

March 31, 1936.

D. M. SUTHERLAND, JR

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FIBER REFINING AND REFINER

Filed Oct. 3, 1934

5 Sheets-Sheet 1

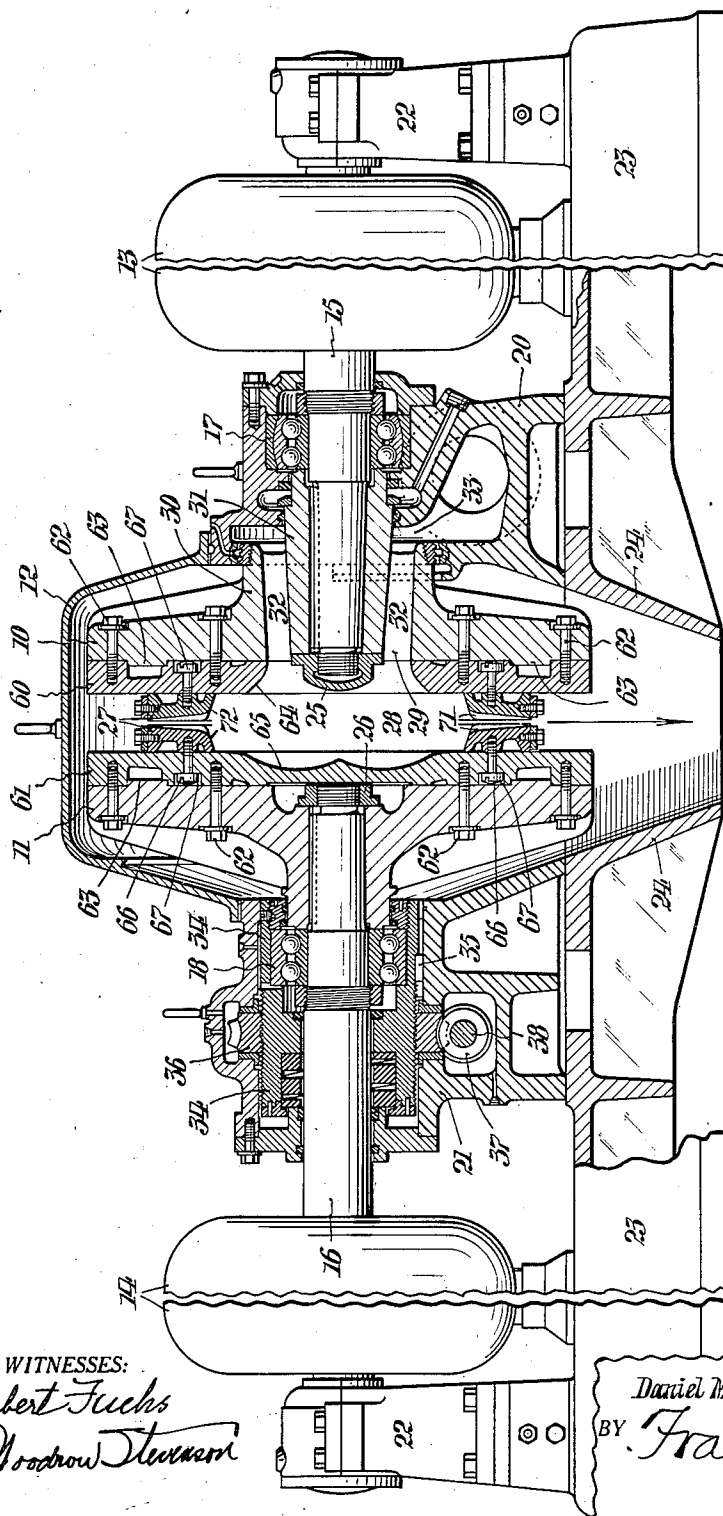


FIG. 1

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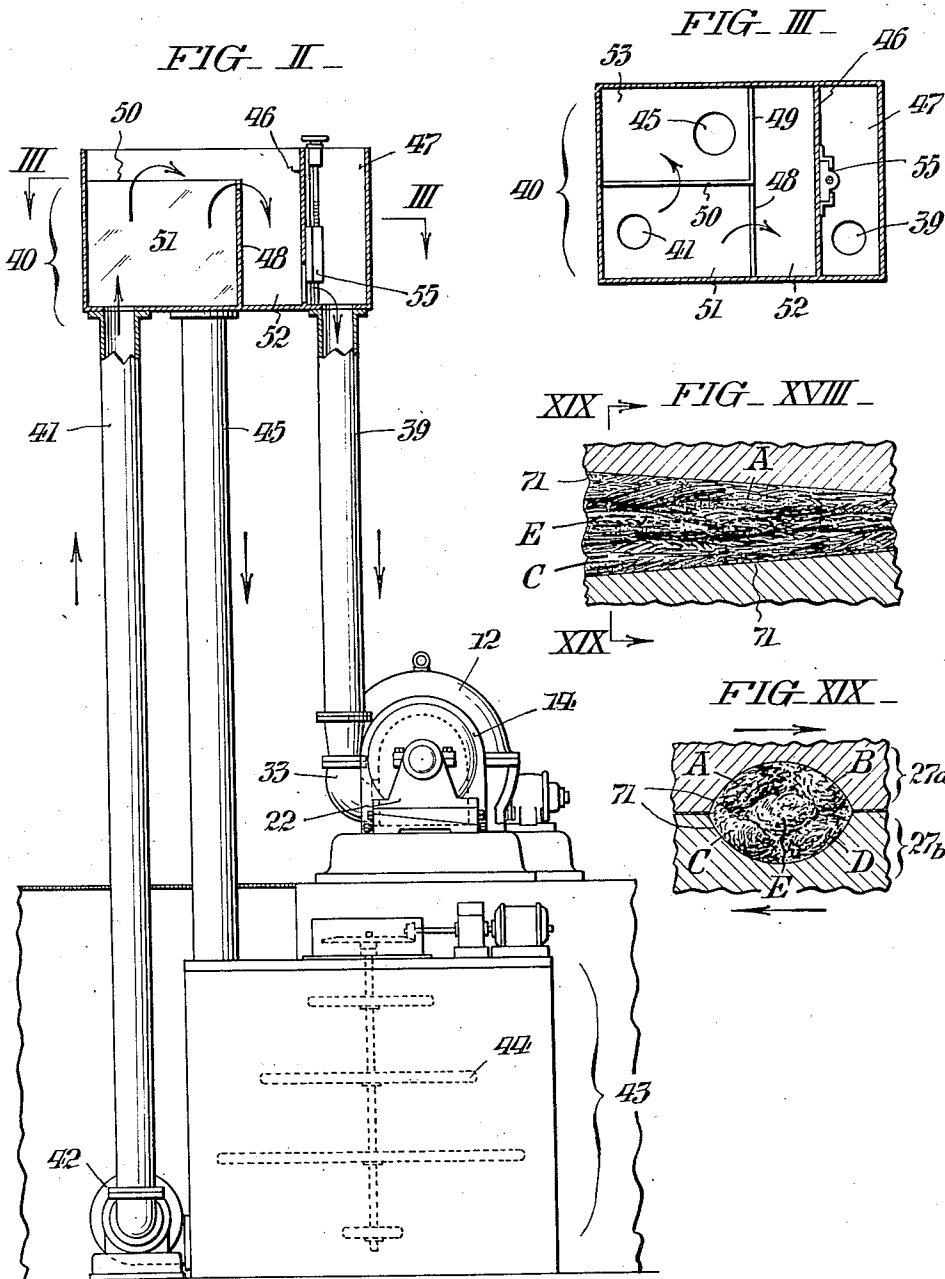
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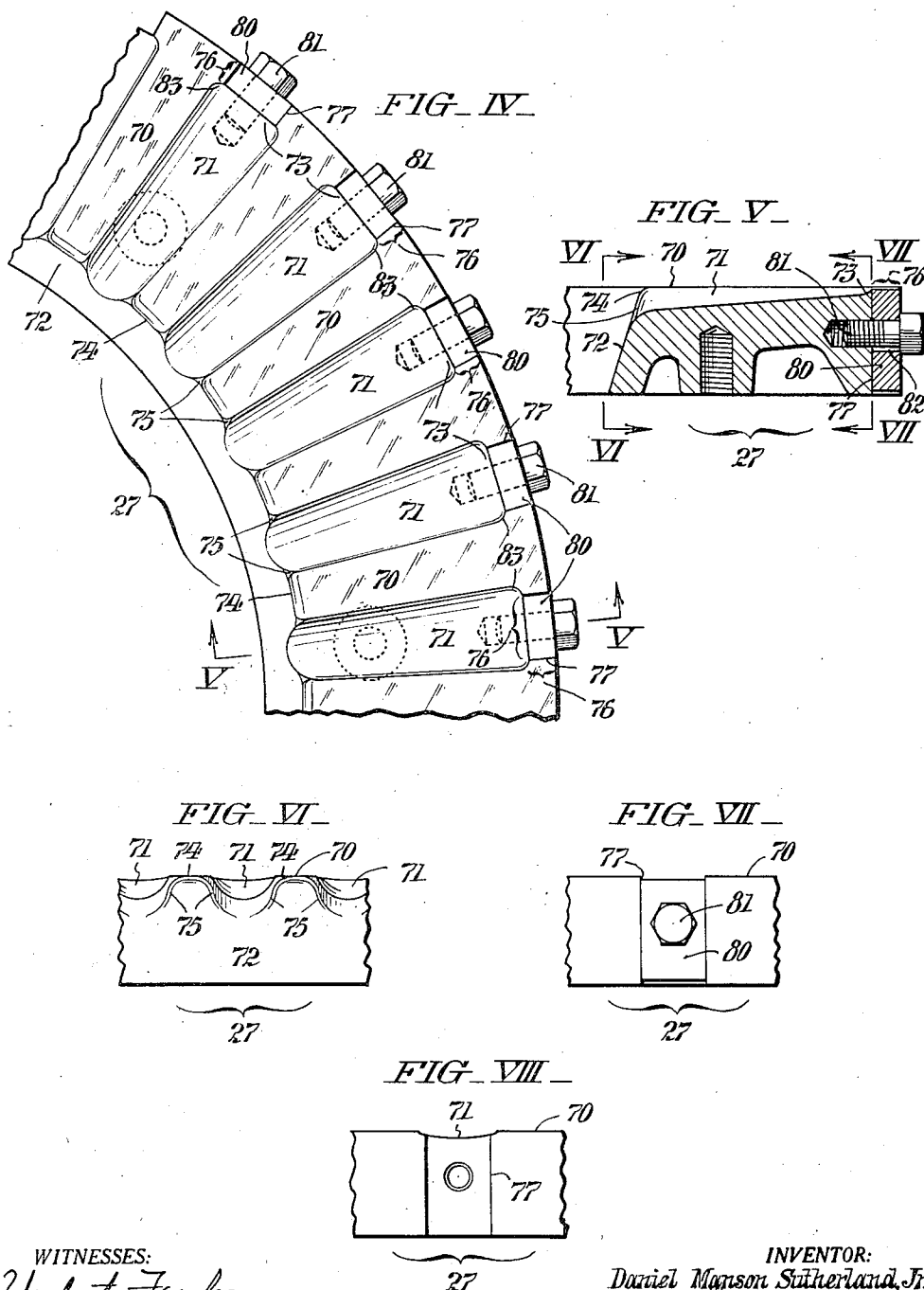
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5 Sheets-Sheet 3



