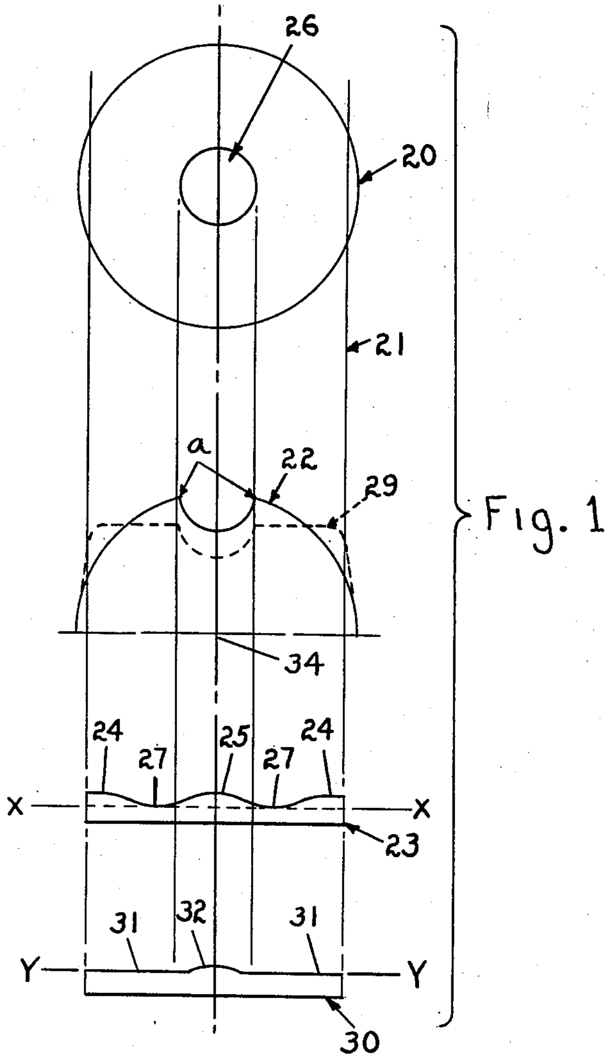
Aug. 4, 1964 J. M. BYAL 3,142,946

GRINDING RUNNER

Filed June 28, 1961 5 Sheets-Sheet 1



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Aug. 4, 1964 J. M. BYAL **3,142,946**

GRINDING RUNNER

Filed June 28, 1961 5 Sheets-Sheet 2

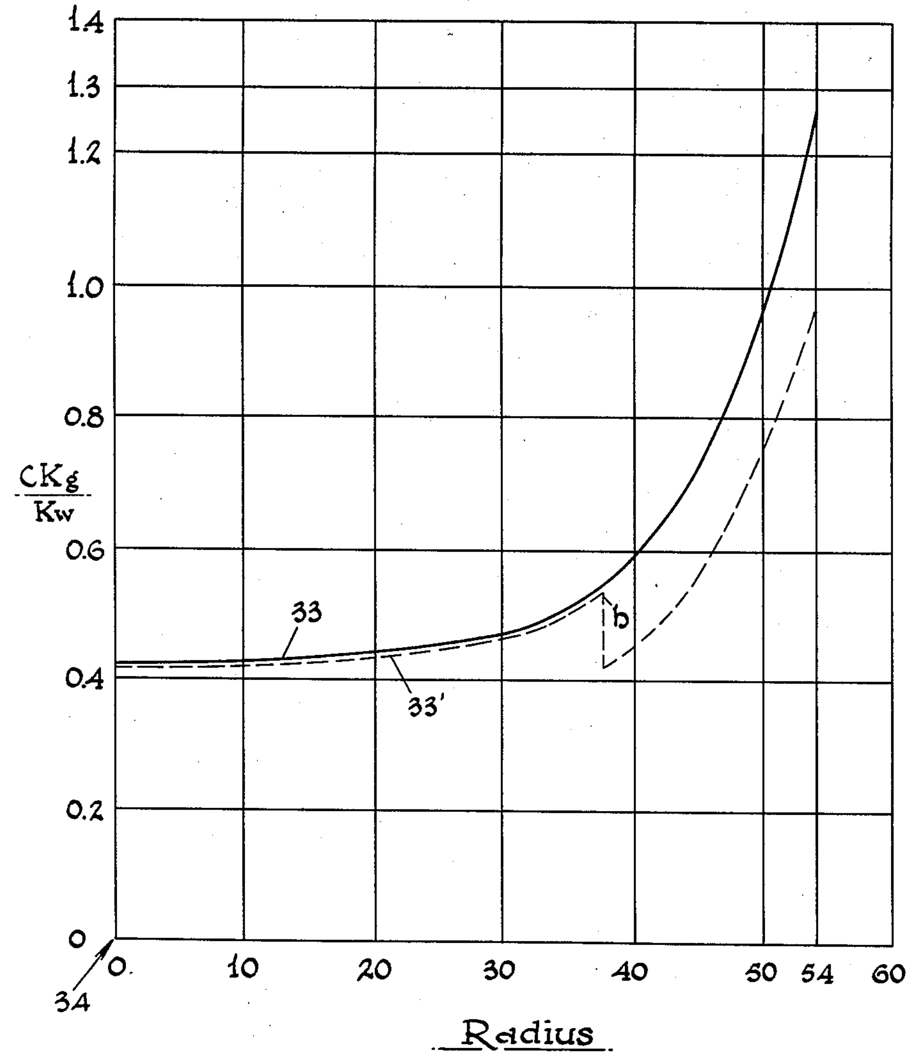

Fig. 2.

