UNUSUAL ZEISS MICROSCOPE OBJECTIVES

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The English Connection

The microscopes of the early nineteenth century reflected the talent and creativity of individual craftsmen. Standardization and the concept of interchangeability were not part of this period. Thus the the demise of a craftsman left the microscope owner with little interchangeability for objective threads and also for the slide-in sleeve eyepieces. The Royal Microscopical Society of London finally decreed a "standard" objective thread - naturally called the "Society Thread". It followed the then-popular Whitworth thread form with 36 threads per inch, and about 0.796 inch outside diameter. A standard sleeve diameter was also established. These dimensions are still in use today - a pretty good record for durability.

The English microscopes of the nineteenth century were tall instruments in comparison with later microscopes. They used long tubes, with 10 inches being about the most popular length. Some boasted tubes two feet long!

One technical advantage of the long tube was that long focal length objectives are composed of flatter glass elements and thus are easier and cheaper to manufacture. (Without going into optical theory - think of the telephoto lens structure of a modern 35 mm. camera and compare that with a wide-angle lens for the same camera.)

Zeiss and Abbe started the scientific microscope design concept. This covered the theory of image formation, lens design and fabrication, glass formulation, and the mechanical dimensions of the complete microscope. Zeiss and Abbe felt that a shorter microscope tube had numerous advantages (again the details are outside the scope of this short article). They were not afraid to tackle the consequently more complex objective construction, and standardized on a 160 mm. mechanical tube length. (See Fig. 1 to clarify the nomenclature.) It should be noted in passing that, by the twentieth century, most microscope makers adopted Zeiss' lead and standardized on 160 mm. or 170 mm. tube length for biological microscopes.

After the introduction of the Zeiss apochromats in 1886, Zeiss wanted to penetrate the English microscope market. Interchangeability of the microscope threads was no longer an obstacle. However, attaching a highly touted apochromat designed for the 160 mm. tube length to a long English microscope tube would have negated most of the claimed superiority for the Zeiss optics.

Zeiss decided to design and manufacture special apochromatic microscope objectives specifically for the English market. These objectives were designed for the 250 mm. tube length (about 10 inches long). This writer could not track down the exact release date for these special objectives. But the following information may help to bracket the period. The 1891 Zeiss microscope catalog lists the following dry apochromatic objectives made for the 250 mm. long English tubes: 24 mm., 12 mm., and 6 mm. focal lengths, providing approximately 10x, 20x, and 40x objective magnifications respectively.

Subsequent catalogs carried this listing (see fig. 2 copied from the 1902 catalog). The 1913 catalog still mentions the special English objectives, but without the details previously provided. It

