May 10, 1960 A. G. WINCHESTER ET AL 2,935,822

WORK FINISHING MACHINE

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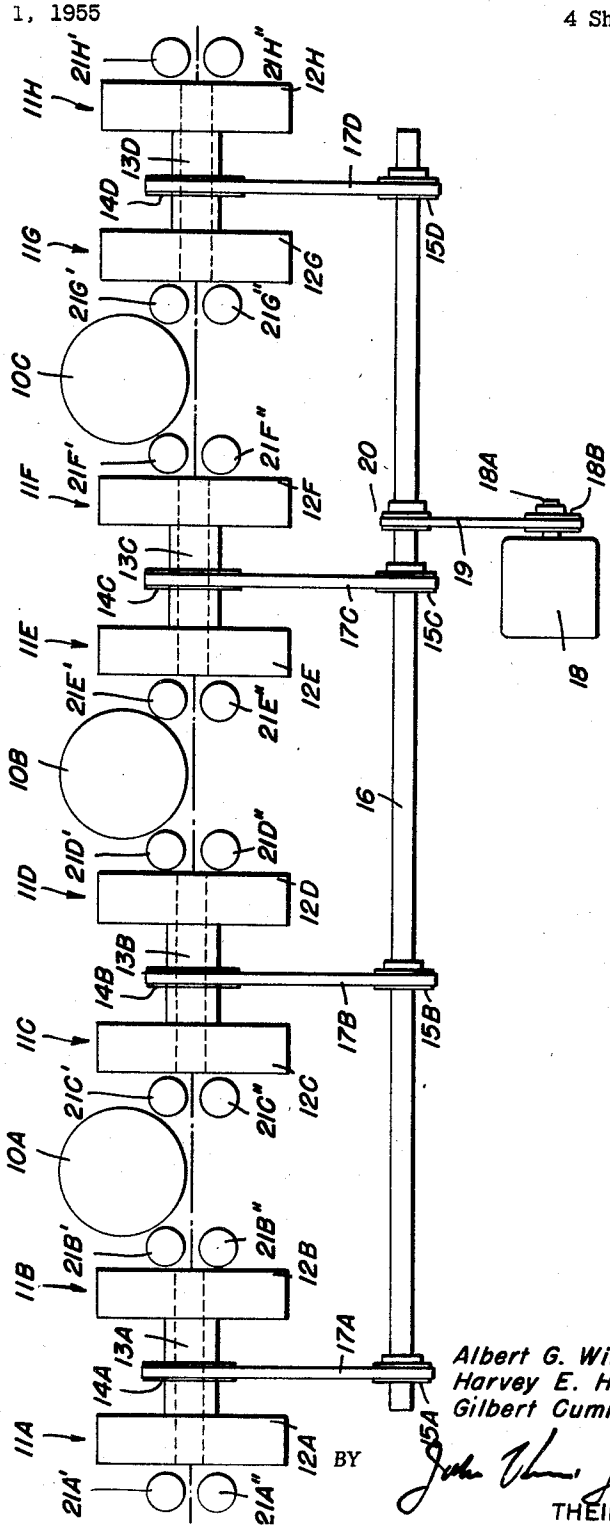


FIG. 1

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WORK FINISHING MACHINE

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FIG. 2

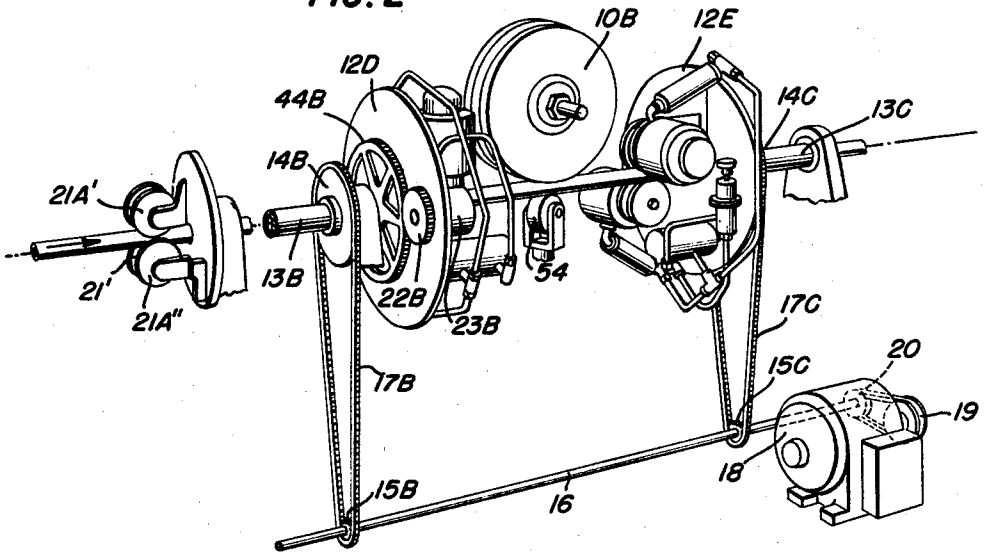
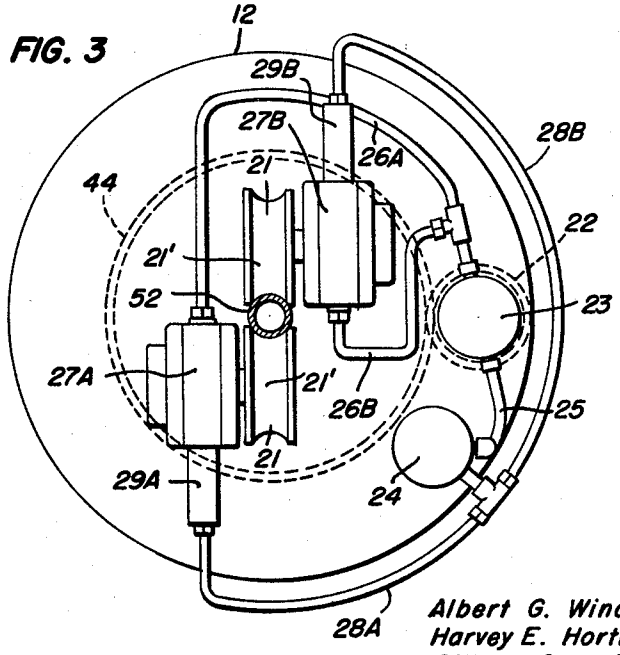


FIG. 3



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WORK FINISHING MACHINE

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FIG. 4

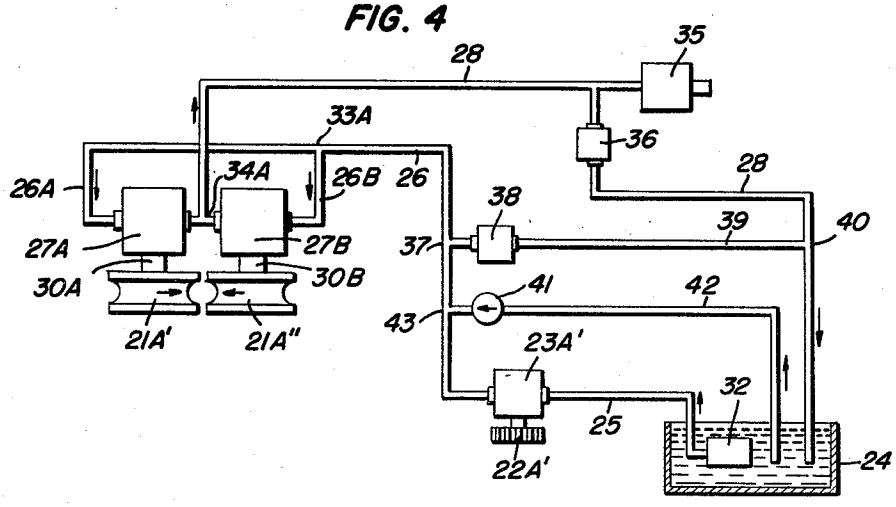
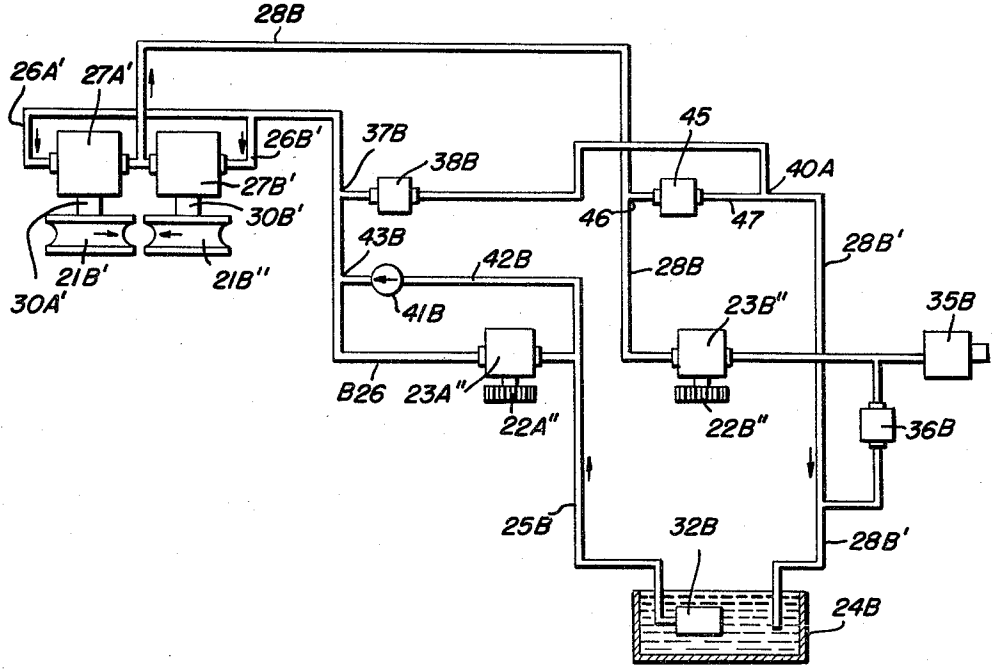


