*Kernon, the Improved Projection Lens of the Hypergon Type**

H. YZERMAN,
Kern & Co. Ltd., Aarau, Switzerland

ABSTRACT: *This paper analyzes the distortion of the projection lens of the Hypergon type, and shows means for its more than tenfold reduction.*

PROJECTION lenses of the Hypergon type are used in stereo restitution instruments with optical reconstruction of the bundles of rays. These lenses must be as far as possible free from distortion, cover an angular field of at least 100 degrees, and have a small aperture in order to achieve a depth of field of up to 30% of the average distance of projection. They consist of two symmetric meniscus shaped elements and an aperture stop in the plane of symmetry. Computations have shown that the distortion of a 6″ restitution camera with a lens of the Hypergon type can be kept within $\pm 16\,\mu$ for an angular field of 100 degrees and a projection distance of 25″. A distortion of this magnitude is not acceptable by modern standards of photogrammetry.

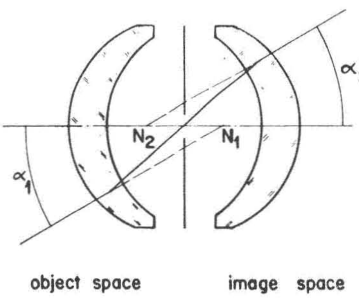

FIG. 1

There are two well known methods to compensate the distortion by either a mechanical or an optical correcting system. A mechanical correcting system impairs the rigidity of the inner orientation and the optical correction plates near the plane of the diapositive are rather expensive.

It is necessary to analyze the cause of the distortion in order to find means for reducing it.

A symmetric lens with an aperture stop in the plane of symmetry has the feature that the slope angle in the image space is equal to the slope angle in the object space for a ray which passes through the center of the aperture. Virtually this ray also passes through the centers of the entrance and exit pupil, which are called the nodal points. This central ray acts as an axis of symmetry for the narrow bundle of rays it represents and so defines the direction of a pencil as it traverses the optical system.

The distortion should be corrected not only for the average distance of projection, but over the whole depth of field. The projection lens of the Hypergon type would satisfy this condition if the nodal points were at exactly the same place for different slope angles. But the position of the nodal points usually depends upon the slope angles, because the nodal points are the images of the center of the aperture formed by each meniscus shaped element. These images are usually not free from spherical aberration except if formed by an aplanatic lens, and the meniscus shaped elements of the lens of the Hypergon type are not aplanatic. The author studied the character of the spherical aberration in the images

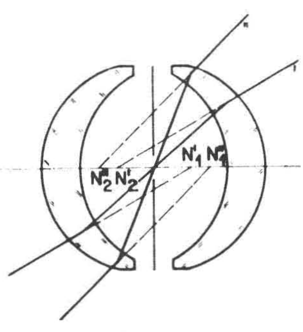

FIG. 2

* Presented at the Society's 26th Annual Meeting, Hotel Shoreham, Washington, D. C., March 23–26, 1960.

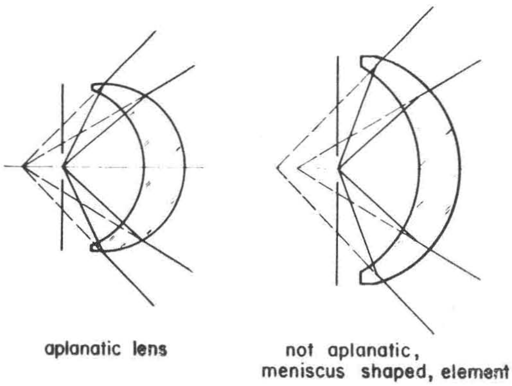

Fig. 3

of the center of the aperture, and it was his good luck to find that it was opposite and closely equal to that of a very thin plane parallel plate.

The improvement of the projection lens of the Hypergon type is therefore brought about by the introduction of two thin plane parallel plates one on each side of the aperture stop.

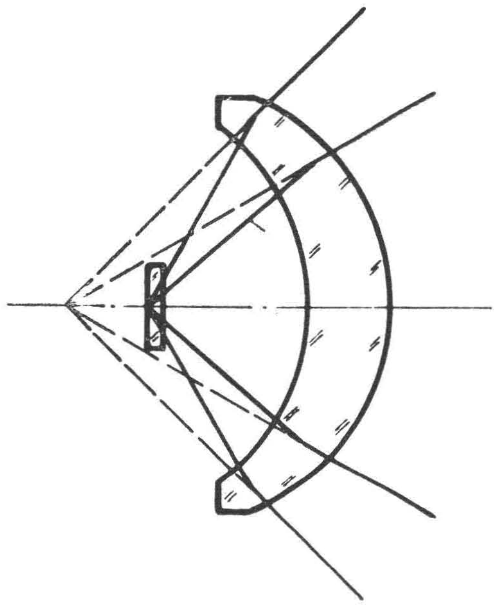

Fig. 4

The images of the center of the aperture are now up to a high degree free from spherical aberration. In other words, the position of the nodal points varies much less for different slope angles. This results in a more than tenfold reduction of the distortion. The plane

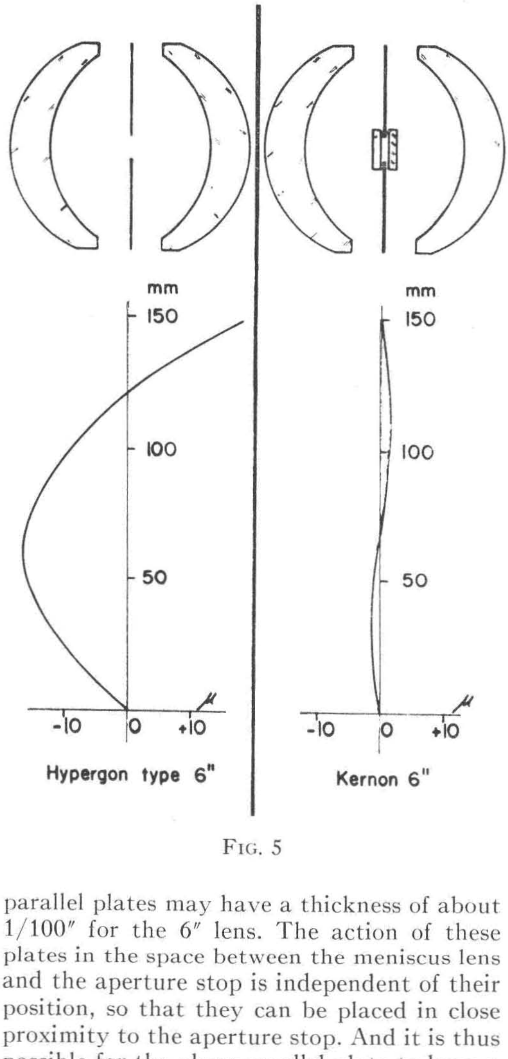

Fig. 5

parallel plates may have a thickness of about 1/100″ for the 6″ lens. The action of these plates in the space between the meniscus lens and the aperture stop is independent of their position, so that they can be placed in close proximity to the aperture stop. And it is thus possible for the plane parallel plate to have a diameter which is only slightly larger than the aperture.