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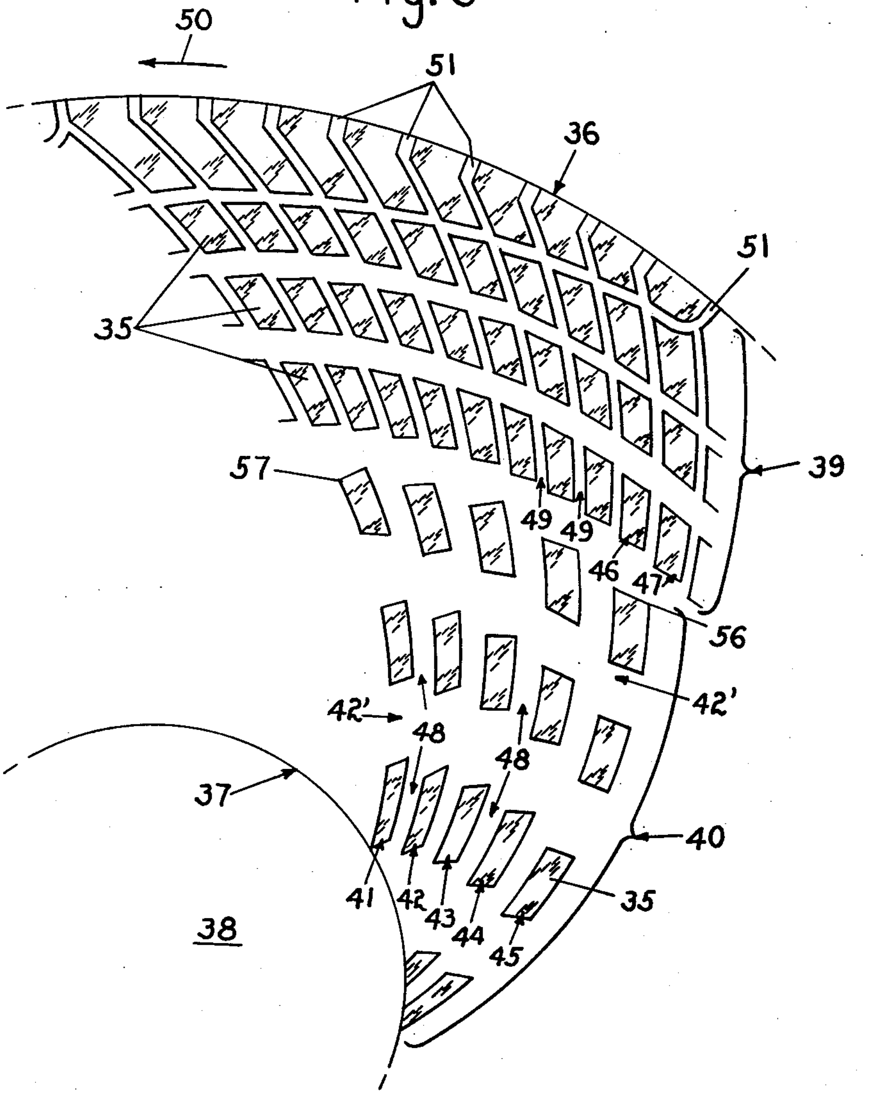
Fig. 3



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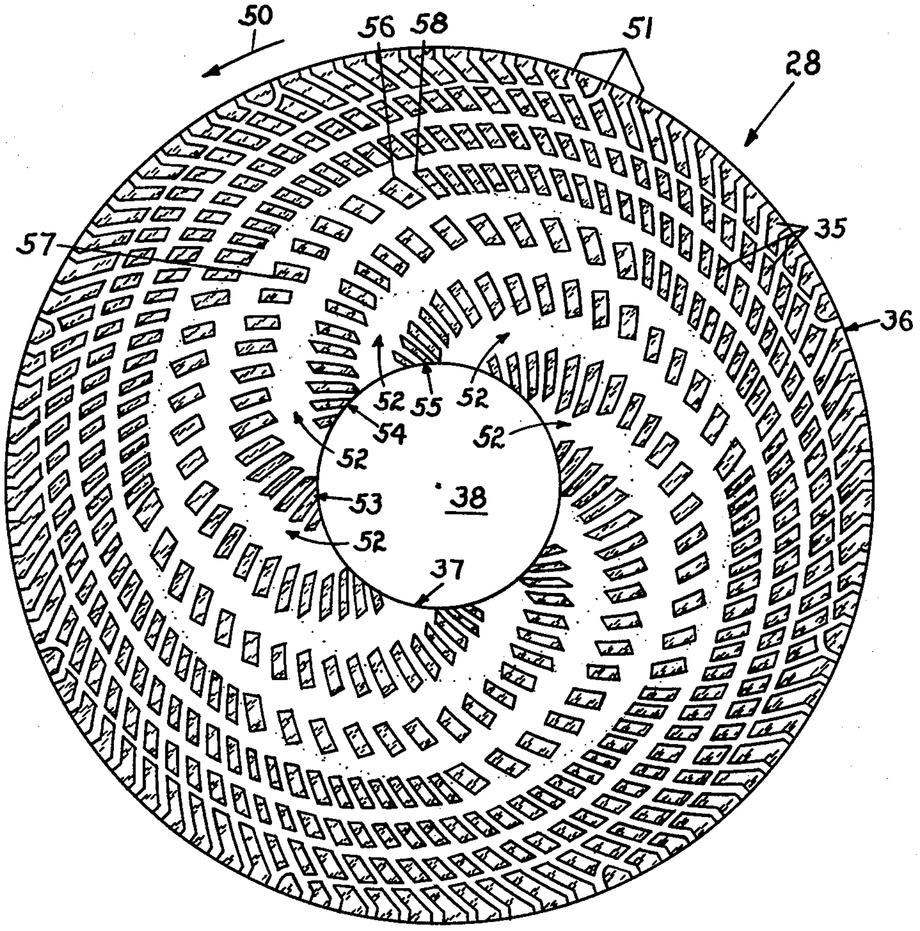
GRINDING RUNNER