FIG. 5



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WORK FINISHING MACHINE

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FIG. 6

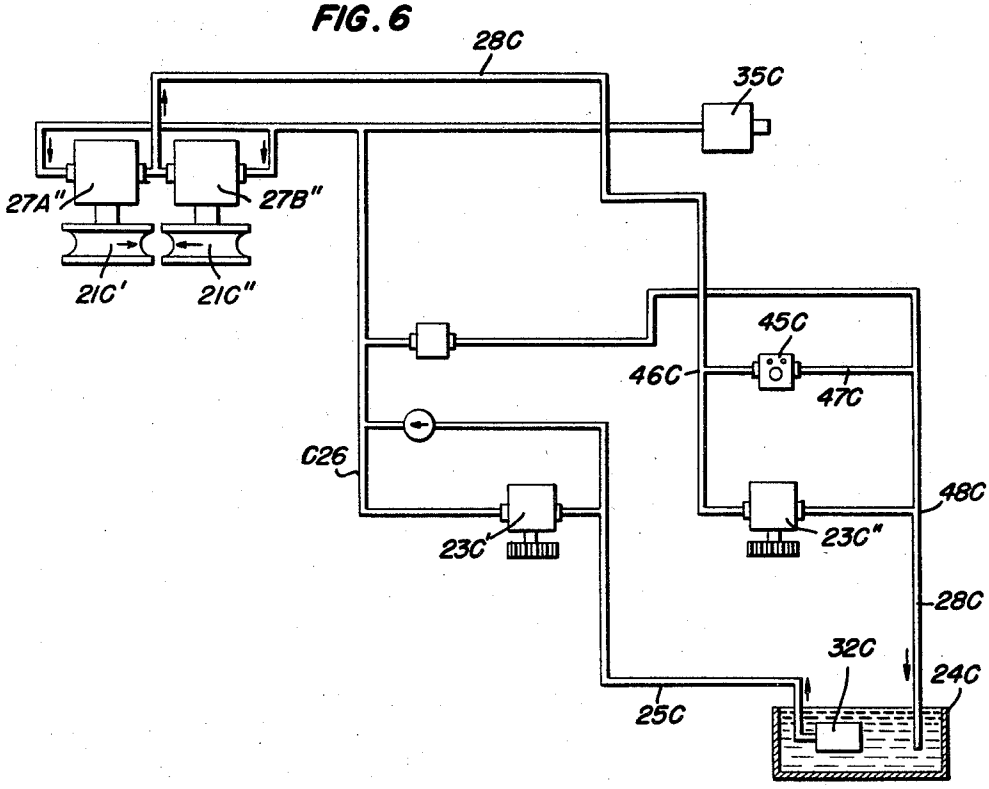


FIG. 7

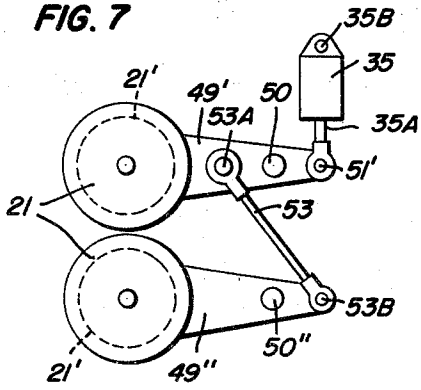
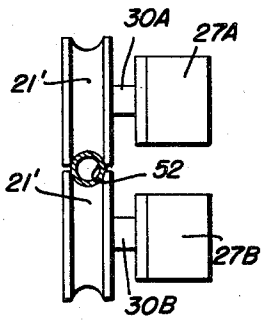


FIG. 8



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United States Patent Office 2,935,822 Patented May 10, 1960

2,935,822

WORK FINISHING MACHINE

Albert G. Winchester, Catonsville, Harvey E. Hortman, Jr., Elkridge, and Gilbert Cummins, Baltimore, Md., assignors to Buffing, Incorporated, a corporation of Maryland

Application July 1, 1955, Serial No. 519,458

15 Claims. (Cl. 51—79)

Our invention relates generally to finishing metals. More particularly, it concerns imparting a high finish, substantially free of all scratches and streaking, to tubing, rods, and the like formed of metal, plated surfaces, plastics or generally similar materials capable of receiving and retaining a high finish.

An object of our invention is to provide a machine which, itself is simple, rapid, certain and almost foolproof in operation, displaying long useful life and requiring only limited stand-by attendance, utilizes parts which similarly are simple in design and sturdy in construction, the entire assembly being low in cost both as regards initial outlay and as concerns maintenance during operation, which machine provides longitudinal grinding, sanding, polishing or buffing of tubing and generally similar fabricated or molded articles in manner which is precise and low in cost, giving rise to highly satisfactory results achieved almost entirely in the absence of detrimental streaking, such microscopic buffing lines as do appear extending lengthwise of the work product, whereby beams of undesired reflected light are suppressed in large measure.

Another object is to provide a machine of the general type described in which high polish is rapidly imparted in certain and direct manner to the work product, all in the substantial absence of scratch-line reflection, barber-pole striping or spiral lines within the polish.

All the foregoing as well as many other highly practical objects and advantages attend the practice of our invention, which in part will be obvious and in part more fully pointed out hereinafter during the course of the following disclosure, particularly when construed in the light of the accompanying drawings.

Accordingly our invention may be considered as residing in the several component parts, elements, mechanisms and features of construction, in the several sub-combinations and interrelations therebetween, and in the combination of each of the same with one or more of the others, the scope of the application of all of which is more full set forth in the claims at the end of this specification.

In the several views of the drawings wherein we have disclosed, illustratively, one embodiment of our invention which we prefer at present,

Fig. 1 is a schematic side elevation depicting a machine constructed in accordance with our invention;

Fig. 2 is a perspective view, skeletonized and fragmentary, disclosing certain essential features of our new machine;

Fig. 3 is a detailed elevation of the motor side of the rotatable head at one of the drive stations;

Fig. 4 is a fluid circuit diagram disclosing a first drive unit providing rapid initial drive to the work product, typically tubing, and to which a high degree of finish is to be imparted, to bring it rapidly into work position in the region of the first buffing station;

Fig. 5 discloses, in diagram, a hydraulic circuit for the second drive unit, which latter slows the initial advance of the tube, imparted by the high-speed, low-torque first drive unit, until the advance speed of the tube is reduced to a value consistent with the desired relationship of advance speed to peripheral speed.

Fig. 6 discloses, in hydraulic circuit diagram, a typical example of all subsequent drive units of the machine, these in reality comprising braking units and serving both to brake the tubing as it passes through the machine under the driving impetus imparted thereto by the rotating buffing heads, and to control the linear speed of passage of such work stock through the machine; while

Figs. 7 and 8 respectively are fragmentary side and end elevations of details of the mounting of the tube rollers in each of the drive units of Fig. 1.

Throughout the several views of the drawings, like reference characters denote like structural parts.

For more ready and thorough understanding of our invention it may be noted at this point that in recent years consumer preference has strongly favored highly-polished metal products. And this, in a wide variety of ornamental uses confined not alone to the household but as well extending to widespread commercial and industrial applications. Typical among these, are bathroom and kitchen fixtures, soda fountain and architectural trim, stainless steel and chromium-plated legs of chairs, tables, ironing boards and the like. Moreover, such requirements are strongly reflected where highly sterile and antiseptic conditions must maintain, as in the operating theater. In common in all these is the presence of highly-polished metal surfaces. The more highly polished be the product, the greater is its acceptability to the user.

And high polish of course means the almost total absence of detrimental scratch lines. From a practical standpoint, therefore, a high degree of care in the polishing process is indicated. The polishing operation must be rapid and certain. Simplicity, not only in apparatus but in operation and quality and quantity of labor required, is essential to render the polishing operation practical and competitive. For it is apparent that any notable complexity, delicacy or uncertainty of operation is at once accompanied by rapid build-up in production cost and in price tag of the fabricated product. The inevitable result would be that both the operation and the product would become too expensive, noncompetitive and impractical. Moreover, it is apparent that to be acceptable, the buffing machine itself must impart no undesired qualities to the work product. Too, for practical results, the polishing machine must be readily adapted to the treatment of a wide variety of lengths and diameters of work stock.

Now, the art has directed much attention to this polishing problem. Acid treatment and electrolytic polishing techniques have found some favor. In many applications however such treatment has been replaced by buffing operations. But right here difficulties, severe and important in nature, have been encountered. For no matter how carefully the polishing be carried into practice, some scratching of the surface is almost certain to be imparted by the buffing operation itself.

We have found that at least one cause of unsatisfactory mechanical buffing is the creation of laterally-extending scratch lines during the course of buffing crosswise of the work stock. For we find that when light is incident upon and reflected from these laterally extending lines, such reflected light fully discloses these fine cross scratches. These are disturbing to the eye since they interrupt the continuity of the reflected light beam. They impart discontinuous pattern and disturb the pleasing appearance of smoothness of the polished and buffed surface of the tubing or other work stock.

We have found that quite on the contrary, when the buffing operation is performed lengthwise of the work

stock then any light which is incident upon the latter is not nearly so likely to be reflected from minute longitudinal scratch lines which the buffing operation may occasion nor to disclose these latter. This phenomenon is especially important in the production of the highly polished metal products for which our machine is especially intended. We have evolved our present finishing machine to utilize and take advantage of that phenomenon.

