into the vertical direction with respect to the principal meridian curve Ps has a relation Pt>Ps. Consequently, at each corresponding point, the desired relation between the curvature along the principal meridian curve ρt and that into the vertical direction with respect to the principal meridian curve ρs is $\rho t < \rho s$.

If the optic axis of the lens is at the center of the far zone or adjacent thereto, the center of the far zone is supposed to be the cardinal point of the change of the difference of curvature along the principal meridian curve in the far zone. At the cardinal point, the difference of curvature $\Delta\rho=0$. In the near zone of the lens, on the other hand, the center thereof is apart from the optic axis by ten or more mm. Accordingly, it is required that the difference of curvature $\Delta\rho$ is equivalent to 0.2 or less ($\Delta\rho \leqq 0.2$) in focal power at the center of the near zone selecting the desirable value with respect to the degree of unsuitability of the base curve.

When increasing the difference of curvature $\Delta\rho$ along the principal meridian curve, it is better to decrease the curvature along the principal meridian curve ρt while fixing the curvature into the vertical direction with respect to the principal meridian curve ρs at a constant value. By taking the above method, the average power of the lens along the principal meridian curve becomes close to the power at the optic axis of the lens.

The other constituent of the convex surface of the lens, namely, the intersections which are vertical to the principal meridian curve are designed in the following manner according to this invention. That is, in the far zone, the intersection is designed so that the curvature thereof increases as the point along the intersection is more distant from the principal meridian curve and the increasing rate of the curvature decreases as the intersection moves apart from the center of the far zone. In the near zone, the intersection is designed so that the curvature thereof decreases as the point along the intersection is more distant from the principal meridian curve and the decreasing rate of the curvature decreases as the intersection moves downward apart from the center of the near zone. By designing the near zone of the lens as mentioned above, the umbilical curve u shown in FIG. 9A moves toward the side portion of the lens as proceeding downward. Thus, the clear viewing zone in the near zone is enlarged.

Additionally, changing the curvature of intersections in the far zone or the near zone as mentioned above is advantageous with respect to reducing the distortion in various cases. For example, in the case where the far zone is designed as mentioned above when a strong plus lens is prescribed, so-called drum-like distortion in which the image is expanded laterally at the upper part of the lens (it is a characteristic of a plus lens) is reduced. As another example, the near zone of the lens is designed as mentioned above when a strong minus lens is prescribed, so-called barrel-like distortion in which the image becomes narrower at the lower part of the lens (it is a characteristic of a minus lens) is reduced.

FIG. 11 shows another example of the lens which the present inventor introduced in the aforementioned U.S. patent application Ser. No. 327,288 now U.S. Pat. No. 4,580,883. In the lens shown in FIG. 11, both the far and the near zones have spherical surfaces. The base curve thereof is 7.5D and the prescribed power is +4.5D.

FIG. 12 illustrates a second embodiment according to the present invention in which the principle of this invention is applied to the lens of FIG. 11. In this embodiment, the curvature into the vertical and horizontal directions ρt and ρs along the principal meridian curve in the far zone is changed in the same manner as in the first embodiment described hereinbefore. The intersection which is normal to the principal meridian curve in the whole far zone is a spherical curve. Compared with the lens of FIG. 11, the astigmatism adjacent to the principal meridian curve in the far zone is largely reduced and thus the clear viewing zone is enlarged in this embodiment.

FIG. 13 illustrates a third embodiment of the present invention. In this embodiment, besides the modification added in the embodiment of FIG. 12, the intersection which is normal to the principal meridian curve is further modified in the following manner. In the far zone, the intersection normal to the principal meridian curve at the lowest end of the zone is spherical. Gradually as the intersection moves upward, it becomes aspherical in which a point on the intersection is farther from the principal meridian curve, the curvature at the point is less. The lens designed as mentioned above is provided with still a larger clear viewing zone than the lens shown by FIG. 12. The reason why the large clear viewing zone is provided may be easily understood from the explanation of the aspherical surface factor and the base curve factor of astigmatism described with reference to the first embodiment.

As described above, astigmatism of a lens is caused by various visual conditions which are peculiar to the progressive multifocal lens (for example, difference of the visual angle and the visual distance between when using the far zone and when using the near zone) and the inadequacy of the combination of the power and the base curve of the lens which occurs when the base curve is to be determined which is common in lenses which have different additional power respectively, or when the lens is to be made thinner, or the like.

According to this invention, the astigmatism is largely reduced and so is the image distortion, and thus a large clear viewing zone is provided. Especially in the case that the lens for correcting the strong hyperopia is prescribed, this invention provides a progressive multifocal lens which is visually satisfactory even with being made thinner and less in weight. It is also to be understood that the content of this invention can be applied either as a whole or as a part according to the case without decreasing the effect of this invention as described before.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above constructions without departing from the spirit and scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A progressive multifocal ophthalmic lens comprising a refractive surface divided into a far vision viewing zone, an intermediate vision viewing zone and a near vision viewing zone, a substantially vertical principal meridian curve, an optical center of said far vision viewing zone being at the lower end of said principal merid-