Trace of the Rays through a Microscope

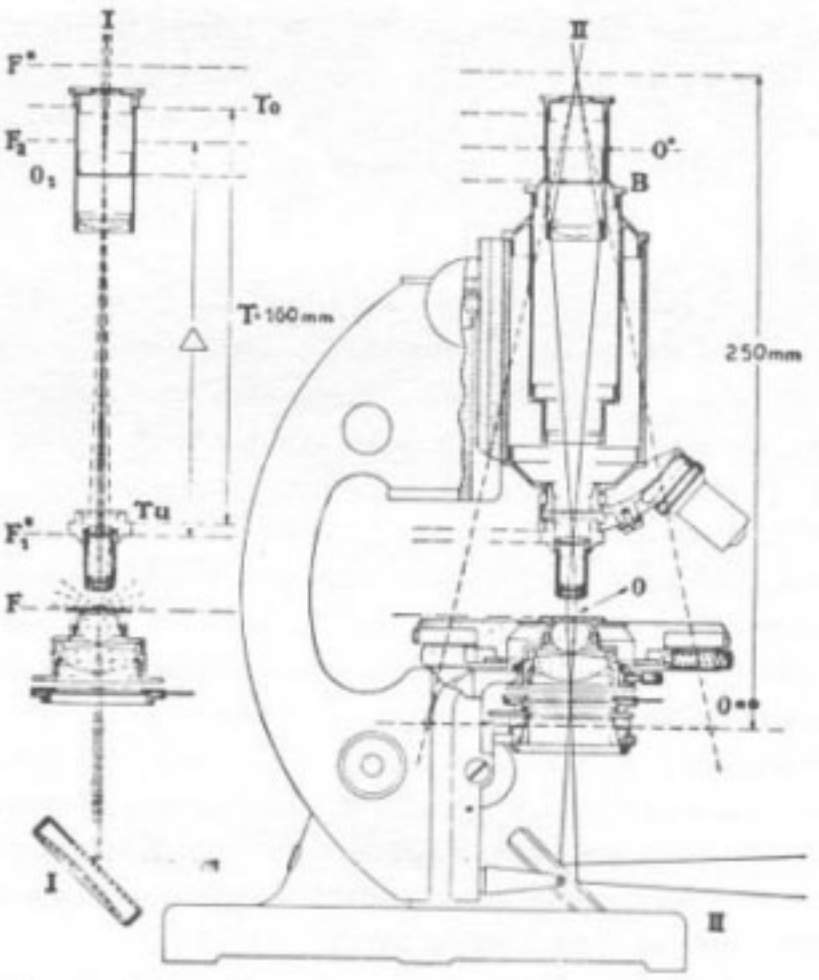

Figure 1. Catalog page shows 160 mm. tube length.

seems that after World War I it was dropped from the production line - probably because by that time the English manufacturers also adopted the shorter tube lengths.

The author has a sample of the 12 mm. and 6 mm. objectives made for the long English tubes - and obtained a 4 mm. focal length apochromatic objective with cover glass thickness adjustment collar also marked for the 250 mm. tube length. It is not clear from the lack of catalog listings whether the 4 mm. was a custom order or if it slipped by the catalogers. Figs. 3 and 4 illustrate these special objectives.

Zoom Objectives

The microscope objective can be considered as a specialized lens that projects a magnified image of the object into the focal plane of the eyepiece located at the top of the microscope tube (refer to fig. 1 again). The effective focal length of the objective determines the primary magnification of the microscope. Magnification is varied by changing the objectives, the eyepieces, or both.

A desire to vary the instrument's magnification without changing optics led Zeiss to pioneering development of a variable focal-length microscope objective. Zeiss used small and capital letters to identify specific objectives, and this variable magnification objective was designated "a*". The 1889 catalog listed this model (I could not locate earlier catalogs) and it was carried at least through the 1937 edition.

The 1895 catalog gives the following description: "Objective a* consists of two achromatic lenses combined after a formula peculiar to ourselves. By means of a ring rotating like a correction

collar, the distance between the two lenses can be varied, whereby, using one of the lower eyepieces, the magnification is variable in the proportion from about 1 to 2." The technical specification gave the equivalent focal length as 38 to 26 mm.

List of the Apochromatic Objectives.

	Description		Initial Magnification	Combined with Compens. Eye-piece 4. Tube-length 160 mm (about 6 1/8 in.)		Prices	Code-words
	Equivalent Focus mm	Numerical Aperture		Free Working Distance mm	Diameter of visible area of object mm	*Marks*	
Dry Series	16	0.30	15.5	5	2	80.—	Pacato
	8	0.65	31	1.0	1	100.—	Pacetor
	4	0.95	63	0.2	0.45	140.—	Pacer
	3	0.95	83	0.15	0.35	160.—	Paciencia
Water Immersion	2.5	1.25	100	0.13	0.25	250.—	Pacificar
Homogeneous Immersion	3	1.30	83	0.16	0.35	300.—	Pactar
	3	1.40	83	0.16	0.35	400.—	Padilla
	2	1.30	125	0.14	0.25	300.—	Padrastro
	2	1.40	125	0.14	0.25	400.—	Padre
	1.5	1.30	167	0.09	0.20	350.—	Padrino

Figure 2. Objectives available in the 1902 catalog.

It seems that the earliest variable-magnification lens commercially produced was the Zeiss a* microscope objective. The term "zoom lens" was not coined until after the advent of television, but this model was probably the first zoom lens. (Zeiss introduced a variable-magnification hand telescope in the 1920's - but that instrument used a different optical principle).

After World War II, Zeiss Oberkochen again marketed a highly refined version of this concept. In the booklet "Optical Systems for the Microscope" (various editions in the 1960's and 1970's) it is described under the heading of special-purpose objectives for the normal transmitted-light microscope: Planachromat, 1.6-5.0 magnification, Catalog number 46 20 13. Note that Zeiss increased the zoom range to about 1 to 3, and used a flat-field design. Fig. 5 illustrates two examples of the a* objective.

