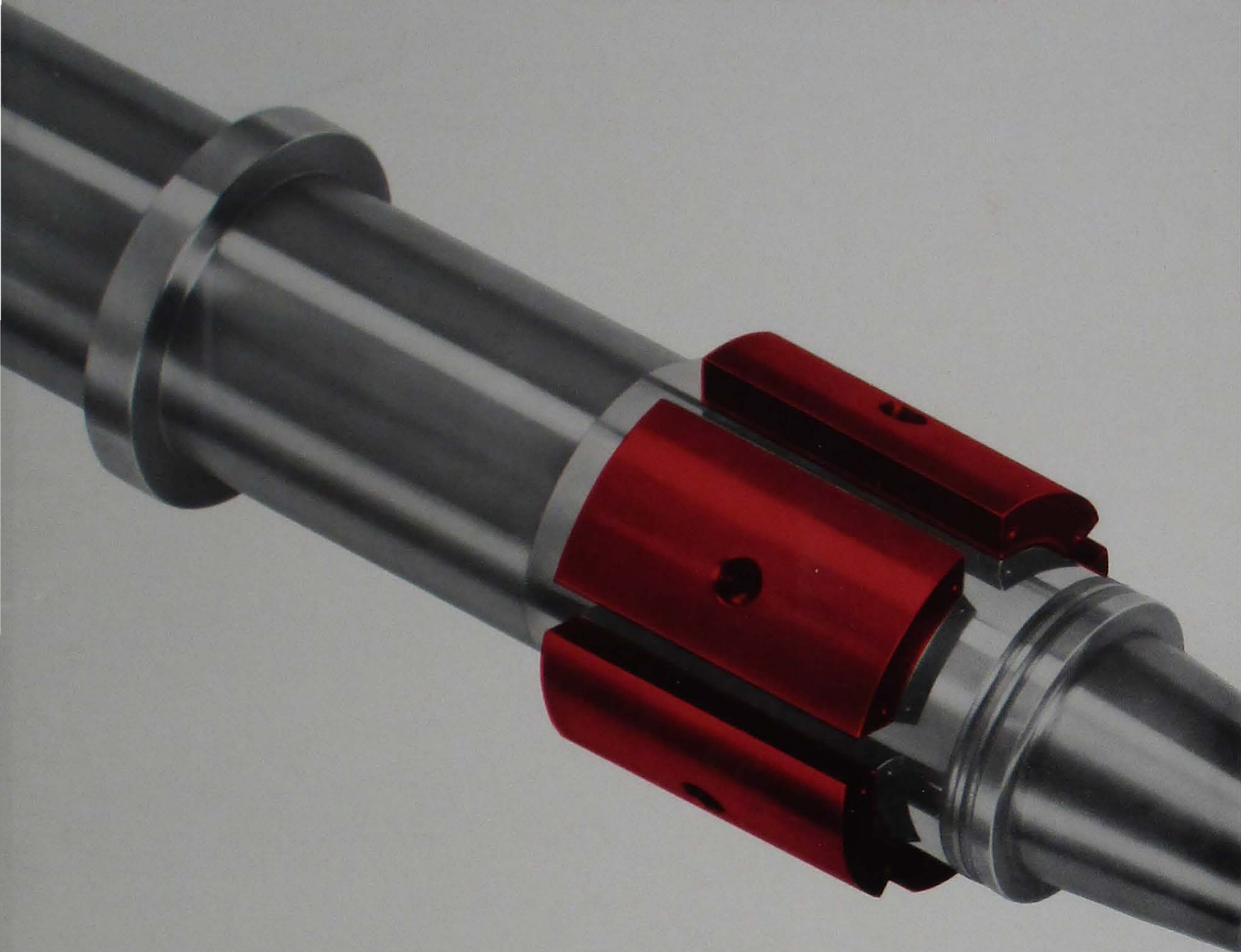
CINCINNATI



FILMATIC

Grinding Wheel Spindle Bearings

Introduction

This booklet explains the technical theory and development of the CINCINNATI FILMATIC GRINDING WHEEL SPINDLE BEARING. Herein lies a major solution to the grinding wheel spindle bearing problem, which, of course, is only one of many that must be overcome when designing precision grinding machines.

