

Nov. 21, 1939.

E. D. TILLYER

2,180,887

OPHTHALMIC LENSES, SERIES OF SAID LENSES, AND METHOD OF MAKING THE SAME

Filed March 31, 1937

2 Sheets-Sheet 1

True Front Surface Powers(Index 1.5232)										
Series	I	II	III	IV	V	VI	VII	VIII	IX	X
Thickness in mm	1.904	2.176	2.539	3.046	3.385	3.805	4.352	5.077	6.093	7.616
Mag. S-I										
0.25%	+1.995	+1.746	+1.496	+1.247	+1.122	+0.998	+0.873	+0.748	+0.623	+0.499
0.50	3.980	3.483	2.985	2.488	2.239	1.990	1.741	1.492	1.244	0.995
0.75	5.955	5.211	4.466	3.722	3.350	2.978	2.606	2.233	1.861	1.489
1.00	7.921	6.931	5.940	4.950	4.456	3.960	3.465	2.970	2.475	1.980
1.25	9.876	8.642	7.407	6.173	5.556	4.938	4.321	3.704	3.086	2.469
1.50	11.823	10.345	8.867	7.389	6.650	5.911	5.172	4.434	3.695	2.956
1.75	13.759	12.039	10.319	8.599	7.740	6.880	6.019	5.160	4.300	3.440
2.00	15.686	13.725	11.765	9.804	8.824	7.843	6.863	5.882	4.902	3.922
2.25	17.604	15.403	13.203	11.002	9.901	8.803	7.702	6.602	5.501	4.401
2.50	19.512	17.073	14.634	12.195	10.976	9.756	8.537	7.317	6.098	4.878
2.75		18.735	16.058	13.382	12.044	10.706	9.368	8.029	6.691	5.353
3.00			17.475	14.563	13.107	11.651	10.194	8.738	7.282	5.825
3.25			18.886	15.738	14.165	12.591	11.017	9.443	7.869	6.295
3.50				16.908	15.217	13.526	11.836	10.145	8.454	6.763
3.75				18.072	16.265	14.458	12.651	10.843	9.036	7.229
4.00				19.231	17.308	15.385	13.461	11.539	9.615	7.692
4.25					18.345	16.307	14.269	12.230	10.192	8.153
4.50						17.225	15.072	12.919	10.766	8.612
4.75						18.138	15.871	13.604	11.335	9.069
5.00						19.048	16.667	14.286	11.905	9.524
5.25							17.459	14.964	12.470	9.976
5.50							18.246	15.640	13.033	10.427
5.75								16.312	13.593	10.875
6.00								16.981	14.151	11.321
6.25								17.647	14.706	11.765
6.50								18.310	15.258	12.207
6.75									15.808	12.646
7.00									16.357	13.084
7.25									16.900	13.520
7.50									17.442	13.953
7.75									17.981	14.385
8.00									18.519	14.815
8.25										15.242
8.50										15.668
8.75										16.092
9.00										16.514
9.25										16.934
9.50										17.351
9.75										17.768
10.00%										18.182

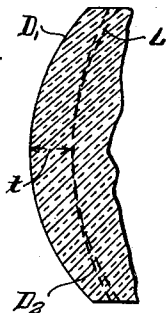


Fig. I

Fig. III

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OPHTHALMIC LENSES, SERIES OF SAID LENSES, AND METHOD OF MAKING THE SAME

Filed March 31, 1937

2 Sheets-Sheet 2

Tabular Values Give Zero Effective Power.
For Power Lenses Add The Rx To The Ocular Surface.