UNITED STATES PATENT OFFICE

2,035,994

FIBER REFINING AND REFINER

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Application October 3, 1934, Serial No. 746,646

38 Claims. (Cl. 92—26)

My invention relates to the reduction and refining of fibrous materials, such as wood, leather, or cork, and especially to the treatment of "fiber pulp", consisting of fibrous particles in association with liquid, generally water. With sufficient water or the like, the aggregate or suspension itself behaves as a liquid, and can thus be more easily fed and handled. For wood pulps, it is generally satisfactory to use from three to six parts fiber and ninety-seven to ninety-four parts of water, although other proportions may be used, if preferred for any reason. Materials may be treated dry, provided they can in that condition be fed without clogging between the relatively moving refining surfaces or members by whose coaction the fiber particles are reduced.

The machines generally used, heretofore, for reducing and refining fiber pulp stock for paper or for fiber board are of two broad types, represented by "beaters" and "Jordans". They are used complementarily, for successive treatment of the same pulp stock, rather than alternatively. The "beater" has a rotor with a series of peripheral knives or bars separated by axially extending "gutters", and coacting with a stationary (segmental) bed-plate in the bottom of a tank containing the fiber pulp to be treated, which bed-plate may have similar "gutters". The "Jordan" has a conical shell in which revolves a conical core, and the fiber pulp flows in an axial direction through the conical pass between these mated members, which may have longitudinally extending bars separated by "gutters". The beater is used to draw and brush out fibers so as to maintain high tear strength in paper made from the refined product, while the Jordan is used to cut and shorten the fibers and close up the sheet, and also tends to reduce the freeness of the product. In both beaters and Jordans, only the plain "peripheral" surfaces of the beater bars and bed, or of the Jordan shell and plug,—and the corners of the gutters or any other openings in or amongst the parts,—are really effective in working or refining the fibrous material: i. e., the openings or gutters themselves serve only as clearances, or for the circulation of the pulp.

The beater operates on a batch basis, with a cycle of $\frac{1}{2}$ hour to 18 hours per batch, according to the kind of fibrous material used and the grade of paper to be made. Previously "beaten" stock is passed continuously through a Jordan, and usually only once,—although sometimes the resultant product is recirculated one or more times.

The use of beaters and Jordans requires relatively complicated auxiliary systems of pipes,

valves, chests, etc., which increase the operating cost and add to the risk of trouble from dirt, rust, etc., getting into the pulp. Beaters and Jordans also require skill and experience on the part of the operators, to obtain the necessary quality and uniformity of pulp for any particular kind of paper or board; and even with great skill, variations of the refined fibers occur which result in variations in the resulting paper or fiber board.

"Attrition mills," sometimes used for refining fiber pulp, have relatively revolving abrasive discs between which the pulp stock flows radially outward. The mating abrasive disc faces are generally recessed or grooved,—either in such wise that all the pulp has to pass between the plain surfaces of the discs, or else so that the material can travel outward unrestrained through the grooves, without proper refining. In either case, very much as in beaters and Jordans, only the plain facial surfaces amongst the disc openings or grooves (and their corners) are effectively used for working or refining the fibrous materials; so that the actual working surface area of a grooved or recessed disc is considerably less than if it were entirely plain. Also, regulation of the degree of refining has to be effected by varying the fine gap or working clearance between the disc faces—insofar, that is, as any such regulation is really possible. And when all the pulp must pass between the plain surfaces of the discs, very considerable pressure is produced on them.

Attrition mills heretofore used require a high power consumption for a relatively slight degree of refining, and will not—in a single pass of the stock between the discs, at any rate—produce a refined pulp equal in quality to that produced by the successive action of beater and Jordan. The metal or stone disc faces used in attrition mills wear rapidly, and do not give uniform results. Sometimes the refining discs are held together by spring pressure, so as to yield and separate temporarily if extra large or hard fibrous particles come between the discs,—thus allowing any and all other particles to pass with little or no reduction in size, until the extra large particle gets through. Generally, the gap or working clearance between the discs is purposely varied as a means of controlling the amount or degree of refining and the particle size in the refined product; but this is very unsatisfactory, because a large gap gives very poor efficiency, and also changes the capacity or throughput of the refiner. This is less detrimental than might be expected, however, owing to the peculiar method of pulp infeed to an attrition mill: by means of a mechanical feeding de-

vice, separately driven and regulated, without any nice regard to the capacity to receive the pulp between the refining discs. Such a method of feeding meets the practical necessity that the refiner throughput should correspond with the demand for pulp for the Fourdrinier or other paper making machine that is being served, but does not give constancy of infeed pressure, or of pressure between the refining discs.

All in all, the refined pulp from attrition mills is irregular and subject to wide variation in sizes of refined particles, so that it has usually been necessary to screen it to eliminate oversize particles and secure a reasonably uniform product. Even then, such pulp may contain an excessive proportion of very fine short particles or "fleur", as it is called.