Our investigations further disclose, however, that even when resort is made to longitudinal buffing, problems arise which are inherent in such operation. Illustratively, with longitudinal buffing streaking quite likely will be encountered. Or spiral lines may be observed, these within the polish itself. Research disclosed that such incomplete polishing perhaps is due to rotation of the work product at too low a rate during its passage through the buffing station, while rotation at too high a rate caused spiral lines within the polish itself. Our research discloses, however, that with nice selection of the rate of lateral rotation of the work product such as tubing, rods or the like, about the longitudinal axis of the latter during its longitudinal feed through the buffing machine, and closely correlated with the rate of feed through the machine, highly satisfactory operation resulted. The relation appears to be critical.

An important object of our invention, therefore, comprises the provision of a finishing machine which, through a longitudinal finishing operation, imparts a desired surface to a variety of types and dimensions of metal tubing, rods and the like, all in the substantial absence of objectionable scratching or longitudinal or spiral streaking or lines within the finish, which machine finishes uniformly the entire extent of the work product, all with high unit productivity, certainty of operation and with minimum of rejects, combining basic simplicity both in the machine itself and the mode of operating it with low cost in initial production, attendance, supervision and maintenance.

So that the detailed explanation of the parts of our machine in connection with the several views of the drawings may be more thoroughly understood it should be noted that, in general, this machine comprises an elongated frame of required substantial length, typically about 12 feet. In this frame are provided a number of finishing stations. Structurally these stations are each largely independent of each other and of the other components of the machine. They have in common, however, that each station comprises a grinding, sanding or buffing wheel rotatable at extremely high speeds, say 3000 revolutions per minute. They are so correlated that work product passing through the machine is subjected to a complete finishing operation.

Each surface finishing station comprises a separate powering machine of conventional satisfactory design, usually an electric motor. The wheel of each station will have a head of selected material. For example, to achieve a high final polish and employing three finishing stations, the finishing wheel of the first finishing station, which at first encounters the work product undergoing polishing, is clad with 120 grit. In this typical instance the wheel of the second finishing station is covered with 240 grit. While at the third station the polishing medium comprises a polishing cloth. Each finishing wheel is rotated in such direction that it impels the work product forwardly through the polishing machine, from the inlet end thereof towards its outlet end. The polishing wheel works against an anvil or rotatable back plate which is located beneath the work product as the latter passes under the finishing head. Typically this comprises a rotatable idler wheel. Where desired, however, and as an alternate embodiment, we employ like finishing wheels opposite each of the three noted, these serving to back up the wheels previously mentioned and aid in finishing the work, as well.

It is necessary to feed the work product into the machine and up to the region of the first finishing station. For until the work product is introduced to the first finishing station it is not yet subjected to the impelling action thereof. Accordingly, our machine comprises a first driving station as an essential component thereof. This first driving station imparts high speed, low-torque linear feed to the work product. This insures that each piece undergoing finishing is brought rapidly up, either to position where it comes into the zone of the first station, or into contact with that work element immediately ahead of it within the finishing machine.

It may be noted that the products undergoing surface finishing treatment have been prefabricated for the particular purpose for which they are intended, and are roughly finished to final dimensions. Thus, while each machine can be pre-set, prior to any run, for work product of any of a variety of external dimension, it is essential that this dimension be substantially the same for the work product undergoing finishing in any particular run. Moreover, each such element of the work product has a particular length determined by the fabricated assembly into which it is to be incorporated following the finishing operation. And with a product say 12 inches in length there will be about 12 such elements of work product within the machine at any one time after steady operating conditions have been established.

The high speed of the first station is to bring the work product rapidly and without delay up to the operating zone, while the low-torque requirement is to insure that the work product will not be forced through the machine after it either comes into contact with the work product immediately ahead of it in the machine or into the zone of the first finishing station, as the case may be.

A second drive station, disposed immediately beyond the first drive station in the direction of travel through the machine but before the first finishing station, operates at lower linear speed and with higher degree of torque. It serves to pull the work product at slower linear speed than does the first station, through the machine and up to the first finishing station. Also it serves to brake the speed of the work product, in controlled and regulated manner to that rate of speed, say 30 feet per minute, as is best suited for introducing the work product into the first finishing zone. This is in contrast with the linear feed of say 50 feet per minute imparted by the first driving station.

The finishing wheel of the first station and as well, of all subsequent finishing stations, tends to impel the work product forwardly at high linear rates of speed. And this tendency is effectively resisted by all subsequent driving stations, which in reality serve as high torque braking stations, effectively braking the speed of the linear advance back to the controlled and regulated speed of approximately 30 feet per minute. For reasons to be discussed, the relation between the finishing stations and the subsequent braking stations is such that the driving impetus imparted to the work product by the finishing wheels will not in itself overcome the retarding action of the subsequent braking stations. This means that it is the impelling impetus imparted at the first and second drive stations which forces the work product through the machine.

We find that when the work product is passed beneath the finishing stations in the manner just described and without more, detrimental streaking results. This is because a surface finish is imparted to the work product only along the region of contact with the buffing wheels. Streak lines result, extending sharply laterally across the surface. To achieve exact and uniform finish through the entire surface area of the circular-sectioned work product we rotate the work product relative to the finishing wheels. And we do this by so disposing the drive or support rolls which grip the work product as to rotate this latter during its linear passage through the machine. We find that a rotational speed about five times the rate

of linear advance is normally satisfactory, i.e., a rotational surface speed of about 150 feet per minute for a rate of advance of 30 feet per minute in case of tubing of 1½ inch outside diameter. Slower rotational speed, i.e., a lower ratio of rotational speed, gives rise to spiral streaking. And higher rotational speed results in spiral streaking within the polish. The relation between rotation and forward advance therefore is critical.

In furtherance of the foregoing we provide, at each driving station, a rotatable head. Each head is mounted for rotation from a common drive source and is driven at a constant rotational speed. The speed conveniently is the same for all such rotatable heads. A fixed gear is mounted on the frame at each station, concentric with the rotatable head. It serves as a sun gear. It has a fixed diameter for each drive station. Planet gears, each of fixed diameter, are provided, two on each rotatable head and meshing with the associated sun gear. The drive rolls for each driving station are mounted for carriage on the associated rotatable head.

It is the rotation of the driving head which imparts the revolving action to the associated drive rolls and causes turning of the work product during its linear advance through the machine. It is to be kept in mind that the rate of linear feed and the degree of torque may vary from drive station to drive station, in the manner hereinbefore pointed out. While the stationary gear is fixed as are the diameters of the planet gears at the same time, the rotatable head revolves at constant speed. To secure the required variations in speed in the rotation of the drive rolls, the tooth ratio between the stationary gear and the planet gears in each drive station is nicely selected.

We find it to be essential that no slippage occur between the grooved drive wheels at each drive station and the work product passing therebeneath. For if such slippage does take place, the finish of the work product becomes marred. It is for this reason that torque limitation is placed upon each drive station. To achieve the aforementioned pre-controlled drives we employ fluid means, powered from each rotatable head, for rotating the drive rolls. To this end we provide one or more rotatable pumps mounted on each rotatable head and powered from the related planet gears. As will be recalled these planet gears are powered by their revolving about the associated stationary gear as the rotatable head rotates about its axis. The pumps, supplied from a suitable reservoir through associated filters, serve to power fluid motors provided one for each drive roll. Exhaust fluid from these motors returns to the reservoir for renewed cycle.

With the foregoing general description in mind, reference now is made to the schematic diagram of Fig. 1 and the skeletonized view of Fig. 2. It can readily be seen that the work product undergoing surface finishing treatment, for example a tube, rod or the like, passes from the intake end of the machine, at the left in each view, to the right through the machine to the outlet or exit end, located to the extreme right in each view.

As stated, in all instances the work product must be suitable in section for finishing in this manner. It may, however, vary in length within wide limits. As well, it may vary appreciably in size, such as in diameter, from one series of work products to another. It may be comprised of stainless steel, chromium-plated material, or any other suitable material requiring finishing. It may be tubular, or it may comprise a rod. The particular material, diameter and other essential characteristics depend of course upon the precise use intended. Usually, it is nicely tailored for its particular purpose.

A machine of the general type shown in Figs. 1 and 2 has an overall length of some 12 feet or more. We provide a single frame which is common for all parts of our machine. Since such a frame is conventional in design, for clarity we omit the details thereof in the drawings.

In conventional manner we provide a number of surface finishing stations in the frame. Here we provide three such stations, indicated generally in Fig. 1 at **10A**, **10B** and **10C**. While we have shown three such stations, there is no important criticality as to the exact number of stations. This number may be more or less as required for the particular work undergoing finishing treatment. Conveniently, however, we have found three such stations to be satisfactory for most requirement. Usually, and as pointed out later herein, each station performs its characteristic function. In sum, these separate stations combine in effective manner to impart a high finish to the work product. This finish is complete, uniform and without streaking.

Each surface finishing station comprises a comparatively large-diameter, high-speed wheel fast on shaft geared to a heavy-duty driving motor. All this is conventional per se and is shown only schematically in Figs. 1 and 2. With its high rotational speed and its comparatively large diameter, the wheel rotates at a very high linear rate of speed, typically about 8,000 feet per minute. Usually the motors for driving the finishing stations **10A**, **10B** and **10C** are separate both from each other and from any other source of energy powering other components of the machine.

As fully disclosed in Fig. 1, support and driving stations are associated with each finishing station. These stations are indicated generally at **11A** through **11H**, respectively. And they will be discussed in greater detail hereinafter. It is also disclosed in Fig. 1 that at least to a certain extent stations **11A** and **11B** are associated with each other, as are stations **11C** and **11D**. This is true also of stations **11E** and **11F**, and of stations **11G** and **11H**. This will be discussed at a later point herein.