Filed June 28, 1961 5 Sheets-Sheet 4

Fig. 4



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GRINDING RUNNER

Filed June 28, 1961 5 Sheets-Sheet 5

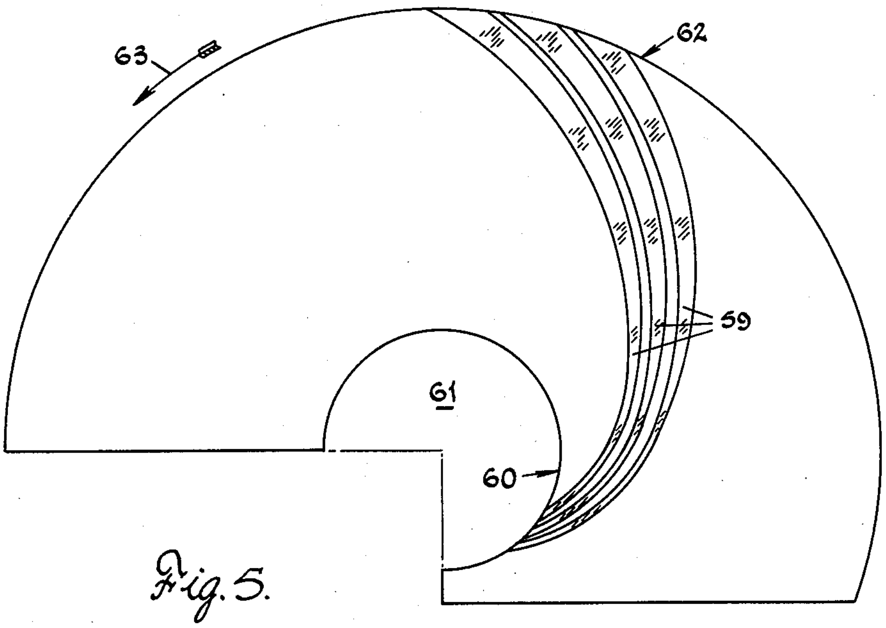

Fig. 5.

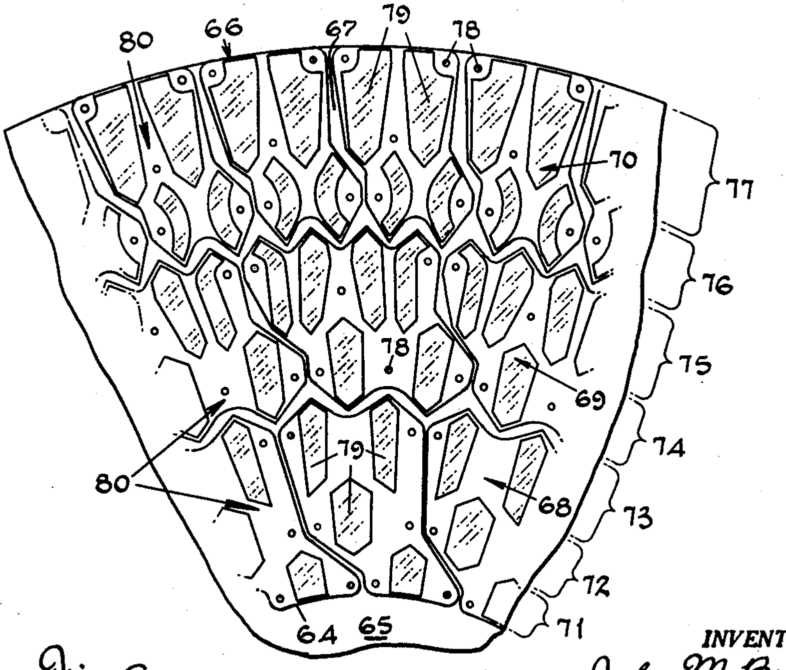

Fig. 6.

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United States Patent Office

3,142,946

Patented Aug. 4, 1964

3,142,946

GRINDING RUNNER

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Filed June 28, 1961, Ser. No. 120,899
7 Claims. (Cl. 51—209)

This invention relates broadly to the surfacing of flat sheets and particularly to improvements in surfacing tools for use in the grinding and polishing of plate glass.

This application is a continuation-in-part of my copending application Serial No. 761,820, filed September 18, 1958, now abandoned.

It is conventional when grinding a continuous ribbon of glass, which has been formed from molten glass in a tank, to grind the opposite faces of the ribbon, either simultaneously or by two separate operations, after it emerges from the annealing lehr. This grinding can be performed either by a series of single spindle grinding runners, positioned to operate on one surface, or by a series of opposed pairs of single spindle grinding runners positioned so as to operate upon both surfaces simultaneously, the runners being usually provided with generally uniformly spaced glass contacting noggins arranged around a central opening, and in any event, an abrasive fluid or slurry such as a mixture of sand and water is applied between the surface of the glass and the runners during grinding. The noggins generally are in the form of raised bosses or other upwardly extending projections and constitute the physical means by which the glass surface is ground.

It has been found that a glass ribbon, ground by either of these methods as heretofore practiced, shows a variation in thickness on its ground surface that reflects a grinding pattern established by the portion of the grinding runner that engages the glass to be ground. Thus a glass ribbon or sheet, when ground under the action of a rotating runner, has thick outer edges from which the thickness gradually decreases on moving towards the center of the ribbon, to the central portion of the sheet in proximity to the central hole or well of the runner where it slightly thickens again.

Because of this variation in thickness, when the sheet subsequently passes between either another opposed pair of substantially parallel grinding runners or under a second single grinding runner, it will be subjected to unequal pressures. If the difference in thickness is too great, the pressure in the thicker areas near the edges or at the center of the ribbon will be sufficient to cause breakage, with a resultant waste of material and loss of time in removing broken pieces from the grinding area.

It is, therefore, a primary object of the present invention to provide more uniform grinding action across the surface of a glass ribbon when acted upon either by a conventional table runner or twin type grinding runner so as to produce a glass ribbon of relatively uniform thickness and uniform quality after grinding.

