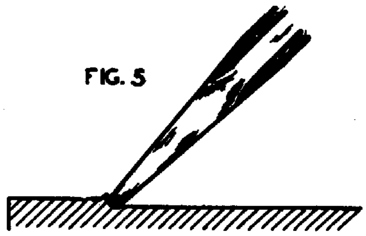
CORRECT CUTTING ANGLE

FIG. 4



CUTTING ANGLE TOO BLUNT

FIG. 5



POINT DULLED THEN ROUNDED

NOTE: If the chisel is held too high, it will cut deep. If held too low, the chisel is apt to slip while chipping.

4. Grasp the hammer near the end of the handle so that it can be swung with an easy forearm movement.

5. Strike the head of the chisel with a firm sharp blow.

   NOTE: As you strike the blow, watch the cutting edge of the chisel and not the head end. In this manner, the cut can be directed much better. With a little practice, one can soon acquire the "knack" of striking the head of the chisel without looking at it.

6. Reset the cutting edge of the chisel on the work and repeat the above steps.

   NOTE: Raise or lower the chisel as needed, in order to chip to the desired depth.

   NOTE: It is good practice to begin chiseling at the outer edges of a piece and work toward the middle. This method prevents tearing and breaking of the edges and corners.

HOW TO SHEAR A DRILLED SECTION

OBJECTIVES OF UNIT

1. To explain how to lay out a job for a drilled out section.

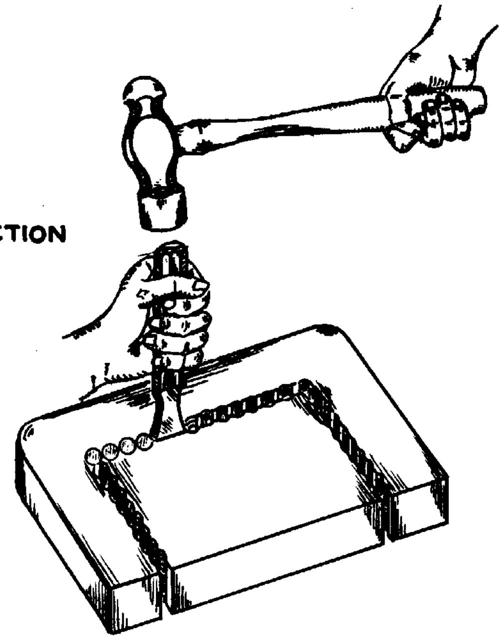
2. To point out the use of a drift or shearing punch.

3. To show how to shear or drift a drilled section.

INTRODUCTORY INFORMATION

In order to save the time of lengthy machining operations on jobs which require a cut out section, it is often advisable to drill and drift out the metal which is to be removed. A series of closely spaced holes are drilled (on the waste portion) along the contour of the desired form. The thin webs between the holes are sheared with a drift, causing the excess metal to fall away. (Fig.1).

In some cases, a series of holes are drilled and the webs sheared to form a starting point for sawing or filing elongated slots or irregular shapes.



SHEARING A DRILLED SECTION WITH A DRIFT
FIG. 1

TOOLS AND EQUIPMENT

Shearing Punch (Drift)
Ball peen hammer
Center punch
Layout Tools
Vise
Bench Block
File
Hacksaw

PROCEDURE

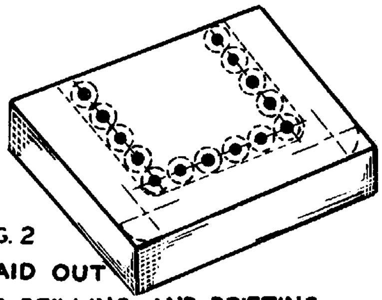


FIG. 2
JOB LAID OUT FOR DRILLING AND DRIFTING

1. Lay out and scribe shape or form as specified for the job.

2. Lay out lines along the waste side of contour of job with approximately 1/32" allowance for machining or filing to a line. The holes should be evenly spaced with a minimum web of metal between them. Center punch intersections for holes. (Fig.2).

3. Drill holes in drill press.

4. Remove work to bench for drifting. If the job is small, it may be held in the bench vise (for finished surfaces use safety jaws). Large pieces should be placed on an iron bench block or anvil. Place the shearing punch on the web along the row of holes and drift out the metal from both sides of the job. (Fig.1)

   NOTE: Avoid using a cold chisel to cut out a drilled section. The chisel has a wedging action which tends to spring and distort the work when forced into a narrow slot.

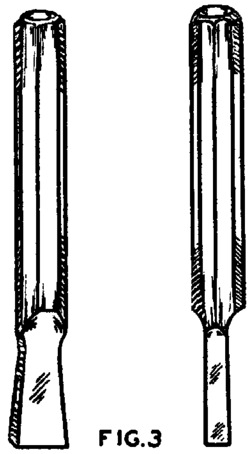


FIG.3
SHEARING PUNCH (DRIFT)

5. After the drilled section is removed, it may be finished to layout lines by machining or filing away the crests of the webs.

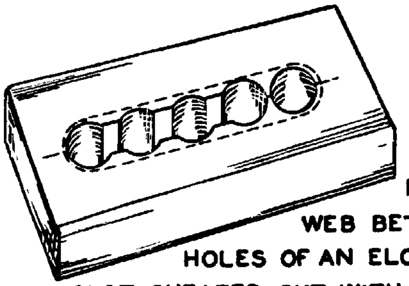


FIG.4
WEB BETWEEN HOLES OF AN ELONGATED SLOT SHEARED OUT WITH A DRIFT

6. On jobs requiring a narrow elongated slot, a single series of holes are drilled and the webs punched out wide enough with a drift so that a file may be inserted to finish the job to size and shape. (Fig.4).

DESCRIPTION OF FILES

OBJECTIVES OF UNIT

1. To define and explain the parts of a file.
2. To describe and illustrate the cuts and shapes of files.
3. To explain why files are made convex, taper, or have a safety edge.
4. To explain why file handles are a necessary part of the file.
5. To explain the use of removable jaws in the bench vise.

INTRODUCTORY INFORMATION

The file is an indispensable tool used in the machine shop. It has a wide range of application for roughing and finishing surfaces. It may be used to shape small parts, slightly reduce the size of parts to fit together, remove tool marks, prepare surfaces for polishing, and for many other operations where a job is to be altered and shaped.

The file is a cutting tool which has a large number of teeth cut diagonally on the face. Most files are made of a high grade tool steel and are properly hardened and tempered. Files are manufactured in a variety of shapes and sizes adaptable to the job at hand. They are known either by the cross section, the general shape, or by their particular use. The cuts of files must be considered when selecting them for various types of work; such as roughing, finishing, or draw filing.

PARTS OF A FILE

The parts of a file are known as the tang, heel, face, edge, and point. They are illustrated in Figure 1 below. The length of a file is measured from the heel to the point, not including the tang.

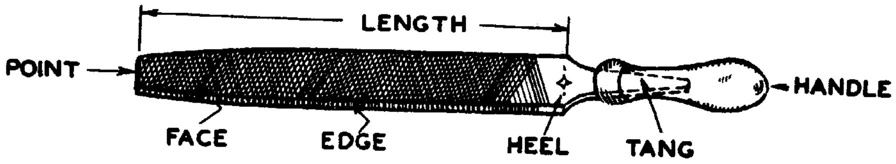


FIG. 1 PARTS OF A FILE

DEFINITIONS OF THE PARTS OF A FILE

TANG ------ That part of a file to which the handle is fitted.

HEEL ------ Next to the tang is a small portion of the file which has no teeth; this is known as the heel. The number of the cut is usually stamped on this part.

FACE ------ The face is that surface of the file upon which the teeth are cut. It is also known as the cutting surface.

EDGE ------ The edge of the file is the narrow portion upon which teeth are sometimes cut. When the edge is left smooth, it is called a "safe" edge file.

POINT ----- The point is the tip end of the file.

SHAPES OF FILES

The proper selection of a file for the job at hand requires a knowledge of the various shapes and their application. A flat file is used to file flat surfaces. The mill file is a general all-round file especially adapted for finish filing on the lathe. Half round files are used on concave surfaces and large radii; while round files are better suited to smaller radii. The most commonly used shapes are illustrated in Figure 2.

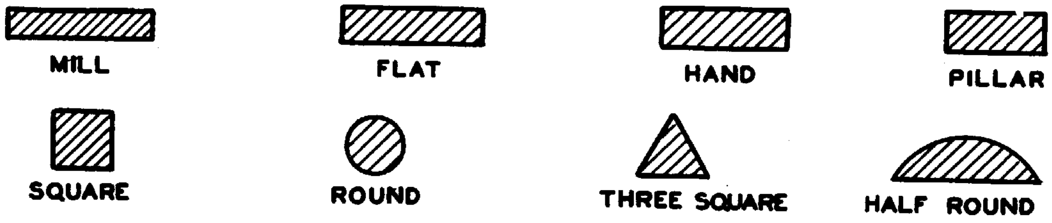


FIG. 2 SHAPES OF MOST COMMONLY USED FILES

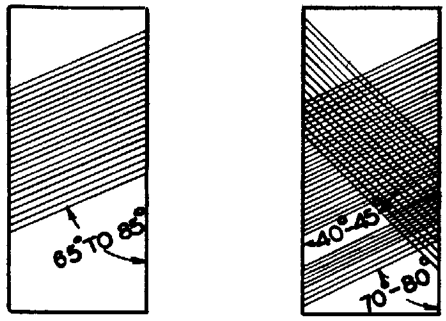
CUTS OF FILES

The cut or coarseness of the teeth is designated by a series of numbers. The numbers range from the coarsest to the finest and are: 00, 0, 1, 2, 3, 4, 5, 6, 7, and 8, respectively. The cuts are sometimes known by the terms: rough, coarse, bastard, second cut, smooth and dead smooth. (Fig. 4-A). Although the designated number of the cut remains the same for files of different lengths, the distance between teeth becomes narrower as the length of the file is decreased. For example, the number 00 cut of a four-inch file is finer than the number 00 cut on a twelve inch file.

CUTS OF FILES

The teeth are cut parallel to each other for the length of the file. Some have a single set of teeth which are cut at an angle of from 65° to 85° (see Figure 3-A) and are called the single cut files.

Double cut files (Figure 3-B) have two sets of teeth that cross each other. One set is cut at 40° to 45°; the other set is cut at 70° to 80°. The teeth (see Figure 4-B) are shaped to form a cutting edge similar to a tool bit. They have a rake and clearance angle.



SINGLE CUT (A) FIG. 3 DOUBLE CUT (B)

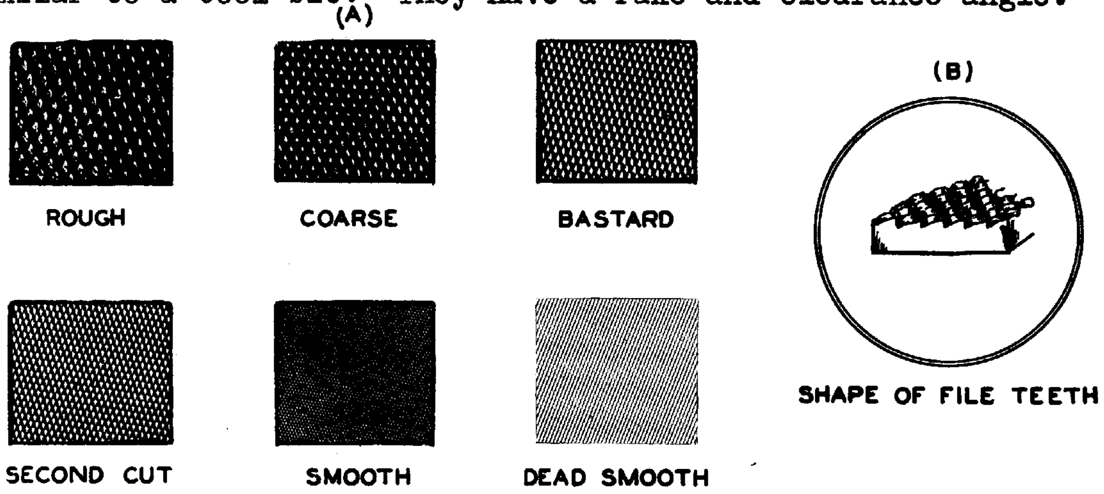


FIG. 4 CUTS OF FILES

REMOVABLE SOFT JAWS FOR THE BENCH VISE

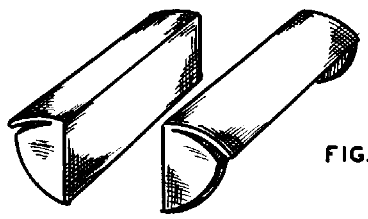


FIG. 5

SOFT REMOVABLE JAWS

When gripping work in the bench vise for filing, it is protected from being marred by the use of soft jaws. The vise jaws are hardened and serrated to grip rough work more rigidly.

The removable jaws (Figure 5) are made of soft materials such as; brass, copper, or leather. These materials will not mar the surfaces but still grip the work tight enough for filing.

FILE HANDLES

A file should be properly fitted with a handle before being used.

CAUTION: The file should not be used without a handle, as the tang may be driven into the palm of the hand, resulting in injury.

The size of the file and the nature of the work determines the size handle to use for balance. Handles purchased from hardware stores have a hole drilled in them to guide the tang and also prevent splitting of the handle.

SELECTED REFERENCES

Burghardt ------------------ Part I ---------- Machine Tool Operation

Jones ---------------------- Book I ----------- Machine Shop Practice

Henry Ford Trade School -------------------------------- Shop Theory

Machinery's Handbook

HOW TO FILE IN A BENCH VISE

OBJECTIVES OF UNIT

1. To explain how to stand at a bench vise and hold a file when filing.
2. To explain how to file flat and square.
3. To describe the method of filing a rounded corner.
4. To tell how to file sharp corners and remove burred edges.
5. To show how to draw file.

INTRODUCTORY INFORMATION

Where machined parts are to be fitted and a slight reduction in size is required, the file is indispensable. Many parts made in a machine shop are frequently shaped entirely with a file. Filing is also used when smoothing rough surfaces, removing sharp corners, or for burring.

The mastery of the art of filing promotes pride in workmanship and skill. To become efficient, patience and practice are necessary.

TOOLS AND EQUIPMENT

File with handle
File brush
Bench vise
Steel rule
Square - combination or solid steel
Auxiliary jaws such as: brass, copper, lead, fiber, leather, or wood

PROCEDURE

1. Select the proper file (See Description of Files, Unit 1-T11)

   CAUTION: A file should always be fitted with a handle to prevent personal injury.

   NOTE: If the work has finished surfaces, use soft jaws in the vise to prevent marring.

2. Clamp the work to be filed in a vise. When possible, the work should be held at the level of the elbow of the workman as he files. This position enables him to get the full swing of the arms from the shoulder.

3. The body should be in the correct position so the muscles can move freely without tiring. The left foot should point forward toward the bench with the right foot close enough to the left to give the necessary balance.

When filing, the body should lean forward at the hips on the forward stroke for about two-thirds of the distance, returning to the original position at the end of the stroke (Fig. 1).

NOTE: Hold the file straight. Avoid rocking the file as this will produce a rounded or uneven surface.

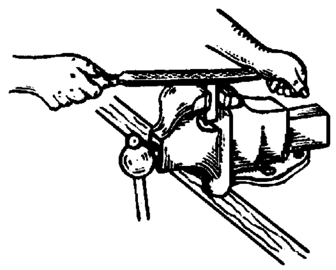


FIG. 1 FILING IN A BENCH VISE

4. For taking a heavy cut, grasp the file in the right hand with the handle of the file in the palm; the end of the handle resting against the junction of the thumb and the palm - with the thumb resting on top. Place the left hand at the end of the file with the base of the thumb on top of the file and the fingers curled under. (Fig. 1).

5. Hold the file parallel to the surface to be filed. Push the file and bear down on the forward stroke.

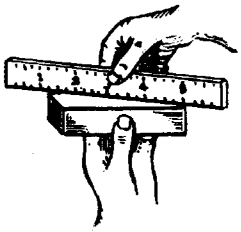


FIG. 2 TESTING FOR FLATNESS

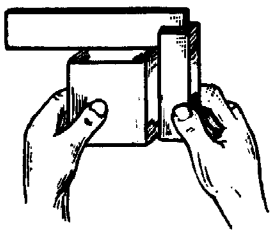


FIG. 3 TESTING FOR SQUARENESS

6. Release the pressure and return the file to the original position for the next stroke.

NOTE: Test the work frequently with a combination square or steel rule to determine if filing is flat and straight (Fig. 2) and with the solid steel square to determine if filing is square (Fig. 3).

7. In rough filing with a "double cut coarse" file, use the crossing stroke at about 30° from the previous stroke (Fig. 4)

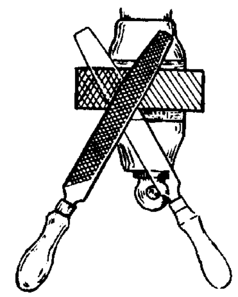


FIG. 4 CROSSING STROKE

8. When finish filing, use a "fine cut" file. Grasp the file handle with the thumb and index finger of the right hand, the end of the handle resting lightly against the base of the thumb. The end of the file is guided with the thumb and index finger of the left hand with the end of the thumb on top and the tip of the index finger beneath. (Fig. 5).

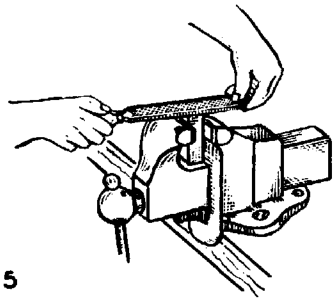


FIG. 5
HOLDING A FILE FOR A FINISHING CUT

9. Test with straight edge or solid steel square.

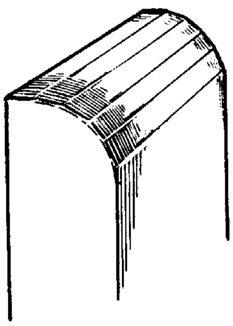


FIG. 6 ROUNDING A CORNER

10. When rounding a corner, clamp the work in the vise so that the layout line is above the vise jaws. Rough file to the line by filing across the piece. Reduce the corner with a series of angles until the desired radius is obtained. (Fig.6). Finish filing with a fine cut file by following along the "rounded surface".

11. Sharp corners, ragged edges, burrs, and "fins" are removed with a file while the work is held in a vise. For short distances, file across the edge. When the edges or corners are long, hold the file at a slight angle and push the file along the edge. A chamfered edge is produced in the same manner.

DRAW FILING

Draw filing is a process used to produce a "grained" finish. This method of filing is well adapted to jobs where a smooth finish is desired on edges and narrow surfaces of work. Tool marks, coarse file marks, and deep scratches are easily removed by draw filing. Single cut files are used for draw filing, because the cut of the teeth produces a shearing action in removing the metal. This type of file is less apt to "pin" and scratch than a double cut file.

PROCEDURE

1. Secure the work in the bench vise with the length of the piece parallel to vise jaws.

2. Select a single cut (mill) file. Make sure that the file is provided with a handle.

3. Grasp the file with both hands so that the thumbs will be located about 3/4 inch in from each side of the job as shown in Fig. 7.

4. Place the file crosswise on the work. Apply pressure evenly to both ends of the file, so that it lies flat on the surface to be draw filed.

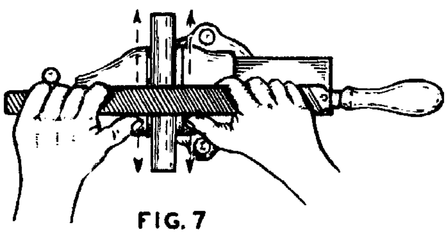


FIG. 7
DRAWFILING

5. Push and pull the file along the entire length of the job, being careful not to rock the file on straight surfaces. On rounded surfaces, follow the contour of the work, making sure that an even grain is produced all over.

NOTE: The file must be kept clean at all times when draw filing, in order to prevent deep scratches in the work.

NOTE: "Pinning", or the wedging of small steel particles between the teeth, can be partly avoided by chalking the file.

NOTE: The degree of smoothness in draw filing is determined by the cut of file. Ordinarily, a bastard cut mill file is used for draw filing soft materials and a second cut file where a smoother surface is required. The surface may be polished still finer by holding a piece of emery cloth under the file and moving it over the work in the same manner as for draw filing.

HOW TO CLEAN A FILE

OBJECTIVES OF UNIT

1. To explain the need for cleaning a file.
2. To explain how a file is cleaned.

INTRODUCTORY INFORMATION

The cutting action of a file produces small chips called filings. These small particles of metal frequently become wedged between the teeth of the file due to the pressure exerted. These tiny particles, when drawn across the work, tend to scratch the surface and impair the free cutting action of the file. Frequent cleaning is necessary in order to produce a smooth surface free from scratches and to obtain the maximum efficiency of the file.

TOOLS AND EQUIPMENT

File card and brush with scorer
Files
Small strip of brass or copper
Chalk

FILE CARD
FIG. 1

PROCEDURE

1. Place the wire brush side of the file card on the file and brush parallel with the teeth to remove small metal particles.

2. To remove the remaining particles of metal which are wedged (or "pinned") between the teeth, push the "pins" out with the wire scorer held in the handle of the file card.

3. To remove soft metal particles which clog the file, a better method is to use a narrow strip of brass or copper. The strip of metal is pushed across the file parallel with the teeth, so that an impression of the file teeth is cut into the strip. This action dislodges the particles from the teeth (Fig.2).

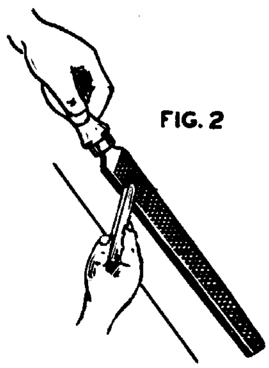


FIG. 2

4. If a smooth finishing cut is desired, rub a piece of chalk lengthwise on the file. This keeps chips from clogging the teeth and scratching the work, because the chalk fills the spaces between the teeth and tends to prevent particles from clinging to the file.

NOTE: Rapping a file on the bench or vise should be avoided, since the hard edge of the file damages softer materials.

DESCRIPTION OF ABRASIVE CLOTHS

OBJECTIVES OF UNIT

1. To point out the use of abrasive cloth as a polishing medium.
2. To explain briefly the grading of abrasive grains.
3. To point out the application of the various grades of abrasive cloth.

INTRODUCTORY INFORMATION

Abrasive cloth is used in machine shop to produce a smooth or polished surface, and to remove very slight amounts of material. The irregularity of the edges of the abrasive grains, together with their ability to break up and form new edges as they wear, make abrasive cloth better for polishing than a fine file.

Abrasive cloths are coated with either natural or artificial abrasives. Emery is the more commonly used natural abrasive for metal finishing. Silicon carbide and aluminum oxide are the artificially produced abrasives which are rapidly replacing the use of emery.

These cloths are manufactured in sheet and rolled strip form and are made in a number of grades to remove varying amounts of material and to produce varying degrees of finish.

THE GRADING OF EMERY AND THE MANUFACTURE OF EMERY CLOTH

Emery is a natural hard abrasive which is broken into small particles, sifted through screens, and graded according to size. Emery cloth is made by gluing or cementing these particles of grit to a cloth backing. Emery cloth is furnished in sheets 9" x 11" and is woven so that strips may be torn lengthwise from the sheets.

APPLICATION OF GRADES OF EMERY CLOTH

Different grades of emery cloth may be obtained ranging from #3/0 (fine) to #3 (coarse). The coarse grades are used for removing greater amounts of materials or where the finish is not important. The coarse grains will cut more rapidly (Fig. 1-A).

The medium grades are used to remove scratches and slight tool marks (Fig. 1-B). The fine grades are used for polishing and finishing surfaces (Fig. 1-C).

ARTIFICIAL ABRASIVES

Silicon carbide and aluminum oxide are artificial abrasives, produced in huge electric furnaces. These abrasives are being more widely used than natural abrasives, because they cut faster, retain their cutting properties longer, and are more dependable for uniformity in quality. Coated artificial abrasives are available in a wider range of grit sizes than emery.

The grit sizes for artificial abrasives range from #600 (a very fine flour size) to #12 (a very coarse grain size). By comparison: #180 cloth has a grain size similar to that of #3/0 emery cloth; #80 cloth is similar to #1 emery; and #30 cloth is similar to #3, a coarse emery.

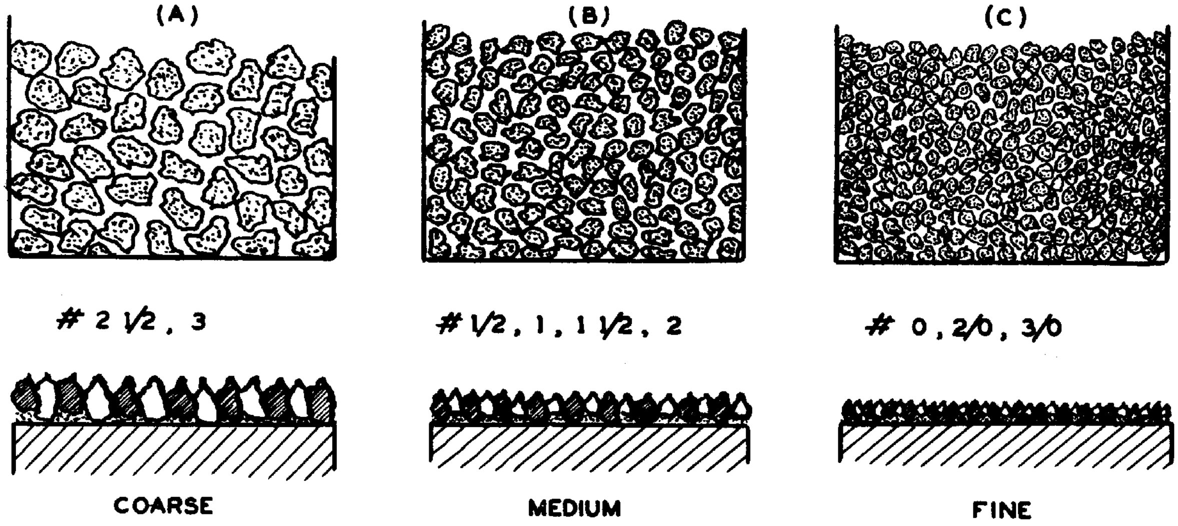


FIG. 1 ENLARGED SECTIONS OF EMERY CLOTH SHOWING RELATIVE SIZE OF GRITS

SELECTED REFERENCES

Burghardt ------------------- Part I -------- Machine Tool Operation

Norton Company ------------------ Lectures on Abrasives and Grinding

Norton Company ---------------- A Lecture Course on Coated Abrasives

Machinery's Handbook

HOW TO POLISH WITH ABRASIVE CLOTHS

OBJECTIVES OF UNIT

1. To point out the application of the various kinds of abrasive cloths.

2. To show how to tear sheets of emery cloth into strips for polishing.

3. To show how to polish with abrasive cloths.

INTRODUCTORY INFORMATION

Polishing is the process of producing a smooth surface by the use of an abrasive material. Abrasive cloths are used to polish, smoothen, and clean metal surfaces.

The surfaces of machined parts and tools, which do not require great accuracy in fit and dimension, can be polished or finished in varying degrees of smoothness with abrasive cloths.

While abrasive cloths are not intended for use in removing metal to any appreciable extent, they are sometimes used to polish off small amounts to make a "fit" possible.

TOOLS AND EQUIPMENT

Bench vise	Flat file
Soft jaws	Abrasive cloth

PROCEDURE

1. Select the proper grade of abrasive cloth for the job at hand. If much material is to be removed, use a coarser grade of abrasive cloth and change to a finer grade as the job progresses.

2. Tear off a narrow strip of cloth from the long edge of the sheet, wide enough to cover the width of the file to be used. (Fig. 1).

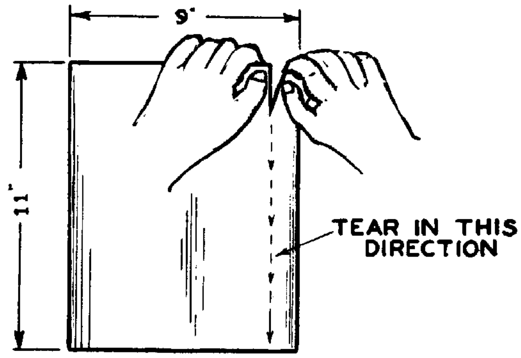


FIG. 1 TEARING A STRIP OF EMERY CLOTH

3. Grip the work firmly in the vise.

   NOTE: Protect any finished surfaces by using soft jaws.

4. Fold one end of the emery cloth over the end of the file and grip firmly between the thumb and forefinger of the left hand (Fig. 2).

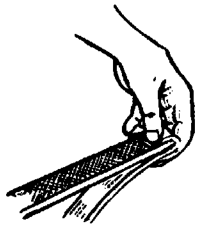


FIG. 2

FOLDING EMERY CLOTH OVER END OF FILE

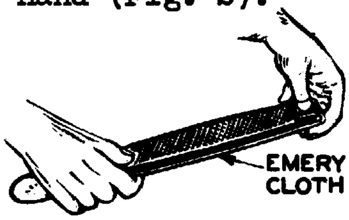


FIG. 3 HOLDING EMERY CLOTH AGAINST BOTTOM OF FILE

5. Grasp the handle of the file in the palm of the right hand and with the forefinger hold the other end of the emery cloth against the bottom of the file. Place the thumb on the top and the other fingers around the handle (Fig. 3).

6. Place the emery cloth on the surface to be polished. Move across the work in a forward and backward motion. Repeat the process until the desired finish is obtained. (Fig. 4).

   NOTE: Avoid a rocking motion when working on a flat surface.

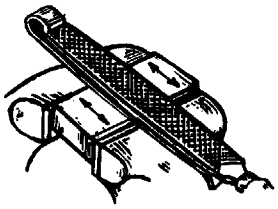


FIG.4 WORKING WITH EMERY CLOTH

DESCRIPTION OF TAPS AND TAPPING

OBJECTIVES OF UNIT

1. To describe hand taps and tap sets.
2. To describe the common types of tap wrenches.
3. To explain the method of determining tap drill sizes.
4. To show the use of tables of tap drill sizes for American National Standard Screw Threads.

INTRODUCTORY INFORMATION

A hand tap is a small tool used for cutting an internal thread.

The tap is accurately threaded and grooved, or "fluted". The flutes are milled the length of the threaded portion to form a series of cutting edges. Taps are made of tool steel and are carefully hardened and tempered. The tap is a fragile tool and, because of its peculiar shape and brittleness, can easily be broken if not carefully used. One end of the tap is made square so that a tap wrench may be used to turn it into a hole. The squared end of the tap is usually provided with a "center hole" which may be used to guide it when started in a machine.

Taps are manufactured in all of the standard sizes and pitches for the standard forms of threads. The tables on sheet 4 show the commonly used standard screw sizes. The smaller machine screws are designated by number, as 0-80, which is the smallest size, or 12-24, which is a larger size. The size is indicated by the first figure. For example, in the expression 12-24, the 12 refers to the size of the body of the screw, while the 24 refers to the number of threads per inch.

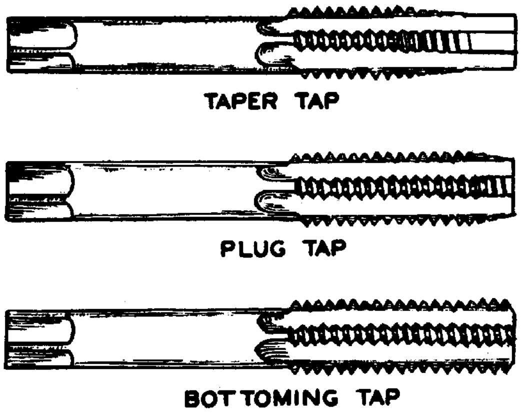


FIG. 1-SET OF HAND TAPS

TAP SETS

Taps of standard sizes and pitches over 1/4" diameter are made in sets of three taps called Taper, Plug, and Bottoming. (Fig. 1).

The "Taper tap" or starting tap is turned down to the root diameter of the thread for a length of about three or four threads, and then about six threads are chamfered or tapered until the full diameter of the tap is reached. The "Plug tap" is chamfered for about three or four threads at the point. The "Bottoming tap" is backed off or chamfered on the end teeth for about one thread. The taps in this set are all the same diameter. The taper tap is used first, the plug tap second, and the bottoming tap third in a shallow hole.

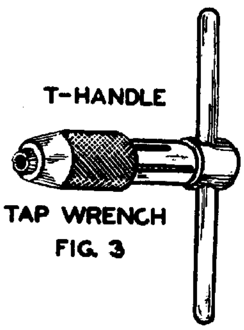
The smaller or numbered size taps are not usually used in sets of three, since the finer pitches do not require a series of taps to thread a hole.

Ordinarily, when the size of the tap is small and great accuracy is not important, the plug tap can be used alone to produce a satisfactory thread.

TAP WRENCHES

Tap wrenches are manufactured in a variety of types and sizes. Three of the more commonly used types are shown in the illustrations below. Figure 2 is the double-ended adjustable tap wrench which is constructed to accommodate a variation in size of taps; Figure 3, the T-handle wrench with adjustable jaws; and Figure 4, the solid tap wrench with a fixed hole to receive the squared end of the tap.

SOLID TAP WRENCH
FIG. 4



T-HANDLE TAP WRENCH
FIG. 3

ADJUSTABLE TAP WRENCH
FIG. 2

When working on a surface where there is room enough, the double-ended wrench should be used; when working at depths where space does not permit the turning of long handles, the T-handle wrench is used; and when working against a shoulder, a single-ended or a special ratchet type wrench must be used.

TAP DRILL SIZES

Tapped threads for commercial purposes are not required to be cut 100% full thread. Therefore, the tap drill size is larger than the root diameter of the screw thread. The accepted practice is to use a tap drill which will give an approximately 75% thread. It is interesting to learn from tests made that an ordinary nut drilled out so that it has barely more than half of the full depth of thread is sufficiently strong enough to hold, and the bolt will break before the threads strip in the nut.

The risk of tap breakage is lessened when holes are tapped for approximately 75% of a full thread.

The full double depth of an American National Standard Thread is found by dividing 1.2999 by the number of threads per inch.

$$(100\%)\ \text{Double depth of thread} = \frac{1.299}{\text{No. of threads per inch}}$$

The approximate tap drill size may be found by using the following formula:

$$\text{Approximate Tap Drill Size} = \text{Outside Diameter} - \left(.75 \times \frac{1.299}{\text{No. Thds.per In.}} \right)$$

then, select nearest standard size drill.

American National Standard Screw Thread and Recommended Tap Drill Sizes

Fractional Screw Sizes

COARSE THREAD SERIES (N.C.)
Formerly U.S. Standard

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1/4	20	.250	7	.2010
5/16	18	.3125	F	.2570
3/8	16	.375	5/16	.3125
7/16	14	.4375	U	.3680
1/2	13	.500	27/64	.4219
9/16	12	.5625	31/64	.4843
5/8	11	.625	17/32	.5312
3/4	10	.750	21/32	.6562
7/8	9	.875	49/64	.7656
1	8	1.000	7/8	.875
1-1/8	7	1.125	63/64	.9843
1-1/4	7	1.250	1-7/64	1.1093

FINE THREAD SERIES (N.F.)
Formerly S.A.E. Thread

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1/4	28	.250	3	.2130
5/16	24	.3125	I	.2720
3/8	24	.375	Q	.3320
7/16	20	.4375	25/64	.3906
1/2	20	.500	29/64	.4531
9/16	18	.5625	.5062	.5062
5/8	18	.625	.5687	.5687
3/4	16	.750	11/16	.6875
7/8	14	.875	.8020	.8020
1	14	1.000	.9274	.9274
1-1/8	12	1.125	1-3/64	1.0468
1-1/4	12	1.250	1-11/64	1.1718

TAP DRILL SIZES

Tapped threads for commercial purposes are not required to be cut 100% full thread. Therefore, the tap drill size is larger than the root diameter of the screw thread. The accepted practice is to use a tap drill which will give an approximately 75% thread. It is interesting to learn from tests made that an ordinary nut drilled out so that it has barely more than half of the full depth of thread is sufficiently strong enough to hold, and the bolt will break before the threads strip in the nut.

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1/2	13	.500	27/64	.4219
9/16	12	.5625	31/64	.4843
5/8	11	.625	17/32	.5312
3/4	10	.750	21/32	.6562
7/8	9	.875	49/64	.7656
1	8	1.000	7/8	.875
1-1/8	7	1.125	63/64	.9843
1-1/4	7	1.250	1-7/64	1.1093

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Formerly S.A.E. Thread

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
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5/16	24	.3125	I	.2720
3/8	24	.375	Q	.3320
7/16	20	.4375	25/64	.3906
1/2	20	.500	29/64	.4531
9/16	18	.5625	.5062	.5062
5/8	18	.625	.5687	.5687
3/4	16	.750	11/16	.6875
7/8	14	.875	.8020	.8020
1	14	1.000	.9274	.9274
1-1/8	12	1.125	1-3/64	1.0468
1-1/4	12	1.250	1-11/64	1.1718

MACHINE SCREW SIZES

COARSE THREAD SERIES (N.C.)

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	64	.073	53	.0595
2	56	.086	50	.0700
3	48	.099	47	.0785
4	40	.112	43	.0890
5	40	.125	38	.1015
6	32	.138	36	.1065
8	32	.164	29	.1360
10	24	.190	25	.1495
12	24	.216	16	.1770

Rule for finding the diameter of number size screws: Multiply the screw size number by .013 and add .060.

FINE THREAD SERIES (N.F.)

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
0	80	.060	3/64	.0469
1	72	.073	53	.0595
2	64	.086	50	.0700
3	56	.099	45	.0820
4	48	.112	42	.0935
5	44	.125	37	.1040
6	40	.138	33	.1130
8	36	.164	29	.1360
10	32	.190	21	.1590
12	28	.216	14	.1820

SPECIAL SERIES

NATIONAL SPECIAL (N.S.)

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1	56	.073	54	.0550
4	32 36	.112	45 44	.0820 .0860
5	36	.125	40	.0980
6	36	.138	34	.1110
7	32	.151	31	.1200
8	30 40	.164	30 28	.1285 .1405
9	32	.177	26	.1470
10	28 30	.190	23 22	.1540 .1570
12	32	.216	13	.1850
14	20 24	.242	10 7	.1935 .2010
16	18	.268	3	.2130
18	18	.294	B	.2380

NATIONAL SPECIAL (N.S.)

Size of Screw	Threads per inch	Major (Outside) Diameter of Screw	Tap Drill Sizes	Decimal Equivalent of Drill
1/4	24 27 32	.250	4 3 7/32	.2090 .2130 .2187
5/16	20 27 32	.3125	17/64 J 9/32	.2656 .2770 .2812
3/8	20 27	.375	21/64 R	.3281 .3390
7/16	24 27	.4375	X Y	.3970 .4040
1/2	12 24 27	.500	27/64 29/64 15/32	.4219 .4531 .4687
9/16	27	.5625	17/32	.5312
5/8	12 27	.625	35/64 19/32	.5469 .5937
3/4	12 27	.750	43/64 23/32	.6719 .7187
7/8	12 18 27	.875	51/64 53/64 27/32	.7969 .8281 .8437
1	12 27	1.000.	59/64 31/32	.9219 .9687

SELECTED REFERENCES

Machinery's Handbook
Burghardt ---------------------- Part I ------ Machine Tool Operation
Henry Ford Trade School ------------------------------ Trade Theory
South Bend Lathe Works ----------------------------- Bulletin #36A

HOW TO USE A HAND TAP

OBJECTIVES OF UNIT

1. To describe the method of tapping hole by hand.

2. To point out some of the frequent causes of tap breakage.

INTRODUCTORY INFORMATION

Internal threads are usually cut with taps. Machine methods of tapping are more efficient in production work, however, many threads must be tapped by hand.

Taps are manufactured in all of the standard sizes and pitches (See tables Unit 1-T14). The smaller machine screw taps are delicate

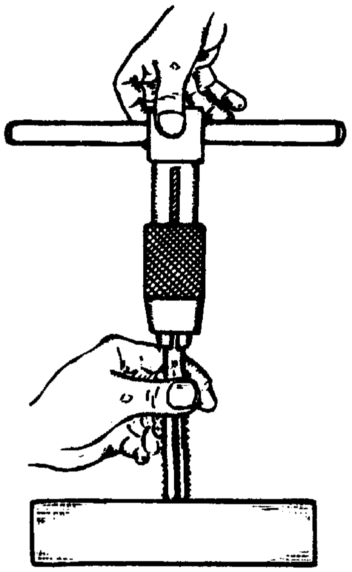


FIG. 1 – TAPPING WITH A SMALL TAP HELD IN A T-HANDLE TAP WRENCH

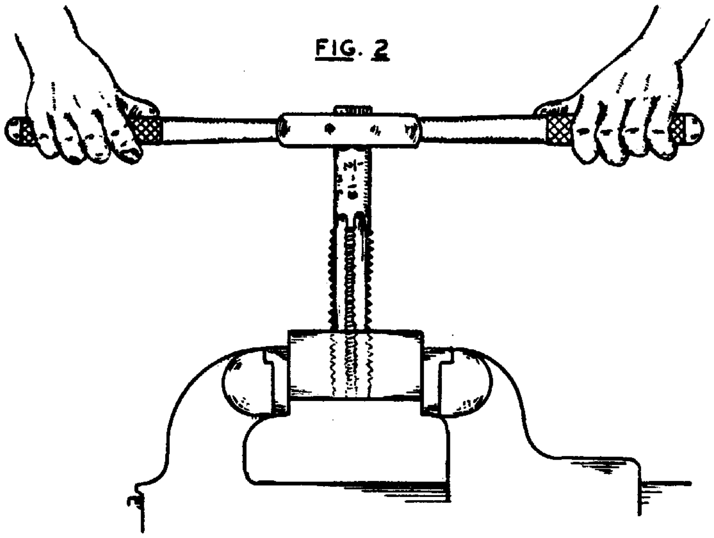


FIG. 2

TAPPING IN A BENCH VISE

and easily broken. They must, therefore, be handled carefully. The principal cause of breakage in taps is that of pulling the tap unevenly, thereby causing it to bend and break.

TOOLS AND EQUIPMENT

Tap or Tap Set
Tap Wrench
Lubricant (Cutting Oil)
Bench Vise (with soft jaws for finished work)
Small Steel Square

PROCEDURE

1. Select proper size tap and wrench.

2. Check drilled hole for proper sized tap drill.

3. Start thread with a taper or plug tap. Use sufficient pressure to insure threads will "catch" or start without tearing or reaming the top of the hole.

4. Check to make sure that the tap is entering the hole squarely.

   NOTE: If the tap does not enter squarely at the beginning of the operation, it can be straightened by removing it from the hole and restarting it with pressure applied in the direction from which the tap leans. Be very careful that too much pressure is not exerted at any one time in the straightening process. It is safer to repeat this operation a second or third time if necessary.

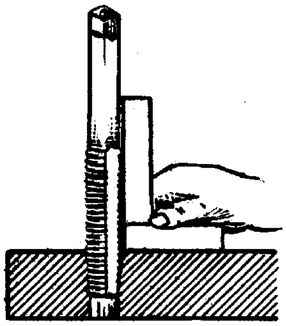


FIG. 3 — CHECKING A TAP WITH A SQUARE

5. When a tap has been properly started, it will follow and feed itself into the hole by turning the tap wrench.

   NOTE: When tapping steel, bronze or wrought iron, always use lard oil for a lubricant. If the material is very hard, a little turpentine on the tap will help materially. For hand tapping brass and cast iron, no cutting lubricant is needed.

6. Turn the tap forward a part turn and then turn the tap backward about a half turn to break the chip. Be careful to see that this is done with a steady motion and turning pressure so as to avoid breaking the tap. Continue until the hole is completely tapped.

