Machine Tools Souvenir

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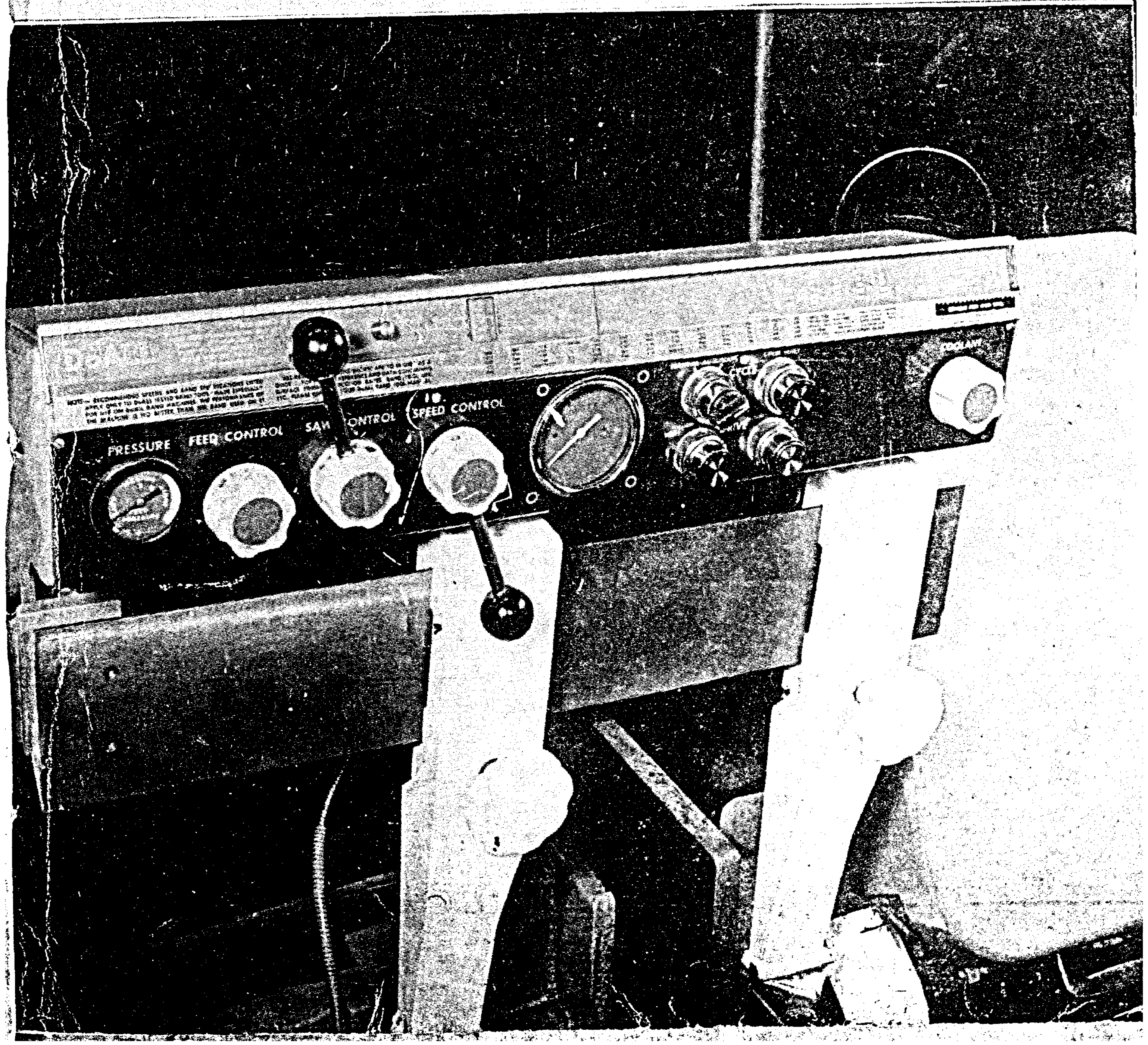
MACHINE TOOLS SOUVENI

(A QUARTERLY TECHNICAL JOURNAL DEVOTED TO MACHINE TOOL INDUSTRY)

Vol. I No. 3 APRIL 1955 Price A



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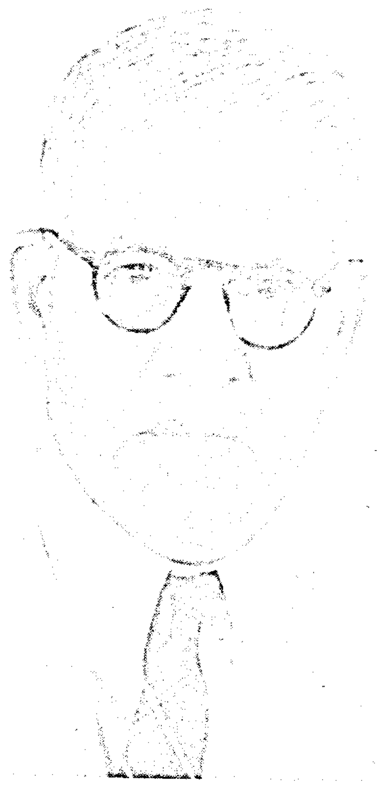

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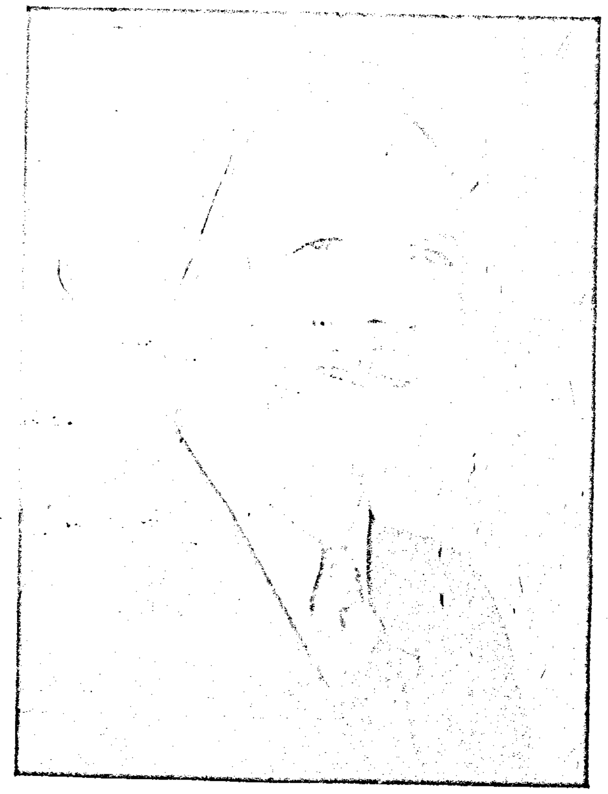

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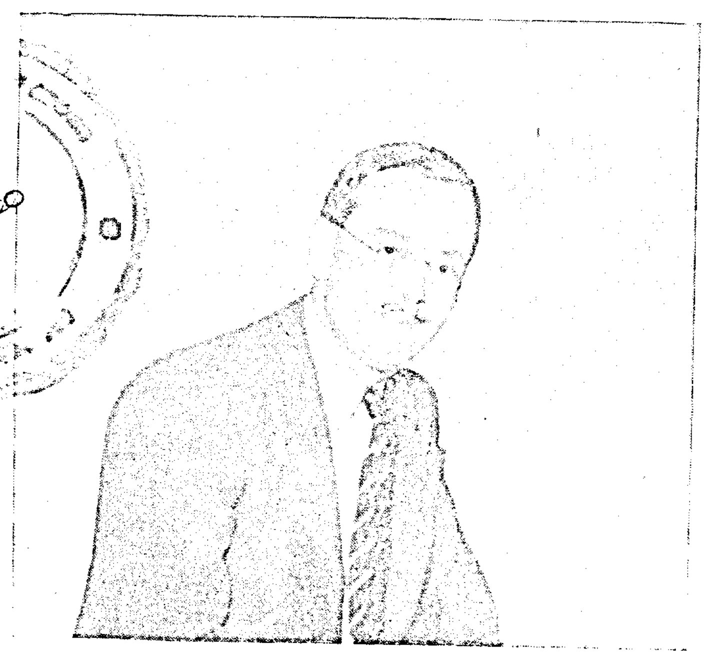

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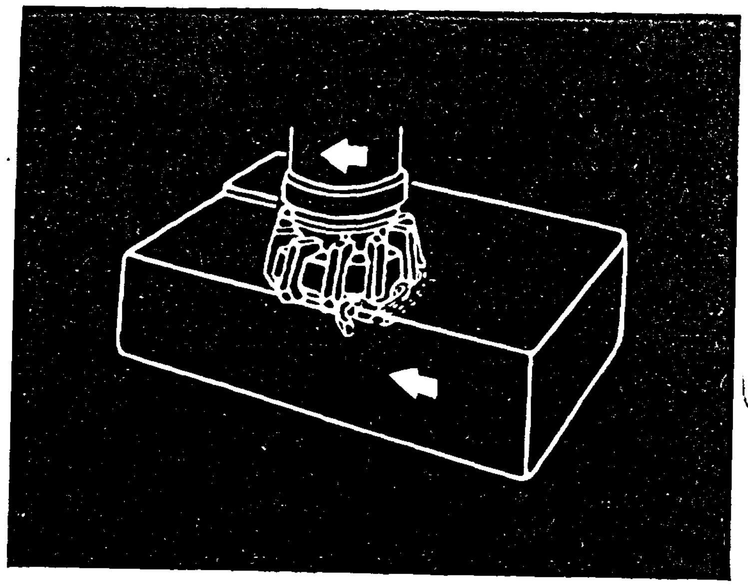
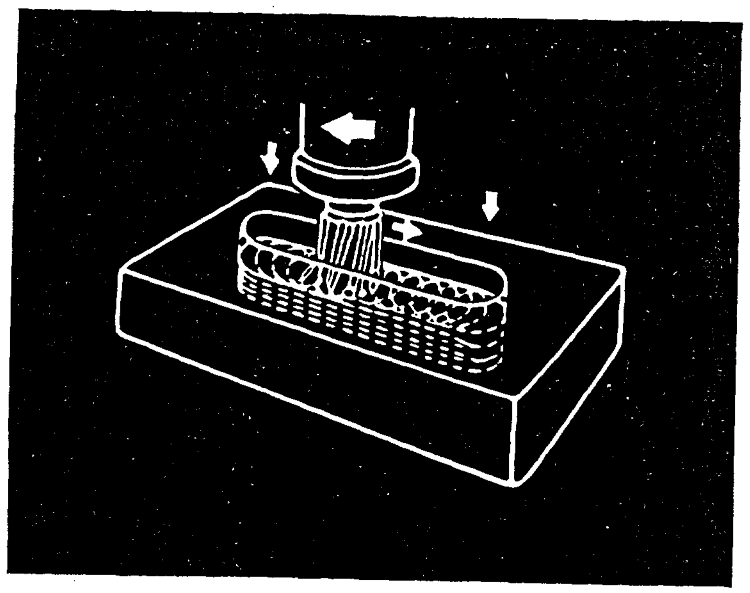


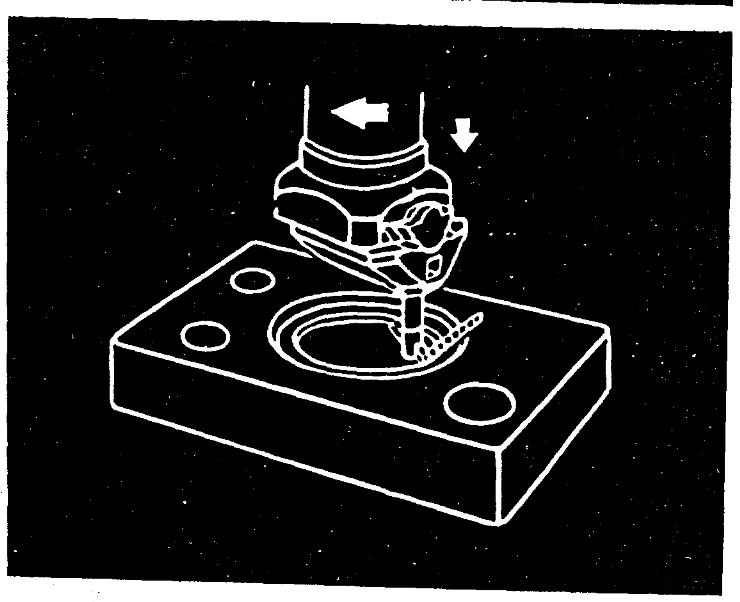
The HURTH V10a

A Three-in-one Machine Tool

1. VERTICAL MILLING



2. INFEED MILLING



3. JIG BORING

MODERN TOOL ROOM MACHINERY

By F. Fuchs V.D.I.

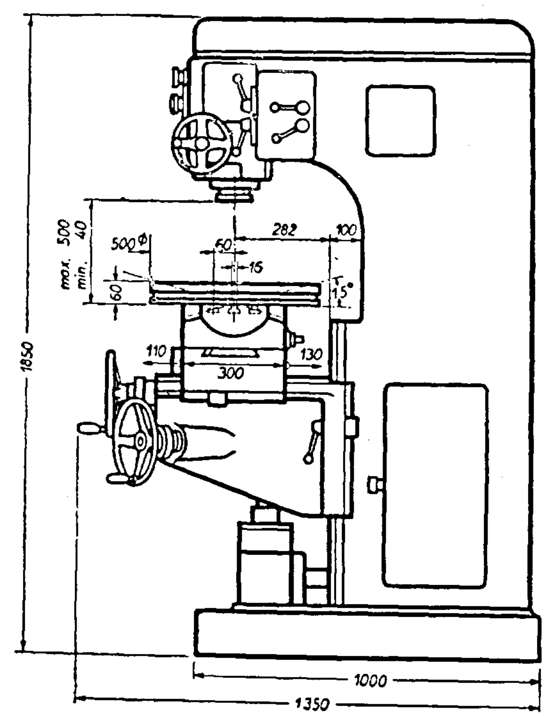
THE precision Toolroom Boring & Milling Machine HURTH V10a combines in a single machine tool three different cutting operations which are of equal importance for the toolroom as well as for the construction of jigs and fixtures:

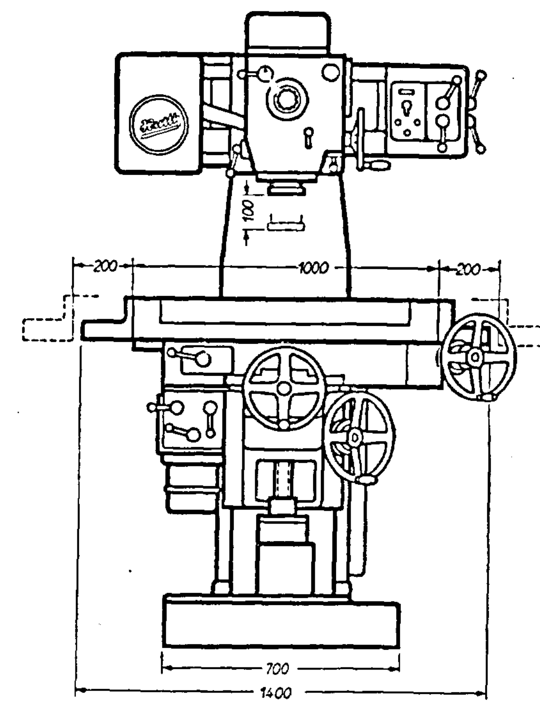
(1) Vertical Milling, using the longitudinal traverse of the worktable which can be tilted in two directions.

(2) Downfeed Milling, using the longitudinal traverse of the worktable and the graduated downfeed of the cutter spindle.

(3) Jig Boring, using the continuous spindle downfeed which can be varied in extremely small steps.

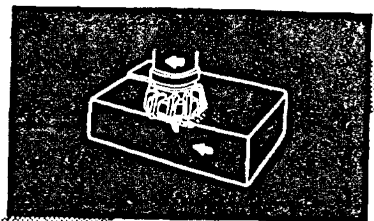
This wide range of usefulness of the HURTH V10a enables even the most intricate workpieces to be machined to very close tolerances *at one set-up*. The machine fully meets the requirements made of a boring and milling machine used in the manufacture of tools, jigs and fixtures, gauges, moulds, punches, and pressing dies. In small-lot and long-run production, too, the HURTH V10a has proved its efficiency. Its range of usefulness in every conceivable field of mechanical production can be further extended by using it in combination with a variety of attachments.



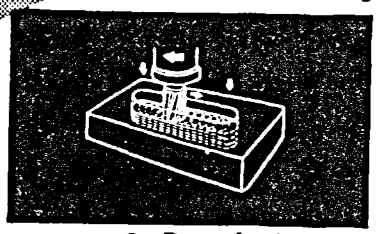


SPECIFICATIONS

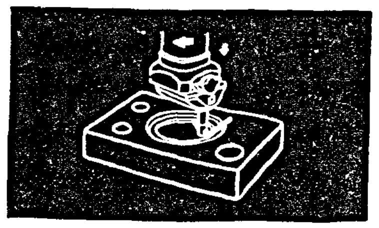
Worktable area	11¾"×39¼"
Longitudinal traverse of worktable (power and hand operated)	max. 15¾"
Transverse traverse of worktable (hand operated only)	max. 9½"
Vertical adjustment of knee (power and hand operated)	max. 14"
Tilting range of worktable (to front and rear)	15°
Width of three T-slots	.632"
Largest size of tool shank received by spindle Nose	1.26" dia. or Morse No. 3 or ISA 40 or 32 mm dia.
13 Spindle speeds	45, 63, 90, 125, 180, 250, 355, 500, 710, 1000, 1400, 2000, 2800 r.p.m.
10 Downfeed rates of spindle (using the crank mechanism)	.002"-.020" p. trav.



1. Vertical Milling



2. Downfeed Milling



3. Jig Boring

Programme includes Vertical Milling Machines and Universal Power Presses.