It is another object of this invention to eliminate longitudinally extending quality streaks in the ground glass surface.

It is still another object to reduce the amount of grinding by finer sands required to reduce ridges resulting from rough grinding.

It is yet a further object of this invention to improve the uniformity of the finished surface of ground plate glass.

It is still a further object of this invention to provide a grinding runner for a grinding unit used in surfacing sheet material having a grinding surface accurately controlled across its entire width with respect to its sheet surface contacting area.

Other objects and advantages of the invention will become more apparent during the course of the following description when taken in connection with the accompanying drawings.

In the drawings, wherein like numerals are employed to designate like parts throughout the same:

FIG. 1 is a graphic representation of the surfacing action of different surfacing runners on a glass ribbon;

FIG. 2 is a graphic representation of the noggin concentration curve for a runner made according to the present invention;

FIG. 3 is a plan view of one octant of the grinding surface of a runner made according to the present invention;

FIG. 4 is a plan view of the entire grinding surface of a runner made according to the present invention;

FIG. 5 is a plan view of another embodiment of the improved grinding runner made in accordance with the present invention; and

FIG. 6 is a plan view of yet another embodiment of the improved grinding runner made in accordance with the present invention.

With particular regard to FIG. 1, there is shown a conventional grinding runner **20**, normally operating on a glass ribbon **21** and in contact therewith during grinding. When the runner **20** is of the present conventional design, that is, when the ratio of the effective grinding area of the noggins, lying in a concentric ring or annulus at any selected radius on the runner to the total area of the same ring is substantially the same as the ratio for a concentric ring taken at any other selected radius, the runner will develop the grinding energy curve shown at **22**. While it is true that the width of the ring itself might have some effect upon the ratio due to the size and location of the individual noggins, particularly if an extremely narrow ring is chosen, this effect will be negligible since it has been found that the ratio is substantially the same for a ring having a width of one inch as for a ring having a width of one foot. This effective noggin grinding area is actually the total of all of the glass contacting portions of each of the individual noggins over which the concentric ring passes, or it might be described as the total area of the runner, within a complete concentric ring at a selected radius, actually in contact with the glass. The total runner area within the ring includes the effective grinding area as well as the area of the slurry distributing spaces between the individual noggins within the same ring. As described above, in conventional runner design it has been noted that the ratio of the effective noggin grinding area to the total runner area is substantially the same for concentric rings taken at any radius across the entire surfacing face of the runner. As the specification proceeds, it will become apparent that this is not true of the runner of the present invention.

Now referring again to FIG. 1, the curve **22**, representing the energy curve of the conventional runners made in accordance with the aforementioned principles, is derived on the basis of the following assumptions:

(1) The energy curve is calculated as though there is no overhang (complete coverage of runner face by the glass). Effect of runner overhang at edges of glass can be ignored without serious error.

(2) Wear rate of noggins is directly proportional to pressure (P) times distance traveled on the glass per revolution (S) and since, for purposes of plotting the curve, it is assumed that the noggins wear down essentially uniformly; $SP=K$ where K is a constant.

(3) Energy expended on any point of glass is proportional to total noggin length passing over point times pressure.

(4) Slurry action at all parts of all noggins is the same.

(5) Effect of glass travel is negligible.

Referring further to FIG. 1, there is shown at **23** the general physical appearance of the glass after rough grinding by a runner developing the energy curve **22**. The glass presents high spots or ridges along the edges of the glass at **24** and at the center **25** of the sheet substantially coincident with the central cutout **26** of runner **20**. These high spots **24** and **25** extend longitudinally of the glass, parallel to the line of movement of the ribbon **21**, and appear essentially as ridges. Between ridges **24** and **25** are valleys **27** which shall herein later be referred to as primary streaks in the glass surface being ground. In order to facilitate the description, only the contour of one glass surface has been shown, that is, the surface ground by a single grinding runner. However, it is understood that the same effect would result on both faces of the ribbon if simultaneously ground by opposed pairs of grinding runners.

The valleys **27** are the result of over grinding because of the greater energy expended at these points. They are referred to as primary streaks because they show up as streaks of poor finish in the glass ribbon when there is insufficient grinding in these areas by later grinding runners.

It is well understood that in order to obtain a plate or sheet having a uniformly smooth surface, all of the glass above line *x—x* (FIG. 1) must be removed by fine grinding. Therefore, if the primary streaks **27** could be eliminated or their depth into the glass surface substantially reduced, the work subsequently required in removing the glass above line *x—x* by fine grinding could instead be used to improve the smoothness of the entire glass ribbon surface.

We have found that the depth of these primary streaks can be eliminated or substantially reduced by the provision of a special type of substantially circular grinding runner **28** (FIG. 4), which will develop the grinding curve **29** shown in dotted outline in FIG. 1 instead of the curve **22** as hereinbefore described. As seen in FIG. 1, this curve **29** does not have excessively high energy peaks such as the energy peaks *a* of curve **22**, but rather has a substantially uniform, i.e. flat or even, contour. Therefore, the primary streaks that are caused by these energy peaks *a* are substantially eliminated from a glass sheet or ribbon ground according to curve **29**, and a substantially flat contour on the glass surface, as seen at **30**, is achieved. The contour is substantially flat along the portions **31** and there is a single ridge **32** along the center coincident with opening **26**. It naturally follows that a lesser amount of grinding is required to remove the glass above line *y—y* when the glass is ground by a runner developing curve **29** than is required to remove the glass above line *x—x*.

It has been found that a grinding curve **29** (FIG. 1) will be developed by a runner in which the area of the runner face portion or working surface which engages the glass to surface the same is controlled across the face of the runner so that the ratio of the effective noggin grinding area to the total runner area, as above defined and discussed, is greatest about the periphery of the runner and gradually diminishes across the runner grinding face on moving towards the runner center.