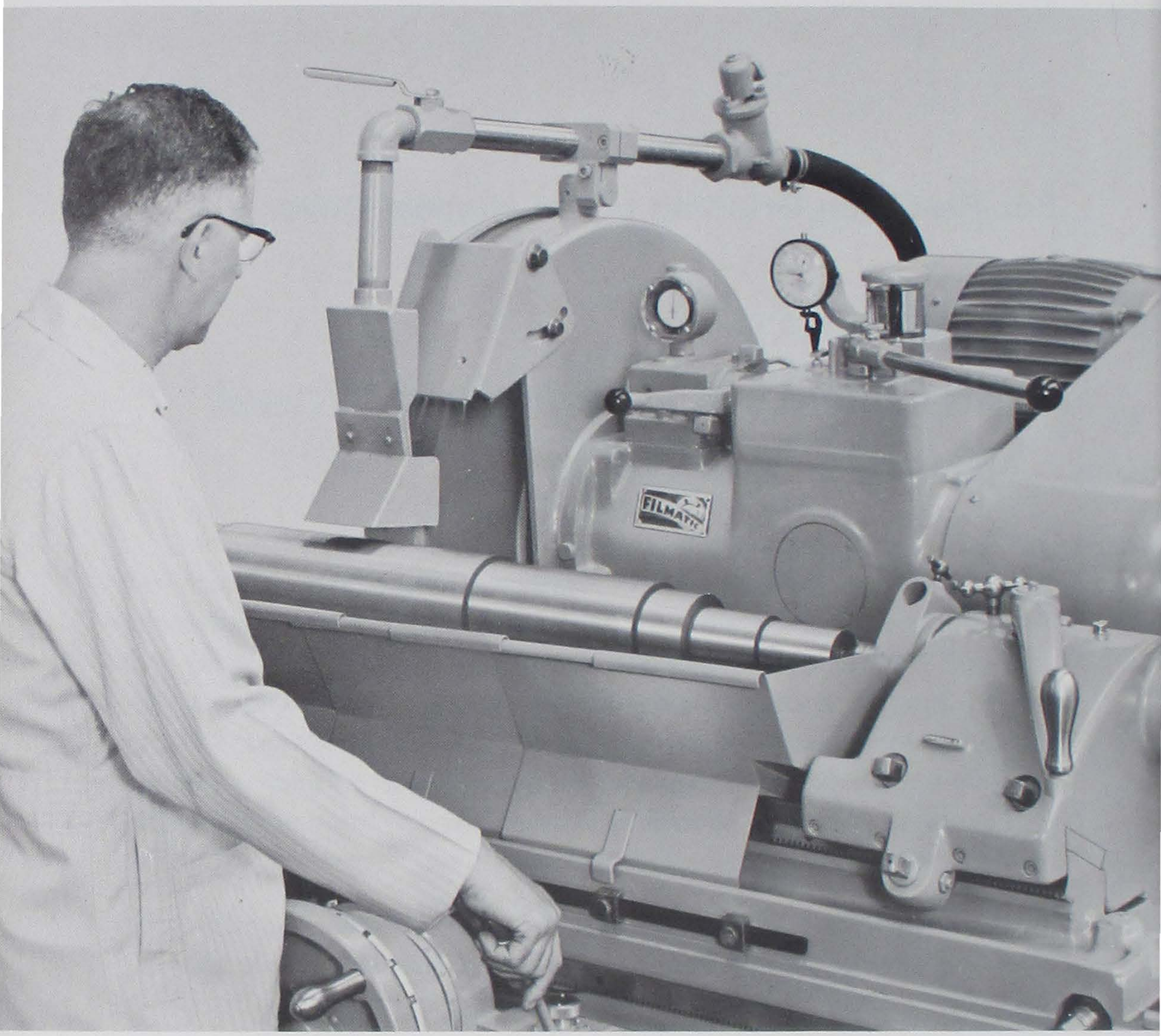
GRINDING MACHINE DIVISION
THE CINCINNATI MILLING MACHINE CO.
CINCINNATI, OHIO 45209
CINCINNATI® FILMATIC®

For Precision Grinding of the Highest Order—

CINCINNATI FILMATIC Grinding Wheel Spindle Bearings

"What is the single most important unit on a precision grinding machine?" This is like asking: "What is the most important unit on an automobile engine?" Both of these questions have merit; however, when you really stop to consider them, it becomes obvious that all of the functional units—the carburetor, spark plugs, oil pump and others—contribute to the smooth operation of the engine. The same situation is true of a grinding machine, only more so. All units contribute in some way to the operation of the machine, otherwise they wouldn't be there.

Most manufacturers admit that certainly one of the most important units on a precision grinding machine is the grinding wheel spindle bearings. For precision grinding of the highest order, it is essential that rigidity (flutter-free rotation) and low friction be maintained in precision grinding wheel spindle bearings. To do so, certain requirements must be maintained. These are outlined on page five of this booklet. Following them is a brief discussion of the theory and development of the CINCINNATI FILMATIC BEARING.



CINCINNATI FILMATIC 14″ x 48″ Plain Hydraulic Grinding Machine.

REQUIREMENTS

For a
Precision Grinding Machine Spindle

1. An uninterrupted fluid film must be positively maintained between the spindle and bearing so as to prevent metallic contact and failure in service.
2. The axis of rotation when running idle must be maintained in a constant position—no fluttering or wavering can be tolerated.
3. Change in position of spindle axis with change in grinding forces must be as small as possible.
4. The bearing must be capable of supporting a load which varies in direction through a wide angle.
5. Frictional losses in the bearing should be substantially independent of applied load.
6. Bearing must be as foolproof as possible, with minimum wear, and must not require adjustment for varying grinding conditions such as finishing and roughing.

CINCINNATI

FILMATIC BEARINGS

assure lifetime reliability on grinding wheel spindles

Since the earliest days of precision grinding machines it has been generally recognized that the heart of the machine is the grinding wheel spindle bearing. Insufficient rigidity of the spindle and bearing often develop chatter. Wear on the bearing surfaces and occasional seizure resulted in frequent shutdown for adjustment and repair.

Among the many plain bearings used have been the tapered box, the half bearing without cap, the half bearing with cap, or with one or more loading shoes to provide a certain measure of stability in the vertical plane. Many combinations of special bearing materials have been used in an effort to reduce the hazard of seizure under abnormal loads or improper adjustment. With all of these structures extremely close fits have been necessary between the spindle and bearings, and consequently precise and sensitive adjusting means and expert manipulation were necessary.

Thus grinding machine designers have always been faced with the dilemma of selecting between a bearing which would have long life but low rigidity and one which would have high rigidity but relatively short life.

Referring to the accompanying list of spindle requirements, Item 2 (Page 5) is essential for precision grinding machines, because, under idle conditions the wheel is trued by a diamond or other means, and obviously a smooth true is essential for a smooth grind.

QUICK SPARK-OUT

Rigidity is essential in a grinding machine spindle bearing in order to minimize the likelihood of chatter and feed lines. It also permits a more accurate duplication in plunge cut grinding, and provides a quick "spark-out," thus giving higher speed in the production of accurate dimensions.

The phenomenon of pressure development in an oil film was explained mathematically in 1886 by Osborne Reynolds in his classical paper on the interpretation of certain experiments in bearing lubrication by Beauchamp Tower. In this analysis it was proved that the requisites for the generation of pressure in a film of fluid between two relatively moving surfaces are: adhesion of the fluid to both surfaces, viscosity of the fluid, and ability of the surfaces to form a wedge-shaped space.

When a journal (such as A, Fig. 1) is rotated in a bearing element, fluid from the "lead-in" B is drawn between the relatively moving surfaces because of the adhesion between fluid and journal. Since the fluid must have intermolecular friction, or what is commonly called viscosity, other layers of molecules are also drawn into this space.