   NOTE: Care must be taken not to bear too heavily on only one handle of the tap wrench or to force the tap as it is apt to break off in the hole.

7. When tapping a blind or shallow hole, a bottoming tap must be used to finish the threads on the bottom.

8. Remove burrs and clean chips from the tapped hole.

DESCRIPTION OF THREADING DIES

OBJECTIVES OF UNIT

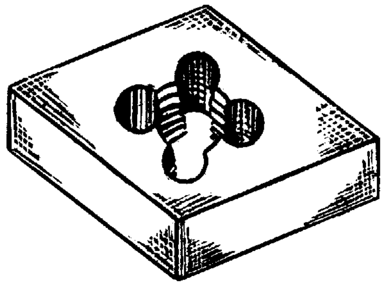
1. To describe various types of dies.
2. To point out the application of dies used for threading by hand.

INTRODUCTORY INFORMATION

A threading die is a tool used for cutting external threads. Dies are made in a variety of sizes and shapes, each suited to the particular kind of work for which they are intended.

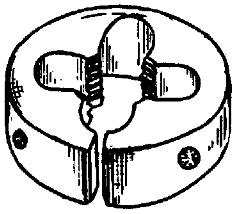
Some dies are made solid and have a fixed size; others are split on one side to permit adjustment; while others are made like chasers and are held in a collet.

Hand threading dies are used to cut threads on bolts, screws, and other work which does not require precision threading. The following illustrations show a few types of dies commonly used.



SOLID SQUARE DIE
FIG. 1

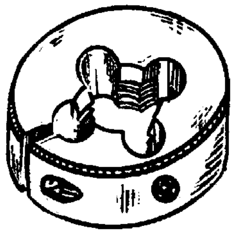
Figure 1 shows the solid square die which is fixed and not adjustable. These dies are useful for chasing or recutting a damaged and burred thread.



ROUND SPLIT DIE
FIG. 2

Figure 2 shows a round split die which can be adjusted in the die holder to cut threads either slightly over or under the standard depth. This type of die must be reset every time it is changed in the holder.

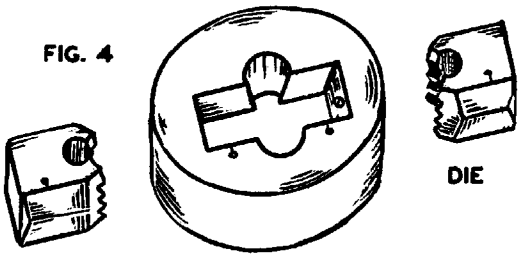
Figure 3 shows an adjustable round split die. This type of die is commonly used for hand threading. It can be easily adjusted and the setting may be retained.



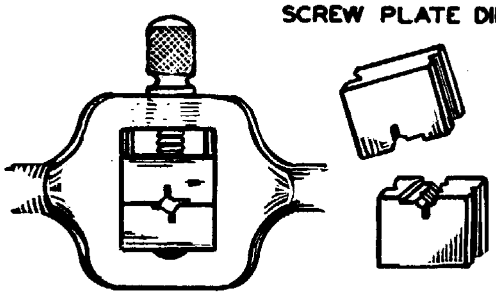
ADJUSTABLE ROUND SPLIT DIE
FIG. 3

Figure 4 shows an adjustable die made in two halves. This type of die is furnished with screw plate sets. The dies are held in a collet. The adjusting screws are contained in the collet.

FIG. 4

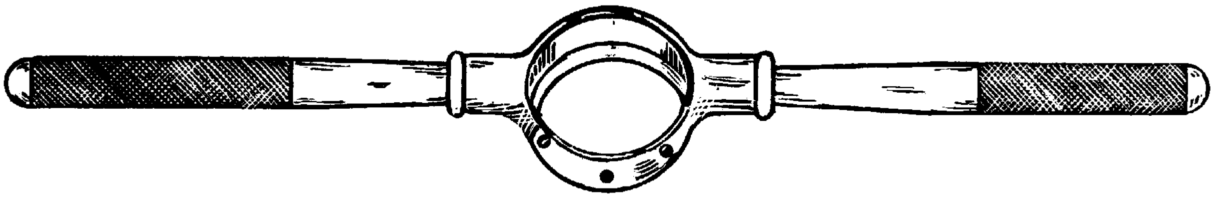


ADJUSTABLE AND REMOVABLE SCREW PLATE DIE



SCREW PLATES IN HOLDER
FIG. 5

Figure 5 shows another type of screw plate die. These sets permit ease of change from one size thread to another in the same die holder.



DIE HOLDER OR DIE STOCK
FIG. 6

Figure 6 shows a die stock or die holder used for holding round adjustable dies.

SELECTED REFERENCES

Burghardt ------------------- Part I ---------- Machine Tool Operation

Machinery's Handbook

HOW TO CUT A THREAD WITH A DIE

OBJECTIVES OF UNIT

1. To explain how to adjust a threading die in a die holder.

2. To show how to cut a thread.

INTRODUCTORY INFORMATION

Most manufactured threaded parts are cut with dies in screw machines or turret lathes. Often, however, it is practical to cut a thread "by hand". In this case, the die is held in a die holder or die stock.

TOOLS AND EQUIPMENT

Bench vise	Lard oil
Threading die	Gauge or nut for testing thread
Die holder or stock	Screw driver

PROCEDURE

1. Grip the work firmly in a vise.

2. Insert die in holder with the slot in line with the spreading screw. (Fig. 1).

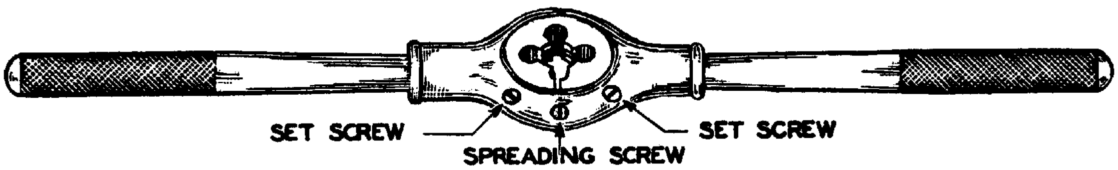


FIG. 1 DIE HOLDER WITH A SPLIT DIE INSERTED

3. Tighten spreading screw until die is opened in the holder.

   NOTE: Spreading or closing the die excessively will cause it to break.

4. Tighten set screws to hold the die firmly in place in the die holder.

5. Apply cutting oil to the chamfered end of the screw blank.

6. Place the chamfered side of the die on the chamfered end of the screw blank, holding the die stock squarely.

7. Press down firmly and start turning the die slowly until the first threads take hold. After that the die will follow without pressure.

8. Cut three or four threads. Then stop and make sure that the threads are being properly formed and that the die is square with the work.

   NOTE: After squaring the die, use a generous amount of cutting oil; otherwise, the threads are apt to tear.

   NOTE: Turn the die backward frequently (a quarter or half turn) in order to break the chip.

   NOTE: After cutting a few threads, back the die off the work and test the threads for size. Always clean threads before testing for size. Blow chips out of the die.

9. If thread is too large, release the spreading screw slightly and tighten set screws.

10. Run die over threads again and test for size.

11. Repeat this operation until the desired fit is obtained.

Suggested Unit Course in

BENCH WORK

Machine Shop Series

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SHOP THEORY

In Two Volumes
Volume One

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Purdue University
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National Machine Tool Builders' Association
Machine Tools · The Master Tools of Industry
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Washington, D.C. 20007

Revised Edition 1967

FOREWORD

This text is the result of a need in industry for an updated explanation of machine shop operations and related topics ranging from use of hand files to an explanation of numerical control. The reader who will use this text in his effort to cover the area of knowledge referred to as "shop theory" will find a comprehensive body of material compiled to enable the reader to absorb as many fundamentals as possible in a short period of time. Because of the comprehensive treatment accorded to this text not all the material will be used in all training situations; the reader will determine which sections pertain to his area of interest and may pursue some topics lightly and others in depth. NMTBA's Training Committee is constantly searching for and developing new techniques and improved methods for skills training. This text is one result of this constant search. Machine shop trainers and trainees gratefully acknowledge the generosity of Professor Orville D. Lascoe's work in the development of this text. Professor Lascoe is internationally known and respected for his contributions to research and training and for his dedicated interest to the machine tool industry.

John Mandl

John Mandl
Director of Training
National Machine Tool Builders' Association

SHOP THEORY

TABLE OF CONTENTS

CHAPTER I

INDUSTRIAL PROCESSES

In order to minimize waste in both time and materials, a number of industrial processes produce pre-worked shapes that are to be finished by machine tools. These pre-worked shapes are generally produced in the approximate size and form desired by one of the following processes:

(1) Castings

(2) Forgings

(3) Mill shapes

Typical piece part shapes preworked by castings are automotive cylindrical block, pistons, and fly wheels. By forging processes --crankshafts, valves, connecting rods and cam shafts. Steel mills produce the mill shapes in the forms of sheet, plate, bar stock, and structural shapes.

CASTING PROCESS

Castings are the products of foundries and are used in many lines of manufacturing. Castings are grouped into six general classes known commercially as common:

(1) gray cast iron

(2) alloy gray cast iron

(3) malleable cast iron

(4) steel

(5) alloy steel

(6) non-ferrous metal castings

In order to produce castings made from different metals, several types of melting furnaces are employed. The cupola furnace is normally used for melting gray iron. Electric furnaces are used for producing malleable iron castings. For melting steel, the open-hearth, crucible or electric furnace is used. The non-ferrous metals are generally melted in a crucible by gas-fired or electric furnaces.

The casting process may be defined as pouring molten metal into a mold containing a cavity of the desired shape of the piece part desired. Molds are made of sand which are destroyed upon solidification of the metal. If the mold is of the permanent type, it is separated to remove the casting. Castings range in weight from a few ounces to many tons. In order to make different sizes of castings, a variety of materials are employed to construct molds. Molding operations are classified under five classifications, according to the material used and the techniques of working the mold:

(1) Green sand molding --the most economical method of making a casting.

(2) Skin-dried molds --a green sand mold mixed with wheat flour and dried with a torch flame before pouring.

(3) Dry-sand molds --are made of green molding sand mixed with a binder consisting of wheat flour, resin and linseed oil; the entire mold is baked in an oven before pouring.

(4) Loam molds --are forms built of bricks and plastered over with loam mortar rich in clay. These molds are used in the production of large castings.

(5) Iron molds --as the name implies are made of iron. Their advantage is that many castings can be made before a replacement is necessary.

Cast metals are generally classified in two groups: Ferrous and non-ferrous. Each of the classifications is furthur subdivided according to its compositions. The following diagram illustrates the principle classifications (Figure 1).

ADVANTAGES OF CASTING PROCESSES:

(1) Casting process is the most economical method for producing complicated shapes in quantity production.

(2) Metal can be placed where it will do the most good and can be better distributed for fatigue strength. Recesses and undercuts can be cast to reduce or eliminate machining. Properly designed castings often result in weight saving over other methods of fabrication.

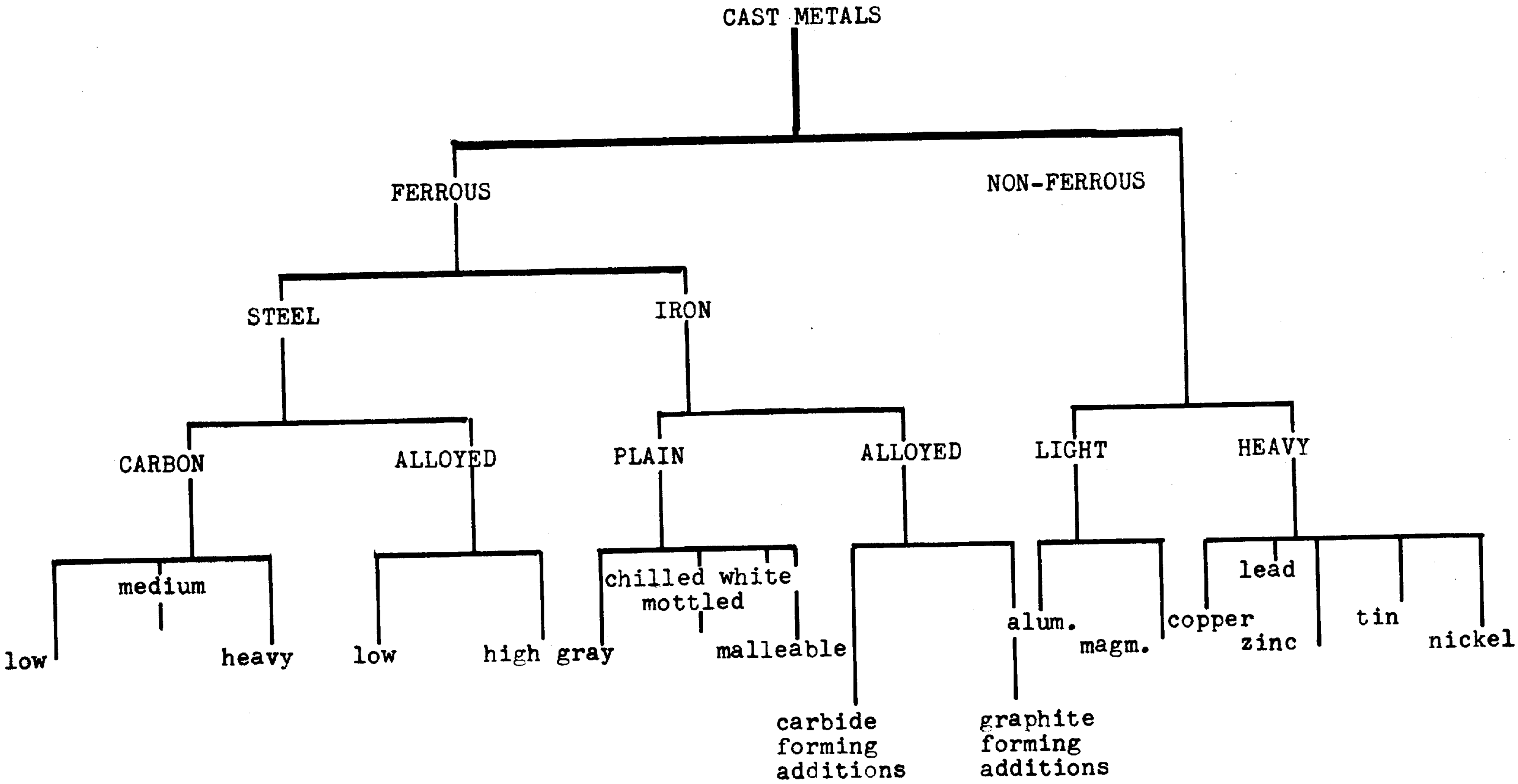
(3) Precision castings have reduced machining time.

(4) Cast structures have higher resistance to creep and better dampening characteristics.

FORGING PROCESS

The shaping of metal in either the hot or cold state by some mechanical means defines forging and cold forming of metals. When a piece of hot metal is hammered or pressed into a steel die a preworked shape is formed to the desired form and size.

In most cases, the metal to be forged is heated to



(Figure 1) Cast Metals Classifications

its correct forging temperature. Cold forging is accomplished in the range from room temperature up to the critical temperature of the metal. The properties of the metal are actually improved by mechanical working, since grain refinement is caused by the process. Both hot and cold working produce a structure elongated in the same direction as that of rolling, drawing or other forms of mechanical working.

FORGING OPERATIONS

There are basically three forging operations performed by mechanical forming:

(1) Drawing out --this increases length and decreases cross-sectional area of a piece part.

(2) Upsetting --this increases cross-sectional area and decreases length.

(3) Squeezing --this compresses the material in a closed impression die.

Forgings are generally superior in mechanical properties to castings of the same chemical analysis; therefore, parts which must withstand severe stresses are preferably made by forging.

Forgings have better mechanical properties than castings because:

(1) the fiber flow lines when properly controlled and directed tend to provide greater strength;

(2) hammering or pressing operations produce a

dense structure free from voids, blow holes, or porosities;

(3) the working of the metal breaks up coarse grains by producing a slip along crystallographic planes.

The forging processes are generally grouped under four principal methods:

(1) Smith Forging

(2) Drop Forging

(3) Press Forging

(4) Upset Forging

Smith Forging --is performed in a pair of dies with flat surfaces . The shaping of the part depends upon the skill of the smith who moves the metal and directs the operation. Smith forgings are made to approximate dimensions; therefore, machining is necessary for surfaces requiring close tolerances. This method is used for production of small quantities. The size of the forgings range from one pound to over 200 tons. Machine tools used to perform these operations are steam hammers, large hydraulic presses and air hammers.

Drop Forgings --operations are accomplished with closed impression dies. Closed impression dies consist of two halves. The upper die is fastened to the ram of the press and the lower die to the anvil cap of the machine. The impact of the hammer on the heated metal forces it into every part of the mating dies. The Drop forging method is used producing forgings weighing from less than an ounce to several hundred pounds.

Press forging --is similar to drop forging since closed impression dies are employed; the difference is that metal is squeezed into the die cavities using a sustained pressure. The operations are performed in large mechanical or hydraulic presses. Press forging is faster than drop forging since only one blow is needed for the metal at each die cavity and ejector pins remove the part on the return stroke.

Upset Forging --is the operation of upsetting or gathering of metal to form heads on bolts. The forging machine used to perform such operations is essentially a double action press with its motions in a horizontal plane instead of vertical as in the hammers and presses used for drop forging operations. Dies used to perform upsetting operations are closed impression dies consisting of two die blocks and a set of heading tools.

ADVANTAGES OF THE FORGING PROCESSES

The main advantage of forgings is their greater strengths possible with the process compared with castings. Close dimensional tolerances are possible and assembly operations can be performed by welding.

ROLLING PROCESSES

The rolling of metal into sheet, plate and bar forms by the steel mill operations produce the greatest tonnage of steel used in all manufacturing operations. The products produced are generally referred to as <u>mill shapes</u>.

Mill shapes of all sizes and forms are used extensively in machine shop operations along with castings and forging.

Ferrous and non-ferrous sheet and plate metal is for press operations, weldments, and flamed cut shapes for machining. Bar stock in rounds, squares, hexagon and flat shapes of various sizes are the most essential materials used in machining operations consisting of low, medium, and carbon compositions and alloyed steels.

Rolling process is accomplished by passing a hot ingot of steel between two large rolls made of chilled white cast iron. A rolling mill may consist of one or more stands permitting the ingot to be roughed to shape by the first stands and passed on to the finishing stands for final drawing to size and shape.

Rolling refines the grain structure of the metal and develops fiber flow lines in the direction of the rolling.

In order to produce desired shapes such as bars, plates or sheets, the rolling is done in two or more rolling operations with repeating operations when necessary. Products produced by the hot rolling processes are generally referred to as hot-rolled products. In order to improve and size these products to closer dimensional tolerances, they are re-rolled by cold drawing, the main advantages being:

(1) Shapes can be finished to close tolerances. Dimensions can be held to within 0.002" to 0.004";

(2) Surface improvements by removing oxidations;

(3) Tensile strength is increased;

(4) Hardness is increased.

Mill supply houses provide a complete stock list of steel and aluminum shapes available as standard shapes and sizes with complete data on chemical compositions and heat-treatment. Skilled machinists frequently use these catalogs for selecting materials and determining the workability characteristics of each metal.

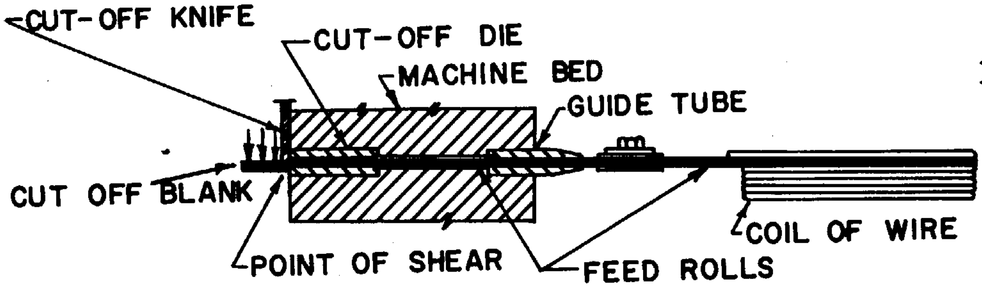
COLD FORMING

Cold forming, frequently referred to as cold heading, cold upsetting, or cold forging, is an automatic process in which sections of wire are sheared to length and then formed cold by pressing between two dies. The shapes of the die cavities determine the resulting form (Figure 2)

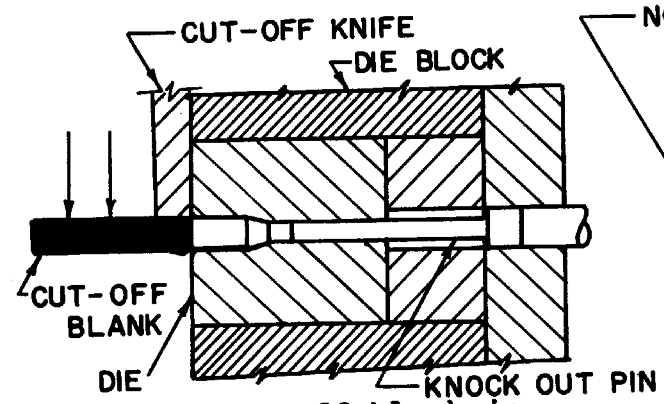
Ordinary bolt and screw blanks, rivets and nails are made by this process as are many special shapes for particular applications. It is primarily with these special items that this series will be concerned.

Cold forming machines run at speeds varying from 2,000 pieces per hour to 30,000 pieces per hour. Pressures

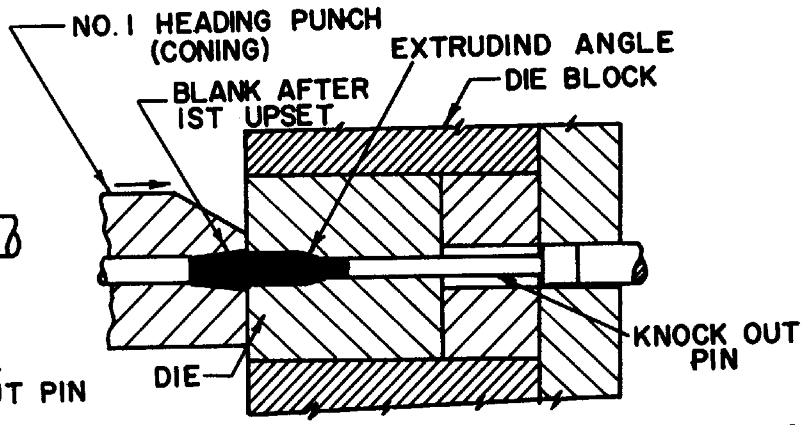
THE COLD FORMING (COLD HEADING) OPERATION



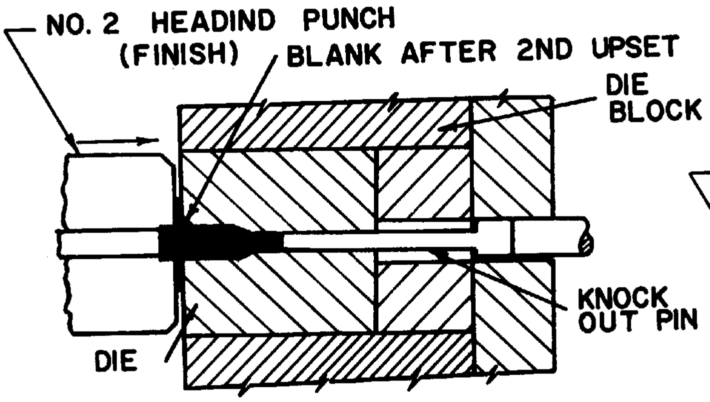
I The wire is fed automatically from a coil and sheared to length with a lateral motion of the cut-off knife.



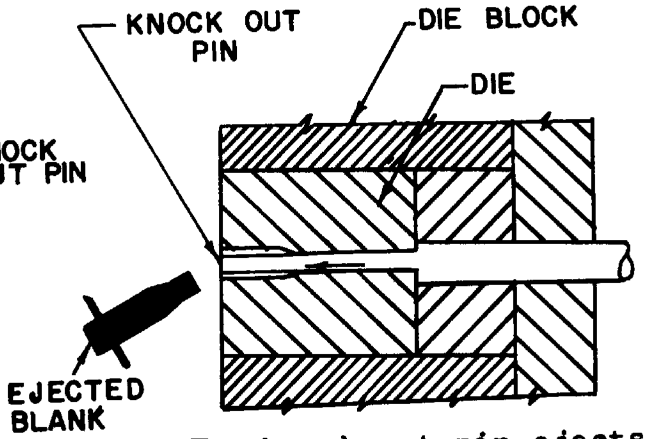
II The cut-off blank is positioned in front of a cylindrical die.



III The first punch travels forward forcing the blank into the die thereby extruding one end (reducing diameter) and making the first upset on the other end of the blank.



IV The second punch moves forward to complete the forming of the washer and hexagon head.



V The knock-out pin ejects the finished part.

(Figure 2)

developed in this operation vary from 2 tons in the small machines to over 100 tons in the large machines.

A cold header or cold former is in many respects similar to an automatic press operating in a horizontal rather than a vertical position (Figure 2 and 3).

Parts produced on headers are frequently subjected to secondary automatic operations such as thread rolling, knurling, extruding, flattening, piercing, drilling, broaching, bending, etc.

THREAD ROLLING BY COLD FORMING

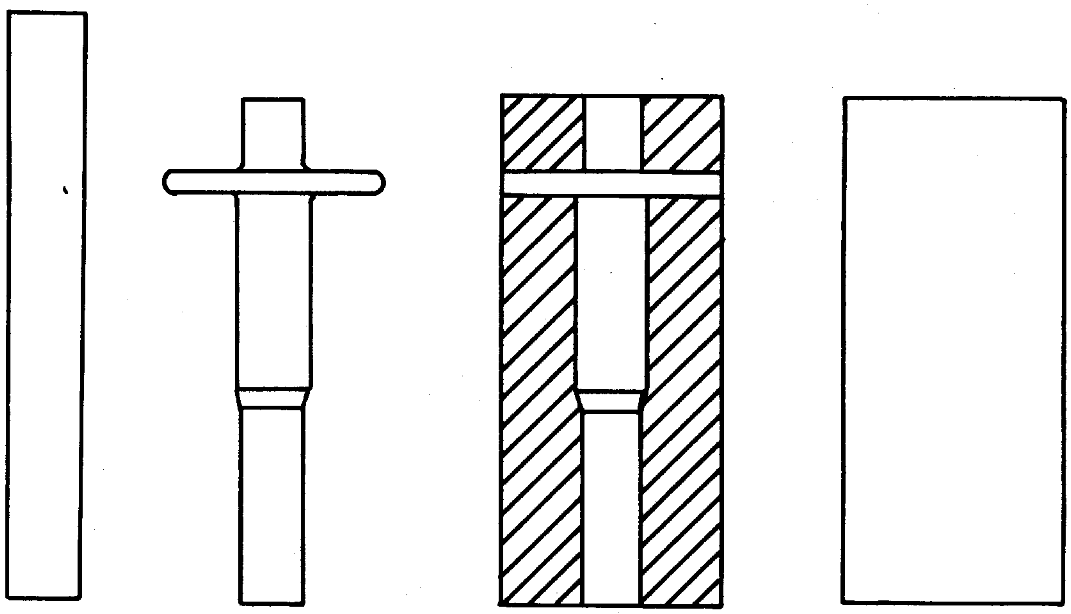
Thread rolling is a cold forming process which forms the thread by displacement of metal rather than by removal of metal.

This operation is performed by rolling and squeezing a metal blank between two dies which have been machined in a pattern similar to the finished thread (Figure 4 and 5).

Rolled threads are usually superior to those produced by other methods for the following reasons:

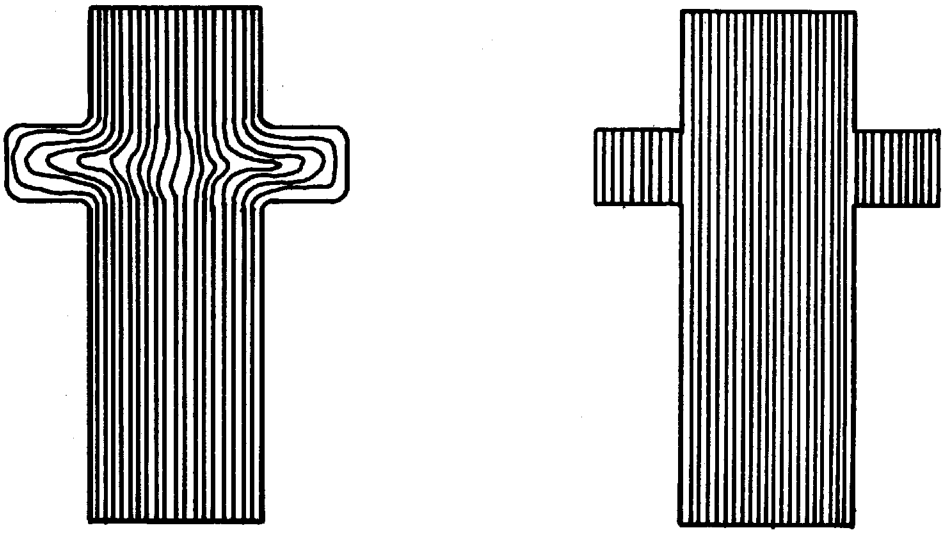
(1) Cold working increases the tensile strength. Tests on straight tension loads indicate rolled threads are 10 to 25 percent stronger than cut or ground threads of similar size and material. In tests under fatigue loads an increase as great as 50 percent is sometimes recorded.

(2) In rolling, the fibers are elongated and rearranged in unbroken flow lines following the thread contours; when a thread is cut or ground, these lines are severed since they



COLD HEADING STOCK — COLD HEADED PART — SCREW MACHINE PART — SCREW MACHINE STOCK

 = 85% SCRAP



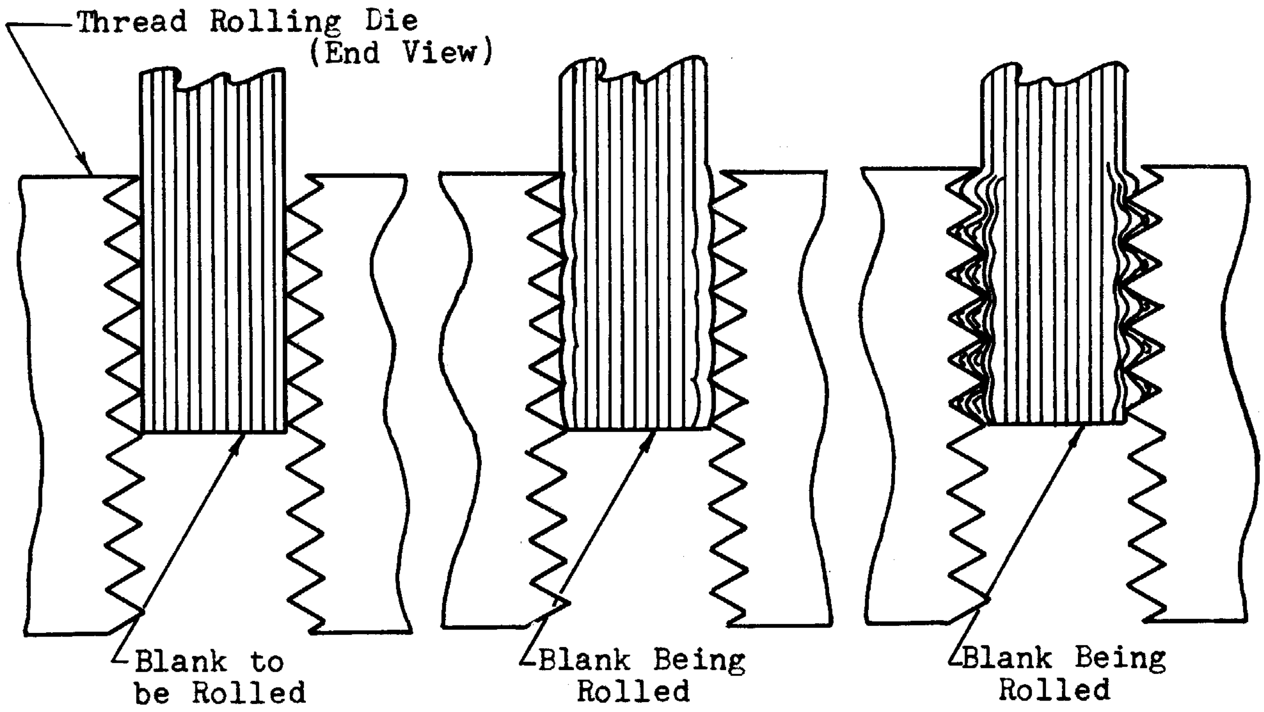
COLD HEADED PART

Flow lines follow contour of upset section, imparting strength.

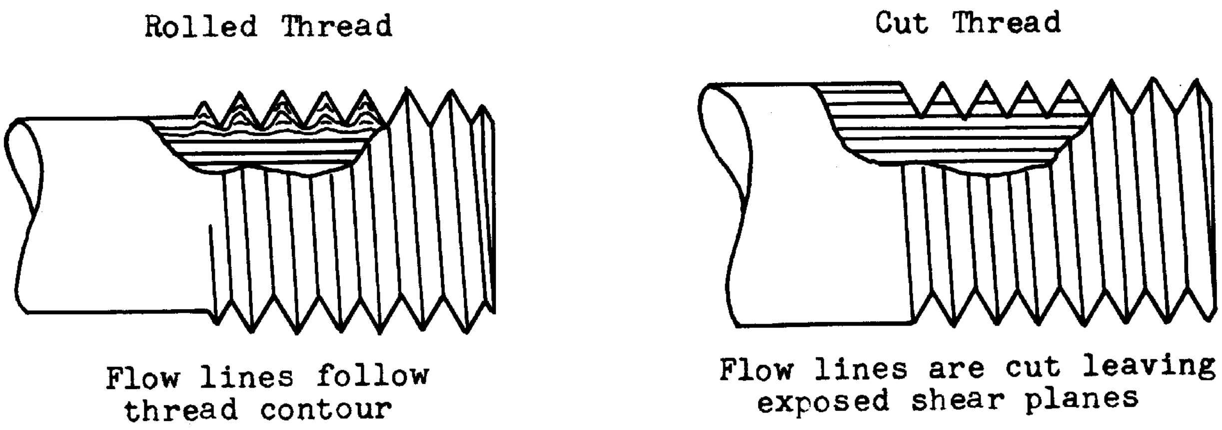
SCREW MACHINE PART

Flow lines are parallel to axis.

(Figure 3)



Lines show how fibers are rearranged to follow thread contours. This cold working increases tensile strength.



Rolled threads have greater resistance to shear or stripping failure.

(Figure 4)

remain parallel to the axis. This leaves exposed shear planes which decrease the resistance to stripping and other shear failures (Figure 5).

(3) Because of precision manufacture of rolling dies, very accurate threads can be produced by this method.

(4) Rolling tends to harden and burnish the surface making it non-porous and free from tears thus providing some protection against surface corrosion and also improving the appearance.

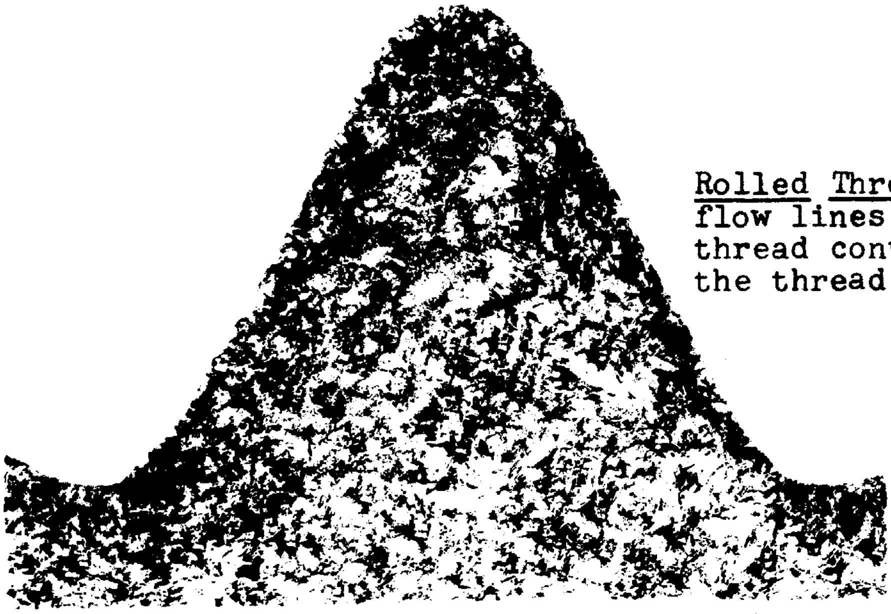
(5) Rolling can be performed effectively on a wider variety of materials than can cutting.

(6) Pointing is usually unnecessary on rolled threads because the elongating effect of rolling will provide undersize starting threads.

(7) There is considerable material saving because the rolling blank is smaller than the finished thread and no material is removed. Material savings range from 13 to 27 percent depending on thread size.

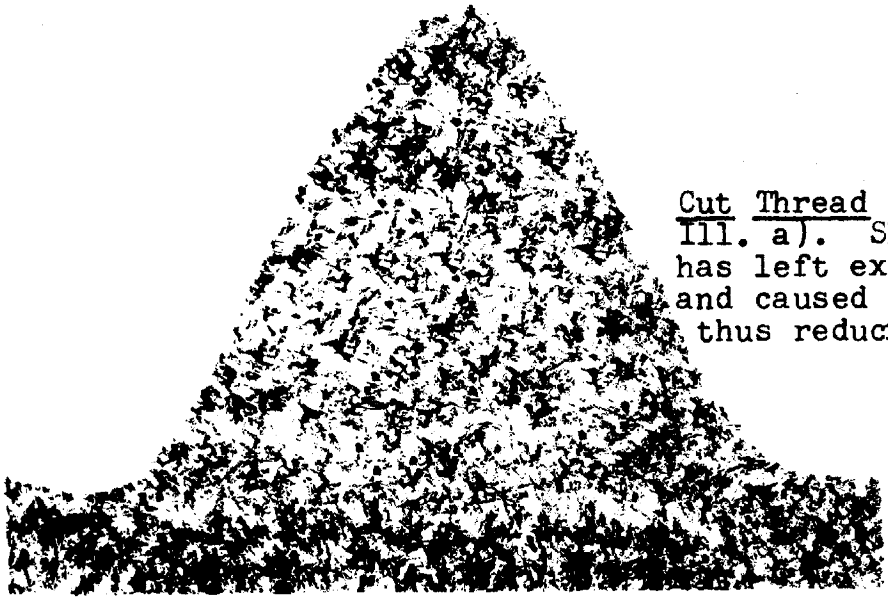
(8) Rolling is fast and therefore economical.

PHOTOMICROGRAPH OF ROLLED THREAD & CUT THREAD



Rolled Thread - Shows how flow lines follow the thread contour thus making the thread stronger.

Illustration (a)



Cut Thread - (Same steel as Ill. a). Shows how cutting has left exposed shear planes and caused surface irregularities thus reducing thread strength.

Illustration (b)

Thread in Illustration (a) in straight tension load is about 15% stronger than thread in Illustration (b). Under fatigue loads, the disparity is even greater.

(Figure 5)

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CHAPTER II

MATERIALS, PROPERTIES & HEAT-TREATMENT

The engineer and toolmaker has at his disposal many types of metals of widely differing properties. One must consider the several physical properties of metals and then the ways and means of obtaining the most desirable properties. For a given metal, there are several conditions under which it may exist and each of these conditions has a definite bearing upon its usefulness for a particular application. Once this has been established, the various uses and properties of several metals can be applied to fabrications of machines and structures by casting, forging, welding and machining.

PHYSICAL PROPERTIES

In order to understand some of the terms used defining physical properties of metals, it will be necessary to define some of the common terms which are applied in describing metals.

A load applied to a part causes a stress to be set up in that part which resists the action of the load. There are three kinds of elementary stress:

1. Tension, which may be illustrated as the stress in a rope which is holding up a load;
2. Compression, which may be illustrated as the stress in a column or pedestal which is holding

up a load;

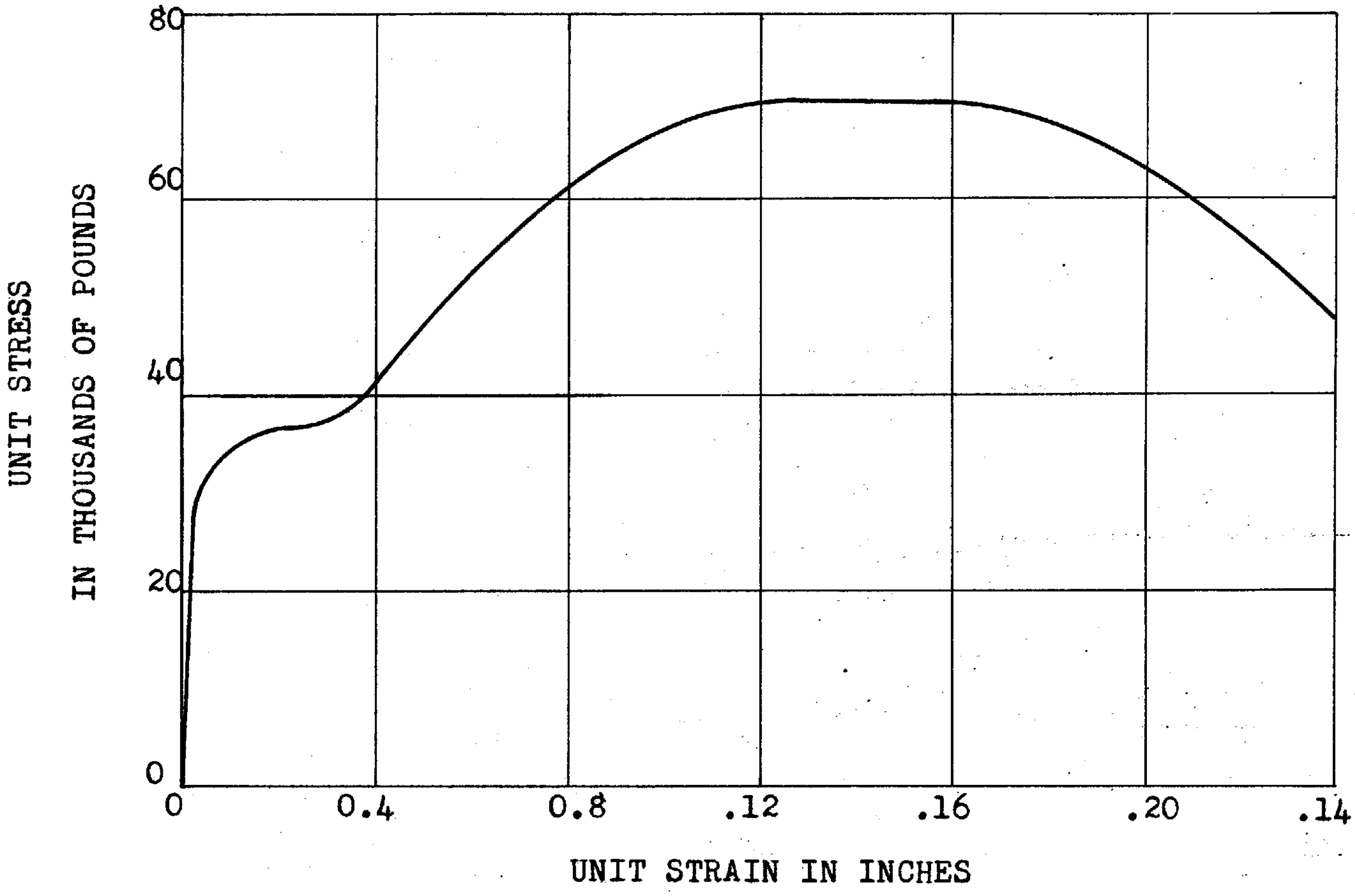
3. Shear, which may be illustrated as the stress in a rivet which holds two plates in tension.