This principle will be best understood if it is examined in its basic concept without referring to the glass per se. Therefore, the principle will be expressed by a ratio, to be more particularly defined hereinafter, and this ratio will be identified throughout this specification as the "noggin concentration" of the runner, a term familiar to those versed in the plate glass grinding art.

The term "noggin concentration" is best defined by first considering an arc of a circle as being drawn about or on the surfacing face of the runner of the present invention at any given radius from the runner center, this surfacing face itself being defined by a plurality of individual noggins as hereinbefore defined, with spaces therebetween. The arc, whose length will be defined in detail as the description proceeds, will pass over the noggins as well as the spaces between the noggins. Therefore, the noggin concentration will be, in fact, the ratio of the summation of all the parts of the arc that pass over the noggins only (identified as L_n) divided by the total length of the arc (identified as L_a). Expressed mathematically, this true ratio relationship would be expressed as follows:

$$\text{Noggin concentration} = \frac{L_n}{L_a}$$

This ratio (expressed above as a mathematical equation) of the length of the arc that passes over the actual runner surfacing area determined by the noggins to the total length of the arc, including those areas covered by the arc which are actually the spaces between the noggins, is therefore a value capable of mathematical determination along any arc of any runner independently of the shape, dimensions, area and orientation of the noggins.

Ideally, the noggin concentration value should be uniform along any arc at any given radius no matter how small in length be the reference arc chosen to make the determination. However, since the noggins have a finite size, as do the spaces between the noggins, there is a minimum practical length of arc which may be used in the determination of noggin concentration. Actually, in the design of a runner, it is practical and advisable to have a modular noggin pattern (i.e. in other words, a circumferentially repeating noggin pattern). It follows, therefore, that for a selected radius, the length of arc chosen for the determination of noggin concentration at that particular radius should be a whole multiple of the circumferential length of the smallest module of the noggin pattern at that radius. For example, referring to FIG. 4, this would be ⅛ of the circumference or some whole multiple thereof.

Now considering the runner as a whole, rather than only a segment of the runner, the circumference of a circle at a selected radius can be substituted for the value of the length of the arc (L_a) so that the expression of the noggin concentration mathematically becomes:

$$\text{Noggin Concentration} = \frac{L_n}{2\pi R}$$

To relate this to the derivation of the calculated grinding action curve, and for this curve to be rigorously accurate considering noggin concentration only, the noggin concentration would have to be the same at every point on the circle described at any radius. This is important to consider since it must be remembered that the glass is moving as it is ground. Actually, the noggin concentration, as hereinbefore defined, at every single point along a given circumference is not the same because the runner face has spaces as well as surfacing noggins. Therefore, to achieve as closely as possible on the glass a surfacing action in accordance with the calculated grinding action curve **29**, the modules should be made as small as possible. In other words, considering a point on the glass, its travel should be as short as possible during the time that one module of the runner is passing over the point.

In the present conventional runner, i.e. that developing curve **22**, this noggin concentration, as above defined, is normally substantially constant or has only slight differences in its value on moving across the operating surface of the runner from the center cutout to the periphery. However, the noggin concentration of the improved runner of the present invention follows a graduated curve, or it has a progressively decreasing value on moving from the periphery to the center cutout. This is illustrated by the curve **33** in FIG. 2. In FIG. 2, the horizontal axis represents the radius of the runner as measured from its center **34**, and the vertical axis represents the ratio

$$\frac{CKg}{Kw}$$

where C is the noggin concentration as above described, while K*g* and K*w* are the glass removal coefficient and noggin wear coefficient, respectively, for a particular type of glass, grinding slurry and noggin material.

In this regard, it has been found that for a given grinding system including a particular glass, grinding slurry and noggin material, the rate of glass removal and the noggin wear rate are related to noggin speed and noggin pressure as follows:

$$G=SPKg$$

where

G=rate of glass removal
S=noggin speed with respect to the glass
P=noggin pressure
Kg=glass removal coefficient

$$W=SPKw$$

where

W=noggin wear rate
Kw=noggin wear coefficient
S and P are as above defined

K*g* and K*w* are, in general, constant for a given grinding system, that is, for a uniform glass sheet being surfaced by a single type of runner and grinding slurry. If the system is changed, as for example by changing the noggin material as will later be described, then the values of K*g* and K*w* may be altered. It will thus be seen that for a grinding system using runners having a single, uniform noggin wear coefficient, the ratio of

$$\frac{Kg}{Kw}$$

will be constant. As a result, the curve **33** of FIG. 2 will represent the noggin concentration C, multiplied by a constant

$$\frac{Kg}{Kw}$$

which can be disregarded when considering the noggin concentration ratios across the face of the runner. Curve **33** thus becomes the noggin concentration curve for the runner and is plotted by joining the individual noggin concentrations at different radii of the runner as measured from the center of the runner. It is here noted that curve **33** is a specific noggin concentration curve for a 108 inch runner, surfacing a 100 inch glass ribbon. The zero point **34** represents the actual center of the runner, and the radius values (i.e. R) represent the runner radius moving from the center **34** toward the runner periphery. Although the curve **33** has been shown as theoretically extending to the center of the runner, it will be understood that there are no noggins in the central cutout **26** for reasons to be hereinafter explained, and therefore in actual runner design the curve **33** would stop at the edge of the cutout.

The results achieved by the use of the improved runner are, as above noted, best illustrated in FIG. 1 where there is shown at **30** the general contour of a glass sheet after grinding by the improved runner developing curve **29**. It is specifically noted that in addition to the flat contour **31**, the ridge **32** (FIG. 1) is of substantially reduced height as measured from flat portions **31** when compared to either ridges **24** or **25**. Accordingly, much less fine grinding will be necessary to remove the ridge **32** to secure a uniformly smooth surface across the entire sheet than would be needed to level the contour of a sheet ground according to curve **22**. The resulting saving of energy necessary for fine grinding can therefore be used to improve the uniform smoothness of the sheet and, accordingly, an improved ground glass ribbon can be obtained.

