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Progress of Optical Properties of an Aerial Lens Type

Abstract

The development of the optical properties of aerial wide-angle lenses used in Wild RC-8 and RC-10 cameras during a period of 20 years has been dealt with. The lens types 15Ag, 15UAg, 15UAg II and 15/4 UAg are taken into the comparison. All determinations are made with the horizontal goniometer of the laboratory of photogrammetry of the Helsinki University of Technology (HUT) in the years 1975 - 79. The prototype of the 15/4 UAg lens was in the HUT for measurements in 1977. The characteristics to be determined were the radial distortion and its asymmetry, calibrated focal length, tangential distortion, lateral color, resolving power and MTF. The image quality of the three first mentioned ones was about the same, but the 15/4 UAg was remarkably better.

Introduction

In the period 1969-74 a horizontal goniometer for the calibration of aerial cameras was developed in the HUT. All aerial cameras used in Finland have been tested with this equipment with intervals of 1-3 years. The characteristics to be determined are: Radial distortion and its asymmetry, calibrated focal length, main component of tangential distortion, lateral color, resolving power and MTF.

The study relates to the lens series for RC-8 and RC-10 wide-angle cameras. The lenses are:

			First calibration by Wild
1)	15Ag	No. 102	1960
2)	15UAg	No. 246	1964
3)	15UAg II	No.3014	1973
4)	15UAg II	No.3058	1975
5)	15/4UAg	No.13001	1977 (prototype)

The whole calibration program was performed for the lenses 15UAg No. 246 and 15UAg II No.3014 in 1975. The 15UAg II No.3058 lens was measured in 1977. Wild Heerbrugg delivered the prototype of the new type 15/4UAg to the HUT for comparison measurements in the same year. the author made the determinations for this lens in October-November 1977. The 15Ag No.102 has been measured several times, last time in 1979.

Radial and tangential distortion

In the determination of the radial distortion in principle the same method is used as that used by Wild Heerbrugg and Carl Zeiss Oberkochen. The observations are made from both sides of the goniometer two times. The origin of the measurement is the principal point of autocollimation. Twenty points on one semidiagonal are measured. The standard error of the distortion is ± 2 µm.

The symmetrical component of tangential distortion is determined by measuring the bending of a horizontal straight (diameter)line of the grid. The bending is caused by the aerial lens. The systematic errors caused by the goniometer are eliminated wholly. The standard error of the tangential distortion determined by this method is $\pm$ 1 µm.

The geometrical errors of the lens series studied are presented in the figures 1 and 2. The radial distortion of the cameras 1-4 is notified only to the value r = 100 mm, because in the corner area of the image the phase shift phenomen causes remarkable lack of clearness in the image of the grid crosses in the calibration when the lines are in diagonal direction as the situation is in the goniometer of the HUT. This lack of clearness does not appear in the 15/4UAg lens.

All properties listed in the introduction are almost characteristic to the lens type, except the components of decentering distortion, the asymmetry of the radial distortion and the tangential distortion which are in principle individual. The symmetry of newer lenses of Wild (after 1968) has, however, been excellent in all five lenses measured in the HUT, the maximum value of tangential distortion being $\pm$ 1 µm.

Calibrated focal length

Lens		Wild		HUT	
15Ag	No.102	153.34	1979	153.35 (.347)	1979
15UAg	No.246	152.14	1972	152.14 (.137)	1974
15UAg II	No.3014	153.07	1975	153.06 (.062)	1975
15UAg II	No.3058	153.13	1976	153.13 (.132)	1977
15/4 UAg	No.13001	153.24	1977	153.24 (.244)	1977

The variations in the spectral distributions of light and in the temperatures may be reasons for the differencies. The standard error of determination of the cfl generally seems to be $\pm$ 0.01 mm by visual goniometers. There are 6 cameras calibrated by Wild Heerbrugg, 5 cameras calibrated by Carl Zeiss Oberkochen and these 11 cameras calibrated in the HUT in the sample.

Lateral color

The lateral color was determined by using a continuous interference filter behind the eyepiece of the observing telescope in the goniometer. The radial distortion was determined with 9 wave lengths of light from 450 nm to 650 nm. The results are in the fig. 3.

Resolving power

The RP of the lens cone was determined without the influence of film. In this method the camera is in the horizontal position in the goniometer. The test plate with 9 groups of test figures at field angles from 0^{o} to 43^{o} is placed onto the camera frame. The figures can be observed with different filters visually through the lens or they can be photographed through the observation telescope and the camera with an enlargement of about 10x. The register camera is Nikon F 1.4/ 50 mm, the film Kodak Panatomic-X, the developer D-76 undiluted. The determination of the resolving power is made from the prints made from the register negatives. In this manner it is possible to compare the resolving powers of different cameras better than by microscope observing. In the four first mentioned lenses there appears rather strong phase shift and spurious resolution in the corner of the image even at relatively low frequencies. In the 15/4 UAg lens the spurious resolution begins at so high a frequency that it does not have detrimental effect either on aerial photograph or on geometrical calibration any more. The results are in the figure 4. In the figures we can see that in newer cameras an attempt has been made by focusing to achieve the optimum quality for the whole image.