Strain is the deformation of a material when stressed.

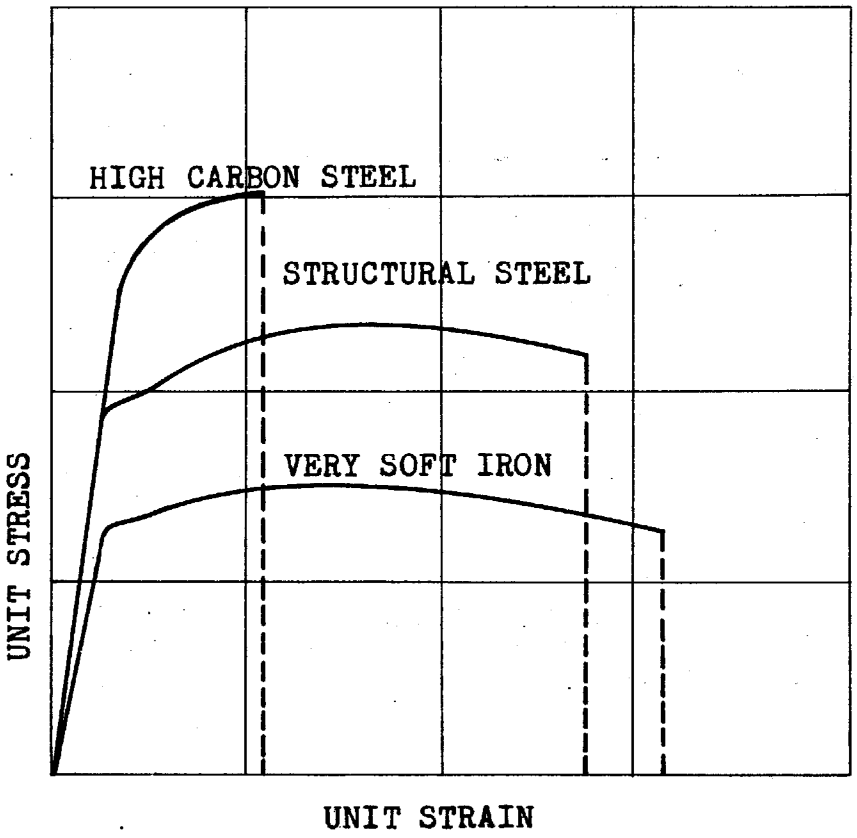
Metals are well known to be elastic in varying degrees; that is, when a load is applied, the metal deforms, and then, when the load is removed, the metal returns to its original shape. Now if a curve is plotted, having unit stress on the vertical axis and unit strain or deformation on the horizontal axis, it is seen that when a metal such as mild steel is stressed, the strain is small and of uniform degree up to a stress of about 35,000 pounds per square inch. The additional strain is noted without a corresponding increase in stress. This first indication of an increase in the rate of strain without a corresponding increase in stress is called the yield point of the metal.

As the study of the accompanying stress-strain curve indicates, the limiting strength of the metal has not yet been reached at the yield point, but the load continues to increase until what is called the ultimate strength is reached. After reaching the ultimate strength, the metal gradually stretches, weakens and ruptures at a stress less than that at the ultimate. A metal which is stressed below its yield point is still elastic and will return to its original form.

Toughness is the ability of a metal to stand great



STRESS-STRAIN CURVE FOR MACH. STEEL



COMPARATIVE STRESS-STRAIN DIAGRAM

deformation at high stress without rupture. The opposite of this characteristic is brittleness, shown in a type of material which ruptures with little warning deformation. Structural steel and rubber are examples of materials which possess great toughness, and on the other hand, glass and cast iron are both very brittle materials. The amount of toughness possessed by a material is indicated quantitively by the total area under the stress-strain curve up to a point of rupture as indicated by the accompanying curves for high carbon steel, structural steel, and soft iron. It is evident that structural steel is the toughest of those depicted; i.e., it has the greatest deformation at the highest stress. The high carbon steel exhibits the highest tensile strength of the three, and soft iron is the most ductile.

Ductility, as was noticed in the soft iron, is the property which allows a metal to deform a great amount, regardless of the stress which is necessary to cause the deformation. The definition of toughness which requires that a material stand great deformation at high stress points to the essential difference between toughness and ductility, for ductility requires only large deformation of the metal.

Hardness is a term which may be exactly defined only in terms of the tests which are used to determine it. Hardness includes resistance to abrasion, to cutting, or to wear.

The Brinell Hardness Tester operates on the principle of forcing a 10 mm. hardened steel ball into the surface of the piece being tested by applying a load of 3000 kilograms (6614 lbs.). The diameter of the indentation is then measured with the aid of a microscope, having a transparent millimeter scale in the optical system. Brinell hardness numbers are calculated from the load applied, diameter of ball, and the diameter of the ball impression. The diameter of impressions used is the average of two measurements at right angles to each other. The reading error of the instrument should not be more than 0.02 mm. A table of Brinell hardness numbers corresponding to different diameters of impressions is used in computing results of tests instead of the basic formula. Since no grinding is necessary, the Brinell Hardness Tester is suitable for rough material such as castings and drop forging, and it yields accurate results on nearly all types of ferrous and non-ferrous metals. The Brinell machine, like all indentation machines, allows an accurate record to be kept of testing. The large indentation which the machine leaves, and the length of time necessary to make Brinell Tests are principal disadvantages of the Brinell Tester. In addition, the size of the specimen is limited, this method cannot test thin stock and is not particularly accurate for very hard metals.

The Rockwell Hardness Tester measures the depth of residual penetration by a steel ball 1/16" in diameter or a diamond cone under certain fixed conditions of load. A minor load of 10 Kg. is first applied, which seats the penetrator in the surface of the specimen and holds it in position. The dial is then turned to the point marked "set" and the major load applied. After the pointer comes to rest, the major load is removed, leaving the minor load still on. Rockwell hardness numbers are based on the difference between the depth of the penetrator at major and minor loads. This difference is automatically registered when the major load is released (the minor load still being applied) by a reversed scale on the indicator dial which thus reads directly Rockwell hardness numbers. Every report is used, or else its interpretation becomes a matter of guess work. The scales are indicated by letter and are necessary because of the several combinations of major load and penetrator. Accurate testing can be done more quickly with the Rockwell machine than with the Brinell tester, the direct hardness reading on the scale being the principal reason for the lessened testing time. The Rockwell machine is good for all types of metal, ferrous and non-ferrous, both soft and hard, and records can be kept of the testing. The Rockwell machine is also limited as to the size of specimen and it makes a small indentation which may be objectionable.

The principle employed by the scleroscope is the drop and rebound of a diamond tipped hammer. This hammer drops by the force of its own weight from a fixed height to the surface of the test specimen. The readings of the resulting rebound in the Model D instrument are recorded on a dial after the strike and rebound of the hammer. The dial remains fixed until it is released for another test. The reading is made from the height of the first rebound noted on the scale at the top of the hammer. The scale consists of units which are determined by dividing the average rebound from quenched high carbon steel into 100 equal parts. The scleroscope should always be set level when making a test. The scleroscope test is a rapid, fairly accurate means of testing metal and is very good for smooth surfaces and if the specimen is not finished originally, a great deal of preparation is required. The scleroscope is limited by the size of stock and is not useful for non-ferrous metals.

The file test is used to determine whether a steel is as hard as a file. There are no degrees of file hardness, --either it is or is not as hard as the file being used. To make a file test, the handle of the file is grasped in the hand with the index finger extended along the file, and the surface to be tested is rubbed slowly but firmly with the sharp teeth. Just as soon as it is apparent whether or not the file will bite into the piece being tested, it is removed. The simplicity and the rapidity of this method of hardness testing are strongly in its favor for the control of hard surfaces in production. In the period of a few seconds, the tester can determine the hardness of each tooth in a gear, various surfaces of a ball or bearing, or other hardened parts such as tool without injury to the surface. Comparisons of file hardness are dependent on the size, shape, and hardness of the files; the speed, pressure, and angle of the file while moving across the hardened part; and the composition and heat treatment of the steel being tested. The file test is a rapid, inexpensive test which requires no preparation of the specimen and is suitable for testing knife edge cutting tools without being limited as to the size of stock. The file test is inaccurate, no record can be made of the test, and testing requires a great measure of skill and experience.

REVIEW QUESTIONS

T F Unit stress may be correctly expressed as follows: 6000 pounds.

T F Total stress is expressed in units which involve weight and area.

T F Steel is more elastic than lead.

T F Lead is more elastic than steel because it will stretch out further under a load.

T F The elastic curve is plotted with unit stress on one axis and unit strain on the other.

T F There is a straight line relationship between unit stress and unit strain below the yield point.

T F The yield point is that point on an elastic curve where an increase in stress is noted without a corresponding increase in strain.

T F All metals exhibit a marked yield point.

T F The yield point is the maximum amount of stress which a ductile metal will stand without rupture.

T F The ultimate strength is the greatest unit stress which a metal will withstand.

T F A metal which is stressed above the yield point will have a permanent deformation.

T F Stressing a metal above the yield point will cause a raising of yield point for the metal.

T F Toughness is the ability of a metal to stand great deformation at high stress.

T F Copper is a good example of a very tough metal.

T F Toughness of metals increases only as the hardness of the metal increases.

T F The higher the carbon content, the tougher the metal.

T F Toughness is indicated by the area under the stress-strain curve.

T F Toughness and ductility are identical in meaning.

T F Hardness may be defined as resistance to abrasion.

T F Resistance to indentation is a frequently used measure of hardness.

T F The Brinell Tester measures the width of indentation of a ball under a standard load.

T F Brinell hardness may be determined in one operation.

T F The Rockwell Tester measures the depth of indentation of a ball under a standard load.

T F The Rockwell machine is a direct reading machine.

T F The scale used is an important part of a Rockwell hardness reading.

T F The principle of the scleroscope is resistance to abrasion.

T F The file test is of little practical value.

T F A piece tested with a file is too badly marked to be of use.

STEEL

In order to understand how the properties of steel are controlled, it is necessary to have a conception of what steel is. Steel is defined as an alloy of iron and carbon in which the amount of carbon is less than two per cent. When the amount of carbon exceeds this value, it is cast iron. Wrought Iron, although containing up to .30% carbon, differs from steel mainly in the process of manufacture. Wrought iron contains slag, whereas steel is entirely free from it.

In practice, a steel consisting of iron and carbon alone never occurs. Other elements are present in various quantities. These quantities in ordinary carbon steels are too small to have an appreciable effect on the properties of the steel. The elements that occur in steel may be divided into two groups, one of which is detrimental, the other beneficial. The detrimental elements are sulfur, oxygen, arsenic, phosphorus, and nitrogen. These elements decrease the strength, ductility, and toughness under various conditions. The group of elements that are beneficial to steel may be further divided into those that are added to steel for purification and those that are added to make alloy steel. The elements added for purification are silicone, manganese, and occasionally aluminum. Titanium and vanadium may also be used, but they are too expensive for ordinary use. The effect of these elements is to cause oxidation of the impurities which are then removed with the slag.

CARBON STEELS AND THEIR PROPERTIES

Iron and carbon alloys, when cooling, undergo definite changes, depending upon the percentage of carbon and the rate of cooling.

From the time steel begins to solidify until it reaches its final condition it passes through several crystalline stages which have varying characteristics. Pure iron is made up of crystals called ferrite. When carbon is added, it combines with the iron to form the chemical compound of iron carbide, known as cementite. The amount of carbon in cementite is 6.677% by weight. Where the carbon content of the steel is .9%, called the eutectoid mixture, ferrite and cementite form crystals at the same time which mutually tend to interfere with each other's growth. As a result, a peculiar mixture is formed consisting of alternate layers of ferrite and cementite; this is called pearlite. For carbon values below the eutectoid, a mixture of ferrite and pearlite will result; above 0.90% carbon, the mixture will consist of pearlite and cementite. Steels then, may have a structure consisting of ferrite and pearlite, pearlite and cementite, or pearlite alone. The proportion in which these occur is fixed by the carbon content.

The crystalline structures have different properties. Ferrite is soft, very ductile, weak, strongly magnetic, and has a low yield point and low shearing strength, the maximum engineering tensile strength being about 40,000 lbs. per square inch. Cementite is harder than glass, brittle, of very high breaking strength in shear (about 300,000 lbs. per sq. in.) but of low tensile strength. Pearlite is a fine crystalline structure and has an engineering strength from 120,000 to 160,000 lbs. per square inch. The hardness is much greater than that of ferrite but less than cementite. In the same way the ductility is less than that of ferrite but greater than that of cementite.

Since the crystalline formations are in direct proportions to the carbon content, the properties of steel depend on the amount of carbon present.

CONTROL OF PROPERTIES OF STEEL

The properties of steel may be changed by cold working, but in general, this method is insufficient to give the properties required in special steels such as tool steels. The greatest control of properties can be obtained by heat treating. As an example, a .34 carbon steel in the normal condition has a maximum tensile strength of 85,000 pounds, after heat treatment, it was found to have a tensile strength of 200,000 pounds. The strength after heat treatment, however, will depend largely on the manner in which the steel is heat treated.

The principles of heat treating are based on three facts:

1. Steels have different internal structures at high and low temperatures;
2. An appreciable time is required for change in structure at any temperature;
3. The time required for a change in structure is very short at high temperatures and approaches infinity at low temperatures.

Certain changes take place in the structure and the properties of the metal as it cools. These changes are considered allotropic according to most authorities. Allotropy is the variation in physical properties, such as crystalline structure, without change of chemical composition. The temperatures at which these changes take place are called critical temperatures and are more or less definite for a given carbon content.

Allotropic changes in steels up to about .9% C, or the eutectoid mixture, affect only the pure iron and are considered as the allotropic forms of iron. Steels up to about .9% C, as indicated by the point O (Figure 6), undergo two distinct transformations, and eutectoid steel changes directly from the eutectoid austenite to pearlite.

In cooling from the molten state, steel first appears as a solid in the austenitic formation. Carbon and the carbide of iron are in solid solution with the iron. Austenite is the only formation which can hold the carbon or its compound in solid solution. This solid solution can be pictured as salt dissolved in ice. A frozen solution of salt and water, however, is impossible, as salt is thrown out of solution with water when low enough temperatures are reached. Steels which cross the temperature line K-O when cooling, liberate part of the iron in the Alpha allotropic formation. When the temperatures drop to the line L-N-O, steels become magnetic. At temperatures M-O, only the eutectoid mixture remains as austenite, which changes to pearlite on furthur cooling.

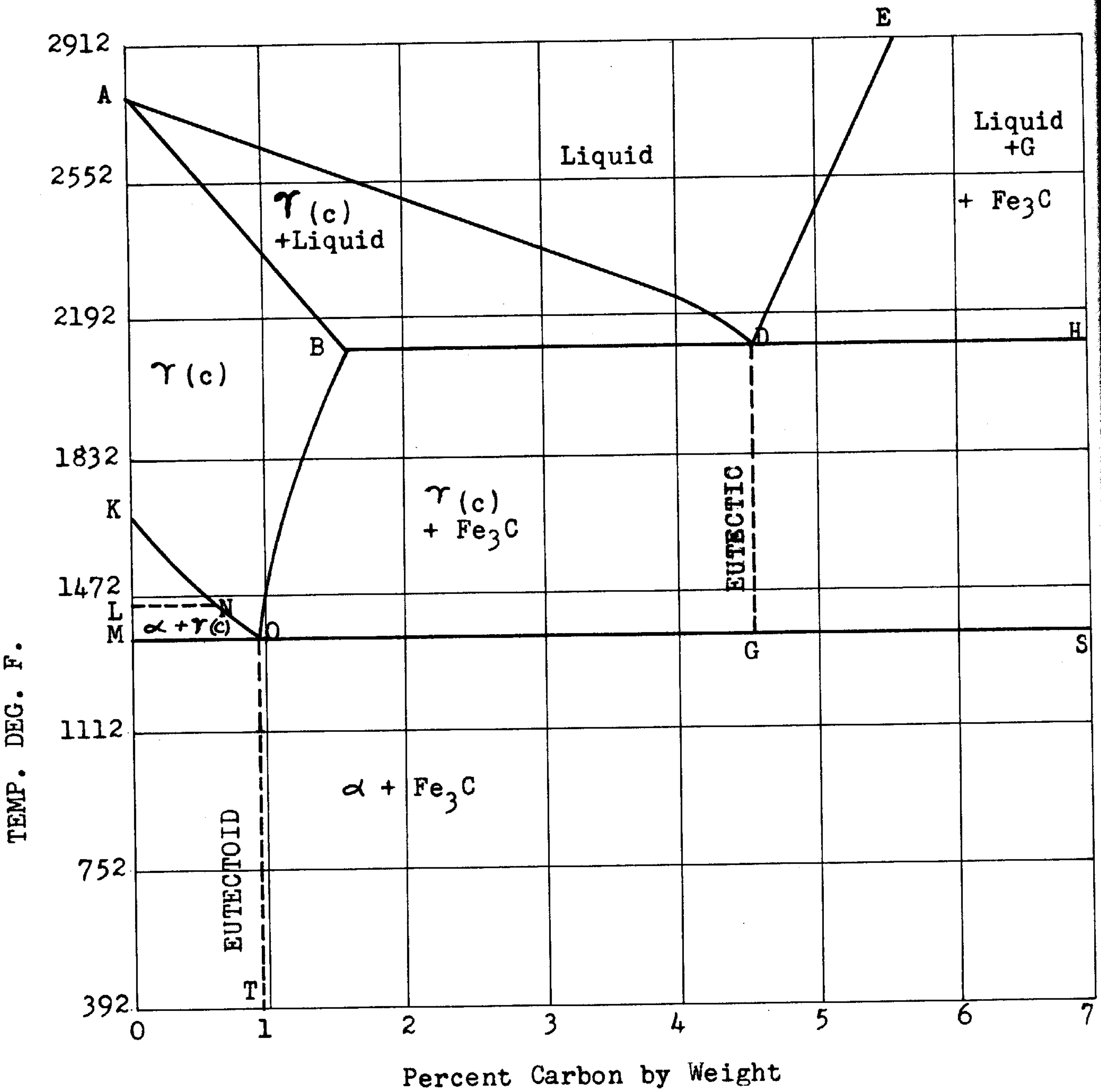
Steels with a higher carbon content than the eutectoid mixture liberate the carbide of iron (Fe_3C) when cooling, until only the eutectoid mixture is left in solid solution.

So far, changes occurring while cooling the steel have been discussed. When steel is heated, these changes take place in reverse order with a perceptible lag. Thus, the critical temperatures when heating the steel are somewhat higher than when cooling it. This may be explained by the assumption that a certain length of time is required for any change to go to completion. The time of the transformation at red heat is estimated at ten to thirty seconds.

SIMPLIFIED EQUILIBRIUM DIAGRAM OF IRON-CARBON ALLOYS

(C) - Austenite; (γ) -Ferrite; Fe_3C-Cementite; (G)-Graphite

Critical Temperature Line--L-N-O-S



(Figure 6)

If a high carbon steel is quenched at a sufficiently rapid rate, such as secured with liquid air or iced brine, the transformation is entirely prevented and the quenched steel consists of austenite. If, on the other hand, the quenching is done in the common bath of either water or oil, the structure obtained is principally martensite. With a somewhat slower rate of cooling, which may be obtained by quenching in certain oils or in a heated lead bath, other structures called troostite or sorbite may be obtained. These structures may also be obtained by reheating when tempering as mentioned later.

The different structures may be explained by describing their properties.

Austenite is soft, ductile, and tough. Martensite is the hardest stage and is responsible for the hardness of cutting tools. Troostite is intermediate between martensite and pearlite (see carbon steel) in its physical properties. It has a finer crystalline structure, however, than pearlite. When a piece of steel is quenched, large internal stresses are set up which reduce the strength of the steel. Thus the available strength of the quenched steel is the difference between the natural strength and the cooling stresses. The internal stresses may be removed by tempering but not without a certain amount of softening of the steel. For these reasons, the natural strength of hard steel is never fully available.

If the rate of the transformation could be appreciably reduced at the higher temperatures, it would not be necessary to quench steel at such a rapid rate and most of the internal stresses could be avoided. The heat treated steels would not only be extremely hard but would have their full natural strength available for use.

Although the heat treatment of steel is still in a state of development, it is known that all elements that go into solid solution in steel retard the rate of the reactions.

It is known that the higher carbon steels when heat treated are harder and better adapted for cutting tools than the low carbon steels. The effect of the carbon is to retard the rate of the transformation, and the more carbon there is in the steel, the slower is the rate of the transformation, and therefore, better results are obtained with high carbon steels. There is, however, a limit to the amount of carbon that steel may contain, as above 2%, carbon tends to crystallize in the form of graphite and produces structures different from those of steel. These structures are characteristic of cast iron. Carbon, fortunately, is not the only element that will go into solid solution in the iron, but it is the cheapest and most effective for a given amount used.

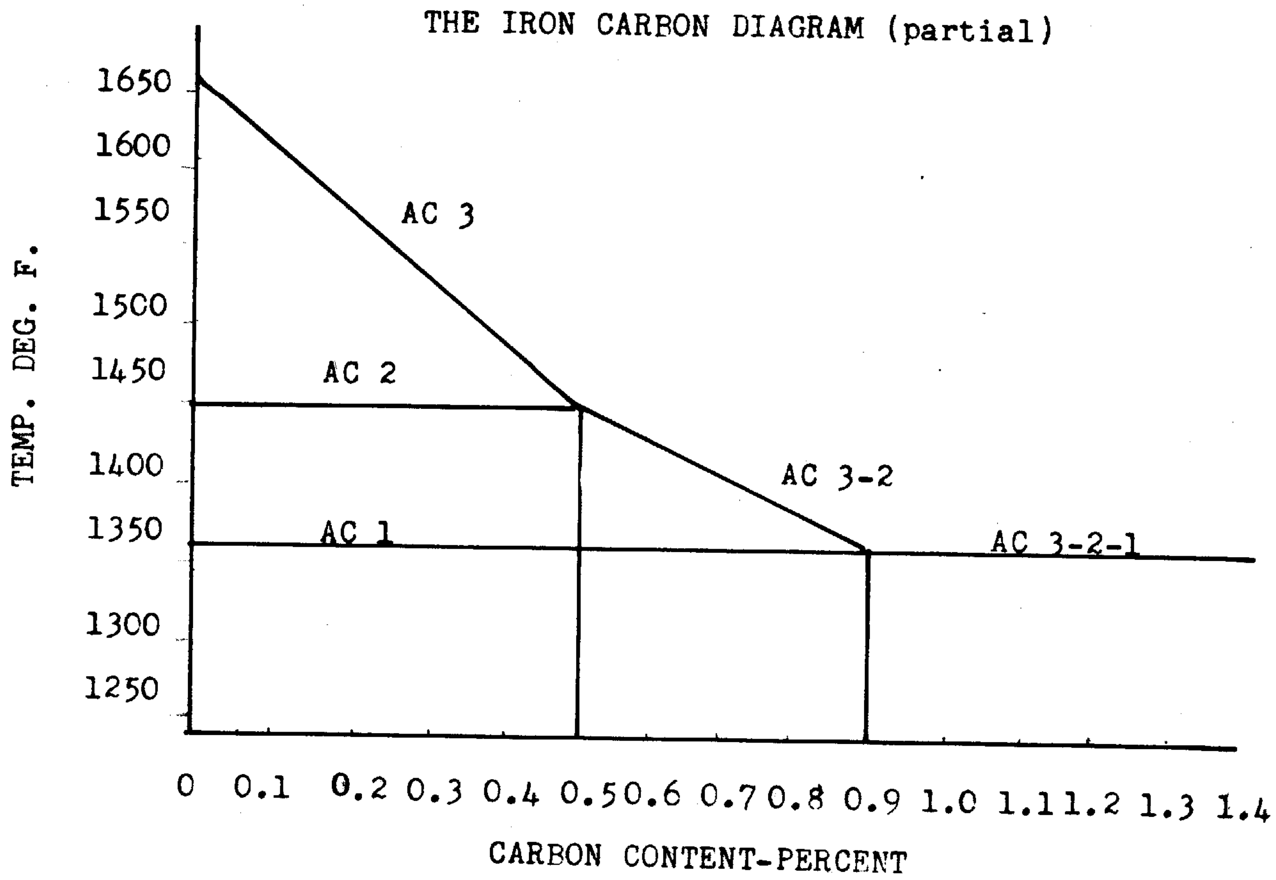
The accompanying partial Iron-Carbon Diagram represents that portion of Figure 7 as indicated by KLMON. This gives a clearer graphic picture of that section of the Iron-Carbon diagram up to the eutectoid point.

The Critical Points. The phase changes liberate heat when they take place on cooling, and absorb heat on heating. These evolutions and absorptions of heat are shown by halts or arrests in cooling curves and heating curves, which indicate the temperatures at which the changes take place, and these are usually called thermal critical points or critical temperatures.

The "Critical Range" as used in the definitions is the temperature range between the lines AC_1 and AC_3 as illustrated by the diagram given on the following page.

How the Diagram is Plotted. The temperature is plotted vertically and the carbon content horizontally. Any point on the diagram represents a definite alloy or carbon content. The carbon content is shown on the lower horizontal line, while the temperature is shown on the vertical line at the left of the diagram.

In order to know at just what temperature the end of the AC_3 critical range (which must always be exceeded for annealing, normalizing or quenching for hardening) comes for a given steel, we must either (a) make a thermal analysis on that particular steel, (b) have a complete and



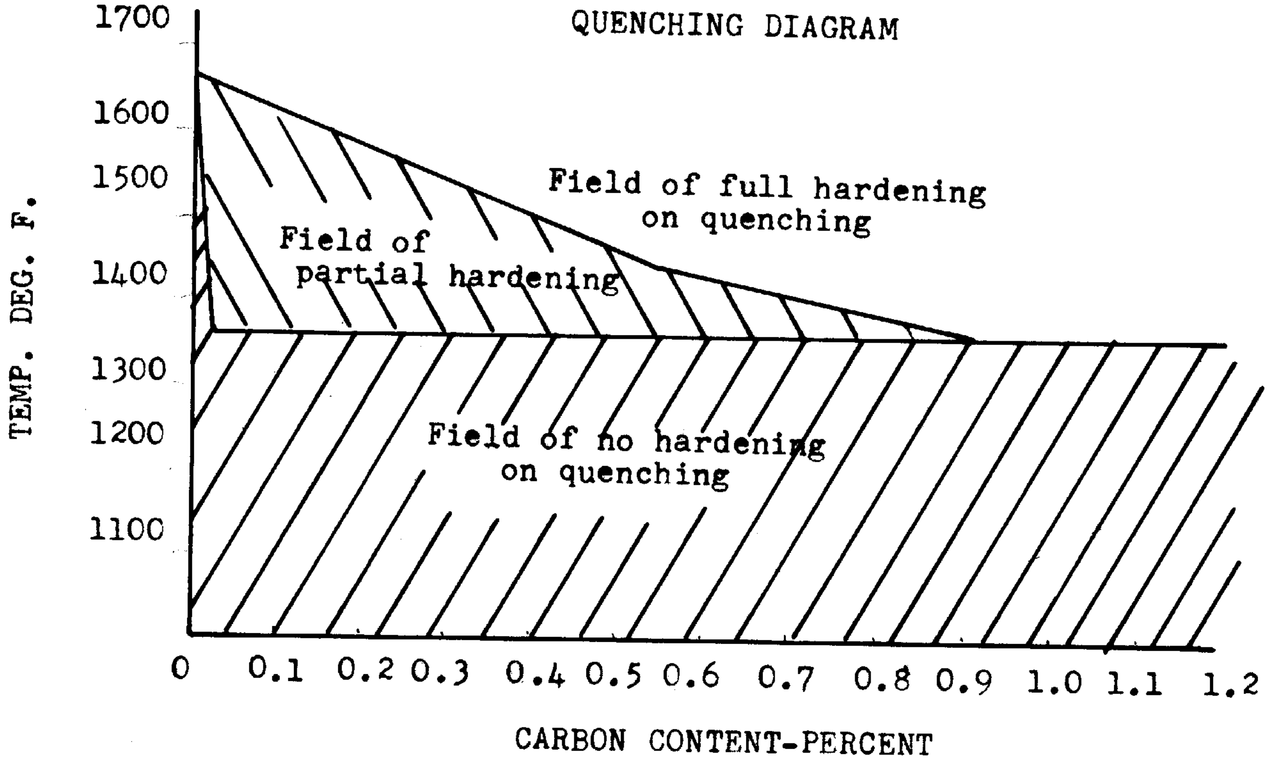


CHART SHOWING TEMPERATURE REQUIRED TO PRODUCE HARDENING ON QUENCHING OF STEELS OF DIFFERENT CARBON CONTENTS

(Figure 7)

accurate chemical analysis and compare the analysis with known AC_3 end temperatures for steels of varying composition, or (c) heat a number of specimens of the steel, take out specimens at different temperatures and quench them. The hardness will, except in extremely low carbon steels show a sudden jump as AC_1 is passed and increasing hardness as the temperature rises to the end of AC_3. The fracture will show the smallest grain size at about the best temperature for annealing, normalizing or quenching. As the temperature rises above the end of AC_3 the grain size increases. Examination under the microscope will show the grain size more certainly than will the fracture. After the critical temperature has been found it then remains to determine the proper time at the chosen temperature, which will be a little above the end of AC_3.

PROPERTIES AND USES OF HIGH CARBON STEELS

High carbon steel has a carbon content of .6% to 1.6%, and is used mostly for cutting tools and other articles requiring hardness. For this reason, it is often referred to as "tool steel". As will be later shown, it has the desired hardness not merely because its carbon content gives greater hardness and strength, but because by proper heat treatment it is possible to increase the hardness to a much greater degree. Unfortunately, increased hardness is always accompanied by increased brittleness. The tool steel is useless as a cutting tool until it has been

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accurate chemical analysis and compare the analysis with known AC_3 end temperatures for steels of varying composition, or (c) heat a number of specimens of the steel, take out specimens at different temperatures and quench them. The hardness will, except in extremely low carbon steels show a sudden jump as AC_1 is passed and increasing hardness as the temperature rises to the end of AC_3. The fracture will show the smallest grain size at about the best temperature for annealing, normalizing or quenching. As the temperature rises above the end of AC_3 the grain size increases. Examination under the microscope will show the grain size more certainly than will the fracture. After the critical temperature has been found it then remains to determine the proper time at the chosen temperature, which will be a little above the end of AC_3.

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hardened, and if in service it becomes heated to 600 F or more, it rapidly loses its hardness and must be hardened again to be useful. This property of "losing its temper" has led to the development of the newer cutting tool materials, and explains why high carbon steel is limited to uses where high temperatures are not involved. Common tools made of this steel are: cold chisels, punches, screw drivers, wood chisels, plane bits, and other wood working tools, and drills for light service. For drills and tools for cutting metal under high speed production methods, however, the ordinary tool steel is unsatisfactory, and in its place is used one of the newer materials.

HIGH SPEED STEEL

High speed steel is an alloy steel used chiefly for cutting and forming tools. It has displaced carbon steel for machine tool work, because, as its name indicates, it can be used for cutting at higher speeds. Most of the various compositions contain: carbon, tungsten, chromium and vanadium. A typical composition is as follows: carbon, 0.60 - 0.75%; tungsten, chief element, 13-19%; chromium, 3-4%; and vanadium, 1%.

This steel is air-hardening or self-hardening; that is, if overheated in service, even at a red heat, it will recover its hardness on cooling in air. It is not easily forged at ordinary forging temperatures, but is usually purchased from the manufacturer in bars of the desired size, which need only to be ground to shape, having been hardened at the mill. Annealed bars may be obtained; these may be machined to shape and then hardened. This steel will hold its hardness at a temperature of approximately 1200 F, about twice that of carbon steel.

COBALT-CHROMIUM-TUNGSTEN ALLOYS

Alloys of this group, of which Stellite is a representative example, are not steels at all, but are non-ferrous alloys chiefly of cobalt, chromium, and tungsten. Usually carbon is present, in amounts up to slightly over 2%. The tool grade of stellite can not be rolled or forged; tools made of it must be cast and ground to shape. It requires no heat treatment, but is used as cast. It is not affected by heat up to a temperature of 1800 F, and is tougher at red heat than when cold. The tool grade is used principally for cutting tools and for hard surfacing softer materials. For hard surfacing, it is applied from a welding rod by a welding process. It fuses at 2600-2800 F, and has a UTS as high as 92,000 psi., and an ultimate compressive strength as high as 280,000 psi. This high compressive strength in any material is an important factor in its effectiveness as a cutting tool material.

CEMENTED CARBIDES

Cemented tungsten carbides and tantalum carbides are used for cutting tools. Cemented tungsten carbide, which is sold under trade names such as: Carboloy, Diamondite, etc., consists of very small particles of tungsten carbide held together in a matrix of cobalt. The density of tungsten carbide is almost that of tungsten, which is 2½ times that of iron. It cuts glass, porcelain, hardened steel, chilled cast iron, concrete, bakelite, and hard rubber. Its hardness is exceeded only by that of silicon carbide and the diamond, both of which are used in grinding wheels for grinding the carbide tools. It was originally produced in Germany as early as 1926, as "Widia", and "Hartmetall", and has been commercially produced in the United States since 1929. Its use has revolutionized machine tool design because of the enormously increased speeds and cuts it has made possible.

It has a UTS as high as 300,000 psi. and an ultimate compressive strength as high as 540,000 psi. Its hardness is between that of the sapphire and the diamond; its red hardness is probably higher than that of any other known cutting tool material; the upper limit of its working temperature is uncertain.

HIGH CARBON TOOL STEELS AND THEIR USES

Carbon Per Cent	Uses
0.60 - 0.70	Dies for drop forging or bolt-heading: plate punches.
0.70 - 0.80	Cold chisels, pick axes, wrenches, vise-jaws, shear blades, band saws.
0.80 - 0.90	Rock drills, circular saws, machine chisels, punches and dies, shear blades, hot and cold sets, set hammers, swages, flatteners, smiths' tools.
0.90 - 1.00	Punches and dies, machinists' hammers, small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, mill picks, circular cutters.
1.00 - 1.10	Cutting tools for lathes, planers, shapers, and slotters, mandrels, lathe centers, taps, small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, mill picks, circular cutters.
1.10 - 1.20	Taps, thread and metal-cutting dies, milling cutters, twist drills, reamers, knives for woodworking machinery, carpenters' tools, wood cutting tools.
1.20 - 1.30	Files, taps, milling cutters.
1.30 - 1.50	Engravers' tools, knives for cutting paper, tools for turning chilled iron rolls, dies for wire drawing.
1.50 - 1.60	Saws for cutting steel, dies for wire drawing.

REVIEW QUESTIONS

T F Wrought iron and steel differ principally in carbon content.

T F A steel consisting of iron and carbon alone is not obtainable commercially.

T F Oxygen, arsenic, and nitrogen are particularly beneficial in steel.

T F Vanadium may be used in small amounts for purifying steel and in larger amounts as an alloying element.

T F Carbon has a greater effect on the physical properties of steel than any other element.

A steel is observed as being very soft, ductile, magnetic, and has a low yield point. What type of structure would it be expected to show: Ferrite, Pearlite, Cementite, Austenite, Troostite, Sorbite?

T F Steels have different structures at high and low temperatures.

T F Pure iron is composed of crystals of ferrite.

T F The eutectoid point is at 1.12% carbon.

T F A steel composed of ferrite and pearlite is weaker than a steel composed of all pearlite.

T F Cementite weakens a steel and causes it to have a lower yield point.

T F The ductility of pearlite is less than that of ferrite.

T F Tempering steel means hardening steel.

T F Changes in the structure of steel at high temperature are instantaneous.

T F A steel heated to 1800 F would be expected to have a ferritic structure.

T F Time for structural changes in steel at low temperature approaches infinity.

T F The temperatures at which changes in structure of steels occurs are called critical temperatures.

T F A different iron-carbon diagram is necessary for each steel of varying carbon content.

T F In cooling from the molten state, steel first occurs as a solid in the austenitic formation.

T F Martensite is very hard and brittle.

T F Troostite is weaker and more ductile than pearlite.

T F As steel is being heated it absorbs heat as it passes through its critical temperatures.

T F The behavior of practically any steel of any carbon content may be predicted by the use of one drawn-carbon diagram.

ALLOY STEEL

Even though the carbon content of steel is limited to 2%, greater and more accurate control of the properties of the steel can be obtained by adding other elements. Other elements are not as effective as carbon, but their quantity is not limited as carbon is. By adding a sufficient amount of some of the elements, it has been possible to slow down the rate of the transformation to a point where the steel consisted of the first structure austenite when cooled slowly in air. Steels which contain elements other than carbon and iron in quantities sufficient to affect the control of the properties are called alloy steels.

Alloying elements may be divided into four groups according to the way in which they function.

The elements of the first group form exactly the same kind of structures, in combination with carbon, that iron does. The main effect produced by the elements of this group is to depress the critical temperature and that way decrease the necessary reduction in temperature for stopping the reaction or transformation. The principal elements of this group are nickel and manganese.

The second group is represented by the element chromium. Its effect on the critical temperature is similar to that of the first group. However, the carbide of chromium does not act like that of iron, and the effect of this group in reducing the critical temperature is not as great as that of the first.

The elements of the third group form structures only partially similar to the iron and the iron carbide structures of the first two groups with the result that the critical temperatures are only slightly depressed. In this group belong such elements as tungsten, molybdenum, vanadium, and probably copper, titanium, and aluminum.

In the first three groups the alloying elements act with the carbon in much the same way that iron does. In other words, the alloying elements to a certain extent take the place of iron in the various crystalline structures.

There is a fourth group of elements, however, which take the place of carbon in the steel. The critical temperatures are affected very little. The structures of these steels are similar to those of the straight carbon steels. If the percent of the alloying element reaches a quantity where it forces the free crystallization of carbon into the form of graphits, the steel becomes too brittle for use. The elements of this group are silicon and boron. Silicon steel has the special property of having an unusually low magnetic resistance and is used in making laminated cores for transformers.

The heat treatment of alloy steels follows the same general principles as that of carbon steels. The greatest difference is in the time element. In the alloy steels the rate of the transformation has been slowed down to a point where accurate control of the properties can be obtained. In special steels, such as the high speed steels, the rate of the transformation is so slow that cooling in air gives a quenching rate fast enough to produce the desired hardness. Such a steel may be subjected to high temperatures for a considerable length of time without having its properties affected. Properly heat treated carbon steel, however, can be made harder than high speed steel and is better suited for some finishing operations.

HEAT TREATMENT

Heat treating of steel usually consists of heating, quenching, tempering (drawing), and normalizing.

HEATING

The heating of steel may be accomplished in several ways, the most common of which is in furnaces especially designed for the work. The furnaces are usually heated with gas, oil or electricity. Provisions are made for accurate measurement and control of the temperatures within the furnace. Baffles are sometimes constructed in the furnace to keep the steel out of direct contact with the flames. The furnace is usually kept at a constant temperature and the piece of steel allowed to come up to the temperature of the furnace. The temperature to which the steel is heated depends upon the chemical composition and the size, and should be from 50 to 150 F above the critical temperature so as to assure a uniform structure. The range of critical temperatures of carbon steels is shown on the equilibrium diagram Figure 6. Alloy steels usually have lower critical temperatures, depending upon their composition.

In heating steel up to the critical temperature, the crystals making up the structure do not change in size. At the critical temperature, where the carbon or carbide goes into a solid solution in the iron, a decrease in size of the crystals is affected due to the change in the structure. Above the upper critical temperature, the growth of the crystals proceeds at a fairly rapid rate. The higher the temperature the faster is the rate. The growth of the crystals will continue up to a point where oxidation or burning of the metal takes place. The coarser crystalline structures are weaker and more brittle and care must be taken not to heat the steel unnecessarily. Many failures in steel are due to improper heat treatment. Failures due to unnecessary heating show a very coarse crystalline structure at the break which is entirely different from the structure when the piece fails from fatigue.

Steel which has been heated too long or too high above the critical temperature, providing it has not been burned, can have its properties restored and the crystalline structure refined by special heat treatment. The treatment consists in heating the steel just above the critical temperature where maximum grain refining takes place, and then quenching or cooling it.

Besides heating the steel in furnaces, in preparation to quenching, small pieces are sometimes heated in molten lead or salt baths.

When the steel has been properly heated it is ready for the quenching bath.

QUENCHING

The rate of the reactions and the desired properties in the finished steel will determine the rate of quenching. Since the rate of the transformation is fastest in the low carbon steels and slowest in alloy steel, the low carbon steels will require the fastest quenching medium. Besides the quenching rate, other properties of the quenching medium such as odor, corrosiveness, stability and flash point must be given due consideration.

The factors that determine the quenching rate of a medium are the specific heat, viscosity and the temperature of vaporization. The medium with the higher specific heat will absorb a greater amount of heat and its cooling action will be more effective. Viscosity, being a measure of fluidity, will indicate the ability of the medium to carry away heat by natural or forced circulation. Thus, a quenching medium with a high viscosity will be more sluggish and a less effective carrier of heat. The formation of vapor around the object prevents proper contact between the quenching medium and the object, producing an insulating effect. The medium with the lower temperature of vaporization will give off vapor sooner and will be less effective as a cooling medium. Furthermore, it is apt to cause unequal cooling of various parts of the object, due to local insulation by the vapors.

The quenching mediums employed in general practice are air, water, brine, mineral oils, compounded oils, animal oils, fish oils, vegetable oils and special liquids.

With but a few exceptions, air is not used as a quenching medium. Formerly high speed tools were air quenched but more recent practice is to use oil. Very small objects are unavoidably air quenched due to their size. The desired physical properties in such cases are obtained by very careful tempering.

Water quenching is one of the most rapid methods of cooling. It has several disadvantages, however, in the way it affects the properties of the steel. The quenching rate, especially in small objects is usually so rapid that undue stresses are set up in the piece. These stresses may cause distortion or even exceed the natural strength of the steel, thereby rupturing it. Water, furthermore, has the disadvantage that it loses its cooling efficiency more rapidly than oil with increases in the temperature. If uniform results are required, precautions must be taken to keep the bath at a nearly constant temperature. The vaporization temperature of water under normal conditions is 212 F which is comparitively low and vapor formation will affect the rate as well as the uniformity of cooling.

Oils are coming more and more into use as quenching mediums. The oils available for quenching purposes are numerous, some being less desirable than others. Fish oils have the disadvantage of giving off offensive odors, especially when heated by the steel, and like the vegetable oils, they oxidize readily and become gummy. This increases their viscosity and reduces their quenching speed. Animal oils gradually become rancid, which is undesirable. The mineral oils are best suited for quenching purposes as they are comparatively stable and do not give off bad odors. Some metallurgists claim that better results can be obtained with mineral oils which have been compounded with some animal or vegetable oil, but there are no data available to support this claim.

Oils have a slower cooling rate than water or brine but for that reason the cooling stresses set up in the piece are much smaller and the available strength of the steel is greater. Alloy steels, furthermore, do not require such a rapid quenching rate as is obtained with water or brine. As a result, oils are used almost exclusively. Oils vaporize at a much higher temperature than water or brine and their cooling effect is only slightly reduced by a considerable increase in the temperature of the bath. For uniform results it is sufficient to keep the temperature of the bath within a range of 50 F. For this temperature range, the quenching rate varies only 2 to 3 per cent.