My invention affords a means of refining fiber stock rapidly; economically, with low power consumption in proportion to the refining accomplished; and to reasonably uniform and readily controlled particle fineness, fraying, and degree of hydration of fiber. At a single pass of the stock through it, and in a few seconds, a refiner embodying my invention can be made to produce stuff properties that would require hours in a beater, and could not be obtained at all in a Jordan. My refiner affords a readily controlled brushing and rubbing of the fiber particles, as in a beater, and concurrently produces all necessary cutting of the fibers to give satisfactory sheet formation, as in a Jordan. It also permits of varying the degree of refining and the capacity or throughput independently of one another,—to a considerable degree,—and without altering the gap or working clearance between the refining surfaces. As compared with beaters, Jordans, and attrition mills hitherto used, my invention can be made to produce a superior pulp, characterized by longer average length of fibers, by the development of more fibrillae on the ultimate fibers, by a freeness the same as that of similar pulp produced by the beaters and Jordans, and by greater strength of the paper made from the pulp.

For the purposes of my invention, I employ relatively revolving refining members with parallel-moving "mated" or mutually corresponding main rubbing or abrasive surfaces, which may be flat, conical, or even radially curved in profile, and may revolve substantially coaxially relative to one another,—either in opposite directions, or in the same direction at different speeds, or merely relatively: i. e., only one may revolve, while the other is stationary. Hence in speaking of the refining members as "rotary", and of their working faces as "parallel-moving", I refer only to the character of their relative movement, without any implication as to whether both members actually move, or only one of them. The working faces of these members are traversed by the stock or pulp transversely of the direction of their relative rotary movement; and these faces preferably enlarge circumferentially in the direction of stock or pulp flow, so that centrifugal force tends to produce or maintain the flow of the stock. The members may be of stone, steel, iron, bronze, or other materials, or combinations of materials. My invention is concerned both with the process or mode of coaction by which the desired results are produced by the mating refining members, and with certain important facial features of the members.

In the practice of my invention, I maintain the main plain rubbing or abrasive surfaces of the

relatively rotating refining members at a close clearance,—which may preferably be as fine, ordinarily, as about one or two thousandths of an inch, since a much larger gap or clearance (such as ten thousandths of an inch) does not usually give sufficient refining action or reduction in particle size for most papers of good quality. I provide the mating surfaces with radially extending flow grooves that permit continuous passage therethrough of much of the stock or pulp, including the larger fiber particles or bundles to be reduced. These flow grooves may extend circumferentially as well as radially,—e. g., spirally,—or if the mating surfaces are conical or of curved profile, the grooves may extend both axially and radially or spirally. Hence in speaking of the grooves as "radially extending" I refer only to the fact that their direction has a radial component, without meaning either to exclude or to imply a diagonal direction, with a circumferential or an axial component,—or even both. With the gap or clearance between the main rubbing surfaces so fine that, in general, the greater part of the stock or pulp treated passes through the flow grooves "behind" these main surfaces, so to speak, high pressure on the refining members is avoided, and the power required to operate the refiner is minimized. At the same time, with the grooves sufficiently shallow and of suitable depth and conformation, great reduction and working of the fibrous particles in the grooves can be effected, since many of the larger particles (at least) are forced outward to protrude slightly above the main surface of the member in whose grooves they are travelling,—so as to be squeezed and crushed, torn, or frayed by the interaction of particles in the grooves of the two members, or rubbed or brushed against the plain, rubbing surface of the other member, or hit by the corners of the grooves in said other member, etc. With suitable grooving of this character, the entire surface of each disc becomes effective in working or refining the fibrous material: i. e., its total working area equals the plain surface area amongst the grooves plus the "developed" internal surface area of the grooves themselves.

To assure sufficient reduction or working of the fibrous particles in the flow grooves, as well as of such particles as pass between the plain surfaces of the refining members, I retard the movement of the stock, by limitation or diminution of the effective area and width of passage for the stock and its fibrous particles. Thus I control the dwell of the stock in the refiner and the maximum fibrous particle size in the refined product. For this purpose, the refining members may have co-acting outer flow-control zones, with only limited effective area and width of passage between them; or the flow grooves may be reduced in cross-section and depth, gradually or at intervals; or both these means of flow control may be combined. In addition, I preferably supply the stock or pulp to the refiner under such definite, constant (but regulable) pressure or head and in such ample quantity as to assure that the refiner will always operate with the refining "pass" between the refining members (including their grooves) full of pulp, thus obviating any variation or irregularity of the work done on the pulp due to partial and variable emptiness of grooves from time to time. This can be done by supplying the pulp from a constant-head head-box, such as known in the art for other purposes.

Instead of controlling and varying the amount of work done on the stock and the capacity or

throughput of the refiner by varying the gap or clearance between the mating surfaces of the refining members, as has heretofore been the practice in Jordans and attrition mills, I hold this gap substantially constant, and effect the desired control by varying and adjusting other influential factors: viz., the width of the working faces in the direction of pulp flow, and their facial features (grooving); the effective area and width of passage for the pulp and its fibrous particles afforded by the flow grooves and the outer control zones; the inlet head or pressure under which the stock is fed to the refiner; and the speed of rotation of one or both refining members. The maximum particle size can be controlled especially by the depth of the grooves and the effective width of passage or gap between the control zones,—one or both,—while the capacity and output can be controlled by the cross-section and number of flow grooves, by the inlet pressure or head, and by the speed. Even after the groove depth and control-zone width of passage have been fixed, the throughput can still be more or less independently adjusted by varying the inlet pressure and the speed,—although these factors may also influence the average particle size, since if the speed of rotation and the flow of stock through the flow grooves are very low, the average reduction of particle size in the grooves may materially exceed what would suffice to let the particles through. In some cases, a slight variation of the gap or clearance between the main surfaces may be resorted to, in order to control and adjust the freeness of the refined fiber as desired consistently with the desired capacity. This, however, is in the nature of a last fine adjustment, since any very material increase of the gap or clearance above the limits already indicated will give poorer and less economical refining.

While variation of either inlet pressure or speed of rotation of one or both refining members affects the throughput of the refiner, the effects are not by any means identical. Increase of the pressure under which the stock is fed to the refiner tends to increase the throughput and reduce the dwell of the stock in the refiner without any compensatory increase or intensification of the work done on the stock. Hence such increase of inlet pressure tends to become less and less effective in increasing throughput of stock containing any quantity of large fibrous particles: e. g., if the inlet pressure is doubled or quadrupled, twice or four times as much stock will not go through, because the large particles cannot be sufficiently reduced in one-half or one-fourth the time. On the other hand, any increase in the speed of rotation of either refining member which also increases the rate of relative rotation of the members does tend to be self-compensatory; because the work done on the stock and the reduction of its particles naturally increases according to (and almost *pari passu* with) the relative rotation of the coacting mating surfaces of the members,—and vice versa. In general, therefore, speed variation may be preferred to inlet pressure variation as a means of controlling output.

Various other features and advantages of my invention will appear from the following description of species thereof, and from the drawings.

In the drawings, Fig. I shows a vertical axial section through a flat-faced rotary disc or attrition mill type of refiner conveniently adapted for the purposes of the invention.

Fig. II is an end elevation of the machine and its pulp-feeding provisions, certain parts being in vertical section; and Fig. III shows a horizontal section through part of the pulp-feeding means, taken as indicated by the line and arrows III—III in Fig. II.

Fig. IV is a plan or facial view of a segment of one of the refiner discs shown in Fig. I, on a larger scale.

Fig. V is a sectional and edge view with the refiner disc in radial section, as indicated by the line and arrows V—V in Fig. IV.

Fig. VI is a fragmentary inner edge view, and Fig. VII a similar outer edge view, taken as indicated by the lines and arrows VI—VI and VII—VII in Fig. V, respectively.

Fig. VIII is a fragmentary outer edge view similar to Fig. VII, but with a part removed.

Fig. IX shows an axial section through part of a coacting pair of refined disc faces different from those shown in Figs. I and IV—VIII, on a larger scale than Figs. I and IV.

Fig. X is a plan or facial view of a segment of one of the refiner discs shown in Fig. IX.

Figs. XI and XII show fragmentary radial sections of one of the discs, taken as indicated by the lines and arrows XI—XI and XII—XII in Fig. X, respectively,—on a larger scale than Figs. IX and X.

Figs. XIII, XIV, XV, XVI, and XVII show fragmentary circumferential sections of one of the discs, taken as indicated by the correspondingly numbered lines and arrows in Fig. X, respectively.

Fig. XVIII shows a radial section through co-operating grooves of the discs shown in Figs. I, IV, and V, with fiber pulp passing through them; and Fig. XIX shows a cross-section through these grooves as indicated by the line and arrows XIX—XIX in Fig. XVIII.

Fig. XX shows an axial section through part of a refiner disc generally similar to that of Figs. IX to XVII, but with a facing of sectional construction.