Unit Magnification

One of the first questions usually asked is "What is the power of your microscope?" Imagine an answer: it does not magnify at all! While this extreme case does not occur to my best knowledge, Zeiss Oberkochen did produce a highly specialized microscope objective with a low power eyepiece, whose total magnification can be as low as 5x, lower than the magification produced by most pocket magnifiers.

This objective was also described in the literature mentioned above, again under the listing of special purpose objectives. Catalog number 46 20 10, Planachromat 1x, focal length 134.7 mm. Used with the 160 mm. mechanical tube length, it managed to shorten the objective's physical dimension - just as a true telephoto lens has a shorter tube length than focal length. This objective was not parfocal with the regular objectives, and had to be used with obvious care. Fig. 6 shows such an objective along with the two conventional objectives.

Figure 3. 4 mm., 6 mm., and 12 mm. objectives.

Figure 4. 12 mm. objective for the 250 mm. tube.

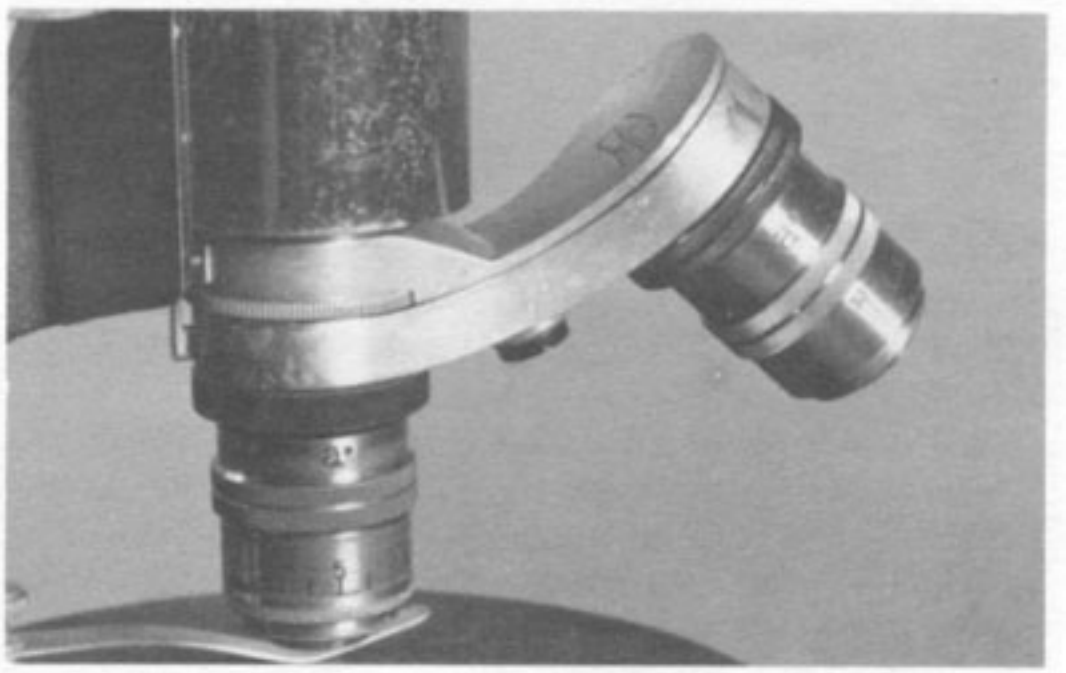

Figure 5. Two variable magnification a objectives.*

Done With Mirrors

Optical instruments use lenses or mirrors - or a combination of the two to produce images. The process using lenses is called "refraction" (Latin root means "breaking", or "dioptric" meaning "see through" in Greek. For the process using mirrors the English language adopted the Latin root "reflection"; the Greek term being "catoptric". The debate over the merits of the two types of image-forming systems spans the whole history of optical instrument making.

The major advantage of the mirror system is the absence of chromatic aberration. It is then an obvious idea to use mirrors as the image-forming elements in a microscope objective. Indeed, this idea was put into practice. An early reference is found to "F.H. Smith's Reflecting Microscope" in the book "The Microscope and Its Revelations" by Carpenter, 7th edition, 1891.

The concept was again revived in Jena after World War II, probably stimulated by the success of the compact mirror-lens combination telescopes, designated as catadioptric lenses. These mirror microscopes objectives are described in "Jena Review", 1964, Special Fair Issue.