Referring to FIGS. 3 to 6 inclusive, there are illustrated a number of specifically different forms of grinding runners which can be used to achieve the uniform smooth distribution of grinding energy and to develop the grinding curve **29** in accordance with this invention. In connection with these, it will be understood that it is most desirable to strive for structural simplicity and yet at the same time to achieve the improved results that follow from the application of this invention. Since the general configuration of conventional grinding runners is well known, only those portions of the runner which are believed to be necessary for a complete understanding of this invention have been shown and will now be described.

In FIGS. 3 and 4, there is shown one runner which will develop the curve **29**. While this embodiment of FIGS. 3 and 4 will be described by reference to a specific number of noggin lines and their arrangement within two general areas, it is to be understood that this embodiment represents but one application of the broad concept of the invention to a particular runner, and it is not intended to restrict or limit the invention to the specific configuration illustrated and hereinafter discussed. The runner surface or operating surface is composed of a plurality of noggins **35** disposed so that the noggin concentration, as above defined, diminishes on moving from the periphery **36** of the runner to the edge **37** of the central opening **38**. In FIG. 3, there is shown one octant of the improved runner and the noggins **35**, as shown in this preferred embodiment, are arranged in two general areas, one indicated at **39** adjacent the periphery **36** and the second indicated at **40** adjacent edge **37** of the central opening **38**. In area **40** there is illustrated, in this embodiment, five outwardly spiraling noggin lines **41**, **42**, **43**, **44** and **45**. Each of these noggin lines is composed of a series of individual noggins **35** that form what is similar to a continuous bar that has been interrupted by graduated spaces **42′**. These spaces form a channel to be later described. The number, size and shape of the noggins **35** in each line, as well as the number of lines of noggins, will vary in a manner calculated to provide the desired noggin concentration as above defined, it being necessary according to the present invention to increase the noggin concentration, or grinding area per unit of runner area, in moving from the central portion toward the outer edge or periphery in order to attain the grinding curve **29**.

As each noggin line in area **40** passes into the second area **39**, it is noted that instead of a line of single noggins, each noggin line, for example line **45**, is composed of two parallel noggin lines **46**, **47** of single noggins **35** that continue the general spiral noggin line form toward the outer edge **36**. Therefore, the even spiral initiated by the noggin line **45** in area **40** is split into two noggin lines **46**, **47** that continue spiraling outwardly toward the periphery **36**. Likewise, the outwardly directed channels **48**, between the noggins in area **40**, split into an increased number of additional channels **49** between the more numerous noggins **35** of area **39**. The channels **49**, however, remain in parallel relationship to one another and continue the same spiraling pattern established by channels **48**. The channels **49**, on arriving at the periphery **36**, turn slightly in a direction away from arrow **50** which indicates the direction of rotation of the runner, and channels **49** are in free communication with openings **51** formed in periphery **36**.

Each octant (FIG. 3) is the same as all others, and when each is placed in proper relationship to all others, they combine to form a runner as shown in FIG. 4. In FIG. 4, the spiral form of the noggins **35** in each octant is clearly evident from the joining of all octants into a single unit. Thus, it is seen that the spiraling noggin lines **41–45** of each octant are all formed so as to spiral from the center opening **38** and to bend or spiral toward the direction of rotation of the runner (arrow **50**), while the channels **52**, to be later described, spiral outwardly and counter to the direction of rotation.

The 2:1 ratio of lines of noggins between areas **39** and **40**, as shown in the embodiment of FIGS. 3 and 4, has been found desirable under certain circumstances. However, other ratios of lines of noggins could be used, or the noggins could be arranged in more than two areas as long as their arrangement would result in the noggin concentration across the operating surface of the runner being substantially that shown by curve **33** in FIG. 2. In addition, if desired, there could be a single noggin area instead of the separate areas **39** and **40** shown and discussed above, in which case the noggin lines **41** through **45** could be continued and only the size of the noggins **35** increased or otherwise varied on moving toward the periphery of the runner, it being necessary only to secure the proper progressive variation of noggin concentration according to the curve **33** (FIG. 2). Furthermore, it is desirable that when the proper noggin concentration is realized, the noggins themselves be individually arranged to avoid discontinuities as will later be discussed.

Referring to FIG. 4, it is noted that the noggins **35** are positioned and shaped to follow a second series of spiral lines or rows, i.e. rows **53**, **54** and **55**, which spiral outwardly with respect to the runner center **38**, and describe a spiraling path of ever increasing radius which follows a course substantially counter-directional to the path of rotational movement of the runner indicated by arrow **50**.

The channels **52** formed between rows **53**, **54**, **55** which decrease in width in running from the center **38** toward the periphery **36**, have been carefully located so as to avoid any discontinuities in the noggin concentration curve **33** which would produce secondary streaks. Such secondary grinding streaks across the face of the surfaced glass result when the runners used have concentric rings of grinding noggins with the rings of noggins being separated by channels also formed concentrically about the center of the rotating runner. Thus, according to the present invention, the noggins are overlapped to avoid discontinuities in the noggin concentration curve, that is, the rows of noggins spiral in a manner which insures proper noggin overlap so that the noggin concentration at any radial distance from the center of the runner, determined in the manner earlier defined, will fall along the desired noggin concentration curve, in this instance the curve **33** of FIG. 2.