With continued rotation, the layers adjacent to the journal A are moving therewith, while the layers adjacent to the bearing C are stationary. It is obvious, therefore, that all of the fluid between these surface layers is in a continual state of slip (or shear). When these surfaces are relatively close to each other, and converge in the direction of motion, the shear forces in the fluid are very great, and thus a pressure is built up normal to the bearing surfaces, supporting the journal and its load, and preventing all contact between journal and bearing.

The distribution of this radial pressure about the axis of the journal is shown by the curve D, where the maximum value occurs on the line E.

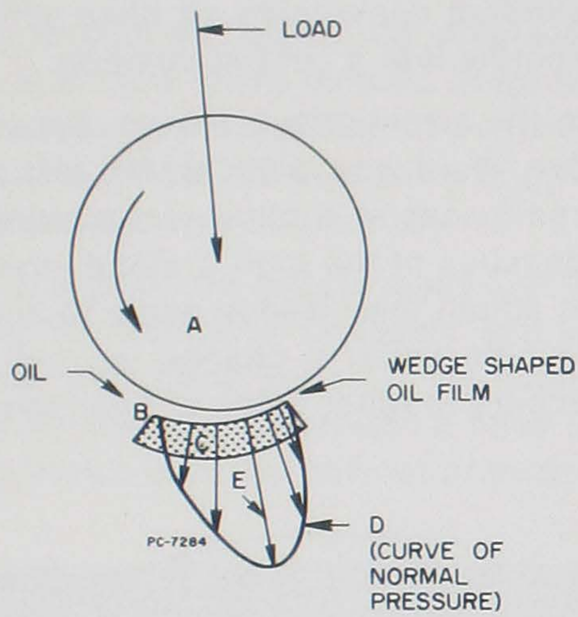


Figure 1—When a film of lubricant is drawn into the wedge-shaped space between a journal and a single bearing segment, pressure is built up and distributed as illustrated.

FILM PRESSURE IN PLAIN BEARING

The common journal bearing utilizes this principle of lubrication by developing a wedge-shaped oil film which converges in the direction of rotation, the journal axis being displaced eccentrically in amount and direction in accordance with the amount and direction of the applied load. Obviously, only one converging film can be developed in such a bearing, and thus a somewhat unstable condition results as the position and shape of the converging film changes with every change in amount and direction of the load. Where the oil film is divergent, a subatomspheric pressure may develop, with a possible additional instability due to the induction of air. (For a theoretical treatment of this subject, see "The Theory of Film Lubrication," by R. O. Boswall; Longmans, Green & Company.)

In the past, many attempts have been made to increase the stability and rigidity of plain journal bearings for grinding machine spindles by providing grooves or scrapers so as to interrupt the oil film or to reduce its thickness.

This procedure, however, must obviously decrease the carrying capacity of the oil film and must lead in the direction of lower safety and shorter bearing life.

In the FILMATIC bearing, developed by THE CINCINNATI MILLING MACHINE CO., and shown in Fig. 2, the instability which is inherent in the single oil film structure is completely eliminated. In this design, three or more separate self-adjusting shoe members are used to produce independent converging oil films which develop radial pressures, forcing the spindle into a central position.

In the arrangement shown, the spindle is located in a central position by five "fluid vise jaws" which still permit perfect freedom of rotation with a coefficient of friction almost identical with that of anti-friction bearings. Because of the high preload, and also because of the ability of the shoes to adjust their wedge angle to accomodate the load, the movement of the spindle under a change in load is only a minute fraction of that which occurs in other types of bearings.

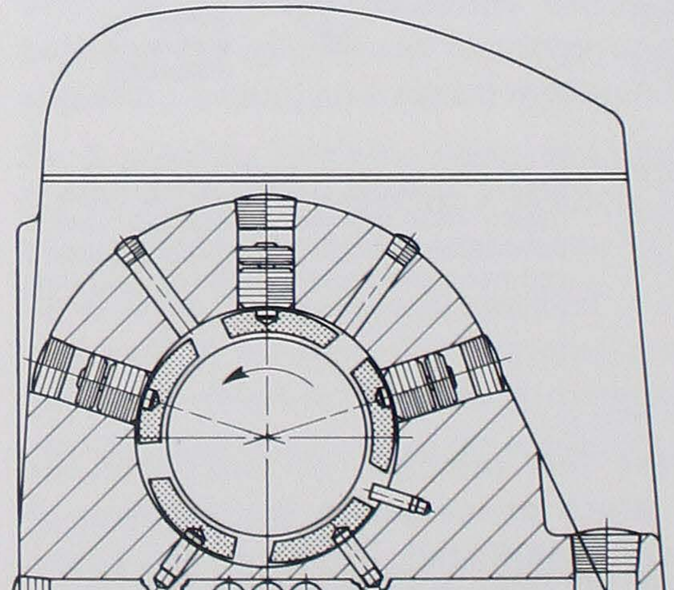


Figure 2—The entire bearing chamber of the FILMATIC bearing is maintained under a pressure substantially above atmospheric.

Among the first things discovered in the early stages of this bearing research was the explanation of the cause of the hitherto mysterious "pecking" of the diamond in truing. From the early days of precision grinding, the irregular sound of the diamond in passing across the wheel has plagued the lives of grinding machine operators, particularly when taking fine cuts in an attempt to obtain high finishes. These irregular changes in sound were produced by minute changes in position of the spindle axis due to the slight inherent instability of older types of spindle bearings.

Even with the arrangement of rocking shoes as described before to hold the spindle rigidly on a given axis, minute irregular movements on the order of 50 micro-inches were still found to exist. After much patient investigation, these were traced to momentary fluctuations in the oil supply to the bearing shoes, and to the presence of entrained air. This condition was eventually completely eliminated in the FILMATIC bearing by maintaining the oil supply in the bearing chamber at a pressure substantially higher than atmospheric and by providing an effective air bleeder system. Figs. 3 and 4 are reproductions of oscillograph records showing a comparison of the steadiness of rotation of a spindle carried in a FILMATIC bearing, and in an older precision bearing of the cap type. The latter bearing was provided with a former standard lubrication system wherein the supply of oil was limited so as to produce relatively thin films.