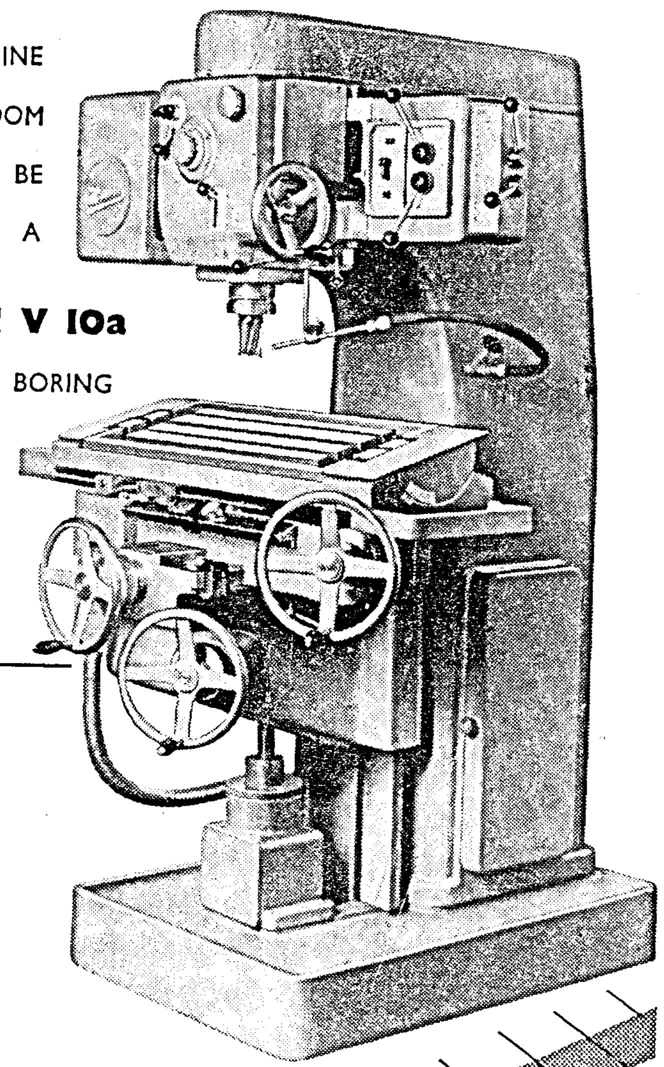
CARL HURTH

MUNICH, GERMANY

NO MACHINE TOOL ROOM SHOULD BE WITHOUT A

HURTH V 10a

PRECISION, BORING AND MILLING MACHINE



SPECIFICATIONS

Worktable area		11-3/4″ x 39½″
Longitudinal traverse .... of worktable (power-and hand-operated)	max.	15-3/4″
Transverse traverse of worktable (hand-operated only)	max.	9-1/2″
Vertical adjustment of knee (power-and hand-operated)	max.	14″

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9 Speeds of spindle head slide (using the crank mechanism) traverses per min.		2-2.8-4-5.6-8-11.2-16-22.4-31.5
9 Boring feed rates of spindle		.22″-.31″.44″.63″-.88″ 1.24″-1.77″-2.48″-3.54″ p.m.
6 Table longitudinal feed rates		5/8″ - 1″- 1.9/16″-2½″-4″ 6¼″ per.min.
6 Speeds to circular table		6.8-68 r.p.m.
Vertical travel of spindle (down, power and hand operated; up, hand operated	max.	3-15/16″
Spindle head traverse (by crank mechanism)	max.	5-29/32″
Distance, spindle nose to table	max.	25-3/4″
Diameter of tilting table		19-¾″
Spindle and gearbox motor		2.2 kw-1400 r.p.m.
Table feed motor		.3 kw-1400 r.p.m.
Knee elevating motor		.6 kw-2800 r.p.m.
Over-all height of machine		73″
Space required		71″×53″
Weight of the machine net approx.		4300 lbs.

ACCESSORIES–TOOLS–ATTACHMENTS

Standard equipment of the V10a

Complete electrical equipment for standard voltage three-phase current.

1 Plug receptacle (with protective condenser) for machine lamp.

1 Complete coolant system, including immersion pump.

1 Stieber quick-action chuck, hand-operated, with spring collet 3/16″ (5 mm) dia.

1 Dial Indicator for worktable zero adjustment in horizontal position.

1 Set spanners — 1 Instruction Book.

Special equipment of the V10a

1 Swivel table, model ST 500, indexing by 15-deg. intervals, 19¾″ dia.

2 Dial indicators with mounting brackets for work by co-ordinates, using gauge blocks.

1 Circular Table, model RV 315, 12-3/8″ dia. also with index plate attachment.

1 Universal Dividing Head with tailstock, Model LT10, for use with index plates and index bolt.

1 Swivel-type machine Vise, Model LSt. 2, max. gap. 15/16″.

Self-centring Vises, Model LZ3, for clamping round work.

1 Face milling Cutter, model MK110, with carbide tipped blades 4-21/64″, for cast iron, including arbor.

1 Set of clamping sleeves model SP 1/4″ - 1″ dia. for cutters having cylindrical shanks.

Adapter sleeves, model MH, Morse Nos. 1 - 3 for quick action chuck.

1 Drill chuck model BF 10 for cutting tools up to 25/64″ shank dia.

1 Boring Head model AK 2, for hole up to 4-21/64″ in dia.

1 Universal dial indicator for accurate loacting of work.

Keyway and slot milling cutters, for use with the down-feed milling feature.

1 End mill gauge model FPL for checking cutting edges on keyway and slot milling cutters.

End mills for jig boring work, model STS, with Morse Taper 5/16″—1-9/16″ in dia.

1 Machine lamp, with universal joint arm.

THE CUTTER SPINDLE OF THE V10a

The spindle is the most vital component of any machine tool. A spindle of expert design therefore is essential to accurate work. The design of the boring and milling spindle of the V10 a is based on many years' experience in spindle construction, extensive research work, and shop tests of the most exacting nature.

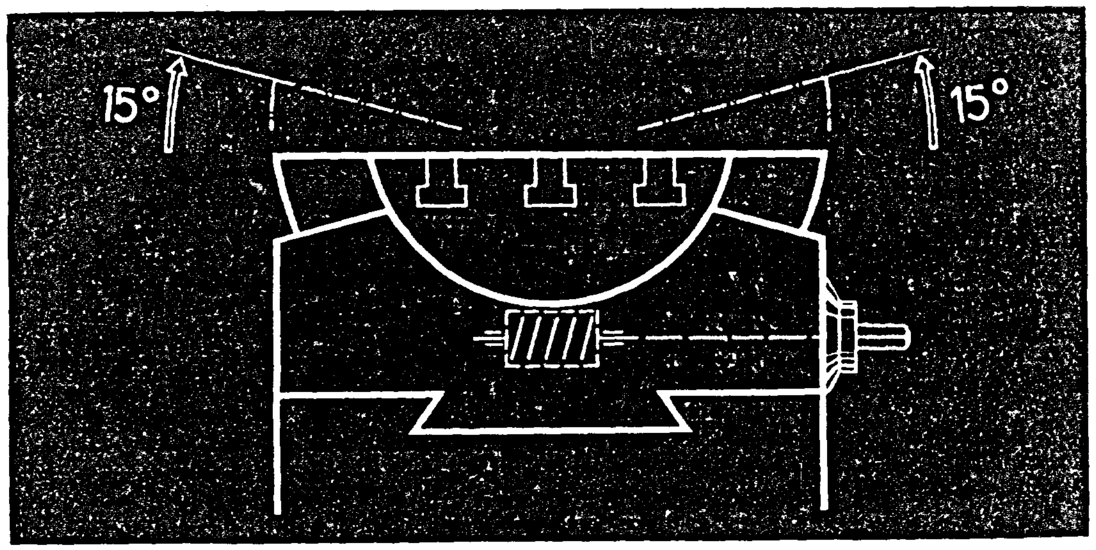
Lasting accuracy is ensured by two design features; the massive construction of the machine which virtually eliminates distortion under load, and the extremely long spindle quill guided in a precision-bored hole in the spindle head. True running of the spindle is guaranteed by the use of a carefully selected double-row roller bearing on the lower spindle end.

From the gear box spindle is driven through a multi-layer flat bed running over a tightening idler. Proper selection of cutting speeds to suit the work diameter and the material to be cut is made possible by the provision of 13 spindle speeds covering an extremely wide range of between 45 r.p.m. and 2800 r.p.m. In order to increase belt pull in cases where low spindle speeds are used in combination with large diameter cutting tools, a 4-to-1 planetary reduction gear has been provided within the spindle pulley. The spindle is completely relieved of belt forces, as the spindle pulley is independently supported by its own bearings. In order to facilitate the changing of tools, the spindle can be locked.

For each spindle speed nine different boring feeds are available, this enabling the most favourable conditions to be selected for any particular job. For example with the smallest possible spindle speed of 45 r.p.m. boring feeds range from .005" to .080" per revolution, while the maximum spindle speed i. e., 2800 r.p.m., feeds range from .00008" to .0012" per revolution.

For the purpose of locking the spindle quill in any desired vertical position during face milling and similar operations, an adjustable concentric-action quill clamping device has been provided. The special design of this clamping device excludes the application of lateral forces on the quill and thus prevents premature wear of the quill guide hole in the spindle head.

The spindle nose is arranged with National standard taper 40. As a rule, cutting tools, such as twist drills, end mills, for jig boring work, face mills, boring heads, etc., are held in the hand-operated true running Stieber



chuck enabling tools to be changed in a few seconds without using a spanner.

WORKTABLE WITH GAUGE BLOCK MEASURING EQUIPMENT

The warktable of the V 10a has been carefully designed to meet the many and varied requirements of toolroom practice. In contrast to conventional milling machine worktables, it serves the dual purpose of holding the work in position and of enabling accurate measurements to be made. While the worktable slide can be adjusted in longitudinal, transverse and vertical directions, the clamping plate proper can be tilted 15° to the front and to the rear, respectively. In addition a circular swivel table 19-3/4" in diameter with index positions spaced 15° can be placed on the worktable. Besides manual adjustment, the worktable slide has six different power feeds in either direction, these feeds ranging from 5/8" to 6¼" per minute.

The guide ways of both the worktable and the cross slide serve as reference axes for work by rectangular co-ordinates, while the circular table, model RV 315, when placed on the worktable, enables work to be performed by polar co-ordinates.

The worktable as well as the cross slide can be adjusted in their respective direction of movement either by means of rules and large-size graduated collars reading .001" or with the aid of gauge blocks, the latter affording greater accuracy. The machine is fitted with gauge block measuring equipment, the gauge blocks being brought into contact with dial indicators reading .0005" correct settings being indicated by the pointers registering with the zero marks.

A push-button controlled elevating motor affords rapid and convenient vertical adjustment of the knee.

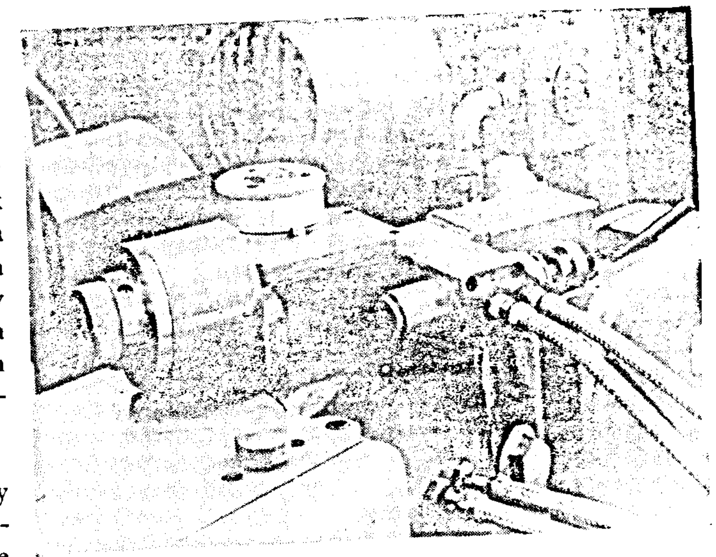
AUTOMATIC MICRO-SIZING

DEVELOPMENTS IN CONTROL OF CENTRELESS GROUND WORK

On centreless grinding machines, previous methods of fine feed adjustment of the control wheel (or grinding wheel) for the correct sizing of work have all depended upon the rotation and adjustment of a graduated index wheel, a process which demands a certain visual aptitude combined with manual dexterity for setting correctly—in much the same way as does a micrometer or a slide rule—and this is an aptitude which is not always possessed by the average operator, especially if an unskilled worker.

The push-button micro-sizer recently developed by Arthur Scrivener Ltd., Birmingham 24, is an hydraulically-operated mechanism, so arranged that on the pressure of an operating button the fine feed shaft of the machine is rotated a pre-determined amount. The actual amount that the wheelhead is fed forward by each pressure of the push-button can be selected at will by the rotation of the selector knob to be seen at the other end of the device. This knob giving a range of five increments varying from .0001" to .0005", the exact amount being clearly indicated by numbers disclosed as the knob is turned. This device is particularly useful in shops on long runs of work to close limits where female or unskilled labour is employed to operate the centreless grinders, as it is only necessary for the operator, on gauging the work and finding it to be growing above the upper tolerance limit, to press the button and so advance the wheel the predetermined amount to compensate.

The equipment shown in the photograph is the hand-operated type, but a second type extends the principle to electrical operation of the micro-sizer under the control of accurate pneumatic measuring equipment, and this second type is applicable for the continuous automatic control of size on throughfeed centreless work. This latter combination has been worked out in conjunction with Sigma Instrument Co., Ltd., and utilizes their twin-jet ring gauge through which the work leaving the centreless grinder is continually fed. The ring gauge is provided with two measuring jets and a monitoring jet, the purpose of the latter being to ensure that the measuring jets only function when work is actually in the gauge so that the intermittent gaps caused by the passage of the ends of the workpieces through the gauge have no effect upon the accurate recording of the size. A controller under the influence of the measuring jets is arranged to switch power impulses to the micro-sizer



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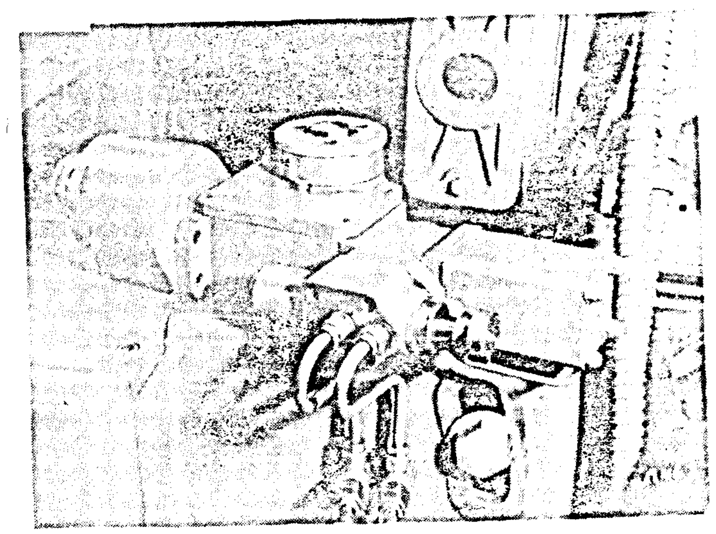

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1. Micro-sizer from selector end, set at .0004"
2. Instrument from push-button end.

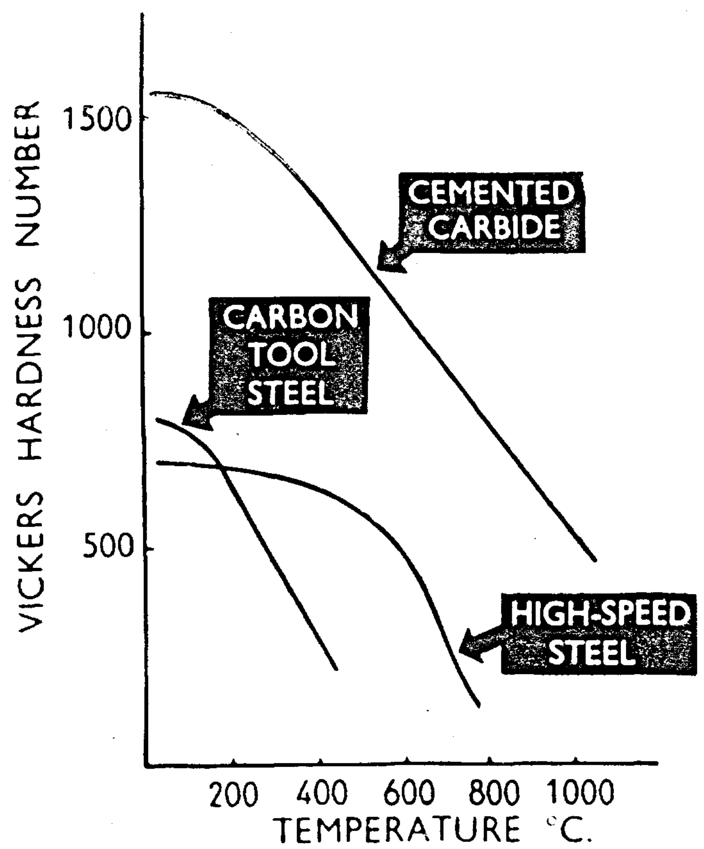
when the size of the work being gauged reaches the upper tolerance limit.

A third type is intended for application to plunge-grinding operations when it is not possible for the work to pass continuously through a ring gauge. Similar equipment to the second type is again used, but instead of the ring gauge being fixed on the outgoing side of the machine, a suitable gauging head is mounted in a convenient position near the operator, so that as the work is ejected from the machine he places it in this head which automatically checks the piece for size, and if it should be larger than the upper tolerance limit the

(*Continued on page 18*)

Some Aspects of Wimet Tungsten Carbide Tools

METALS were first machined with high-carbon steel, a metal which can be heat-treated to relatively high hardness but loses its hardness rapidly when heated to temperatures above 300 degrees centigrade. Not only is the hardness of carbon steel at this temperature low, but on cooling to room temperature it remains low. For this reason, low cutting speeds are necessary in order that the temperature at the cutting edge shall not exceed the temperature at which the hardness of the tool drops rapidly. The development of the alloy tool steel compositions containing first chromium and then increasing proportions of tungsten, molybdenum and other alloying elements, resulted in big improvements. While no harder than carbon steels, their advantage lies in the fact that they retain their hardness to a much higher temperature. As shown in the accompanying graph they loose hardness seriously only at temperatures over 600 degrees centigrade. It has been known for a long time that the carbides which occur as a minor constituent in steels are very hard, and that another carbide, tungsten carbide, is amongst the hardest substances known. Efforts have been made to cast carbide, but their extremely high melting point and the brittleness of the resulting substance rendered it unsuitable for use as cutting tools. It was in the methods of powder metallurgy that the solution was ultimately found. Small particles of tungsten carbide were cemented together by a metal of lower melting point, cobalt, resulting in an alloy hard than any known tool metal which retained its hardness during and after being subjected to high temperatures. This hardness varies between thirteen hundred and seventeen hundred Vickers Diamond Hardness. It has since been found that other hard carbides, in particular titanium carbide, confer special and very useful properties on the alloy, and by varying the composition of the carbide and other elements, a wide range of grades is produced to deal with the increasingly wide field of application now evident. Cemented carbides can be classified under two main headings, Tungsten Carbide and Titanium tungsten Carbide.