As perhaps best disclosed in Fig. 2 and as is also evident from Fig. 1, each driving station comprises a rotatable head of comparatively large diameter, say about 14 inches in diameter. As shown in Fig. 1 with particular reference to the second or **11B** driving station located just in advance of the first wheel **10A** (to the left in Fig. 1), rotatable head **12B**, is fast to a corresponding central tubular shaft **13A**. At its left end in Fig. 1 shaft **13A** is fast to a first rotatable head **12A**.

Similarly, rotatable support heads **12C** and **12D** (Fig. 1) are directly interconnected through central hollow shaft **13B**. In like manner, hollow shaft **13C** interconnects rotating heads **12E** and **12F**, while hollow shaft **13D** interconnects heads **12G** and **12H**. Thus each assembly of two adjacent rotatable heads and interconnect-hollow shaft rotate as a unit, and are powered from a common power source. We provide four such assemblies on the machine disclosed, and each assembly is driven at the same rotational speed from a single power source.

We provide driven sprockets **14A** through **14D**, one on each hollow shaft **13A** through **13D**, respectively. Corresponding drive sprockets **15A** through **15D** are carried on line shaft **16**, disposed near the bottom of the frame of the machine (Figs. 1 and 2). Chains **17A** through **17D** extend between like or paired sprockets **14A** through **14D** and **15A** through **15D**.

An electric motor **18** or other suitable power source turns line shaft **16**. To this end motor **18** has power take-off shaft **18A** on which is mounted a drive pulley **18B**. We mount power take-off sheave **20** on line shaft **16**. Belt **19** or other suitable power transmission extends between pulley **18B** and sheave **20**, serving to transmit power from motor **18** to line shaft **16**.

From the foregoing it will be seen that motor **18** operates at fixed rotational speed. Through drive shaft **18A** it rotates drive pulley **18B** at the same constant rotational speed. Since drive pulley **18B** powers belt **19**, while belt **19** rotates power take-off sheave **20** fast on line shaft

16, this latter also rotates at constant speed. So, too, do the driving sprockets 15A through 15D inclusive, which are fast on line shaft 16. These sprockets drive chains 17A through 17D, inclusive. Through the take-off sprockets 14A through 14D, respectively, these chains rotate the central tubular shafts 13A through 13D, respectively. These shafts, made tubular for the passage centrally therethrough of the work product in manner hereinafter to be explained, serve to power the support or driving stations of each associated assembly. As part of these stations the rotatable heads 12A through 12B turn therewith, at constant rotational speed.

Considering any one of the several support and driving stations 11A through 11H it will be seen that associated with each such driving station, and comprising part thereof, are paired support rolls for the work product. Indicated at 21A' and 21A" through 21H' and 21H", respectively, these support rolls are paired, one being disposed above and one below the work stock. Preferably, but not necessarily, we so dispose the support rolls on the related rotatable heads that the work product is gripped at various points about its circumference as it passes from one drive station to another. These rolls are grooved at 21', as best indicated in Fig. 2, for the ready reception of the work product within the rolls and for passage therethrough, all in the complete absence of slippage. For it is requisite that there be no slippage between the rolls and the work product, as more fully disclosed at a later point herein. To that end we form the rolls of soft rubber or other suitable product capable of gripping the work product tightly.

The rolls 21A'–21A" through 21H'–21H" are carried on the associated rotatable heads 12A–12H, respectively, and revolve therewith. Such revolution is about the axis of the associated tubular shafts indicated generally at 13A through 13D, and through which passes the work product. That is, the revolution of the rolls is about the work as an axis. In addition to such revolution, for proper operation these rolls rotate about their own axes to move the work forward through the machine with required controlled rate of speed. To that end, they are mounted for rotation in bearings of conventional type and carried on the corresponding rotatable head. Paired rolls rotatae in opposite directions, the top roll underrunning and the lower overrunning.

Directing attention now particularly to the skeletonized disclosure of Fig. 2 it will be seen here that we associate with and dispose alongside rotatable head 12D, a stationary ring or sun gear 44B about which revolves corresponding planet gear 22B. Like construction of stationary gear with cooperating planetary gear is employed in connection with all rotatable heads 12A through 12H. Their ultimate function is to power, in controlled manner, the rotatable rolls previously referred to.

As stated, the planet gears are mounted for rotation on their corresponding rotatable head. Each is attached to an associated hydraulic pump indicated generally at 23 in Fig. 3 and each is fast on the corresponding rotatable head. Preferably, for each drive station 11A through 11H there are two corresponding pump elements. For convenience in description, we indicate the hydraulic elements, i.e. the pumps, for each station by a corresponding lettered suffix. Illustratively, the hydraulic elements for station B are indicated at 23A", 23B", respectively (see Fig. 5).

It will be in order here to give further consideration to the details of the hydraulic system at each rotatable head. This is best disclosed in Fig. 3. There, hydraulic element 23 comprises a pump, fast to and driven by a pinion or planet gear 22 (see Fig. 4). This pump is conveniently mounted for rotation on associated rotatable head 12. As the planet gear 22 of the pump 23 revolves around and in mesh with stationary ring gear 44, it is caused to rotate about its own axis, carrying with it for rotation, its associated hydraulic element 23. Typically, this hydraulic element 23 is of the well known Gerotor type, wherein two asymmetrically-toothed elements are constantly intermeshed and rotate one within the other, thereby producing constantly varying compression components on the fluid medium present therein. Oil or other hydraulic activating fluid is drawn into pump 23 through intake oil line 25, from a suitable reservoir 24 fast on head 12 and revolving therewith.

From pump 23 the activating fluid is pressure-forced through supply lines 26A and 26B to fluid motors 27A and 27B, respectively. These latter, fast on the rotatable head 12 for turning therewith, typically are generally similar to pump 23, differing therefrom largely in that they are connected in circuit so as to operate as motors. Thus, they have fluid power inlet and mechanical power takeoff. They power the support and drive rolls 21 (Fig. 3). From motor 27A and 27B the spent fluid returns through exhaust lines 28A and 28B and corresponding filters 29A and 29B to reservoir 24 (Fig. 3). Thence, a continuous supply of oil is recirculated through renewed cycle to pump 23 through inlet or suction line 25.

By way of further background, it is to be noted that the various drive stations A, B, C, etc., impart controlled driving impetus to the work product during its passage through the machine. These drive stations operate closely correlated with the impelling action imparted to the work at the several finishing stations. It follows that certain of the drive stations are inclined to operate at speeds and under torque conditions differing from those at other drive stations.

Thus, as risk of being repetitive, but for both illustration and emphasis, we design first drive station A to feed the work product coming into the machine at substantial linear speed under low torque conditions, say 50 feet per minute. This brings the work product to the region of initial surface finishing as quickly as possible. If there be no other work product already in the machine, first drive station A brings the work product rapidly to the second drive station B, where its speed and torque is conditioned closely to that required for proper initial finishing operation. If the work product is already in the machine, however, interposed somewhere between the first station 11A and the first drive station 10A, then this latter brings the work product rapidly into abutting contact with the rear end of that element of work product immediately ahead of it in the finishing machine. It is there slowed to the speed of steady flow through the machine, all at required speed for good surface finishing, say 30 feet per minute. And it is here that the low torque characteristics of the first drive station are advantageously displayed. For it does not tend to force the work product through the machine against the retarding action of the subsequent high-torque drive stations at B, C, D, etc.

From the foregoing it will be seen that second drive station B serves to slow to some extent the initial high linear speed imparted to the work product at drive station A and to correlate it properly with the rotational speed of the finishing wheel at the first station A.

The wheel at station A is capable of rotation at high rotational speeds, say 8,000 ft. per minute. It contacts against and brushes the work product in such direction as to tend to impel it forwardly through the machine. We have found that with a surface speed of about 8,000 feet per minute, forward advance of the work product at about 30 feet per minute gives rise to satisfactory finishing conditions.

Since station A and all subsequent finishing stations tend to impart substantial speed to the work product, all subsequent drive stations C, D, E, etc., operate as controlled retarders, braking the speed of the work product to required linear progress through the machine. We defer further discussion of the finishing stations to a later point herein. Mention is here made of the finishing stations, only to disclose their place in the machine.

All drive stations serve to rotate the work product in order to suppress tendency towards streaking in the polish. As stated, we accomplish this by revolving the drive rolls of each driving station along with the associated rotatable head. At this point it should be recalled that the central tubular shafts 13A through D which interconnect the associated drive stations into four unitary assemblies, all rotate at fixed and constant speed which is the same for each shaft. Each such assembly comprises the rotatable heads of two adjacent drive stations together with the aforesaid interconnecting tubular shaft 13A through 13D. The working faces of related rotatable heads of any such drive assembly are directed away from each other. Hence they rotate in opposite directions, carrying with them their related support rolls and associated hydraulic equipment.

With reference now to the detailed Fig. 2 disclosure and recalling that each rotatable head (12D and 12E in Fig. 2) rotates at the same fixed angular speed along with tubular shaft (13B and 13C in Fig. 2) which carries it and through which passes the work product, it is readily appreciated that since the support rolls 21 are carried on the related rotatable head in suitable mounts, they are constrained to revolve along with the rotation of head 12, and about the same central axis. This axis is located internally of the support rolls.

