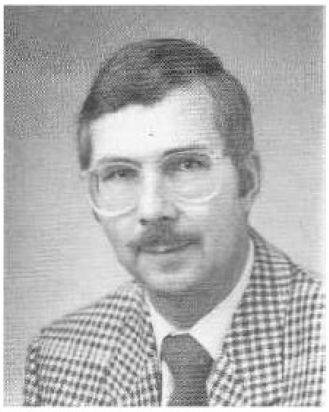

**Dipl.-Phys.
Werner Köppen,
Créteil/France**

Varilux Multi-Design: more comfort for the spectacle wearer, more reliability for the ECP

To date: 1st and 2nd generation progressive lenses

The theoretical preparatory work for the progressive lens in spectacles extends back to the beginning of this century, but the actual hour of birth was in the year 1959 when the production of Varilux, the first progressive lens with modern character was achieved (figure 1). This 1st generation lens was designed with a distance and near portion with stabilized power that were connected by the "progression channel".

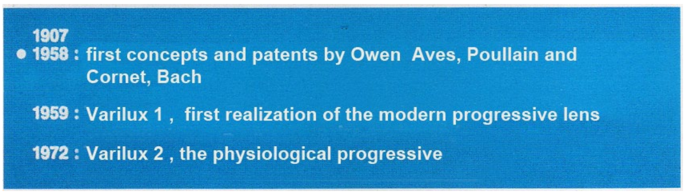

Figure 1 Development of the progressive lens

The breakthrough for the progressive lens took place in 1972 with the Varilux 2. Its inventor, Bernard Maitenaz, had recognised the decisive significance of the peripheral zones of the lens for adaptation and tolerance and considered the special requirements of peripheral, dynamic and binocular vision in construction of the lens (figure 2). The "physiological progressive lens" was therefore created which offered the spectacle wearer significantly improved visual comfort. In contrast to the 1st generation lens, the new surface was fully aspherical and, in order to ensure good conditions for binocular vision, it was also asymmetrical, which means that the right and left lenses were manufactured separately.

In the years after invention of the Varilux 2, other manufacturers presented a number of further variations of the progressive design. Among the almost 50 different types that are now offered throughout the world, the lenses that have achieved the highest significance confirm the Varilux 2 concept. The priorities given to the surface construction are sometimes different - some lens types place more emphasis on the foveal visual functions whereas the quality of peripheral vision properties are at the forefront of other designs — fundamentally new elements can rarely be discovered in theconstruction of these lenses that belong to the 2nd generation.

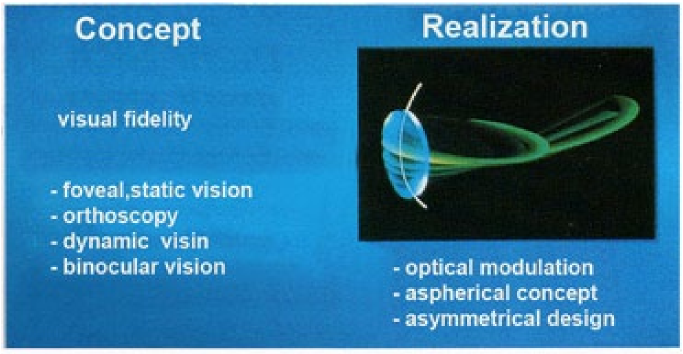

Figure 2 Varilux 2, the physiological progressive lens (patents DE 20 44 639, DE 23 36 708)

The optimum lens designed using physiological research and computer-aided design

This makes it clear that the margin for the conceptualisation of improved progressive surfaces has become more restricted. As shown by our studies, new possibilities can only be opened up if the development work is increased a great deal than was previously the case. Even more than in the past, it becomes clear that progressive lenses cannot be optimised with physical-optical considerations alone; this is only possible through an "iterative" development, closely integrating the spectacle wearer (figure 3). In the case of this gradual optimisation, an initial surface is produced and tested for strengths and weak points using various physiological tests. This then results in the necessary surface correction, which leads to a 2nd improved surface. The new surface is then tested once again by the spectacle wearer and his or her criticisms are considered in the second surface correction etc. The cycle is continued until the optimum surface has been found, i.e. the surface which cannot be improved any further by making corrections.