This overlapping of the noggins is best illustrated by reference to FIGS. 3 and 4. It will be seen therein that the noggins **35** of adjacent octants which lie in the same spiral noggin row, i.e. rows **53**, **54**, **55**, are positioned so that, for example, point **56** of one noggin is located a further lineal distance from the center opening **38** along the spiral noggin line **45** than is point **57** on a corresponding noggin in spiral noggin line **41** of the same octant. The point **58** of the first noggin in the adjacent octant in row **53** is aligned with point **56**, and the same relationship exists between points of the first and last noggins of this octant as exists between the points **56** and **57** of the preceding octant. In other words, in going from the center **38** to the periphery of the runner along the spiral noggin rows, i.e. **53**, **54**, **55**, each succeeding noggin extends outwardly from the center of the runner a greater distance than the noggin preceding it, while at the same time extending inwardly beyond the outer end of the preceding noggin. It will be seen, therefore, that as the runner rotates through one complete revolution, each row of the noggins **53**, **54**, **55** etc. will traverse the entire surface of the glass ribbon passing therebeneath, thereby minimizing secondary grinding streaks.

As a result of the arrangement of the noggins, eight outwardly spiraling channels **52** are formed between the rows of noggins. Each channel **52** sweeps successively through adjacent octants, intersecting channels **48** and **49**, and terminates at periphery **36** in an opening **51** where two adjacent octants meet. It is therefore seen that channels **48**, **49** and **52** constantly intersect across the surface of the runner to direct the flow of abrasive around all the grinding noggins and outwardly toward the periphery of the runner.

Referring now to FIG. 5, there is shown a modification of the present invention wherein the solid bar type of noggin **59** extends from the edge **60** of center opening **61** to the peripheral edge **62**. It is noted that the continuous bar **59** spirals generally in the direction of arrow **63**, the direction of rotation, and also that the individual bars **59** are of a reduced width at or near the edge **60** of center opening **61** and progressively increase in size on moving towards peripheral edge **62**. Thus, the runner conforms to the noggin concentration curve **33** of FIG. 2, while at the same time eliminating the possibility of discontinuities in the curve.

With grinding runners of the type heretofore used, it is necessary to leave a rather large central opening, or area free of noggins, in the runner to eliminate possible breaking of the glass ribbon caused by excessive pressure at the runner center. The greater pressure at the center of the runner is caused in part by the natural tendency of the runner to distort when a load is applied at its center. However, a greater portion of the variation in pressure across the face of the runner is caused by uneven wearing of the noggins. Since the noggins near the periphery of the runner travel a greater distance in contact with the glass ribbon than do the noggins nearer to the center of the runner, they tend to wear down faster than the interior noggins. Consequently, the noggins exert a greater pressure on the central portion of the ribbon than on its edges and may cause it to break.

To overcome this variation in pressure across the face of the runner, noggins having different wear coefficients may be provided in different areas of the runner. Thus, the noggins near the central opening of the runner may be made of a material having a faster wear coefficient than the noggins near its periphery. By the proper selection of noggin materials, it is possible to compensate for the difference in distance traveled in contact with the glass ribbon by the noggins located at different positions on the runner face, thereby causing the noggins near the center of the runner to be worn away, or shortened, by the same amount as those near the periphery during each revolution of the runner. As a result, the noggins, even after extended use, will exert approximately the same pressure upon the ribbon near the periphery of the runner as at the center thereof.

Referring to FIG. 6, there is shown a further modification of the present invention wherein the noggins are positioned upon the runner according to the noggin concentration principles hereinbefore discussed, that is, so that the noggin concentration progressively increases from its minimum at or in proximity to the edge **64** of the central opening **65** of the runner to a maximum value at the peripheral edge **66**. Additionally, the embodiment of FIG. 6 is particularly adapted to the use of noggins having different wear coefficients, although it will be understood that the principle of varying the wear coefficients of the noggins may also be applied to any of the earlier described runners.

Thus, attached to the runner deck **67** in a series of repeating modules are an inner pad **68**, an intermediate pad **69** and an outer pad **70** having rows of noggins **71**, **72**, **73**, **74**, **75**, **76** and **77** cast integral therewith. The pads **68**, **69** and **70** are secured to the runner deck at **78** by bolts or other suitable fasteners. The individual noggins **79** in adjacent rows are positioned so that the channels **80** between the noggins are irregular, thereby insuring an adequate flow of abrasive completely around each grinding noggin during rotation of the runner. Discontinuities in the noggin concentration curve are avoided by overlapping the noggins in adjacent rows (i.e. rows **71–77**) an amount sufficient to provide the desired noggin concentration in the region of overlap. By this overlapping of the noggins, secondary streaking of the glass ribbon being ground is avoided.

While the noggins of the embodiment of FIG. 6 have been shown as attached to three separate pads or bars **68**, **69** and **70**, it is contemplated that each row of noggins **71–77**, or any combination of the rows, may have a different wear coefficient to thereby provide the desired variation from the center opening to the periphery of the runner. The variation in noggin wear coefficient may be obtained in a number of ways, as for example by making the noggins from different materials or by heat treating or annealing the noggins differently. Cast iron, hot-rolled steel and cast aluminum are examples of metals which have been found satisfactory as noggin material.

Substantial reductions in the variation of pressure across the runner face have been obtained in the embodiment of FIG. 6 by providing noggins attached to the outer pad **70** having one wear coefficient and noggins attached to the intermediate pad **69** and the inner pad **68** having a second, faster wear coefficient. Thus the noggins in rows **71–75** may be made, for example, from annealed cast iron while these in rows **76** and **77** may be made from unannealed cast iron or some other material having a slower wear coefficient than annealed cast iron.

When the wear coefficient of the noggins is varied across the face of the runner, the value of

$$\frac{Kg}{Kw}$$

as hereinbefore described also may vary, that is, each different noggin wear coefficient may produce a different value of

$$\frac{Kg}{Kw}$$

Since it is desirable to obtain the flat grinding energy curve **29** of FIG. 1 with the runner having noggins of varying wear coefficient, it is necessary that the values of

$$\frac{CKg}{Kw}$$

for the runner, as earlier defined, fall along the curve **33** of FIG. 2. The curve **33** may not, however, represent the noggin concentration because the value of

$$\frac{Kg}{Kw}$$

may have changed. Instead, for a runner having noggins with two different wear coefficients as described in connection with the embodiment of FIG. 6, the noggin concentration curve may appear as shown in broken lines at **33'** in FIG. 2, with *b* representing the radius at which the noggins change from the faster to the slower wear coefficient. It will be seen that in order to obtain a continuous curve **33** for the value of

$$\frac{CKg}{Kw}$$

in a runner having noggins with different wear coefficients, that is, so that the curve will not be offset at the point or points where the noggin wear coefficient changes, it is necessary to increase or decrease the noggin concentration by an amount inversely proportional to the relative values of the ratio

$$\frac{Kg}{Kw}$$

for the different noggins.