As seen in the several views of the drawings the rubber support rolls 21 are grooved at 21' so as to receive the work product nicely between cooperating paired rolls. The radius on which these groves 21' are struck bears close relationship to the diameter of the work product. This is required to provide tight gripping contact of the rolls about the work. For it is essential, for satisfactory results, that all relative movement between the work and the support rolls be effectively suppressed; that is, there must be no slippage. Any such slippage as might occur conduces to detrimental blemishes in the polished surface of the work product. As well, indeterminent variants can well be introduced through such slippage, in the mathematical relationship existing between the component parts of the machine. These strong reasons require that the support rolls 21 grip the work firmly. The good geometry of the rolls and the resilient character of the rubber from which they are formed cooperate to ensure required good gripping action.

Since support rolls 21 revolve with the corresponding rotatable head 12 on which they are mounted, they rotate the work product as themselves, they are revolved. At a later point herein further description will be given concerning the precise manner in which the support rolls are pre-loaded against and about the work product. It is sufficient to recall here that typically, and with work product of, say 1½ inch outside diameter to be polished, for example, we find a rotational speed about five times that of the inner feed to give satisfactory polishing results, using speeds at buffing heads of about 8,000 feet per minute. That is, in such typical instance we rotate the work product at a surface rate of 150 feet per minute with forward feed at about 30 feet per minute.

From the foregoing it is evident that rolls 21 exert two-fold action on the work product. Firstly and through their revolution about the work product, they rotate this latter at predetermined rotational speed. Secondly as each roll 21 rotates about its own axis, the rolls of each pair rotating in directions opposite to each other, they grip, support and feed the work product therebetween. Such rotation is due to the impelling action of the associated fluid motors 27A, 27B. This rotation of the rolls 21 about their own axes imparts to the work product either forward driving impetus or braking action, as the case may be. Thus the speed of revolution of the driving rolls about the work product as an axis is fixed while their rotational speed, about their own axes, varies from station to station in dependence upon the gear ratio between the particular assembly of stationary gear and associated planet gears at any selected driving station.

It follows from the foregoing that we preferably employ three basic types of drive stations in our machine. First station 11A serves only to impart initial drive impetus to the work stock and to bring it rapidly into position to be presented under the first finishing station 10A, all as referred to hereinbefore. To this end, drive station 11A moves the work stock rapidly, thereby insuring both rapid initial operation of the machine and thereafter, steady flow of work product into the machine after normal operating conditions have established.

As has been stated before second drive stations 11B, in contrast with station 11A, provided station-impelled movement of the work product along with careful control of its rate of movement along the assembly line. This rate of flow is closely correlated to the speed of the initial finishing station 10A.

Further consideration of all the foregoing will show that generally speaking, first drive station 11A provides for judicious combination of high speed with low torque. On the other hand second drive station 11B provides controlled speed with torque potential substantially greater than that at station 11A. Thereby and when required, station 11B is capable of exerting braking action on the work product.

All subsequent drive stations 11C, 11D, etc., are located following the first finishing station in the direction of movement of the work product through the polishing machine. Each subsequent drive station possesses like structural and operating characteristics. It will be sufficient in the following disclosure to discuss but a single one of the stations of this third category.

With the foregoing generalized description in mind, there remains for discussion the details of the surface finishing stations, the detailed manner in which the support rolls are mounted on the rotatable head and are pressed against the work product, and a detailed description of the fluid circuits employed in each drive station together with their mode of operation. Attention will first be directed to the several drive stations, and the first such detailed description will relate to the initial drive station 11A. It will be recalled that there is only one such station.

The first drive station serves only for initial feed of the work stock

First drive station 11A serves only to impart high speed linear feed to the work product to quickly bring it up to the first finishing station. While for simplicity of construction the work product is rotated at the same rotational speed as is imparted to such product at all other drive stations in the machine, from an operational standpoint such rotation is not essential at this particular station. This is because the work product has not yet been subjected to the first finishing operation. All that is required at this first drive station is that the work product be brought rapidly through the inlet end of the machine up to the zone of the first surface finishing station. At this station, 11A, and as disclosed in Fig. 1, rotatable head 12A carries thereon its associated fluid motors 27A and 27B, both disclosed in Fig. 4. These fluid motors cooperate to drive related support rolls 21A' and 21A". While these motors are driven through motor shafts 30A and 30B at the same rotational speed, they are turned in opposite directions. The directions of rotation of these drive rolls is so selected as to cause linear feed of the work product (see Fig. 4) at right angles to and beyond the plane of the paper; that is, the feed is forwardly through the polishing machine. At the same time, the rotatable head 12A is rotated in such direction as to revolve the rolls 21A' and 21A", at right angles to the plane of the paper (Fig. 4) about the center of the work product as an axis. This imparts rotation to the work product during its advance through

the machine. The geometry is such that the work product has surface rotational speed five times that of its linear advance.

Pump 23A' is carried on the rotatable head 12A. Its corresponding planet gear 22A' meshes with stationary ring gear 44. And as the planet gear revolves about gear 44 it is thereby caused to rotate about the axis of its associated pump, carrying with it the pump itself. Pump 23A', thus powered, vacuum-draws oil or other motivating fluid from reservoir 24 through suction line 25 and strainer 32.

While each drive station has its own reservoir 24, there is no requirement that these reservoirs each have the same capacity. Preferably, the reservoirs are nicely tailored to the required content at each driving station.

Through power line 26 (Fig. 4) the oil or other fluid is pumped to junction 33A. Part of the fluid thence passes through oil line 26B and power motor 27B. Part of the oil continues through line 26A to motor 27A, thereby powering the latter. Junction 34A connects the exhaust lines from the two motors. From junction 34A the spent oil traverses return line 28 to reservoir 24.

It has been suggested hereinbefore, as we will disclose in greater detail hereinafter, that the feed rolls are preloaded against the tube stock with predetermined fixed loading. This, we disclosed, is required to prevent slippage between feed rolls and work product. To enable such pre-loading we provide, in return line 28, a hydraulic cylinder 35 which occasions this preloading. As an adjunct of cylinder 35 we include an adjustable relief valve 36 (Fig. 4). By adjustment of valve 36 we accurately fix the amount of pre-load. Details of the mechanical construction of this pre-loading assembly will be set forth in connection with description of the disclosure of Figs. 7 and 8.

As to first drive station 11A, it must be recalled that planet gear 22A' bears such ratio to the corresponding stationary gear that it imparts comparatively high rotational speed to corresponding drive rolls 21A' and 21A''. And as has also been stated, this insures that work product is brought rapidly to first finishing station 10A. For proper operation, however, the advance of this work product is instantly slowed as soon as it reaches initial work position, within the zone of influence of the first surface finishing station. There, it is readied for passage under the first finishing wheel. Thus, from supply line 26 extending between pump 23 and the motors 27A and 27B, and at junction 37 we shunt off excess energizing oil to a release valve 38 which is series-connected in supply line 39. This supply line then passes to junction 40 where it rejoins the return line 28. In effect, then, the valve 38 serves as a torque-limiting and relief means.

Better to understand the operation of relief valve 38, consider that pump 23A provides to the two motors 27A and 27B and through supply line 26, a quantity of oil sufficient to cause these motors to operate at high rate of speed under low-load conditions. That is, these motors rotate associated feed rolls rapidly to bring the work product quickly up to the zone of influence of the first surface finishing station. And while the motors are so operating, all energizing oil from the pump 23A is channeled through these motors, returning directly through line 28 to reservoir 24.

When the work reaches the first surface finishing station 10A, however, or comes against that element of work product which is immediately ahead of it in the machine, say in advance of or at the second drive station 11B, this piece of work thereupon encounters resistance to further advance through the machine as its initial high speed. Accordingly, when this condition develops, the force exerted by pump 23A is in excess of the requirements of its corresponding motors 27A and 27B, and this excess must be bled off before it reaches the motors. We establish this relationship to insure that the particular work piece which is momentarily under the influence of drive station 10A will not jam the advance element, ahead of it, through the machine. In other words we provide for bleeding excess energizing fluid at the roll-operating motors at the first drive station. To that end we channel such excess fluid through check valve 38, pre-set to determine the maximum pressure exerted by supply fluid on motors 27A and 27B, i.e. the maximum torque which can be developed.

As a final refinement, we provide a check valve 41. This is shunted off the main feed line 26 at junction 43. We provide this check valve 41 in a shunt line 42 which is directly supplied from the reservoir 24, without passage through pump 23A. Check valve 41 permits operation of the fluid motors by hand, as for initial adjustment, preliminary set-up or the like. Without this construction we find that hydraulic line becomes locked at 23A. With shunt 42 provided, however, requisite oil from reservoir 24 is supplied through shunt line 42, past check valve 41 to junction 43, and thence through supply line 26 to the motors. Check valve 41 effectively prevents the passage of oil in a reverse direction from supply line 26 at all times that pump 23A is in operation.

It will be seen from the foregoing that at the first drive station 11A, disclosed in Fig. 4, the particular element of work product passing through this station is rotated at fixed speed by corresponding rotatable head 12A. And that the two motors 27A, 27B, carried on head 12A, are rotated at comparatively high speeds with fixed low maximum torque, required energy being supplied from the single pump 23A. Drive station 11A serves to bring the work product smartly up either to the first finishing station or into contact with that element of work product which is immediately ahead of it in the direction of advance through the machine. When either such condition is established the torque supplied to the motors from the pump at this first drive station is incapable of forcing the work product through the machine against the braking load exerted by the advance or subsequent drive stations.

As stated, in a typical installation of which that undergoing description is characteristic, the motors at the first drive station under low-load conditions will advance the work product at the rate of approximately 50 feet per minute until this latter is brought into the zone of influence of the first finishing station. There, and throughout all subsequent zones of the machine, rate of advance is typically reduced to about 30 feet per minute.