As shown in more detail in the following, we have carried out the development process for each addition of the new lens type separately. In order to manage the extreme amount of work involved, it was necessary to refine our physiological tests on one hand, while significantly increasing the speed of the calculation methods on the other hand. Only one example for both activities is indicated respectively: on the one hand, the measuring apparatus in figure 4, which is used to determine how the natural

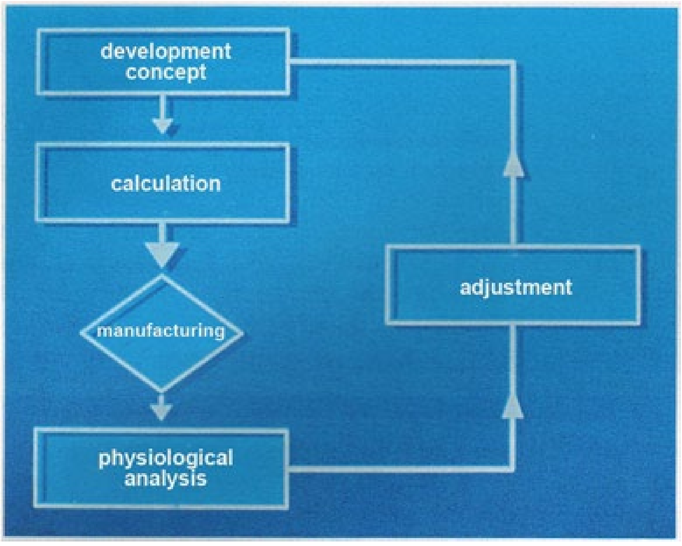

Figure 3 Iterative development of progressive surfaces

interaction of eye and head movements is influenced by a progressive lens. On the other hand, we deployed Computer-Aided-Design (C.A.D.) in order to be able to calculate the progressive surfaces much more quickly than previously. The computer independently runs through the whole construction routine so that a specified surface can be modified in any way in just a few minutes (figure 5).

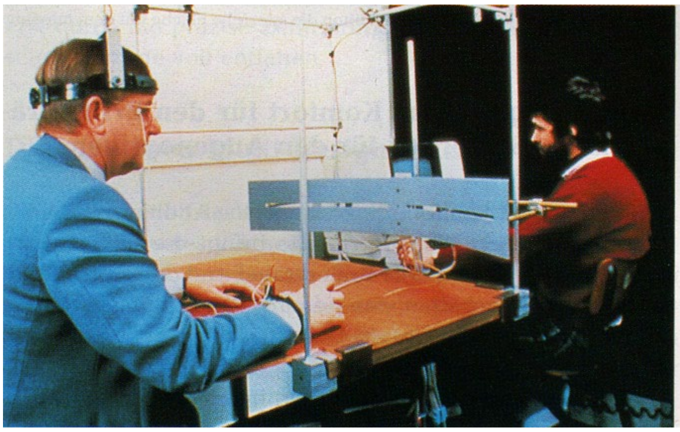

Figure 4 Measurement of eye-head movements with a progressive lens

Figure 5 Surface calculation with C.A.D.

Multi-Design: A special surface for each addition

Equipped with these high-performance aids, we were able to undertake the targeted development of a new, improved progressive lens. 150 different surface types - the various additions are, of course, not included in this figure, have been constructed since the development of the Varilux 2, checked for their optical-physical properties and tested by spectacle wearers. Some of these designs have been modified and realised for specific lens types such as Varilux Omega, Alpha, Visa, Delta and Datacomfort.
However, the most important factor is the result of these studies with respect to the all purpose progressive lens and the successor for the 2nd lens generation, which took time to find. Although the development was complex, the result was simple and clear (figure 6) there is no special progressive surface which is optimal for all additions.