It will be noted from the curves showing vertical and horizontal displacements in the cap type bearing, that in this case there existed irregular motions of about 60 micro-inches in the vertical plane and 25 micro-inches in the horizontal plane, while in the case of the FILMATIC bearing (Fig. 4) the displacements are so small that they are scarcely discernible.

By maintaining the bearing chamber under a pressure substantially higher than atmospheric, it has been possible to provide a relatively simple means for safe-guarding the entire spindle lubricating system. This safety means comprises a pressure switch, Fig. 5, which acts through a relay to prevent the starting of the spindle driving motor until the desired pressure

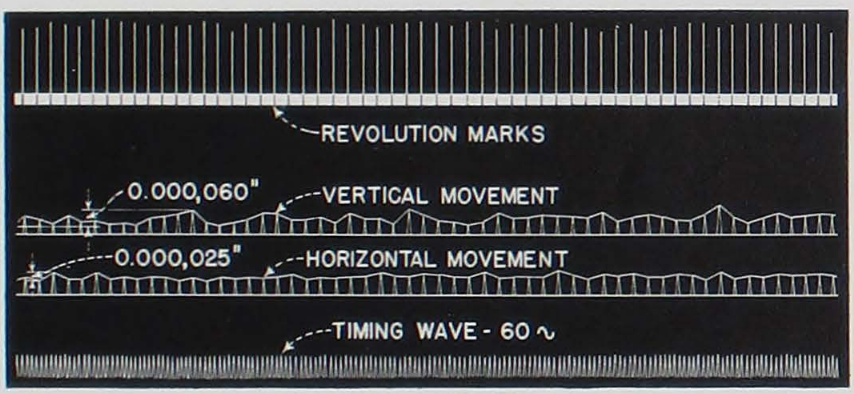


Figure 3—Old style bearings —60 millionths vertical flutter; 25 millionths horizontal flutter. Tips of the wave peaks indicate the spindle position once each revolution. The irregularity in position of the wave tips in this oscillogram indicates a slight fluttering of the spindle axis.

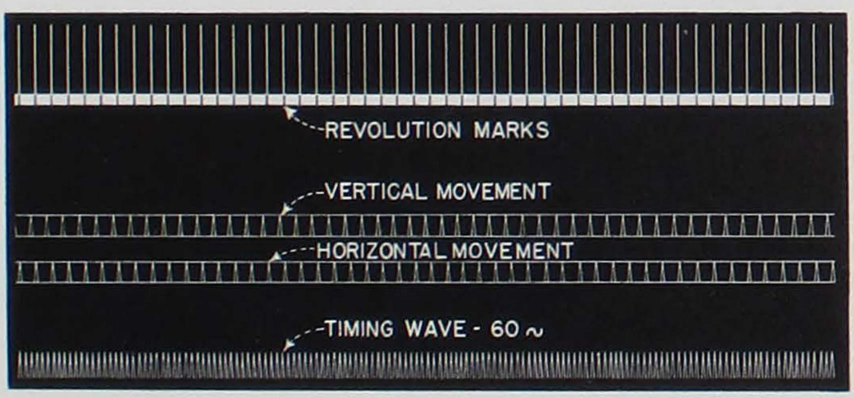


Figure 4—FILMATIC bearing —no discernible spindle flutter. The even alignment of the wave tips in this oscillogram indicates a true running spindle.

has been built up within the bearing chamber. An independent motor drives tandem oil pumps. One of these pumps supplies oil through a filter to the by-pass valve which maintains the chamber pressure at the desired value. The oil is then pumped to the front bearing chamber which includes both the FILMATIC bearing and the thrust bearing. From here the oil goes to the rear FILMATIC bearing chamber and on to the pressure switch and drain. When the pressure switch closes, the grinding wheel drive motor can be started. The circulating oil system automatically removes air from the oil lines.

Because of the fact that, in this bearing, an uninterrupted oil film is positively maintained between the journal and bearing surfaces, its operation is virtually independent of the materials used for journal and bearing and the nature of the lubricating fluid. The present standard construction employs a chrome-nickel steel spindle and steel bearing shoes lined with a high lead bronze, identical with that used in certain airplane engine bearings, but satisfactory operation has also been experienced with various other types of bronze, and even with cast-iron and phenolic-resinoid bearings. In the operation of thousands of machines equipped with FILMATIC bearings, some of which have been in service over a period of more than