There are several ways in which the quenching bath may be cooled, all of which are useful depending upon the particular conditions. The most simple method is to rely on the natural dissipation of the heat from the tank to the air. This method may be used where the quantity of the quenching liquid is large in comparison to the amount of steel quenched.

Where quenching is done on a quantity production basis, some means must be employed for cooling the quenching bath. There are three general methods by which this can be done. One is to circulate the oil in a radiator or coil which may be air, water, or brine cooled. Another method is to circulate water or brine through a coil which is immersed in the bath. The third method is to use compressed air.

The extent to which any of the above methods is employed depends on the individual requirements of the work under consideration.

Best results in keeping down the temperature of the oil bath are undoubtedly obtained when the oil in the tank itself is circulated. By circulating the oil through external cooling coils or radiators, cooled oil is continually brought into the vicinity of the hot metal and the heated oil is carried away. It is possible by this method to maintain more constant temperatures in the bath.

The most efficient of the methods in which the oil is circulated is the one which employs brine cooling of the coils or radiator. The brine is cooled in a regular refrigerating plant and is circulated around the coils carrying the oil. The oil can be cooled very quickly and to almost any desired temperature by regulating the flow of the oil through the coils and the temperature of the brine. Where the size of the plant does not warrant such an expensive installation, the coils may be cooled by submerging them in a tank of running water, or by spraying them with water. The method of circulating the oil through air-cooled radiators is the least efficient of these methods, but is serviceable where the amount of work handled is small in comparison to the quantity of oil carried in the circulating system.

Systems which rely on convection for the circulation of the oil to carry the heat from the steel to water-cooled coils immersed in the tank are not so efficient as the systems in which the oil is mechanically circulated. This is due to the fact that very little of the heat is dissipated by conduction through the oil, and the natural circulation of the oil is comparatively slow.

In systems where the oil is not circulated, air is sometimes used for agitating purposes. However, care must be observed in its use. It must come in direct contact with the steel as soft spots would result. It should not be used in animal or vegetable oil baths, and is undesirable where compounded oils are used because of the rapid oxidation it causes. If properly used, it will assist considerably in cooling the bath.

The volume of the quenching medium to be used, and hence the size of the tank, depends upon the size and the number of pieces to be quenched per hour and the method of cooling the bath. Where means are provided for cooling the bath, good practice is to use 15 lbs. of oil for each pound of steel quenched per hour; a ratio of less than 10 to 1 should not be used. For uncooled baths, the ratio of oil to steel quenched per hour should be higher. A tank should be of sufficient size to handle with ease the largest pieces to be treated and leave a generous allowance for the circulation of the quenching medium. The tank, of course, must be designed to handle the full working capacity of the plant, and it is much more desirable to have the tank too large than too small.

TEMPERING

The rate of the transformation, especially in carbon steels, is so rapid at red heat that it is almost impossible to cool or quench the steel at the instant that the desired structures are present. Tempering is therefore sometimes used for agitating purposes. However, care must be observed in its use. It must come in direct contact with the steel as soft spots would result. It should not be used in animal or vegetable oil baths, and is undesirable where compounded oils are used because of the rapid oxidation it causes. If properly used, it will assist considerably in cooling the bath.

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TEMPERING

The rate of the transformation, especially in carbon steels, is so rapid at red heat that it is almost impossible to cool or quench the steel at the instant that the desired structures are present. Tempering is therefore resorted to.

Although the time of the complete transformation at red heat is from ten to thirty seconds, the rate drops off very rapidly with a decrease in temperature, thus at 1300 F approximately one minute would be required; at 750 F, two hours, and at 400 F it would take about a hundred days.

Tempering consists in raising the temperature of the steel, after it has been quenched to give a structure slightly harder than necessary, to a point where the transformation proceeds at a controllable rate. When the steel has reached the desired structure, it is again rapidly cooled.

As stated before, quenching leaves the steel hard but brittle and subjected to severe internal stresses. Tempering reduces these stresses, making the steel stronger and tougher but softer, and the only way to obtain a hard and strong steel is by using alloying elements which decrease the necessary quenching rate, thereby eliminating to a large extent the internal stresses.

Tempering Control

The amount of tempering may be closely estimated by the color of the oxide film which forms on a polished surface of the steel when heated in the open fire, or open furnace. The corresponding colors and temperatures of steel during tempering are given in the following chart:

Temperature		Color
Deg. C.	Deg. F.	
225	440	Light Straw
240	466	Dark Straw
255	493	Yellowish Brown
265	511	Reddish Brown
275	530	Purple
285	547	Violet
305	585	Blue
330	627	Gray

The above table may be used as a comparison, only when the steel is heated at a moderately rapid rate, as the time element has a decided effect. Thus the steel, when heated at a given temperature for a period of time, will also change color in the order indicated in the chart. Of course, the higher the tempering temperature the faster will be the rate of tempering. The fact that the tempering color includes both the time and temperature elements makes it a fairly reliable means for controlling the tempering effect. For best results, especially in quantity production, it is advisable to control the amount of tempering by standardizing the time and the temperature at which the tempering is done. For these reasons steel is usually tempered by heating it for a definite time in ovens or baths which are kept at a certain temperature. Constant temperature oil baths are most desirable in heating steel to temperatures below 525 F, as with these it is possible to obtain more uniform heating with less trouble than by other means. Above 525 F fused salts or lead must be used for the heating bath.

APPLICATION OF ALLOY STEELS

In order to select the proper type of steel for a particular application, something of the characteristics of the steel must be known. Since these characteristics vary, not only with the analysis of the steel, but also with the heat treatment to which it may be subjected, it is advisable to know something about the heat treatment required to bring out the characteristics required.

Heat Treatment

When steel is heated beyond a certain temperature, certain internal structural changes take place in the metal. The temperature at which these changes take place is known as the critical temperature. These changes do not take place instantaneously. There is a time element present, and by taking advantage of this time element, the process of heat treating is made possible in that the steel is heated above the critical temperature and cooled more rapidly than a reversal of internal changes can take place.

At normal or room temperature, steel can exist in four states:

(1) "as rolled" condition, either hot or cold rolled

(2) Annealed condition and/or normalized

(3) Fully hardened

(4) Drawn or tempered after hardening

The "as rolled" steel is most common in industry today. Cold rolled or cold drawn steel is hot rolled steel which has either been rolled or drawn through dies while cold. The bars are sized by this process and are given a smooth bright finish.

Annealing

Annealing is defined as "a uniform heating above the critical temperature followed by slow cooling". Annealing produces three results:

(1) Softens steel for better machining

(2) Relieves stresses due to rolling or forging

(3) Refines the grain

Normalizing

Normalizing consists in heating the steel to approximately 100 F above the critical temperature and cooling in still air at ordinary temperature. Normalizing relieves strains due to machining, rolling, etc., and prevents distortion in subsequent heat treatment.

Hardening

A hard surface can be produced in a steel in two ways:

(1) By heating a high carbon alloy above the critical temperature and quenching.

(2) Case hardening a low carbon alloy by carburizing and hardening.

All carbon steel can be hardened to a degree depending upon the carbon content. The maximum hardness is obtained at about .85% carbon. Alloying other materials with the iron and carbon does not change this fundamental law. With alloys, however, the critical temperature will vary with the kind of alloy.

REVIEW QUESTIONS

T F In heating steel up to the critical temperature, the crystals making up the structure do not change in size.

T F As the steel is heated above the lower critical temperature an increase in size of grain will be expected.

T F Above the upper critical temperature, the growth of crystals proceeds at a fairly rapid rate.

T F Burned metal can have its properties restored and crystalline structure refined by special heat treatment.

T F Alloy steels have critical temperatures which are determined only by their carbon content.

T F The rate of transformation of grain structure is fastest in alloy steel.

T F Low carbon steels require the fastest quenching medium.

T F Water is a faster quenching agent than oil.

T F Tempering reduces the hardness of steel.

T F Tempering reduces the ductility of steel.

T F Tempering makes steel tougher.

T F Tempering reduces internal stresses set up in quenching.

T F Tempering is resorted to because of the slow rate of transformation of structure above the critical temperature.

T F The temperature is the only essential item in satisfactory tempering.

T F Alloying elements which go into solid solution decrease the necessary quenching rate.

T F Alloy steels are usually subjected to higher internal stresses on quenching than are plain carbon steels.

DIFFERENCE BETWEEN TEMPERING AND QUENCHING OILS

The difference between quenching and tempering oils lies not only in their use but also in their properties.

Quenching oils, as previously explained, are used for removing heat from steel. They are kept cool so that they would be more effective in removing the heat from the steel. The temperatures of the quenching baths seldom exceed 150 F. This permits the use of comparatively light oils which circulate readily and carry away the heat more rapidly. These oils have a low flash point corresponding to their viscosity.

Tempering oils, on the other hand, are used for heating the steel for drawing. The temperatures of oil heating baths run as high as 525 F. The baths are held at constant temperatures and the oil must be of such consistency as to withstand these high temperatures over long periods of time. These oils must be heavy in body so that minimum vaporization takes place and must have a high flash point in order to reduce the fire hazards.

The fallacy of the improper use of these oils cannot be stressed too much, and before making any recommendation, the problem on hand should be carefully considered.

ANNEALING

Annealing is a heat treating process used for three purposes in general:

(1) To soften the steel, thereby making it more machinable;

(2) To relieve internal stresses;

(3) To refine the grain.

Annealing consists in heating the steel uniformly above the upper critical temperature, and then cooling it slowly as desired.

Not only shrinkage stresses caused by unequal cooling of complicated sections, but also fatigue stresses due to alternate loading and unloading, such as occur in moving parts of machinery, can be removed by annealing.

CASE HARDENING

Case hardening is used where it is desirable to have a tough and resilient piece of steel with a very hard surface to resist wear.

Carburizing consists in heating a piece of low carbon steel (.15 to .22% C) usually above the critical temperature in the presence of some carburizing material, such as charcoal. Carbon monoxide gas is given off by the carburizing material and acts as a carrier of carbon to the surface of the steel. The oxygen which is released when the carbon is absorbed forms more carbon monoxide gas with the carburizing material and in that way the process of carburization is carried on. It is necessary to heat the steel at a temperature corresponding to at least the lower critical temperature (M-O, Figure 6), as a part of the steel is then in the austenitic formation and capable of absorbing the carbon in a solid solution. A greater degree of carburization is possible with the higher temperatures, as the amount of steel in the austenitic state increases with the temperature, reaching a maximum at the upper critical temperature.

Care must be taken to exclude excess air, as oxidation instead of carburization of the steel would take place. In practice, the piece of steel is packed with the carburizing material inside of a cast steel or cast iron box, which is then sealed. The time of heating will depend upon the desired depth of penetration of the carbon into the surface of the steel and the temperature of heating. The higher temperatures up to a certian point give a higher rate of carburization. The rate of diffusion of the carbon into the interior of the steel must be considered, as it is possible to carburize at a rate slow enough to give the piece of steel a uniform structure thoughout. On the other hand, if the rate of carburization is too high, the surface of the steel may become oversaturated with carbon, leaving an uneven structure. The proper rate is best determined by experiment. All indications are that steel which has been carburized at a lower temperature and longer period of time shows the best properties.

After the steel is carburized, it must be heat treated in order to bring out the properties of case hardened steel. The heat treatment of carburized steel will vary according to the temperature and time of heating. The piece of carburized steel may be considered as being made up of two or more steels having different carbon contents. The low and the high carbon parts have different critical temperatures. When the steel has not been heated too high above the upper critical temperature of the original piece, the core part usually does not require a special treatment for the refining of the grain. The case, however, being of higher carbon content and heated for a considerable length of time has a coarse grain structure. Therefore, the carburized piece after it has cooled is reheated to the upper critical temperature of the case portion and is then quenched. The second heating does not affect the core and gives the case the proper treatment. When the steel has been heated above the upper critical temperature of the core (1800 F), the grain throughout the piece requires refining. The carburized piece is first heated just slightly above the upper critical temperature of the core, giving that part the maximum grain refining. It is then quenched or cooled slowly and reheated to the upper critical temperature of the case. After quenching again, the case is left very hard, but the core comparatively soft. Any internal stresses produced in the core by the first quenching are relieved by the second heating.

CYANIDING

Cyaniding is used where a skin hardness is desired. The steel is immersed in a bath of molten potassium cyanide (1560 F) which produces a quick but superficial case. Although the case is hard, it is very thin and will not stand the wear or abuse that a carburized type of case will.

NITRIDING

Nitriding is a more recently developed form of case hardening in which the heated steel is subjected to ammonia gas, from which it absorbs nitrogen. The nitrides thus formed give the steel a hard surface with need of furthur heat treatment. The steel used generally contains at least 1.00% aluminum, but even cast iron has been successfully nitrided.

HEAT TREATING DEFINITIONS (Especially as Related to Ferrous Metals)

Steel. An alloy of iron and carbon with a carbon content less than two percent, initially cast and malleable in some range of temperature.

Carbon Steel. Steel which owes its properties chiefly to various percentages of carbon without substantial amounts of other alloying elements. Also known as ordinary steel or straight carbon steel.

Alloy Steel. A steel made by incorporating with the iron some element in addition to carbon, in sufficient quantity to confer special properties on the steel.

Alloy Elements. Elements other than carbon added for the purpose of improving properties.

High Speed Steel. An alloy steel used for tools. It owes its properties chiefly to the alloying elements, which are tungsten and chromium in addition to carbon.

Cast Steel. Any object made by pouring molten steel into molds.

Heat Treatment. An operation or combination of operations involving the heating and cooling of a metal or alloy in the solid state for the purpose only of obtaining certain desirable conditions or properties.

Quenching. Rapid cooling by immersion in liquids such as brine water and oil solutions.

Hardening. The heating and quenching of certain iron base alloys from a temperature either within or above the critical range.

Tempering. The reheating, after hardening, to some temperature below the critical range, followed by any desired rate of cooling. NOTE: Annealing is a comprehensive term. The purpose of such a heat treatment may be:

a. To remove stresses;
b. To induce softness;
c. To refine the crystalline structure;
d. To alter the ductility, toughness, electrical, magnetic, or other physical properties;
e. To produce a definite microstructure.

Normalizing. Heating iron base alloys to approximately 100 F above the critical temperature range followed by cooling to below that range in still air at ordinary temperature.

Spheroidizing. Prolonged heating of iron base alloys at a temperature in the neighborhood of, but generally slightly below, the critical range, usually followed by slow cooling.

Carburizing. The adding of carbon to iron base alloys by heating the metal below its melting point in contact with a carbonaceous material.

Case Hardening. The carburizing and subsequent hardening by suitable heat treatment, of all or part of the surface of an iron base alloy.

The Case of a carburized or case hardened iron base alloy article is that portion in which the carbon content has been substantially increased.

The Core. That part wherein the carbon content has not been substantially increased.

Cyaniding. The surface hardening of an iron base alloy article by heating at a suitable temperature in contact with a cyanide salt, followed by quenching.

Nitriding. Adding nitrogen to iron base alloys by heating the metal in contact with ammonia gas or other suitable nitrogenous material. NOTE: Nitriding is conducted at a temperature below the iron-carbon critical range and produces surface hardening of the metal without quenching.

Decarburization. The removal of carbon usually refers to the surface of solid steel.

Decalescence. The absorption of heat which occurs when steel is heated through the AC_1 point shown on the iron-carbon diagram.

Recalescence. The liberation of heat when steel is cooled through the AR_1 point.

Fracture. The irregular surface produced when a piece of metal is ruptured or broken.

Fracture Test. Breaking a piece of metal for the purpose of examining the fractured surface.

Grains. Groups of crystals in metals. Each grain consists of crystals oriented in one direction.

Grain Growth. An increase in the grain size of metals.

Overheating. Heating to such high temperatures that the grains have become coarse, thus impairing the properties of the metal.

Burning. The heating of a metal to temperatures sufficiently close to the melting point to cause permanent injury.

MACHINING HINTS

Metals vary greatly in cutting characteristics, and must be machined with suitable techniques. The following hints on machining the more common of them are intended as an aid in setting up jobs initially. On long runs or repetitive jobs, adjustments may be made by analysis of tool wear.

STEEL

Carbon and Alloy Steels

These have much the same cutting characteristics. Both cut with a continuous chip and form a built-up edge on the tool if run at low speeds. As speed increases, a "Critical" point is reached above which the built-up edge is swept away and cutting is more efficient, tool life greatly extended, and finish improved. This critical speed is affected by hardness of the steel, chip thickness, and to a lesser degree by the depth of cut. Good cutting practice is usually 50% to 100% above critical speed. Soft "gummy" steels, such as boiler plate or SAE 1010, require very high machining speeds to remain safely above the critical speed and thus cut efficiently, whereas steel hardened to 300 Brinell cuts efficiently at less than 1/2 the speed. Similarly, light cuts (chip thickness and depth) require more speed than heavy cuts.

Because of the strong, continuous chip, steel tends to crater or erode the top face of the tool. A flat chip will curl away from the top face of the tool with comparatively light force, whereas the same amount of steel in a channel shaped chip has greater structural rigidity and requires more force to deflect. When the tool has a large nose radius, a curved or channel cross section is produced in the chip thus requiring higher tool pressure and power.

When the tool has a small nose radius, a flat ribbonlike chip is produced, tool life is better, and less power is required.

Stainless Steels

From the standpoint of machining characteristics, these steels divide into two groups: the hardenable (magnetic), and the austenitic (non-magnetic). Hardenable stainless steels machine much the same as alloy steels of equal hardness, and the foregoing recommendations will apply. Austenitic stainless steels such as 18-8, type 300, etc., are work hardening, yet soft and gummy in their tendency to tear and to build up on the cutting edge. The build-up tendency calls for high speed, whereas the work-hardened chip and machined surface call for speeds in the lower ranges to prevent excessive tool wear. The best condition is therefore a compromise, with a feed rate heavy enough to get under the work-hardened surface of the previous cut, recognizing that tool life will be shorter than with equivalent jobs on other steels.

High Manganese Steels

For applications involving severe impact and wear, steels with 12 - 14% of manganese are frequently used because of their extreme work-hardening properties. Cutting speeds of 35 to 100 feet per minute and feeds not less than .020", and preferably 1/16", stock should be allowed so that the finishing tool can get under the work-hardened surface.

Gray Iron

This machines with a crumbling chip and has very little tendency to build up along the cutting edge. Machining techniques are therefore quite different than for steel. Because of freedom from a built-up edge, there is no lower limit or critical speed to be considered, and tool wear is almost directly proportional to speed of cutting. Speeds up to 400 ft. per min., depending upon feed rate and depth of cut, are common. For normal cutting, such as .025" feed and .200" depth of cut, speeds of 275 ft. per min. where cutting speed is more important than tool life, are common.

The low strength chip breaks into a crumbly powder, so a large nose radius has no disadvantages, and does permit better finish, faster feed, and longer tool life.

High Tensile Cast Iron

Addition of alloys such as nickel, or use of steel scrap in cast irons to obtain higher strength cast irons, has become almost universal. These additions have little effect on the machining characteristics except that the chip is mechanically stronger and has some tendency to crater the top surface of the tool.

Chilled Iron

Surfaces of cast-iron parts deliberately chilled to high hardnesses, such as rolling mill rolls, are very abrasive on the cutting tools. Tool life is extended to a practical range by use of lower cutting speeds and stretching the chip out over a long cutting edge to finish the job with a minimum of footage passing under the cutting edge. Use of large diameter rounds or extreme lead angles on longitudinal feeds, or broad tools on cross feeds, accomplish this purpose.

NON-FERROUS MATERIALS

Copper Alloys

The alloys of copper machine with a low strength chip and can be run 500 to 1000 ft. per min. with good tool life. The aluminum bronze alloys have some tendency to build up on the cutting edge, but a speed of 250 to 500 feet per minute, depending upon hardness, will prevent this build-up.

Aluminum and Magnesium Alloys

These light-weight alloys machine readily at speeds over 500 ft. per min. The low tensile chip exerts little pressure on the tool. Rakes and clearances may therefore be increased to as much as 15^{o} for greater life and freer cutting.

Plastics

None of the common types present great machining problems but when they are combined with fillers or fibers such as clay, asbestos, cotton, paper, glass, etc., they may become quite abrasive. The more abrasive the filler, the lower the practical machining speed and shorter the tool life.

TYPES AND IDENTIFICATION OF METALS

There are three general tests which may be used to help tell ferrous metals (iron base) from non-ferrous metals (non-iron base). However, these three tests will not always give a final identity of ferrous or non-ferrous. They will, however, separate all metals into three groups making it possible to know what furthur tests should be made. These three tests are: weight test, spark test, and magnet test.

(1) Weight Test: All light weight metals are non-ferrous. Heavy metals will usually be ferrous metals. However, there are a few heavy non-ferrous metals such as nickel alloys, lead, etc. Steel, stainless steel, and cast iron are heavy ferrous metals.

(2) Spark Test: Touch a piece of metal to a grinding wheel and watch for sparks. Each type of ferrous metal will give off a distinctive spark stream. Non-ferrous metals will usually give off no sparks. The exceptions to this are: titanium, nickel and tungsten. They will give a very small spark stream which differs from the sparks made by steel.

CAUTION: DO NOT TOUCH LIGHT WEIGHT OR SOFT NON-FERROUS METALS TO AN ORDINARY GRINDING WHEEL. THEY MAY CLOG UP THE WHEEL AND CAUSE IT TO BREAK.

(3) Magnet Test: Most ferrous metals will be attracted by a magnet. Most non-ferrous metals will not be attracted by a magnet. The "300" type stainless steel used in the Air Force are ferrous metals which are non-magnetic. Nickel-chromium-iron alloy (Inconel)

is a non-ferrous alloy that is very similar to stainless steel. It is also heavy and non-magnetic. Nickel-copper alloy (Monel) is a nickel alloy that is heavy and slightly magnetic.

These three tests will separate the metals into three groups so that you will know what furthur tests should be made for final identification.

(1) Light Weight, Non-magnetic Metals: These metals are non-ferrous. The main alloys in this group will be aluminum and magnesium alloys.

(2) Heavy, Non-magnetic Metals: These metals may be either ferrous or non-ferrous. Stainless steel and Inconel will both fall in this group.

(3) Heavy, Magnetic Metals: Steel and cast iron are the main metals in this group.

RESISTANCE TO SHAPING

PLAIN CARBON ALLOYS

Material	TOOLABILITY: Hand Tools	Machine Tools	Special Tools	WORKABILITY: By Hammer: Cold	Hot	Pressure Rolls, etc.: Cold	Hot
Wrought Iron	Good	V. Fair	--	Excellent	Excellent	Excellent	Excellent
Mild Steel	V. Good	V. Good	--	Good	V. Good	Good	V. Good
Medium Carbon Steel	Good	Good	Good	V. Fair	Good	Only Fair	Fair
High Carbon Steel	V. Fair	V. Fair	Good	Poor	Only Fair	Unsuitable	Unsuitable
Cast Steel (Skin removed)	V. Fair	V. Fair	Good	Poor	Only Fair	Unsuitable	Unsuitable
Cast Iron (Skin removed)	Good	Good	V. Good	Fractures	Crumples	Unsuitable	Unsuitable

OTHER CARBON ALLOYS

Material	Hand Tools	Machine Tools	Special Tools	By Hammer: Cold	Hot	Pressure Rolls: Cold	Hot
Chromium Steel	V. Fair	Difficult	V. Fair	Tough	Good	Tough	Good
Nickel Steel	Good	Good	Good	Good	Good	Good	Good
High Speed Steel	Good	Good	Good	Cracks	Fair	Cracks	Fair
Nickel Cast Iron	Good	Good	Good	Fractures	Crumples	Unsuitable	Unsuitable

NON FERROUS ALLOYS

ALLOY	TOOLABILITY AND WORKABILITY
The Alpha Brasses	File readily with new files. Unpleasant to machine. Chip comes away in long ribbons with sharp jagged edges leaving surface torn and rough. Will stand large amount of Cold Work (draws readily) [illegible] for Hot Working.

NON FERROUS ALLOYS (continued)

ALLOY	TOOLABILITY AND WORKABILITY
The Alpha Beta Brasses	File readily. Readily machinable particularly if Brass is "Leaded." Small 'grain' chips. Poor Cold Working qualities but Hot Works very well.
The Bronzes	In general all these have fair to good cutting properties.
The Cupro Nickels	Machinable and readily Hot Worked.
The Aluminums	All readily machinable. Some Die Castings tend to be very short.

WHICH METAL IS IT - A REFERENCE CHART

Material	Appearance (a) Surface	(b) Fracture	Sound
Wrought Iron	Red or black and scaly	Fine fibrous fracture	Dull note
Black Mild Steel Bright	Grey, black and rough. Polished bright grey	Light grey. Medium crystalline structure	Dull clang
0.4% Carbon Steel	Grey-black	Light grey. Medium crystalline	Dull clang
1.0% Carbon Steel	Blue-black patches of smooth scale	Very light grey Fine crystalline	Medium to high ring
(As Cast) Grey Cast Iron (Machined)	Dull grey, rough, pitted, sandy Light grey, dirty Fairly smooth	Dark grey, coarsely crystalline. Dark blobs.	Very dull note
High Speed Steel	Fine blue-black sheen, or "Bright ground"	Fine sparkling crystals	Very high ring
Brasses	Bright yellow. May be due to oxides	Coarsely crystalline	Sonorous
Aluminum (pure)	Very light or silvery grey	White crystalline	Dull note
Copper	Reddish-brown to green due to oxides	Bright fine crystals	Sonorous

WHICH METAL IS IT - A REFERENCE CHART (continued)

Material	Spark Type	Toolability	Heated Red Hot and Quenched	
		Held in Vice and filed	(a) File Test	(b) Work on Anvil Under Hammer
Wrought Iron	Medium forked sparklers, Yellowish-red	File drags. Slag threads damage tool.	No change	No change
Black Mild Steel Bright	Many white sparks with few forked sparklers	Cuts very readily	No change	No change
0.4% Carbon Steel	Many white sparks with few forked sparklers	Cuts quite readily	Hardening just noticeable	No appreciable difference
1.0% Carbon Steel	Many small repeating whitish-red sparklers	Marked resistance to cutting	Will not file Glass hard	Very brittle Splinters
(As Cast) Grey Cast Iron (Machined)	Short stream of small repeating sparklers. Red to yellow	Hard skin damages tool edges - remove this, files well	No appreciable difference	No appreciable difference
High Speed Steel	A few dull red sparklers	Resists strongly Work hardens badly	Will not file	Shatters
Brasses	No spark	Files well (use new file)	No appreciable change	Varying effects
Aluminum (pure)	No spark	Cuts very easily File clogs	No appreciable change	No change
Copper	No spark	Cuts easily File clogs	Cuts very easily	Increased ductility

WHICH METAL IS IT - A REFERENCE CHART
(continued)

Material	Spark Type	Toolability	Heated Red Hot and Quenched	
		Held in Vice and filed	(a) File Test	(b) Work on Anvil Under Hammer
Wrought Iron	Medium forked sparklers, Yellowish-red	File drags. Slag threads damage tool.	No change	No change
Black Mild Steel Bright	Many white sparks with few forked sparklers	Cuts very readily	No change	No change
0.4% Carbon Steel	Many white sparks with few forked sparklers	Cuts quite readily	Hardening just noticeable	No appreciable difference
1.0% Carbon Steel	Many small re-peating whitish-red sparklers	Marked resistance to cutting	Will not file Glass hard	Very brittle Splinters
(As Cast) Grey Cast Iron (Machined)	Short stream of small repeating sparklers. Red to yellow	Hard skin damages tool edges - re-move this, files well	No appreciable difference	No appreciable difference
High Speed Steel	A few dull red sparklers	Resists strongly Work hardens badly	Will not file	Shatters
Brasses	No spark	Files well (use new file)	No appreciable change	Varying effects
Aluminum (pure)	No spark	Cuts very easily File clogs	No appreciable change	No change
Copper	No spark	Cuts easily File clogs	Cuts very easily	Increased ductility

WHICH METAL IS IT - A REFERENCE CHART
(continued)

Material	Workability Tests			
	Hammered Cold		Hammered Hot	
	(a) On Anvil	(b) In Vice	(a) On Anvil	(b) In Vice
Wrought Iron	Flattens well before cracking	Bends repeatedly before cracking	Works easily Hand welds readily	Bends freely
Black Mild Steel Bright	Flattens reasonably before cracking	Bends well before fracture	Works and welds well	Bends well
0.4% Carbon Steel	More resistance to flattening	Bends. Slight spring	Works well between bright and dull red	Bends well
1.0% Carbon Steel	Resists strongly Finally fractures	Resists-bends a little-then snaps	Works reasonably but only between bright and cherry red	Bends quite well
(As Cast) Grey Cast Iron (Machined)	Shatters	Snaps short Brittle	Collapses (is "hot short")	Snaps easily Hot short
High Speed Steel	Great resistance Finally shatters	Snaps without bending	Can be worked	Bends - some resistance
Brasses	Considerable variations Ductile to brittle		Considerable variations Ductile to brittle to "Hot Short"	
Aluminum (pure)	Flattens readily	Bends well	Collapses (Hot Short)	Collapses
Copper	Flattens easily Work hardens	Bends very easily	Works easily	Bends easily

CHAPTER III

HAND TOOLS

A machinist must be skillful in the use of a number of hand tools that are used in bench work operations. He may be assembling a piece of equipment or fitting metal parts. Such work commonly includes small pieces which are finished by hand or must be fitted together after they have been machined.

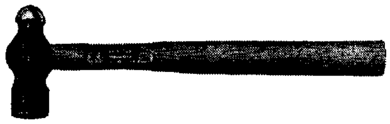
Bench and assembly work require skillful use of hand tools; therefore a machinist must develop manual skills through constant use and practice. The condition of hand tools relates the efficiency of a mechanic's work. All tools should be kept clean and in first class condition.

The most common hand tools used by machinists are hammers, files, hack saws, chisels, punches and wrenches. These tools are frequently used for metal fitting and assembly work, along with a number of basic layout tools, such as scribes, steel rules, dividers, prick and center punches, combination squares, and layout plates. The following descriptions identify some of the most used hand tools.

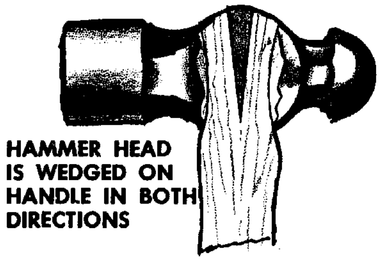
IMPACT TOOLS

Ball Peen Hammers

The typical hammer used by machinist is the ball peen hammer. The flat face of the hammer is used for general work and the ball end for peening or riveting. Peening or swaging may be defined as the stretching or spreading of metal by hammering. Ball peen hammers are classed according to the weight of the head ranging from 4, 6, 8, 12 oz. and 1, 1 1/2, and 2 lbs. (Figure 8)

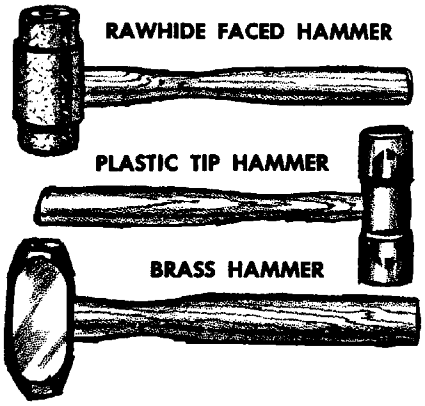


(Figure 8)



Soft Head Hammers

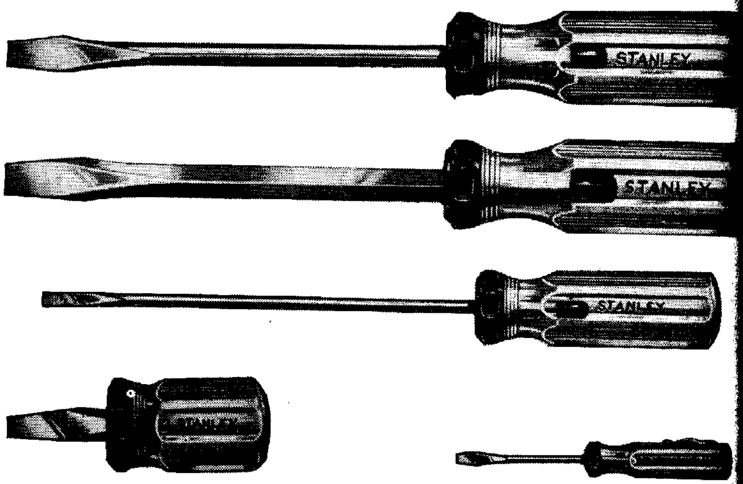
There are several types of hammers that are required for general machine work that will not mar or upset metal parts when hammering. These hammers are made of lead, plastic, rawhide or brass.



(Figure 9)

Screw Drivers

For loosening and tightening screws, and bolts, the screw driver is the most frequently used tool in the shop. It is also one of the hand tools quite frequently misused (Figure 10)



(Figure 10)

Slots and grooves on screws and bolts will vary in width; therefore the selection of the correct size screw driver is very important. The use of the screw driver for prying or as a chisel should be avoided.

Phillips type screw drivers have become very popular in recent years because of the many Phillips head screws used by automobile and truck manufacturers, especially on mouldings and other trim. The heads of these screws have two slots which cross at the center. Their advantage over screws with standard slots is that the screw driver can't slide sideways out of the slot and mar the finish. However, more downward pressure must be exerted on the Phillips screw driver to keep it in the cross slot than to keep a correctly ground standard screw driver in a standard screw slot.

An offset screw driver is frequently used where there isn't sufficient space to work a standard screw driver. The offset screw driver has one blade forged in line with the shank or handle and the other blade at right angles to the shank. With such an arrangement, when the swinging space for the screw driver is limited, the mechanic can change ends after each swing and thus work the screw in or out of the threaded hole.

If a screw driver blade becomes damaged through misuse or if a corner chips off because the blade is too hard, the screw driver can be made serviceable again by grinding it on an emery wheel.

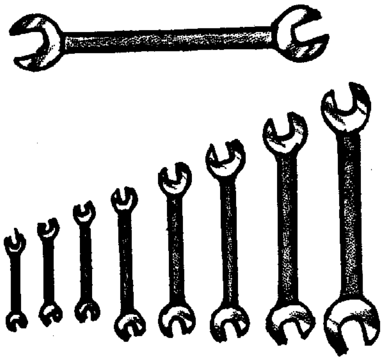
WRENCHES

Open-end Wrenches

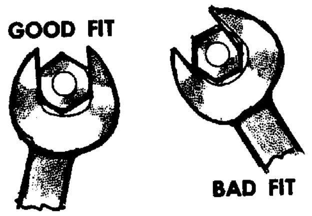
Solid, non-adjustable wrenches with openings in each end are called open-end wrenches. The average set in a good tool kit numbers about 10 wrenches with openings that range from 5/16 to 1 inch in width. This combination of sizes will fit most of the nuts, cap-screws and bolts (Figure 11)

The size of the openings between the jaws determines the size of the wrench. The smallest wrench in the ordinary set has a 5/16 inch opening in one end and a 3/8 inch opening in the other. Consequently, it would be called a 5/16 by 3/8 open-end wrench.

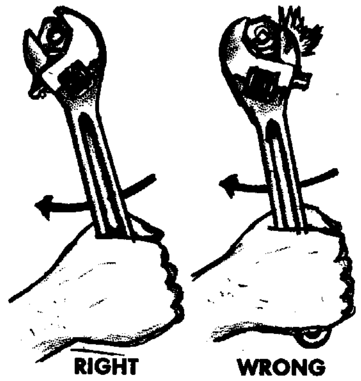
There are a few simple rules for the correct use of open-end wrenches: Be sure that the wrench fits the nut or bolt head. When you have to put a hard pull on a wrench, such as when loosening a tight nut or tightening a loose nut, make sure the wrench seats squarely on



Open-end



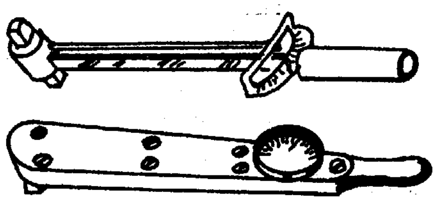
(Figure 11)



Adjustable
(Figure 12)

Box
(Figure 13)

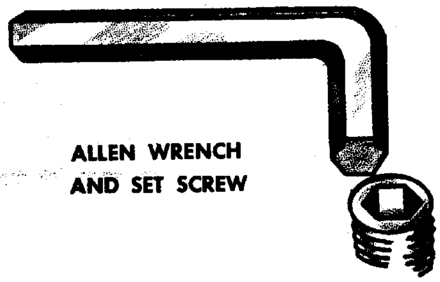
the sides of the nut. Always pull on a wrench - don't push: Pushing on a wrench is dangerous. When you push on a wrench to loosen a tight nut and the nut breaks loose unexpectedly, you will invariably strike your knuckles against some part you overlooked (Figure 11).



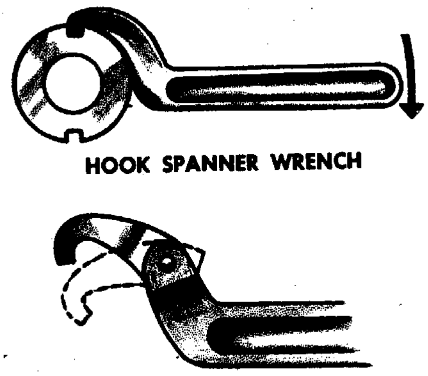
(Figure 14)

Adjustable Wrenches

Adjustable wrenches are shaped somewhat similar to open-end wrenches but have one jaw adjustable. The name is somewhat confusing because the ordinary monkey wrench is also adjustable. However, whenever the term "adjustable wrench" is mentioned, it refers only to a wrench which is somewhat like an open-end wrench but has an adjustable jaw. The angle of the opening to the handle on an adjustable wrench is 22-1/2 degrees. The usual set of adjustable wrenches consists of a 4, 6, 8, 10 and 12-inch wrench, but they also are made in 15 and 18-inch. A large 18-inch adjustable wrench is very useful for maintenance work on tanks. Some wrench manufacturers make double-end adjustable



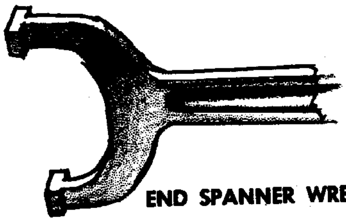
(Figure 15)

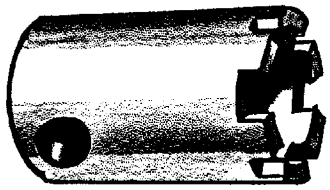


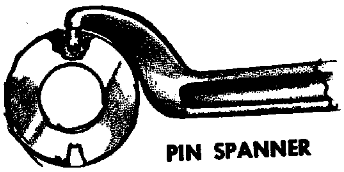
(Figure 16)

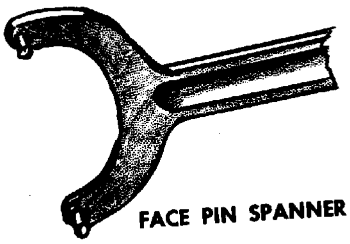
wrenches with an adjustable opening on each end.

Adjustable wrenches aren't intended for hard service - treat them gently. Whenever you have to exert any amount of force on an adjustable wrench to "break loose" a tight nut or "snug down" a nut which is being tightened - there are two important points to remember. First, always place the wrench on the nut so that the pulling force is applied to the stationary jaw side of the handle. Adjustable wrenches can withstand the greatest force when used in this manner. Second, after placing the wrench on the nut, tighten the adjusting knurl so the wrench fits the nut snugly. If these two precautions are not observed, the life of an adjustable wrench will be short (Figure 12).


END SPANNER WRENCH


END SPANNER WRENCH


PIN SPANNER


FACE PIN SPANNER

(Figure 17)

Box Wrenches

Box wrenches are very popular among mechanics. One reason for this is that they can be operated in very close quarters. They are called "box" wrenches because they box or completely surround the nut or bolt head. In place of a hexagon or six-sided opening, there are 12 notches arranged in a circle. A wrench with this type opening is called a 12-point wrench. A 12-point wrench can be used to continuously loosen or tighten a nut with a minimum swing of the handle of only 15 degrees compared to a 60-degree swing of the standard open-end wrench, or to a 30-degree swing with the open-end wrench if it is flopped after every swing. A 60-degree swing is one-sixth of a full circle. Another advantage of the box wrench is that there is no chance of the wrench slipping off the nut and it can't spread on the nut. Because the sides of the opening in a box wrench are so thin, it is ideally suited for nuts which are hard to get at with an open-end wrench.

Torque Wrenches

Another accessory for the socket wrench set is a handle which measures the amount of pull you put on the wrench. This is called a "torque wrench." Torque is the amount of turning or twisting force applied on the nut. On some makes of torque wrenches a pointer indicates on a scale the amount of force being applied. On others you set the dial for the amount of torque or twisting effort you wish to apply. Then, when you pull on the wrench, a light flashes the instant that amount of force is applied.

The accuracy of torque-measuring depends a lot on how accurately the threads are cut, the amount of lubrication applied to the threads and the type of lubrication. Readings shown by the wrench are much more accurate when the threads are lubricated (Figure 14).

Set-screw Wrenches

The most common type is hexagonal to fit the hexagon socket in the set screw. The trade name for this type is an Allen wrench. The other two types are made from round bar stock and each end is fluted to fit the flutes or little splines in that type set screw (Figure 15)

Spanner Wrenches

Spanner wrenches are special wrenches for special jobs. They are supplied as special wrenches in the tool equipment furnished to service certain units (Figures 16 & 17)

There are a number of types. The "hook spanner" is for a round nut which has a series of notches cut in the outer edge. The hook or lug is placed in one of the notches with the handle pointing toward the direction in which the nut is to be turned. Some hook spanner wrenches are adjustable and will fit nuts of various diameters.

U-shaped hook spanners have two lugs on the face of the wrench to fit notches cut in the face of the nut or screw plug.

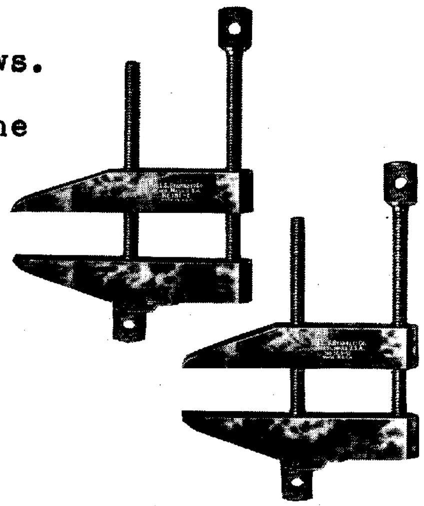
End spanners resemble a socket wrench but have a series of lugs on the end that fit into corresponding notches in the nut or plug.

Pin spanners have a pin in place of a lug and the pin fits into a round hole in the edge of the nut.

Face pin spanners are similar to the U-shaped hook spanners except that they have pins instead of lugs.

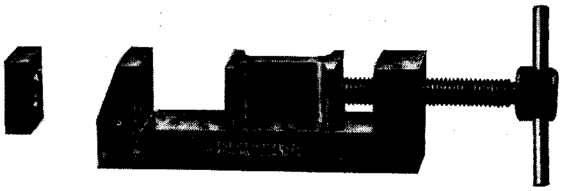
CLAMPS AND VICES

TOOLMAKERS' PARALLEL CLAMP



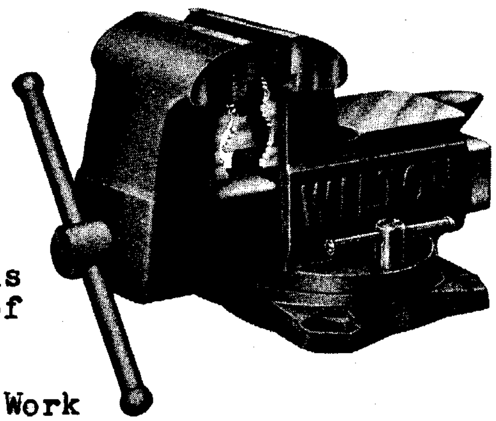
The parallel clamp has two knurled screws. The screws on the outside push the jaw apart. The resulting leverage clamps the work when the jaws are parallel. The jaws must be parallel so that the full surface of the jaws covers the work. If the jaws do not clamp the work evenly, the work will slip. Parallel clamps are extremely useful for holding work together in tapping and drilling small parts.