Figure 6

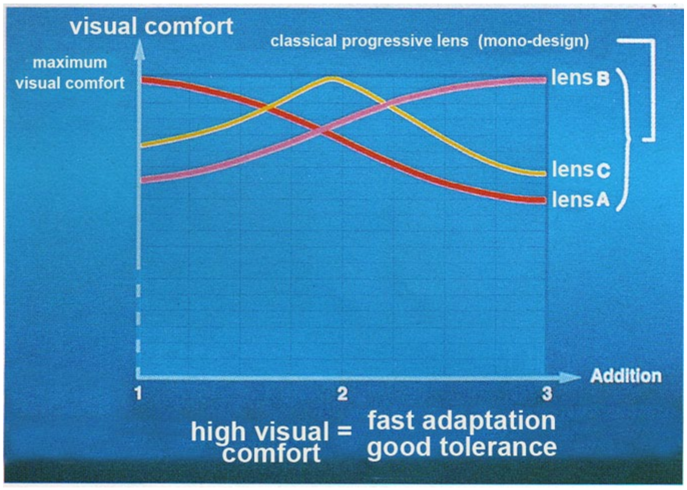

Figure 7 One single specific surface type (examples A. B, C) provides the optimum comfort only for specific additions

The graph in figure 7 illustrates this result. The visual comfort of the various examined progressive surfaces is entered on the vertical axis of the coordinates system. The higher the visual comfort, the easier the adaptation and the better the tolerance of the lens is. For example, the dark red curve shows that lens type A offers the maximum visual comfort[1)] for the lower additions, but displays certain disadvantages for the higher near additions. The opposite is true for lens type B, and there are other surfaces, such as example C, where this optimum visual comfort is achieved for the middle additions. There is no single surface which is optimum for all additions.

[1)]As" maximum visual comfort" is to be understood the visual comfort which is achievable today with the current available calculation processes, production methods and lens materials.

If we still want to develop a progressive lens which offers the optimum visual comfort for all additions, we are forced to develop a special surface type for each individual addition.
For the progressive lenses to date, each individual lens type has a typical optical „design“, but the design is the same for all twelve additions from 0.75 to 3.50. All these common progressive lenses represent a „Mono-Design“. The power distributions for add. 1.0 and add. 3.0 are shown for this type of „Mono-Design“ lens in figure 8. Of course, the power in the near portion for add. 3.0 is three times larger than for add. 1.0, but that is the only difference. If the powers of the add. 3.0 lens are divided by the

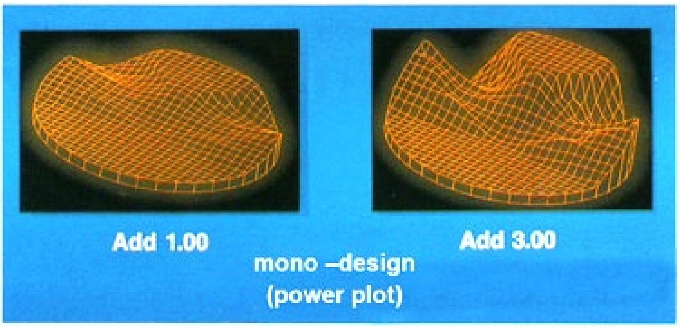

Figure 8 Power increase for a common progressive lens for add. 1.0 and add 3.0.

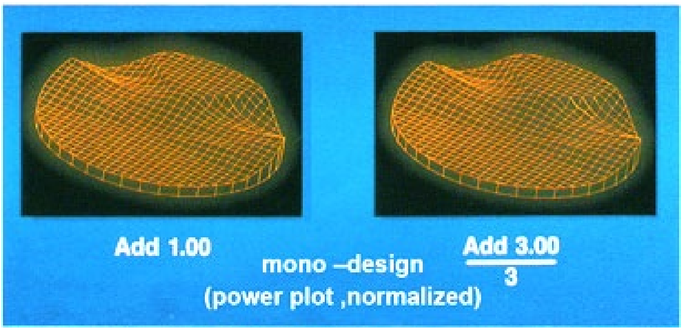

Figure 9 Normalized power increase for a common progressive lens for add. 1.0 and add. 3.0

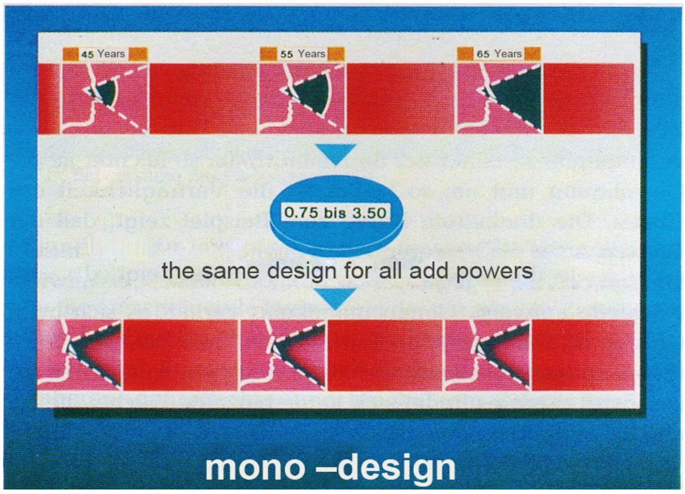

Figure 10 Common progressive lenses only have one surface type for all additions

amount of the addition, therefore by three, this precisely results in the add. 1.0 lens (figure 9). We therefore have the same surface type for all additions and that applies to all progressive lenses offered to date, as symbolically represented in figure 10.