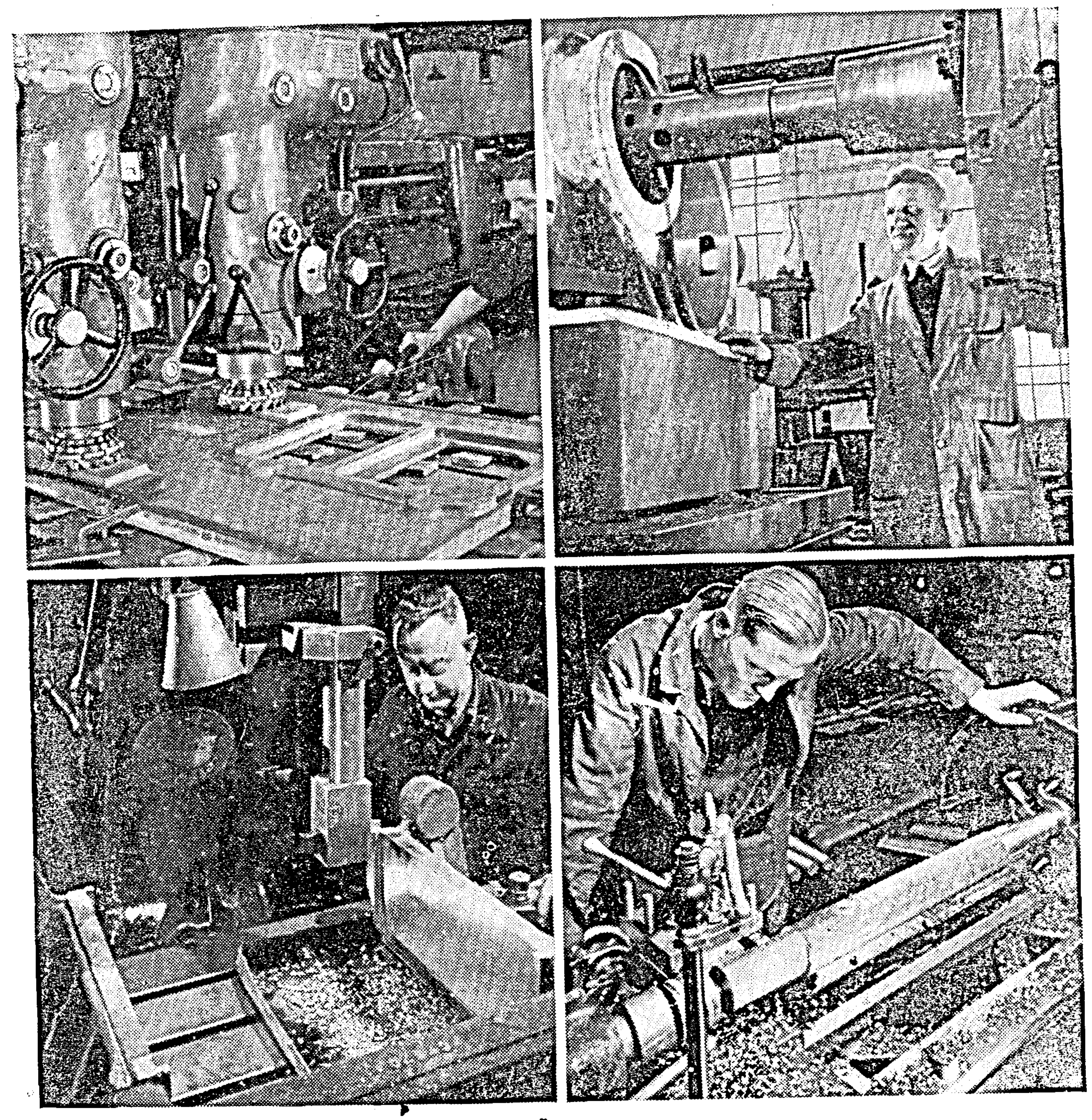
Tungsten Carbide is used for those materials having relatively high abrasion characteristics, such as iron and bronzes which, generally, do not impose high cutting pressures by the separation of the chip from the workpiece. Instead, the function of the carbide is to resist the wear induced by friction.

Titanium Tungsten Carbide is basically Tungsten Carbide but with Titanium added during manufacture. The effect of this addition is to reduce the hardness of the carbide, but it also supplies another characteristics which resists the tendency for chips of ductile material to "weld" to the carbide. Titanium Tungsten Carbide is intended, therefore, for cutting steels.

Literature is available showing the range of Wimet cutting grades now being produced and the tools now obtainable with recommendations for their use. when considering the application of Wimet cutting tools these recommendations will assist in determining the best tool and grade for job. By understanding the basic principles controlling cutting tool design, production engineers, shop supervisors and operators will be better able to achieve the higher production which correctly designed and applied carbide tools can bring.

DESIGNING CARBIDE TOOLS

We deal here principally with design of single point tools, beginning with the nomenclature, but it should be appreciated that although different terms are used the same principles of design apply equally to milling cutters or any similar multi-tooth tools. In fact all the features in a turning tool have their counterpart in a milling



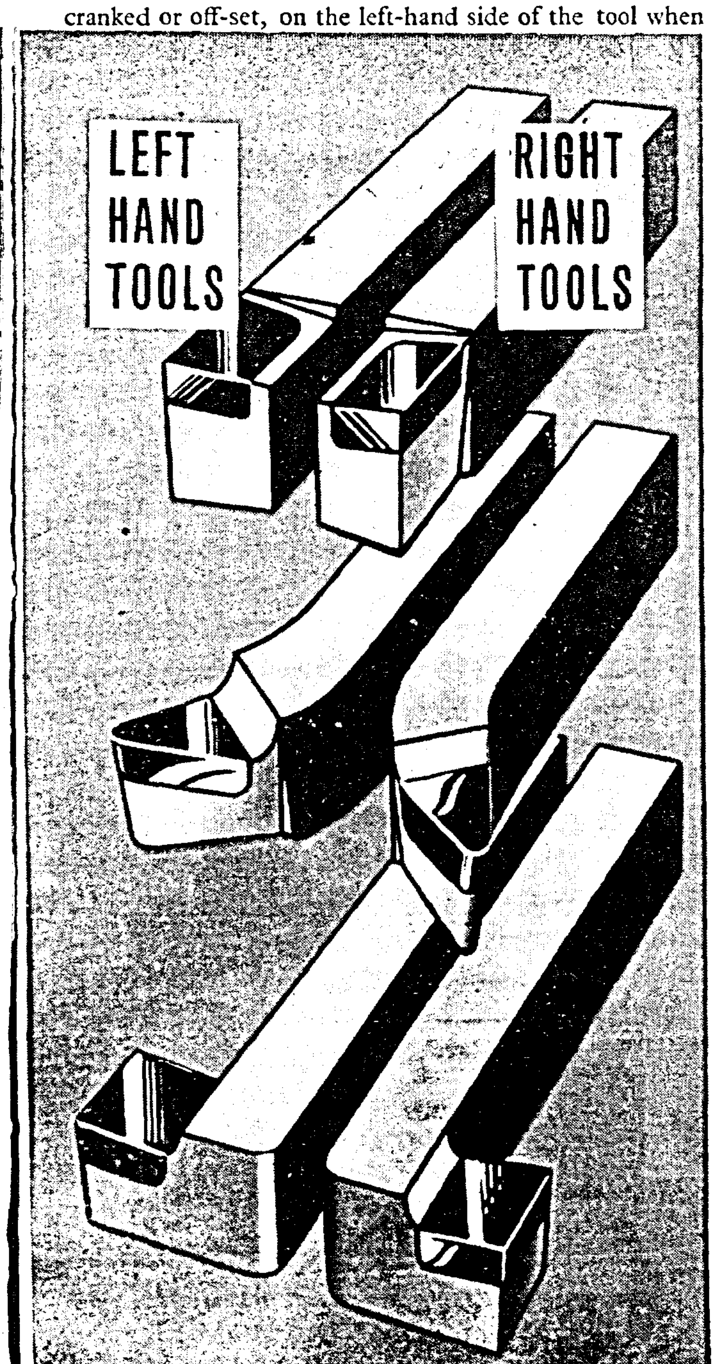
Wimet
TUNGSTEN CARBIDE
CUTTING TOOLS
– for every metal-working application
MADE BY WICKMAN OF COVENTRY, ENGLAND AND SOLD IN INDIA BY
MACHINE TOOLS (INDIA) LTD.
CALCUTTA - BOMBAY - BANGALORE

cutter blade, so that a milling cutter may be described as a rotating holder carrying a series of single point turning tools.

HAND OF TOOL

A certain amount of confusion is often encountered regarding the definition of a left-hand and right-hand tool, off-set or cranked.

A left-hand tool is one which has a cutting edge, cranked or off-set, on the left-hand side of the tool when



viewed from above, with the cutting end of the tool towards the viewer.

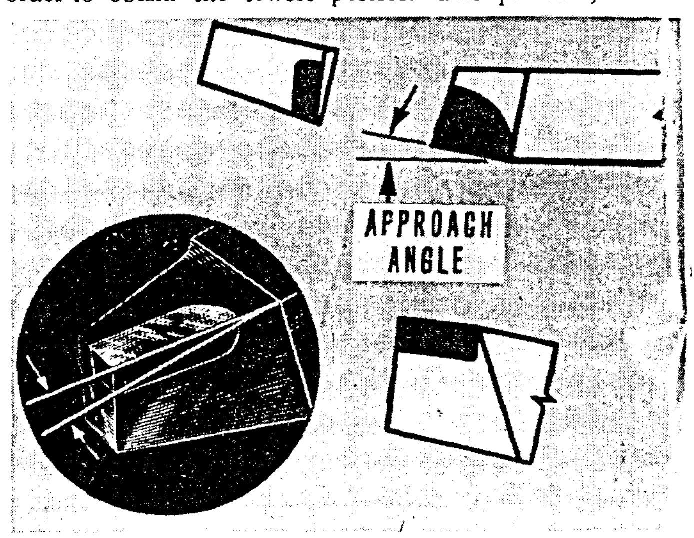
CUTTING SPEED

Cutting speed is usually quoted in feet per minute and is the distance the surface of the workpiece has travelled past the tool, or the tool has travelled past the workpiece is that time. If the circumference of the workpiece in a turning operation is multiplied by the number of revolutions of the work spindle in one minute, we obtain the cutting speed. This does not apply of course to shaping, or planing. In these cases, the cutting speed is the actual traversing speed of the machine stroke.

Depth of Cut is the distance from the unmachined surface to the machined surface.

Feed is the incremental travel of a tool or workpiece per revolution or stroke of tool or workpiece, designated in terms of inches per revolution, or inches per stroke.

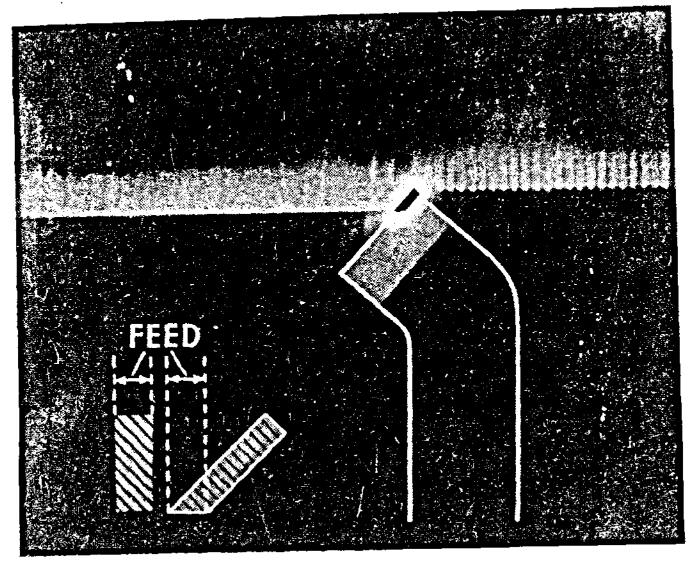
Approach Angle of a single point tool is the angle between the side of the shank and the cutting edge. The effect of chip pressure at the start of a cut is a major factor in the choice of the shape of a tool, and in order to obtain the lowest possible unit pressure, the



cutting edge should be as long as practicable. The length of the cutting edge is determined by the approach angle, which may be as much as 45 degrees.

CHOICE OF APPROACH ANGLE

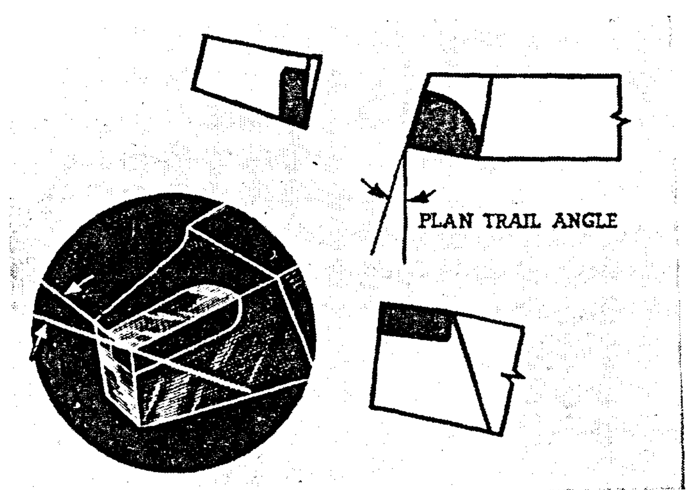
Chip pressure *per unit of length* is at its maximum when a tool with zero approach angle is used. This shape of tool produces a chip with thickness equal to feed per revolution, but a tool with an approach angle and



cutting at the same depth of cut, has to resist the same total cutting pressure, but has a lower cutting pressure per unit of length. The chip is thinner although of the same cross-sectional area.

PLAN TRAIL ANGLE

The plan trail angle on a turning tool is the clearance angle between the workpiece and the trailing edge of the

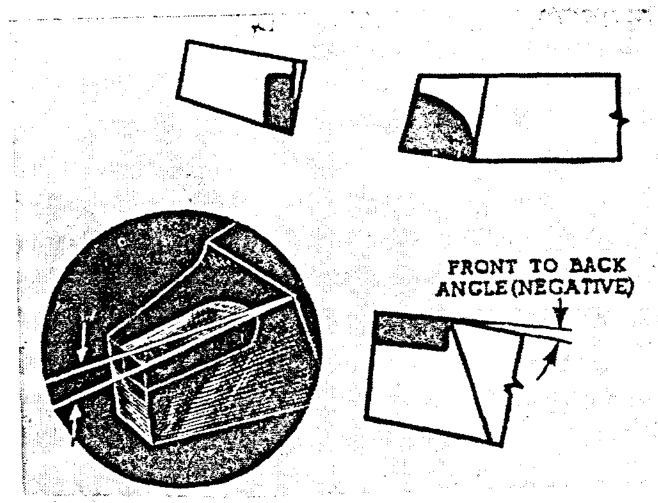


tool. It should be small to provide maximum resistance to pressure at the tool point in the direction of travel.

The Wickman standard heavy duty turning and facing tool is designed with small trail angles so that maximum resistance to cutting pressures is provided for both turning and facing operations.

FRONT TO BACK ANGLE

The provison of a negative front to back angle on WIMET Tools induces a shearing cut which tends to guide the chip in a direction away from the workpiece,

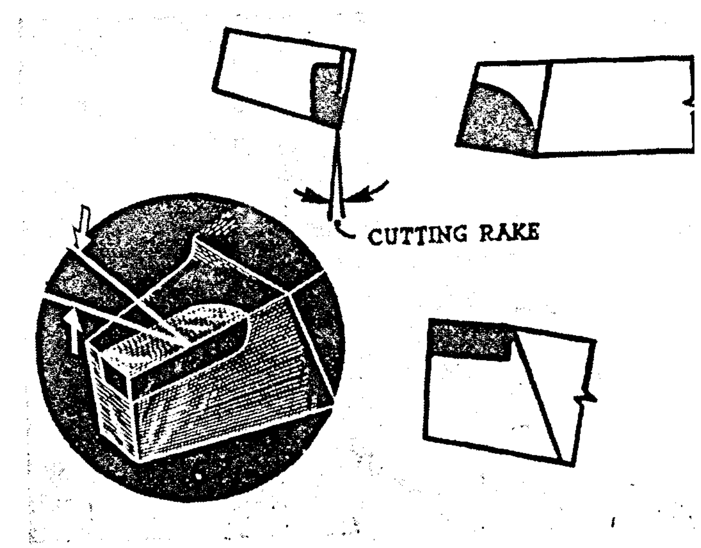


the lowest point of the cutting edge being at the point of deepest cut. This principle applies to tools with any approach angle and possesses the following advantages.

The chip, in being parted from the parent metal, tends to curl away from the surface of the workpiece and avoids damage to the finish of previously machined surfaces. An increased angle of approach also increases the pitch of the chip-curl so that an increase in the depth of cut may require an increased approach angle to provide sufficient pitch on the chip-curl to prevent it fouling the work. Any tendency for the point of a cutting tool to dig in is lessened when a front to back angle is employed, and results in minimised front clearance wear, as compared with a tool which has a cutting edge higher at the point of deepest cut.

CUTTING RACK

Cutting rake or top rake can be described as the angle which parts the chip from the workpiece and should not be confused with the front to back angle. It is measured in a plane approximately at right angles to the cutting



edge, but the chips do not necessarily flow in that direction since the combinations of front to back angle, approach angle and cutting rake, can produce different dispositions of the top surface of the tool.

DETERMINING CUTTING RAKE

The cutting pressure exerted on a turning tool is generally the influencing factor determining cutting rake. Aluminium alloys require very little horse-power to part the chip from the workpiece so that cutting pressures are light and high positive rakes are suitable. On the other hand, high tensile nickel chrome steels require more horse-power, and cutting pressures are, therefore, heavy. In such cases negative cutting rakes are necessary in order to provide a cutting edge able to withstand the high pressures.

The breakdown of a cutting edge invariably begins on the front clearance and an appreciation of the effect of cutting pressure will also assist in choosing cutting rake. If the top rake were acute, the cutting pressure applied by the chip would have a twisting effect on the shank forcing the tool into the work and causing additional rub on the front clearance. This twisting effect would be minimised if a reduced positive rake or a negative rake were employed under similar conditions.

PRIMARY AND SECONDARY CUTTING RAKES

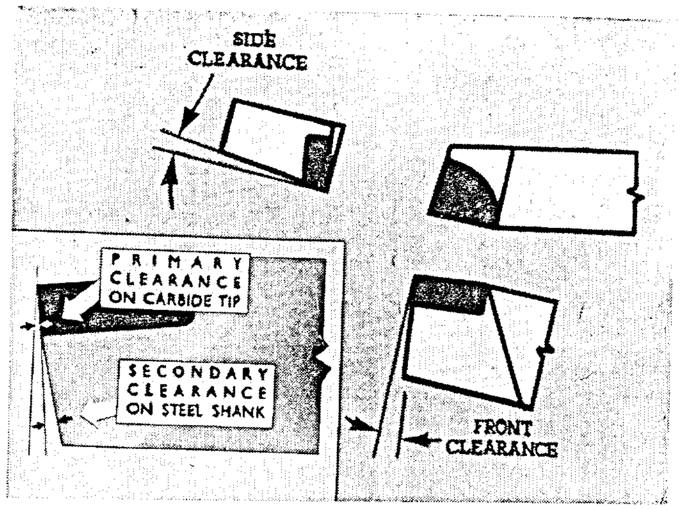
Wimet engineers have for long advocated the use of primary and secondary rakes, and it has now become common practice to employ this system in order to obtain the advantages of both negative and positive rakes. For example, when cutting a high chromenicked steel with a tensile strength of something over 70 tons per square inch, longer tool life is obtained with a negative top rake of about 3 degrees. Since the horse-power consumption with this rake is high, arising out of the friction under high pressure between the chip and the surface of the tool, it is good practice to grind the top surface of the tool with a primary rake land of 3 degrees negative immediately behind the cutting edge, and an 8 degrees positive secondary rake across the remainder of the surface. The primary rake stiffens the cutting edge, and the secondary rake reduces the pressure between the chip and the cutting tool, allowing the chip to flow freely over the tool face with consequent saving in power. The width of the primary rake should normally be four times the feed.