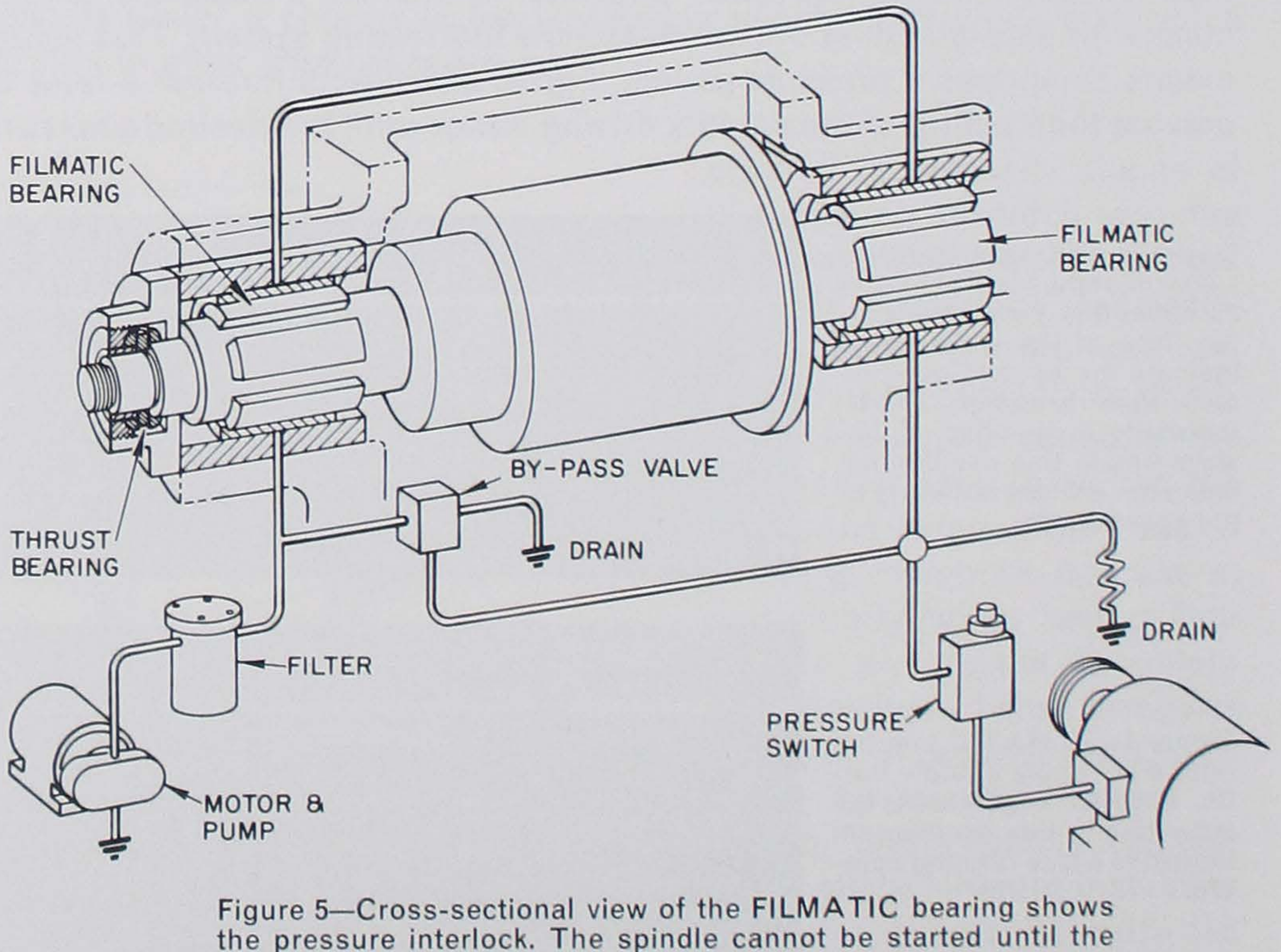


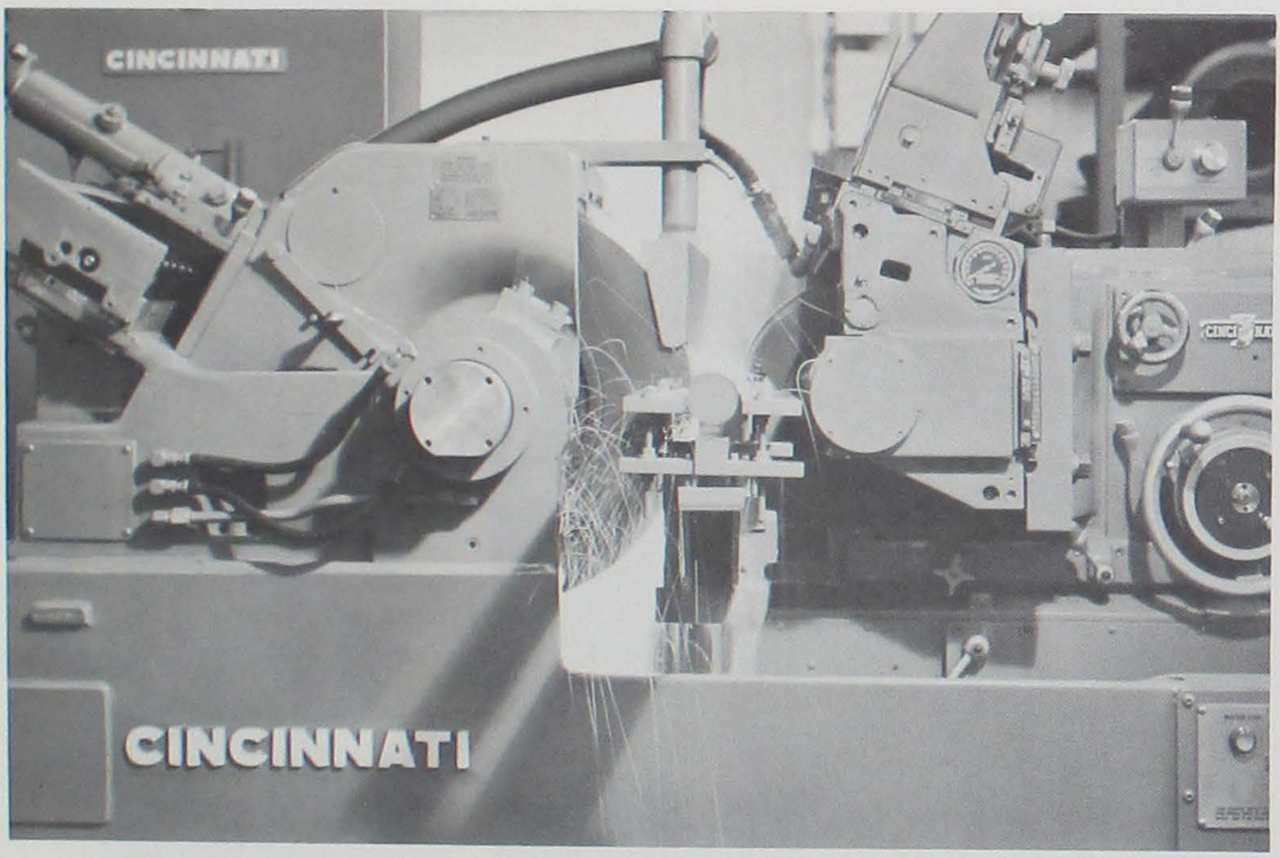
Figure 5—Cross-sectional view of the FILMATIC bearing shows the pressure interlock. The spindle cannot be started until the correct pressure is built up in the bearing chamber.

twenty-five years, it has been found that all of the requirements mentioned previously have been fulfilled. These machines have ranged in power from 3 to 100 hp, and in speed from 1,000 to 5,000 rpm.