However, the tests we performed, and that are described further above, resulted in each addition requiring its own surface type, i.e. a special design, in order to maintain maximum visual comfort. This type of lens with maximum visual comfort therefore consists of several different surface types, of twelve different „designs“ to be exact, according to the twelve different additions. This new lens type is a „Multi-Design“ (figure. 11).

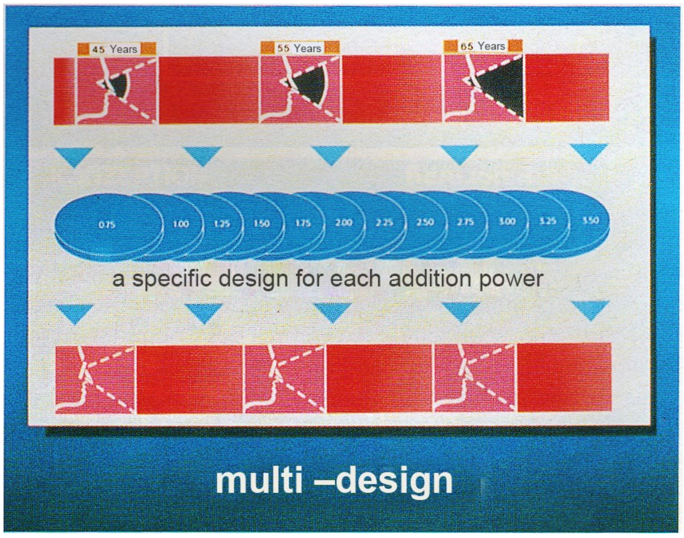

Figure 11 Essilor VMD: the specific surface with maximum comfort for each addition

Multi-Design: more comfort for the spectacle wearer, more reliability for the ECP

Optimum visual comfort for each individual addition: what does that actually mean? Which advantages does the optimisation add by add provide for the spectacle wearer and the ECP? The properties of the new progressive lens „Essilor VMD (VMD = Varilux Multi-Design)“ are compiled in figure 12:

- Extremely soft transition between distance and intermediate zone,
- Very wide progression zone,
- More favourable, dynamic vision,
- Improved binocular symmetry.

The transition between the distance and progression portion is designed particularly gentle for lower additions. This means that the young presbyope finds it noticeably easier to adapt to his first progressive lens. Additionally, according to the mathematical rules of differential geometry, the very gentle power increase means that the Multi-Design surfaces have a particularly wide intermediate portion. „More favourable, dynamic vision conditions“ means that the new lens is perceived to be still more comfortable than the Varilux which is already very comfortable when moving the head and eyes. In comparison to the Varilux, the optical characteristics between the right and the left lens for lateral eye movements are more symmetrical. Due to these improvements the new Essilor VMD is characterised by faster adaptation and an improved tolerance.

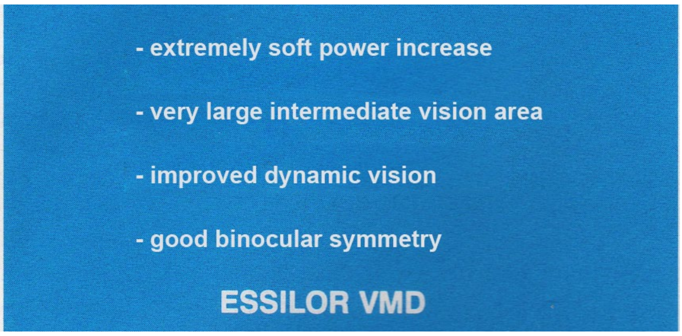

Figure 12

The characteristic surface properties compiled in figure 12 also support reliable centering of the lens to the eye. Practice shows us that adaptation difficulties can arise with any progressive lens in special cases. This may be due to the person wearing the spectacles, who is particularly sensitive, or possibly due to an unfavourable addition of tolerances in lens or spectacle production. It is clear that the number of these problem cases that can be traced back to production and centering tolerances becomes less when the progression zone is particularly wide and the surface particularly soft. In this sense, the Essilor VMD provides additional reliability for centering process. However, as before, the same applies to the new lens type: namely that its full advantages are only achieved after precise centering by the ECP.