In general machining, this practice can be used with considerable advantage on the majority of steels, other than mild steels, particularly for roughing cuts on forgings and intermittent cutting. A difference of only 2 degrees between the primary and secondary rakes will release power which can then be more usefully employed in increasing the metal removal rate.

CLEARANCES

Grinding wheel life can be increased by the use of secondary clearances under the tip to allow for the grinding of the tip only.

The secondary clearance angle should be 2 degrees to 4 degrees greater than the clearance required on the tip. This means that if the tip is reground with



4 degrees clearance it will be necessary to set the grinding machine table between 6 and 8 degrees when grinding the clearance on the shank.

Considerable economy in cost of grinding wheels is effected since if the recommended wheels for Wimet grinding are used on the shank, loading of the wheels will result, necessitating frequent redressing, leading to excessive wheel wear.

MILLING CUTTERS

Radial Rake : Radial Rake on a milling cutter is equivalent to cutting rake on a turning tool. Positive radial rakes have been proved suitable for cast-iron and steels up to 45 tons tensile strength, whereas certain other materials require reduced positive rakes, or negative rakes.

Helix Angle : Helix angle on a milling cutter is equivalent to front to back angle on a turning tool. The milling cutter has a negative helix angle and is intended for use on materials which induce high cutting pressures. Materials in the low tensile range may be cut more efficiently with positive helix angle, and the range of Wickman cutters includes some types for this purpose with positive helix angle.

CHOICE OF MILLING CUTTER RAKES

Milling is a form of intermittent cutting and it is generally desirable when dealing with such an application to dispose the blade in the cutter body in such a way that the initial impact on the blades is directed away from the cutting edge.

Maximum resistance to impact can be achieved by the use of a negative helix angle, in combination with a positive radial rake, as in the case of the Wickman ' Multimill ', or by a combination of positive helix angle and negative radial rake, as applied to the Wickman ' Hevimill '.

BEVEL ANGLE

Bevel angle on a milling cutter is equivalent to approach angle on a turning tool. Experiments and experience suggests that a bevel angle of 15 degrees on a face milling cutter results in optimum metal removal rate on normal workpieces, but where extreme rigidity is present, the bevel angle can be increased to the maximum of 50 degrees as in the Wickman ' Hevimill '. Remember, the wider the bevel angle, (or approach angle in a turning tool) the thinner the chip produced and consequently the lower the unit pressure along the cutting edge.

CHIP BREAKERS

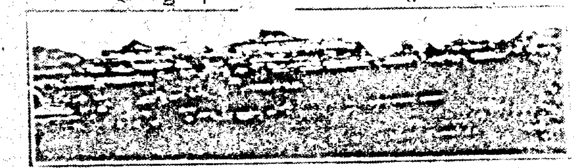
Most metals possess characteristics which cause the production of a continuous chip during machining. For easy chip disposal, and to protect the operator from injury, the continuous chip must be either curled or broken into short lengths. Chip breaking can be carried out by incrersing the feed to obtain a larger cross-sectional area (feed times depth of cut) which causes the chip to break. Alternatively, there is the chip breaker formed or ground into the tip itself. Chip breakers vary in width, dependent upon the feed and depth of cut.

Where extreme difficulties are encountered in the breaking of chips, various methods of chip flow control can be applied in the form of deeper and wider grooves than those associated with chip breakers, with modifications in the form of blending radii and inclination of step. These are chip *curlers.* As so many variables, such as degrees of ductility, feeds, speeds, depth of cut and diameters of workpiece enter into this subject, correct form can only be resolved by the tool user.

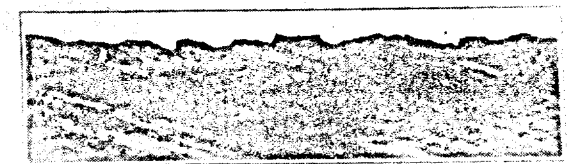
TOOL SETTING

Wimet standard tools are made with a small front to back negative angle, and consequently the point of the

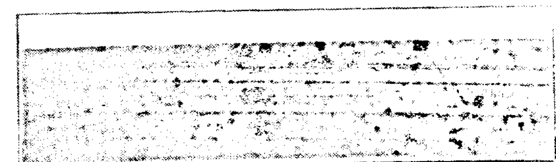
Photographs times magnification.



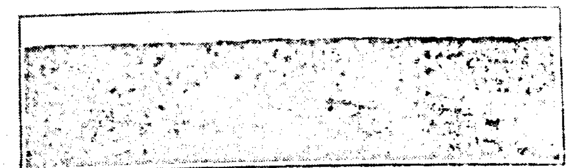
Wimet Brand Cutting Tool rough ground.



Wimet Brand Cutting Tool finish ground



Wimet Brand Cutting Tool lapped with Spedia Wheel.



Ordinary Razor Blade (for comparison purposes)

tool should be set just below centre, with the front to back angle intersecting the centre line half-way in the depth of cut.

In recessing and plunge cut turning, setting is rather more critical when the front to back angle is positive since the effect of setting the tool point above or below centre is to modify the cutting rake and front clearance. A tool with a positive front to back angle should be set on the centre line of the work.

In the boat-type tool holder is used, care must be taken when setting the tool to see that the shank is set horizontal, otherwise the front to back angle and clearances are affected.

FEEDS

In determining feed rates, we should consider just what happens when a tool enters the cut. Immediately the cutting edge touches the workpiece, spring in the tool and the elastic resistance to penetration of the tool into the workpiece causes an initial rub, until the machine forces a penetration by the cutting edge. Gradually, but very quickly of course, the tool is able to take the

(Continued on page 14)

Power Saw Designed for High-speed Steel Band Sets New Production Records

DoALL's First Entry in Power Saws is Distinguished by Unique Hydraulic Controls Plus Optional Full Automatic Operation.

THE extraordinary cutting rates achieved by the recently developed Demon high-speed steel saw band on contour sawing machines, has prompted The DoALL Company's design of a new type power cut-off saw—their first, and notable entry into this field.

Long established as a leader in the design and manufacture of contour sawing machines for metal, DoALL has incorporated into this new power saw, significant new features and improvements to meet the acknowledged cutting capabilities of this new H.S.S. band tool.

The new power saw is in addition distinguished by a whole set of exclusive adjustments and hydraulic controls for feed pressure, band tensioning and infinitely variable speed change which together constitute one of the most radical advances in many years in the design of this commonly used shop tool. These make the cut-off task considerably more simple, faster and more accurate and less costly in man hours and tool use. The new machine outperforms power hack saws at least 2 to 1 and is available with either manual or completely automatic stock indexing. Standard automatic indexing affords production of blanks up to 24″ long. With slight modification automatic indexing for blanks of any reasonable length can be provided.

Adding to its efficiency are the inherent advantages of the band machining method in parting materials—the use of a continuous band tool moving always in a cutting direction; distribution of wear over hundreds of teeth for relatively longer tool life and the not-to-be ignored savings in material because of the narrower path cut by the more slender saw band.

MORE POWER, SPEED, STRENGTH

The high-speed steel saw band, like the high-speed steel tools used on other types of machine tools is capable of accepting greater work loads. It accepts greater feed pressure at considerably greater tool speeds because of its "red heat hardness" characteristic that enables it to retain tooth hardness and sharpness at the extremely high temperatures created by strenuous cutting. This increased load capacity, as is well known, requires the use of a machine capable, in turn, of accepting such loads. The DoALL Power Saw was designed to meet this requirement with extra rugged, steel box-frame construction, and extra horsepower and speed.

PACE SETTING FEATURES

Many adjustments either ignored or regulated manually on cut-off sawing machines, are maintained hydraulically and with great accuracy on the new DoALL Power Saw, thereby reducing operator effort and *responsibility* while assuring optimum cutting results. Included among these features are :

(A) *Automatic feed pressure control*—maintains pressure of blade against work at value set by operator—automatically compensates for greater resistance as saw encounters thick cross-sections—allows adjustment for optimum production commensurate with desired tool life, or accuracy and finish requirements.

Range of adjustment is so broad that cutting efficiency is obtained on all structural forms ranging from thin-wall tubing to heavy bar stock.

(*Continued from page 13*)

full feed but during this initial rubbing, prior to penetration, damage has been caused to the front clearance. This is why a tool producing components with a relatively short cut does not produce the same footage of cutting as a tool used on a job of greater length.

The life of a tool, therefore, is determined by the number of starting cuts during its life, or the number of components rather than the amount of surface area machined. A practice in general use is to provide a trailing edge, overlapping three feed distances, to smooth out the cut marks and improve the finish produced. It will, of course, be recognised that this practice produces the rubbing effect previously mentioned, where the feed, or the depth of cut, is below the economic minimum, and some sacrifice of tool life is normally expected when this practice is followed.

Every material has an optimum cutting speed that will give the maximum tool life for the maximum metal removal rate, and this is determined by taking a check-cut at various speeds; the lowest speed which shows sudden improvement in finish is that which should be normal machining operations.

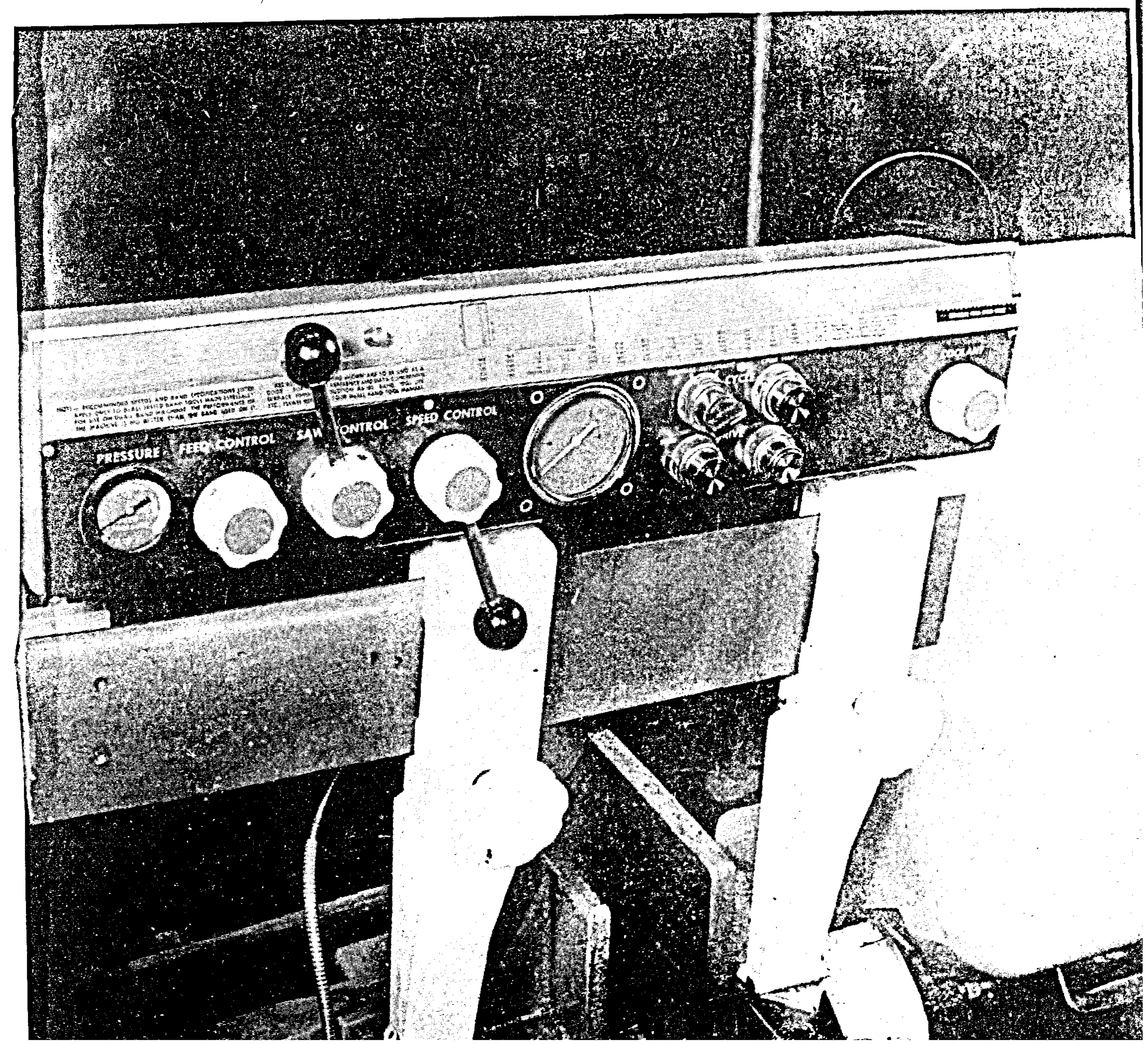
As it is not so necessary in finishing cuts to consider the effect of cutting pressure, speeds can be increased to maximum.

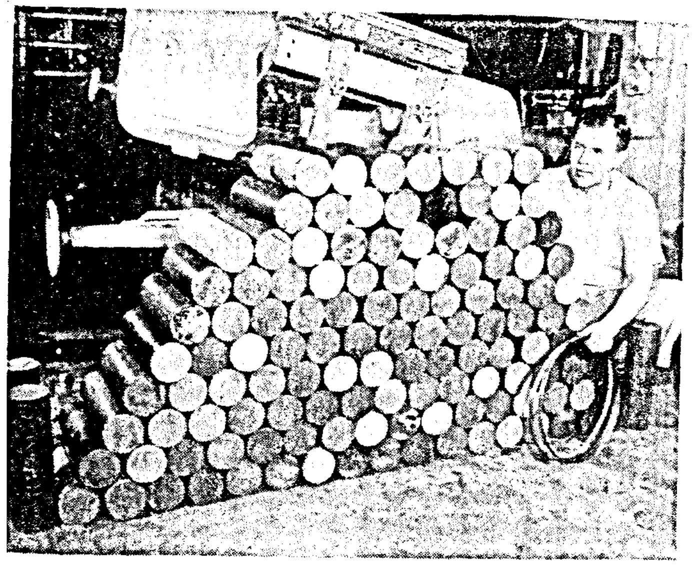
Little can be done about obtaining a uniform finish throughout a facing cut unless a stepless speeds variation drive is employed in the machine being used, although speed is maintained at a more uniform rate by previously determining at what diameters the revolutions per minute should be increased.

BORING SPEEDS

Generally on internal work where single point tools are used, cutting speeds of about two-thirds of those used for turning are employed. This is because a boring tool is not as well supported below the cutting edge as a turning tool and is consequently not able to withstand the same cutting pressures. The feed should be reduced, however, with due regards to the need to avoid rubbing.

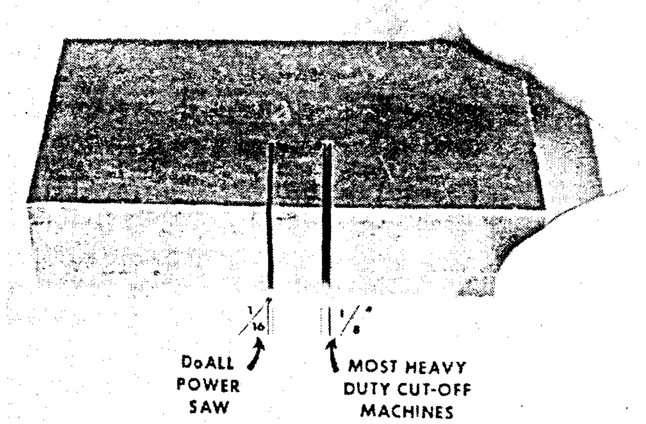
Photo shows close-up of the control panel on an automatic model. All phases of machine operation are easily regulated from this highly accessible position. Included are controls for blade speed, feed pressure, coolant. Band tension, pre-set at factory, is maintained hydraulically.





The significantly rapid cutting obtained with the DoALL Power Saw using the Demon H.S.S. blade for which it was designed, is unmistakably reflected in greater output per unit time and longer tool life. A nationwide demonstration program is being conducted by DoALL to establish this fact.

(B) *Infinitely variable tool speed*—a "first" on continuous band power saws. Used on DoALL contour metal cutting saws for years, it permits selection of proper tool speed for optimum cutting results on a given material which considerably broadens the range of materials that may be cut with efficiency—also helps to



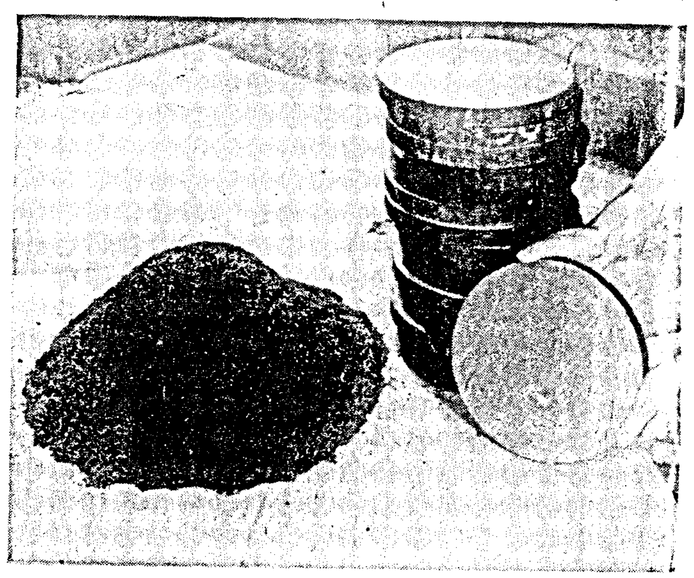
Material is saved with the band sawing method used on the new power saw. Cut on left made by DoALL saw band is half the width of cut made by many power saws. Therefore, less material is reduced to useless chips by the saw band in parting materials.

prolong tool life. The variable speed ranges from 90 to 350 feet per minute and changes are made effortlessly with a simple control on operation panel. No heavy cranks or levers to turn, speed adjustment is accomplished hydraulically.

(C) *Hydraulic band tensioning*—Another exclusive feature on continuous band power saws that eliminates another operator factor. Blade tension is automatically maintained at the proper level for efficient cutting and reasonable tool life. No need for wrenches, gages or adjustment—proper tension is regulated at the factory. The tool is not under tension when the machine is not in use but sufficient tension is provided to keep the tool in place.