MTF

The films exposed for the determination of the RP are used also for determining the MTF. The main steps of the MTF method are the following:

1. Goniometer photography
2. Measurement of the negatives with a microdensitometer
3. Sensitometric exposure of the register film. The characteristic curve constructed in non-logarithmic form

4. Transformation of the microdensitometer values into effective exposure values by using the characteristic curve.
5. Calculation of the square wave modulation.
6. Square wave modulation to sine wave modulation with Fourier analysis.
7. Corrections caused by the microdensitometer slit (modulation 98-99.5%) and the object figures (modulation 96-98%).
8. MTF of the Panatomic-X and the adjacency effect influence in the opposite directions. The errors caused by them and the influence of the goniometer optics remain as error factors of the method.

The accuracy of the MTF-method used was studied by making the determinations for the camera 15Ag No.102 in 7 field angles in the PTB in Braunschweig, FRG, and in the HUT. The difference of the MTF values determined by the two methods was mainly from 3 to 10 % depending somewhat on the field angle. In general the method used in the HUT gives a little greater values than the EROS method used in the PTB. The results of lens series are in the figures 5.

Conclusion

In the 15UAg II lens the radial distortion is already ± 2 µm except in the corner of the picture. In the 15/4 UAg type it has further been a little smaller. It seems that the centering of the lens elements of the modern cameras is more succesful than that of the older cameras. (The sample is about 20 cameras measured in the HUT.) From the 15Ag to 15UAg II the lateral color has remarkably reduced but from that on it has not changed substantially. In the types 15Ag, 15UAg and 15UAg II the resolving power and MTF are practically on the same level. In all three phase shift phenomena and spurious resolution appear in the corners of the picture. The RP of the 15/4 UAg lens is essentially better in these areas. The 15/4 UAg type has also a better MTF at greater values of the field angle than the former types and much better MTF with the aperture of 1:4 than the 15UAg II type.

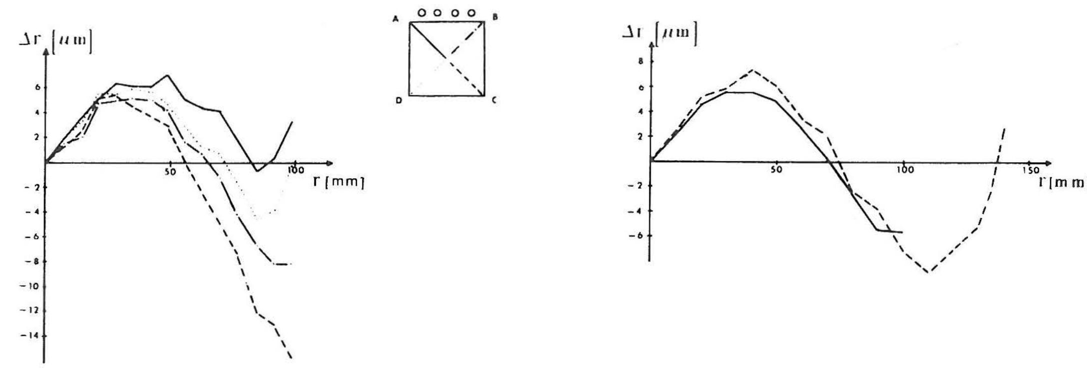
Acknowledgements

The author wishes to thank the Institute of Photogrammetry of the Helsinki University of Technology, where all measurements were possible to do, and Wild Heerbrugg, who sent the 15/4 UAg prototype to the HUT in the year 1977 for comparison research.

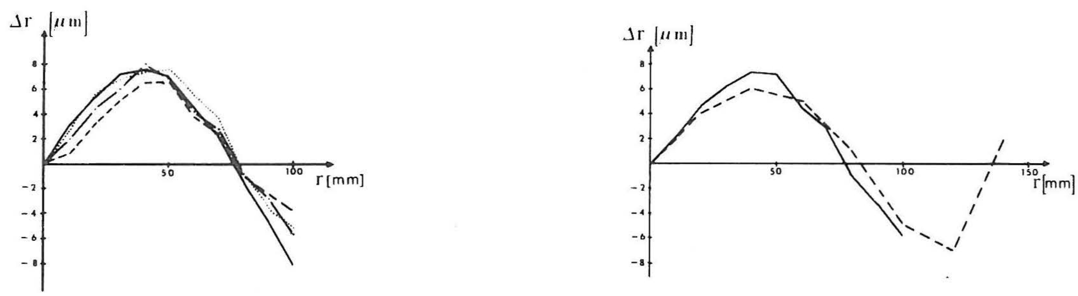
References

Hakkarainen, J. : On the Use of the Horizontal Goniometer in the Determination of the Distortion and Image Quality of Aerial Wide-Angle Cameras. 163 p., Helsinki 1976