The individual Multi-Design surfaces

In order to turn the new Multi-Design lens concept into reality, an adequate surface concept was necessary whichmeant creating a surface that is so variable that it can be
flexibly aligned to the different requirements for the various additions. This design concept newly developed from our researchers is the surface with „Integral Optical Modulation".
In order to be able to understand the characteristic properties of this surface, we must initially look at the surface types that the spectacle wearers preferred for the different additions in the wearer tests. From the range of twelve surfaces, we selected two examples; the surfaces for add. 0.75 and add. 3.50. With the lower additions, the spectacle wearer perceives a lens as particularly comfortable if the optical power from the distance portion to the near portion increases very gently (figure 13). The very good distance portion quality and the soft transition into the progression make it easy for the young presbyope to adapt to his first progressive lens. With this type of design, the aberrations are particularly concentrated in the lower, peripheral portion of the intermediate zone where they do not disturb the spectacle wearer. In contrast, a surface design is preferred for higher additions with which the optical power in the lateral portion starts to increase somewhat higher and in the near portion drops more rapidly towards the edge (figure 14). This surface type is characterised by very good orthoscopy and binocular symmetry. In order to avoid a less comfortable concentration of aberrations in the lower progression zone due to the higher addition, the peripheral astigmatism is evenly spread out in the lateral surface parts.