In these machines, the sound from the truing diamond is absolutely uniform, simulating the tone produced when tearing a fine silk cloth. The entire bearing structure is so rigid that the ideal wheel for a given job is usually from one to two grades softer than with the older machines with other designs of bearings, thus giving more efficient grinding with consequent less frequent wheel truing and longer wheel life.

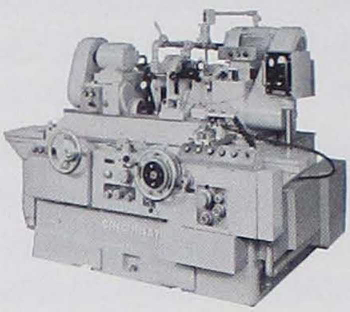
Friction horsepower, with these bearings, is virtually independent of the applied load. In actual operation it has been found that, over a wide variety of work, it has not been necessary to make adjustments when changing from heavy roughing cuts to fine finishing cuts. Maintenance cost of these bearings has been virtually zero.

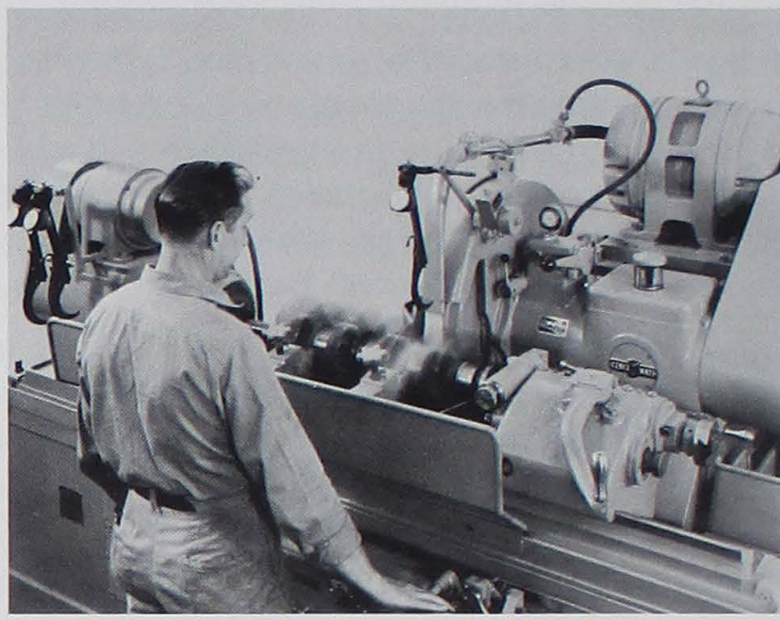
FILMATIC bearings are used on all CINCINNATI precision grinding machines. They are on Super Precision Grinders which hold tolerances to a few millionths for size, roundness and finish on a semi-automatic production basis. Also on larger grinders these same FILMATIC bearings support a spindle and wheel assembly weighing 1,400 pounds and capable of taking 100 horsepower cuts.



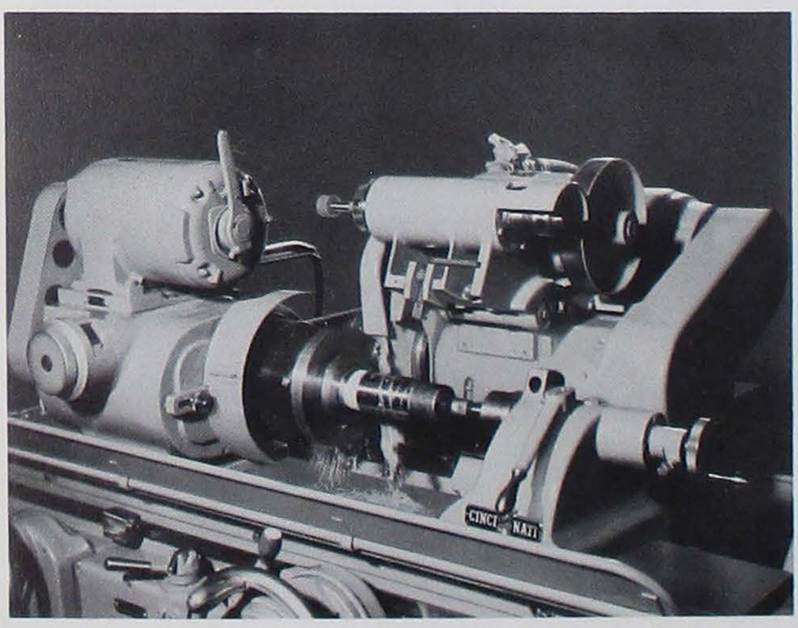
CINCINNATI TWINGRIP Centerless Grinding Machine