Index 1.5232
True 1.5232 Powers On Ocular Surface, (Concave)

B

H K J

Series	I	II	III	IV	V	VI	VII	VIII	IX	X
Thickness in $\frac{1}{16}$ "	1.904	2.176	2.539	3.046	3.385	3.805	4.352	5.077	6.093	7.616
Mag. S-1										
+ 0.25%	-2.	-1.75	-1.50	-1.25	-1.12	-1.00	-0.87	-0.75	-0.62	-0.50
0.50	4.	3.50	3.	2.50	2.25	2.	1.75	1.50	1.25	1.00
0.75	6.	5.25	4.50	3.75	3.37	3.	2.63	2.25	1.87	1.50
1.00	8.	7.	6.	5.	4.50	4.	3.50	3.	2.50	2.
1.25	10.	8.75	7.50	6.25	5.62	5.	4.37	3.75	3.12	2.50
1.50	12.	10.50	9.	7.50	6.75	6.	5.25	4.50	3.75	3.
1.75	14.	12.25	10.50	8.75	7.87	7.	6.12	5.25	4.37	3.50
2.00	16.	14.	12.	10.	9.	8.	7.	6.	5.	4.
2.25	18.	15.75	13.50	11.25	10.12	9.	7.87	6.75	5.62	4.50
2.50	-20.	17.50	15.	12.50	11.25	10.	8.75	7.50	6.25	5.
2.75		-19.25	16.50	13.75	12.37	11.	9.62	8.25	6.87	5.50
3.00			18.	15.	13.50	12.	10.50	9.	7.50	6.
3.25			-19.50	16.25	14.62	13.	11.37	9.75	8.12	6.50
3.50				17.50	15.75	14.	12.25	10.50	8.75	7.
3.75				18.75	16.87	15.	13.12	11.25	9.37	7.50
4.00				-20.	18.	16.	14.	12.	10.	8.
4.25					-19.12	17.	14.87	12.75	10.62	8.50
4.50						18.	15.75	13.50	11.25	9.
4.75						19.	16.62	14.25	11.87	9.50
5.00						-20.	17.50	15.	12.50	10.
5.25							18.37	15.75	13.12	10.50
5.50							-19.25	16.50	13.75	11.
5.75								17.25	14.37	11.50
6.00								18.	15.	12.
6.25								18.75	15.62	12.50
6.50								-19.50	16.25	13.
6.75									16.87	13.50
7.00									17.50	14.
7.25									18.12	14.50
7.50									18.75	15.
7.75									-19.37	15.50
8.00										16.
8.25										16.50
8.50										17.
8.75										17.50
9.00										18.
9.25										18.50
9.50										19.
9.75										19.50
10.00%										20.

The front surface powers, (convex) are given on Chart A.
For convenience the eighths are given to the nearest 0.01D
The exact eighths are 0.005 D greater.

Fig. II

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2,180,887

OPHTHALMIC LENSES, SERIES OF SAID LENSES, AND METHOD OF MAKING THE SAME

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Application March 31, 1937, Serial No. 134,076

4 Claims. (Cl. 88—54)

This invention relates to improvements in ophthalmic lenses and has particular reference to improved lenses, series of lens blanks and method of making the same.

5 One of the principal objects of the invention is to provide a series of semi-finished lens blanks graded in each series in equal steps of shape magnification and method of making the same whereby the ocular surface of each lens blank may be altered to introduce the required prescriptive focal power without introducing odd fractions of the diopter so that the tools available in the usual prescription shop can be used for putting on these finished surfaces.

10 Another object of the invention is to provide a series of lens blanks having factory made specially formed curved surfaces on one side thereof which with a given thickness will produce the shape magnification factor of the finished lens and which will enable the selection of a power surface to be added to the ocular or opposite surface of the lens which may be generated by the commercial curve generating tools now in common use by lens dispensers to obtain the focal power desired in combination with said shape magnification.

15 Another object is to provide an improved lens and method of making the same of such a thickness that the shape magnification is an integer per cent and an integer fraction of a per cent greater than unity when the ocular surface power is made in integer diopters and integer fractions of a diopter for a focal power prescription in integer diopters and an integer fraction of a diopter combined with a front surface power which gives the required focal power.

20 Another object is to provide lens blanks giving desired shape magnification values to which the desired prescriptive focal power may be added without changing said shape magnification values.

25 Another object is to provide a method of dispensing ophthalmic lenses whereby a plurality of lens blanks having characteristics producing shape magnification values in graded percentages may be carried in stock by the dispensers and which may be selected in accordance with predetermined figures giving the resultant characteristics which the lens should have in order to obtain the shape magnification desired and the ocular surface power which is to be added to the prescriptive focal power to obtain the required optical surface power while maintaining the shape magnification value.