CONTROLS - CAPACITIES - ACCURACIES

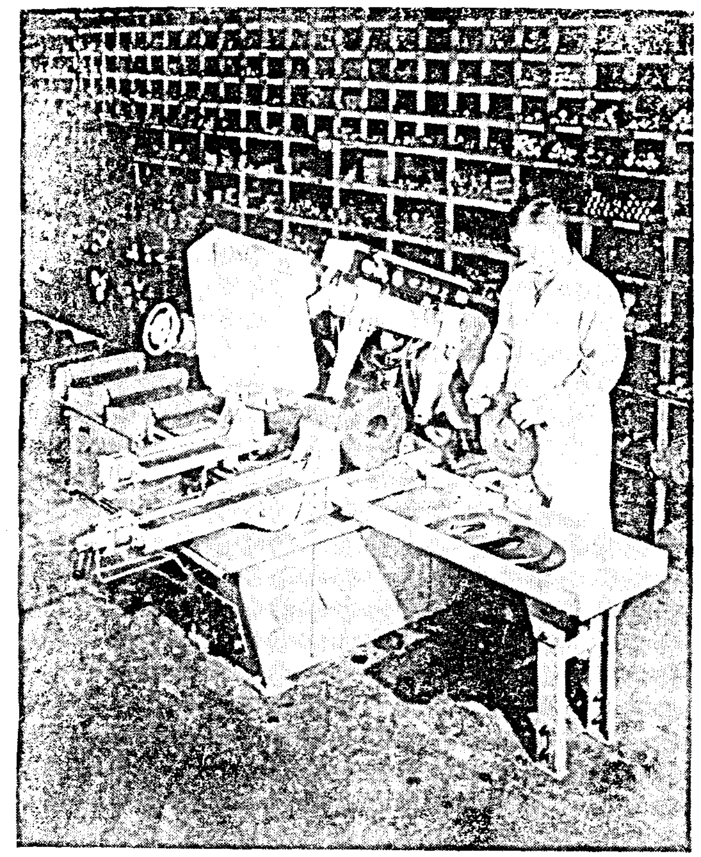
Levers and knobs controlling every phase of machine operation are centred on an attractive panel on the saw head. By simple hand manipulation the operator adjusts (1) up or down direction of saw head; (2) sawing or



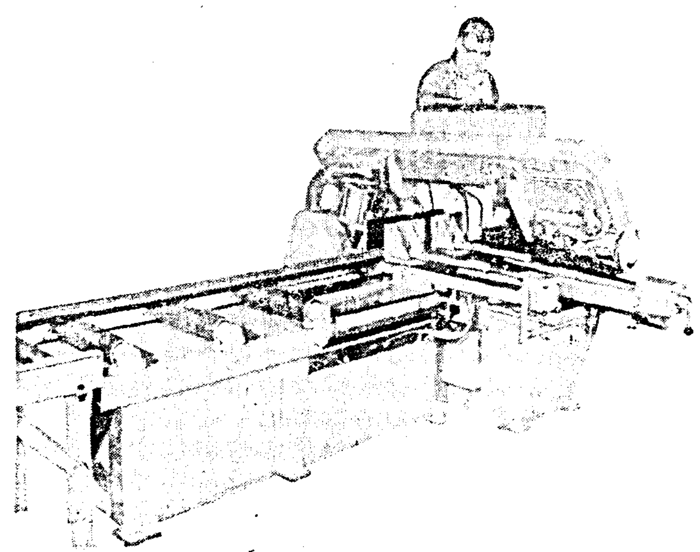
A graphic example of savings in material effected with the power band saw. In cutting 1" blanks as shown, the thin gage blade of the band saw will produce 17 pieces to the hack saw's 16 pieces *from the same amount of stock.* In essence, the thicker hack saw blade reduces a possible 17th piece to chips. With other cut-off methods, the waste is even greater.

feed pressure (thereafter hydraulically maintained by machine); (3) blade speed; (4) rate of coolant flow; (5) automatic or manual indexing (on automatic machines).

The machine accepts rounds up to 12 inches in diameter and rectangular or square bars up to 12 × 20 inches (up to 12 × 12 inches on the automatic index model).



Front view of the C-56, a completely automatic model in DoALL's line of new-type power saws. Designed for Demon high-speed steel saw band, these will automatically produce blanks up to 24" long and stop upon depletion of stock. They are intended for high production cut-off operations.



Side-rear view of the DoALL automatic model power saw showing the automatic index table.

Squareness of cut to axis of bar is maintained within .002" per inch of diameter.

THE AUTOMATIC POWER SAW

The addition of the "automatic stock indexing table" to the basic power saw adapts it to full automatic operation. Added to the advantages offered by the use of Demon high-speed steel blade and the machine features enumerated above, the automatic feature affords unsurpassed cut-off production. It is intended to fit the needs of mass-production industries confronted with the ever-present problem of reducing raw stock to workable sizes at minimum cost. So self-sufficient are these automatics that one man can reload and tend a sizable battery. Standard automatic operation provides for the cutting of blanks up to 24 inches long and remarkable accuracy is maintained by the automatic indexing unit. With minor modification, blanks of any reasonable length can be automatically indexed.

SAFETY

A careful regard for safety has governed the design of the machines with automatic stoppage in the event of tool breakage. In the automatics, stoppage also occurs on depletion of stock. A limit switch prevents machine operation in the event of improper band tension. The sawing head locks regardless of position if the control circuit is interrupted and so the machine may be stopped in the middle of a cut with the assurance that the sawing frame will not "drift" down and damage blade or work.

FLEXIBLE DESIGN

While an extremely rigid, box-frame steel construction is employed, a most pleasant, modern and eye-appealing design is achieved. Steel hydraulic tubing is used throughout. The hydraulic pump is the "*variable delivery*" type, adjusting its output to the drain on the system. This contributes to efficient use of the common drive motor and reduces power waste and heat loss since the drain on the hydraulic system is greatest when the machine is not sawing that is, during the automatic cycle—and lowest during sawing when the working blade requires more power

Farsighted design of the basic chassis of this power saw permits ready factory adaptation of this unit into four distinct models. These encompass every industrial application from intermittant use employing manual stock indexing to sustained high production sawing on an automatic index basis for long periods.

The four basic models are:

Model	*Stock-Indexing*	*Transmission*
C–55	Manual	Single Speed
C–56	Automatic	Single Speed
C–57	Manual	Variable Speed
C–58	Automatic	Variable Speed

DEMONSTRATION PROGRAM

Acting on the presumption that "it has to be seen to be believed", The DoALL Company has inaugurated a nation-wide demonstration program to show the capabilities of this new type power cut-off saw. The demonstrations will be conducted from the 38 DoALL stores throughout this country and Canada. Requests for demonstrations should be addressed to The DoALL Company, Des Plaines, Illinois.

SPECIFICATIONS

Capacity	Rounds, 12" diameter; Flats, 12"×20", (12"×12" with automatic index). Maximum weight-4000 lbs.
Over-all Height	Minimum $49\frac{1}{2}$"; Maximum $78\frac{1}{2}$"
Floor Space	$86\frac{1}{8}$"×$92\frac{3}{4}$" (Index table included)
Indexing	Manual or Automatic (Standard—for any blank size up to 24" long. With slight modification, blanks of any reasonable length can be indexed.)
Operating Controls	located in a single enclosure on sawing head.
Blade	1" high-speed steel, 144" long (carbon steel blade may be used).
Blade Tension	Automatic, factory set.
Blade Speed	Fixed, Stepped or Infinitely Variable (90 to 350 FPM). Infinitely variable speed is adjusted at control panel; tachometer speed indicator calibrated in blade FPM
Blade Feed Pressure	Infinitely variable throughout range with direct reading gage at control panel.
Job Selector	Slide rule type, listing suggested feeds and speeds for SAE steels and other materials.
Accuracy	Under average conditions, accuracy of plus or minus 1/64" per blank and .002" per inch diameter on squareness of the cut face.

(Continued from page 7)

micro-sizer would again be automatically operated to advance the wheels the predetermined amount to compensate.

In the case of a fully-automatic machine arranged for long runs on a plunge-ground component, it is sometimes possible for the feeding gear which places the piece between the wheels also to transfer the finish-ground piece to the measuring instrument, thus relieving the operator even of the task of transfer and rendering the operation entirely automatic.

These developments will now make possible, particularly when used on multi-head transfer centreless grinders, the entirely automatic control of grinding operation, leaving only the frequency of the wheel-truing operation, to be determined, and this can often be arranged on a fixed time basis providing that control is maintained over the amount of variation of stock removal with which the machines have to deal. This latter would of course affect the rate of wheel break-down and thereby the quality of the surface finish obtained.

Carbide High-Velocity Turning

By Leif Fersing *

THE term "carbide high-velocity turning," has lately come into use to indicate higher turning speeds than heretofore have been considered economical or practical for machining steel. Turning speeds of 350 to 400 fpm were generally considered high, whereas today turning speeds for steel from 400 to 1400 fpm are actually used in production with great success. This paper deals with factors affecting turning of steel and presents measurements of chip temperatures, load on tools, effect of chip breakers, and the effect of turning speeds on the quality of finished surfaces. Illustrations of tools in cut at surface speeds up to 2400 fpm are shown. Descriptions of instruments are included, together with references to parts now being machined in the "high-velocity turning range" in production.

INTRODUCTION

For a given pair of materials, rate of wear between them is a function of surface finish, load, rubbing speed, hardness, and temperature. When turning steel, machinability becomes a very important variable. Correlating available information and extensive tests under actual production conditions, improvements in tool materials and machinability of steel, machine design and methods are problems which continuously confront the tool engineer. The wear at the tool point must be kept within economical range as speeds and feeds are increased if the increase in production is to result in a reduction in total cost.

Most tool-load data in this paper are obtained from turning cuts on $3\frac{1}{2}$-in-diam solid bars and on two types of normalized steel, SAE-C-1118, cold-rolled, and SAE-8747, hot-rolled. The cuts were taken on a J&L No. 5 ram-type turret lathe provided with a 15-hp motor. Spindle speeds 123, 253, 365, 510, 734, 1041, and 1500 rpm and feeds 0.007, 0.011, 0.015, and 0.022 in. per revolution (ipr) were used for a representative range of cuts with carbide tools. These steels were chosen as their machinability is fairly representative of steels used in manufacture today. All turning cuts were taken with tools having the cutting edge perpendicular to the axis of the work and a 0.015-in. nose radius, when not otherwise stated.

AVERAGE TEMPERATURE OF CHIPS

An interesting phenomenon when cutting steel without coolant is the change in color of a chip as cutting speed is varied. For example, when machining C-1118 steel at 2400 fpm using 0.015-in. feed and a tool having 10-deg positive side rake angle, the chip discolors only slightly to a light straw color. As the cutting speed is reduced to below 1000 fpm, the chip starts to darken, turning purple-blue between 200 and 300 fpm, whereafter the chip again becomes lighter, showing only a slight discoloration at 100 fpm. A similar though much less pronounced condition exists when 8747 steel is machined under the same conditions. The mean temperature of this chip is higher and rapid oxidation takes place, producing a purple-blue color as the chip is left in the air to cool.

The calorimeter method was used for determining the average temperatures of chips at various cutting speeds. The average temperature of the chips as cutting speed is increased above 450 fpm remains approximately constant. The variation in color of the chips at high cutting speeds is probably due to variations in the thickness of chips and in the rate of air cooling at different speeds. The calorimeter method required the development of a chip breaker which would break the chips of both types of steel at all speeds into somewhat similar shapes. The temperature of each point on the curves is the average of three tests. It was necessary to keep close dimensional control of the chip breaker and to maintain a sharp cutting edge in order to duplicate results. Inspection of the chip breaker was made on a comparator at 31.25:1 magnification, permitting dimensions to be controlled within 0.001 in.

Chip breakers and rake angles on tools have a great influence on the average temperature of a chip. The average temperatures of the chips from 8747 steel followed, whereas for C-1118 steel the average temperature of the chips increased very rapidly when cutting speed was reduced to below 250 fpm, reaching a temperature of about 780 F at 112.5 fpm. This chip breaker was definitely of a poor design for C-1118 steel at low

* *Experimental Engineer, Jones and Lamson Machine Company.*

cutting speeds as evidenced by the shapes of the chips and their purple-blue color.

When cutting conditions were alike, the cross section of a chip from 8747 steel was always smaller both in width and thickness than of a chip from C-1118 steel. A chip is more or less trapezoidal in cross section and always thicker than the feed and wider than the depth of cut, although this effect is reduced as speed is increased. Furthermore, the average temperature of a chip taken at a certain speed and feed increases when a tool breaks the chips into smaller parts and/or forms a heavier cross section.

MEASUREMENTS OF TOOL LOADS

SR-4 type bonded-wire strain gages were used to measure deflections in a specially designed toolholder. Three components of the load were recorded simultaneously with the help of direct-inking oscillographs.

The load curves are similar to the average heat curves. Above a certain speed, about 450 fpm, the temperature of the chips remained approximately constant, whereas tool loads, especially for C-1118 steel, continued to drop.

The effect of coolant (50 parts water to 1 part wetting agent) on tool loads is plotted in dot-and-dash lines. All tool loads increased when coolant was used. It is obvious from these curves that the coolant had no lubricating value, but that a quenching of the chips took place. The cooling effect was excellent as all chips remained silver-white. The chips became more broken and slightly smaller in cross section than when turning dry. In order to complete the picture, loads on a tool with 10-deg side rake, no chip breaker, and without coolant are plotted in dotted lines. Note that at certain speeds for C-1118 steel the loads on the tool without the chip breaker are greater than on the tool with the chip breaker. The reason for this phenomenon may be that at higher speeds the chip did not follow the contour of the chip breaker. The contact between the chip and the tool was along the cutting edge and against the heel of the chip breaker. This condition existed for all cuts on 8747 steel.

The rate at which heat is generated by the tangential load at the tool point and the rate of heat generated in the chip are plotted against cutting speed. The tangential work equivalents in Btu are obtained from the tangential loads (cutting dry with chip breaker) and the "heat into chips" from the temperature rise of chips, used for plotting curves.

Two other curves are shown and represented as "per cent" of heat into chips. They are obtained by dividing heat into chips by "tangential work equivalent".

Tangential work equivalent = power/778, Btu per min.

Heat into chips = $(T—t)\ CW$, Btu per min.

where $T—t$ = temperature rise of chips, deg F

C = average specific heat of chips

W = weight of chips, lb per min

Power = tangential load × feet per min

Friction between the tool and the chip, deformation of the chip by the chip breaker, and heat going into the workpiece and the tool are variable factors accounting for the difference in the "percentage" curves. In this connection it may be pointed out that the difference in machinability of the two steels was quite noticeable during test cuts. The C-1118 steel was very free-machining and the limitation on speed and feed for the desired depth of cut was the capacity of the motor (30 hp at 100 per cent overload). The test cuts were short, however, ranging from $\frac{1}{2}$ to 1 in. When machining 8747 steel, especially with positive rakes, difficulties in tool life started at about 700 fpm cutting speed. Only by paying constant and careful attention to the lapped finish on the cutting edge of a tool was it possible to obtain the stable condition necessary for solid comparison. Five-degree negative rake angles gave no difficulties in this respect even though tool loads were higher than for positive rakes.

The tangential work equivalent and the tool load are two of the factors controlling the speed at which steels can be turned with carbide. A combination of the effects of pressure, speed, temperature, rate of chip flow, coefficient of friction and/or surface roughness on a tool, tool angles, duration of cut, and rate of cooling, together determine a critical speed above which heat becomes excessive, causing pitting of the carbide and rapid breakdown of the cutting edge. The percentage curves are of particular interest in that they show a great difference between the two steels. C-1118 steel, which is freer-machining, produces the heaviest chip, that is,

there is greater deformation at the tool point than with 8747 steel. Disregarding extreme conditions, the thickness of a chip generally indicates the machinability of a steel, the heavier the chip the more free-machining the steel and the higher the percentage of heat carried away by the chip.

The feed load has four components; penetration load forcing the tool point into the parent metal, friction load from the chip flowing over the tool surface, crowding by a chip breaker where a breaker is used, and a component of the tangential load depending on the side rake angle, increasing the feed load for negative rakes and decreasing it for positive rakes and zero for zero rake angle. As the nose radius in increased, the feed load remains almost constant whereas the radial load increases. Even with a pointed tool, the chip widens and flows away from the work, thus producing a frictional component in a radial direction. The effect of the variation in relief angles is not noticeable as long as the tool is sharp, but becomes very prominent, especially for small relief angles, when the tool starts to wear. The penetration load of a cutting edge is very small as long as the tool is sharp and the frontal penetrating area at a minimum.

The feed load shown by the curve is the friction force between the tool and the chip as the rake angle is 0 deg.

The importance of carefully designed chip breakers is emphasized by the marked effect of breaker dimensions on feed loads. All combinations of width and depth broke the chip.

The test cuts were taken by holding constant first the spindle speed and then the feed rate. After a series of test cuts had been completed, the first cut was repeated and the loads were checked to insure that the tool had remained sharp. The characteristics of the load curves for the two steels are very different, especially at speeds below 500 fpm. The loads for 8747 steel increase rapidly as speed is reduced, whereas the loads for C-1118 steel go up and down except for negative rake tools. All radial loads were only about 10 per cent of the feed load and therefore are not included. Undoubtedly the surface finish on tools and variations in stock produce some irregularities in tool loads. Of special interest is the slight change in feed load for 10-deg. positive rake, as feed was increased from 0.011 to 0.022 ipr and the almost proportional increase for 5-deg. negative rake angle. As a whole, the loads are higher for 8747 steel than for C-1118 steel.

Indications are that the difference between tensile strength and yield point affects the thickness of chips. Obviously, since temperature determines the tensile strength and the yield point, it has considerable influence on tool loads. This probably explains some of the adverse effects of coolant on tool loads.

SURFACE DEFORMATION

Cutting speed also affects the amount of deformation at and below the finished surface of a turned piece. The steels are the same as in previous tests with the exception that the C-1118 steel has not been normalized. Although the greatest deformation penetrates only 0.001 to 0.002 in. below the surface, it is clearly demonstrated that the cutting speed influences the surface structure. Deformation decreases with increased speed, this being less pronounced in the high-velocity range, is less without coolant than with coolant, and is less for steel with higher tensile strength.

PRODUCTION APPLICATIONS

Test results and experimental work give the engineer a good base to work from for planning future developments and improvements. In machining, the variables are many and results often contradictory because components of many factors are hard to control and difficult to evaluate. Hence the ultimate value of pioneering work is determined on the production line rather than in the laboratory. Although cutting without coolant has shown certain advantages in the laboratory, these are generally far out-weighed by disadvantages appearing on the production line such as heat expansions, preventing holding close dimensions, tool life, handling of hot workpieces and chips, and so forth. There are occasions, however, when cutting dry is the most practical solution, for example, when intermittent cuts are taken at high cutting speeds where the repeated quenching of a carbide tip by coolant quickly shatters a cutting edge.

Cutting speeds in the high-velocity range already have proved themselves on the production line. An amazing example is the turning of automotive drive pinion forgings with the tooling on a 16-in. The forging (SAE 8620 steel Bhn 176) is driven by a chisel drive and completely machined in 8.5 sec, as follows:

Spindle speed . . . . 1200 rpm

Cutting speed (max)......1185 fpm

Turning feed............0.0148 ipr

Facing feed.............0.012 ipr

Cutting time.............8.5 sec.

Floor-to-floor time........17 sec.

Maximum stock removed..$\frac{3}{8}$ in. total, 2 lb. (approx.)