Fig. XXI shows a fragmentary plan or facial view of the disc and facing shown in Fig. XX; and,

Fig. XXII shows a fragmentary facial view of the disc of Figs. XX and XXI with its facing sections reversed.

To assure a clearer understanding of my invention, I will first briefly explain the general construction of the refiner in which it is here shown.

The refiner shown in Fig. I comprises oppositely rotating coacting refining members or rotor discs 10, 11 enclosed in a housing 12 and driven by separate (electric) motors 13, 14 mounted directly on the disc or rotor shafts 15, 16. One or both of the motors 13, 14 are preferably variable speed motors. The shafts 15, 16 are mounted in inner anti-friction (thrust and journal) bearings 17, 18 in pedestal supports 20, 21 located closely adjacent the rotors 10, 11 and forming part of the housing structure 12, and in outer (journal) bearings in other pedestals 22, 22 located at the outer sides of the motors 13, 14. The pedestals 20, 21 are rigidly tied together (and united to the housing 12) by longitudinal webs below the shafts 15, 16, and all of these and other parts are mounted on a common rigid base 23. This construction obviates deflection and untruing of the rotor discs 10, 11 under the working thrust between them. The base 23 has therein an opening with a depending inward-sloping apron or flange 24 that forms a downward extension of

the housing 12 and a downward discharge for the pulp refined between the rotors 10, 11. The rotors 10, 11 are keyed fast on the shafts 15, 16 and secured by nuts 25, 26.

The working faces 27, 27 of the rotors 10, 11 are preferably separate parts and detachable. As shown, the rotors 10, 11 have substantially identical, flat, annular facing discs 27, 27 with a central cavity or chamber 28 whence the stock or pulp flows outward through the annular "refining pass" between the faces 27, 27. Pulp is admitted to the cavity 28 through the rotor 10, which has an annular intake passage 29 in its central hub portion 30 around its inner hub 31,— in which the shaft 15 is keyed and secured. The inner hub 31 is connected to the outer hub by vanes 32 between which the pulp can pass freely. The pulp is supplied through a passage 33 in the pedestal 20 (below the shaft bearing 17), which passage extends up around the hub 31 and opens into the annular intake 29. The box 34 of the thrust bearing 18 in the pedestal 21 is movable lengthwise in the pedestal, but is kept from turning therein by a groove and feather engagement at 35, and is externally threaded to take a worm wheel nut 36 that can turn between abutment shoulders in the pedestal. The nut 36 can be turned either way by a subjacent worm 37 on a transverse shaft 38 mounted in bearings in the pedestal 21.

By turning the shaft 38 and the nut 36 one way or the other, the rotor 11 can be shifted toward the rotor 10, into effective refining proximity thereto, or away from the rotor 10, so as to afford a large interval between the faces 27, 27. Also, the gap or clearance between the faces 27, 27 can be adjusted to just the number of ten-thousandths of an inch desired, according to the character of the pulp being treated and the maximum fineness of fiber desired in the product. When thus adjusted, the machine operates with its faces 27, 27 "dead set" at the desired working clearance; i. e., the clearance is positively and unyieldingly fixed and held until and unless adjusted. For many kinds of pulp, 900 R. P. M. of the rotors 10, 11 is a favorable speed; but wide variation is admissible, e. g. speeds of 300 to 900 R. P. M. can readily be used.

As shown in Fig. II, the stock or pulp to be refined may be supplied to the passage 33 through a feed pipe connection 39 from a regulable, constant-head head-box 40 of any suitable type and construction, located at a height above the machine corresponding to the inlet head or pressure desired. The stock or pulp is delivered to the head-box 40 through a supply pipe 41 by a (centrifugal) pump 42 drawing from the usual "stuff-chest" 43, with agitator 44; and any excess returns to the chest 43 through an overflow pipe 45. As shown in Figs. II and III, the head-box 40 is divided by a partition 46 into an outlet chamber 47 and another (larger) chamber, which latter is divided by aligned transverse dams 48, 49 and a longitudinal dam 50 into an inlet chamber 51 to which the supply pipe 41 delivers; a constant head chamber 52; and an overflow chamber 53 into which opens the overflow pipe 45. There is a variable opening or passage from the chamber 52 through the partition 46 into the chamber 47, controlled by any suitable regulating means, such as a gate valve 55. As shown, the dam 48 for the inlet chamber 51 is about an inch lower than the dams 49, 50 around the overflow chamber 53, so that the pulp first overflows from inlet chamber 51 over dam 48 into constant head chamber 52,

and only overflows dams 49 and 50 into overflow chamber 53 when not carried off by feed pipe 39 as fast as supplied through pipe 41. Ordinarily, pump 42 will be operated to deliver an excessive supply to the head-box 40, so that there would be some overflow into chamber 53 even with valve 55 wide open. By adjusting valve 55, the height of the pulp in outlet chamber 47 can be regulated, and the pressure head and throughput of pulp correspondingly varied.

The annular refining disc facings 27, 27 are mounted on metal supporting plates 60, 61 which are secured to the rotors 10, 11 by bolts 62 extending through the rotors and taking into the plates 60, 61. The plates 60, 61 are centered on the rotors 10, 11 by engagement of annular grooves in the plates over annular ridges 63, 63 on the rotors. The center of the plate 60 is open at 64 around the nut 25 that holds the rotor 10 on its shaft 15, to admit the pulp from the intake 29 between the plates 60, 61. The center of the plate 61 is closed, thus excluding the pulp from the nut 26 that holds the rotor 11 on its shaft 16; but it is annularly recessed or dished to an arcuate profile at 65, to spread the axial pulp stream from intake opening 64 into an annular outflow into the annular refining pass between the facings 27, 27. The disc facings 27, 27 are secured to the supporting plates 60, 61 by bolts 66 extending through the plates 60, 61 and taking into the facings 27, 27. The heads of the bolts 66 are accommodated in seat recesses 67 counter-sunk in the plates 60, 61.

The general operating and structural features of the particular refiner here illustrated have been thus described for the sake of clearness and as a background for the explanation of my present invention, now presently to follow. The refiner and head-box construction can be widely varied, or even radically changed, since its features and details are mainly illustrative, as far as my present invention is concerned.

Referring, now, to Figs. IV—VIII as well as to Fig. I, it will be seen that each of the disc faces 27, 27 has in its main plain, rubbing surface 70 that mates and coacts with the other face 27 a plurality of radially extending flow grooves 71, similar to one another and equally spaced. Thirty-two such grooves 71 to the total circumference are indicated in Fig. IV, although a much less or much greater number might be used. Each groove 71 extends across the flat surface 70 from the inside facing-bevel 72 substantially or nearly to the outer facing periphery, and has its bottom rounded transversely: i. e., circumferentially of the face 27. In the present instance, the grooves 71 gradually or progressively diminish in depth from their inner to their outer ends, and their bottoms gradually "flatten" with a diminishing (arcuate) curvature and an increasing radius. As shown, the grooves 71 also gradually widen a little outward across the face 27, though not so much as would correspond to the flattening of their bottom curvature; for their edges for at least part of their length are much steeper than would correspond to the general curvature of their bottoms. The annular corner between each flat main working surface 70 and the inner bevel 72 is eased or rounded at 74, and the walls of the grooves 71 at their inner ends merge into the bevel 72 with like rounding 75.

Besides the control of the outflow through the grooves 71 by their outward-diminishing depth and cross-section, an outer flow-controlling facial zone 76 is preferably provided adjacent the

periphery of the face 27, affording more limited cross-section and width of passage thereacross for the stock and its fibrous particles than the grooved facial refining areas or working zone inside of it. Any degree of restriction desired may be provided at this outlet-controlling zone 76, from total absence of any outflow grooves or channels thereacross as one extreme, up to grooving virtually equivalent to the outer ends of the grooves 71 in cross-section or depth as the other extreme. As regards maximum fibrous particle size in the pulp, the effective width of outlet passage across the zones 76, 76 of the coating faces 27, 27 is equal to the gap or clearance between the surfaces 70, 70 at these zones plus the depth of the deepest outflow grooves in the zone 76 of either face 27, 27. As shown in Figs. I, IV, V, and VII, provision is made for adjustably-variable flow-control grooving across the zone 76. One way of doing this is to provide the outer edge or margin of each facing 27 with recesses or notches 77, preferably in line with the grooves 71, and of a depth equal to the full width of zone 76,—with inset (brass) blocks 80 adjustable therein in the direction of the thickness of the facing 27. For this purpose, bolts 81 are shown extending with suitable clearance through holes or slots 82 in the blocks 80 and taking into the edge of the facing 27. By loosening the bolts 81 and shifting the blocks 80, any desired number of these blocks can be set either flush with the surface 70 or at distances below it affording shallow grooves of just the desired depth and cross-sectional area across the zone 76. In this way, various grooves 71 can be made to deliver fibers of various different sizes, and the proportions of such fibers in the pulp thus varied and controlled pretty much as desired. As shown, the notches 77 are narrower than the outer ends of the grooves 71, and the latter have rounded corners 83 just inside of the notches 77.