30 Other objects and advantages of the invention will become apparent from the following description

taken in connection with the accompanying drawings and it will be apparent that many changes may be made in the various details, arrangements and methods herein described without departing from the spirit of the invention as expressed in the accompanying claims. I, therefore, do not wish to be limited to the exact details, arrangements and methods shown and described, as the preferred forms only have been set forth by way of illustration.

Referring to the drawings:

Fig. I is the chart A embodied in the invention and listing the convex surfaces or front surfaces; and

Fig. II is a similar view of another chart B embodied in the invention, giving tabular values for zero effective power.

Fig. III is a sectional view through one of the lens blanks of the series and illustrating the essential features of the invention.

Heretofore, it has been usual in the forming of ophthalmic lenses embodying both a correction for shape magnification and for focal power to compute and manufacture said lenses individually. Such computations have been lengthy, difficult and costly and also hindered the dispensing of the lenses due to the time required in computing and forming such lenses with the result that the lenses have been difficult to obtain.

It, therefore, is one of the primary objects of this invention to overcome the above difficulties by providing a series of lens blanks graded in step percentages of magnification which may be supplied the dispenser and which may be finished in the manner usual in the art by his usual stock tools in obtaining the focal prescriptive power desired in combination with said shape magnification values.

Referring more particularly to the drawings, it will be noted that the chart A, shown in Fig. I, gives the true front or convex surface powers for lenses formed of glass having an index of refraction of 1.5232. In this chart the first column of figures under the heading "Mag. S'—1" indicated at E, is given per cent magnifications in steps of 1/4 per cent. The front surface curvatures of each series numbered with headings I, II, III, etc., are given in each corresponding column as indicated at F. The thickness to which each lens of a series is to be formed in combination with the front surface powers listed in each column is indicated at G alongside of the title "Thickness in mm.". Therefore, if a lens having a 0.25 magnification is desired with the thickness 1.904 mm. a blank having a front surface power of 1.995 is se-

lected. If the finished thickness is to be 2.176 mm. a blank having a front surface power of 1.746 is selected, etc. If the magnification desired is 0.50% and the thickness is to be 1.904 a blank having a front surface power 3.980 is selected. If the thickness is to be 2.176 a blank having a front surface power of 3.483 is selected, etc. It will be seen from the above that by reference to chart A lens blanks having the desired characteristics for obtaining the magnification value of the prescription may be quickly and easily selected. It is to be noted, however, that these blanks are selected to their resultant aesthetical and optical features, that is, some of the lens blanks by which the desired per cent magnification will have better optical properties as regards marginal, focal and astigmatic errors than other of said lens blanks and will also be better appearing. This, however, is well known in the art and due to the fact that several lens blanks having this different front surface powers and different thicknesses producing the same magnification values are provided in the chart, knowledge as to the resultant optical characteristics and appearance of lenses having different front surface and thickness will enable the dispenser to select the most practical lens blank for the lens desired.

It will be noted that these front or convex surfaces are to be made at the factory and require the use of special tools. By special tools it is meant that the usual standard lens surfacing tools used by the dispenser cannot be employed in forming these front or convex surfaces as they do not possess the proper surface powers.

Blanks having the surface powers listed in chart A and having thickness in excess to the thicknesses listed alongside of the title "Thickness in mm." are, therefore, provided the dispenser and are adapted to be finished in the same manner as other commercial lens blanks used in the art.

The chart B shown in Fig. II lists in the columns I, II, III, etc., the ocular surface powers which may be combined with the corresponding convex of front surface powers given in each respective column I, II, III, etc., of chart A to produce lenses having zero effective power.

It will be noted that chart B has magnification values listed under the title "Mag. $S'-1$ " as shown at H similar to the corresponding magnification values listed at E in chart A and that alongside of each given per cent magnifications in each of the columns I, II, III, etc., as illustrated at J is given the ocular or concave surface which is to be combined with the front or convex surfaces listed at F in columns I, II, III, etc., of chart A. As stated above these ocular or concave surface powers when combined with the corresponding front or convex surface powers will produce a lens having zero effective power. To obtain the focal power desired with the shape magnification value of the respective blank selected the focal power is added algebraically to the ocular surface power. This will be set forth more in detail in the following discussion of the invention.