In other words, the first driving station is solely for bringing the work product to the first finishing station, so as to rapidly bring about initial finishing action. The first driving station operates at high driving speed until the work product passing therethrough for advance to the subsequent driving station encounters resistance to rapid passage due to the influence of the second drive station. It thereupon slows to the speed controlled by said second drive station, and excess drive fluid from pump 23A is by-passed through shunt valve 38, to the reservoir.

The second driving station receives and slows the work product to a speed correlated with that of the first surface finishing station. It provides for positive advance of the work along with control of the rate of advance

Drive station 11B is shown in Fig. 1 as disposed just to the left of the first surface finishing station 10A. Viewed in the direction of the advance of the work product through the machine, second driving station 11B is disposed just in advance of the first surface finishing station. That is, station 11B is disposed between first drive station 11A and first finishing station 10A. Its function is to feed the work product into the first surface finishing station 10A, but at reduced and controlled speed, say about 30 feet per minute in a typical instance. As at first drive station 11A, the corresponding rotatable head 12B rotates at constant rotational speed. This is the same, it will be recalled, for each drive station. Moreover, ring gear 44 is stationary at each station. At sta-

tion 11B provision is made for driving pump 23B' at a speed which is less than that of pump 23A at first drive station 11A. We bring about reduction in speed by increasing the ratio between the gear teeth of the planet gear 22A' and the corresponding stationary gear. It follows that motors 27A' and 27B' at station 11B are operated at lower rotational speeds.

With particular reference to Fig. 5 it will be seen that pump 23A'' pulls oil from reservoir 24B through strainer 32B up through intake line 25B to pump 23A''. The pump then forces the powering fluid through supply line B26 to the motors 27A' and 27B'. Returning, the spent fluid exhausts through outlet line 28B during travel to hydraulic element 23B''.

At this point in consideration of the second drive station it should be noted that physically the circuit thereof, together with its component parts, is substantially the same at second station 11B as at first station 11A. this with the exception of two important additions. One of these is the provision of the rate control or rotary-flow control unit 23B'' and its corresponding drive pinion or planet gear 22B'', along with relief valve 45 which is adjustable and is shunted across the unit 23B'' to serve as a limit for braking control or torque over-load. The other is in the period of adjustment. Where the check valve 41 permits oil to be shunted about pump 23A' from reservoir 24 of the first drive station, the second pump 23A'' is shunted in generally similar manner by opening the adjustable valve 45 which serves as a torque over-load limit relief element.

Just as in the Fig. 4 embodiment, where the oil to hydraulic unit 23B' is supplied from reservoir 24B through filter 32B, pressure developed in pump 23A'' is transmitted through supply line B26 to motors 27A' and 27B'. Relief valve 38B, shunted across the supply line B26, determines the maximum pressure transmitted from pump 23A'' to the motors. The pressure relief line including relief valve 38B joins return line 28B' at junction 40A and returns excess energizing fluid direct from pump 23A'' to reservoir 24B. This serves to limit the maximum pressure of fluid delivered to the motors and hence limits maximum torque development there.

Now, pump 23B'' disposed in the return line of the energizing motors, serves as a rate control for these fluid motors 27A' and 27B'. This we bring about by series-connecting the hydraulic element 23B'' in the main branch of the return line 28B between the motors and the reservoir. Now, to produce the required hydraulic action and hence desired tube speed under required torque control at this second station 11B, we impart to pump 23B' a work capacity greater than that required at the corresponding motors. That is, this pump is capable of pumping more oil than is required for desired tube speed. We so design hydraulic element 23B'', however, that it permits only the proper amount of oil to be delivered from the motors 27A' and 27B', to give the required tube speed at this station. To understand this it must be kept in mind that the motors at station 11B will rotate no faster than the operator permits the oil to flow from them.

Now, at station 11B the feed rolls have the dual function of firstly, feeding the tubing or other work product to the buffing station. The power required for this is low. After the leading end of the tube has passed under the surface finishing wheel, however, but before it enters the next driving station and before the trailing end of the work product has left the second driving station, these feed rolls also serve as a brake, to resist the intense pulling action imparted by the adjacent finishing wheel. Greater torque is required here.

Where braking takes place, however, this is achieved through the absorption of energy. We accomplish this by converting the hydraulic energy from the outlet end of the motors back into mechanical energy through hydraulic element 23B''. Thus it will be seen that the element 23B'' of second station 11B actually serves as a motor. The mechanical energy produced therein is imparted to its rotatable head 12B. This is achieved through its related planet gear 22B''. This rotates and thrusts against its related stationary gear 44B. The effect is that the planet gear thrusts against the rotatable head 12B. The overall effect of this action is to reduce the load on the electric motor 18 (Fig. 1) which powers the rotatable heads.

Consideration discloses the desirability of protecting the affected parts of our machine from the detrimental effect of employing either the wrong grinding, sanding or finishing wheel or, given a proper wheel, improperly loading it against the related work product, tending to produce excessive pull on the latter through the machine. For without such provision this would occasion pressure on the controlling hydraulic element 23B''. To avoid resulting damage from such a condition we relieve excess pressure through a relief valve 45. This valve is series-included in hydraulic line 47, shunted at 46 from main return line 28B and connected at junction 40A with return line for relief valve 38B (which limits power development from pump 23A''), and empties through branch return line 28B' to reservoir 24B.

Additionally, relief valve 45 serves to predetermine the braking effect of the motors by spilling off some of the spent fluid from these motors which otherwise would be returned through hydraulic element 23B''. Such excess fluid, if permitted to pass through hydraulic element 23B'', causes additional tendency to slow the speed of the motors, and hence of the rolls and the work stock. In short, relief valve 45 limits the braking effectiveness of the hydraulic element 23B''.

The third, and all subsequent driving stations, located after the first finishing station, serve only as a braking station. The first pump at these driving stations serves only to supercharge the motors

In the third embodiment of driving station, only controlled braking action takes place. All drive stations after the first two, and including stations 11C, 11D, 11E, 11F, 11G and 11H, respectively, are disposed following the first buffing station. After the work product comes under the influence of the surface finishing wheel at the first station all subsequent forward feed of the work product through the machine is accomplished by nice correlation of the energy imparted to the work product by the finishing wheels and that imparted by the second drive station. The so-called drive stations of this third group of stations in reality serve only as braking stations. Each station of this group differs largely from the second station in the omission of the relief valve 38 disposed between the first pump and the hydraulic motors to bypass excess fluid from the motors. This is not required in this third group of stations, where the motors themselves actually serve as pumps, and the first pump serves only to supercharge, supplying additional fluid to and supplementing the vacuum draw of these motors from the reservoir.

Structurally, all braking stations are much alike. Braking and motor control is the problem at these stations, rather than linear feed of the work product. The motors at these stations, 27A'' and 27B'', etc., actually serve as pumps, rather than as motors. They receive the mechanical work from the work product and translate this to pumping action to the second hydraulic element at each station, which now displays motor action. This action is brought about through the wheel of the related finishing station powering the work product passing therethrough. The product is passed through the related drive rolls of a subsequent drive station, which rolls are associated therewith in anti-slip fashion. These drive rolls power the associated motors. The motors, thus rotated, pull fluid from the reservoir 24C (see Fig. 6), through filter 32C, and line 25C to first hydraulic element 23C'. Thence the fluid passes through line C26 to the motors 27A'' and

27B", respectively. As the motors are rotated, actually as pumps, by their corresponding drive rolls 21C', 21C", respectively, they pull the fluid from the reservoir 24C and pump it through return line 28C. The motors are aided in this pumping action by pump 23C'. This pump serves solely as a supercharger to boost the amount of fluid which is supplied to the motors, and to insure that at all times, the supply of this fluid is sufficient to insure proper pumping action at the motors. And similarly, a check valve is provided for shunting the motor 23C' and drawing requisite oil directly from reservoir 24C to the motors 27A" and 27B" when setting up or adjusting these motors by hand.

It is apparent from the foregoing that at the third and all subsequent drive stations, where no work product is in the machine the motors of these stations, now serving as pumps, do not rotate, even though the corresponding rotatable head is being powered from line motor 18. This is because the first pump 23C of each such station is of such low power rating that it will not of itself, tend to rotate the hydraulic elements 27A" and 27B" as motors, its sole function being that of comparatively low-power supercharge.

The second drive station and all subsequent drive stations do have in common, however, that braking and rate control is provided, this through the provision of a second hydraulic element 23C". Hence the second hydraulic element 23C" is series-connected in hydraulic return line 28C just as in the second drive station embodiment. And this second hydraulic element spills its exhaust fluid through line 28C back to the reservoir 24C. Similarly relief valve 45C connected in line 47C which in turn is branched off return line 28C at 46C, rejoining the same at 48C, serves to limit the control action of hydraulic element 23C" by spilling excess fluid in return line 28C directly to the reservoir 24C.

From the foregoing it will be seen that theoretically, it is possible to dispense with first pump 23C' in this Fig. 6 embodiment. But we find that the supercharging action of this element gives rise to better performance than if these pumps were required to vacuum-draw energizing fluid directly from the supply reservoir. Moreover, the pump element 23C' serves to provide fluid required for properly energizing the hydraulic cylinder 35C which pre-loads the feed rolls of each related station against the corresponding work product passing therethrough.

Certain details of the finishing stations are best shown in Fig. 2

Each surface finishing wheel operates at substantially constant linear speed. Moreover, each rotates in a direction of movement of advance of the work product through the machine. To this end, and as illustrated, the wheels are undershot and operate counterclockwise in the drawings. These wheels bear heavily against the work product. Thus they tend to impart to the work product a component of high linear speed, in the direction of advance of the work product through the machine. The subsequent driving stations are required to retard this movement in controlled manner.