Wild Heerbrugg : Calibration Certificates of the RC-8 15Ag No.102, RC-8 15UAg No.246, RC-10 15UAg II No. 3014, RC-10 15UAg II No.3058 and measurements of the 15/4 UAg No.13001.



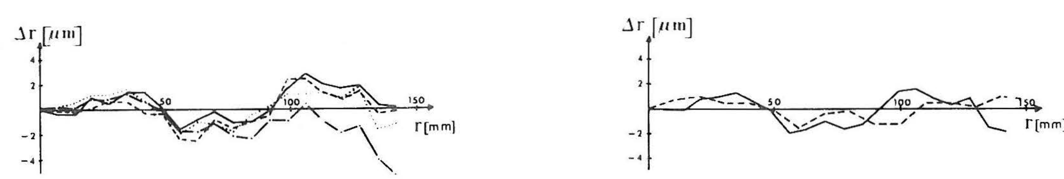
15Ag No. 102



15UAg No. 246

15UAg II No. 3058

(15UAg II No. 3014 is similar)

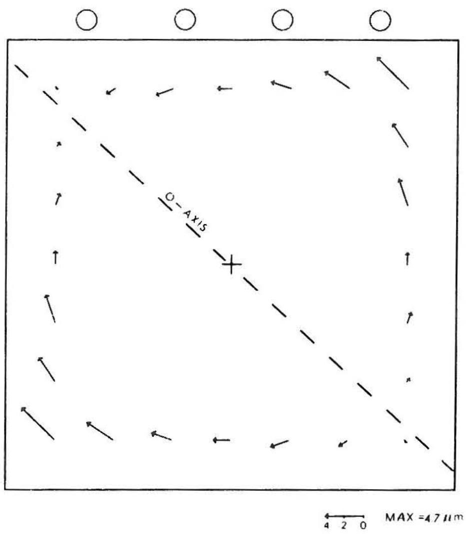


15/4 UAg No. 13001

Four semidiagonals, origin at PPA

Mean radial distortion
——— HUT - - - - Wild

Fig. 1. Radial distortion.



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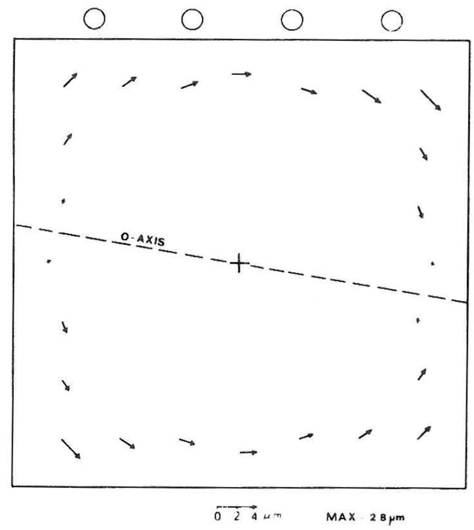

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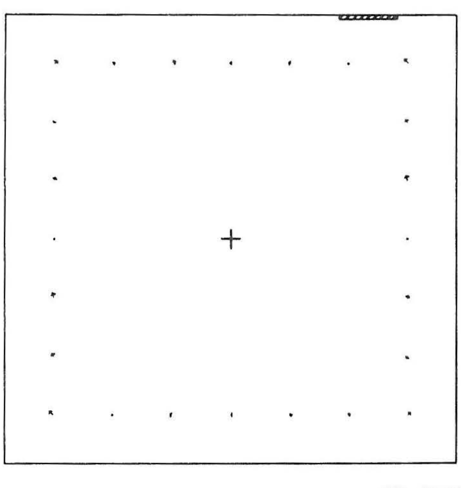