Referring to chart B it will be noted that the finished thickness of the lenses of each series are given alongside of the title "Thickness in mm." as illustrated at K. The thickness for each lens series given in the columns I, II, III, etc., correspond with the thicknesses given in the respective columns of chart A.

It is to be noted that when the focal power

to which the lens is to be formed is added algebraically to the ocular surface powers indicated in columns I, II, III, etc., the resultant required surface power which is to be formed on said ocular surface will follow directly within the range of the surface powers of commercial tools carried in stock by lens dispensers so that a convenient method of forming such lenses has, therefore, been worked out particularly for lenses of the usual commercial type.

Shape magnification lenses which require a different magnification in one meridian than in the other are obtained from the tables in the same manner as magnification lenses with the same magnification in all meridians with the exception that any one column must be used twice to obtain the two curves of the toric surface corresponding with the two magnifications required.

In the rare case of toric lenses in which the shape magnification axis does not coincide with the cylinder axis then the usual shop procedure for combining two oblique axis cylinders must be employed.

The mathematical theory of size lenses has been given in Tillyer Patent No. 2,077,134, issued April 13, 1937. In this patent I have shown that the total magnification M' can be separated into two factors, one involving the focal power and position of the lens system P' and the other involving the shape magnification of the lens system S' arrived at by the formula

$$S' = \frac{1}{1 - sD_1}$$

Also, I have shown that the ocular surface of the lens system does not produce any effect upon the shape magnification S' .

For convenience in this discussion we are going to consider only a single lens system, as shown in Fig. III, not a multiple lens system. From my patent referred to above we have

$$S' = \frac{1}{1 - sD_1}$$

where S' is the shape magnification, s is the reduced thickness, that is, the actual thickness of the lens divided by its refractive index and D_1 is the surface power of the first surface of the lens, see Fig. III. Then,

$$(S' - 1) = s \left(\frac{D_1}{1 - sD_1} \right)$$

$S'-1$ is the amount of shape magnification greater than unity and may be expressed in per cent for convenience in tabulation as will be noted by the tables given in the drawings.

Also, we have the equation for the effective power or vertex refraction

$$De = D_2 + \left(\frac{D_1}{1 - sD_1} \right)$$

Now if we determine a group of zero power lenses, then as has been shown in my patent referred to above I can add the power to the ocular surface without changing the shape magnification thereof. In the equation just given De is the vertex or effective power of the lens and D_2 is the ocular surface power. We will now let $De=0$ to obtain the zero power lenses. Eliminating in this equation

$$\left(\frac{D_1}{1 - sD_1} \right)$$

from the shape magnification equation previously given, we have $S'-1 = -sD_2$. From this equa-

tion, if s is a constant for a series of lenses, we see that $S'-1$ varies linearly with D_2 , or expressing this linear relation as a variation we have $\delta(S'-1) = -s\delta D_2$. This shows that by choosing the thickness factor s with care, we can make even fractional values of D_2 equivalent to fractional values of $S'-1$.

As an example of this let us assume that we wish an integer fractional value of the variation of $S'-1$ to be one-fourth of one per cent, that is, 0.0025, and for this value of the variation of $S'-1$ we wish δD_2 to be -1 diopter. Then we would have the equation $0.0025 = -s \times (-1)$ or $s = 0.0025$. Therefore, if we are using a glass of a refractive index $n = 1.5232$, the actual thickness t will be 0.0025×1.5232 which is equal to 0.003808. This is expressed in meters as all diopter values, etc., are on the basis of meters in practice. We will then call this 3.808 mm. the actual thickness of this lens. Therefore, if each front surface power in a series is chosen to give zero focal power with the chosen ocular surface for that lens and we then make the ocular surfaces in equal steps of one diopter we will have the shape magnification of each lens of the series varying by $\frac{1}{4}\%$, and have no focal power, so that we can add the required focal power to the ocular surface without changing shape magnification.