Consideration discloses the advantages attending rotation of the finishing heads counterclockwise, in the direction of movement of the work stock. For as stated, by so doing, the wheels not only finish the work, but impel it through the machine. The only other impelling action imparted to the work while in the machine is through the first and second drive stations 11A and 11B, both of which are located in advance of the first surface finishing station. No subsequent driving impulse is imparted to the work product, other than through the wheels themselves.

The drive stations following the first surface finishing station exert only a braking action, to slow the work product to proper linear advance through the machine. After the work comes through the first finishing station all subsequent driving impulse is imparted to the work product by the wheels alone. With this in mind it will be understood that should the wheels be rotated in the opposite direction, that is, clockwise, surface finishing of the work product against its direction of linear movement through the machine, would necessitate providing gripping heads to pull the work through the machine. Additionally, the finishing action would be both uncertain and scratchy.

Although as stated the number of surface finishing stations employed in our particular machine is not necessarily critical we prefer to employ three such stations. The finishing wheels typically will be different at each station as previously indicated. It is important to maintain control of the rate of feed of the work, whether or not the same be in the zone of influence of the finishing station. For should the work suddenly slip while under the wheel, detrimental marring would inevitably result.

At each surface finishing station a wheel is powered from any suitable means, usually an electric motor which drives only its related wheel, usually through step-up gearing. A back-up roll 54 serves as an anvil against which the wheel may work. It is set slightly askew or at a slight angle, the better to distribute wear on it. And it is disposed slightly on the advance side of the related wheel, viewed in the direction of feed through the machine, so that the drag of this take-up roll on the work product will be on the unpolished surface of the latter; that is, the surface which has not yet passed beneath the related wheel, rather than on the finished surface thereof.

The support rolls at each driving station are pre-loaded to determined extent against the related work product, and are linkage-mounted on the associated rotatable head

Frequent reference has been made here to pre-loading the drive rolls at each drive station against the work product. Such construction contributes appreciably to insure that all slippage is suppressed between rolls and work product. We find, however, that it is necessary to proper operation of the rolls that such pre-loading be limited in value to avoid the possibility of jamming and attendant detrimental results, either damage to the machine or marring of the work. Accordingly, we prefer not to mount the support rolls directly from the corresponding rotatable head. Rather, we provide a flexible mounting therebetween, through which the rolls are pre-loaded to determined and adjustable extent against the work. Illustratively, this comprises a spring-biased mounting.

In the embodiment illustrated we dispose the drive rolls 21' at each drive station A through H, respectively, on carrying links 49' and 49", respectively (Fig. 7). These links, here shown as bell cranks, are pivoted at 50' and 50", respectively, to the corresponding rotatable head. Link 49' is pivotally connected at its end remote from its related drive wheel 21', at 51', to the piston 35A of hydraulic cylinder 35. In suitable manner 35 is made fast at 35B to the related rotatable head 12. This cylinder is shown in the circuit diagrams in Figs. 4, 5 and 6. As the hydraulic system is energized, retracting piston 35A, the right end 51' of link 49' is drawn upwardly in Fig. 7. As the link 49' pivots about pivot point 50', support roll 21', is drawn downwardly on the work which passes therebetween (see 52 in Fig. 8).

The degree of pre-loading is controlled by the relief valve 36 for the cylinder 25, as typically shown in Fig. 4. Cross-linkage, comprising connecting shaft 53, interconnects link 49' with follower link 49". And this is achieved by pinning shaft 53 at 43A to link 49' at a selected point thereon intermediate drive roll 21' and pivot point 50'. The other end of shaft 53, remote from link 49' and adjacent follower link 49", is connected to the free end of this follower link 49", remote from its associated drive wheel 21", at 53B. The action brought

about through this connecting shaft 53 is such that when roll 21' is pre-loaded downwardly against the top surface of the work product 52, connecting shaft 53 is likewise forced downwardly and rocks follower link 49'' clockwise about pivot point 50''. This pre-loads the roll 21'' upwardly against the undersurface of the work product in direction and in amount exactly opposite to the underlying feed roll 21''. Controlled gripping of work product is brought about. One important and highly advantageous result attending pre-loading is that this firm contact between rolls and tubing is insured at all times despite any important wear which may occur during use.

The operation of our surface finishing machine will in large measure be clear from the foregoing description.

To bring the machine into operation, line motor 18 is started. And so too are the motors at the various buffing stations. The work product is introduced at the left or inlet end of the machine to the first drive station 11A. The work product is advanced through the machine at a comparatively high rate of speed, say 50 feet per minute, under conditions of low torque. Rotation is imparted at approximately 150 feet per minute. First drive station 11A therefore provides only for forward feed at high speeds and under low-torque conditions. The work product thus is brought rapidly into the machine.

At the second drive station, 11B, forward advance of the work is continued, but at reduced speed and under controlled higher torque conditions, say 30 feet per minute. This second drive station gives rise to both forward feed of the work product and regulated advance thereof. The speed is reduced to that most compatible with the rotational speed of the first surface finishing station to which the work is next to be subjected, as noted.

And at the second drive station, and all subsequent drive stations, the work product is rotated, similarly at linear speed of approximately 150 feet per minute, in a ratio of about five times that of the forward advance of the work product through the finishing stations of the machine.

As it comes from the second drive station 11B in the direction of advance through the machine, the work is subjected to the first surface finishing station 10A. Here initial polish or other surface finishing is imparted. It is carried across a back roll or rotatable anvil (like 54 for the wheel 10B of station B), and is held against the wheel.

From the first station 10A, the work is subjected to subsequent drive stations and buffing stations, in alternation. All forward advance of the work product is in large measure received from the surface finishing wheels after it has been subjected to the first finishing operation. And all subsequent drive stations serve simply to retard such forward feed in controlled manner. Additional and refined surface finishing is imparted to the work product at each subsequent station.

It will be recalled that structurally, paired rotatable heads 12 are joined together by a common shaft for powering from the line motor 18 while functionally, each such rotatable head is related to a separate drive station. Moreover, viewed from a functional standpoint each unit comprises a surface finishing station with a drive station, one disposed in advance of and one subsequent thereto, viewed in the direction of advance of the work through the machine. Now, the rotatable heads associated with and comprising part of each unit are mounted on separate drive shafts. Accordingly, and for proper operation, the various heads rotate in opposite directions, as required. In each drive assembly of two rotatable heads 12 and interconnecting drive shaft 13 the working faces of the two heads are disposed in opposite directions. With the heads rotated in the same direction the working face of one head rotates clockwise, while that of the other head turns counterclockwise.

Now, in the operation of our machine the surface condition of the tubing to be polished and the particular motor employed for the finishing heads in large measure determine the speed of the entire feed apparatus. The operator selects this on the basis of his experience. The ratio between turn and speed is in large measure fixed, however, regardless of the linear advance through the machine. To change this ratio means changing the gears on the rotatable driving heads. While from time to time this ratio may be changed from one type of work to another, this is not usually required. Thus, increase or decrease in the speed of the main line shaft correspondingly affects the speed of the entire apparatus including both speed of linear feed and, with fixed ratio, the speed of rotation of the work product.

Where desired, however, as a preliminary surfacing operation for example, the ratio of rotation speed to linear speed may be substantially increased, or substantially decreased. In this manner a cross-surfacing effect is achieved. And we contemplate a substantial increase of ratio in one surface finishing unit and a substantial decrease in the next, as in grinding or sanding operations to quickly remove surface material, followed by further finishing at proper ratio to give a fine ultimate finish.

While the number of surface finishing stations is in large measure determined upon the results to be achieved, an entirely different criterion controls the selection of the driving stations. Here the length of the tubing undergoing finishing is controlling. Where small or short pieces of tubing or the like are undergoing surface finishing, this condition interposes a problem. And a large number of driving and support stations is required.

As a final point, it should be noted that as the tail end of the work departs from each surface finishing station, and since the pick-up roll or rotatable anvil is disposed rearwardly of the wheel, this tail end of the work falls out of contact with the wheel. By consequence, the wheel does not tear into the hollow end of tubing undergoing finishing or the sharp edge of bar or rod stock.

Each piece of work is pushed through the machine by the next following piece. And after the first leaves the feed rolls at the first and second drive stations it stops. The brake rolls of the opposed head have this effect. And it is not overcome by the force of the wheel. Unless there are additional pieces fed into the machine, the work in the machine stops its advance until the supply is replenished at the inlet end of the machine.

It is apparent from the foregoing that our new machine is at once simple, sturdy and substantially foolproof in operation. High degree of surface finish is imparted in rapid and certain manner. Operation is predictable and requires minimum of supervision and attendance.

All the foregoing, as well as many other highly practical advantages attend the practice of our invention. It is apparent that once the broad aspects of our invention are disclosed, many embodiments thereof will readily occur to those skilled in the art, as well as many modifications of the embodiment here disclosed. Accordingly, we intend the foregoing disclosure to be construed as purely illustrative, and not as limitative.

We claim as our invention:

1. A work-finishing machine comprising in combination, a plurality of drive stations and a plurality of finishing stations, each finishing station providing a particular step in the finishing operation and each such step being correlated to produce desired end results, the first drive station in direction of advance of work product through the machine being disposed between the inlet end of the machine and the first finishing station and imparting high speed low-torque advance to the work product, the second such drive station, also disposed between the inlet end of said machine and the first finishing station, operating at reduced speed with increased torque to correlate the linear speed of work product with the surface speed of the first finishing station, all subsequent drive stations in direction of advance of work product through the machine, and following the first finishing station, serving to brake the

work product to advance through the machine at controlled rate against the impelling action of the finishing stations; and drive means for said drive stations for rotating the work product at selected rotational speed.