Maximum horsepower.....66

Improvements in tool life after a year's production are still being made and some remarkable results are worth mentioning. As many as 660 pieces per index have been obtained on the square insert turning the large tapered diameter of the pinion, and over 1000 pieces per index on several of the triangular inserts. Note that all tools are of the carbide-insert type, requiring a minimum time for tool changes, and that toolholders are built as heavy as space permits. The coolant is supplied through holes integral with the toolholders and thus always forcibly directed at the cutting edges of a tool. To gain full advantage of cutting speeds in the high-velocity range other refinements than maximum rigidity and quick tool change become vital engineering problems. The loading time in this setup is reduced to a minimum in the following way: The operator puts the forging which has been faced to correct length and centered in both ends on the two brackets shown underneath the finished piece and pushes a button which starts the entire automatic cycle. The ram, with a live center, moves forward, catching the forging on centers, forcing the knife-edges into the face of the forging by hydraulic pressure to provide the drive, the splash guard closes and the spindle starts. When the piece is finished-machined, the spindle stops, the hood opens, the ram withdraws, and the finished piece drops down on the two brackets to be replaced with a new forging by the operator. Stopping and starting the spindle without appreciable loss of time is in itself a problem. The spindle comes to full speed in less than $1\frac{1}{2}$ sec. and at maximum production $3\frac{1}{2}$ times per min. The kinetic energy of rotating parts is about 10,000 ft-lb. per start, or 35,000 ft-lb. per min, which has to be dissipated as heat between the clutch and brake surfaces of reasonable size without excessive wear. A total of 100,000 stops and starts is considered a short life.

The importance of tool-point surface finish is emphasized in another example from the production line with machining operations, feeds, and speeds. The cutting of the $1\frac{1}{4}$-in-long thread at B is made with carbide chasers in about $\frac{1}{3}$ sec. cutting time. It used to be necessary to resharpen the chasers after every 250 pieces, but the chasers are now provided with superfinished cutting surfaces, and 700 pieces are made without resharpening. The material in the bolt is SAE 1040 steel.

A steel considered difficult to machine is SAE 52100, commonly used in antifriction bearings. This steel has a machinability rating, using the drill method of penetration, of about 40 per cent lower than 8747 steel. The ring forging is approximately 12 in. diam. and $11\frac{1}{4}$ in. long with $\frac{3}{16}$ in. of stock coming off on the side. The race is finished-machined with only one cut taken on each surface in two operations, at cutting speeds of 594 fpm at 0.015 in. feed per revolution for boring and 655 fpm at 0.020-in. feed per revolution for turning the outside diameter in 3.35 and 2 .76 min. cutting time, respectively, and with a tool life of 17 to 20 pieces for boring with a shank tool and 25 to 30 pieces per index for turning with a round insert. Tool-setting gages permit replacing of shank tools in about $1\frac{1}{2}$ min. a piece. Therefore any gain in tool life from reduced speeds would have to be considerable to increase production.

A ball-bearing outer race, also of 52100 steel, which for several years has been machined by the author's company in three operations to demonstrate possibilities in carbide high-velocity turning. The ball groove 0.161 in. deep is machined in the third operation by a form tool at 945 fpm cutting speed and 0.006 in. feed in $2\frac{1}{2}$ sec. cutting time, using about 50 hp. The average number of pieces per tool grind is about 220. The groove has been machined in only $1\frac{1}{2}$ sec. by increasing feed and without appreciable reduction in tool life. The gain in floor-to-floor time was, however, so small from 15 to 14 sec. that no gain was made in a day's production on account of a few extra changes of tools. To increase production it would be necessary to reduce chucking time rather than cutting time. Similar grooving operations are run on the production line by bearing manufacturers at cutting speeds between 500 and 600 fpm. Of further interest is the fact that the grooving operation is run successfully both wet and dry since the tool is in the cut too short a time to become overheated.

TEST ARRANGEMENTS

Average Temperature of Chips: A calorimeter was made from thin tin, double-walled with $\frac{1}{2}$-in. asbestos

insulation between the walls. A square hole in one side fitted snugly around the tool, and a round hole in an adjacent side permitted the workpiece to enter with a slight clearance to prevent rubbing. Two covers were used, one during the cut, and one made from wood and insulated with felt. This latter cover fitted inside the calorimeter below the hole for the workpiece and underneath the tool and was provided with a small hole in its center, permitting a thermometer with 5 graduations per deg. F to be inserted for stirring and reading of temperatures. The two covers were exchanged immediately after a cut had been taken. The length of cut for each speed was 1 in. and depth, 0.150 in. One pound of distilled water was used for each test, providing a depth in the calorimeter of about 2 in. Temperatures of all component parts were permitted to level off at room temperature before each test cut. The peak temperature of the water after each cut was recorded while the stirring took place and was used for determining the temperatures of the chips. The temperature would rise very rapidly, level off, and drop slowly. The chips from each cut were weighed and the weight was used in calculations.

The calorimeter was calibrated by heating chips of both steels from a number of cuts to various measured temperatures. The chips were heated in covered Incone trays provided with a thermocouple connected to a millivoltmeter calibrated directly into degrees F. The procedure for obtaining the temperature of the mixture of chips and water was the same as for a cut. The difference between the recorded temperature rise of the water and the theoretical temperature rise of an equal amount of water for perfect heat transfer was accepted as the loss in the calorimeter. The mean specific heats of steels of similar compositions within the known temperature ranges were used in the calculations and later for plotting the curves. The heat loss of the calorimeter was approximately proportional to the temperature rise of the chips. Radiation and vaporization losses were neglected when computing various temperatures. These errors are small, though greatest at slow cutting speeds.

The quantity of heat was obtained from

$$\text{Heat units} = CW(T - t)$$

where

C = specific heat of material (average)

W = weight of material

$T - t$ = temperature rise

The specific heat of C-1118 steel increases from 0.116 to 0.143 as temperature is increased from 120F to 750F, and of 8747 steel from 0.114 to 0.142 (Metals Handbook, American Society for Metals).

Components of Tool Loads: In developing a special toolholder for measuring components of tool loads, emphasis was placed on rigidity without loss of sensitivity and accuracy. Furthermore, recording instruments were desirable. The toolholder was provided with four integral diaphragms. The slotted, viselike tool post was provided with a round hole made to receive the outside diameter of the diaphrams. A sturdy sheet-steel cover with ample clearance around the toolholder was used for protection of strain gages and wiring and also for preventing chips from producing undue loads on the holder. Sets of sensitive SR-4 strain gages were commented to the holder in such a way as to measure only one component of a tool load per set. The tangential load on the tool was indicated by two gages placed on top and bottom of the holder, and the feed load by two gages placed on the sides of the holder. The radial or shank load was indicated by a set of gages on a cantilever in juxtaposition with the rear end of the toolholder. The surface of this cantilever was square with the axis of the toolholder and concentric with the rear diaphragm. The cantilever was slightly preloaded against the ball in order to assure good contact. The position of the ball was chosen so that bending loads on the toolholder would have minimum effect on radial tool loads. Only the three rear diaphragms were clamped in the tool post, the diaphragm closest to the tool being an extra protection for the electrical components The toolholder was provided with a square hole to receive 1-in. × 1-in. tools, and located so that the cutting edge of the tool always could be located on the axis of the holder, thus reducing errors from torque interferences between components of tool loads to a minimum. The toolholder was hollow except for the part where the tool was clamped and at the rear end where a pressed-in plug was used for holding the ball. The three sets of strain gages on the toolholder were connected to universal analyzers and direct-inking oscillographs. All three components of a tool load were recorded simultaneously. The calibration of the instruments was made with known loads applied in the same direction as the components of the tool loads.

The lever arm was supported by a fulcrum point on the turret with a link abutting against or pulling on the tool. The width of engagement between the link and the cutting edge of the tool was made equal to the depth of the cut to be tested except for radial loads. Before a known weight was attached to the lever, the systems were balanced electrically, thus eliminating the lever and permitting use of loads in round figures for calibration, for example, 100 or 500 lb. Any cross-effect of one calibration load upon the other two sets of strain gages was recorded and compensated for when calculating loads. To calibrate with weights was necessary only once for each depth of cut as the instruments were provided with an auxiliary electrical calibration system which could be switched in at any time to check for drift. Full gain of the analyzers was always used and the lowest attenuation which would keep the inking pen inside the chart paper.

CONCLUSIONS

Both production experience and experimental tests have shown that higher cutting speeds for machining steels have many advantages, such as lower tool loads and less surface deformation on finished parts; and that tool life can be very economical even though the rate at which heat is generated at a tool point is practically proportional to cutting speed. Improvements in the quality of tools, coolants, machine construction, materials, methods, and controls have resulted in higher permissible cutting speeds with increased production and possibilities for greater economical benefits. It is not suggested that cutting speeds should or can be doubled or tripled on present equipment without careful attention to all factors involved not that the limit in production capacity has been reached in examples from the production line. The various test show that there are no drastic changes in tool loads and chip temperatures as cutting speeds are increased from 300 to about 1400 fpm, that tool finish and angles have a vital effect on tool life, and that chip breakers and cutting angles on tools should be modified to suit both cutting speed and type of steel for obtaining highest efficiency in chip removal. A few years ago when carbide was introduced, most machine tools lacked power, speed, and rigidity for efficient use of carbide tools. The recent successes in the high-velocity range indicate that a similar era is approaching when a large proportion of existing machine tools are rapidly becoming obsolete.

ACKNOWLEDGMENTS

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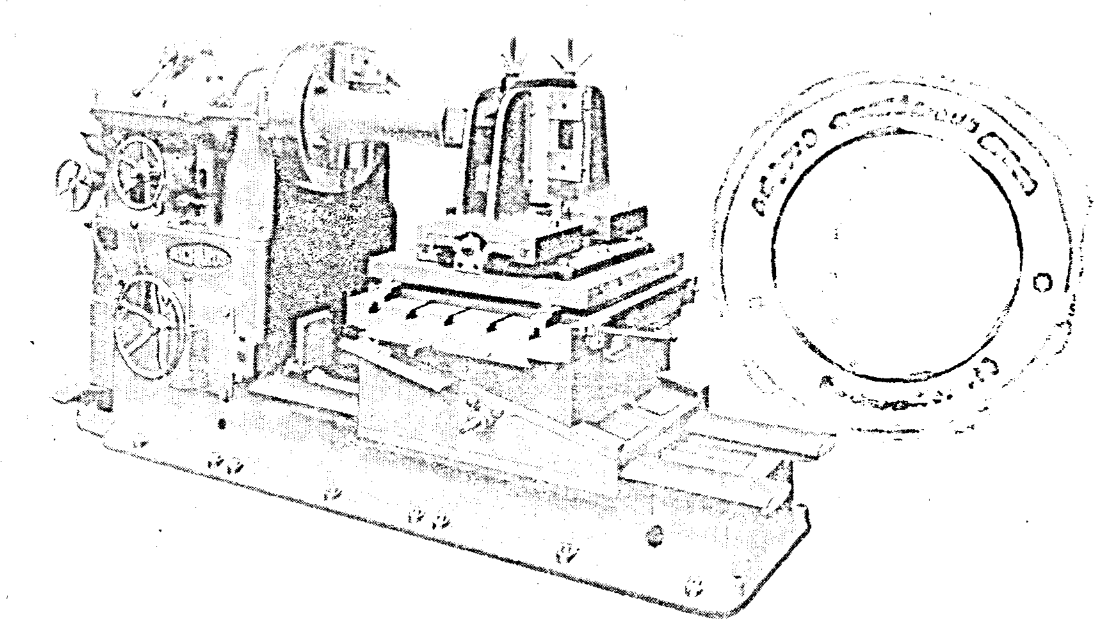
RICHARDS AXLE BORING MACHINES

THE 'AB' Type patent Axle Box Boring, Facing and Radiusing Machine illustrated below represents the very latest development in this class of machine tool. It is specially designed for dealing with axle boxes and is of compact and robust design.

THE FACING HEAD

The machine incorporates a facing head capable of facing up to 24-in. diameter with a slide having automatic feeds for facing operations, as well as hand adjustment. It has inward and outward feeds for surfacing the front and back sides of axle boxes, and in addition carries a tool for facing.



For the boring and relieving operations, the facing head also carries a powerful snout bar, the base of which is of bridge formation to span the facing slide. The snout bar mounted on the facing head can be seen on Page 26, and the facing tool can also be seen in position on the facing slide.

It will be observed that both the rough and finish boring tools are shown, but this is merely for illustration purposes, as in actual practice, the finishing tool is not placed in the bar until the roughing operation is complete. The tool for cutting the side relief and the clearance in the keep is mounted at the end of the snout.

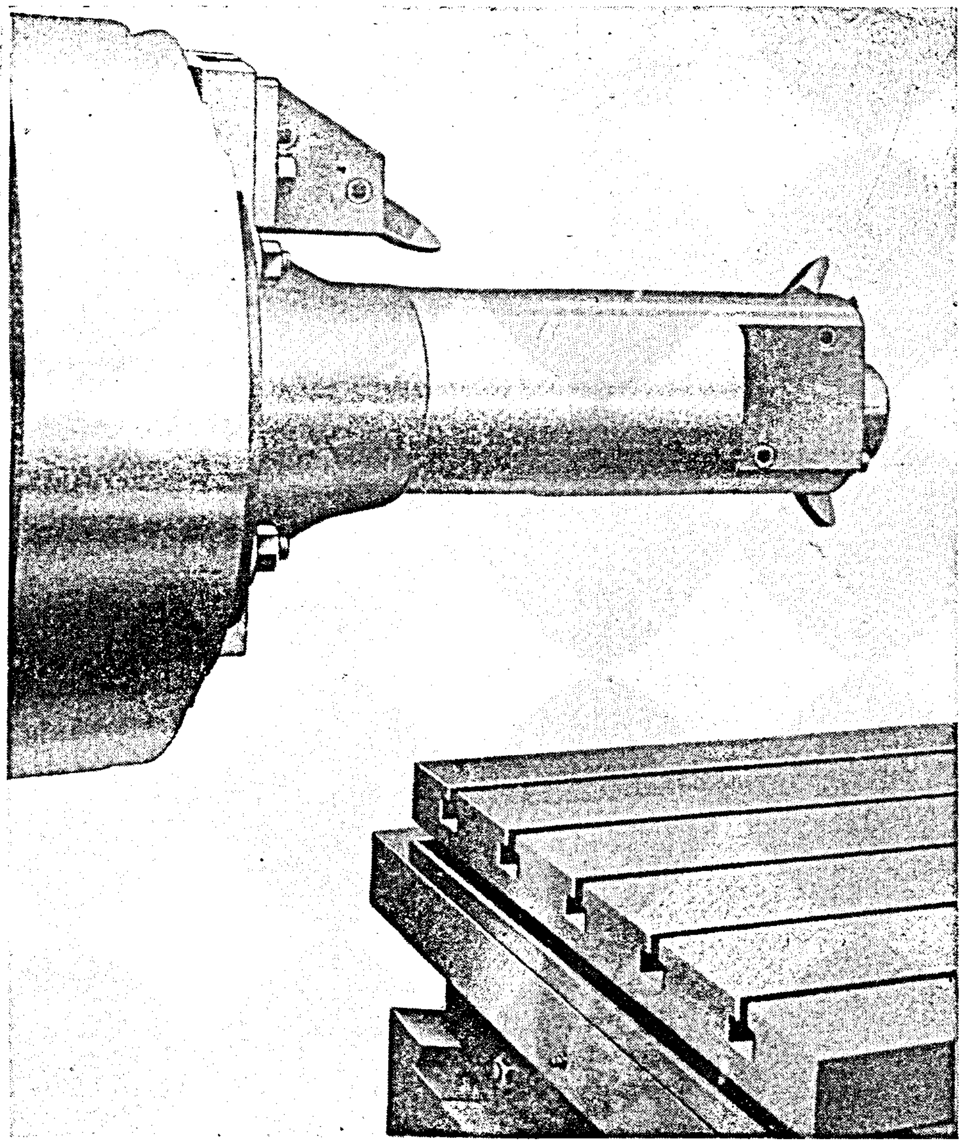
The snout bar illustrated is 7 in. diameter, but bars of smaller diameter can be supplied if required.

SADDLE AND TABLES

On the bed of the machine is mounted an incline saddle which has three rates of automatic feed longitudinally, and is also provided with rapid power traverse. On top of this saddle is mounted an auxiliary incline saddle, having longitudinal hand adjustment to accommodate different sizes of axle boxes. A vernier rule reading to .001 in. is fitted to the incline plane for convenience in setting the vertical height of the axle boxes.

A tee-slotted table, having hand cross movement, is mounted on top of the auxiliary saddle, and here again vernier scale reading to .001 in., is provided. A stop for locating the table exactly central is also fitted.

On top of the main table is fitted a square revolving table incorporating a lifting arrangement by means of which the table can be lifted and moved round with ease. This table is fitted with Richards' Patent Squaring Lock, by means of which the table can be set square to the



spindle with absolute accuracy. This device comprises a wedge which fits the whole length of the table, and is actuated by a lever, pinion and rack.

The axle box is held on the revolving table by means of a fixture, which is included with the machine, and is always made to suit client's particular boxes.

The cycle of operations on a typical axle box is as follows :—

1. Rough boring at high speed with single tool in snout bar.

2. Finish boring at 300 r.p.m., with second tool placed in snout bar after rough boring.

Adjustment is then made to the main table transversely to position the axle box for cutting side relief and the clearance in the keep.

3. Cutting side relief and clearance in the keep with eccentric tool. The axle box is then returned to its original centre by the transverse motion of the main table, for the facing and radiusing operations.

4. Rough facing side of box.

5. Finish facing side of box.

6. Radiusing operation. The top table is then revolved 180°.

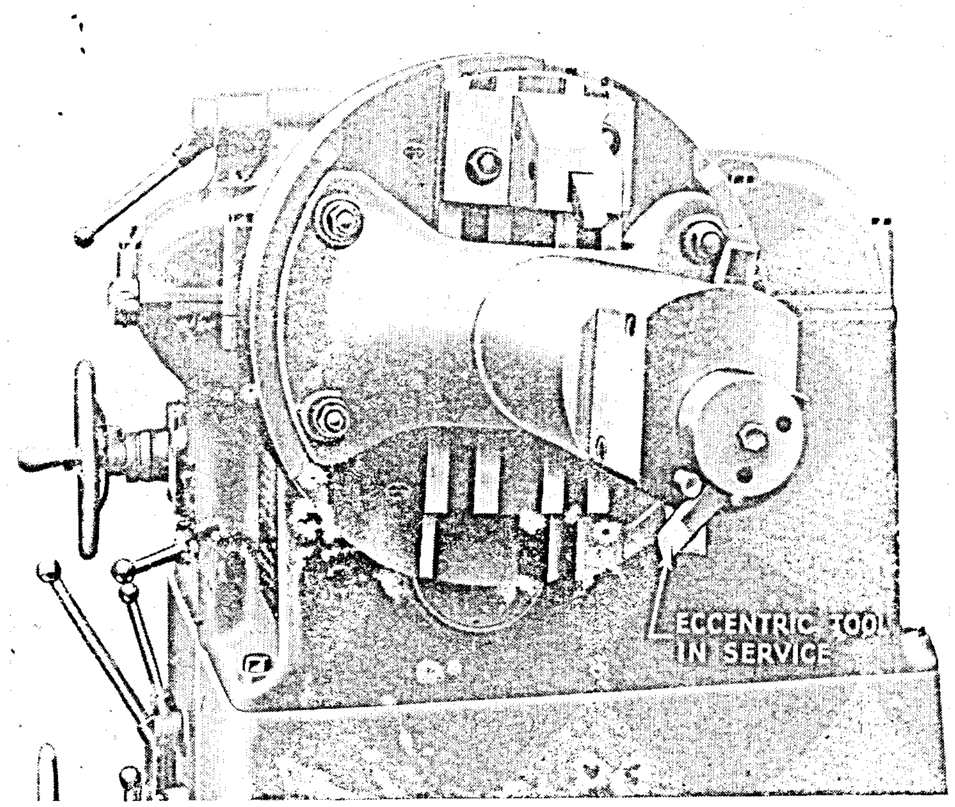
7. Radiusing operation at opposite end of box.