TOOLMAKERS' HAND VISE



The toolmakers' hand vise is a small hand vise with two interchangeable blocks. The choice of block to be used depends on the size of the work to be held by the vise. The vise is used for drilling and tapping small parts.

MACHINIST VISE



The bench vise is the most useful work holding device for clamping work for most bench work operations. On many vises, the immovable jaw is fixed to a swivel base that may be rotated on its axis to secure a better position for the work if it is at an angle to the normal position of the vise.

The vise jaws are hardened and serrated to grip the work rigidly. Work that must not be marred can be protected by using soft removable jaws made of copper.

CHISELS

Cold chisels are made from tough steel containing 70-point to 90-point carbon (meaning .7 per cent to .9 per cent carbon). Chisel steel is usually octagonal in shape, though it may be hexagonal or rectangular. The size of the chisel is determined by the width of the cutting edge, which should not be more than the size of the cross section of the steel used.

The ground surface of a chisel is called the "facet." Flat and cape chisels have two facets, while the diamond point, the round nose, and the gauges have only one facet. The flat and cape chisel to be used for chipping should be ground so that the facets form an angle of 70° for cast iron; about 60° for steel; about 50° for brass; and about 40° for babbit, copper, and other soft metals. Each facet should be uniform, making an equal angle to the axis of the chisel. When using the chisel, too deep a chip should be avoided. About 1/8" is deep enough. The last chip should be about 1/32".

Whenever it becomes necessary to file or work cast iron by hand, the original cast surface (scale) should be removed by chipping since this surface is very hard and would quickly dull a file.

As chipping is done below the scale, the chisel should not be injured. Chipping also saves time, for metal may be removed faster with the use of a hammer and a chisel than with the use of a file.

A flat cold chisel is used for chipping flat surfaces, cutting thin metals, cutting off rivet heads, and splitting nuts that have become rusted on bolts. A cape chisel is used to cut keyways or narrow grooves in metal. A round nose is used for cutting oil grooves in bearings or for making small fillets. A diamond point is used to draw drills back when they start working away from the line they are supposed to drill to; also, to cut square corners. No matter what kind of chisel you are using, keep it sharp.

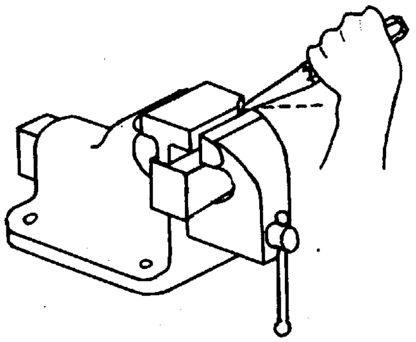
When chipping metal, the depth of the cut is controlled by the angle at which you hold the chisel. Don't try to take too deep a cut. For rough cuts, one-sixteenth of an inch is enough, with half that much or less for finishing cuts.

Keep your eyes on the cutting edge of the chisel. Swing the hammer in the same plane as the body of the chisel. Strike one or two light blows to check your "swing," then increase the force as required.

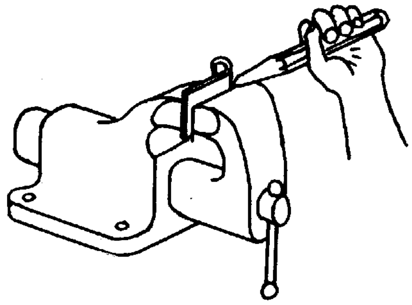
When using a chisel for chipping, always wear goggles to protect your eyes. If there are other men close by, see that they wear goggles or are protected from flying chips, or else put up a screen or shield to keep the chips from hitting anyone. These two precautions can save many a man from losing the sight of an eye.

METAL FITTING

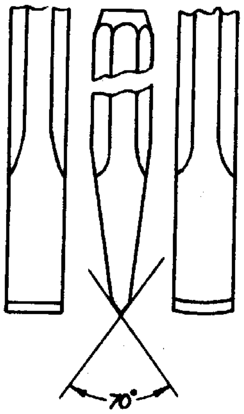
How To Use Cold Chisels



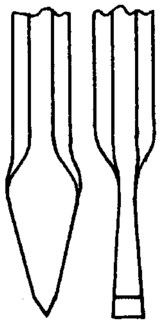
Chipping. Note how the chisel is held.



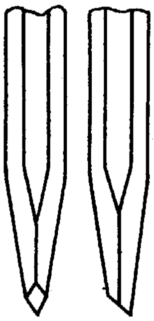
Shearing cut in a vise. Note another method of holding a chisel.



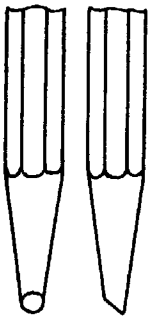
Flat Chisel



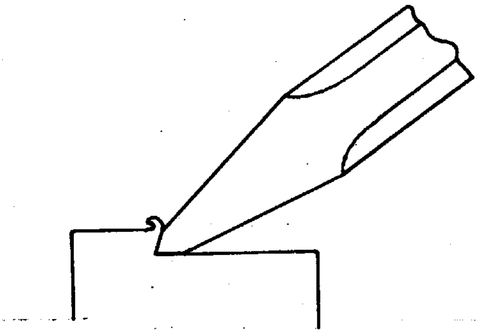
Cape Chisel



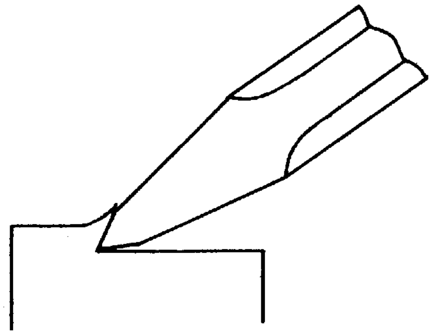
Diamond Point



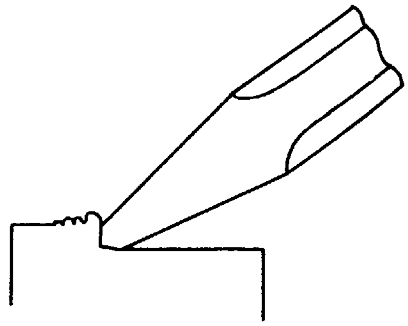
Round Point



Correctly Ground Chisel



Ground Too Sharp



Too Blunt

HAND SCRAPING

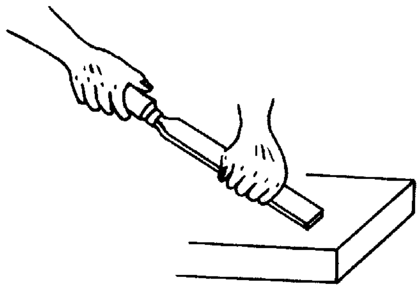
Parts of tools and machines which require contact with each other must have very accurate surfaces in order to work together with the right degree of accuracy. Producing these surfaces is an important problem in the manufacturing of modern machinery.

Until recently, craftsmen made true surfaces exclusively by hand methods, as there were no machines in existence that could make such surfaces. Hand fitting is still one of the most accurate of fitting methods and is still used to a great extent. The usual hand methods employed in accurate fitting work consists of hand scraping and lapping.

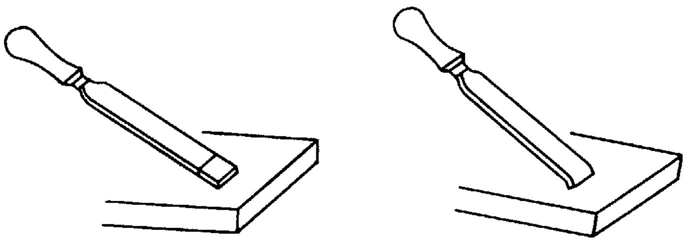
No surface is absolutely true, but by scraping, a surface may be obtained that for all practical purposes may be considered true. In the operation of scraping, we remove the high spots until we get a surface which is fairly true. By an additional scraping operation we can obtain a beautiful "flaky" surface. This operation is done only on flat surfaces which have been scraped. The process of making a surface "flaky" is known as "flaking." Flaking is a hand-scraping process in which the scraper cuts are very light; each cut is made in such a way that some attractive pattern is formed on the surface. By flaking, we get a surface beautiful in appearance. Skilled mechanics recognize that any scraped or flaked surface must be very carefully protected. Any blows or scratches may destroy completely an otherwise perfect surface.

How scrapers are made. Scrapers are made of high-carbon steel and are hardened. They are then ground to the right shape and honed on an oilstone, being made as sharp as possible. Excellent scrapers may be made from old files. The scraper end should be ground at 90° with the sides and edges. Since scrapers are very hard, care should be taken in honing them; otherwise grooves may be worn in the oilstone. This will make accurate honing impossible.

Types of scrapers. The two most commonly used scrapers for flat work are illustrated in Figures 17 a & b. The flat scraper as illustrated in Figure 17a is used for general scraping. It is usually the size of a 10" or 12" hand file. The cutting is done on the forward (push) stroke. The hook scraper, Figure 17b is used for flaking or frosting the work.



(Figure 17a)

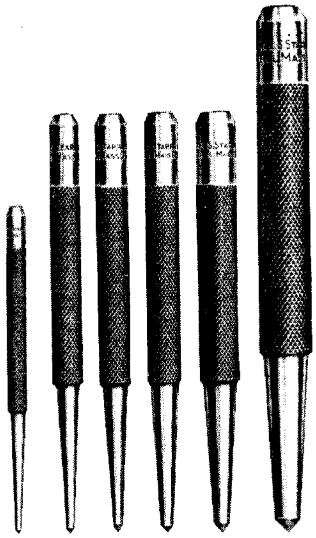


(Figure 17b)

Hints on scraping. Do not get oil on the surface that is being scraped. In order to accomplish anything, scrape hard. If too much metal is to be removed by scraping, file a little until the surface is about true. Not more than two or three thousandths of an inch of metal should be removed by scraping. Dip the scraper in water or turpentine to make it cut better and more easily. When roughing, especially try to keep the cuts about square in shape and cross them in succeeding courses. This will help to make the marking easier to see. Place a very thin coat of Prussian blue on the master surface plate. Place the work being scraped face down on the master plate and move it over the surface using a figure 8 motion. This will spot the work and indicate where to scrape. The best way to apply the Prussian blue is with a rag. Be extremely careful that no grit or dirt gets on the master surface plate. Use the whole master plate - not one spot.

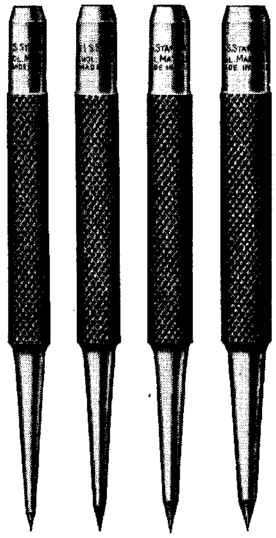
PUNCHES AND SCRIBES

In transferring information from a working drawing to a metal surface, marking scribes and dividers are used to mark layout lines. In order to retain the location of these lines small indentations are made by prick and center punches. The scribe is a piece of hardened steel 6" to 10" long pointed on one or both ends to a needle point. It is used as a pencil to scratch or scribe lines on metal. The prick punch is then used to punch small marks (Figure 19). The point of the prick punch is usually a sharp point of 30°.

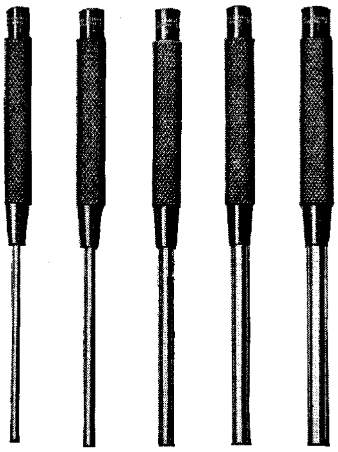


(Figure 18)

Another punch that is very valuable to the mechanic is the center punch. The center punch looks like the prick punch: the difference is in the point angle which is 60° to 90°. This punch is used to enlarge prick punch marks for centers of holes that are to be drilled (Figure 18). Starting or drift punches are used to knock out taper pins or rivets. These punches are available in a variety of sizes. They are blunt on the end and are made to stand heavy shock blows (Figure 20).



(Figure 19)



(Figure 20)

LAYOUT TOOLS

SURFACE GAGE

A surface gage is used for scribing lines on layout work and for checking parallel surfaces. The square or rule holder of the combination set is frequently used in conjuction with a layout plate to set the scribe of the surface gage to a desired height (Figure 21).

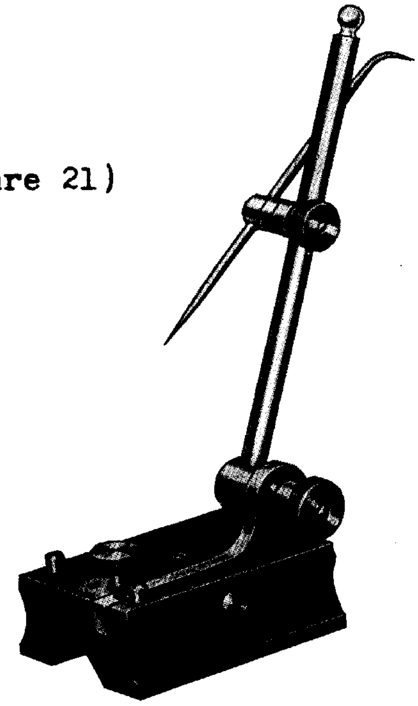
HERMAPHRODITE CALIPER

A hermaphrodite caliper is similar to a divider except one leg is bent like a caliper. Its principle use is to scribe arcs or as a marking gage in layout work (Figure 22).

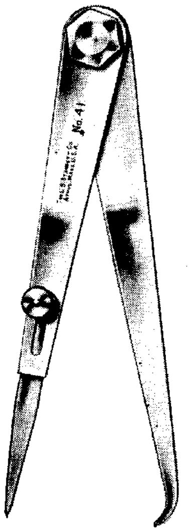
COMBINATION SET

One of the most useful layout tools is the combination set, which consists of a steel rule, a square, a center head and protractor. This tool is used as a rule for making measurements, marking miters, locating centers on ends of round stock or measuring angles and as a depth gage (Figure 23).

(Figure 21)



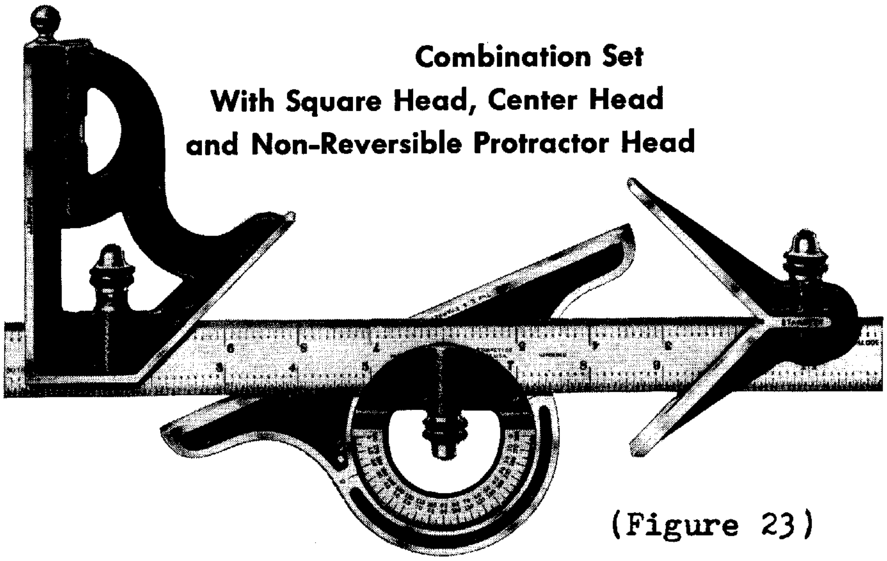
SURFACE GAGE



(Figure 22)

HERMAPHRODITE CALIPER

Combination Set
With Square Head, Center Head
and Non-Reversible Protractor Head



(Figure 23)

COMBINATION SET

FILES AND FILING

To know how to select and use files is one of the important qualifications of a good mechanic. High grade tool steel is used, and great care in heat treatment is important. If the file is too hard, the teeth will be brittle and break; if too soft, the tool is worthless.

Size, shape, cut. A file is usually designated by:

(1) its length in inches, not including the tang which fits into the handle;

(2) its shape or cross section, whether hand, mill, flat, round, square, half-round, three-square (triangular), or any other shape;

(3) its cut (coarseness or number of teeth per inch).

Single cut and double cut. A single-cut file has single rows of parallel teeth, or cuts, extending diagonally the length of the file; the double-cut has two series of parallel teeth, or cuts, crossing each other diagonally, and the second cut is usually finer than the first. The teeth of a double cut file are sharp points, and for this reason they cut faster.

How files are named. The coarseness of files is designated by the following terms: rough, coarse, bastard, second cut, smooth, and dead smooth. The dead-smooth file is double cut. The cut of a file (degree of coarseness or the number of teeth per inch) varies with the length of the file itself and the kind. A rough cut in a short file may be as fine as a second cut of a longer size. In other words, the shorter the file the finer the pitch, or more teeth per inch.

The mill file is flat, tapering in width, and slight in thickness for about one-third of its length. It is used in lathe work because chip clearance is provided by the curvature of the work. It is also used for draw filing and finishing, as well as for sharpening mill saws.

The flat file tapers in both width and thickness and is cut on both edges as well as on the sides. It is in common use by machinists and repair men. This file is usually made double cut.

The hand file is parallel in width and tapered in thickness. Teeth are cut on both sides and on one edge only. This feature permits filing into corners and other work where a "safe" or uncut edge is required. This file is usually made double cut.

A blunt file is the same size its entire length, and has a uniform cross section. Files are more adaptable for a variety of work if they taper to a small cross section at the point. It is necessary to give three details when asking for or ordering a file: (1) shape, (2) cut, (3) length; for example: (a) hand file, (b) bastard, (c) 10 inch.

<u>Hints on filing</u>. The position of the filer should be easy and natural. The file should be provided with a handle suitable to the size of the file and the nature of the job (Figure 24).

The height of the work to be filed when held in the vise should not be above the level of the worker's elbow as he stands erect. Never tap the file on the vise to clean it. Also, the file should never touch the vise jaws while filing.

The work should be held securely so that it does not chatter. The file must be guided by arms and hands, with regular, even, and controlled strokes. Long, slow strokes accomplish more and are less tiring than fast, short strokes. Crossing the cut or filing from different directions will assist in indicating where the file is cutting.

The file does its work on the forward stroke with a shearing cut. The downward pressure should be relieved on the backward or return stroke without lifting the file from the work. If faster cutting is desired, it is better to select a coarser file than to "ride" the one being used.

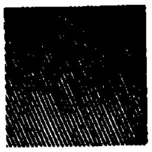
Oil should not be used when filing cast-iron surfaces; neither should chips be removed from cast iron by hand, as grease or moisture will cause the file to slip and dull quickly. When filing wrought iron or steel, oil or grease does no harm. Oil is sometimes used to protect the points of a new file, and also to produce a smooth finish.

Oil may be removed from a file by rubbing chalk across the teeth and then brushing it out. The chips, filings, or "pins" may be removed by tapping the edge of the file on a wooden block, using a file card or by pushing the chips from the gullets (the space between the teeth) with a piece of soft metal.

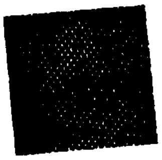
METAL FITTING

Files and Filing

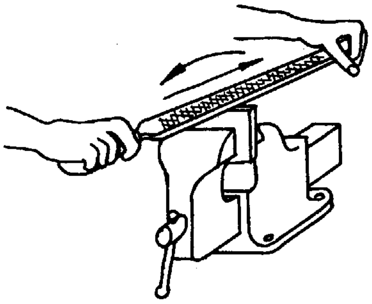
Point Teeth Edge Heel Tang



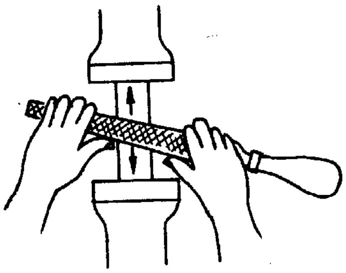
Single - Cut



Double - Cut



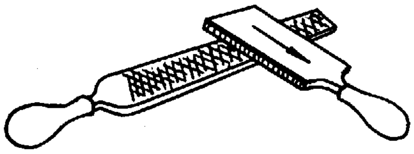
Proper Method of Using the File



Draw Filing

Flat

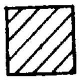
Half Round



Cleaning the file

Three Square

Round



Square

(Figure 24)

Finished surfaces should be protected in the vise by the use of copper or soft metal jaws. If the work to be filed is cast iron, the scale should be removed by machining or by chipping with a cold chisel before an attempt is made to file the surface. A few strokes on cast-iron scale or any hardened surface will ruin a file.

When it is desired to have a more finely finished surface (flat or round), the work should be "draw filed" as the grain or lay produced by draw filing will be in the direction of the stroke. Only the finer files should be used for drawing filing.

To file brass, solder, lead, and aluminum with an ordinary double-cut file is very unsatisfactory, because the teeth quickly become clogged with chips which are difficult to remove. A curved-cut file is very efficient for filing soft metals.

HACK SAWING

The hand hack saw is a metal-cutting saw. It is used for cutting metal that has not been hardened. The blades used for hand hack sawing are usually about 1/2" wide, .038" to .065" thick, and 8" to 24" long.

Hack-saw blades are made from tool steel, high-speed steel, or tungsten-alloy steel. The manner in which they are hardened and tempered gives the blades their toughness, flexibility, and strength. Some manufacturers harden the teeth only, leaving a flexible blade.

The set in a hack-saw blade is generally regular alternate; that is, one tooth is slightly bent or turned to the right and the next to the left. The teeth are turned just enough to insure free, smooth, rapid cutting in a slot a little wider than the blade itself, removing no more stock than is necessary. In certain fine-toothed saws, a pair of teeth is set alternately right and left, a style of setting known as "double alternate." A wave set is often used on fine-pitch saws. It is to be preferred for copper tube cutting. The number of teeth per inch and kind of material to be cut must be considered to get the best results. The following saw blades are recommended by manufacturers for the purposes noted:

Use a 14-tooth-per-inch hack-saw blade on machine steel, cold-rolled steel, and structural steel, because the coarse pitch (the number of teeth per inch) is free and fast cutting.

Use an 18-tooth-per-inch hack-saw blade on a solid stock, aluminum, babbitt, tool steel, high-speed steel, cast iron, and the like. An 18-tooth blade is recommended for general use.

Use a 24-tooth-per-inch blade on tubing, tin, brass, copper, channel iron, and sheet metal over 18 guage. If a coarser pitch is used, the thin stock will tend to strip the teeth out of the saw blade. Two or more teeth should be in contact with the work.

Use a 32-tooth-per-inch blade on small tubing, conduit, and sheet metal less than 18 guage. Two blades with teeth placed in opposite directions are sometimes used on very thin material.

Hand hack-saw frames are made in fixed or adjustable lengths to take from 6" to 12" blades. The length of the blades under 14" is measured from center to center of holes. The 10" blade is most common for hand hack saws.

How to use a saw. The blade should usually be put in the frame with the teeth pitching forward so that the saw will cut on the forward stroke. The blade should be tensioned in the frame so that when it is thumbed with the finger nail it will give a clear note, indicating that it is drawn tight. If the blade is left too loose in the frame, there is danger of kinking the blade, and a kink will ruin the blade. The work should be held firmly in the vise in such a manner that it cannot vibrate or move, and some attention should be given to the angle in which irregular work is held, in order that there will not be danger of the teeth becoming caught and consequently broken on sharp corners.

The frame should be held firmly with both hands. A right-handed person will grip the handle of the frame with the right hand and guide the saw with the left by taking hold of the forward end of the frame. Pressure should be applied on the saw only in the forward stroke. Pressure

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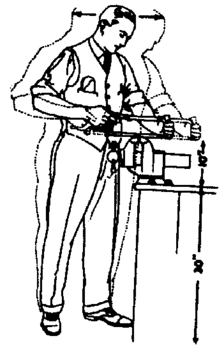
The frame should be held firmly with both hands. A right-handed person will grip the handle of the frame with the right hand and guide the saw with the left by taking hold of the forward end of the frame. Pressure should be applied on the saw only in the forward stroke. Pressure should be entirely relieved on the back stroke; otherwise, there is danger of dulling the blade. The saw should move at a steady even rate not to exceed forty strokes per minute. The strokes should be so made that the entire length of the blade will be used in each cutting stroke; otherwise, the teeth will be dulled at the center of the blade and the end teeth will not be used. The workman should stand so that the body sways with the stroke in order that the arms will not become tired.

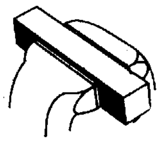
Safety Precautions. The chief danger in the use of hacksaws is in injuring the hand when a blade breaks. Breaking is caused by one of two things - either the operator is bearing down too hard on the blade or else is not pushing the saw straight, thereby twisting the blade which causes it to break. When this latter happens, the hand will sometimes come against the work and a disagreeable and sometimes serious bruise will result.

HAND HACK SAWING

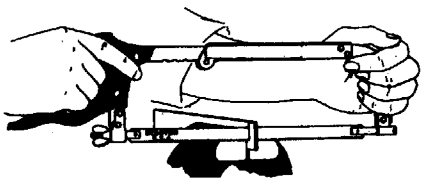
The proper position for the workman to stand in when hand hack-sawing.



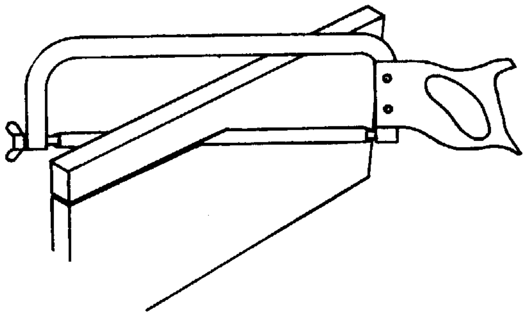
Work to be hand hack-sawed should be first notched with a file.



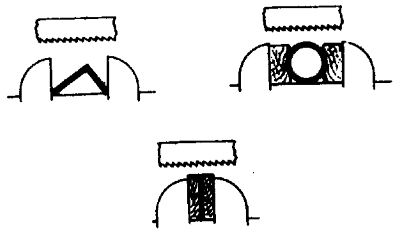
Illustrating the correct manner of holding a hand hack-saw. Note that the saw is guided by both hands.



Illustrating how a hand hack-saw blade may be turned in the frame in order to cut a narrow strip from a large sheet of metal.

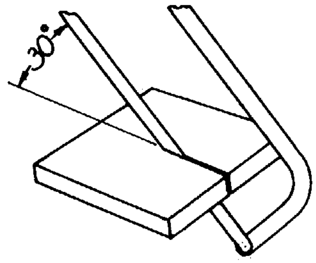


Illustrating how odd-shaped pieces of material should be held in the vise for sawing. Note that the saw goes through the material in such a manner that the blade is not likely to catch on sharp corners.

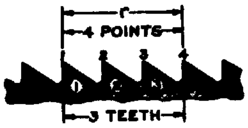


HAND HACK SAWING (cont.)

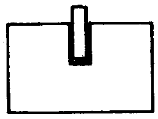
Thin, flat stock should be held horizontally and the saw should make an angle of about 30° with the work.



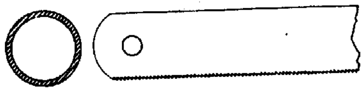
There is always ONE more POINT per INCH than there are TEETH per INCH. This should be kept in mind when specifying.



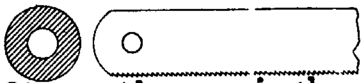
Illustrating how the set of a saw provides clearance for the blade.



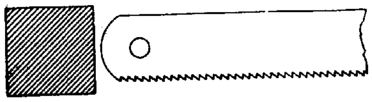
For safely cutting thin tubing such as aircraft tubing, copper refrigerating tubing, copper water pipe BX and electrical conduit use a pitch of 32 teeth per inch wave set.



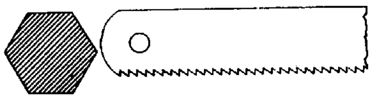
For pipe, angles, channels, heavy tubing and usual structural forms use a pitch of 24 teeth per inch.



For cast iron, machine steel, tool steel, and other solid materials use a pitch of 18 teeth per inch.



For fast cutting on large sections of bronze, aluminum, low-carbon steel, or other solid sections, use a pitch of 14 teeth per inch.



TAPS AND DIES

Taps and dies. Taps are used for cutting internal threads; for example, those in nuts. Threading dies are used for cutting external threads or those on round rods, bolts, and screws. Taps and dies may be had for all standard screw threads. Machine threads must be cut on the engine lathe. The lathe is capable of cutting either internal or external threads. The holder for holding a tap is called a "tap wrench," and the holder for a die is called a "die holder" or "die stock."

Work to be threaded is generally held in a vise or in a lathe chuck mounted on the spindle of the lathe. When held in a vise, the work is stationary, and the tap or die is turned by hand. When held in a lathe chuck, the tap or die is held stationary, and the chuck holding the part to be threaded is revolved slowly by hand.

Taps. The tap is designated by three things: (1) the outside diameter, (2) the number of threads per inch, and (3) the form of the thread. Example: "1/4 - 20 tap, N.C." would mean that the outside diameter of the tap is 1/4", the number of threads per inch are 20 and the form of the thread is of the National Coarse Thread. The parts of a tap consist of the groove or flute, the land, and the shank. The extreme end of the shank is squared to receive the tap wrench.

Threading die. Dies are unlike taps in that those most used are adjustable. Hand dies may be divided into three general classes: the solid die, the split die, and the two, three, or more piece die. A set containing taps, dies, tap wrenches, and die holders is called a "screw plate."

Left-hand taps and dies. Some of the more common sizes of taps and dies may be had in either right-hand or left-hand threads. Left-hand taps and dies, however, are special and are always higher priced than right-hand. Left-hand taps and dies are also marked with the letters L. or L.H. which means left-hand threads.

Hints on tapping and threading. In the actual operation of using taps and dies, the tools must be kept from binding. Metals, such as cast iron and brass, thread easily; thus the tap or die may be continuously turned in a clockwise direction until the operation is completed.

On such metals as machine steel, wrought iron, and alloy steel, taps and dies have a tendency to stick or catch in the work; therefore, it is often necessary to make from one-third to one-half a revolution in a clockwise direction, and then counter-clockwise, thus freeing the tap. This movement back and forth is continued until the job is completed.

If the job to be threaded has thin walls, care must be taken in gripping such a piece in the vise to prevent distortion.

Taps, especially those above 1/2" in diameter, are generally used in sets of three, and are called "taper tap," "plug tap," and "bottoming tap." When using taps it is best to use them in their proper order: first, the taper tap; second, the plug tap; and third, the bottoming tap. The use of a bottoming tap may be left out if the hole to be tapped is of such a nature that the tap may pass through the work. If a full thread is required to the bottom of a blind hole, the bottoming tap must be used.

When using an adjustable die, do not try to finish the thread in one cut of the tool unless the part being threaded is 1/2" in diameter or under. It can be done, but it is certainly poor practice and very hard on the die. Plan on taking at least two cuts and possibly three.

Lubricant or cutting compound should be used when cutting threads on steel such as nuts and bolts. Cast iron should be cut dry; in other words, do not use oil on cast iron when cutting threads.

CHAPTER IV

METAL CUTTING FUNDAMENTALS

METAL CUTTING CONCEPTS

The machining of metals requires an understanding of the theory involved in metal cutting. To design a cutting tool to remove metal with care when machining a given material requires an understanding of the variables involved in the process. There are four major factors that influence the cutting performance:

(1) The metallurgical composition of the cutting tool material and the work material.

(2) The tool geometry and life factors.

(3) The use and effect cutting fluids have on tool life performances.

(4) The physics and mechanics of the actual cutting performances; such factors as forces on tools, speeds and feeds, depth of cuts, chip formation, etc.

Other factors that must be considered are:

(1) The power that is required for the removal of a given amount of metal.

(2) The rate at which the cutting tool is worn away by the machining operation.

MACHINABILITY VARIABLES

Two variables that serve as a simple criterion for evaluating the machinability of a metal are the chip formation and the cutting fluid used. The chip formation will determine the degree of finish, the workpiece will reveal the efficiency of the machining operation, while the cutting fluid contributes to better tool performance and finish.

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CHIP TYPES AND THEIR FORMATION

In metal cutting, the unwanted metal is removed in the form of chips. Turning operations produce three basic chip types.

Type 1. The discontinuous or segmented chip produced when machining cast irons or other brittle metals. Conditions that favor this type of chip are large chip thickness, small rake angles, and low cutting speeds (Figure 25).

Type 2. The continuous chip without a built-up edge. Conditions favoring its formation are when machining ductile materials, small chip thickness, large rake angles and high cutting speeds (Figure 26).

Type 3. The continuous chip with a built-up edge. This type of chip is produced from very ductile materials having high work-hardening properties and machining under heavy cuts (Figure 27).

FACTORS GOVERNING LATHE CUTTING TOOL DESIGN

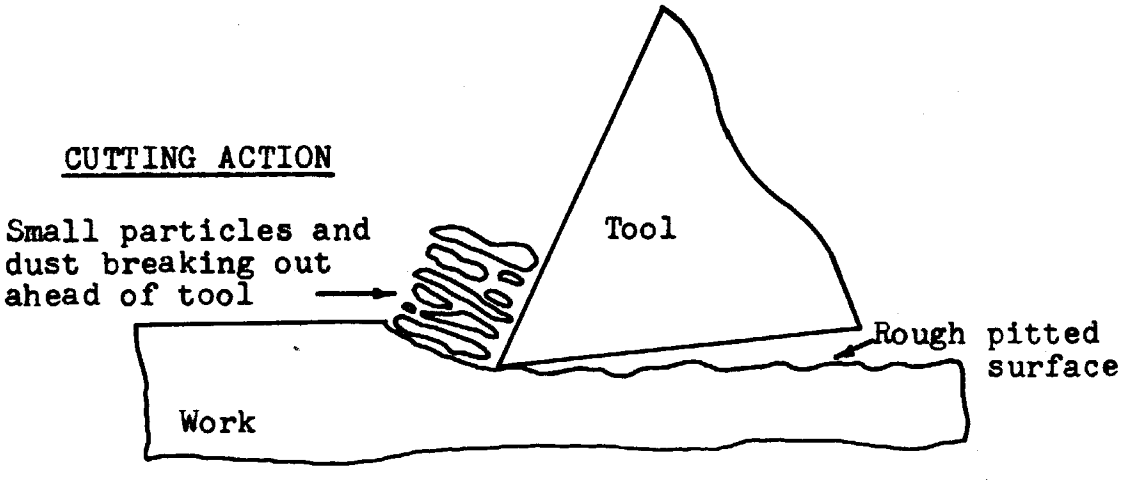
Single point cutting tools play an important part in machining metals, and the tool geometry must be understood in order to grind the correct cutting angles on the tool for efficient metal removal. The forces exerted on the cutting tool occur in three different directions in ordinary metal turning operations:

(1) The forces exerted against the top or face of the tool in a downward direction due to the rotation of the workpiece;

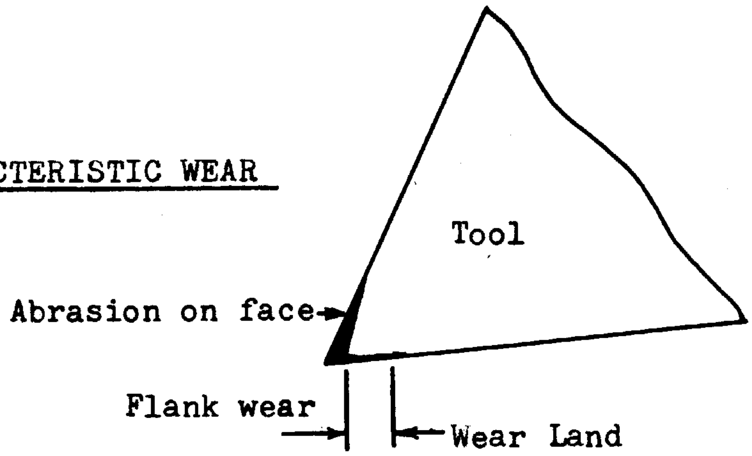
(2) The force exerted against the flank or side of the tool due to the lateral motion or feed of the tool;

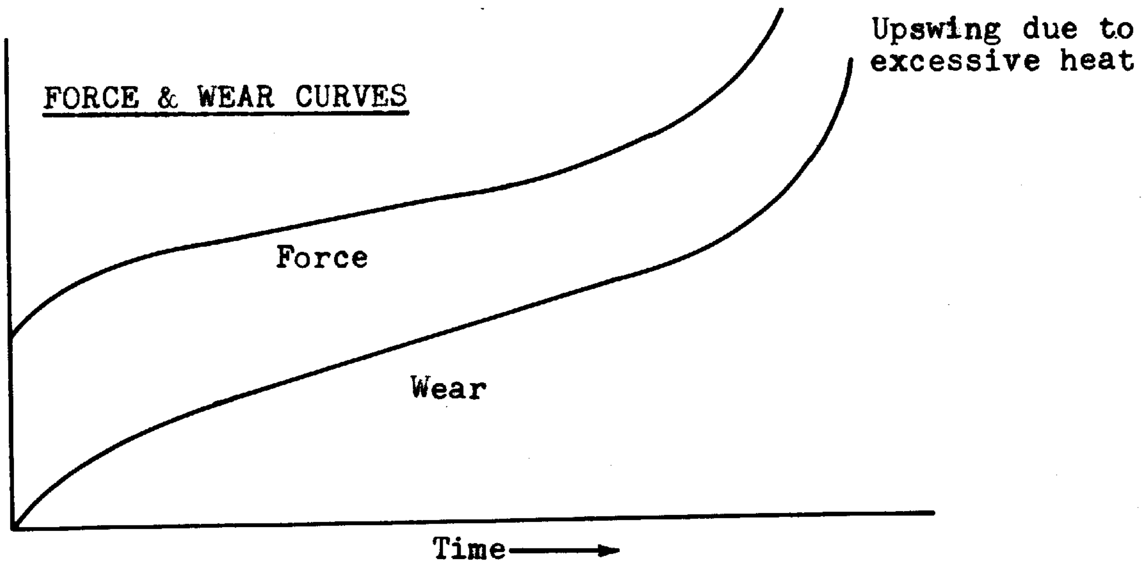
(3) The force exerted against the end or nose of

TYPE 1 -- DISCONTINUOUS OR SEGMENTAL CHIP



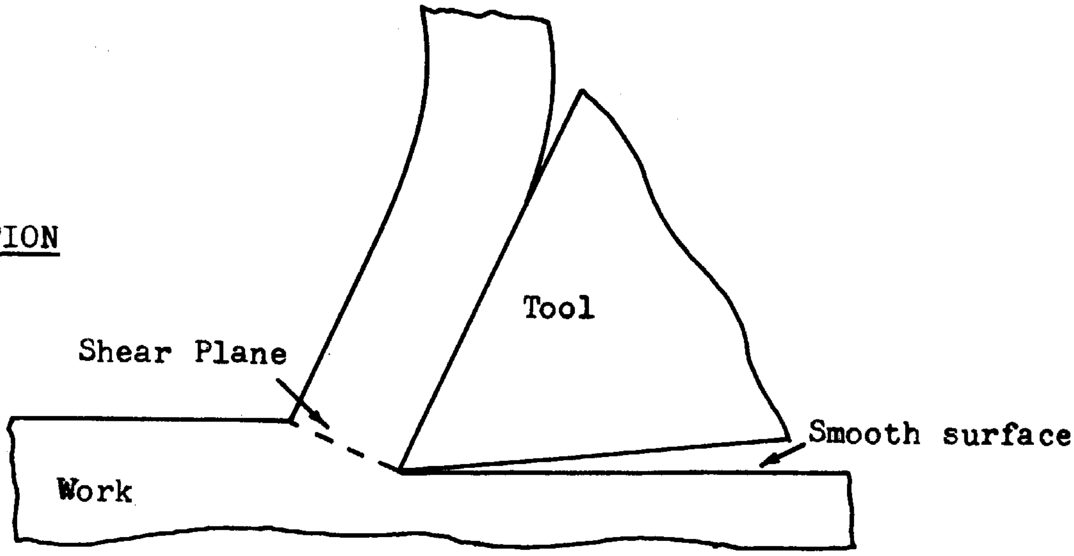
(Figure 25)





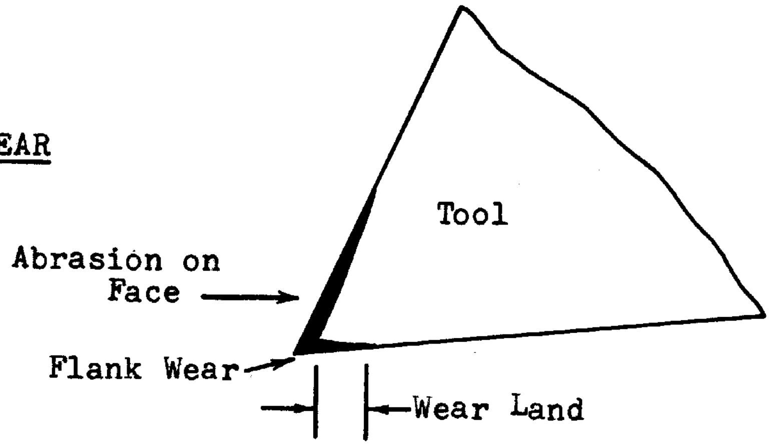
TYPE 2 -- CONTINUOUS CHIP WITHOUT BUILT UP EDGE

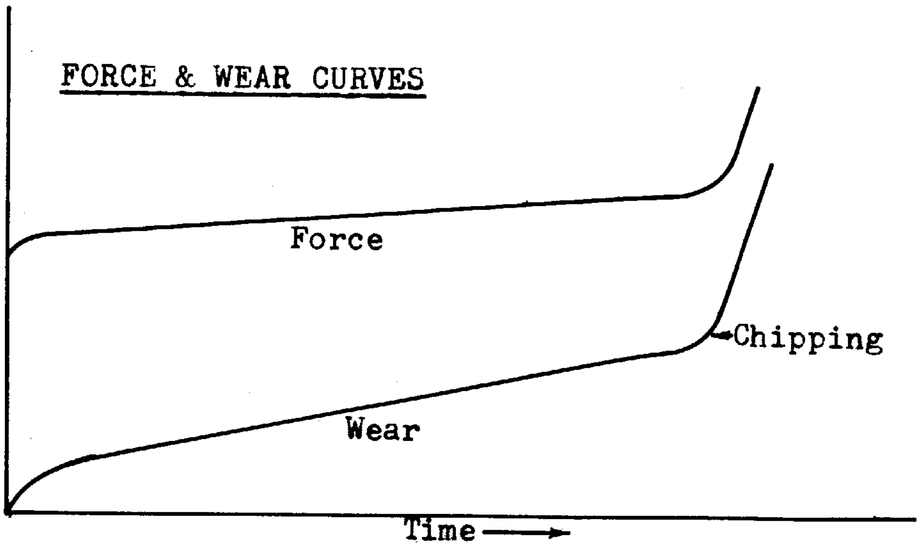
CUTTING ACTION



(Figure 26)