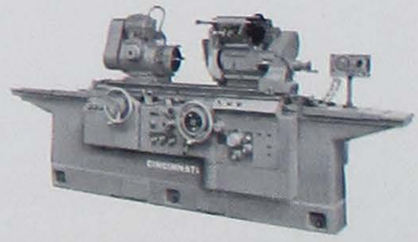
"FILMATICS" *on the JOB . . .*



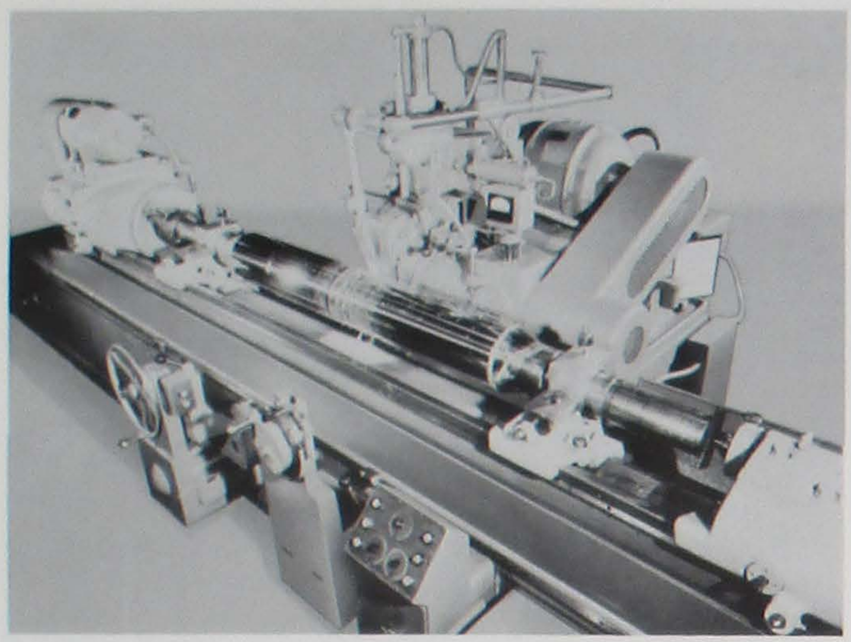


Plunge grinding the main bearing diameters of a crankshaft on a CINCINNATI FILMATIC PLAIN GRINDING MACHINE.

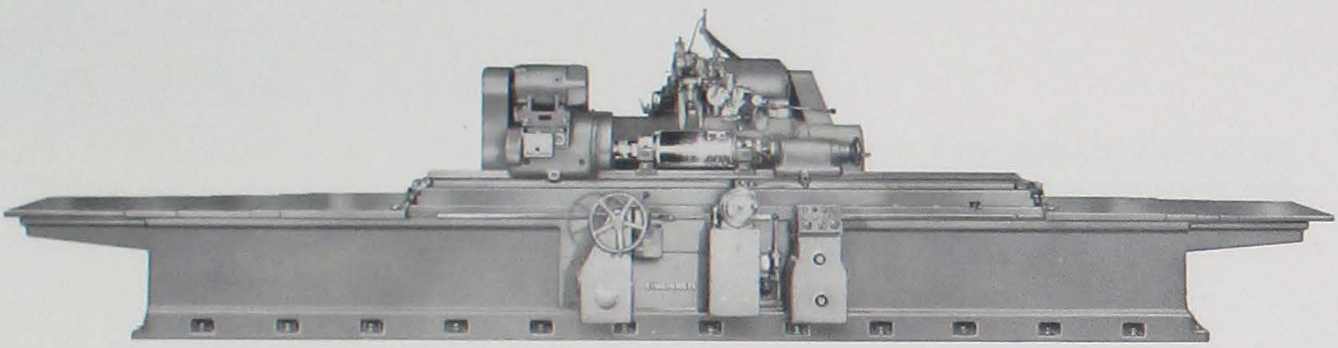


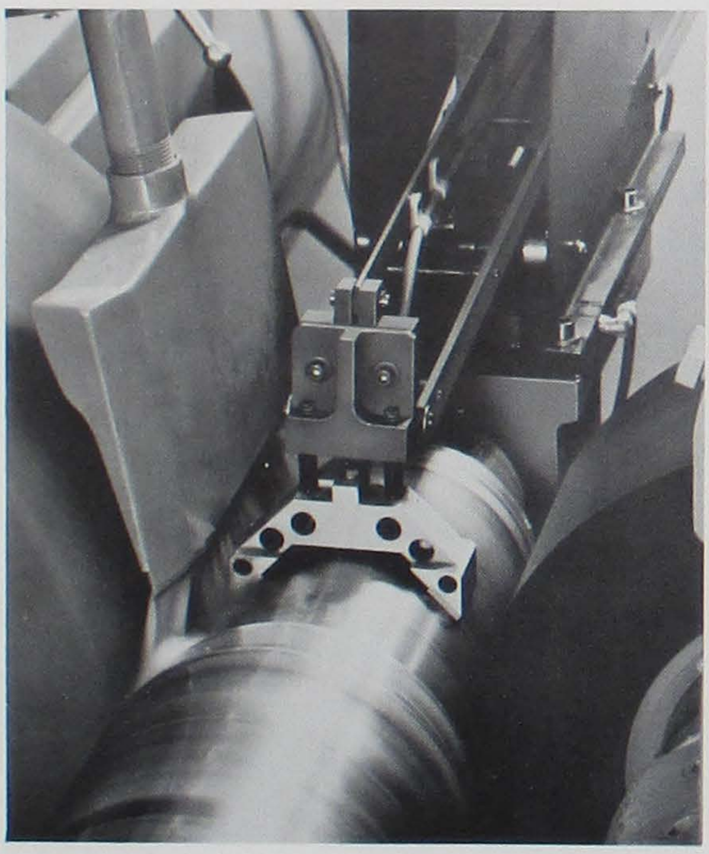


Plunge grinding one section of a multiple diameter shaft on a CINCINNATI FILMATIC UA UNIVERSAL GRINDING MACHINE.

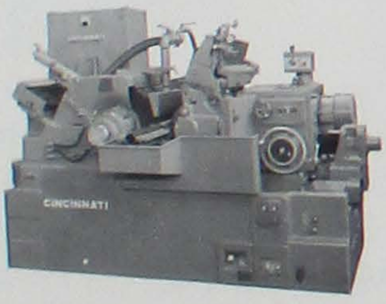


Traverse grinding the working surface of an aluminum foil roll on a CINCINNATI FILMATIC TRAVELING TABLE ROLL GRINDING MACHINE.





Infeed grinding the journals of a steel freight car axle on a CINCINNATI FILMATIC 300 SERIES CENTERLESS GRINDING MACHINE.