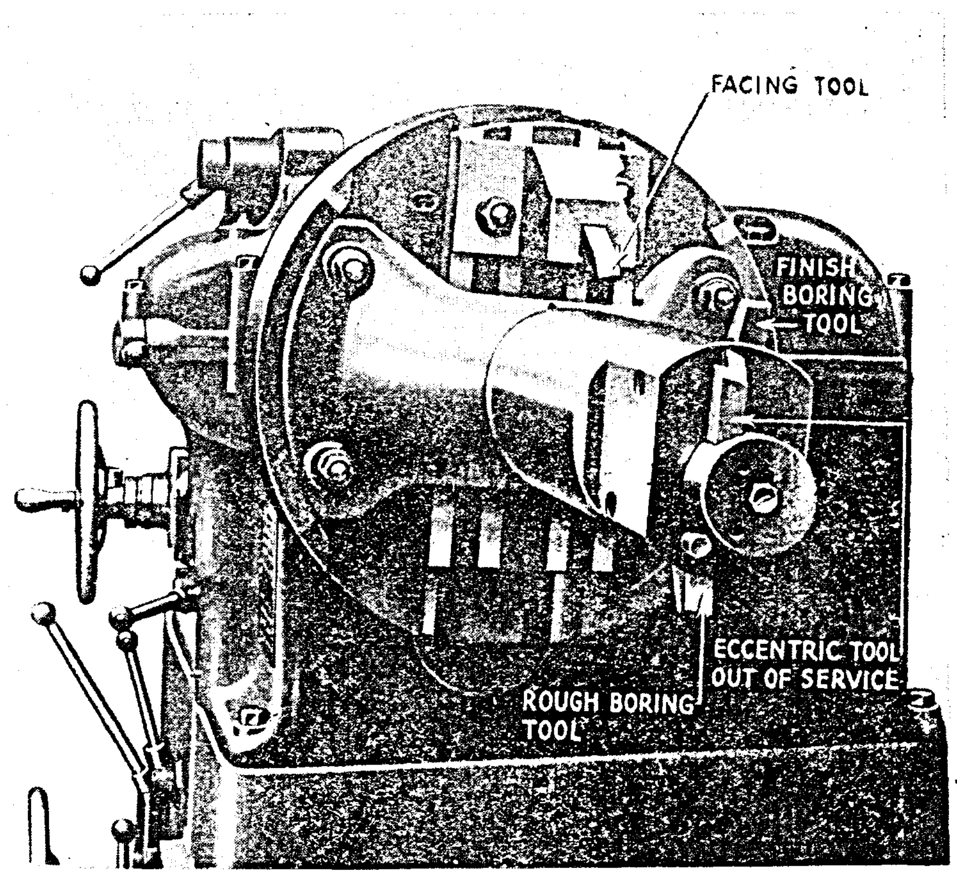
CONTROL

The operation of the machine is very simple, all the control levers being within easy reach of the working position. A footbrake is provided, for rapidly bringing the facing head to rest after the driving clutch has been disengaged by the stop and start lever.

LUBRICATION

Automatic lubrication is provided to the main spindle bearings by gear driven pump contained in the head itself, whilst the speed gear box has splash lubrication.





DRIVE

The machine is electrically driven by a 10 h. p. constant speed motor and the transmission is through completely enclosed Vee ropes.

GENERAL

It will be appreciated from the foregoing that with adjustments provided in all directions, i. e., longitudinally, transversely and vertically, the machine is fully capable of dealing with both now and repair boxes of various sizes in the most convenient manner, the whole of the movements being made with a minimum of effort. Futhermore, by simply extending the length of the bed, the machine can be used with equal success on radial axle boxes.

A very valuable feature of the machine, however, is that with these various adjustments and the range of speeds and feeds provided, it can be adapted for use on other work should the whole of its time not be occupied on the production of axle boxes.

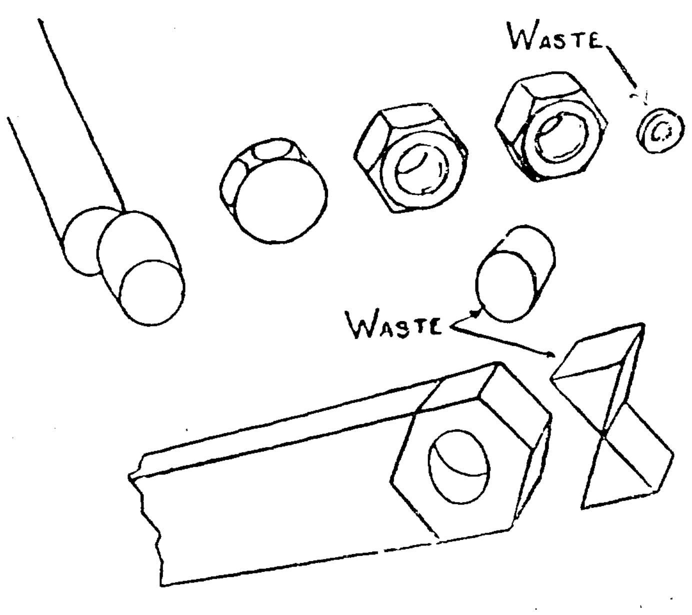
We invite technical articles on the various stages manufacture of Machine Tools, Pneumatic Tools and any technical problem confronting the trade for publicity purposes.

NUT-MAKING FROM ROUND BAR

Some Details of Swiss Practice in a Keenly-Competitive Industry.

A major advantage claimed for nuts made from round bar as compared with the method using flat bar stock the width and thickness of the finished nut is a marked reduction in the volume of waste, as shown by the sketch Fig. 1. This is stated to be in the order of 8 to 10% with round bar and 33.1/3 to 35% with flat bar stock, which is a matter of considerable importance in such a keenly competitive trade as the standard bolt and nut industry in which material costs are a more important factor than in the case of products involving a larger number of machining operations.

Figs. 2 and 3 show an automatic hot nut press which has been developed in Switzerland by the firm of F.B. Hatebur, of Basle, for working on round bar and having a high rate of production, this being in the region of 90 to 100 pieces per minute in the case of standard ¾" nuts. It is a 4-station machine, the sequence of operations



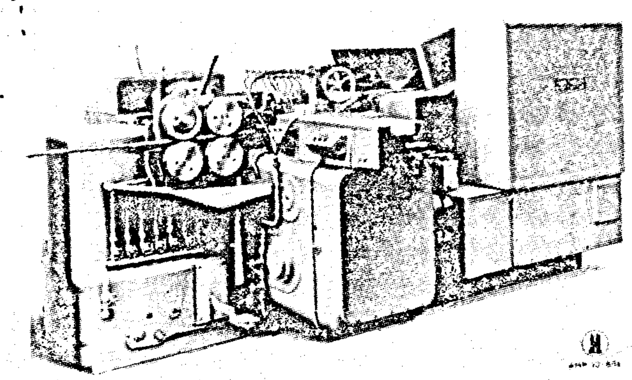
(1) Diagram comparing amount of waste using round bar and flat stock

from left to right being (1) Feed to stop and cut off, (2) Upset and square up blank into rough hexagon shape, (3) Pre-form hole from both sides, counter-sink, and chamfer (at this stage trade or other mark may be impressed), and (4) Pierce out slug and calibrate hole.

Detail views of the tooling are shown by the photographs Figs. 4 and 5. The bar is fed to the machine at forging temperature by means of the feed rolls seen in the left of the photograph of the machine, the bar being fed up against a stop the position of which can be adjusted during operation by a handwheel. Lateral movement of the blank is effected by the transfer fingers shown. On the forward movement of the main ram, the various blanks are brought in front of the appropriate dies and inserted into these by the respective punches, and as the opposing tools contact the blanks the fingers open and withdraw to make way for the punches to enter the dies. During the return strock of the main ram, as the blanks at the second and third stations are ejected into the transfer fingers and the bar again fed forward to re-commence the cycle, the finished nut at station 4 is drawn back by the piercing punch and removed by the stripper plate, the nut blank leaving the machine separated from the waste slug, and completely finished except for the subsequent tapping operation.

The following is the stage in the cycle of operations shown by Fig. 4. At station 1 the shearing slide has just cut off a blank and carried it over to the first pressing die; at station 2 the squared-up blank has been ejected into the transfer fingers and carried over to station 3; at station 3 the pre-formed blank has been ejected into the transfer fingers and is carried over to station 4, where the finished nut blank is stripped off and falls down the chute. Fig. 5 shows blanks being worked at each station, as follows: (1) The shearing slide is on its return stroke, (2) a roughly hexagon-shaped squared-up blank is being formed, the transfer fingers having been opened by reciprocal torsion of the tubular shafts, and (4) the waste slug is being punched out, the transfer fingers have been opened, and are

2



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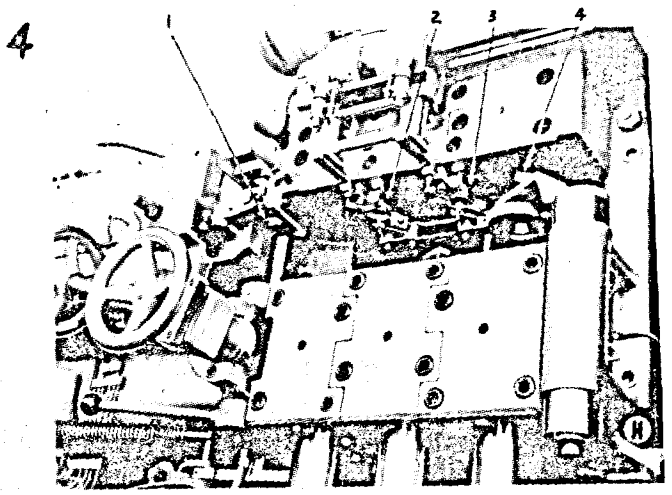

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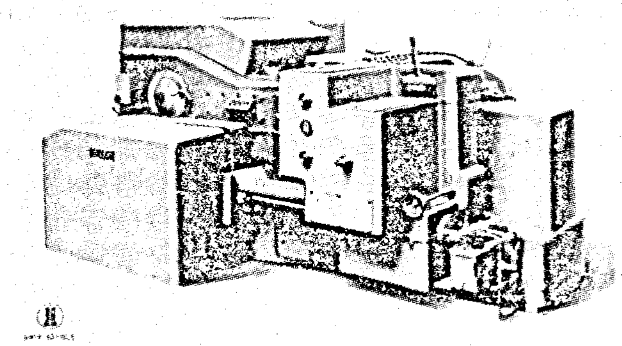

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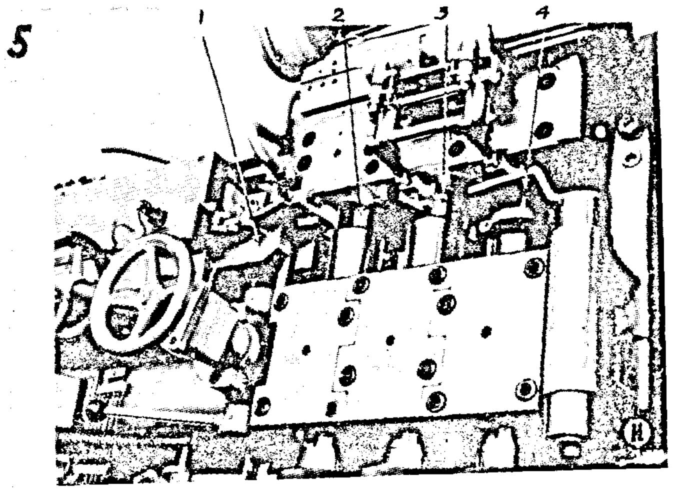

(2) Automatic hot nut press by F. B. Hatebur, of Basle
(3) ditto from rear side
(4) Tooling layout with stations numbered
(5) ditto (at further stage in cycle)

about to return to station 3 to pick up the next preformed blank when ejected.

A number of safety devices are incorporated in the machine to obviate any risk of overloading any of the mechanism as would happen, for instance, if a preformed blank were drawn back by the pre-forming punch, or in the event of any failure in the electricity or compressed- air supplies, in all of which eventualities the machine is stopped immediately. The drive is by 50 h. p. electric motor, and the machine in operation requires a supply of compressed air at 60 to 100 lb. per square inch for the operation of the electro-pneumatic clutch and brake, the consumption being from 350 to 450 cubic feet per hour. The capacity of the machine illustrated is from 3/4" to 1¼" nuts, the production being in accordance with the following table:-

Size	3/4"	7/8"	1"	1.1/8"	1¼"
Production per min.	90-100	80-100	75-100	70-90	70-90
Heated stock required per minute	23 lb.	28	40	50	66 lb.
Size of waste slug dia.	16.5 mm	19.5	22.5	25.1	28.3 mm.
thickness	3.5 mm	4	4.5	5	6 mm.

The machine requires to be run at the foregoing rate of production as for as circumstances permit, as a slow-running press has the disadvantage that the contact time of the tools with the heated material is longer, resulting in a proportionately reduced working life of the tools. The weight is 27 tons.

Diamond Tools for Abrasive Wheel Truing

INTRODUCTION

Industrial Diamonds are used in the production of almost every manufactured article.

Table I is intended to show in the very broadest sense, the different operations on which diamonds of various size ranges and types are used.

TABLE I

Broad Classification

USE	TYPE OF DIAMONDS	SIZE RANGE CARATS
Abrasive Wheel Truing	Roundstones, Octahedrons, Pieces, Ballas, Brazil Carbon	1/10 —15
Rock Drilling	Drill Bortz, Congo, Ballas, Carbon and Boart	1/200— 2
Machining non-ferrous metals, plastics and refractories	High grade flat crystals and Cleft Pieces	½ — 4
Wire Drawing	High grade Octahedrons and flat crystals with clear centres	1/10 — 2
Hardness testing	High grade crystals	1/5 —1/3
Glass Cutting	Vitriers	1/80 —1/5
Gauging	Roundstones, Octahedrons, Cleft Points and Flats	1/20 —½

1 metric carat = .2 gramme (approx. 1/150 oz.)

Abrasive Wheel Truing

The present article will deal only with diamond uses under this heading.

Most diamonds for this purpose are used as mined in their natural shape and condition. As will be seen from the above table, there are several different diamond types and a wide size range suitable for this work. In addition, there are many qualities within each type. In deciding the type, size and quality of diamond to be used in truing a given wheel, it is sometimes supposed that only wheel dimensions need be considered. This is not so as all of the following factors may effect diamond selection :—

Wheel
- Diameter
- Width of face
- Grit
- Grade
- Bond
- Abrasive

Profile
- (a) Plain
- (b) Stepped
- (c) Thread forms
- (d) Other forms

Machine
- Type i.e., centreless, plain, surface, tool and cutter
- Maker
- Condition

Work
- Material to be ground
- Accuracy required
- Surface finish

Operation
- Toolroom standard
- Skilled Grinder
- Semi-skilled Operator
- Unskilled Machine Minder
- Whether shift working is in force

There is no formula yet devised to correlate all these factors to the range of diamond types, qualities and sizes available.

Table 2 shows examples of diamond specifications in relation for specific jobs. It would, however, be quite incorrect to infer from this that the specifications would hold good for the same job under any conditions other than those which obtained in these examples. The size ranges quoted are for new tools. Following successive resetting, the diamonds should in most cases work satisfactorily down to 50% of the mean size stated. If however, more suitable work is available they should be transferred to it after a loss of, say, 25% to 35%.

TABLE II

EXAMPLE NO.	TYPE OF GRINDER	WHEEL DETAILS APPROXIMATE DIA. Ins.	FACE Ins.	GRIT	GRADE	DIAMOND SPECIFICATION APPROXIMATE WEIGHT Cts.	DESCRIPTION
1.	Plain	20	2	60	M	2–3	Medium quality crystal or piece
2.	Surface	7	1	46	K	¾	- ditto -
3.	Internal	2	1½	60	L	½	Good quality crystal with well defined points or wheel type magazine tool
4.	Centreless Work Wheel	24	6	80	L	3–5	Good quality crystal or ballas type
	Control Wheel	12	6	120	Rubber Bond	1½–2	Good quality crystal with well defined points or multi-point type S6
5.	Centreless on fairly open form work Work Wheel	24	6	46	K		Special Blade Truer Type 333R
	Control Wheel	12	6	80	L		Special Blade Truer Type 222V
6.	Universal on circular Form Tool Grinding	7	½	100	G		Special polished Chisel Truers on Diaform Pantograph Forming Attachment

It will be seen that in examples 1 and 2, only single point truers have been mentioned. FIG. 1 illustrates conventional types as well as indexing type tool holders. On most similar jobs such tools would be the best but where for any reason truing tools are likely to be abused on such work, the "impregnated", "multi-point" or "in-line" type of tools should be substituted. For example, a suitable alternative would be the Diatuf type A. 300R. The cutting head of this tool consists of 18 small whole diamonds of equal size set in a regular pattern of 4 layers. The matrix consists of tungsten powder and an alloy binder. This matrix forms a chemical bond with the diamonds and retains them throughout their useful life. Such a tool will stand much more abuse than a single point truer and needs no resetting.