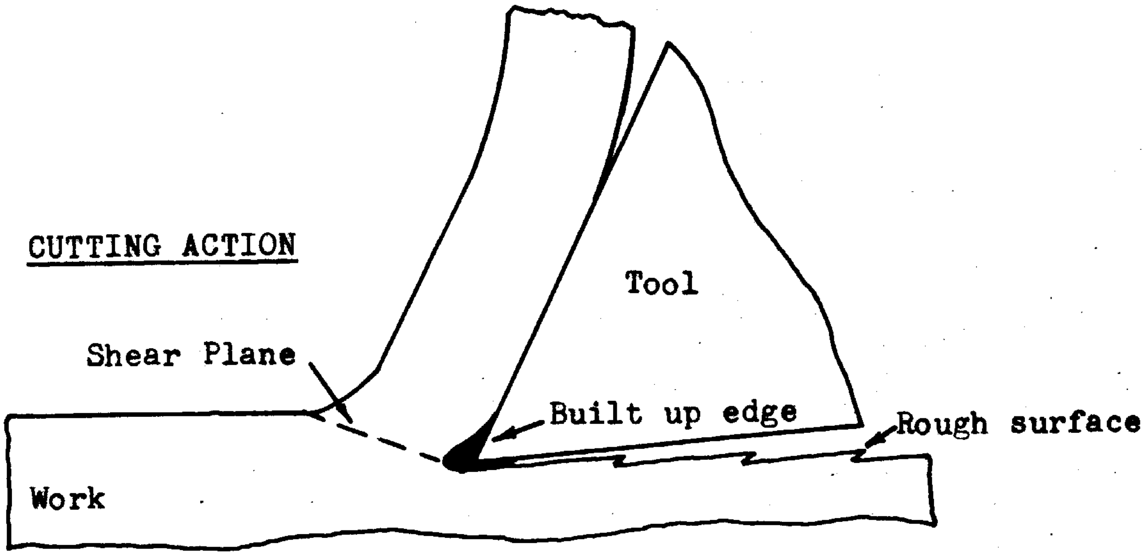
CHARACTERISTIC WEAR





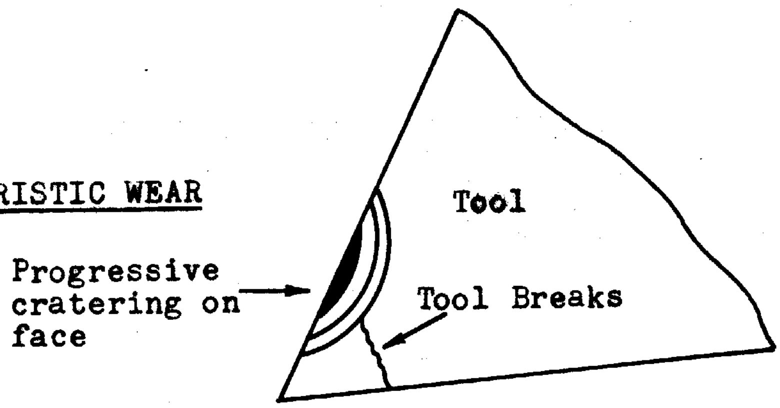
TYPE 3 -- CONTINUOUS CHIP WITH BUILT UP EDGE

CUTTING ACTION

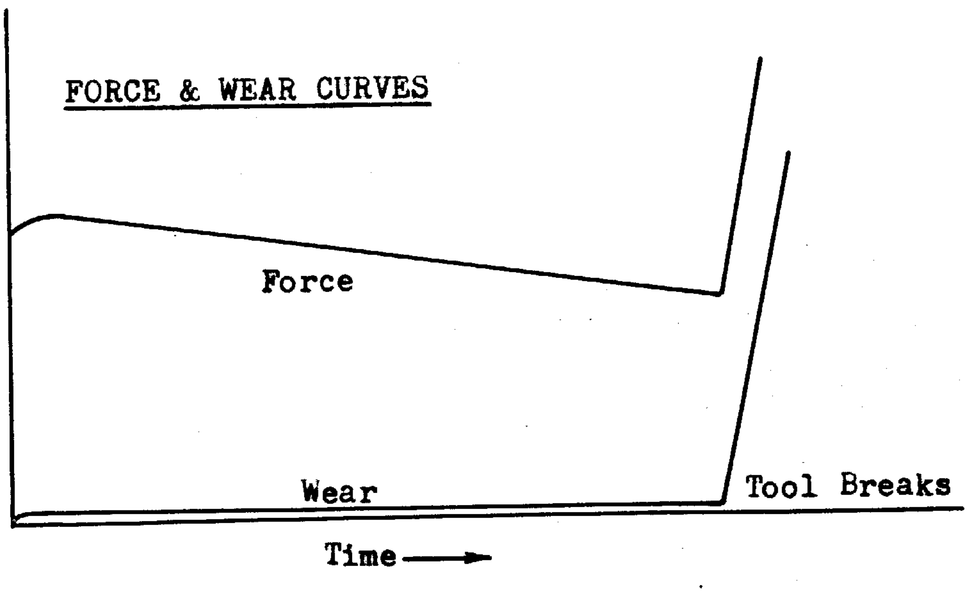


(Figure 27)

CHARACTERISTIC WEAR

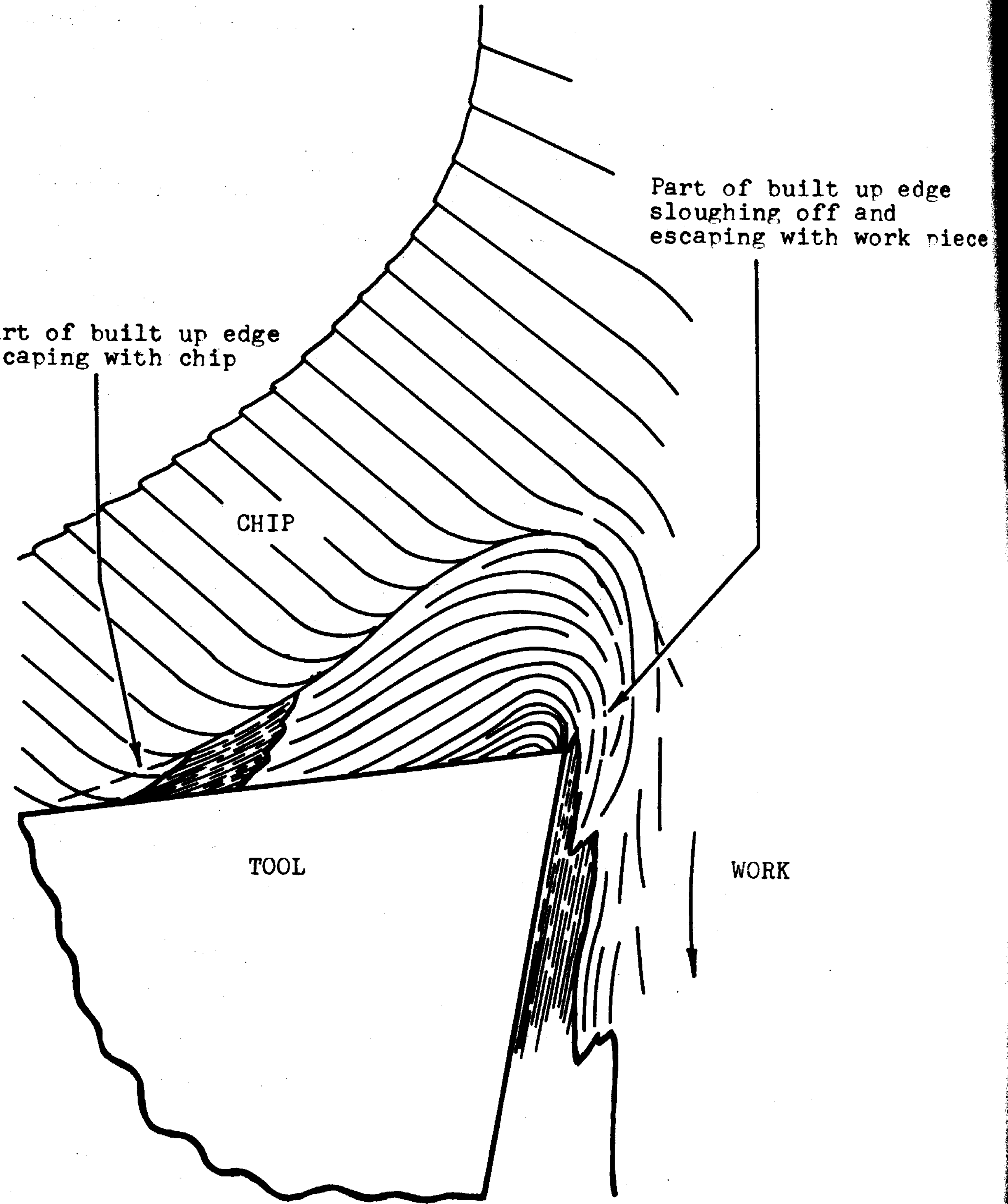


FORCE & WEAR CURVES



UNSTABLE BUILT UP EDGE SLOUGHING OFF

CAUSING ROUGH SURFACE FINISH



(Figure 27a)

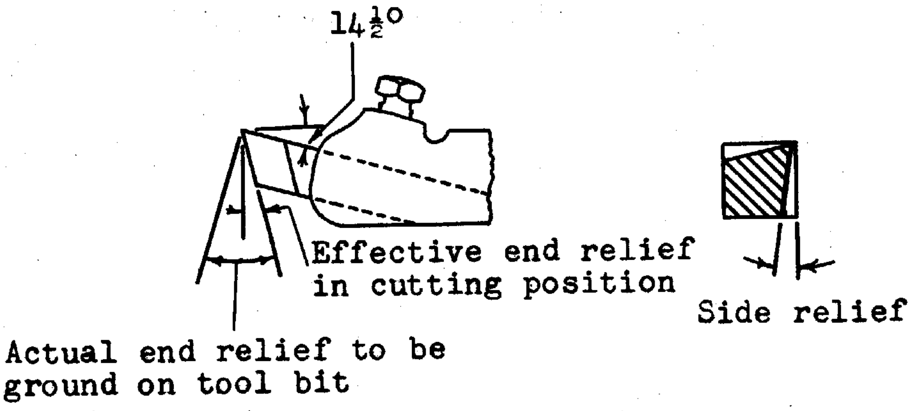
the tool due to the fact that the tool is forced into the material.

These three forces exerted on the tool from three different directions are essential because this makes the cutting action possible. The thrust force exerted on the flank and nose of the turning tool is concentrated on a small area adjacent to the side and end cutting edges.

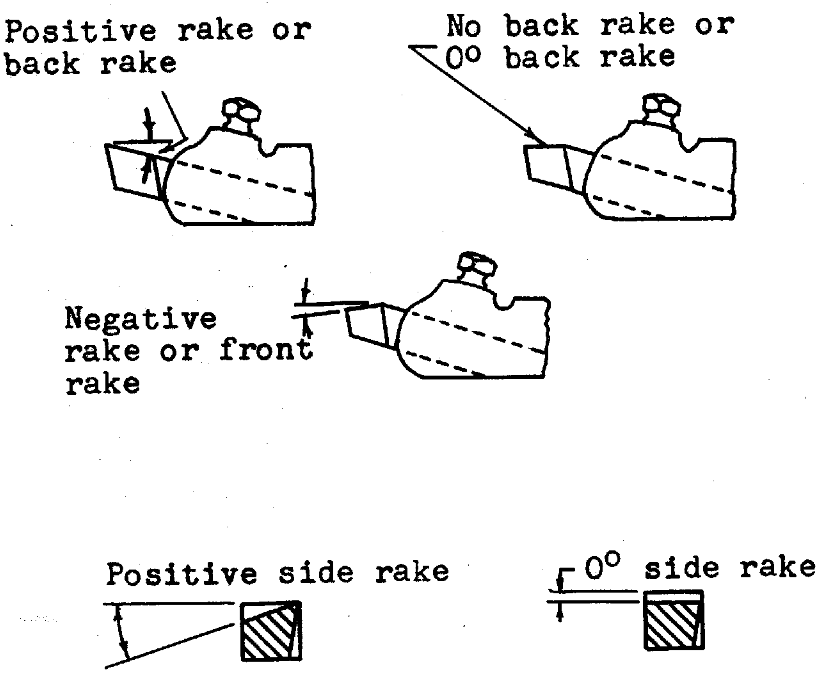
By grinding the flank back at an angle sloping from the side cutting edge, it will improve the tool's cutting efficiency by increasing the effectiveness of the thrust force exerted on the side and end cutting edge angles (Figure 28). The greatest amount of thrust force exerted on the face of a turning tool is concentrated on an area adjacent to the side and end cutting edge angles, (a) by grinding the face back at an angle sloping from the side cutting edge and (b) by holding the tool at an angle sloping from the cutting edge, it will improve the tool's efficiency in cutting tough or ductile metals.

TERMINOLOGY USED TO DESIGNATE SINGLE POINT TOOL GEOMETRY

Tool Grinding. A tool is ground to a given form and shape for two reasons: (a) to produce a cutting edge with the best cutting tool angles that will give the most efficient cutting performance; (b) to grind the most efficient cutting angles for the material that is to be machined,



Relief Angles



Rake Angles

(Figure 28)

TOOL ANGLES AND THEIR FUNCTIONS

Side Rake. Side rake angles may be defined as a plane that forms the face or top of a tool that has been ground back at an angle sloping from the side cutting angle. The extent of side rake influences the angle to which the chip leaves the workpiece as it is directed away from the side cutting angles (Figure 29).

Back Rake. Back rake indicates that the plane that forms the face or top has been ground back at an angle sloping from the nose. When a tool bite is held by a tool holder, the holder establishes the back rake angle. The extent of back rake influences the angle at which the chip leaves the workpiece as it directed against the nose of the tool (Figure 30).

Side Relief. The term side relief indicates that the plane that forms the flank and side of the tool has been ground at an angle sloping down from the side cutting edge. Side relief angles concentrate the thrust forçes exerted on the flank of a tool in a small area adjacent to the side cutting edge (Figure 31).

End Relief. The end relief angle indicates that the nose or end of the tool has been ground back at an angle sloping down from the end cutting edge. End relief concentrates the thrust force exerted on the nose of the tool in a small area adjacent to the end cutting edge (Figure 32).

Side Cutting Angle. The side cutting edge angle indicates that the plane that forms the flank or side of a tool has been ground back at an angle to the side of the shank, establishing the angle of the tool's side cutting edge in relation to the shank (Figure 33).

End Cutting Edge Angle. The end cutting edge angle indicates that the plane that forms the end of a tool has been ground back at an angle sloping from the nose to the side of the shank (Figure 34).

Nose Radius. The nose radius is formed by rounding the point of the tool to blend with the tool's cutting edge angles. The nose radius influences the surface finish performed during a cutting operation.

CUTTING TOOL FORMS FOR VARIOUS LATHE OPERATIONS

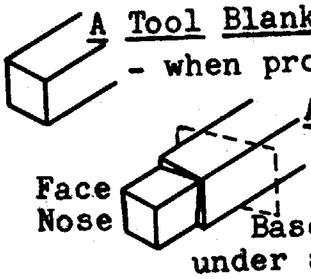
The following are typical examples of tool forms that are used in various turning operations:

Thread Cutting Tool Forms. The following are important factors that must be adhered to when grinding cutting tools for cutting various national standard thread forms:

(1) V-Type Threads. The V-type thread cutting tool is the most widely used in cutting threads. It is always ground so that its cutting edges converge at 60° cutting angles.

(2) Acme Thread. The 29° worm and the acme thread cutting tools are both ground so that the side cutting edges are at a 29° angle.

(3) Square Threads. These tools are ground with a straight cutting edge on its end which is at right angles to the shank. It is ground back of both sides for a depth slightly more than twice the distance of the lap. The purpose is to prevent the flanks from rubbing

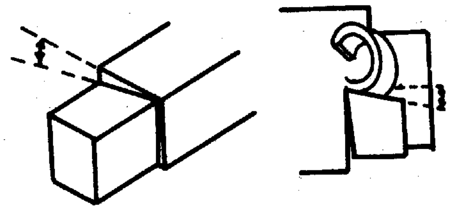


A Tool Blank -
- when properly ground is
A Tool Bit

under side of shank

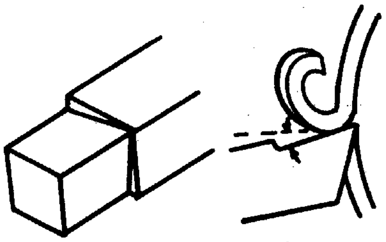
Side Rake

"Side rake" indicates the plane that forms the "face," or top of tool.



(Figure 29)

Back Rake

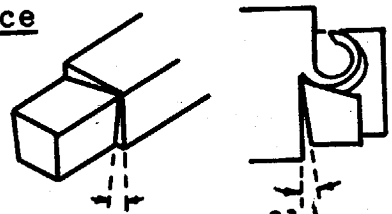


"Back rake" indicates the plane that forms the "face," or top of tool.

(Figure 30)

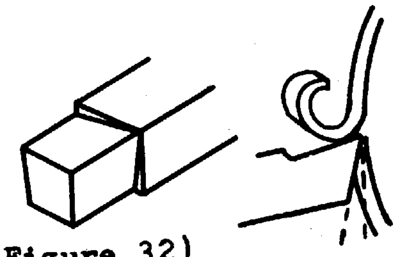
Side Clearance

"Side clearance" (or side relief) indicates the plane that forms the "flank," or side, of a tool.



(Figure 31)

End Clearance

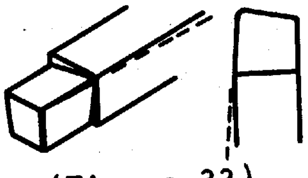


"End clearance" (or end relief) indicates the end of a tool has been ground back.

(Figure 32)

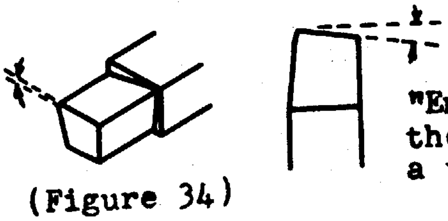
Side Cutting-Edge Angle

"Side cutting-edge angle" indicates the plane that forms the flank, or side, of a tool.



(Figure 33)

End Cutting-Edge Angle

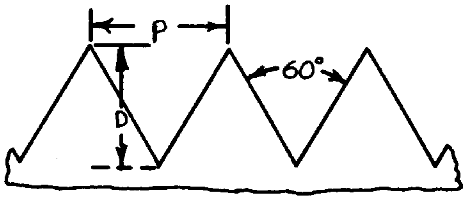


"End cutting-edge angle" indicates the plane that forms the end of a tool.

(Figure 34)

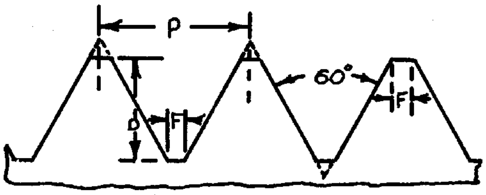
SHARP V-THREAD

Depth D = 0.866 x pitch
Angle = 60 degrees in plane of axis



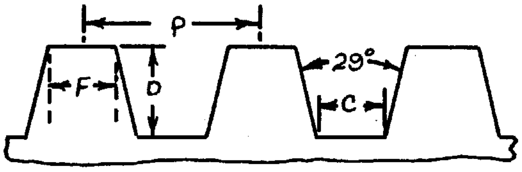
AMERICAN STANDARD THREAD

Depth D = 0.6495 x pitch
Width of flat F = 0.125 x pitch
Angle = 60 degrees in plane of axis



AMERICAN NATIONAL ACME THREAD

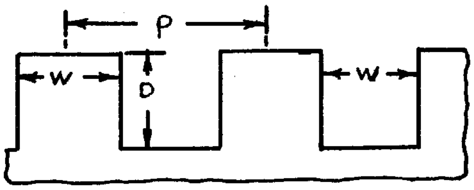
Min,depth D = 0.5 x pitch
Max. depth D = 0.5 x pitch + 0.010 inch
Width F = 0.3707 x pitch
Width C = width F for min. depth
Width C = width F - 0.0052 inch for max. depth
Angle = 29 degrees in plane of axis



(Figure 35)

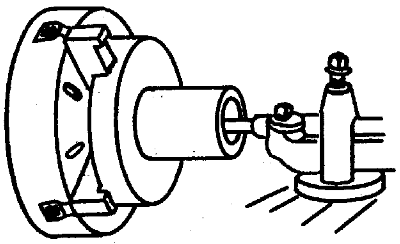
SQUARE THREAD

Depth D = 0.5 x pitch
Width W for screw = 0.5 x pitch
Width thread groove in nut = 0.5 x pitch + 0.001 to 0.002 inch clearance

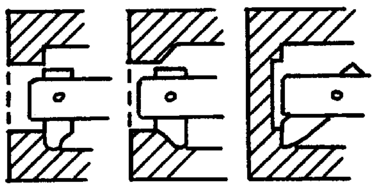


(Figure 36)

BORING SET-UP



(Figure 37)



TOOL BIT POSITIONING FOR BORING BARS

as the tools penetrate the workpiece (Figure 36).

(4) Boring Tools. Single point tools are also ground to be used in boring bars and are used for internal machining of cored or drilled holes. These tools may be inserted in boring bars at different angles and are also ground for the operation desired (Figure 37).

VARIOUS TOOL SETTINGS AND THE EFFECTING RESULTS

The following tool settings indicate the results when tools with different cutting edge angles are set to cut the same depth and are fed at the same rate; the amount of metal removed per unit of time will be the same, but the dimensions of the chip will vary with the angle of the tool's cutting edge. When a tool ground to a given back rake and end relief angles is mounted on center, above and below center, the cutting tool's efficiency is impaired. When the back rake and end clearance angles on a tool are changed by tilting the tool shank at an angle even though the nose is on center position, the tool's cutting efficiency is impaired. The shape of a chip indicates the extent of chip friction to which the tool is subjected. If the tool is tilted down, chip friction is created. A tool bit when mounted on a tool holder should have the minimum projection. The shorter the bit, the more rigid the tool will be held while cutting. The tool holder should also be mounted in a tool post with minimum overhang to provide rigid setting while machining. Boring tools should be carefully set so that the cutting nose of the tool is on the center line of the workpiece and ground with a little more back rake than a turning tool. Incorrect tool grinding and tool setting for boring will greatly affect the performance of a boring operation. When turning sharp tapers, the tool must be set on center. If not, the end section of the taper will remain untapered. If a workpiece mounted between centers is to be faced or squared, it must be held parallel to the length of the bed, and the tailstock center must be perfectly aligned with headstock center; if not the end surface will be cut to a concave or convex form. The shape of a shoulder depends upon the contour of the tool cutting edge, the angle of setting, and the direction of tool feed. These settings produce shoulders having different contours by varying the angle to which the tool is set. When a thread is cut on taper surface, the tools should be set so that the center line of the tool shank is at the center line of the workpiece.

SCREW THREAD FORMS

V-type thread forms may be produced by advancing the tool at a 29½o angle. This method causes the tool to take a light finishing cut on the thread form that carries the thread when in use. Tools used to cut square, acme, and

29^o worm threads are advanced straight into the workpiece for successive cuts. To cut a 60^o type thread on an exterior surface, the compound is set at $29\frac{1}{2}^o$ angle to the right, while when cutting a right hand thread in a bored hole, it is set to the left. To cut a 60^o right thread on taper exterior surfaces, the tool is set at an angle of 90^o through the center line of the workpiece, regardless of whether a taper attachment is used or the offset tailstock method.

TOOL LIFE

Tool life is the type of tool failure caused by abrasive wear on the flank or face of the cutting tool resulting in excessive tool forces. Whenever the cutting forces exceed a critical value for a given tool, small portions of the cutting edge begin to chip off or the entire edge may break away. The high forces could also be caused by excessive vibration (chatter), or the tool could undergo a complete temperature failure. The hardness (and Strength) of a tool varies with temperature and when the tip of a tool becomes very hot, the tool gets too soft to function properly and failure results. This type of failure occurs quite rapidly and is easily observed.

Standard tool life - cutting speed tests have been developed to determine the effect of speed, feed, depth of cut, tool material, tool shape, work material, cutting fluids, etc., on tool life. During these tests, the cutting tools are run to complete failure, or as in the case of carbides to some predetermined amount of wear. The results of these tests when plotted on logarithmic coordinates usually show up as straight lines having the equation $VT^n=C$. The slope of the line, n, is a measure of the abrasive wear on the tool. A 45^o line, n=1, indicates that abrasive action caused failure, while a horizontal line, n=0, indicates that abrasion had no effect and the tool failed by heat. Experimental tests must fall within the limits of the heat or abrasive type of failure as shown in Figure 38.

The height of the curve is designated by "C" and is a measure of the allowable cutting speed. In the equation $VT^n=C$, the value of "C" is the cutting speed for a one-minute tool life. Standard machinability ratings are usually given as $V_{60}=X$, where "X" is the cutting speed for a 60-minute tool life. To compare the machinability ratings of different materials, the A.S.M.E. "Manual On Cutting of Metals" used standard conditions in lathe turning tests of:

Tool life = 60 min.	cutting fluid = dry
feed = 0.010 ipr	cutting tool = 18-4-1 H.S.S.
depth = 0.100 inch	tool shape = 8, 14, 6, 6, 6, 15, 3/64

Similar tool life curves may be obtained for milling and drilling.

EFFECT OF CUTTING SPEET ON TOOL LIFE

When the cutting speed is decreased, the tool life will increase if the tools fail in a normal manner. Figure 39 shows typical results when testing high-speed steel and sintered carbide tools. The equation $VT^{.12} = 92$ for high-speed-steel tools shows that the cutting speed must be reduced 8 percent to double the tool life. For carbide tools, having the equation $VT^{.25} = 460$, the cutting speed must be reduced 13.7 percent to double the tool life.

A chipping type of failure will cause unpredictable tool life. The tool life cutting speed curve for a carbide milling cutter, Figure 40, shows that when the cutting speed was reduced below 300 fpm, chipping of the cutting edge caused early failure. This failure may have been caused by the presence of an unstable built-up-edge or by the strain of the interrupted cut.

EFFECT OF FEED

Increasing the feed will reduce the tool life (in minutes) but is an effective way to increase the rate of metal removal. The highest possible feed should be used and is only limited by acceptable surface finish, excessive tool forces, or tool breakage.

The cutting-speed tool-life lines for three feeds are shown in Figure 41. When the feed was doubled from 0.025 to 0.050 ipr, the cutting speed for a 60-minute tool life was reduced from 45 to 28 fpm (reduced 38%). However, the rate of metal removal was increased from 2.17 to 3.36 cubic inches per minute as shown in Figure 42.

To represent the effect of feed, the feed rate is plotted vs. the cutting speed for a 60 minute tool life. The equation for this curve is: $V_{60}\ (f)^x = C_1$

where: V_{60} = Cutting speed for a 60 minute tool life

f = Feed rate ipr or ipt

x = Slope of the line = $\frac{A}{B}$

C = Constant for these conditions

The following conclusions can be drawn from this curve:

(1) The metal removal rate increases as the feed increases despite the drop in cutting speed as can be seen in Figure 42.

(2) The cutting speed has to be decreased if the feed is increased and the tool life is desired to remain the same.

EFFECT OF DEPTH

Increasing the depth of cut requires only a slight decrease in cutting speed to maintain the same tool life as shown in Figure 43. To show the benefit of increasing the depth in terms of metal removal, the depth of cut was doubled from 0.025 to 0.050 inch and the cutting speed, V_{60}, was only reduced from 71 to 62 fpm, but the rate of metal removal was increased from 0.53 to 0.93 cubic inch per minute. The equation for this curve is:

$$V_{60}(d)^y = C_2$$

where: d = depth in inches

y = slope $\frac{A}{B}$

C_2= constant for the given conditions

The following conclusions can be drawn from these graphs:

(1) The metal removal rate increases as the depth increases despite the drop in cutting speed;

(2) The cutting speed has to be decreased if the depth is increased and the tool life is desired to remain the same.

EFFECT OF METAL CUT

Metals vary greatly in properties and in ease of machining. Some grades of aluminum can be cut at 10,000 feet a minute whereas some steels must be cut at 100 feet a minute for a 60-minute tool life. The physical and metallurgical properties of the material cut have a definite effect on tool life.

EFFECT OF TOOL MATERIAL

There are so many different compositions of tool materials and so many different ways in which they can be used that only a few broad generalizations can be made as a basis for comparison. One of the most significant facts of modern metal cutting in regard to the selection of cutting tool material, is that the latitude of performance between the many grades of sintered carbide is far greater than that offered by different compositions of high speed steel.

Thus an unsatisfactory cutting performance may be rectified simply by using a different grade of carbide whereas a corresponding change in the composition of a high speed steel is rarely sufficient for this purpose.

A rough comparison of four general types of cutting tool materials is given in the following table where the cutting speeds are expressed in percent based on 18-4-1 high speed steel at 100%. Note that ranges are given for sintered carbides in recognition of the considerable latitude represented in different grades.

Relative Cutting Speed - Percent

Tool material	Cutting Steel	Cutting Cast Iron
Carbon Tool Steel	30	25
High Speed Steel	100	100
Cast Non-ferrous	125	200
Sintered Carbides	250-1000	400
Ceramics	1000-1500	

EFFECT OF TOOL SHAPE

Unfortunately, variations in tool shape do not lend themselves to simple correlations as in the case of cutting speed and size of cut. The effect of tool shape is shown qualitatively by curves in Figure 44.

Separate curves are given for high-speed steel and sintered carbide tools in the rake, relief and side cutting edge angle correlations because of the significant differences in their behavior. The location of the optimum rake angle for high-speed steel tools is largely a function of the rigidity of the entire machining setup. At larger rake angles, say, around 35 degrees, the tools begin to chip, but if greater rigidity can be achieved, larger rake angles can be used. Thus, for HSS tools it can be said that greater rigidity will allow the use of larger rake angles, resulting in longer tool life.

The effect of rake angle on tool life is not so simple for carbide tools as shown in Figure 40. The optimum "b" appears to be similar in nature to the optimum for HSS, in that it is a function of rigidity. Carbides are susceptible to increased spalling with increased rake, and hence the optimum occurs at smaller rake angles than for HSS; rigidity is even more important than it is for HSS tools.

The second optimum "a" for carbide tools may not occur at all under certain cutting conditions. If it does occur, it may be higher or lower than the other optimum. However, some recent tests on carbide turning of titanium with higher feeds and speeds did produce this optimum in the region of small negative rakes.

The curves in Figure 40 show the effect of relief angle on tool life for both HSS and carbide tools. For HSS tools, the increase in relief angles after about 13° brings about a decrease in tool life. This is true only if a built-up-edge is present on the tool. For carbide tools, the relief angle can be increased furthur to obtain greater tool life. It is a common mistake to assume that carbide tools require exceptionally small relief angles to prevent spalling. Carbide milling cutters have performed very well with relief angles between 12 and 16 degrees. Good rigidity is, however, essential to achieve this result.

Figure 44 illuatrates the effect on tool life when the side cutting edge angle is increased. In this case, the tool life for both HSS and Carbide increases up to a certain point. Beyond this point, the direction of the resulting force causes chatter (see Figure 44).

EFFECT OF CUTTING FLUIDS

Cutting fluids influence tool wear and surface finish. In general, those cutting fluids which are good coolants will increase tool life by reducing temperatures, thus delaying 'temperature failure'; good lubricants will reduce or eliminate the built-up edge, thereby improving surface finish and extending the tool life. At low speeds, the cutting fluids are far more effective in extending tool life in the form of better finish than they are in delaying 'temperature failure.'

The good lubricants are generally effective through chemical action. In order for a fluid to be effective, it must first penetrate to the point of the tool.

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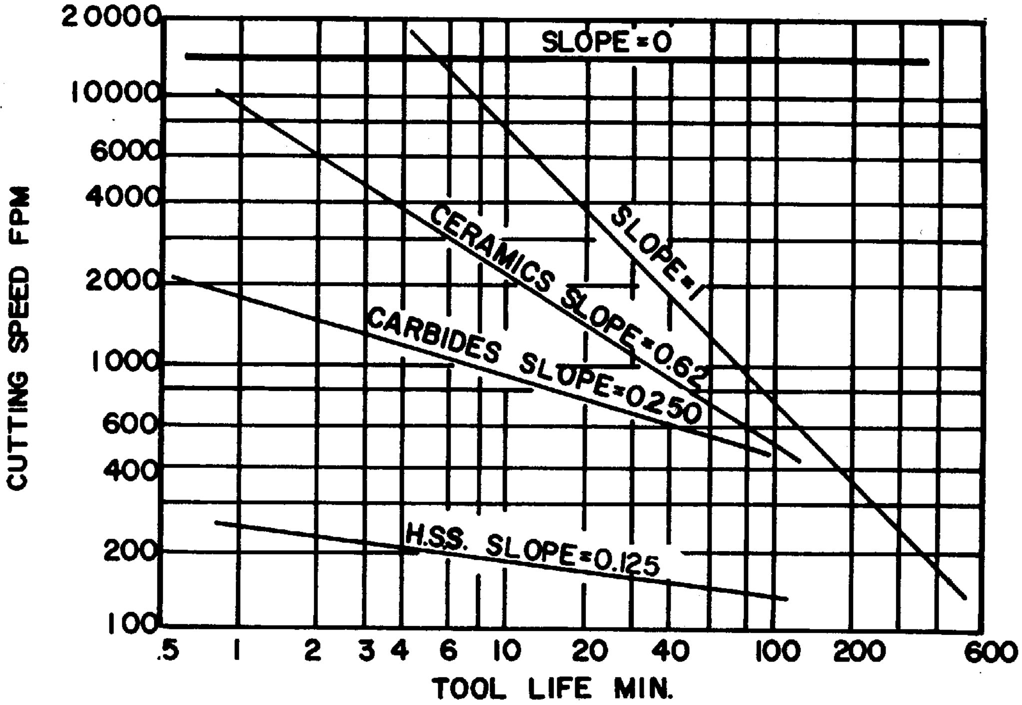
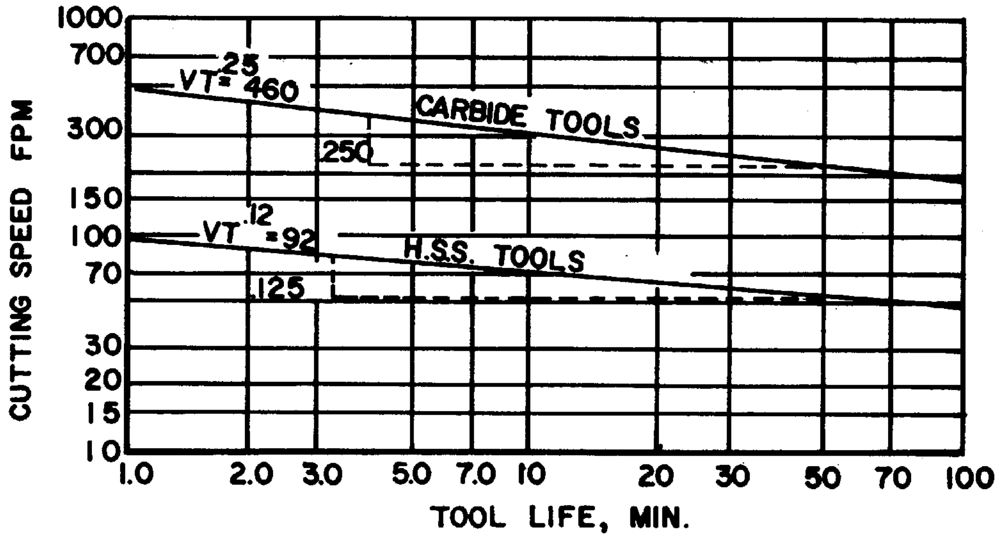


Actual and Theoretical Slopes of Tool Life Lines.

(Figure 38)

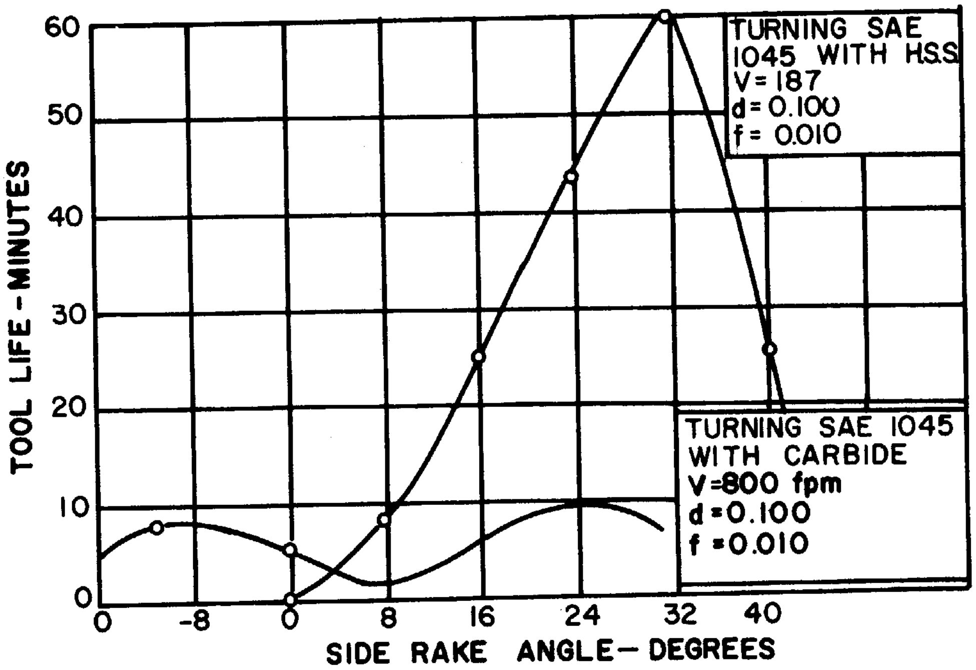
Cutting Conditions: Feed-.0125 ipr, Depth-.100 in.

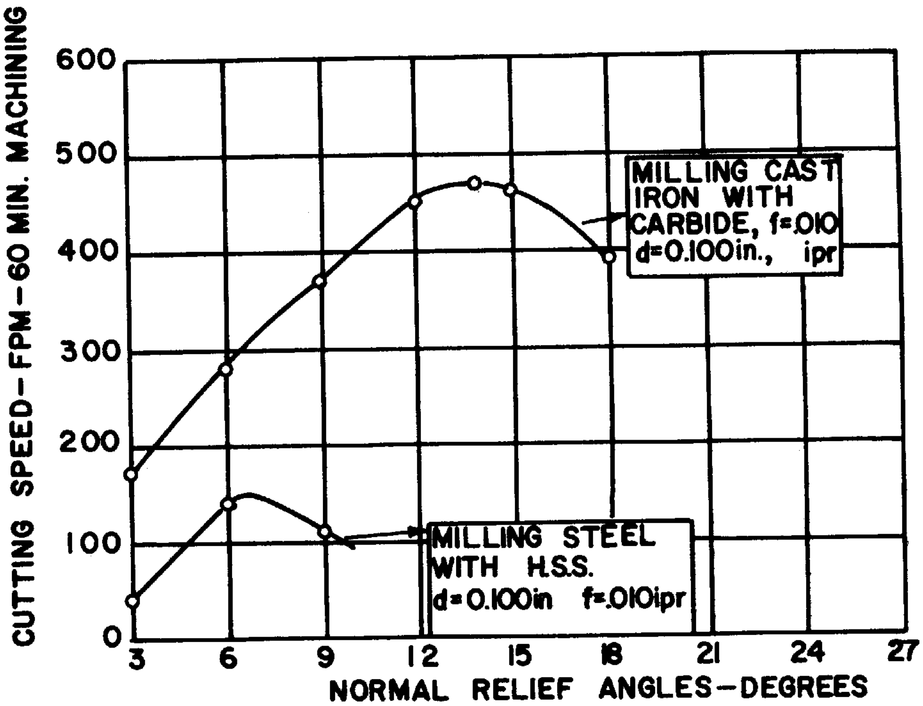


Typical Curves of Cutting Speed vs Tool Life (for steels-350 BHN)

(Figure 39)

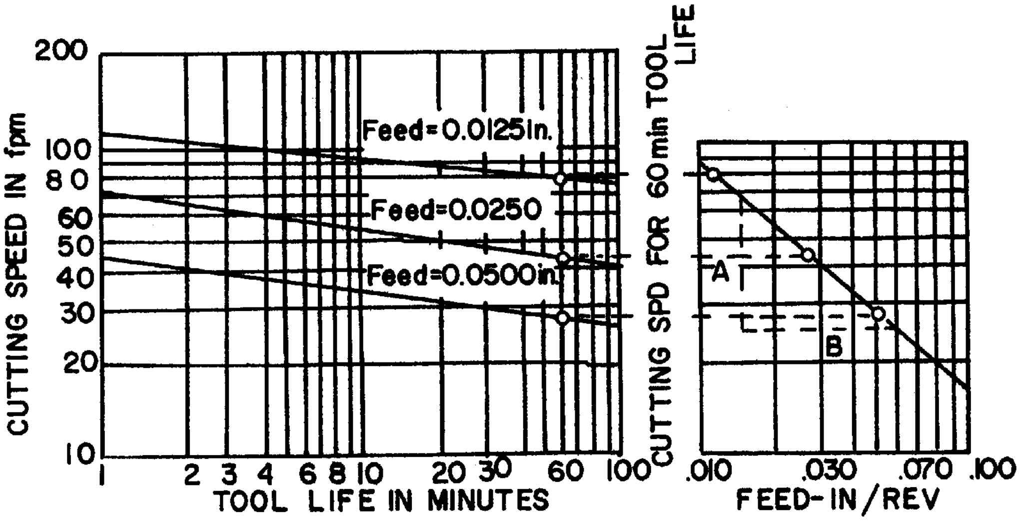
Effect of Side Rake Angle





(Figure 40) Effect of Relief Angle

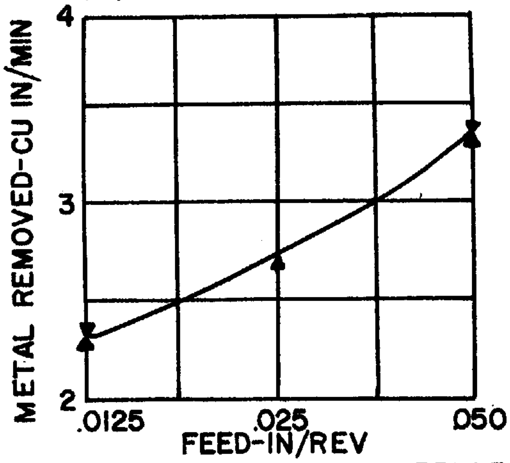
(Figure 41) Effect of Feed on Cutting Speed



<u>Cutting Conditions</u>:

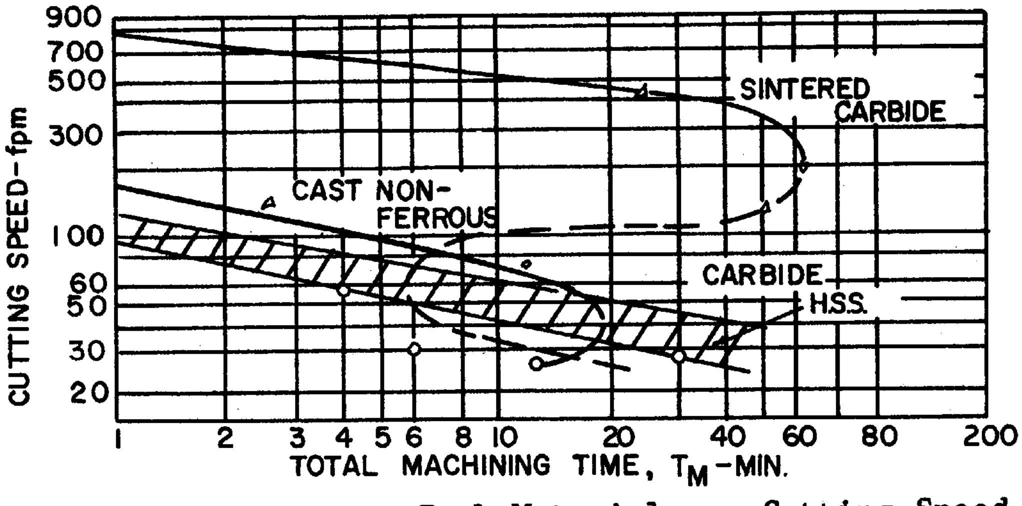
Material Cut-2340 Steel, Tool-High Speed Steel,
Depth-.200 in., Cutting Dry

(Figure 42) Metal Removal Rate vs Feed

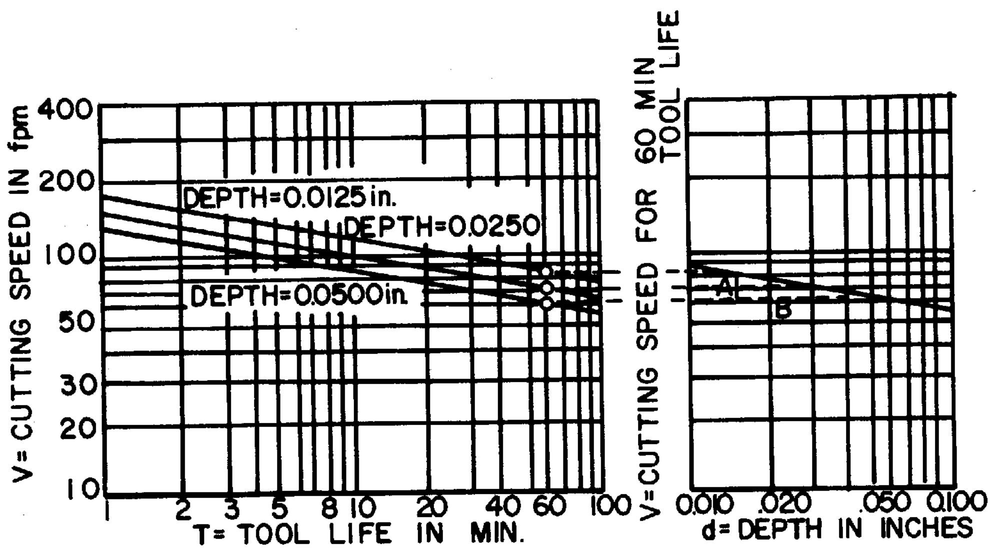


<u>Cutting Conditions</u>:

Milling-4130 Cast Steel, Feed-.0125 ipr, Depth-.100 in.