To illustrate suitable proportions for one of the working faces 27 and its various features for certain uses, it may be of 30 in. outside diameter, 19 $\frac{3}{8}$ in. minimum inside diameter, 20 $\frac{1}{4}$ in. inside diameter to the intersection of the inner bevel 72 with the surface 70,—disregarding the rounding way of their corner at 74,—and 2 in. thick. The grooves 71 may be $\frac{1}{8}$ in. deep at their inner ends and rounded to a $\frac{5}{8}$ in. radius, and at their outer ends $\frac{3}{4}$ in. deep and rounded to a 3 $\frac{1}{4}$ in. radius,—with a minimum depth of $\frac{3}{8}$ in. at the roots of the bevels 73 just inside the rounded corners 83. The width of the plain surface 70 between adjacent grooves 71 may be $\frac{7}{8}$ in. at the inner ends of the grooves. The notches 77 may be 1 $\frac{1}{4}$ in. wide and $\frac{1}{2}$ in. deep, and the blocks 80 may have like dimensions and a length of 1 $\frac{1}{2}$ in. A fair practical range of adjustment for the blocks 80 would be $\frac{3}{64}$ below the surface 70 as a maximum, and $\frac{1}{64}$ in. below as a minimum. The bolts 81 may be $\frac{1}{2}$ in. bolts.

Working faces 27 with grooving, etc., of the form, proportions, and dimensions exemplified in Figs. IV—VIII and in the preceding paragraph are well adapted for treating fibrous particles considerably larger than the ground-wood screenings and the like usually considered proper material for refining,—such, for example, as spruce or other wood chips. It is advantageous, however, to first cook or digest such chips or other large fibrous particles,—even to the extent of a partial chemical digestion, such as a sulphite digestion,—thus softening the large particles and reducing the strength of lateral adhesion amongst

their ultimate fibers. For example, spruce or other chips may be cooked with steam or hot water; or they may be digested in any usual way with an aqueous "liquor" of calcium bisulphite ($\text{Ca}(\text{HSO}_3)_2$) at a temperature gradually rising to about 135° C.,—usually with about 11 hours total treatment of the chips in the digester. Pulp resulting from treatment of these partially digested chips in a refiner with the working faces 27, 27 of Figs. IV—VIII may be screened through a pulp screen of 50 to 60 meshes per sq. in. to remove oversize particles, and then mixed with ground-wood in the proportions required for newsprint, catalogue, or other similar grades of paper.

Figs. IX—XVII illustrate a pair of facing discs 27a, 27b with working faces suitable for finer work than the faces 27, 27 of Figs. IV—VIII, and having correspondingly smaller and shallower but more numerous grooves. These particular facings 27a, 27b are intended to be thicker than the facings 27, 27 of Fig. I, so as to allow the supporting plates 60, 61 of Fig. I to be dispensed with: i. e., the facing discs 27a, 27b may be mounted and secured directly on the rotors 10, 11 of Fig. I, just as the plates 60, 61 are mounted and secured. Accordingly, the disc 27a is shown with a pulp intake opening 64a at its center like the plate 60; while the center of the disc 27b is closed and annularly recessed or dished at 65a, like the plate 61. The mating annular main surfaces 70, 70 of the facing discs 27a, 27b, around the opening 64a and recess 65a, may be just alike. In Figs. IX—XVII, various parts and features are marked with the same reference numerals as in Figs. I—VIII, (with an added letter, where such distinction appears desirable), as a means of dispensing with repetitive description.

On the working faces 27a, 27b, several distinct annular working zones A, B, C may be distinguished. These zones A, B, C are preferably separated from one another and from the circumjacent flow control zone 76a by shallow annular redistributing grooves 84, 85, 86 (Figs. IX—XII). Three such distinct refining zones A, B, C are here shown, but obviously any desired number of them (from one up) might be provided. As these zones A, B, C are successively traversed by the outflowing stock or pulp under the influence of progressively increasing centrifugal force, their main flow grooves 71a, 71b, 71c are of successively or progressively diminishing cross-section and depth (Figs. IX, X, and XIII—XVI). The inner, intake ends of the grooves 71a in the initial zone A are flaringly enlarged and rounded (Figs. X, XVI), to facilitate entrance into them of the large fibrous particles in the raw stock or pulp as it enters the refiner; and their depth is shown as diminishing progressively outward (Fig. IX), with a view to assuring prompt reduction of the large fibrous particles, and also in view of the rapid increase of centrifugal force in the grooves 71a. The first distributing groove 84 is shown shallower than the outer ends of the main flow grooves 71a. The grooves 71a may end in a "bead" 87 short of the middle of groove 84, or on a taper 88 to the outer side of the groove 84 in Figs. IX and X, both of these forms are embodied.

In addition to the main flow grooves 71a, 71b, 71c, some or all of the zones A, B, C may be provided with radially extending intermediate, secondary flow grooves 91, shown as narrower and shallower than said main flow grooves, to receive such smaller fibrous particles as may be

able to enter them (Figs. X and XIII-XVI). As shown in Fig. X, these secondary flow grooves 91 alternate with main flow grooves 71a in zone A (Figs. XV and XVI), and are twice as numerous as grooves 71b in zone B (Fig. XV),—where the number of grooves 71b indicated is the same as that of grooves 71a in zone A. In zone C (Fig. XVI), the difference of width and depth between main and secondary flow grooves 71c and 91 is not very great, and they are arranged in alternation; but their aggregate number much exceeds that of grooves 71b and 91 in zone B, being about double, in fact.

Besides their function of reducing particles too large to enter the smaller or "secondary" flow grooves 91,—when and if such very large particles exist in the stock or pulp,—the main flow grooves 71a, 71b also serve as "feeder" or by-pass channels to the circumferentially more extensive outer zones B and C: i. e., they supply these zones B and C with more stock than could reach them through such number of narrow, shallow grooves 91 as the less extensive inner zones A and B would properly afford room for. As I shall point out more fully hereinafter, a certain amount of ungrooved plain surface 70a is needed amongst the grooves of each zone A, B, C, in order that each zone may do its work on the stock properly. Unless, therefore, some such provision as the deep grooves 71a, 71b were made for supplying stock to the outer zones B and C, the efficiency of the refiner would necessarily be impaired: either by underworking of the more extensive outer zones B and C through failure to supply enough stock to them, or by over-grooving of the less extensive inner zones A and B in order to supply stock to the outer zones B and C.

In addition to flow grooves 71a, 71b, 71c, and 91, some or all of the working zones A, B, C may have "dead" or non-flow working grooves, to assist in reducing the fibrous particles (as hereinafter described) without affecting the pulp flow. As shown in Fig. X, zone A has radially extending "dead" working grooves 94 in alternation with its grooves 71a and 91, and zone B has a radial "dead" working groove 95 between each pair of its grooves 91. In both of zones A and B, the dead grooves 94 and 95 open into the distributing groove 84 between said zones,—although this is not broadly essential.

Preferably, the outer ends of main flow grooves 71a in zone A are not opposite main or secondary flow grooves 71b or 91 in zone B, in order that the redistribution of stock or pulp in groove 84 may be more thorough. This redistribution is not interfered with, however, by having grooves 71a in zone A opposite grooves 95 in zone B, or by having grooves 91 in zone A opposite grooves 71b in zone B, as shown in Fig. X. For similar reasons, alignment of grooves 71b and 71c in zones B and C is preferably avoided, although grooves 91 in zone C may come opposite grooves 71b in zone B without objection.