We determine the front surface from the equation

$$D_1 = \frac{-D_2}{1 - sD_2}$$

Computation will show that for an ocular surface -1 , the zero power lens will have a front surface power of $+0.998D$. To obtain shape magnification of $\frac{1}{2}\%$ with an ocular surface power of -2 diopters, the front surface power will be $+1.990D$. This will be found in series VI of the tables hereinafter given.

We have taken a very simple case of equal steps. We can, however, have δD_2 varying by integer fractions of the diopter, like $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, etc., or any fractions which the optician usually carries in his tool stock, and obtain the necessary thickness to correspond with these even steps to give equal percentages of shape magnification. Likewise, if we wish to take instead of $\frac{1}{4}\%$ steps in shape magnification, we can choose a $\frac{1}{3}\%$ or $\frac{1}{10}\%$ or whatever we may wish and obtain equal diopter steps by properly choosing the thickness.

We have tabulated ten series of these lenses progressing by $\frac{1}{4}\%$ steps because this follows the customary method of prescribing such lenses. It is not necessary, however, to adhere to these step percentages as other sequences can be used.

These two tables are as follows: Table A contains the front surface power which will be put on the semi-finished blanks at the factory. Table B contains the ocular surface power for the zero power lens. To this ocular surface power is to be added the required prescriptive focal power in order to obtain the ocular surface now to be ground on these lenses by the optician who finishes the blank. So far we have said nothing about magnification in one meridian. Obviously, if the magnification is the same in all meridians no one meridian need be considered separately. Referring to the tables let us assume that a lens giving a magnification of 1.5% in all meridians and a focal power in one meridian of 1 diopter and in the other meridian of $+1.50$ is desired. A convenient thickness for this lens will be found in series IV, which is 3.046 mm. in thickness. The front surface power finished at the factory

is found in Table A and is $+7.389$ diopters. The zero power lens would have -7.50 diopters for the ocular surface. To this must be added our prescriptive focal power of 1 diopter in one meridian and $+1.50$ in the other meridian. Adding these respective values together we find that the required surface power as shown at L in Fig. III in one meridian of the ocular surface will be -6.50 diopters and in the other meridian -6.00 diopters. Of course, the axes of these curvatures must be placed at the required angle. Let us now select a lens which must have a magnification of 1.5% in one meridian and a magnification of 2% in the other meridian and a $+1$ prescriptive focal power. Obviously, we must take this lens from any one series because we cannot have two different thicknesses for the same lens. We can take any one of a number of these series in order to obtain a good lens. Series IV or series V could be used.

Let us take series IV again. We have, as obtained before from Table A for the 1.5%, a front surface power of $+7.389D$ and, for the 2% from Table A, series IV, a power of 9.804 diopters. This blank must obviously be a semi-finished toric blank having in one meridian the $+7.389D$ surface power and in the other meridian the $+9.804D$ surface power. From Table B we find the two ocular surface powers to correspond with the above surface powers to give zero focal power. These curves will be -7.50 diopters in the $+7.389$ meridian and -10.00 diopters in the $+9.804D$ meridian. Now since we wish to have a $+1$ focal power on this lens we add to both of the above ocular surface powers $+1$ diopter power. Therefore, the optician must grind on this lens a toric ocular surface power of $-6.50D$ in the same meridian that the $+7.389D$ is in and a $-9.00D$ toric in the same meridian that the $+9.804D$ is in and finish this lens to the thickness that the series IV is to be finished to, that is, 3.046 mm. Now let us suppose that instead of requiring $+1D$ spherical focal power we required $+1D$ in the meridian that the 1.5% was required and a $+1.50D$ in the meridian that the 2.0% was required. We would then add $+1D$ to the $-7.50D$ and get $-6.50D$ for the required ocular surface power in that meridian and to the $-10.00D$ we would add $+1.50D$ and obtain $-8.50D$ for the required ocular surface power in that meridian.