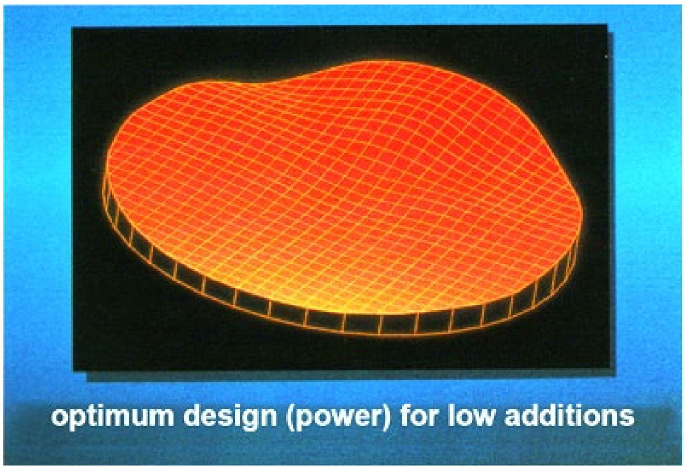

Figure 13 Power increase normalized for Essilor VMD Add. 0.75

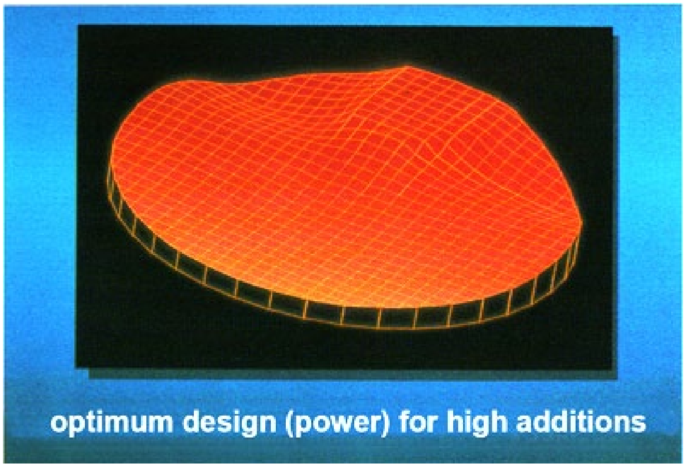

Figure 14 Power increase normalized for Essilor VMD Add. 3.50

Realisation of the Multi-Design: Integral Optical Modulation

The above observations show that, in order to realise the Multi-Design concept, the power distribution has to differ from addition to addition. How can the designer of the lens control the power distribution and which „tool" is available to him?
The previously used mathematical-geometrical models did not provide any satisfactory solutions, so our mathematicians developed a new surface concept, as previously mentioned; the progressive surface with Integral Optical Modulation. From the structure of the Varilux 2, it is known that the optical power in the distance portion increases slightly towards the side, while it decreases slightly in the lateral near portion. With this „horizontal" optical modulation, the horizontal amplification in the peripheral lens zone remains approximately constant so that a vertical line seen through Varilux remains vertical, which we refer to as orthoscopy (figure 15). The „horizontal" optical modulation therefore means a displacement of the optical power, especially in the horizontal direction. However, in order to be able to displace the optical power in any way across the surface, we have also modulated the Multi-Design surfaces in the vertical direction.

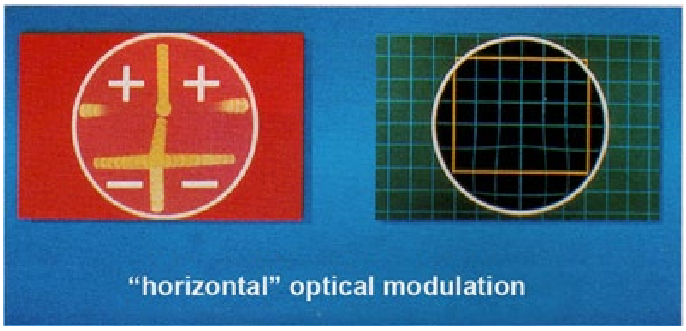

Figure 15 Due to the optical modulation, the orientation of horizontal and vertical lines is maintained

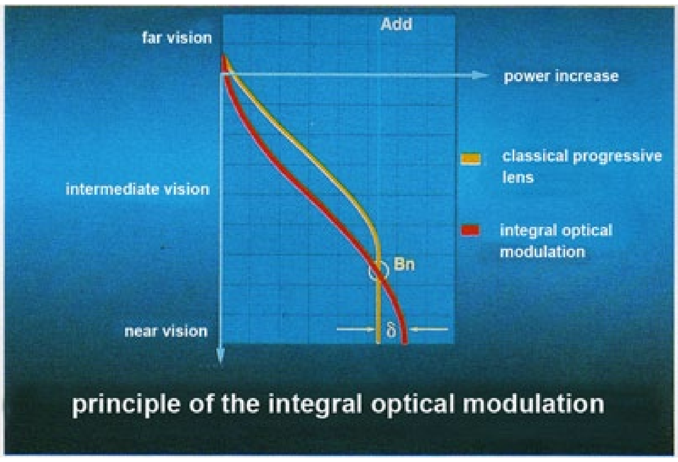

Figure 16 Power increase in the main meridian for a classic progressive lens and the Multi-Design surfaces

In figure 16 , the yellow curve describes how the power along the main meridian increases for the progressives until today. The principal characteristic is that the power above the near reference point Bn stabilises. The gradient of the power increase is specified by the addition power and the length of the progression zone for this classic progressive lens. This no longer applies to the Essilor VMD. The red curve shows that the power for the Multi-Design surfaces increases more slowly for the same addition and the same length of the progression . This means a double advantage for the visual comfort. On the one hand, the gentle progression between the near and distance portion is naturally favourable for adaptation and, on the other hand, the progression zone of the Multi-Design surfaces is wider than for other progressive lenses. Because the following generally applies to all progressive lenses: the slower the power increases, the wider the intermediate zone is.

Furthermore, it is noticeable that the newly developed main meridian does not turn relatively abruptly into the the section of stabilized power above the near reference point, as was previously the case, but rather that stabilisation takes place very gently, noticeably below Bn. Thus the Multi Design surfaces are more comfortable in dynamic viewing conditions, for example the new lens is perceived to be more comfortable than the Varilux when moving the head and eyes Somewhat simplifying the amount, by which the optical power increases below the near reference point can be considered as a measure for the vertical modulation was determined by wearer tests. The result is that the amount of the vertical modulation with increasing addition has to be continually reduced in order to gain the optimum surface. This means that is around 0.5 dpt for add. 0.75 and zero for add. 3.50 (figure 17). In the Multi-Design surfaces, the horizontal optical modulation of the Varilux is superimposed by a modulation of the surface in vertical direction. This integral modulation allows us to displace the optical power in any way over the surface and to develop the design with the best possible visual comfort for each addition group.