The type of adjustably-variable flow and outlet-control grooving here shown for the outermost zone 70a comprises a series of inset (bronze) blocks 80a in recesses in said zone, 70a outside the distributing groove 86, flush with the main surface 70a, and secured by pairs of screws 81a. Any desired number of the insets 80a may have one or more (radial) grooves 96 across their faces, from the distributing groove 86 out to the very periphery of the disc 27a or 27b, as the case may be. The depth of the grooves 96 will determine the maximum fiber particle size in the refined

pulp, and the total area of grooves 96 in all the blocks 80a will determine the refiner capacity or throughput for given intake pressures and disc speeds of revolution. The maximum refined particle size and the capacity may be changed whenever desired by replacing one set of blocks 80a with others.

To illustrate suitable proportions for the facings 27a, 27b and their various features, they may have an outside diameter of about 38 in., an inside diameter for the opening 64 of 11 in., a diameter of 15 in. to the inner edge of the flat surface 70, and a thickness of about $4\frac{1}{2}$ in. The diameters on centers of the annular distributing grooves 84, 85 and 86 may be 23, $30\frac{1}{2}$ and 36 in.; their widths may be $\frac{3}{4}$ in., $\frac{3}{4}$ in., and $\frac{1}{2}$ in.; and their depths may be $\frac{1}{8}$ in., $\frac{1}{4}$ in., and $\frac{1}{4}$ in., respectively. The groove 86 may be semi-circular, and the grooves 84 and 85 may have their corners rounded to radii equal to their depths. The grooves 71a may be $\frac{3}{8}$ in. wide, and vary in depth from $\frac{3}{8}$ in. at their inner ends to $\frac{1}{4}$ in. at their outer ends; and their corners may be rounded to about $\frac{1}{8}$ in. radius,—or more at their widened inner ends. The grooves 71b may be $\frac{1}{4}$ in. wide and $\frac{1}{8}$ in. deep, and semi-circularly rounded; and the grooves 71c may be $\frac{1}{4}$ in. wide, $\frac{1}{4}$ in. deep, and semi-circularly rounded. All of the grooves 91 and 94 may be $\frac{1}{8}$ in. wide, $\frac{1}{4}$ in. deep, and semi-circularly rounded. The grooves 95 may be $\frac{1}{4}$ in. wide, $\frac{1}{4}$ in. deep, and semi-circularly rounded. The insets 80a may have one groove 96 apiece; it may be $\frac{1}{4}$ in. wide and $\frac{1}{4}$ in. deep; and there may be 12 of the blocks 80a, at 30° intervals on centers. In zone A, there may be some 48 to 50 each of grooves 71a and 91, and 96 to 100 grooves 94; in zone B, there may be 48 to 50 each of grooves 71b and 95, and 96 to 100 grooves 95; in zone C, there may be about 128 each of grooves 71c and 91.

In the operation of a refiner with working faces such as 27, 27 in Figs. IV-VIII, or 27a, 27b in Figs. IX-XVII, the stock is fed in axially at 28 or 64a under constant (head-box) pressure, and flows outward through the refining pass between the discs,—including the flow grooves 71 or 71a, 71b, 71c and 91. In the refining pass, the stock is also impelled outward very powerfully by the centrifugal force due to the high speed of rotation,—which force increases outward from the axis. Owing to the small gap or clearance of .001 or .002 in. between the disc surfaces 70, 70, the greater part of the fibrous particles (and of the liquid too) passes through the flow grooves. In these grooves, the fibrous particles are spun around, squeezed, and disintegrated very rapidly,—undergoing a variety of actions that tend to reduce their size, to fray or roughen them, and to hydrate the ultimate fibers.

The coaction of the grooved working faces to produce these effects is promoted by the cross-section of the grooves, with their transversely curved bottoms and sharp, approximately right-angled top edges or corners, as well as by the gradually or successively diminishing depths of the grooves 71 and 71a, 71b, and 71c. The rounded groove bottom is only one of many possible forms: the important points are that the depth of the groove should decrease toward its side, and that at and just below the surface 70, the groove side should be perpendicular to the surface 70,—or at least sufficiently steep to give a fairly sharp corner-angle. However, the "arcual" character of a groove—by which I mean its diminution in depth toward the side—is so much

more important than its sharp corners at the surface 70 that very satisfactory results can be obtained even when the corners are quite rounded, so as to give a maximum of rubbing and a minimum of cutting of the fibrous material. It is not necessary to machine or otherwise cut the internal groove surfaces: on the contrary, the grooves may be cast in a cast-iron facing, without any subsequent work being done on it except to grind its plain surface (intermediate the grooves) and its back, as already mentioned.

The sides of the grooves that count most are their "trailing" or "following" sides,—speaking with reference to the direction of rotation of the discs. By reversing the rotation of the discs after the corners at their trailing sides have worn round, the relatively unworn, sharp "leading" corners will become the trailing corners, and so the necessity of regrinding the working faces 27, 27 (and perhaps recutting their grooves) will thus be deferred.

Main reductive influences on fibrous particles in the grooves of each disc facing 27, 27 or 27a, 27b are squeezing, crushing, and fraying by the interaction of particles in the grooves of the two facings; the abrasive friction with the plain surface 70 of the coating facing; and the impacts against the trailing corners of the grooves in the coating facing. These influences tend to detach small fibrous particles (or even ultimate fibers of the material) from the larger particles. The squeezing and the impacts especially tend to crush, mash, tear, and even shear the fibrous particles, both along the natural cleavages amongst their ultimate fibers, and across the ultimate fibers,—thus shortening them. As the fibrous particles are reduced, they are continually forced outward to undergo further crushing, abrasion, and impact, by the diminution in depth of the grooves, both transversely toward their sides and longitudinally in the direction of pulp flow. Such fibrous particles and fibers as get into the "dead" grooves 94, 95 are swept through and out by the flow between the plain surfaces 70, 70.

How fibrous particles may be reduced by the interaction of material in arcual grooves of co-operating discs is illustrated by Figs. XVII and XIX, and especially in the latter. Here large fibrous particles A and B are shown in a groove 71 of disc 27a, and other large particles C and D in a groove 71 of disc 27b, opposite groove 71 of disc 27a. Smaller fibrous particles and ultimate fibers are also shown in each of these grooves 71, 71. Another large fibrous particle E is shown in the midst of the particles A, B, C, D, being squeezed between particles A and D in the opposite grooves 71, 71. Obviously, this must result in crushing and splitting, tearing, or fraying one or more of these particles A, D, and E. Of course, this is only one of the ways in which the squeezing and reduction of particles may result from interaction of material in grooves 71, 71 as they pass.

Such ultimate fibers as become wholly detached and independent may to a certain extent work in between the plain surfaces 70, 70, and there be further rubbed, brushed, frayed, and hydrated. When the gap or clearance is as much as .002 in. or a little more, some of the smaller fiber bundles (composed of some two, three, four or five ultimate fibers, for example) may work in between the surfaces 70, 70, and be there torn apart, wholly or partially.

As rubbing against the abrasive plain surfaces

70, 70 and impacts against groove edges are both important reductive influences, it follows that adequacy of plain, rubbing surface is important, as well as sufficient total length of groove edges. On the working faces 27, 27 and 27a, 27b here shown, the plain area approximates the depressed or grooved area, including dead grooves 94, 95 as well as flow grooves: on the faces 27a, 27b, indeed, the aggregate plain area very considerably exceeds the aggregate depressed area, the ratio being roughly about 2 to 1. On the other hand, the recessed or grooved surfaces heretofore employed in refiners have had considerably greater depressed area than plain area: i. e., they have relied too much on edge impacts, and have not really utilized the distinctive fiber-working possibilities of abrasive plain surfaces. Neither have the internal groove surfaces been utilized effectively.

Broadly regarded, therefore, my invention involves a recognition and effective utilization of plain, rubbing surfaces to abrade the fibrous particles in combination with flow grooves to hold them and permit their travel while being reduced. Also novel is the recognition and utilization of the internal groove surfaces to cause squeezing and consequent reduction of the fibrous particles as explained in connection with Figs. XVIII and XIX. Important to the efficient utilization of these principles is the retardation or control of the stock-flow through the refining pass to give time for adequate abrasive and impact working of the fibrous material. Likewise helpful are the comparative shallowness of the grooves; their transverse reduction in depth, especially toward the trailing side, so as to force particles outward by a sort of wedging action; and their gradual or successive reduction in depth in the direction of stock flow. All these features make their bottoms more effective in the working of fibrous particles in them. Steepness of the groove sides and sharpness of their corners have already been referred to as important in giving adequate impact-working.

While the flow or outlet control zones 76, 76a are not preferably relied on to do any great amount of work on the fibrous material, they may, nevertheless effect some reduction or working of the particles.