2. In a machine for finishing the surface of tubing or the like, comprising in combination, a drive station comprising a rotatable head; paired support rolls carried on said head for revolving about the axis thereof; a first means on said head and connected with said rolls for rotating the latter about their axes, the said rolls being capable of tightly gripping, in anti-slip manner, work product passing through the drive station; power means carried on said head for imparting controlled power to said first means; power-limitng means for slipping power delivered from said power means in excess of pre-set load limit for said first means; and means for rotating said head to impart energy thereto.

3. In a machine for finishing the surface of tubing or the like, comprising in combination, a drive station comprising a rotatable head; paired support rolls carried on said head for revolving about the axis thereof; a first means on said head and connected with said rolls for rotating the latter about their axes, the said rolls being capable of tightly gripping, in anti-slip manner, work product passing through the drive station; a stationary ring gear mounted adjacent to said rotatable head; power means carried on said head for imparting controlled power to said first means, said power means revolving about and meshing with said ring gear and receiving energy therefrom as said head is rotated; power-limiting means for slipping power delivered from said power means in excess of pre-set load limit for said first means; and means for rotating said head to impart energy thereto.

4. In a machine for finishing the surface of tubing or the like, comprising in combination, a drive station comprising a rotatable head; paired support rolls carried on said head for revolving about the axis thereof; a first means on said head and connected with said rolls for rotating the latter about their axes, the said rolls being capable of tightly gripping, in anti-slip manner, work product passing through the drive station; a stationary ring gear mounted adjacent to said rotatable head; power means carried on said head for imparting controlled power to said first means, said power means revolving about and meshing with said ring gear and receiving energy therefrom as said head is rotated, the gear ratio between said power means and said stationary ring gear being such that the support rolls are rotated at such rate that the speed of advance of the work product therethrough is one-fifth the surface speed at which said work product is rotated along with said rotatable head and said support rolls; power-limiting means for slipping power delivered from said power means in excess of pre-set load limit for said first means; and means for rotating said head to impart energy thereto.

5. A drive station for a machine for finishing the surface of a work product, comprising in combination, a rotatable head; means for rotating said head; a stationary ring gear associated and cooperating with said head; paired support rolls mounted on said head for carrying between them the work product advancing through such drive station; hydraulic pump means rotatably mounted on said head and geared to said ring gear, thereby receiving reaction energy from the ring gear as the head revolves; and hydraulic motors for rotating said support rolls, carried on said head and supplied from said hydraulic pump means.

6. A drive station for a machine for finishing the surface of a work product, comprising in combination, a rotatable head; means for rotating said head; a stationary ring gear associated and cooperating with said head; paired support rolls mounted on said head for carrying between them work product advancing through such drive station; hydraulic pump means rotatably mounted on said head and geared to said ring gear, thereby receiving reaction energy from the ring gear as the head revolves; hydraulic motors for rotating said support rolls, carried on said head and suplied from said hydraulic pump means; and torque-limiting by-pass means disposed between said hydraulic pump and said hydraulic motors for limiting the unit amount of energizing fluid delivered by the pump to said motors.

7. A drive station for a machine for finishing the surface of a work product, comprising in combination, paired support rolls capable of carrying and advancing the work product therebetween and mounted both for revolving about the work product as an axis and for rotating about their own axes; means for revolving said rolls; hydraulic motors for rotating said rolls; hydraulic pump means fluid-connected to said hydraulic motors for energizing the latter; a reservoir in circuit with both said hydraulic pump and said motors for supplying energizing fluid for the hydraulic elements; torque-limiting fluid by-pass means between said pump and motors for limiting the unit amount of energizing fluid delivered by the pump to said motors; and valved by-pass means directly connecting said motors to said reservoir and shunting said pump for facilitating hand-setting the support rolls.

8. A drive station for a machine for finishing the surface of a work product and comprising in combination, paired support rolls capable of carrying and advancing the work product therebetween and mounted both for revolving about the work product as an axis and for rotating about their own axes; a rotatable head carrying said rolls for revolution as it rotates; pre-loading means for carrying said rolls on said head and serving to pre-load the rolls against the work product; hydraulic motors for rotating said rolls; hydraulic pump means fluid-connected to said hydraulic motors for energizing the latter; a reservoir in circuit with both said hydraulic pump and said motors for supplying energizing fluid for the hydraulic elements; torque-limiting fluid by-pass means between said pump and motors for limiting the unit amount of energizing fluid delivered by the pump to said motors; valved by-pass means directly connecting said motors to said reservoir and shunting said pump for facilitating hand-setting the support rolls; and a pre-loading cylinder mounted on said rotatable head and disposed in fluid circuit somewhere in the hydraulic system between the outlet end of said pump and said reservoir and receiving energizing fluid for biasing said roll-pre-loading means against said rolls.

9. A drive station for a machine for finishing the surface of a work product and comprising in combination, paired support rolls capable of carrying and advancing the work product therebetween and mounted both for revolving about the work product as an axis and for rotating about their own axes; a rotatable head carrying said rolls for revolution as it rotates; pre-loading means for carrying said rolls on said head and serving to pre-load the rolls against the work product; hydraulic motors for rotating said rolls; hydraulic pump means fluid-connected to said hydraulic motors for energizing the latter; a reservoir in circuit with both said hydraulic pump and said motors for supplying energizing fluid for the hydraulic elements; torque-limiting fluid by-pass means between said pump and motors for limiting the unit amount of energizing fluid delivered by the pump to said motors; valved by-pass means directly connecting said motors to said reservoir and shunting said pump for facilitating hand-setting the support rolls; a pre-loading cylinder mounted on said rotatable head and disposed in fluid circuit somewhere in the hydraulic system between the outlet end of said pump and said reservoir and receiving energized fluid for biasing said roll-pre-loading means against said rolls; and adjustable valve-controlled by-pass means disposed in said fluid circuit, shunted about said pre-loading cylinder, and operably connecting with said reservoir, for limiting the extent to which said cylinder is energized.

10. In a machine for finishing the surface of metal tubing and the like, in combination, a drive station comprising a rotatable head; paired support rolls carried on said head for revolving about the axis thereof; a first means on said head and connected with said rolls for rotating the latter about their axes, the said rolls being capable of tightly gripping, in anti-slip manner, work product passing through the drive station; power means carried on said head for imparting controlled power to said first means; power-limiting means for slipping power delivered from said power means in excess of pre-set load limit for said first means; means for rotating said head to impart energy thereto; and means carried by said rotatable head for pre-loading the support rolls against the work product to selected and adjustable extent.

11. In a machine for finishing the surface of metal tubing and the like having a powering source and wherein work product is carried between cooperating support rolls disposed on opposite sides thereof and themselves carried from a common frame, and as part thereof; mechanism for pre-loading said rolls, the said mechanism comprising a carrier for each said roll, which carrier is pivotally mounted on and supported by said frame; means for biasing one said carrier in one direction, so as to force its related roll against the work product to determined pre-loading; and a cross-connector between said carriers for employing the energy from said powering means to pre-load the support roll of the other carrier against the work product in like amount but in direction opposite to that of the first-mentioned roll.

12. In a machine for finishing the surface of metal tubing and the like having a powering source wherein work product is carried between cooperating support rolls disposed on opposite sides thereof and themselves carried from a common frame, and as a part thereof, mechanism for pre-loading said rolls, the said mechanism comprising a carrying link for each said roll, and pivoted intermediate its length on and supported by said frame, said links comprising one power link and one idler link; hydraulic means operated from and by said powering source and connected with the free end of the power link for biasing the related roll against the work product to determined pre-loading; and a cross link interconnecting said carrying links for transmitting energy from said hydraulic cylinder through said power link, to pre-load the support roll of the idler link against the work product in like amount but in direction opposite to, that of the first-mentioned roll.

13. A drive station for a work-finishing machine comprising in combination, a rotatable head; means for rotating said head; a stationary ring gear associated and cooperating with said head; paired support rolls mounted on said head for carrying between them work product advancing through such drive station; a first and second hydraulic pump means rotatably mounted on said head and geared to said ring gear, thereby receiving reaction energy from the ring gear as the head revolves; hydraulic motors for rotating said support rolls, carried on said head and supplied from the first said hydraulic means; inlet means for introducing fluid from said first pump means to said motors; and outlet means for spilling spent hydraulic fluid from said motors, said second hydraulic pump means being connected in said return line, for limiting the flow of liquid through said return line and hence through said motors.

14. In a machine for finishing the surface of a work product, a drive assembly for advancing the work product therethrough to finishing stations also included in said machine, comprising paired rotatable drive heads; a hollow connecting shaft therebetween; the working faces of said heads facing outwardly, from opposite ends of said drive shaft; paired support rolls mounted concentrically on each head for revolving therewith and for supporting, advancing and rotating work product as it advances through said hollow shaft; and hydraulic means on each said rotatable head for rotating said support rolls about their own axes in controlled and torque-limiting manner, the said machine in which said drive assembly is included having means for rotating the drive heads of each such drive assembly.

15. In a machine for finishing the surface of an elongated cylindrical metal work product, a finishing assembly comprising a finishing wheel disposed substantially centrally of said assembly; related rotatable heads facing each other, at right angles to and one on each side of said wheel, said rotatable heads being empowered to rotate at the same speed; and generally like hydraulic means, and paired and grooved support rolls of resilient material on each said head, the support rolls gripping the work product and rotating it with rotation of the heads, the first said head, faced in direction of advance of the work product beneath the finishing wheel, serving to supply the work product beneath the wheel in continued and controlled feed, and the second such rotatable head cooperating with the wheel to retard the work product against the impelling action thereto by the finishing wheel itself, thereby to limit advance of the work product beyond the assembly at controlled retarded rate, the action of both said heads being achieved in part by the related hydraulic means powering the associated support rolls.

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