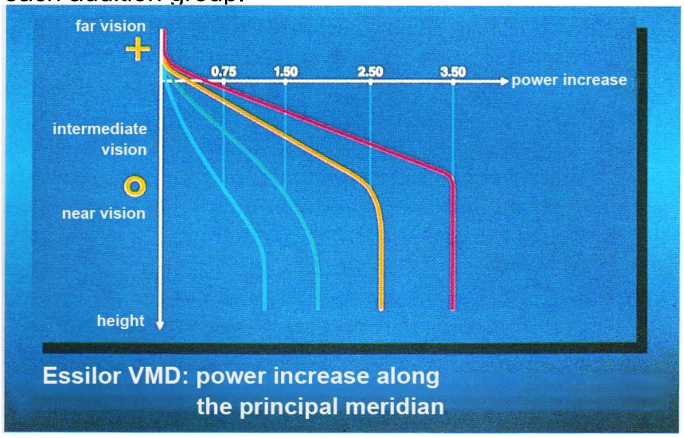

Figure 17 Power increase for Essilor VMD for the additions 0.75, 1.50, 2.50 and 3.50

High-tech quality

Essilor VMD doesn't just mean a revolutionary design concept. The new lens was also a challenge for us to increase the production quality of the progressive lens further. We have described this top quality level, which is characterised by the first-time use of state-of-the-art technologies and highly sensitive control processes, with the catchphrase „high-tech quality". A list of several fundamental components should explain this.

Fully automatic surface production ensures that each lens matches perfectly with the theoretical original design (figure 18) shows the production of the mineral version). We have made special efforts to make sure that the surface corresponds with the target values, not only for the reference points for distance and near, but also in the periphery.

Exact centering to the eye is known to be just as decisive for good comfort of the progressive lens as the optical properties of the lens. With the organic Essilor VMD lenses, a laser engraving in the mould (Figure 19) guarantees precision marking of the surface. In contrast to previous engravings, this micro-engraving remains visible after applying the hard coating on the lens. In order to transfer the accuracy of the engraving to the stamped marking , the micro-circles are made visible on a screen with a high magnification and are aligned precisely to match the stamping tool.

The precision with which all these production processes run becomes clear when we look at the measuring processes which guide and control production. Fractions of light wavelengths are required to describe their accuracy. This means that the 3D scanning head in figure 20 can accurately establish any differences between the