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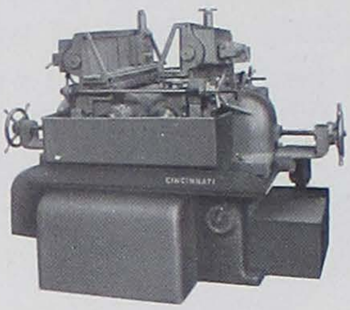
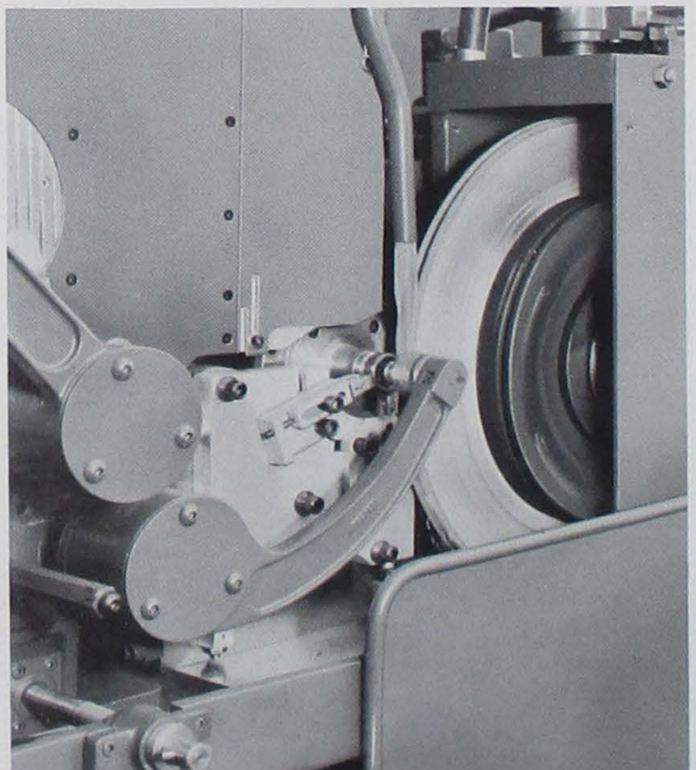
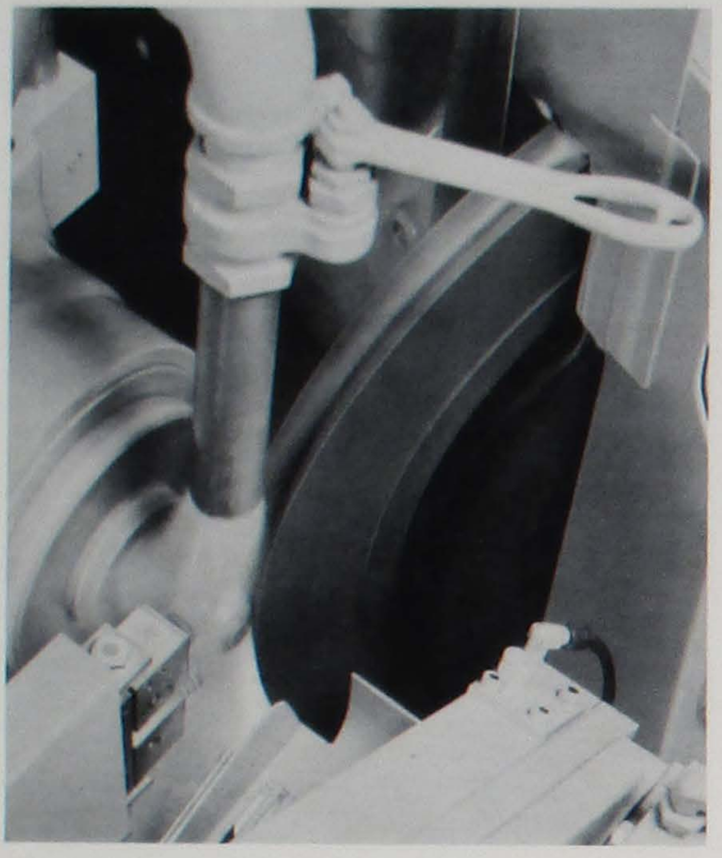
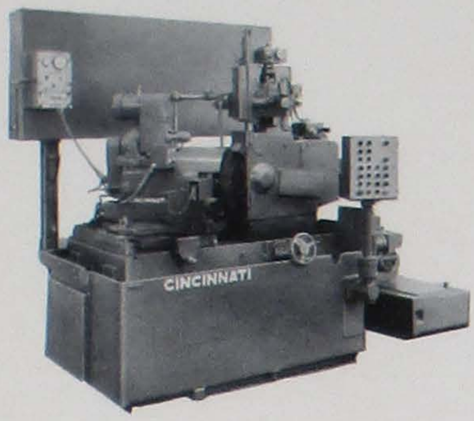


Thrufeed centerless lapping a long steel bar on a CINCINNATI FILMATIC CENTERLESS LAPPING MACHINE.



Plunge grinding the ball track of an inner race on a CINCINNATI FILMATIC MICROCENTRIC GRINDING MACHINE.





Plunge grinding the O. D. and angle of a bevel gear on a CINCINNATI FILMATIC CHUCKING GRINDING MACHINE.

Plunge grinding the "Skirt" of an automotive piston on a CINCINNATI FILMATIC SPECIAL GRINDING MACHINE.

GRINDING MACHINE DIVISION / THE CINCINNATI MILLING MACHINE CO.

CINCINNATI, OHIO 45209 U.S.A.

plain universal roll centerless lapping micro-centric chucking specials

Products of the Grinding Machine Division of The Cincinnati Milling Machine Co. are listed and symbolized here.

Products of The Cincinnati Milling Machine Co.'s other divisions include a complete line of knee type and bed type milling machines, die sinking machines, cutter sharpening machines, optical projection grinding machines, electrical machining equipment, heating machines, metal forming machines, broaching machines, special machine tools and complete production lines, special machinery, numerical control systems, tracing systems, gaging systems, hydraulic motors, hydraulic and electro-hydraulic valves and components, cutting fluids and precision grinding wheels.

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