So far we have only considered cases in which the axis or meridian of magnification coincides with the axis of astigmatism or the cylindrical power. Let us assume the same $+1.5\%$ in one meridian and $+2.0\%$ in the other and let us assume that we have an axis or cylinder power not coinciding with the axis of magnification. We go through and obtain the zero power lens exactly as before. If we are using the same series IV, we have for the ocular surface of the zero power lens $-7.50D$ in one meridian and $-10.00D$ in the other meridian. If the axis of our prescription does not coincide with the axis of these two lenses we take this $-7.50D$ in one meridian and $-10.00D$ in the other meridian and combine it with the prescription the same as we do to cross cylinder prescriptions in the usual ophthalmic methods and obtain the new ocular surface in that manner, or what is even easier we put this $-7.50D$ with the $-10.00D$ on a lens measuring instrument such as the Lensometer in the form of test lenses, and at the same time the required prescription on the Lensometer in the form of test lenses and

measure the resultant power and axis and grind this on the blank to the thickness specified for series IV. In this one case the ocular surface curves required to be ground may not come within the usual range of curvatures of standard ophthalmic tools. Of course, any two oblique axis cylinders without shape magnification when combined do not come always under the range of the usual ophthalmic tools. This is a special case the same as is in the usual combination of two oblique cylinders in regular ophthalmic practice. The procedure of supplying tools for lenses of this character therefore is the same as has been usual in the prior art and the same difficulties are encountered.

Tables A and B have been written as is usual in commercial practice for the formation of torics. The way these tables for factory surface are used is as follows. Let us assume we wish to determine a semi-finished blank for a 1% shape magnification in one meridian and a 1.5% in series IV. The front surface power will be +4.950D by +7.389D in toric form. Now for a shape magnification of 1% in one meridian and 1.75% in the other we will have a toric with surface powers of +4.950D by +8.599D. Of course, in finishing this lens the thickness 3.046 mm. for series IV must be followed. Likewise, for any other series.

The thickness and surface powers are given to very close values. This accuracy is not necessary to this extreme.

In Table A and Table B a varying range of spheres and toric combinations is given. Obviously in practice many of these series would be dropped and only the most used lens blanks would be finished in the semi-finished form.

A number of additional series could be added, for instance, a series between I and II but it is believed to be unnecessary. Likewise, between II and III, etc.

It is also obvious that the lens could be designed for shape magnification other than the $\frac{1}{4}\%$ steps although the $\frac{1}{4}\%$ steps are the ones now employed for testing the shape magnification of the eyes.

From the Table A and Table B, the method of forming such tables, and the examples given in their use, it will be seen that by the proper choice of the thickness it is possible to produce lenses having shape magnification of zero or integer per cent added to integer fractions of a per cent combined with an ocular surface power in integer diopters and integer fractions of a diopter when the prescription is in integer diopters and integer fractions of a diopter.

The integer per cent of shape magnification is 1%, 2%, 3%, etc. The integer fractions of a per cent of shape magnification may be $\frac{1}{4}\%$, $\frac{1}{2}\%$, $\frac{3}{4}\%$ or $\frac{1}{5}\%$, $\frac{2}{5}\%$, $\frac{3}{5}\%$, $\frac{4}{5}\%$ or $\frac{1}{3}\%$, $\frac{2}{3}\%$ or similar values having integers in the numerator and denominator of the fraction.

We have shown in the Tables A and B, such thicknesses as correspond with the integer fractions $\frac{1}{4}\%$, $\frac{1}{2}\%$, $\frac{3}{4}\%$, etc., but other tables may be formed by the methods described with the integer progression $\frac{1}{3}\%$, $\frac{2}{3}\%$, etc., or any similar values.

The integer diopters of surface power, either plus or minus, are 0, 1, 2, 3, etc., the integer fractions of a diopter of surface power, either plus or minus, are $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$. The integer diopters, either plus or minus, of prescriptive focal power are 0, 1, 2, 3, 4, etc. The integer fractional diopters of prescriptive focal

power, either plus or minus, are $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, $\frac{7}{8}$.

A change in the position of these lenses in front of the eyes and a change in magnification due to the change in position has been explained in Tillyer Patent No. 2,077,134, issued April 13, 1937, and has nothing to do with making the individual lenses to the required prescription at the distance at which they are to be placed from the eyes.