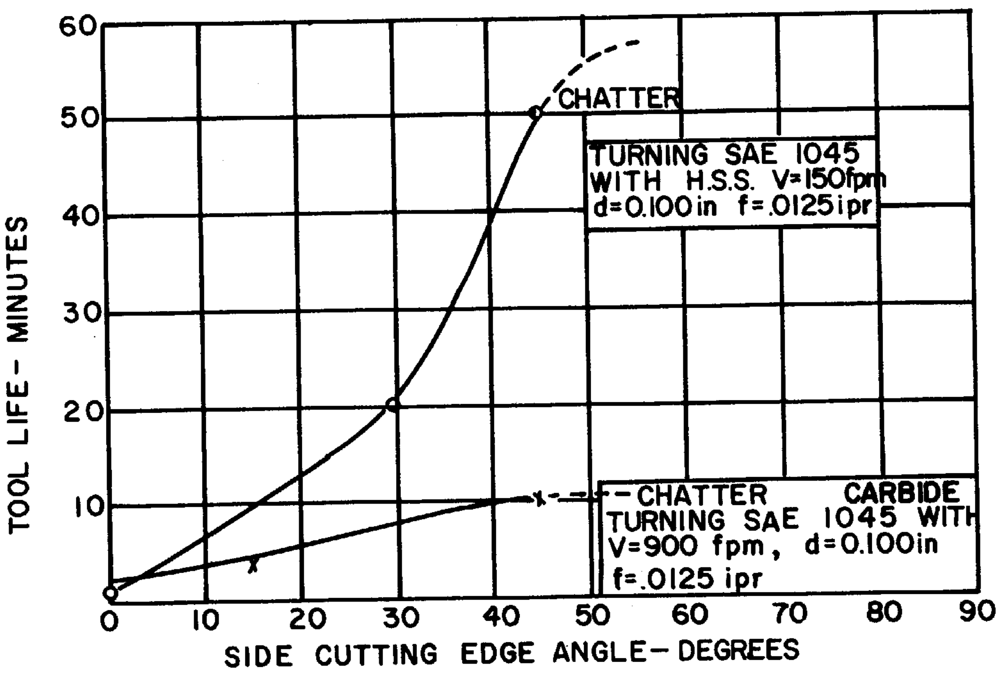
Effect of Different Tool Materials on Cutting Speed



Cutting Conditions:

Material Cut-3240 Annealed Steel, Tool-High Speed Steel, Feed-.025 ipr, Cutting Dry

(Figure 43) Effect of Depth of Cut on Cutting Speed



(Figure 44) Effect of Side Cutting Edge Angle

TOOL LIFE IN GRINDING

Mention should be made of the evaluation of wear of the grinding wheel. The amount that a grinding wheel wears during an operation is conveniently expressed in terms of the grinding factor G.

$$G = \frac{\text{Volume of Metal Removed}}{\text{Volume of grinding wheel consumed}}$$

This ratio is easily determined and can be then used to evaluate grinding variables such as wheel hardness, cutting fluid, cutting speed, cross feed, etc.

The volume of grinding wheel consumed is determined from the change in wheel diameter (D_1-D_2) as measured with a micrometer. The volume is then taken to be:

$$D_1 - D_2 \times \text{width of wheel} \times \pi D_1$$

where:

D_1 = initial diameter

D_2 = final diameter

MACHINABILITY SYMBOLS

V - Cutting speed in feet per minute

V_{60} - Cutting speed for a 60 minute tool life

T - Tool life in minutes

T - Torque in ft. lbs.

n - Slope of the tool life line as in VT^n - C

n - Number of teeth on a milling cutter

C - Constant

N - R.P.M.

F_T - Cutting force in lbs.

F_L - Feeding force in lbs.

F_R - Radial force in lbs.

f - Feed in inches per revolution or feed in inches per tooth

d - Depth in inches

w - Width

D - Diameter of work or cutter

fpm - Surface speed feet per minute

hp_c - Cutting HP

hp_g - Motor HP

uph - Unit hp or hp per cubic inch per minute

METAL CUTTING RELATIONSHIPS

$$fpm = \frac{\pi D N}{12} ; \qquad N = rpm = \frac{fpm \times 12}{\pi D}$$

$$hp_g = \frac{hp_c}{\text{machine eff.}}$$

$$hp_c = \frac{Fc \times V}{33000}$$

$$hp_c \text{ drilling} = \frac{2\pi T N}{33000}$$

$$\text{Unit hp} = \frac{F_T \times V}{33000 \times 12 \, V fd} = \frac{F_T}{360000 \, fd}$$

Approximate metal removal rate in turning in^3/min = 12 Vfd.

Exact metal removal rate in turning

$$in^3/min = \frac{\pi}{4} (D_1^2 - D_2^2) N f$$

Metal removal rate in face milling:

$$in^3/min = N \times n \times f \times w \times d.$$

Metal removal rate in drilling:

$$in^3/min = N \times f \times \frac{\pi}{4} D^2$$

Velocity tool life relationship: $VT^n = C$

Area of a circle $= \frac{\pi D^2}{4}$

Circumference of a circle $= \pi D$

CHIP CONTROL

Unbroken or straight chips are hazardous and troublesome. They pile up in the work area, endanger the operator, and are difficult to remove.

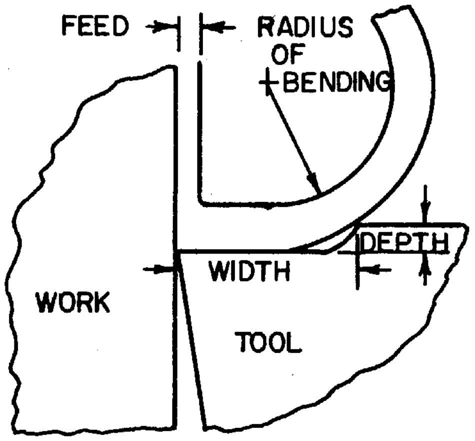
Well broken chips take up less space, make machines easier to keep clean and are much safer to handle.

The first approach to breaking chips is to increase the feed rate. Heavy feeds will generally produce well broken chips without the use of chip breakers. However, if heavy feeds do not produce the desired results, chip breakers will have to be incorporated into the tools.

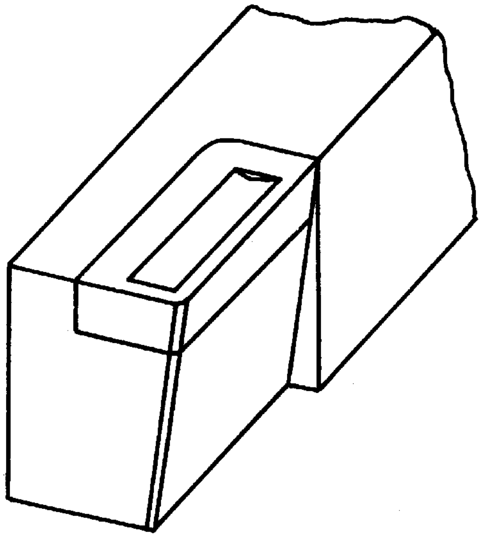
HOW CHIP BREAKERS WORK

Chip breakers are obstructions put in the direction of chip flow causing the chip to curve into a circular path and break. The back rake angle of the tool will direct the chip to break against the tool or the work. The width and depth of the chip breaker will determine the size of the broken chips.

Action of the Chip Breaker in bending a chip.



CHIP BREAKER TYPES

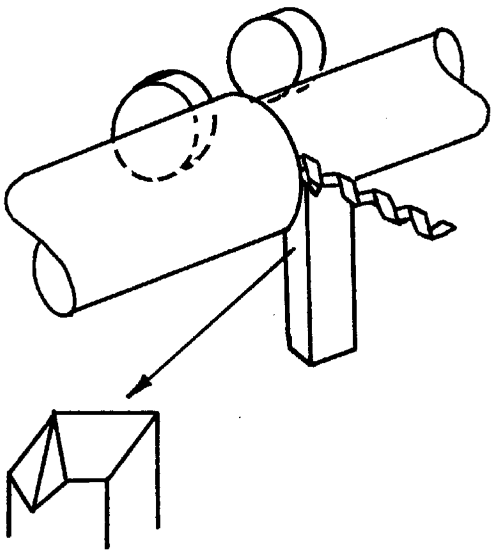


Groeve Type

This style is used for both High Speed Steel and Carbide tools. The high rake angle produced has the advantage of lower power consumption and good tool life.

EXAMPLE:

Roller-turner tool; this groove curls the chip and removes it from the roller supports.

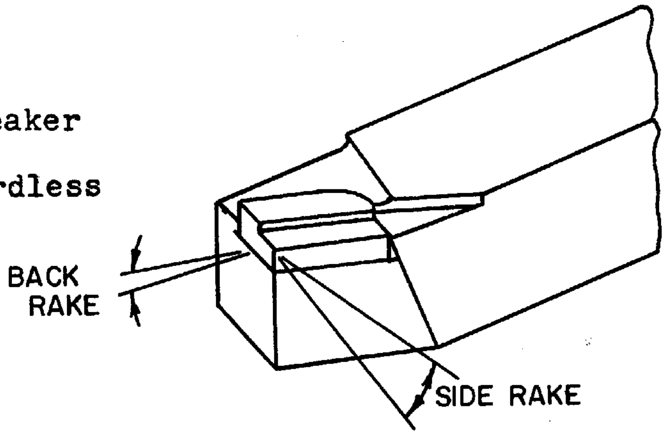


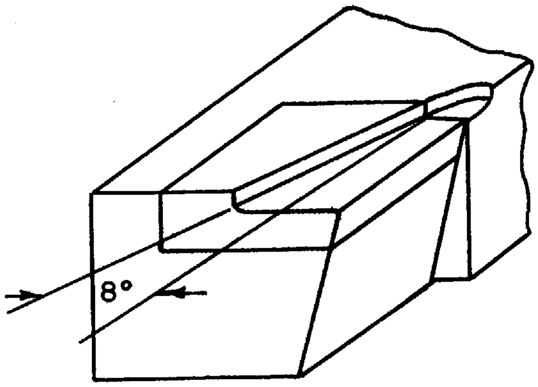
Shelf Type

This is the most common chip breaker for Carbide tools because of the ease of grinding.

Parallel Type

Used for deep cuts. The breaker width remains the same regardless of depth cut.



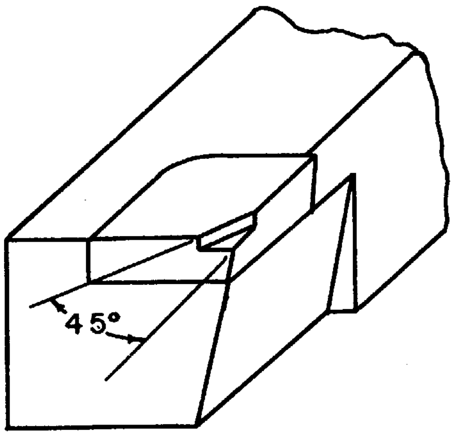


8° Angular Type

Used for most operations.

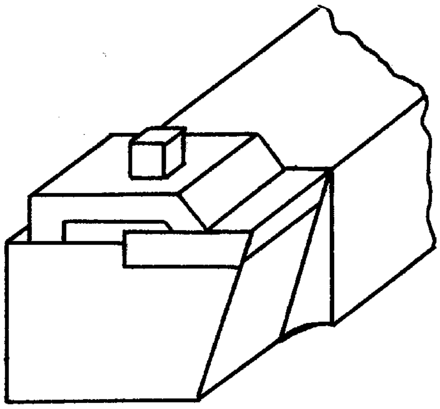
45° Angular Type

Used for light finishing cuts.



Mechanical Type

The mechanically held block is used for large tools, it is adjustable and avoids the necessity of grinding a groove or shelf. This method is used to advantage with clamped on tips.

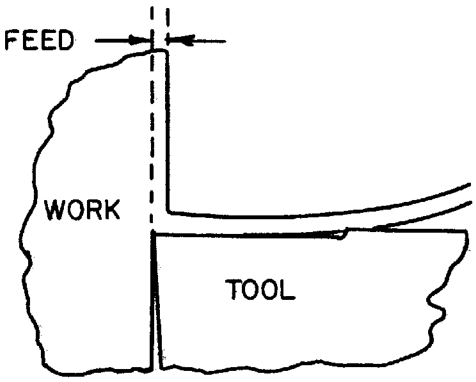


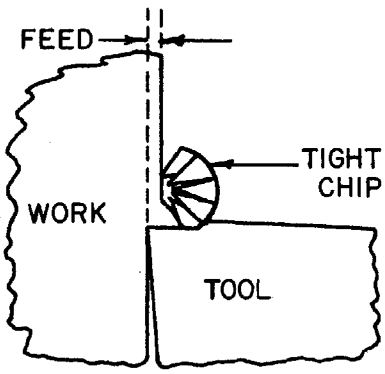
CHIP BREAKER DIMENSIONS ARE CRITICAL

A chip breaker bends the chip so it will break when striking the tool or work. If the radius of bending is too large the chip will not break. If the radius of bending is too small the tool life will be reduced. The factors effecting the radius of bending are feed, breaker width and breaker depth.

Breaker Width

A breaker that is too wide will not break the chip.

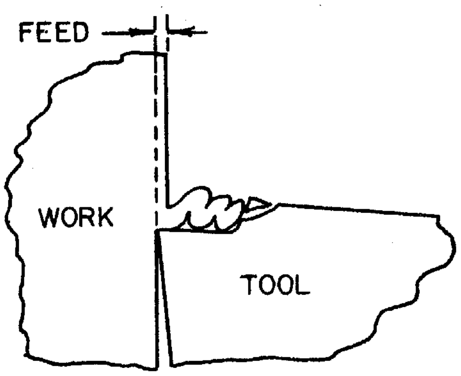




Breaker Width A breaker that is too narrow will crowd the chip, heat the tool, and reduce the tool life.

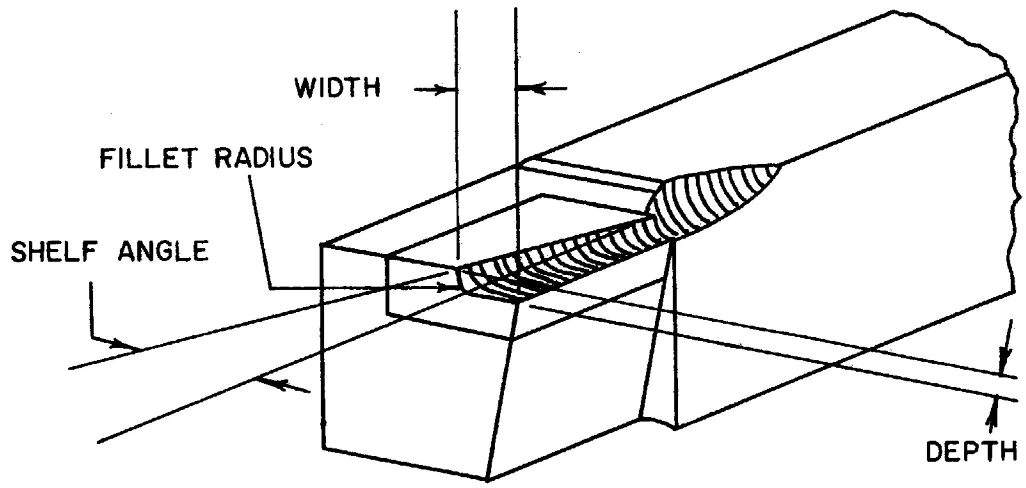
Breaker Depth

A breaker ground too deep and with a sharp fillet radius will catch the chip on the shelf causing chipping, high forces and poor tool life.



DESIGN OF CHIP BREAKERS

A. Design of the Shelf Type Chip Breaker



Important Dimensions for Shelf Type Chip Breaker

1. Determining Shelf Depth

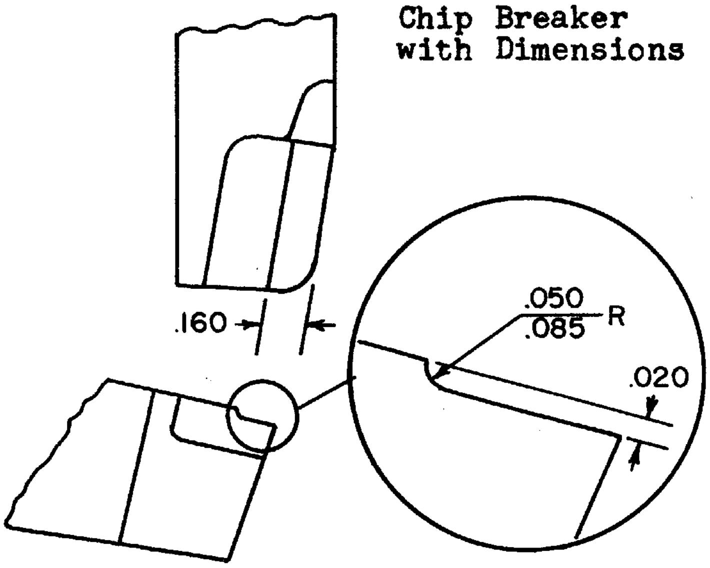
The depth should be proportional to the size of cut and tool size.

Tool Shank Size	Shelf Depth
Less than 3/4"	.015 to .020 inch
From 3/4" to 1"	.020 to .025 inch
Above 1"	.025 to .030 inch

A standardized depth of .020 is recommended

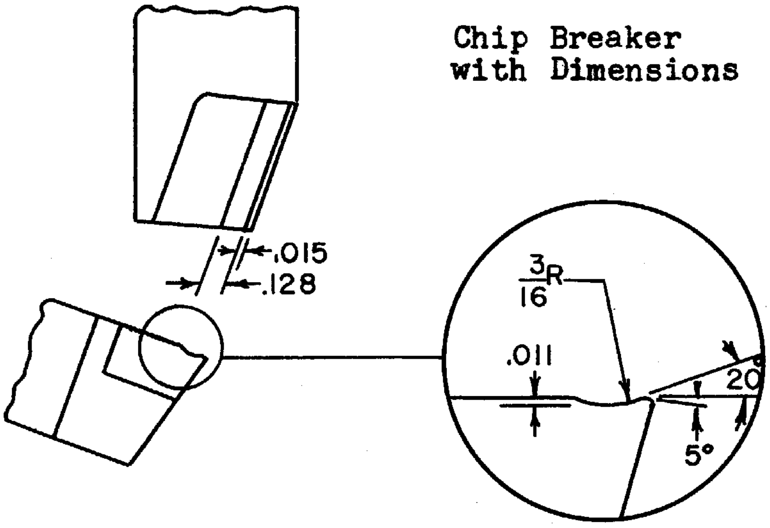
SHELF TYPE

Chip Breaker
with Dimensions

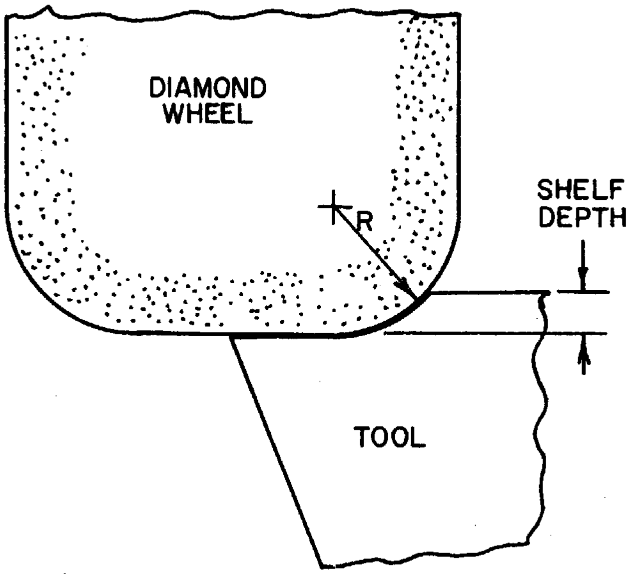


GROOVE TYPE

Chip Breaker
with Dimensions



B. Determining Fillet Radius



Fillet Radii are determined by shelf depth and Diamond wheel corner radius.

Shelf Depth	Fillet Radii in Inches	
	Minimum	Maximum
.015 inch	.035	.065
.020	.050	.085
.025	.060	.100
.030	.070	.125

C. Determining Breaker Width

The breaker width is influenced by:

(1) Material cut

(2) Feed rate

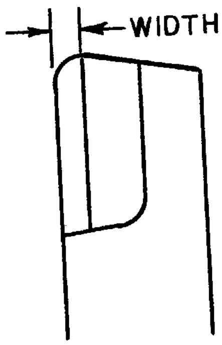
(3) Tool side cutting edge angle

(4) Depth of cut

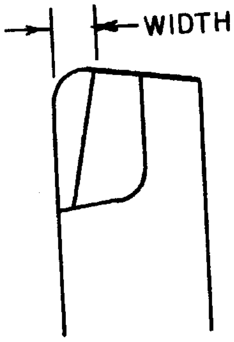
The true chip thickness is a function of the actual feed, side cutting edge angle and depth of cut.

Approximate Chip Breaker Width for a 0.020 Groove Depth

Modified Feed = Chip Thickness	Breaker Width
.005 - .0075	.050
.009 - .012	.076
.015 - .022	.125
.025 - .040	.187



Parallel Type



Angular Type

Recommended Rake Angles

Material Cut	Tool Material: Carbides	Tool Material: High Speed Steel
Ductile, Low Hardness, Below 200 BHN	20°-30°	30°
Med. " , 200 - 300 BHN	10°-20°	20° - 25°
Alloy, Heat Treated 300 - 400 BHN	0°-10°	5° - 10°

SURFACE FINISH

If you can machine a good enough surface finish, a grinding operation can be eliminated. Most product engineers, process planners, time study men, and machine operators know this, but the big question always has been, "How can I predict the setup conditions which will give this good surface finish? What materials, feeds, speeds, and tool shapes must be used? Present surface finish charts give a range of values but no way to obtain them."

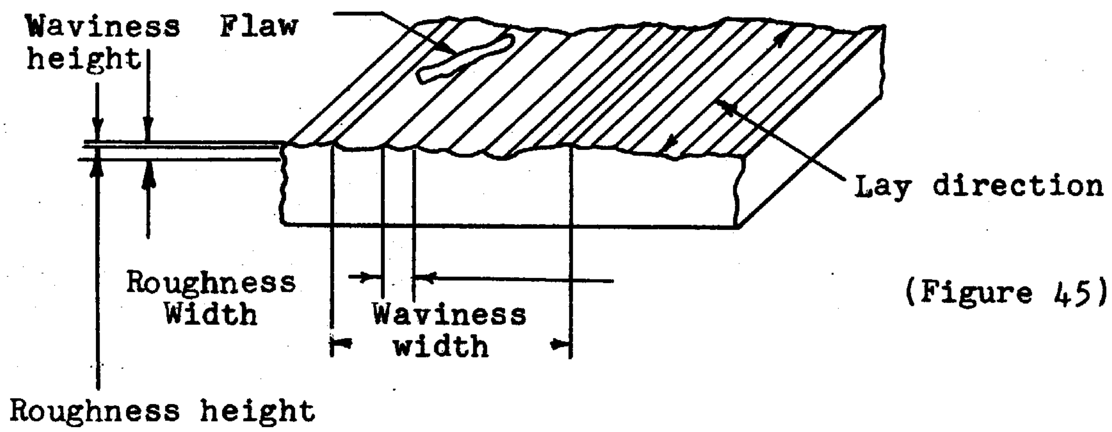
The following will help to eliminate the guesswork from the surface finish problem by illustrating, for single point cutting tools, the effect of the major variables on surface roughness. Easy to use charts have been developed which present the relations between these variables and make it possible to predict the surface roughness.

LIMITATIONS

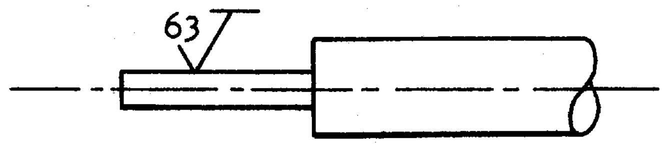
Of course, there are many other factors which affect the surface finish, such as rigidity, cutting fluids, rake angles, and smoothness of the cutting tool, but these will be considered later. It is assumed in this article that dry cutting is used and that there is sufficient rigidity to prevent chatter. The depth of cut is assumed to be uniform and typical of finishing cuts.

WHAT IS SURFACE ROUGHNESS?

Since we are limiting this discussion to the roughness factor of surface finish, it should be mentioned that no attempt is being made to discuss waviness, flaws, or pattern of the roughness which is called lay. These factors are shown in Figure 45 and described in the ASA standard B46.1 "Surface Roughness, Waviness and Lay." In this standard a symbol is given representing all characteristics of surface finish. However, in most cases a simplified symbol, as shown in Figure 46, is used to indicate the maximum allowable roughness.

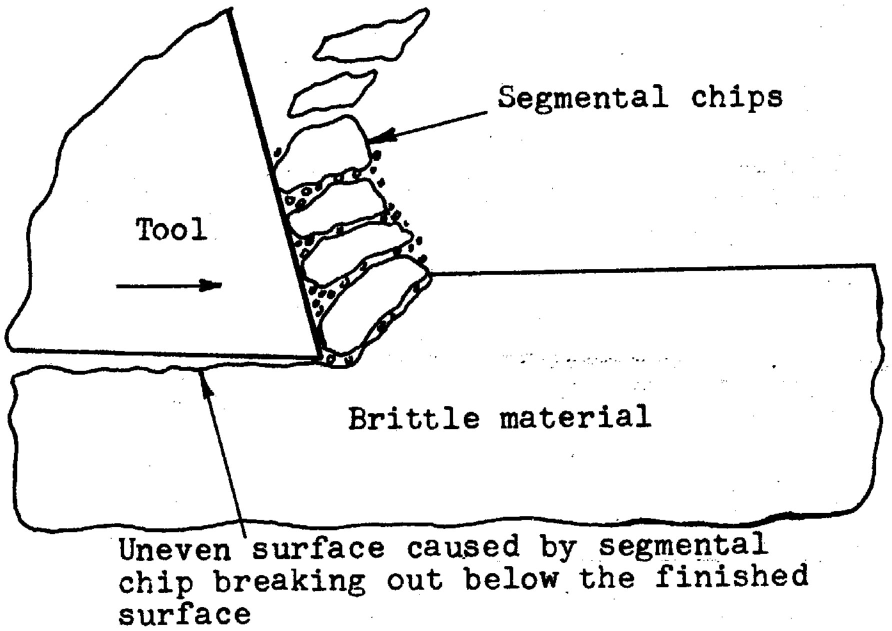


(Figure 45)

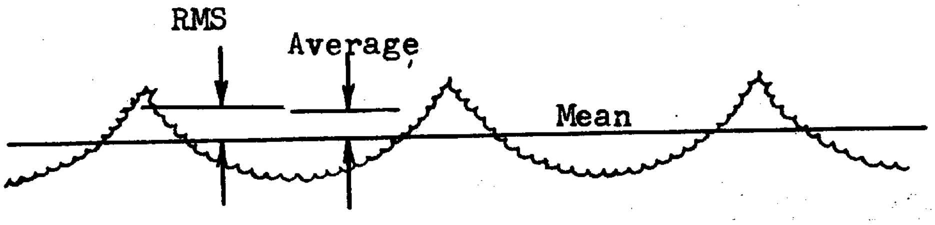


(Figure 46)

SEGMENTAL CHIPPING



Surface roughness is measured in microinches (millionth of an inch, 0.000001) and is the deviation from the mean line, as shown in Figure 47. In the past, the root mean square method (rms) has been used for averaging. This gives a value of approximately 30% of the peak-to-valley height. Recently the arithmetical average height has become more popular, and it gives a value of approximately 25% of the peak-to-valley height, as shown in Figure 47.



(Figure 47)

WHAT FACTORS INFLUENCE SURFACE ROUGHNESS?

The most important factors affecting surface qualities are:

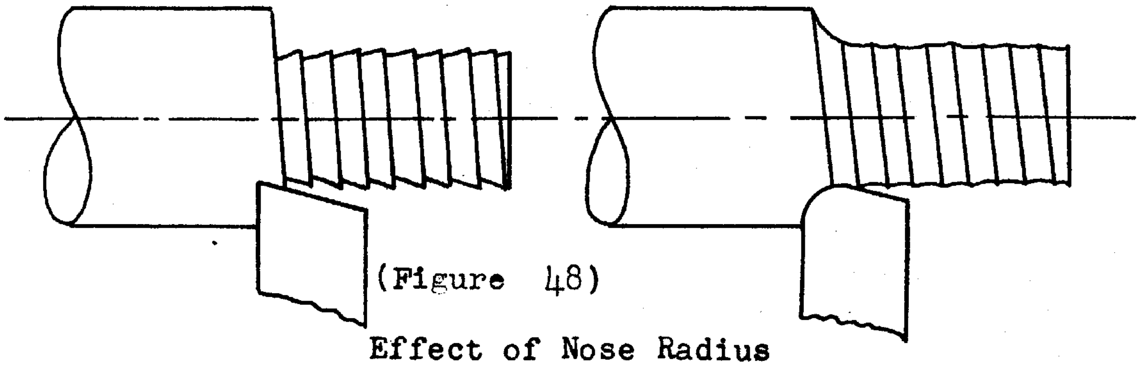
(1) Materials cut - high ductility of the material cut produces rough surfaces at low cutting speeds. Low carbon steels should be normalized, or quenched and drawn to reduce the ductility and improve the finish. Mechanical cold working will also reduce the ductility with beneficial results. Free cutting materials which include lead or sulphur have thinner chips and a minimum of "build up" on the point of the tool, so that the cutting condition is stable and the finish approaches the contour of the cutting edge of the tool. Brittle materials will break out below the surface, creating more roughness.

(2) Cutting speed - At slow cutting speeds a large unstable built-up edge causes high roughness. As the cutting speed is increased the built-up-edge becomes smaller and more stable, and the finish improves.

(3) Nose radius - The profile of the cutting tool is reproduced on the surface of the workpiece under ideal conditions. A larger radius will create a rough surface (Figure 48).

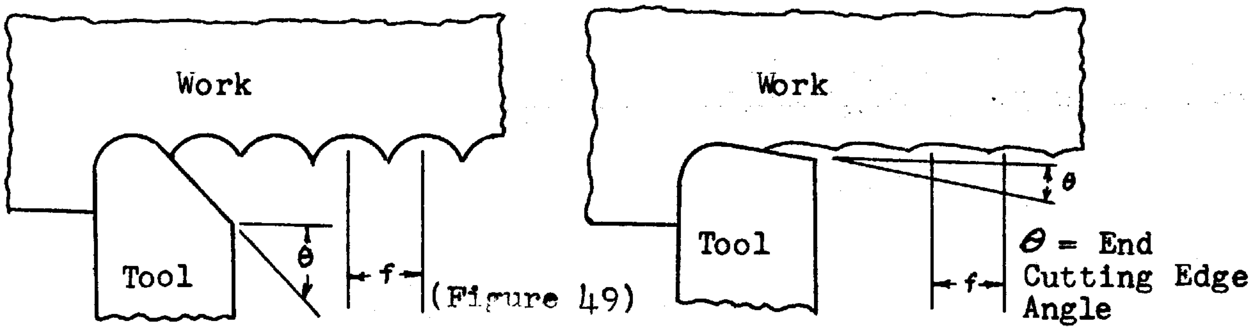
(4) Feed - is the spacing of the tool profile marks. Smaller feeds improve the surface finish.

(5) Smaller end-cutting-edge angles improve the surface finish, as shown in Figure 49, particularly at higher feed rates. Figure 49 is for a 6 degree end-cutting-edge angle.



(Figure 48)

Effect of Nose Radius



(Figure 49)

GRINDING SINGLE POINT TOOL

To grind tool bits to be used on an engine lathe for various turning operations, a bench or pedestal grinder is used for this purpose. The grinder should be equipped with two different grade grinding wheels so that one wheel may be used for roughing the tool angles and the other for finishing grinding to final shape. The pedestal grinder should have proper safety glass shields and the operators should wear safety goggles.

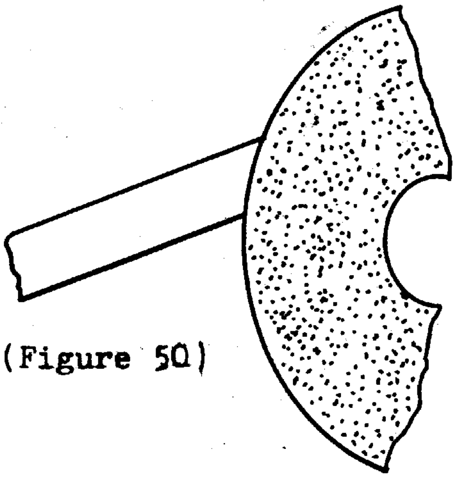
The grinding wheel face should be dressed if needed before the operation is started. The tool bit, depending on the size, may be held between the thumb and index fingers of both hands, and positioned against the grinding wheel face illustrated in Figure 50.

The first angle to be rough ground should be the end cutting edge angle by positioning the tool bit, as illustrated; the relief angle can also be ground at the same time. Tilt the tool bit until the bottom of the tool strikes the face of the wheel face and apply slight pressure on the bit and move the tool bit across the face of the grinding wheel. This prevents glazing of the wheel. (Note Figures 50 and 51). After the end cutting edge and relief angle have been rough ground, reposition the tool bit to grind the side cutting edge angle and the side relief angle at the same time by holding the tool bit parallel with the wheel face and tilting the tool until the bottom of the tool strikes the wheel face (Figure 52). To form the nose radius on a tool bit, position the sharp point of the tool on the face of the wheel, tilting the tool slightly so that the bottom of the tool makes contact with the wheel first and pivot the wheel on a radius to form the round nose (Figure 53). To grind the side rake angles, position the tool bit in front of the grinding wheel face by holding the side cutting edge angle horizontal and parallel with the face of the wheel and tilt the tool until the bottom edge strikes the wheel face first (Figure 54).

This will grind the positive side rake angle, and by pivoting the tool so that the wheel will grind a little more depth towards the body of the tool bit, the back rake angle can be ground while the tool is in this same position (Figure 54).

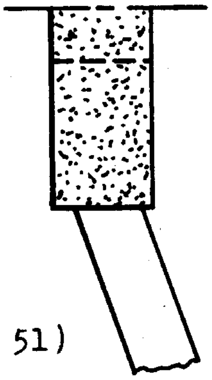
To grind the nose radius, pivit the tool bit slightly upwards and swing to right and left. Large tool bits that are used for heavy depth of cuts quite frequently require a chip breaker. This may be done by grinding a small groove on the top face of the tool close to the cutting edge. For finish turning all tool bits should be stoned with an abrasive stone; this will provide a keen cutting edge. The same practice should be done between several cuts when turning. This will save removing a tool bit for complete grinding.

GRINDING RELIEF AND RAKE ANGLES ON A TOOL BIT



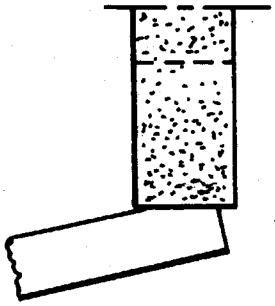
(Figure 50)

A. End Relief Angle



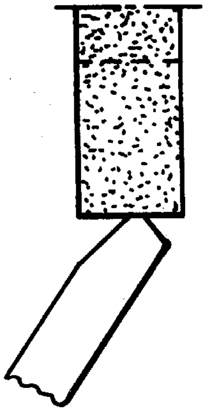
(Figure 51)

B. End Cutting Edge Angle



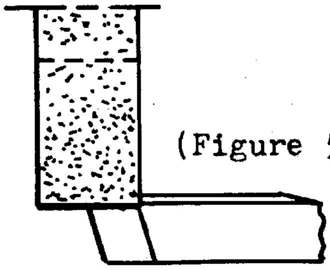
(Figure 52)

C. Side Cutting Edge Angle



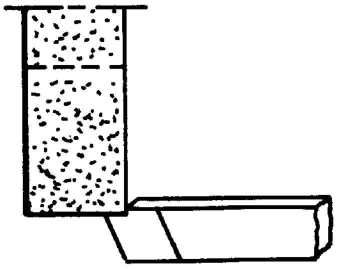
(Figure 53)

D. Nose Radius

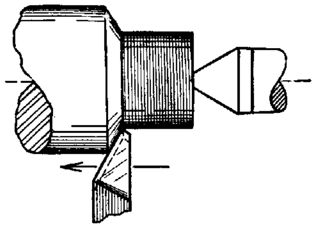


(Figure 54)

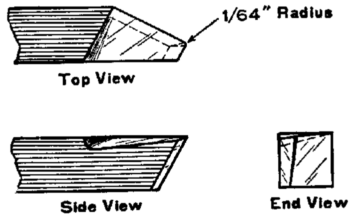
E. Side Rake



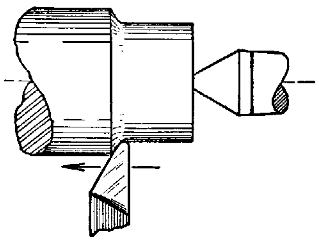
F. Chip Breaker



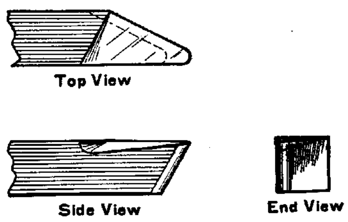
Application of Roughing Tool



Detail of Roughing Tool



Application of Finishing Tool



Detail of Finishing Tool

SPEED AND FEED CALCULATIONS FOR TURNING

In order to machine materials economically and efficiently on a lathe, it is necessary to have a knowledge of feeds and speeds for certain machining conditions. Cutting speed, feed, and depth of cut are terms which apply to all machining operations.

Speed may be defined as the peripheral speed at the cutting edge and is always given in fpm (surface feet per minute) since work diameters vary and the rpm on a spindle of a machine is meaningless without knowing the peripheral speed of the work material. The factors which govern the selection of cutting speeds are:

(1) Metals Being Machined - hard metals require slower cutting speeds than soft or ductile metals.

(2) Cutting Tool Materials Used - high speed steel cutting tools are normally used at slower cutting speeds than tungsten carbide materials or ceramics.

(3) The Tool Geometry and the Operation Being Performed - some machining operations require slower cutting speeds because of greater tool and work surface contact. For example, form turning or cutting off operations should be done at slower speeds than straight turning operations.

(4) Speed and Depth of Cut - when performing heavy roughing cuts, a much slower cutting speed should be employed than when taking light depths of cuts for finish turning operations.

(5) Coolants or Cutting Compounds - Ferrous materials when machined dry require slower cutting speeds than when a coolant or a cutting compound is employed. The coolant will reduce the heat, thereby permitting the speeding up of the cutting operation and increasing the tool life.

(6) Horse Power and Machine Capacity - Machines with higher horse power and speeds are more rigidly

constructed and, if in good condition, would have the capabilities to use cutting tool materials designed for machining at higher speeds. This is essential for tungsten carbide and ceramics cutting tools in order to use these tools at the optimum cutting speeds and feeds.

The cutting speeds given in Table I are considered safe speeds for turning with high speed cutting bits. These are only averages and machine conditions, capacities and setups employed can increase these cutting speeds considerably. To calculate the surface feet per minute of a given workpiece that is being machined when the work diameter and the rpm are given, the following formula will compute fpm:

$$\text{fpm} = \frac{3.1416 \times \text{work diameter} \times \text{rpm}}{12''}$$

For example, assume that it is desired to calculate the surface feet of a piece of work material that is 3 inches in diameter and it revolves at a speed of 250 rpm:

$$\text{fpm} = \frac{3.1416 \times 3 \times 250 \text{ rpm}}{12''}$$

To convert surface feet per minute to rpm, the following formula can be used:

$$\text{rpm} = \frac{12'' \times \text{fpm}}{3.1416 \times \text{work dia.}}$$

For example, assume that it is desired to calculate the rpm for a piece of low carbide steel that is 2 inches in diameter having a surface feet per minute of 100 feet:

$$\text{rpm} = \frac{12'' \times 100}{3.1416 \times 2''}$$

Feed is expressed as ipr (inches per revolution) or the distance that the tool advances for each revolution of the work. Factors governing the selection of feed are:

(1) Rigidity of the Work and the Setup Employed - a coarse feed is used for large rigid work which is held securely in a four-jaw chuck or between centers, while a fine feed would be required for long cylindrical work that may be held in a collet chuck or between centers.

(2) Finish Desired - to acquire a fine finish, a fine feed would be selected while a coarse feed would produce a rough surface.

(3) Depth of Cut - the feed used for heavy cuts cannot be as great as that used for light cuts due to the pressure asserted on the cutting tool when taking heavy cuts. The depth of cut determines how much the work diameter is reduced. Therefore, the workpiece diameter is reduced twice the depth of cut.