By arranging the noggins according to the curve **33** as hereinbefore discussed, the areas of over grinding near the center opening of the runner, as shown at **27** in FIG. 1, are eliminated. Likewise, the excessive pressure at the central portion of the ribbon caused by uneven wearing of the noggins is eliminated by using noggins having different wear coefficients as earlier described. It is thus possible to position noggins closer to the center of the runner than has heretofore been practicable with runners having uniformly distributed noggins of the same wear coefficient, thereby allowing for more grinding action in the central portion of the ribbon.

According to one specific embodiment of the invention, the effective noggin working surface extends to within 15½ inches of the runner center where the runner is 108 inches in diameter and operates on a glass ribbon 100 inches wide. It will be understood, of course, that the same principles are applicable to runners of various diameters operating on different width ribbons. As a result of extending the effective noggin working surface nearer to the center of the runner, the grinding curve **29** of FIG. 1 is further flattened and the central ridge **32** on the glass ribbon coincident with the center cutout **26** of the runner is reduced in width.

It is to be understood that the forms of the invention herewith shown and described are to be taken as illustrative embodiments only of the same, and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of the invention.

I claim:

1. A substantially circular grinding runner adapted to provide more uniform distribution of grinding action across the width of the glass sheet, said runner having a working surface comprising a plurality of noggins positioned so as to provide an ever increasing noggin concentration from the runner center to the runner periphery, said noggins being arranged in individual lines outwardly spiraling from the runner center in the direction of rotation of the runner, a plurality of first channels between said noggins, said first channels spiraling outwardly from the runner center in a direction counter to the direction in which the runner is rotated, and a plurality of second channels formed between said noggins, said second channels spiraling outwardly from the runner center and in the same direction as the direction in which the runner rotates.

2. A substantially circular glass surfacing runner having a working surface engaging the surface of the glass, said working surface comprising a plurality of noggins positioned so as to provide an ever increasing noggin concentration from the runner center to the runner periphery, the noggins in proximity to the runner center having a faster wear coefficient than the noggins positioned outwardly thereof and in proximity to the runner periphery.

3. A substantially circular glass surfacing runner having a working surface engaging the surface of the glass, said working surface comprising a plurality of noggins positioned on the runner in a plurality of concentric rows, the noggins in the rows in proximity to the runner center having a faster wear coefficient than the noggins in the rows positioned outwardly thereof and near the runner periphery, the noggins being arranged so that the ratio

$$\frac{CKg}{Kw}$$

ever increases from the runner center to the runner periphery, where C is the noggin concentration, Kg is the glass removal coefficient, and Kw is the noggin wear coefficient.

4. Apparatus for use in the surfacing of glass sheets to achieve uniform grinding action across the width of the sheet, comprising a substantially circular runner adapted to rotate about an axis normal to said sheet and having a working surface engaging the sheet, said runner including a runner deck, a plurality of pads secured to said runner deck in concentric circles about said axis, said working surface being formed by a plurality of individual noggins cast integrally with said pads and positioned in a plurality of concentric rows about said axis so as to form irregular channels therebetween for receiving a flow of abrasive medium, the noggins in adjacent concentric rows overlapping, and the noggins in the inner concentric rows having a faster wear coefficient than those in the rows positioned outwardly thereof near the runner periphery, said noggins being arranged so that the ratio

$$\frac{CKg}{Kw}$$

ever increases from the runner center to the runner periphery, where C is the noggin concentration, K_g is the glass removal coefficient, and K_w is the noggin wear coefficient.

5. A substantially circular glass surfacing runner having a working surface engaging the surface of the glass, said working surface comprising noggins arranged on the runner face so as to be separated by channels through which the grinding slurry is distributed across the runner face and so that the ratio of the length of the glass engaging portion of all of the noggins encountered by a concentric circle described on the runner face at any radius to the circumference of the circle at the same radius, including the spaces between the noggins, is always greater for a concentric circle taken at a greater radius on the runner face than for a concentric circle taken at a lesser radius, said noggins being positioned about the runner in concentric rows, the noggins in adjacent rows overlapping, and the channels between the noggins being discontinuous to thereby provide an adequate supply of slurry around each noggin.

6. Apparatus for use in the surfacing of glass sheets to achieve uniform grinding action across the width of the sheet, comprising a substantially circular runner adapted to rotate about an axis normal to said sheet and having a working surface engaging the sheet, said runner including a runner deck, a plurality of pads secured to said runner deck in concentric circles about said axis, said working surface being formed by a plurality of individual noggins cast integrally with said pads and positioned in a plurality of concentric rows about said axis so as to form irregular channels therebetween for receiving a flow of abrasive medium, the noggins in adjacent concentric rows overlapping, said noggins being arranged so that the noggin concentration ever increases from the runner center to the runner periphery.

7. A method of increasing the uniformity of distribution of grinding action across the width of a glass sheet to produce a sheet of relatively uniform thickness after grinding, including the steps of moving the glass along a predetermined path at a substantially uniform rate, moving a plurality of noggins, some of which have different wear coefficients than others, in a plurality of circular paths about a common center and in abrasive contact with at least one surface of the glass, with the concentration of said noggins increasing outwardly from said center and with noggins that exhibit the fastest wear coefficient nearest said center.

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