This system is supposed to be applied to a finished prescription specifying the distance at which the lenses are to be placed before the eyes and the focal power and the shape magnification at that distance. However, let us take a simple example of changing the distance of the lens from the eye. Let us assume that we require a +1.75% shape magnification and a focal power of +1 diopter and also that we wish to move this lens $2\frac{1}{2}$ mm. further from the eye than the test lenses were used. Note, we assume that the prescription has been corrected for the shape magnification value of the test lenses as they were used so that the shape magnification given in the prescription is the true shape magnification in front of the eye. Now let us assume that we wish to move this +1 diopter lens $2\frac{1}{2}$ mm. further from the eye. We have the diopter focal power multiplied by the increased distance in meters or numerically $+1.00 \times 0.0025 = 0.0025 = 0.25\%$. Thus we have an increase in the power magnification of $\frac{1}{4}\%$ due to this change in distance from the eye. Therefore, we must take off from the prescribed shape magnification 1.75%, the extra power magnification caused by moving this lens further away and we will, therefore, design the lens for a 1.50% shape magnification in the same manner as previously given.

Obviously, when we consider the two eyes, we will have shape magnification in front of both eyes and it is the ratio of the one magnification to the other that counts. We must, therefore, if we have given that the first eye has a shape magnification of 1% more than the second eye, design the first lens so that it will be of 1% in that eye more than the shape magnification in the other eye. We can add or subtract small percentages of shape magnification although we must multiply or divide S'. Assume we have 1% in the first eye and wish the second eye to have 2% more, this gives the required 3% and is obtained as follows, S' for the first eye is 1.01, S' for the second eye is to be 1.02 times the first eye, that is 1.01×1.02 which is 1.0302 or to sufficient accuracy 3%. For large values such as 10% the actual multiplication should be used.

It will be noted by reference to Fig. III that the front surfaces D₁ of the series of lens blanks which, in combination with the finished thickness t of said blanks, will produce the shape magnification desired are of special curvatures generated by special tools at the factory and that the said curvatures are such that they will permit the use of commercial tools now in common use by lens dispensers in forming the actual ocular surface L of the lens to obtain the focal power desired with said shape magnification.

This enables the provision of series of lens blanks for producing shape magnification in step percentages which may be carried in stock in a manner similar to usual prior art ophthalmic lens blanks and to which the prescriptive curve may be added to the ocular surface of the blanks while maintaining the thickness t to obtain the

focal power desired with said shape magnification.

From the foregoing description it will be seen that a simple, efficient and economical arrangement and method has been set forth whereby series of lens blanks graded in step per cent magnifications may be provided to the dispensers and from which a blank may be selected and finished in the usual prior art manner to obtain the focal prescriptive correction and shape magnification value required.

Having described my invention, I claim:

1. A series of lens blanks for lenses intended to correct refractive as well as shape magnification errors, the blanks of said series comprising pieces of lens medium of given indices of refraction having front optical surfaces D_1 of curvatures calculated for given ocular surface power considerations D_2 graded in equal steps of integer diopters or fractions of said diopters so that each of said surfaces D_1 differ from each other by amounts which, with a given predetermined constant finished thickness consideration t for said series, produce zero power lenses having equally graded percentages or fractions of percentages of shape magnification S' according to the formula

$$S' = \frac{1}{1 - sD_1}$$

with the thickness t of said series obtained from the formula $S' - 1 = -sD_2$ by eliminating from the S' equation

$$\left(\frac{D_1}{1 - sD_1} \right)$$

wherein s is the thickness t divided by the refractive index of the medium, each blank having a thickness in excess of said given predetermined thickness t to receive a final ocular surface which will introduce the focal power correction required, the curvature of said front surface D_1 with said given index of refraction and predetermined thickness t being such that the final ocular surface to be formed on the blank will be of an integer diopter or fraction of a diopter, the curvature thereof being obtained by algebraically adding the prescriptive focal power desired to the given ocular surface power consideration D_2 for said blank, the addition of said final ocular surfaces to said blanks, while maintaining said given thickness t , producing the refractive corrections required with substantially no change in the S' values of the blanks.