SPEED AND FEED CALCULATIONS FOR SHAPERS

To calculate speed and feed for shapers, the ram which moves with a reciprocating motion carries the tool head and the cutting tool over the work surface. The cutting speed on a shaper is determined by the speed at which the tool cuts over the work in feet per minute. Cutting speed for shapers is given in the number of strokes per minute. The shapers ram is adjustable for various settings to acquire the correct number of strokes per minute. The setting is dependent on the length of stroke. To calculate the required strokes per minute, multiply the cutting speed by 7 and divide the product by the number of strokes per minute.

$$N = \frac{CFS \times 7}{L}$$

N = number of strokes per minute
cfs = cutting speed
L = length of stroke in inches which is the length of the work on the machine, plus 1 inch.

This allows the overtravel of the tool to clear the work. For example, to determine the number of strokes per minute for roughing a piece of metal 10 inches long, the length of stroke required would be 10 + 1", giving a stroke of 11". For example, $n = \frac{20 \times 7}{11} = 12.7$. The following table gives recommended cutting speeds for various metals.

Materials To Be Machined	Carbon Steel Tools		High Speed Steel Tools	
	Cutting Speed (feet per minute)			
	Roughing	Finishing	Roughing	Finishing
Cast Iron	30	20	60	40
Mild Steel	25	40	50	80
Tool Steel	20	30	40	60
Brass and Bronze	75	100	150	200
Aluminum	75	100	150	200

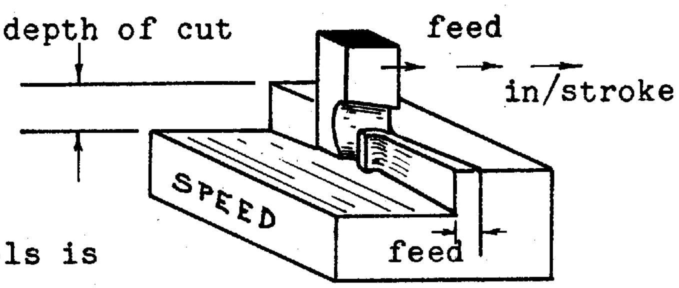
Table I. Recommended Cutting Speeds for Various Metals.

Feed - refers to the distances the tool advances for each stroke of the shaper ram. Shaper feeds ranging from .010" per stroke up to approximately .180" per stroke may be obtained with more shapers.

Finish Desired - a fine feed is used on work desiring fine finish, while a coarse feed should be employed for rough cuts. Depth of cut will vary with fine finishes. Depth of cut for fine finishes with sharp tools should not exceed .005 inches depending on type of cut. When considerable material is to be removed by the feed, the cut should be held to a maximum.

Work-Tool Motion

Speed is relative motion between tool and work expressed in surface feet per minute (FPM).



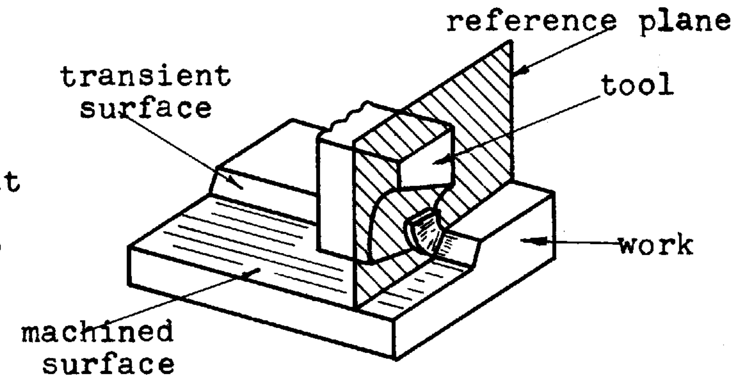
Linear

Feed with single-point tools is the amount the tool or work table is indexed and is measured parallel to the machined surface and perpendicular to tool path.

Depth of cut is the perpendicular height of the transient surface.

Imaginary Reference Plane

Note from illustration that this plane is perpendicular to tool work relative motion and contains the tool point needed in defining all tool lines.

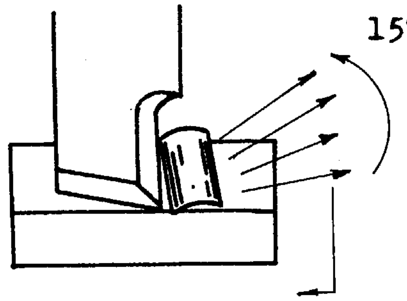


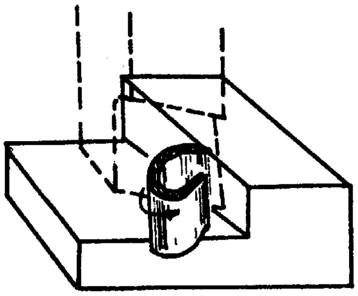
CHIP ACTION IN SHAPING AND PLANING

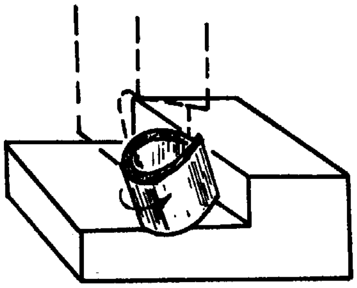
<u>Cutting edge angles</u> - These angles are measured on a reference plane from the machine surface to the end cutting edge and from a normal to the side cutting edge. The tool point is the apex.

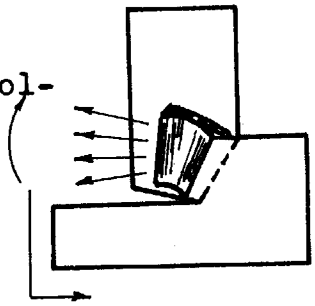
<u>Tool face slope</u> - This is usually given by the four angles, all normal to the reference plane. Back and side rakes are normal to and on machine surfaces. The resultant rake equals rake and inclination are normal to and on transient surface.

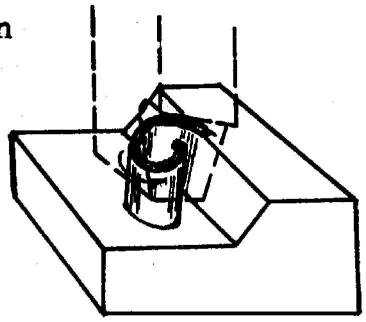
<u>Chip Flow Controlled by Tool Angles</u> - The chip disposal surface finish and tool life are influenced by the direction of chip flow. The following illustrations show the effect of changing inclination and cutting edge angles. Note that as the inclination increases, the cutting edge becomes more inclined in a direction similar to the back rake. This tilts the chip plane to a spiral upward direction directing the chip away from the machine surface. As the side cutting edge angle increases, the transient surface slopes even more, lifting the resulting rake plane and chip spiral, thereby causing the chip to flow away from the surface.

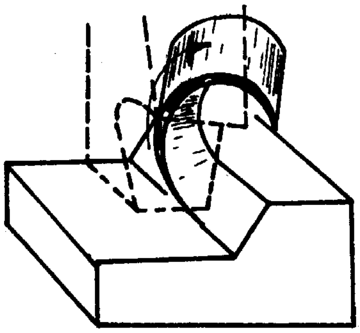


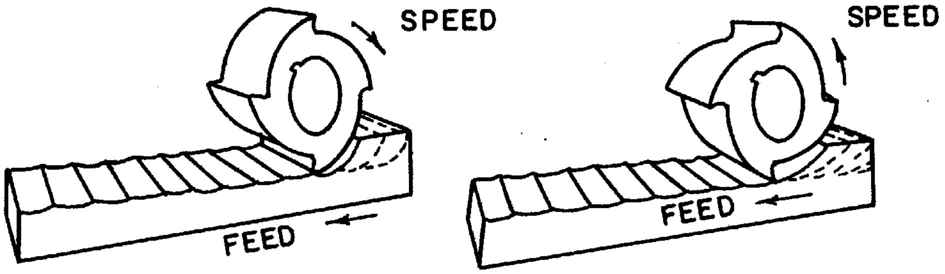












SPEED AND FEED CALCULATIONS FOR MILLING

The proper selection of speeds and feeds is fundamental for the best performance of all milling cutters. Climb cutting and rigid machines with sufficient power are highly recommended for milling with high-speed-steel cutters.

Speeds - exact speed and feed recommendations for milling are difficult because of the number of variables. In general, surface speed of milling cutters should vary inversely with the hardness of the material to be milled. Soft materials can be milled at high speeds; hard materials call for low speeds.

Finish and accuracy improve with higher speed, lower feed and shallow depth of cut.

Where maximum stock removal is the prime objective, milling speeds should be held to the lower limit of the ranges indicated in Table II. If the available horsepower permits faster rates of stock removal, then an increase in the rate of feed or depth of cut should be considered rather than an increase in speed. In every instance, speed will depend upon the condition of the milling machine and the rigidity of the workpiece and fixtures.

Where their application is recommended, Cast-Alloy cutters should be run at approximately twice the speed of High-Speed-Steel cutters. Carbide cutters should be run at approximately five times the speed of High-Speed-Steel cutters. Machine rigidity and climb milling are prerequisites for best results with both Cast-Alloy and Carbide milling.

Feeds - the highest production rate is obtained when each tooth in the cutter takes the largest possible cut. The heat generated in a heavy chip is proportionately less than in a light chip. Cutter life, as expressed in cubic inches of metal removal between grinds, increases with higher feed rates.

All feed rates should be calculated on the basis of feed per tooth. Feed rates expressed in inches per minute of table travel can be misleading because of variations in numbers of teeth in cutters of the same diameter.

Normal feed per tooth can be increased without detrimental effect on cutter life, provided the following conditions exist:

(1) Milling machine is in good condition, with ample power available.

(2) Fixture is rigid and designed to bring cut close to the milling table.

(3) Proper milling cutter selected for the material being machined.

Rigid setups, soft materials, and shallow cuts permit heavier feeds. Frail setups, thin cutters, deep slots, stringy material and high finish requirements call for lower feeds per tooth.

As a guide in setting up an initial job, the following table of suggested feeds should prove of value: TABLE II

Type of Cut	Starting feed per tooth
Face Milling	.008
Straddle Milling	.008
Channel or Slot Milling	.008
Slab Milling	.007
End Milling or Profiling	.004*
Sawing	.002

* For end mills smaller than ½ inch diameter, feeds per tooth must be much lower than the figure given.

Horsepower Comsumption in Milling - With the higher speeds and feeds that are possible with present-day cutters, especially carbide cutters, horsepower requirements are correspondingly higher. It is important, therefore, to ascertain that sufficient power is available to handle the desired cuts with these higher speeds and feeds.

By introducing a constant, C, corresponding to the machinability of the material to be cut, it is possible to calculate the horsepower required for a given cut as follows:

hp = Motor horsepower

d = Depth of cut in inches

w = Width of cut in inches

F = Feed (inches per minute)

f = Feed per tooth in inches

T = Number of teeth in cutter

rpm = Revolutions per minute of cutter

C = Machinability constant

$$\text{Then hp} = \frac{d \times w \times F}{C}$$

$$\text{or hp} = \frac{d \times w \times T \times f \times rpm}{C}$$

Values of C for various materials, based on 60% machine efficiency and a 25% allowance for dulling, are:

Work Material	C (constant)
Aluminum, Magnesium	4.0 plus
Brass	2.5
Bronze, Copper	2.0
Cast Iron	1.5
Steel, up to 150 Brinell	.75
Steel, 300 Brinell	.6
Steel, 400 Brinell	.5

Coolants or Lubricants - On many milling operations, it is important that careful consideration be given selection and application of a coolant. Coolants are used on milling operations for three principal reasons:

> Control of tool temperature. It is important that tool temperature be kept below the point of damage to the tool. Coolant is seldom used on carbide milling applications. Coolant flow on any job should be steady and in sufficient

volume to maintain the desired cooling effects.

Control of work temperature. Close size control of workpieces is possible only if reasonable control of expansion from heating is exercised. Coolant is applied to carry away the full heat generated by machining.

Reduced friction during chip formation. Careful investigation has shown that the action of a coolant on a chip forms a film coating with lubricating properties. The heat generated in chip formation is radically reduced through this lubricating action. Reduction of heat from chip formation automatically reduces the total heat to be absorbed by the tool and the work material. This explains why small amounts of coolant which are effective film formers are often more efficient than copious quantities of coolant which act merely as a refrigerant.

POWER CALCULATIONS

The power requirement for metal cutting under average conditions is calculated from the following formula:

$$HP_{motor} = \frac{A \times B}{0.7}$$

Where:

A = Unit HP factor (hp/in^3/min) from Table III

B = The metal removal rate calculated from Table III

.7 = Average assumed machine efficiency factor

When more than one tool is cutting at the same time, calculate the HP requirements for the individual tools and add for total HP.

If extremely light or extra heavy cuts are taken, a fourth factor, the feed correction factor, should also be used. The formula will then read:

$$HP_{motor} = \frac{A \times B \times C}{0.7}$$

Where: C = feed correction factor from Table IV.

TABLE III

AVERAGE UNIT HORSEPOWER FACTORS

Ferrous Materials:

Work Matl.	Brinell Hardness Numbers Up to 175	Up to 275	Up to 400
Plain Carbon Steel	0.5	0.9	1.1
Free Cutting Steel	0.4	0.5	-
Alloy Steel	0.6	0.8	1.3
Cast Iron	0.3	1.0	-

Non Ferrous Materials:

	Soft	Medium	Hard
Brass	.33	.50	.83
Leaded Brass	-	.25	-
ronze	.33	.50	.83
opper (pure)	-	.91	-
luminum	.25	.25	.33
onel	-	.69	1.4
inc Alloy (die cast)	-	.25	-
agnesium Alloy	-	.10	-

TABLE IV

FEED CORRECTION FACTORS

ght Cuts:

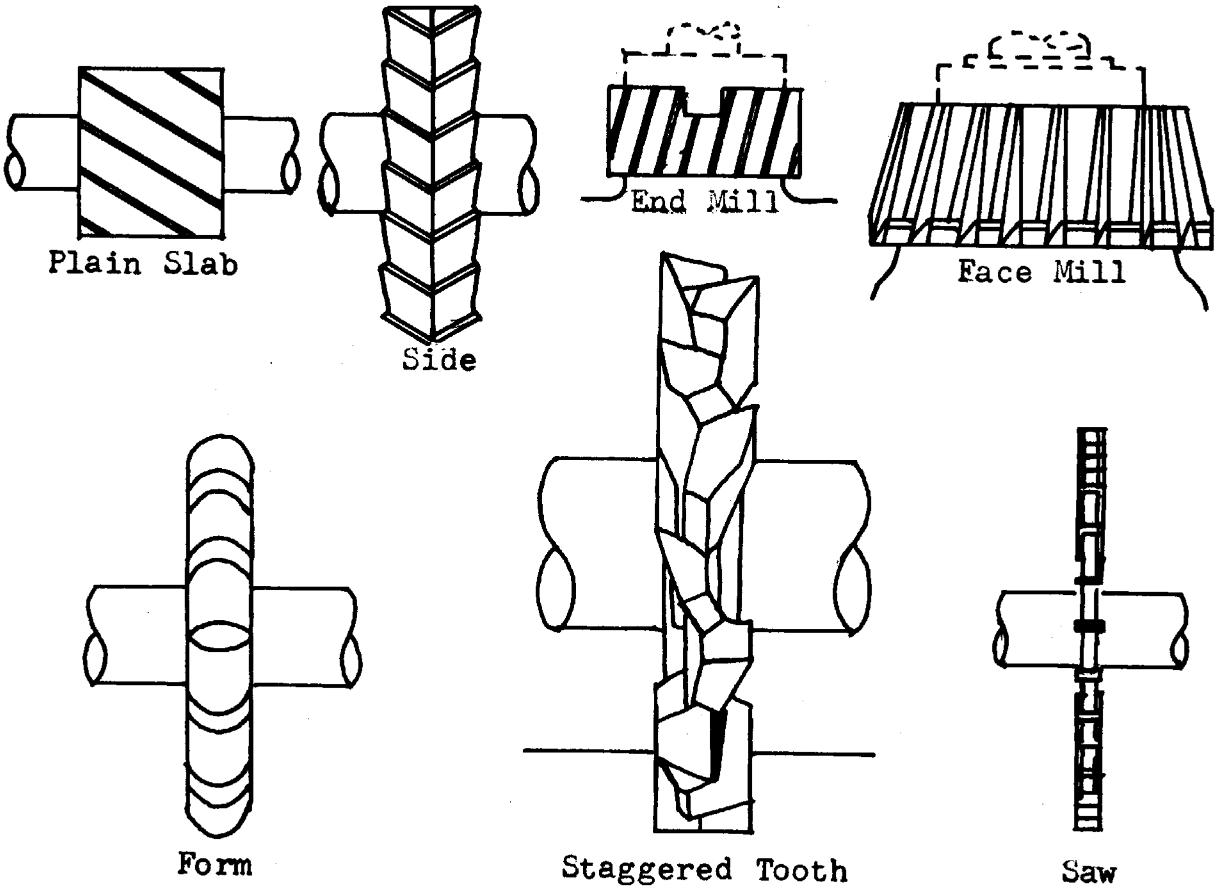
ed ipr or ipt	.001	.0015	.002	.0025	.003	.004
factor	1.55	1.45	1.4	1.33	1.3	1.22

avy Cuts:

ed ipr or ipt	.030	.040	.050	.060	.070	.080
factor	0.86	0.82	.79	.76	.74	.73

GUIDE TO CORRECT FEED SELECTION

Feed Per Tooth per Revolution = Chip Load



RECOMMENDED CHIP LOAD TABLES

Type of Cutter	In Cast Iron	In Steel	In Brass, Bronze Aluminum
Face Mill, H.S.	.020 to .025	Less 40%	Plus 50%
Slab Mill, H.S.	.010 to .015	Less 40%	Plus 50%
Slotting Cutter, H.S.	.006 to .012	Less 40%	Plus 50%
Form Mill, H.S.	.004 to .006	Less 40%	Plus 50%
End Mill, H.S.	.002 to .010	Less 40%	Plus 50%
Saw, H.S.	.001 to .003	Less 40%	Plus 50%
Cemented Carbide Face Mill	.008 to .012	.004 to .008	.010 to .016

TABLE V

In general, select the proper SPEED for work material and cutter; and then determine the feed, within the above limits, according to the cut and the power available or the finish required.

RECOMMENDED CONDITIONS FOR MACHINING HIGH STRENGTH THERMAL RESISTANT ALLOYS

by

METCUT RESEARCH ASSOCIATES INC.
CINCINNATI 9, OHIO

RECOMMENDED CUTTING CONDITIONS FOR MACHINING AISI 4340 STEEL QUENCHED AND TEMPERED TO 49-52 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
Turning 52 R_c	C-8 Carbide	SR: -5° SCEA: 15° BR: -5° ECEA: 15° Relief: 5°	1/2" Sq. Throwaway holder with mech. chip breaker	.100"	-	.009"/rev.	150 ft./min.	47 min.	.016"	None
Turning 52 R_c	T-15 HSS	SR: 15° SCEA: 0° BR: 0° ECEA: 5° Relief: 5°	5/8" Sq. Tool Bit	.060"	-	.009"/rev.	25 ft./min.	65 min.	.060"	Soluble Oil (20:1)
Face Milling 52 R_c	C-6 Carbide	AR: 0° ECEA: 5° RR: -15° Cl: 8° CA: 45°	5" Dia., 5 Tooth Inserted Tooth Face Mill	.100"	2"	.005"/tooth	150 ft./min.	65"/tooth	.016"	None
Side Milling 52 R_c Up Milling Setup	C-6 Carbide	AR: -5° ECEA: 5° RR: -10° Cl: 8° CA: 45°	7" Dia., 6 Tooth Inserted Tooth Face Mill	.100"	1-3/4"	.0075"/tooth	150 ft./min.	65"/tooth	.016"	None
Slot Milling 52 R_c Down Milling Setup	C-2 Carbide	AR: 5° bi-negative RR: -10° ECEA: 1° CA: 45° x .030" Cl: 8°	6" Dia., 6 Tooth Brazed Tooth Slotting Cutter	.250"	1"	.005"/tooth	190 ft./min.	38"/tooth	.016"	None
End Milling 52 R_c	C-2 Carbide	AR: 0° ECEA: 3° RR: 0° Cl: 15° CA: 45° x .030"	1-1/4" Dia., 4 Flute Heavy Duty Brazed Tip End Mill	.250"	1-1/4"	.0015"/tooth	50 ft./min.	78"	.016"	(1) Soluble Oil (20:1)

(1) Applied as spray mist through axis of cutter.

(continued)

RECOMMENDED CUTTING CONDITIONS FOR MACHINING AISI 4340 STEEL QUENCHED AND TEMPERED TO 49-52 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
End Milling 49 R_c	T-15 HSS	35° RH Helix CA: 45° x .060" Per. Cl: 6°	3/4" Dia., 4 Flute End Mill	.250"	3/4"	.001"/tooth	55 ft./min.	70"	.016"	Soluble Oil Flood (20:1)
Drilling 50 R_c	T-15 HSS	2 Flute, 118° Crankshaft Point 7° Clearance	1/4" Dia. Drill 2-1/2" Long	.500" Thru Hole	-	.001"/rev.	30 ft./min.	100 + Holes	*	Highly Sulphur-ized Oil + Light Machine Oil (1:1)
Drilling 52 R_c	Same	Same	Same	Same	-	Same	20 ft./min.	34 Holes	.016"	Same
Tapping 50 R_c	M-10 HSS	4 Flute Taper Tap 60% Thread	5/16-18 NC Taper Tap	.500" Thru Hole	-	-	5 ft./min.	146 Holes	Tap Break-age	Highly Chlorin-ated Oil + Inhib-ited Trichloro-ethane (3:1)
Tapping 50 R_c	(1) Same	4 Flute Taper Tap 75% Thread	Same	Same	-	-	Same	13 Holes	Tap Break-age	Same
Tapping 52 R_c	M-10 HSS Cyan-ided	4 Flute Taper Tap 60% Thread	Same	Same	-	-	Same	65 Holes	Tap Break-age	Same

* Test discontinued before .016" wearland was obtained.

(1) Higher tap life can be obtained using cyanided taps.

RECOMMENDED CUTTING CONDITIONS FOR MACHINING VASCO JET 1000 QUENCHED AND TEMPERED TO 50-52 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
Turning 52 R_c	C-8 Carbide	SR: -5° SCEA: 15° BR: -5° ECEA: 15° Relief: 5°	1/2" Sq. Throwaway holder with mech. chip breaker	.100"	-	.009"/rev.	100 ft./min.	50 min.	.016"	None
Turning 52 R_c	T-15 HSS	SR: 15° SCEA: 0° BR: 0° ECEA: 5° Relief: 5°	5/8" Sq. Tool Bit	.060"	-	.009"/rev.	20 ft./min.	55 min.	.060"	Highly Sulphurized Oil
Face Milling 52 R_c	C-2 Carbide	AR: 0° ECEA: 5° RR: -15° Cl: 8° CA: 45°	5" Dia., 5 Tooth Inserted Tooth Face Mill	.100"	2"	.005"/tooth	125 ft./min.	80"/tooth	.016"	None
Side Milling 52 R_c Down Milling Setup	C-2 Carbide	AR: 0° ECEA: 5° RR: -15° Cl: 8° CA: 45°	7" Dia., 6 Tooth Inserted Tooth Face Mill	.100"	1-3/4"	.0075"/tooth	150 ft./min.	65"/tooth	.012"	None
Slot Milling 52 R_c Down Milling Setup	C-2 Carbide	AR: 5° bi-negative RR: 10° ECEA: 1° CA: 45° x .030" Cl: 8°	6" Dia., 6 Tooth Brazed Tooth Slotting Cutter	.250"	1"	.005"/tooth	190 ft./min.	50"/tooth	.012"	None
End Milling 52 R_c	C-2 Carbide	AR: 0° ECEA: 3° RR: 0° Cl: 15° CA: 45° x .030"	1-1/4" Dia., 4 Flute Heavy Duty Brazed Tip End Mill	.250"	1-1/4"	.0015"/tooth	60 ft./min.	105"	.016"	(1) Soluble Oil (20:1)

(1) Applied as spray mist through axis of cutter.

(continued)

RECOMMENDED CUTTING CONDITIONS FOR MACHINING VASCO JET 1000 QUENCHED AND TEMPERED TO 50-52 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
Drilling 50 R_c	M-33 HSS	2 Flute, 118° Crankshaft Point 7° Clearance	1/4" Dia. Drill 2-1/2" Long	.500" Thru Hole	-	.001"/rev.	40 ft./min.	105 Holes	.016"	Highly Sulphurized Oil + Light Machine Oil (1:1)
Drilling 52 R_c	Same	Same	Same	Same	-	Same	Same	68 Holes	.016"	Same
Tapping 50 R_c	M-10 HSS Cyanided	4 Flute Taper Tap 60% Thread	5/16-18 NC Taper Tap	.500" Thru Hole	-	-	5 ft./min.	75 + Holes	*	Highly Chlorinated Oil + Inhibited Trichloroethane (3:1)
Tapping 50 R_c	(1) M-10 HSS	4 Flute Taper Tap 75% Thread	Same	Same	-	-	Same	8 Holes	Tap Breakage	Same
Tapping 52 R_c	M-10 HSS Cyanided	4 Flute Taper Tap 60% Thread	Same	Same	-	-	Same	40 + Holes	*	Same
Tapping 52 R_c	Same	4 Flute Taper Tap 75% Thread	Same	Same	-	-	Same	7 Holes	Tap Breakage	Same

* Test discontinued; tap still cutting.

(1) Tap life can be improved by using cyanided taps.

RECOMMENDED CUTTING CONDITIONS FOR MACHINING D6AC STEEL QUENCHED AND TEMPERED TO 56 R_c AND 58 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut inches	Width of Cut inches	Feed	Cutting Speed ft./min.	Tool Life	Wear-land inches	Cutting Fluid
Turning 56 R_c	C-4 Carbide	BR: -5° SCEA: 15° SR: -5° ECEA: 15° Relief: 5° NR: 1/32"	1/2" square throwaway holder with mech. chip breaker	.062	-	.005" per rev.	75	38 min.	.016	None
Turning 56 R_c	030 Ceramic	BR: -5° SCEA: 15° SR: -5° ECEA: 15° Relief: 5° NR: 1/32"	1/2" square throwaway holder with mech. chip breaker	.062	-	.005" per rev.	175	26 min.	.016	None
Face Milling 56 R_c Down Milling Setup	C-2 Carbide	AR: 0° ECEA: 6° RR: -15° Clearance: 10° CA: 45°	4" diameter face mill	.060	2	.010" per tooth	65	65" per tooth	.016	None
Face Milling 58 R_c Down Milling Setup	C-2 Carbide	AR: 0° ECEA: 6° RR: -15° Clearance: 10° CA: 45°	4" diameter face mill	.060	2	.008" per tooth	65	25" per tooth	.016	None
Slot Milling 56 R_c Down Milling Setup	C-2 Carbide	AR: -5° bi neg. RR: 0° ECEA: 1° CA: 45° x .030" Clearance: 10°	6" dia. x 1" wide inserted tooth slotting cutter	.125	1	.003" per tooth	230	40" per tooth	.020	None
Slot Milling 58 R_c Down Milling Setup	C-2 Carbide	AR: -5° bi-neg. RR: 0° ECEA: 1° CA: 45° x .030" Clearance: 10°	6" dia. x 1" wide inserted tooth slotting cutter	.125	1	.002" per tooth	125	48" per tooth	.020	None

RECOMMENDED CUTTING CONDITIONS FOR MACHINING
D6AC STEEL QUENCHED AND TEMPERED TO 56 R_c AND 58 R_c

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut inches	Width of Cut inches	Feed	Cutting Speed ft./min.	Tool Life	Wear-land inches	Cutting Fluid
End Mill Slotting 56 R_c	C-2 Carbide	AR: 0° ECEA: 5° RR: 0° Clearance: 15° CA: 45° x .030"	1-1/4" dia., 4 flute heavy duty, brazed tip end mill	.125	1-1/4	.003" per tooth	40	54 inches	.016	(1) Soluble Oil (1:20)
Drilling 56 R_c	C-2 Carbide	Point Angle: 118° Helix Angle: 0° Clearance: 10° Notched Point	.250" dia. carbide tipped die drill	1/2" thru hole	-	.001" per rev.	115	70 holes	.016	Highly Chlorinated Oil
Drilling 58 R_c	C-2 Carbide	Point Angle: 118° Helix Angle: 0° Clearance: 10° Notched Point	.250" dia. carbide tipped die drill	1/2" thru hole	-	.001" per rev.	115	40 holes	.016	Highly Chlorinated Oil
Reaming 56 R_c	C-2 Carbide	Helix Angle: 0° (2) Corner Angle: 45° Clearance: 10°	Standard .272" dia. 4 flute carbide tipped chucking reamer	1/2" thru hole	-	.002" per rev.	65	60 holes	.012	Highly Chlorinated Oil

SURFACE GRINDING

Wheel Grade	Grinding Fluid	Wheel Speed feet/minute	Table Speed feet/minute	Down Feed inches/pass	Cross Feed inches/pass	G Ratio
32A46H8VBE	Highly Sulphurized Oil	6000	40	.001	.050	75

(1) Applied as spray mist through axis of cutter

(2) 5° negative rake land honed on tooth corners approximately .010" wide

RECOMMENDED CUTTING CONDITIONS FOR MACHINING
RENE 41 SOLUTION TREATED AND AGED TO 365 BHN

Operation	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut inches	Width of Cut inches	Feed	Cutting Speed ft./min.	Tool Life	Wear-land inches	Cutting Fluid
Turning	C-2 Carbide	BR: 0° ECEA: 15° SR: 5° Relief: 5° SCEA: 15° NR: 1/32"	1/2" square throwaway holder with mech. chip breaker	.062	-	.009 in/rev	70	28 min.	.016	Soluble Oil (1:20)
Turning	T-15 HSS	BR: 0° ECEA: 5° SR: 15° Relief: 5° SCEA: 0° NR: 1/32"	5/8" square tool bit	.062	-	.009 in/rev	12	81 min.	.030	Highly Chlorinated Oil
Face Milling	C-2 Carbide	AR: 0° TR: 5° RR: 7° Incl: -5° CA: 45° ECEA: 5° Clearance: 10°	4" diameter face mill	.060	2	.0065 in/tooth	63	29 in/tooth work travel	.030	Highly Chlorinated Oil
Face Milling	T-15 HSS	AR: 0° TR: 22° RR: 30° Incl: -22° CA: 45° ECEA: 5° Clearance: 10°	4" diameter face mill	.060	2	.011 in/tooth	22	75 in/tooth work travel	.030	Highly Chlorinated Oil
End Mill Slotting	T-15 HSS	30° RH Helix RR: 10° CA: 45° Peripheral Cl: 10° ECEA: 3°	3/4" diameter 4 tooth end mill 1" flute length	.250	3/4	.002 in/tooth	18	69 inches work travel	.020	Soluble Oil (1:20)
Slot Milling Down Milling	C-2 Carbide	AR: -5° bi-negative RR: 5° ECEA: 1° CA: 45° x .030" Clearance: 10°	6" diameter single tooth inserted tooth cutter	.125	1	.003 in/tooth	61	80 in/tooth work travel	.016	Highly Chlorinated Oil
Drilling	T-15 HSS	118°/90° point angle, 3° clearance 29° helix angle split point	1/4" dia., heavy web type drill 2-1/2" O.L. 1-1/2" flute length	1/2" thru hole	-	.002 in/rev	17	95 holes	.020	Highly Chlorinated Oil

RECOMMENDED CUTTING CONDITIONS FOR MACHINING RENE 41 SOLUTION TREATED AND AGED TO 365 BHN

Operation	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed ft./min.	Tool Life	Wear-land inches	Cutting Fluid
Tapping	M-10 HSS	2 flute plug tap spiral point 75% thread	5/16-24 NF plug tap	1/2" thru hole	-	-	5	140 holes	Tap Break-age	Highly Chlorinated Oil
Reaming	M-2 HSS	6 flute straight chucking reamer CA: 45° Clearance: 10°	.272" diameter reamer	1/2" thru hole	-	.005 in/rev	20	96 holes	.016	Highly Chlorinated Oil

SURFACE GRINDING

Wheel Grade	Grinding Fluid	Wheel Speed feet/minute	Table Speed feet/minute	Down Feed inches/pass	Cross Feed inches/pass	G Ratio
32A46J8VBE	Highly Sulphurized Oil	4000	40	.001	.050	10

RECOMMENDED CUTTING CONDITIONS FOR MACHINING 6Al-4V TITANIUM (1)

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
Turning 312 BHN	C-1/C-2 Carbide	SR: 6° SCEA: 6° BR: 0° ECEA: 6° Relief: 6°	5/8" Sq. Tool Bit	.050"	-	.009"/rev.	165 ft./min.	65 min.	.015"	Soluble Oil (10:1)
Turning 365 BHN	Same	Same	Same	Same	-	Same	150 ft./min.	70 min.	.015"	Same
Turning 312 BHN	M-3 HSS	SR: 5° SCEA: 0° BR: 0° ECEA: 5° Relief: 5°	5/8" Sq. Tool Bit	.050"	-	.005"/rev.	65 ft./min.	65 min.	.060"	Soluble Oil (10:1)
Turning 365 BHN	Same	Same	Same	Same	-	Same	55 ft./min.	70 min.	.060"	Same
Face Milling 312 BHN	C-1/C-2 Carbide	AR: 0° ECEA: 6° RR: -10° Cl: 12° CA: 30°	4" Dia., Single Tooth Face Mill	.050"	2"	.006"/tooth	97 ft./min.	42"/tooth	.015"	Soluble Oil (20:1)
Face Milling 365 BHN	Same	Same	Same	Same	Same	Same	Same	62"/tooth	.015"	Same

(1) For two heat treated conditions:
Annealed to 312 BHN
Solution Treated and Aged to 365 BHN

(continued)

RECOMMENDED CUTTING CONDITIONS FOR MACHINING 6Al-4V TITANIUM

Operation & Workpiece Hardness	Tool Material	Tool Geometry	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-land	Cutting Fluid
Face Milling 312 BHN	T-15 HSS	AR: 0° ECEA: 6° RR: 0° Cl: 12° CA: 30°	4" Dia. Single Tooth Face Mill	.050"	2"	.005"/tooth	78 ft./min.	50"/tooth	.060"	Soluble Oil (20:1)
Face Milling 365 BHN	Same	Same	Same	Same	Same	Same	Same	45"/tooth	.060"	Same
Drilling 312 BHN	M-10 HSS	2 Flute, 118° Standard Point 7° Clearance	13/64" Dia. Drill 2-3/4" Long	.250" Thru Hole	-	.005"/rev.	32 ft./min.	175 Holes	.015"	Highly Sulphurized Oil
Drilling 365 BHN	Same	Same	Same	Same	-	Same	25 ft./min.	59 Holes	.015"	Same
Tapping 312 BHN	M-10 HSS	3 Flute Taper Spiral Point Tap 70% Thread	1/4-20 NC Spiral Point Tap	.250" Thru Hole	-	-	14 ft./min.	150 Holes	Tap Break-age	Highly Sulphurized Oil
Tapping 365 BHN	Same	Same	Same	Same	-	-	Same	30 Holes	Tap Break-age	Same

SPEED AND FEED CALCULATIONS

For Turning Tools, Milling Cutters, and Other Rotating Tools

To Find	Having	Formula
Revolutions per Minute = R.P.M.	Cutting Speed in Feet per Minute = C.S., & Diameter of Tool in Inches (or Diameter of Piece Being Turned) = D	$R.P.M. = \frac{C.S.x12}{Dx3.1416}$
Cutting (surface cutting) Speed in Feet per Minute = C.S.	Diameter of Tool in Inches (or Diameter of Piece Being Turned) = D, & Revolutions per Minute = R.P.M.	$C.S. = \frac{Dx3.1416xR.P.M.}{12}$
Feed per Minute in Inches = Fd.M.	Feed per Revolution in Inches = Fd.R, & Revolutions per Minute - R.P.M.	Fd.M. = Fd.R.xR.P.M.
Feed per Revolution in Inches = Fd.R.	Feed per Minute in Inches = Fd.M, & Revolutions per Minute = R.P.M.	$Fd.R. = \frac{Fd.M.}{R.P.M.}$
Feed per Tooth = Fd.T.	Number of Teeth in Tool = T, & Feed per Revolution in Inches = Fd.R.	$Fd.T. = \frac{Fd.R.}{T}$
Feed per Tooth = Fd.T.	Number of Teeth in Tool = T, Feed in Inches per Minute = Fd.M, & Speed in Revolutions per Minute = R.P.M.	$Fd.T. = \frac{Fd.M.}{TxR.P.M.}$
Number of Cutting Teeth per Minute = T.M.	Number of Teeth in Tool = T, & Revolutions per Minute = R.P.M.	T.M. = TxR.P.M.

SURFACE SPEED TABLE *and* TOOL SELECTOR CHART

TABLE OF SURFACE SPEEDS PER MINUTE

General H.S. Steel Cutting Range — GENERAL TANTUNG CUTTING RANGE — General Carbide Cutting Range

…ACE PER …TE	40	50	60	70	80	90	100	110	120	140	160	180	200	250	300	350	400	450	500	600	SURFACE FEET PER MINUTE
…N.	REVOLUTIONS PER MINUTE																				DIA. IN.
¼	611	764	917	1070	1222	1375	1528	1681	1833	2140	2444	2750	3056	3820	4584	5348	6112	6882	7640	9168	¼
⅜	408	509	611	713	815	916	1018	1120	1222	1426	1630	1832	2037	2546	3056	3563	4074	4584	5092	6112	⅜
½	306	382	458	535	611	688	764	840	916	1070	1222	1376	1528	1910	2292	2674	3056	3438	3820	4584	½
⅝	244	306	367	428	489	550	611	672	733	856	978	1100	1222	1530	1833	2139	2445	2750	3056	3666	⅝
¾	204	254	306	357	407	458	509	560	611	714	814	916	1018	1273	1528	1783	2037	2292	2546	3056	¾
⅞	175	218	262	306	349	393	436	480	523	612	698	786	872	1090	1310	1528	1746	1964	2183	2620	⅞
	153	191	229	267	306	344	382	420	458	534	612	688	764	955	1146	1337	1528	1719	1910	2292	1
⅛	136	170	204	238	272	305	339	374	407	476	544	610	678	850	1019	1188	1358	1528	1698	2038	1⅛
¼	122	153	183	214	244	275	305	336	366	428	488	550	611	764	917	1070	1222	1375	1528	1834	1¼
⅜	111	139	166	194	222	249	277	305	332	388	444	498	554	695	833	972	1111	1250	1389	1666	1⅜
½	102	127	153	178	204	229	254	280	305	356	408	458	509	637	764	891	1019	1146	1273	1528	1½
¾	87	109	131	153	175	196	218	240	262	306	350	392	436	545	655	764	873	982	1091	1310	1¾
	76	95	114	133	153	172	191	210	229	266	306	344	382	477	573	668	764	859	955	1146	2
¼	68	85	102	119	136	153	170	187	204	238	272	306	340	425	509	594	679	764	849	1018	2¼
½	61	76	92	107	122	137	153	168	183	214	244	274	305	382	458	535	611	688	764	916	2½
¾	55	69	83	97	111	125	139	152	166	194	222	250	278	345	417	486	556	625	690	834	2¾
	51	64	76	89	102	115	127	140	153	178	204	230	255	318	382	446	509	573	637	764	3
¼	47	59	70	82	94	106	117	129	141	164	188	212	234	295	353	411	470	529	590	706	3¼
½	44	54	65	76	87	98	109	120	131	152	174	196	218	270	327	382	437	491	540	654	3½
¾	41	51	61	71	81	92	102	112	122	142	162	184	204	255	306	357	407	458	509	612	3¾
	38	48	57	67	76	86	95	105	114	134	152	172	191	239	286	334	382	430	477	572	4
½	34	42	51	59	68	76	85	93	102	118	136	152	170	210	270	297	340	382	420	540	4½
	30	38	46	53	61	69	76	84	92	106	122	138	153	191	229	267	306	344	382	458	5
½	28	35	42	49	55	62	69	76	83	98	110	124	138	175	208	243	278	313	350	416	5½
	25	32	38	44	51	57	64	70	76	88	102	114	128	160	191	223	255	286	318	382	6
½	23	29	35	41	47	53	59	65	70	82	94	106	118	145	176	206	235	264	290	352	6½
	22	27	33	38	44	49	54	60	65	76	88	98	109	136	164	191	218	246	273	328	7
½	20.4	25	31	36	41	46	51	56	61	72	82	92	102	125	153	178	204	229	250	306	7½
	19.1	24	29	33	38	43	48	52	57	66.9	76	86	96	120	143	167	191	215	239	286	8
½	18	22	27	31	36	40	45	49	54	62	72	80	90	110	135	157	180	202	220	270	8½
	17	21.2	25	30	34	38	42	47	51	60.1	68	76	85	106	127	149	170	191	212	254	9
½	16.1	20.1	24	28	32	36	40	44	48	56	64	72	80	100.5	121	141	161	181	201	242	9½
	15.3	19.1	23	27	31	34	38	42	46	54	62	68	76	95.5	115	130	153	172	191	230	10
	13.9	17.4	20.8	24	28	31	35	38	41	48	56	62	70	87	104	122	139	156	174	208	11
	12.7	15.9	19.1	22	25	29	32	35	38	44	50	58	64	79	95	111	127	143	159	190	12
	←HIGH SPEED STEEL→						←TANTUNG→						←CEMENTED CARBIDE→								

TO USE THIS CHART find the proper surface speed and refer to the work diameter columns at extreme right or left. The correct R.P.M. is shown opposite the work diameter to be turned.

The colored areas in the above chart show the general cutting range for high-speed steel, Tantung and cemented carbide cutting tools. These speeds are for broad, general use and are subject to change because of the variables occurring in tools and material. A good rule to observe—start your Tantung at double the speed and carbides at two to three times the speed as used for high-speed steel tools on the same machine and work.

FEED AND SPEEDS FOR DRILLS OF HI-SPEED STEEL

Size of Drill Inches	Feed per Rev. Inches	Cast Steel	Alloy Steel	Tool and Carbon Steel	Hard Cast Iron	Malle-able Iron	Mild Steel	Cast Iron	Bronze Brass
					Feet per Minute				
		40	50	60	80	90	100	110	200
					Revolutions per Minute				
1/16	.003	2445	3056	3667	4889	5500	6112	6724	12224
3/32	.0035	1628	2038	2442	3258	3666	4584	5043	9168
1/8	.004	1222	1528	1833	2445	2750	3056	3362	6112
5/32	.0045	976	1221	1465	1954	2198	2546	2802	5092
3/16	.005	815	1019	1222	1630	1833	2036	2242	4072
7/32	.0055	698	872	1047	1396	1570	1781	1962	3564
1/4	.006	611	764	917	1222	1375	1528	1681	3056
9/32	.0065	542	678	814	1084	1222	1375	1513	2750
5/16	.007	489	611	733	978	1100	1222	1344	2444
11/32	.0075	444	555	666	888	1000	1120	1233	2290
3/8	.008	407	509	611	815	917	1018	1121	2036
13/32	.0085	376	469	563	752	846	946	971	1892
7/16	.009	349	437	524	698	786	874	921	1748
15/32	.0095	326	407	488	652	732	819	881	1638
1/2	.010	306	382	458	611	688	764	840	1528
9/16	.0105	271	339	407	543	611	679	747	1358
5/8	.011	244	306	367	489	550	612	673	1224
11/16	.0115	222	277	333	444	500	555	611	1110
3/4	.012	204	255	306	407	458	508	559	1016
13/16	.0125	188	234	281	376	423	474	521	948
7/8	.013	175	218	262	349	393	438	482	876
15/16	.0135	163	203	244	326	366	407	448	814
1	.014	153	191	229	306	344	382	420	764