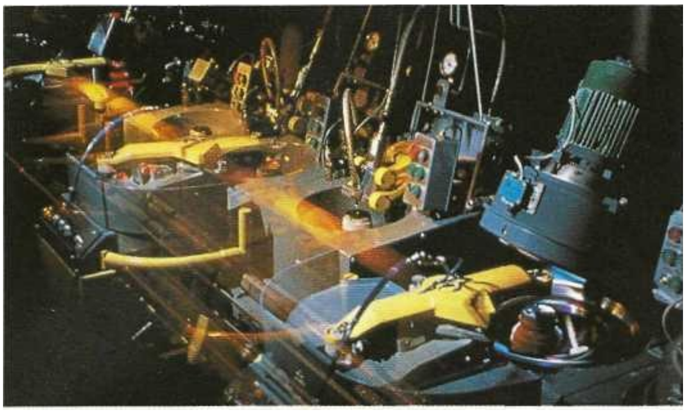

Figure 18 Automatic production of the Essilor VMD

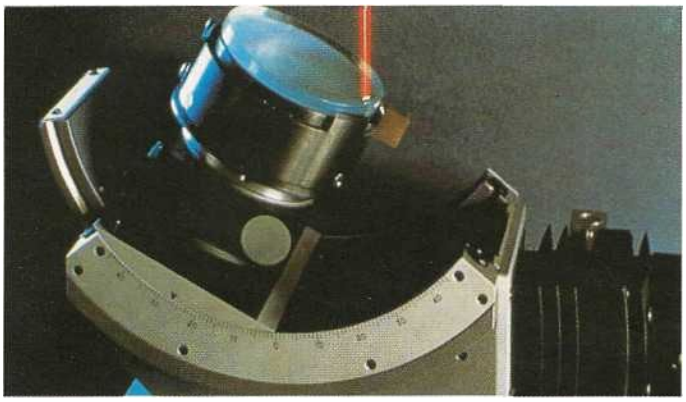

Figure 19 Laser engraving of Essilor VMD moulds

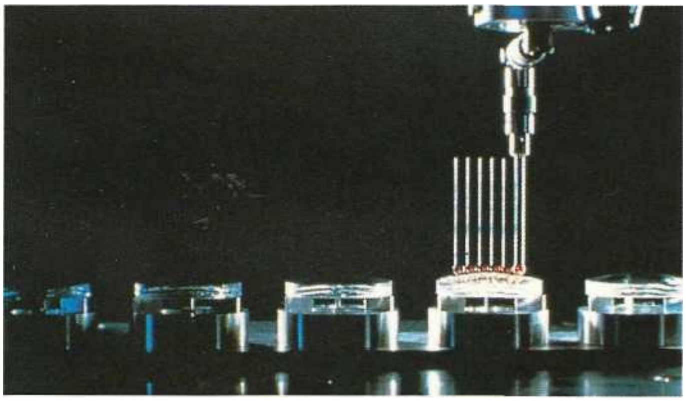

Figure 20 Ultra-precision control (0.1 µm) of the Essilor VMD surface

original surface and the produced surface to a quarter of the light wavelength at any point; this corresponds to one ten-thousandth of a millimetre. Light interferometric methods make the lines with constant prismatic deflection visible on the surface (figure 21). In this way, it is possible to detect the slightest differences to the target geometry at a glance. The optical power in the reference points for distance and near are measured to 0.01 dpt through autocollimation. This takes place systematically for all moulds for the organic lenses and according to a precise random test for the mineral semi-finished lenses.

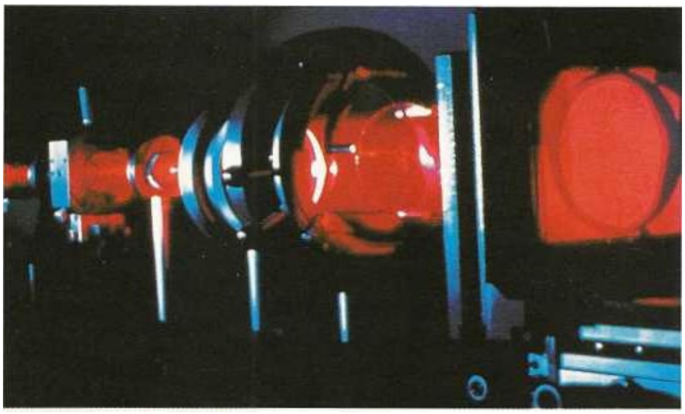

Figure 21 Interferometric control of the Essilor VMD

Special development areas of Essilor were involved in developing the automated, precision production lines on the one hand and in conceiving the various highly-sensitive testing processes and adapting them to the specific requirements of spectacle lens production on the other. This was the only way to realize the new surface concept in a „new“ and improved production quality. This explicitly means that production of the Essilor VMD respects narrower tolerances than previously possible so that the spectacle wearer can enjoy the comfort of the Multi-Design surfaces without any restrictions.

Summary

When designing progressive lenses in past, we had to be satisfied with a single „optical design“ and had to accept that the visual comfort for the wearer changes from addition to addition. The aim of the new Essilor VMD is to keep this visual comfort as constant as possible for all additions. There is therefore an individual design for each addition and it consists of twelve different surface types. The new development therefore presents a family of "progressive specialty lenses" for different presbyope age groups. The lenses are primarily distinguished by the particularly soft power increase and a wider progression zone. Furthermore, in comparison to Varilux, improvement of the conditions for dynamic vision and binocular comfort has been achieved once again. These improvements are responsible for the considerable visual comfort of the new type lens displayed by easy adaptation and very good comfort. The high production quality adds to the revolutionary surface concept. With the fully automatic production lines and high-precision testing processes which are specially constructed to realise the Multi-Design, the lenses can be produced more accurately than was previously possible. Essilor VMD is the "reliable" progressive lens. The reliable lens for the wearer to achieve maximum visual comfort and the reliable lens for the ECP to be able to offer the optimum service.

Address of author:
Dipl.-Phys. Werner Köppen, c/o Essilor International, 1, rue Thomas Edison, F-94028 Créteil