2. The method of forming a series of lens blanks for lenses intended to correct refractive as well as shape magnification errors, comprising forming on pieces of lens medium of given indices of refraction front optical surfaces D_1 of curvatures calculated for given ocular surface power considerations D_2 graded in equal steps of integer diopters or fractions of said diopters so that each of said surfaces D_1 differ from each other by amounts which with a given predetermined constant finished thickness consideration t for said series produce zero power lenses having equally graded percentages or fractions of percentages of shape magnification S' according to the formula

$$S' = \frac{1}{1 - sD_1}$$

with the thickness t of said series obtained from

the formula $S' - 1 = -sD_2$ by eliminating from the S' equation

$$\left(\frac{D_1}{1 - sD_1} \right)$$

wherein s is the thickness t divided by the refractive index of the medium, and providing each blank with a free surface on the side thereof opposite the front surface at a distance from said front surface in excess of said predetermined thickness t to receive the final ocular surface for introducing the focal power correction required, the curvature of said front surface D_1 , index of refraction of the lens medium and predetermined thickness t being so computed that the final ocular surface curvature to be formed on the blank will be of an integer diopter or fraction of a diopter obtained by algebraically adding the prescriptive focal power desired to the given ocular surface power consideration D_2 for said blank, the addition of said final ocular surfaces to said blanks, while maintaining said given thickness t , producing the refractive corrections required with substantially no change in the S' values of the blanks.

3. A series of lenses for correcting refractive as well as shape magnification errors, the lenses of said series comprising pieces of lens medium of given indices of refraction having front optical surfaces D_1 of curvatures calculated for given ocular surface power considerations D_2 graded in equal steps of integer diopters or fractions of said diopters so that each of said surfaces D_1 differ from each other by amounts which, with a given predetermined constant finished thickness consideration t for said series, produce zero power lenses having equally graded percentages or fractions of percentages of shape magnification S' according to the formula

$$S' = \frac{1}{1 - sD_1}$$

with the thickness t of said series obtained from the formula $S' - 1 = -sD_2$ by eliminating from the S' equation

$$\left(\frac{D_1}{1 - sD_1} \right)$$

wherein s is the thickness t divided by the refractive index of the medium, each lens having a given predetermined thickness t and an ocular surface which will introduce the focal power correction required, the curvature of said front surface D_1 with said given index of refraction and predetermined thickness t being such that the ocular surface of the lens is of an integer diopter or fraction of a diopter, the curvature thereof being obtained by algebraically adding the prescriptive focal power desired to the given ocular surface power consideration D_2 for the lens, the curvature of said final ocular surface being such that when combined with the front surface D_1 , while maintaining said given thickness t , it will introduce the refractive corrections required with substantially no change in the S' values of the lenses.

4. The method of forming a series of lenses for correcting refractive, as well as shape magnification errors, comprising producing lens blanks by forming on pieces of lens medium of given indices of refraction front optical surfaces D_1 of curvatures calculated for given ocular surface power considerations D_2 graded in equal steps of integer diopters or fractions of said diopters so that each of said surfaces D_1 differs from each other by amounts which with a given predetermined

constant finished thickness consideration t for said series produce zero power lenses having equally graded percentages or fractions of percentages of shape magnification S' according to the formula

$$S' = \frac{1}{1 - sD_1}$$

with the thickness t of said series obtained from the formula $S' - 1 = -sD_2$ by eliminating from the S' equation

$$\left(\frac{D_1}{1 - sD_1} \right)$$

wherein s is the thickness t divided by the refractive index, and providing each blank with a free surface on the side thereof opposite the front surface at a distance from said front surface in excess of said predetermined thickness t to re-

ceive the final ocular surface for introducing the focal power correction required, the curvature of said front surface D_1 , index of refraction of the lens medium and predetermined thickness t being so computed that the final ocular surface curvature to be formed on the blank will be of an integer diopter or fraction of a diopter obtained by algebraically adding the prescriptive focal power desired to the given ocular surface power consideration D_2 for said blanks, and forming said final ocular surfaces on said blanks, of curvatures controlled according to the curvatures of said front surfaces D_1 while maintaining said given thickness t so as to introduce the refractive correction required with substantially no change in the S' values of the blanks.

EDGAR D. TILLYER.