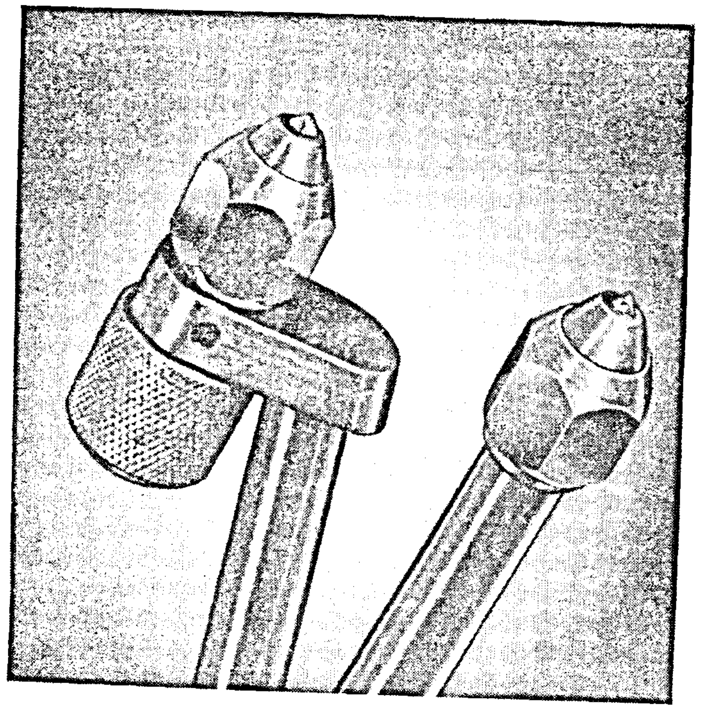

Fig. 1

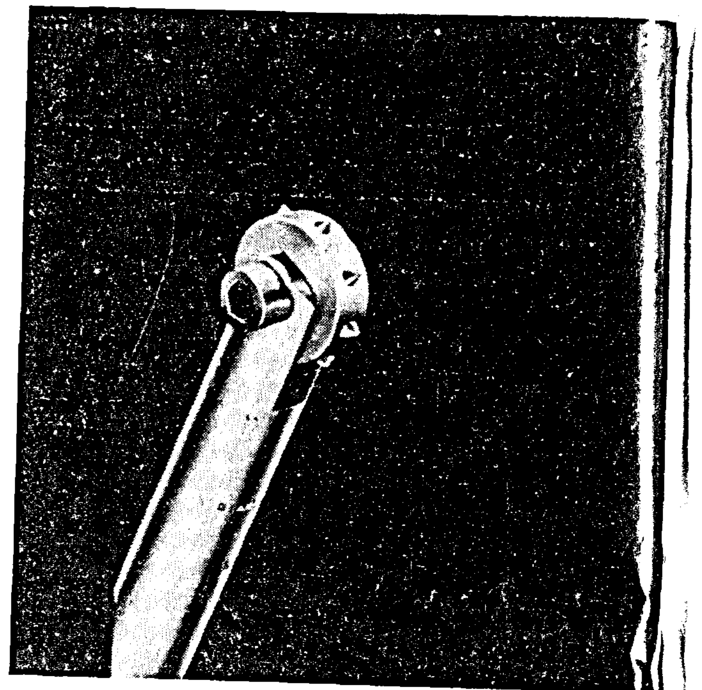

Fig. 3

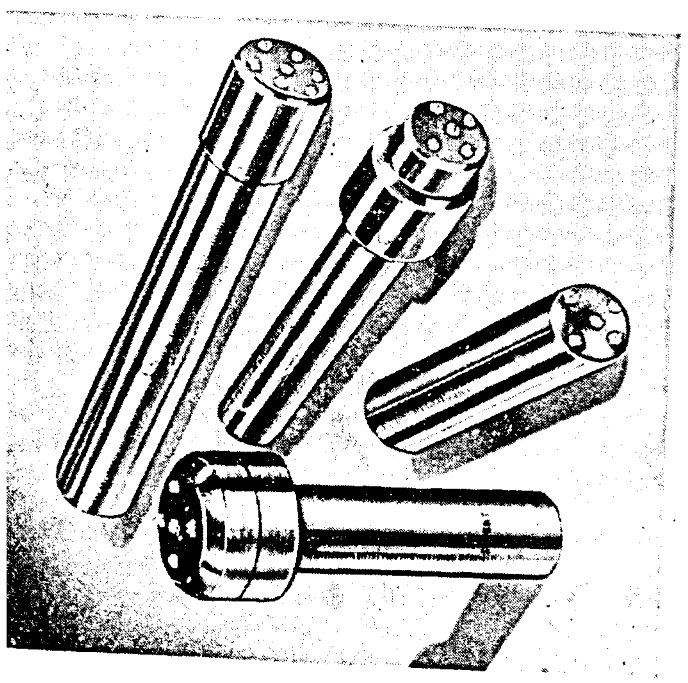

Fig. 2

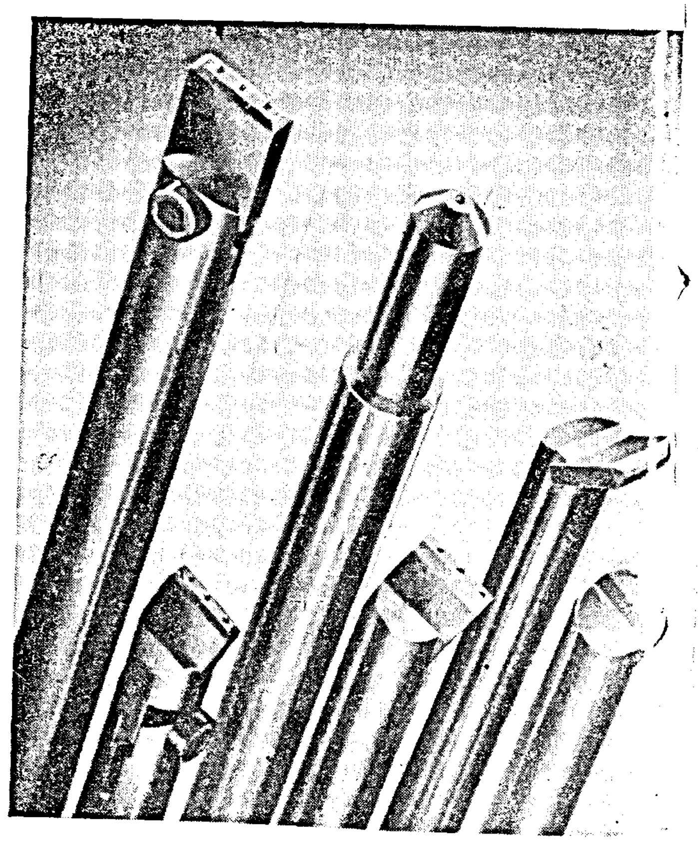

Fig. 4

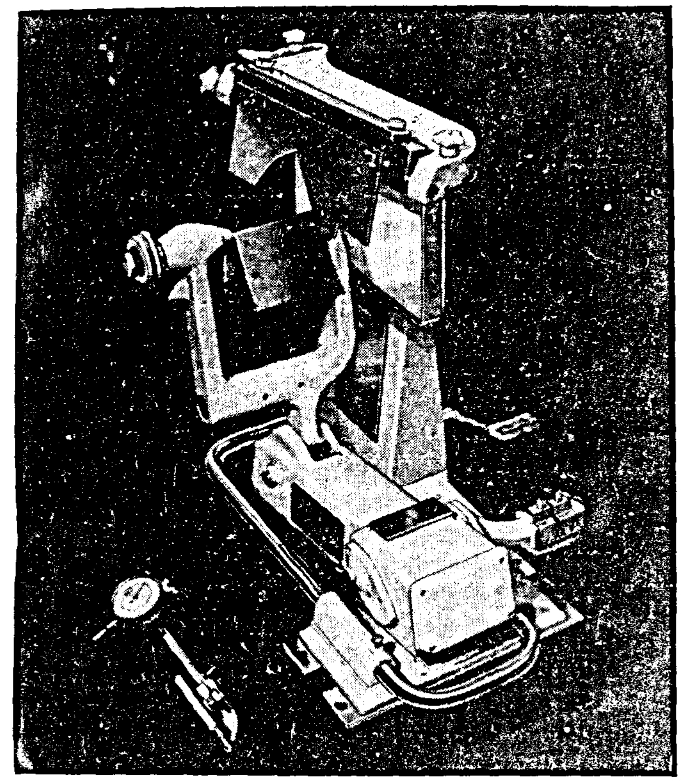

Fig. 5

For example 2, a smaller tool in the same range would be a suitable alternative.

An alternative is given in example 3. This wheel type tool is illustrated in FIG. 2. In order to prevent deflection of the small spindles of internal grinders using wheels up to 2″, it is necessary that the diamond truing tool shall exert a minimum pressure. To do this it is essential that a sharp point be maintained on the too.

The wheel type tool contains eight small diamonds, each set with a good point presented for work. As' each point is worn the next can be brought into use.

The simple action of loosening the Allen Screw, turning the wheel and re-tightening the Allen Screw, is all that is needed. No resetting is required and the maximum use is made of the diamond content of the tool.

An alternative for the work Wheel in example 4 would be an "impregnated" type tool similar to that described or examples 1 and 2. The construction of such a tool would be identical but it would have a heavier diamond content.

A lighter type again would serve on the control wheel if it was of vitrified bond. The tenacious rubber bond, however, requires a sharp pointed diamond. The wheel type presenting one small diamond to this camparatively large wheel would, however, wear rapidly.

The S6 tool illustrated in FIG. 3 is designed to provide the advantage of the sharp point with the wearing qualities of a larger diamond. The head can be adjusted around the centre provided by the retaining Allen Screw. When new, a slight offset on the head brings only one of the end diamonds in contact with the wheel. As the point is dulled in use, the point of the adjacent diamond gradually comes into use and retains the free cutting properties of the wheel. The process is continued until all six points have become too dulled for further use.

For taper or very open radius production form grinding, a single point truer can be satisfactorily used. Example 5, however, pre-supposes that the form is so complex or has other characteristics that prevent the satisfactory use of such tools. The limiting factor usually lies in the increasing width of diamond cutting face as the tool continues to be used. Each Dianyf blade type turer had a specified maximum width of diamond cutting face which is maintained throughout the life of the tool. FIG. 4 illustrates the 333 range of blade tools. The small diamonds are set in the tungsten blade by a patented powder metal process. The result can be likened to a sandwich of which the "bread" is tungsten matrix and the "meat" a layer of diamonds.

The tool requires on resetting and, in fact, need not be re-adjusted in the machine during its whole life. In order to correct the normal "drag" angle on truing tool sockets, the blade is offset so that its centre line coincides approximately with the wheel centre line. The development of the blade type truing tool has greatly facilitated production form tool grinding not only on centreless but on any grinder which can be equipped with a suitable unit to control the path of the truing tool.

Normally, however, the methods available, whilst quite adequate for production work are not sufficiently flexible or accurate for tool room work. The form grinding of punches and dies, as well as flat and circular form tools, has become standard practice. The Diaform Pantograph Wheel Forming Attachment was developed to provide the required accuracy where the form grinding could be done of a normal surface grinder or universal grinder of the Brown & Sharp No. 13 type. FIG. 4 illustrates one of the Diaform range of Attachments.

The sequence of operations required to produce a ground form with such an Attachment as mentioned in Example 6 is :—

(a) By normal plotting and filing methods, cut on a 3/32" Mild Steel plate a X10 copy of the required form.

(b) Attach this template to the carrier of the Attachment.

(c) Select the largest standard Chisel diamond profile that can be accommodated in the form. Normally the choice lies between chisel forms of 40° included angle and .005" radius or 60° included angle and .010" radius. Set up this chisel tool and roughing tool on the truing arm.

(d) Set up the Attachment on the grinder with the wheel in the surface grinding position.

(e) With the stylus held in the highest part of the template form, advance the roughing tool until it contacts the wheel. By advancing the cut in increments of .001" and traversing the stylus across the template at each advance, the rough form is soon produced on the wheel. The final accuracy is imparted to the wheel by centring the finishing diamond chisel in relation to the wheel and continuing the traverses across the wheel face.

(f) Rotate the grinding wheel through 90° to the cylindrical grinding position and set up the blank circular tool.

(g) Grinding the form from the solid fully hardened steel blank. In the case of deep forms it is sometimes advisable to retrue the form before making the final grind.

The procedure is simplified, of course, in the case of punches and dies or flat form tools where the grinding can be undertaken on a normal surface grinder.

The chisel diamonds for these Attachments are set by powder metallurgy and the flanks are ground to the required included angle. The tool is held in a jig attached to the conventional diamond polishing lap. When this operation is complete, the jig is transferred bodily to a special radius grinding machine on which the forming of the diamond radius is optically controlled.

Similar production methods are used in manufacturing chisel truers for other means of form grinding including gear and thread grinding.

In some cases the initial roughing out of the shape on a new wheel can be facilitated by the use of a Diatuf Impregnated Form Tool.

This, however, is only an economical proposition when :—

(a) It is a fairly wide, peep form.

(b) The job is likely to be repeated often enough on new wheels that the total roughing out time will be appreciable.

Such tools consist of a metal compact moulded on one or more faces to the form required and impregnated with small diamonds over that area. This forming tool can be blamped into the position normally occupied by the workpiece and traversed across the wheel as if it was the component being ground. It is fed into the wheel in increments of .002"—.003" and soon transfers the form on the diamond tool to the wheel maintaining an accuracy of within a few thousandths of an inch.

It will be appreciated from this summary of the uses of diamond for abrasive wheel truing, that present practice does not confine the user to the use of the conventional single point wheel true.

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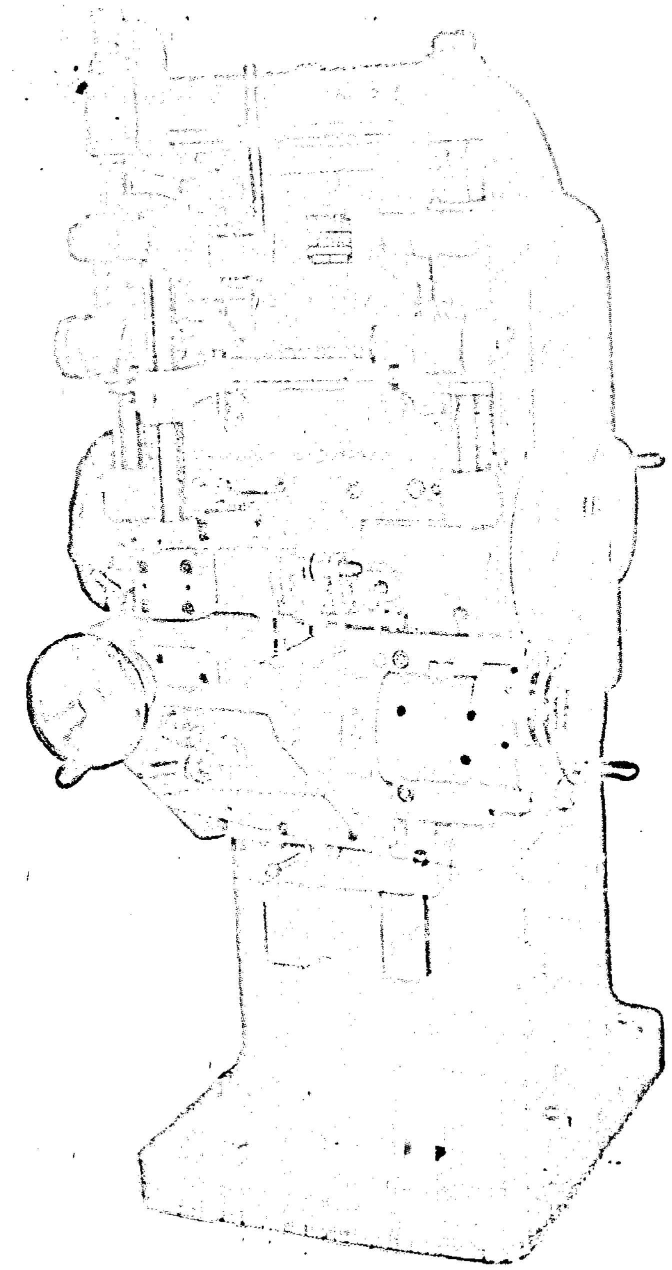
NASSOVIA-THIEL 32, sf



DRIVE

Flanged motor to drive the hydraulic gear unit. Switching on and off through the medium of a motor protection switch.

HYDRAULIC GEAR UNIT

Hydraulic gear unit for lifting and swinging movement of the shaping tool (slotting tool).

LIFT STROKE MOVEMENT

Lever gear produces the straight-line lift movement of the shaping tool; adjustability of stroke: 50 – 150 mm at the adjustment spindle.

SWING-OVER MOVEMENT

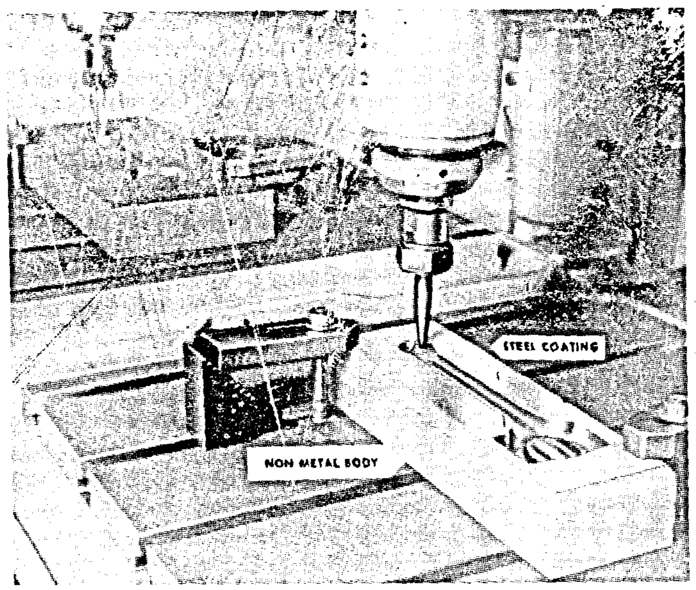
Lever gear produces the swing-over movement of the shaping tool after completion of the straightline lift movement; the swing-over movement can be set as required 0–90° at the adjustment spindle even when the foot does not require a radius.

PUNCH FORMING AND SHAPING MACHINE

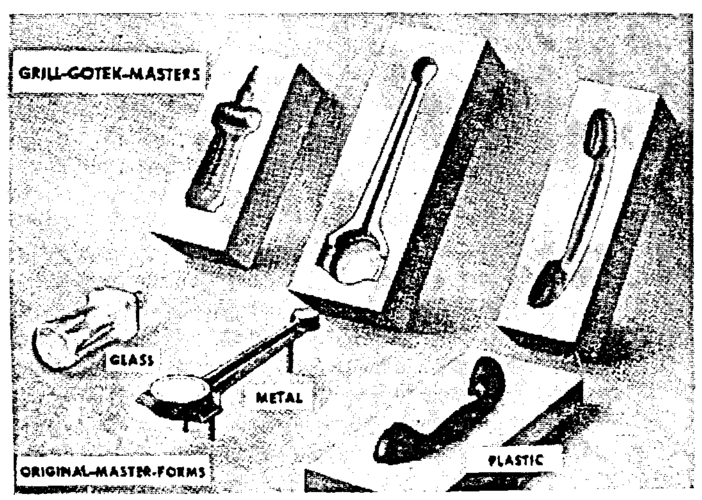
WITH SLOTTING ATTACHMENT

DIE-SINKING-MASTERS

Die Sinkers copy from MASTERS. The copying, a three dimensional milling process for the production of dies on a Die Sinker, demands masters of a high quality and precision. At present it is still difficult to produce **MASTERS** economically. Materials like wood, plaster, plastic, etc. may be easily machined, but they mostly do not have the required precision and durability. **MASTERS** made of steel are by far the best, but also the most expensive.



Simple and relatively cheap production of steel **MASTERS** is possible by the **GRILL-GOTEK-METHOD.** First of all an original master form or "positive" is necessary. This can be either an original or a sample compound of any material. This compound must be provided with a steel coating, which is as strong as required for the intended use, by means of metallisation. This steel coating is an absolutely accurate negative of the original. Then the negative master must be strengthened with a strengthening substance as body. The finished steel **MASTER** embodies maximum accuracy as to detail and size and provides maximum resistance to pressures and deflections. It is also suitable for continued use.



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