When steel refining discs are employed, their plain, rubbing surfaces 70, 70 will preferably be finished true and flat by grinding, which leaves them with slight abrasive roughness or tooth. Their back sides will preferably be also ground true and parallel with their surfaces 70, 70. For greater abrasive roughness or tooth of the plain, rubbing surfaces 70, 70, natural or artificial stone discs may be employed. Artificial stones of grit with a binder (e. g., alundum or carborundum, with a silicious binder) permit a considerable range of roughness and hardness,—such as Norton grades 40—250 of roughness, and grades M—Z of hardness. Abrasive plain, rubbing surfaces of cast iron or bronze alloys with carborundum or other grit cast in may also be used.

In the design of the refining members, their area and width in the direction of stock flow are proportioned to the material to be treated and to the work to be done on it, and so likewise their flow and "dead" grooving. Approximate correspondence between the refiner throughput and the demand of the paper (or fiber board) machine from time to time is secured by suitably adjusting the head or pressure under which the stock is supplied to the refiner and the grooving

in its outer flow-control zone,—due regard being of course had for the fact that the depth of the flow-control grooving determines the maximum particle size in the refined pulp. Final and accurate adjustment of the refiner capacity to the pulp demand of the paper or board machine is made by varying the speed of revolution of one or both refining members: e. g., if 900 R. P. M. be regarded as normal speed, one or both members may be dropped as low as 750 R. P. M. or raised as high as 1050 R. P. M.,—by methods of motor speed control well understood by electricians,—without very materially altering the degree of refining and the quality of the refined pulp.

Final adjustment of the freeness of the refined fiber may be made by varying the gap or clearance between the refining members a few thousandths of an inch, as already mentioned.

Figs. XX to XXII illustrate a sectional construction of a disc or facing that permits of easily changing the outermost flow and outlet control zone 76a', and also makes it easy to change the working zone or zones. The particular disc here illustrated resembles that of Figs. IX—XVII in having three distinct working zones A', B', C': however, the construction is adaptable to a disc with any desired smaller or larger number of zones.

As shown, the outermost flow control zone 76a' consists of a metal ring separate from the rest of the active disc face, and detachably secured to a backing or supporting plate 61' like that of Fig. I by bolts 66'. By unscrewing the bolts 66', the ring 76a' shown can be removed, and replaced with another affording greater or less cross-sectional area or width of outflow passage. In the present instance, each of the working zones A', B', C' is also a separate ring, secured to the backing 61' by bolts 66', and having therein the desired flow and "dead" working grooves 71a', 71b', 71c', and 84', 85', 86', etc., and also having in its edge a rabbet 84', 85', 86' which cooperates with the adjacent ring to form an annular redistributing groove. By unscrewing the proper bolts 66', any one or more of the working rings A', B', C' can be removed, and replaced with a similar one differently grooved. Thus the disc facing can be changed to vary its action on the fibrous material: e. g., it can be given a greater or less total length of grooving in proportion to its plain facial surface, so as to cut the fibrous material more or less in proportion to the abrasive work done on it. As indicated in Figs. XX and XXII, opposite sides of each ring A', B', C' may be differently grooved, so that by reversing one or more of the rings, the effect of substituting a different ring will be realized, as shown in Fig. XXII.

In Figs. XX to XXII, various parts and features are marked with the same reference characters as in Figs. I, IX and X, as a means of dispensing with repetitive description,—with distinguishing "prime" marks where such distinction appears necessary.

Having thus described my invention, I claim:

1. An improvement in refining fiber stock between coacting coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous passage across said faces of fibrous particles to be reduced; which improvement comprises maintaining the coacting surfaces at such close clearance, and feeding in the stock to the refining pass between the members in such quan-

tity, that the major portion of the stock goes through the grooves, and only a small portion passes between the plain surfaces; and also peripherally restricting the effective width of passage and the outflow from between said coacting members and thereby controlling the throughput and the maximum fibrous particle size in the product.

2. An improvement in refining fiber stock between coacting coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous passage across said faces of fibrous particles to be reduced; which improvement comprises maintaining the coacting surfaces at such close clearance, and feeding in the stock centrally to the refining pass between the members in such quantity, that the major portion of the stock goes through the grooves, and only a small portion passes between the plain surfaces; peripherally restricting the effective width of passage and the outflow from between said coacting members and thereby approximately determining the throughput and the maximum fibrous particle size in the product; and varying the speed of revolution of a refining member according to the exact throughput desired.

3. A method of controlling the maximum size of refined fiber from stock fed between coacting relatively revolving refining members with parallel-moving mating working faces having therein radially extending grooves permitting continuous passage therethrough, across said faces, of fibrous particles to be reduced, and also having peripheral outlet-control zones affording limited width of passage for the reduced fibrous particles; which method comprises maintaining a substantially constant gap or clearance between said relatively moving working faces, and varying the effective width of passage afforded by said outlet-control zones according to the desired maximum particle size in the product.

4. A method of controlling the output and maximum size of refined fiber from stock fed between coacting relatively revolving refining members with parallel-moving mating working faces having therein radially extending grooves permitting continuous passage therethrough, across said faces, of fibrous particles to be reduced, and also having peripheral outlet-control zones affording limited width of passage for the reduced fibrous particles; which method comprises maintaining a substantially constant gap or clearance between said relatively moving working faces; varying the effective width of passage afforded by said outlet-control zones according to the desired maximum particle size in the product; and adjusting the rate of relative rotation of the refining members according to the throughput desired.

5. An improved method of refining fiber stock by passage thereof between cooperating relatively revolving refining members having parallel-moving mating plain-surfaced working faces; which method comprises causing the major portion of the stock to pass continuously across said faces through continuous flow grooves in said plain surfaces, and forcing fibrous particles thus travelling and held in such flow grooves of each member outward toward the other member, thus abrading and reducing such fibrous particles against the plain surfaces of the members, besides crushing, reducing, and fraying the particles by

interaction of grooves in said members and by coaction of their plain surfaces.

6. An improved method of refining fiber stock by passage thereof between cooperating relatively revolving refining members having parallel-moving mating plain-surfaced working faces; which method comprises causing the major portion of the stock to pass continuously across said faces through continuous flow grooves in said plain surfaces, and forcing fibrous particles thus travelling and held in such flow grooves of each member outward toward the other member, thus abrading and reducing such fibrous particles against the plain surfaces of the members, besides crushing, reducing and fraying the particles by interaction of grooves in said members and by coaction of their plain surfaces; and restricting and retarding the outflow of stock from between said members and its passage through their said flow grooves, so as to give time for adequate working and reduction of larger particles in the grooves.

7. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow and working grooves therein permitting continuous passage across said faces of fibrous particles to be reduced, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and being provided with means at the peripheries of their working faces for restricting the outflow from the members and controlling the dwell of fibrous particles in the refining pass.

8. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous passage across said faces of fibrous particles to be reduced, and revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, the depths and bottom configurations of said grooves being such as to wedge fibrous particles in the grooves of one member toward the other member.

9. A refiner of the character described comprising coating coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces with radially-extending sloping-sided flow and rubbing grooves therein permitting continuous passage across said faces of fibrous particles to be reduced but so shallow that substantially the entire internal groove surfaces are active in working the fibrous particles, as well as the plain surfaces amongst the grooves and the corners of the latter, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and being provided with means at their peripheries for restricting the outflow from between them and controlling the dwell of fibrous particles in the grooves.

10. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous passage across said

faces of fibrous particles to be reduced, and revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, said grooves diminishing in depth in the direction of flow therein.

11. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having radially extending working grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, and also having coating peripheral flow-control zones affording more limited area and width of passage for the stock and its reduced fibrous particles.

12. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, and also having outer facial outflow control zones, with flow grooves thereacross in at least one of the members, affording more limited area and width of passage for the stock and its reduced fibrous particles, and coating to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

13. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, said grooves diminishing in depth toward either side, and also having outer facial outflow control zones, with flow grooves thereacross in at least one of the members, affording more limited area and width of passage for the stock and its reduced fibrous particles, and coating to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

14. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having round-bottomed grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, and also having outer facial outflow control zones, with flow grooves thereacross in at least one of the members, affording more limited area and width of passage for the stock and its reduced fibrous particles, and coating to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

15. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, said grooves diminishing in depth toward either side and also diminishing in depth in the direction of flow therein, and further having outer facial outflow control zones, with flow grooves thereacross in at least one of the members, affording more limited area and width of passage for the stock and its reduced fibrous particles, and coating to control the dwell of the

stock in the refining pass between the members and the maximum particle size in the refined product.

16. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members with parallel-moving mating plain, rubbing working faces having radially extending grooves therein permitting continuous passage therethrough across said faces of fibrous particles to be reduced, and also having coating flow-control zones affording limited effective area and width of passage for the stock and its reduced fibrous particles and provided with means for adjusting and varying said effective area and width of passage independently of the gap or working clearance between said refining members.

17. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein, permitting continuous passage across said faces of fibrous particles to be reduced, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and being provided with means at their peripheries for restricting and varying the outflow from between them independently of the gap or working clearance between said refining members.

18. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow and working grooves therein permitting continuous passage across said faces of fibrous particles to be reduced, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and having circumferentially extending grooves dividing the working faces into annular zones and permitting redistribution of fibrous particles amongst the flow grooves in successive zones, and also having coating zones at the peripheries of their working faces for restricting the outflow from between the members and controlling the dwell of fibrous particles to be reduced in the refining pass.

19. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous passage across said faces of fibrous particles to be reduced, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and having circumferentially extending grooves dividing the working faces into annular zones and permitting redistribution of fibrous particles amongst the flow grooves in successive zones, and also having intermediate working grooves amongst said flow grooves each opening into one circumferential groove only.

20. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous outward passage across said faces of fibrous particles to be reduced, said

members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and having by-pass channel means for passing stock behind the inner portions of the faces of said members to the outer portions thereof and thus substantially compensating for the greater circumferential extent of the outer portions and utilizing the areas of the inner and outer portions substantially alike in working the stock, and being further provided with means at the peripheries of their working faces for restricting the outflow from the members and controlling the dwell of fibrous particles in the refining pass.

21. A refiner of the character described comprising coating coaxial refining members having parallel-moving mating plain, rubbing working faces with radially extending flow grooves therein permitting continuous outward passage across said faces of fibrous particles to be reduced, said members revolving relative to one another with such close clearance that the major portion of the stock entering the refining pass between the members goes through the grooves, and only a small portion passes between the plain surfaces, and having by-pass channel means for passage of stock behind the inner portions of the faces of said members to the outer portions thereof, and also having outer facial outflow-control zones affording limited area and width of outflow passage, so as to restrict the rate of flow through said grooves and channels and the maximum fibrous particle size in the product.

22. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces that are traversed transversely of the direction of their relative movement by the stock being treated, and that enlarge circumferentially in the direction of stock flow, so that centrifugal force maintains the flow; the said plain, rubbing working faces of said members having therein radially extending working grooves permitting continuous outward passage therethrough of fibrous particles to be reduced, and also having coating outer zones receiving the flow from the grooved facial areas but affording more limited effective area and width of passage for the stock and its fibrous particles, so as to control the dwell of the stock in the refiner and the maximum fibrous particle size in the refined product.

23. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces that are traversed transversely of the direction of their relative movement by the stock being treated, and that enlarge circumferentially in the direction of stock flow, so that centrifugal force maintains the flow; the said plain, rubbing working faces of said members having therein grooves of progressively decreasing depth permitting continuous outward passage therethrough of fibrous particles to be reduced, but forcing the particles in the grooves of each member more and more to its surface as they travel outward.

24. In a refiner of the character described, the combination of coating coaxial relatively revolving refining members having parallel-moving mating plain, rubbing working faces that are traversed transversely of the direction of their relative movement by the stock being treated, and

that enlarge circumferentially in the direction of stock flow, so that centrifugal force maintains the flow; the said plain, rubbing working faces of said members having therein radially extending grooves permitting continuous outward passage therethrough of fibrous particles to be reduced, but so shallow, and with their bottoms so inclined transversely of the direction of movement of the fibers, that the groove bottoms of each member coact with the other member in the working of the fibrous particles, and also having coacting outer zones receiving the flow from the grooved facial areas but affording more limited effective area and width of passage for the stock and its fibrous particles, so as to control the dwell of the stock in the refiner and the maximum fibrous particle size in the refined product.

25. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, the depths and bottom configurations of said grooves being such as to wedge fibrous particles in the grooves outward against said coacting member.

26. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending arcual flow grooves permitting continuous passage therethrough across said face of fibrous particles to be reduced and working and reducing fibrous particles by interaction of fibrous material in them with such material in the grooves of the coacting member.

27. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, said grooves diminishing in depth outward so that fibrous particles travelling therein shall be forced more and more against said coacting member as said particles are reduced during their outward travel.

28. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, said grooves having their bottoms rounded transversely so as to force fibrous particles travelling therein against said coacting member, and also diminishing in depth outward so as to force the particles more and more against said coacting member as said particles travel outward.

29. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending working grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, and also having an outer facial out-

flow-control zone for coacting with said coacting member to control the dwell of the stock in the refining pass between the coacting members and the maximum particle size in the refined stock.

30. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, and also having an outer facial outflow-control zone with outflow grooves therein affording more limited area and width of passage for the stock and its reduced fibrous particles.

31. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding refiner member, and having in its said plain, rubbing working face arcual flow grooves permitting continuous passage therethrough across said face of fibrous particles to be reduced, and working and reducing fibrous particles by interaction of fibrous material in them with such material in the grooves of the coacting member, and also having an outer facial outflow control zone, with flow grooves thereacross affording more limited area and width of passage for the stock and its reduced fibrous particles, for coacting with said coacting member to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

32. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary refiner member, and having in its said plain, rubbing working face grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, said grooves diminishing in depth toward either side, and also having an outer facial outflow control zone, with flow grooves thereacross affording more limited area and width of passage for the stock and its reduced fibrous particles, for coacting with said coacting member to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

33. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding refiner member, and having in its said plain, rubbing working face grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, said grooves diminishing in depth toward either side so as to force fibrous particles traveling therein against said coacting member and also diminishing in depth outward so as to force the particles more and more against said coacting member as said particles travel outward, and further having an outer facial outflow control zone, with flow grooves thereacross affording more limited area and width of passage for the stock and its reduced fibrous particles, for coacting with said coacting member to control the dwell of the stock in the refining pass between the members and the maximum particle size in the refined product.

34. A rotary-refiner member having a plain,

rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding refiner member, and having in its said plain, rubbing working face flow and working grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, and a removable ring detachably secured to said member affording an outflow control zone at the periphery of its working face, for coacting with said other member to restrict the outflow from the members and control the dwell of fibrous particles in the refining pass between them, said ring having flow grooves across its face providing more limited area and width of passage than the grooves in the working face of the member.

35. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous passage therethrough, across said face, of fibrous particles to be reduced, and also having a facial flow-control zone for coacting with said coacting member to control the dwell of the stock in the refining pass between the coating members and the maximum particle size in the refined stock, and provided with means for adjusting and varying said area and width of passage independently of the gap or working clearance between said refining members.

36. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending grooves for permitting continuous outward passage therethrough, across said face, of fibrous particles to be reduced, and also having an outer facial outflow-control zone for coacting with said coacting member to control the dwell of the stock in the re-

fining pass between the coating members and the maximum particle size in the refined stock, and provided with replaceable means for adjusting and varying said area and width of passage.

37. A rotary-refiner member having a plain, rubbing working face, for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending flow and working grooves for permitting continuous passage therethrough, across said face, of fibrous particles to be reduced and also circumferentially extending redistributing grooves dividing said working face into annular zones and permitting redistribution of fibrous particles amongst the flow grooves of successive zones, and being provided with an outflow control zone at the periphery of its working face, for coacting with said other member to restrict the outflow from the members and control the dwell of fibrous particles in the refining pass between them.

38. A rotary-refiner member having a plain, rubbing working face for coaction with the relatively revolving parallel-moving mating working face of a corresponding rotary-refiner member, and having in its said plain, rubbing working face radially extending flow grooves for passage of fibrous particles to be reduced across said faces, and also having by-pass channel means for passing stock behind an inner zone of the face of said member to an outer zone of said face and thus substantially compensating for the greater circumferential extent of the outer zone and utilizing the areas of the inner and outer zones substantially alike in working the stock, and being further provided with an outflow control zone at the periphery of its working face, for coacting with said other member to restrict the outflow from the members and control the dwell of fibrous particles in the refining pass between them.

DANIEL MANSON SUTHERLAND, JR.