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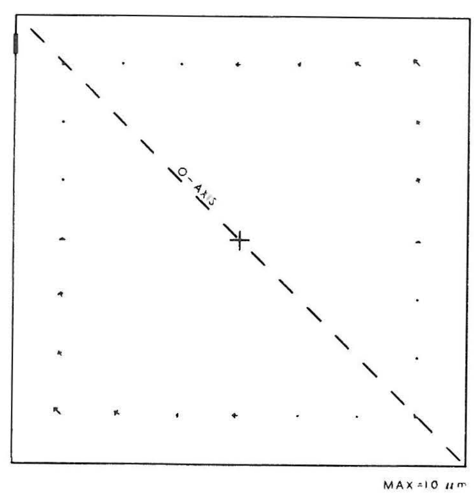
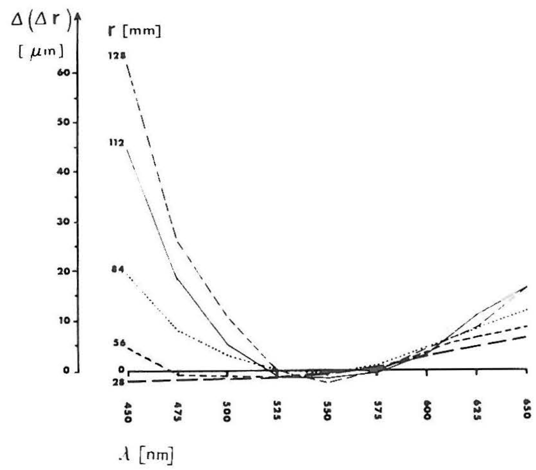


15/4 UAg No. 13001

Fig. 2. Main component of tangential distortion.



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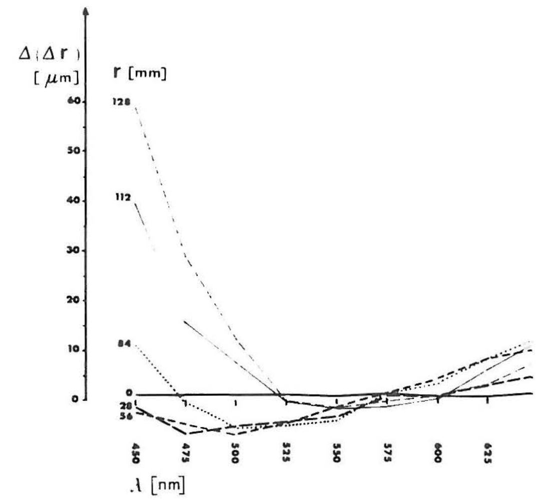

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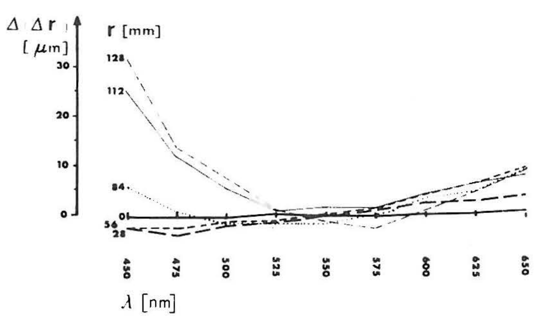

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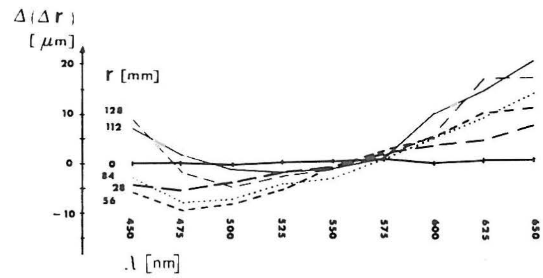

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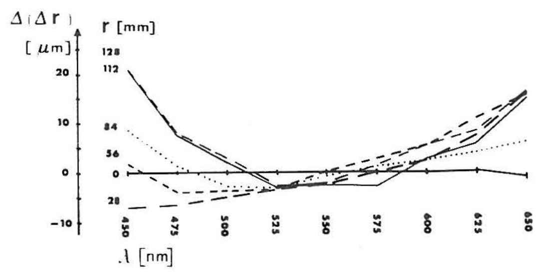
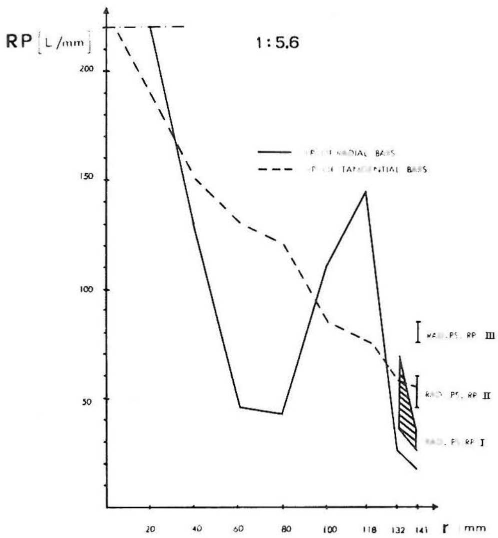


15/4 UAg No. 13001

Fig. 3. Lateral color.



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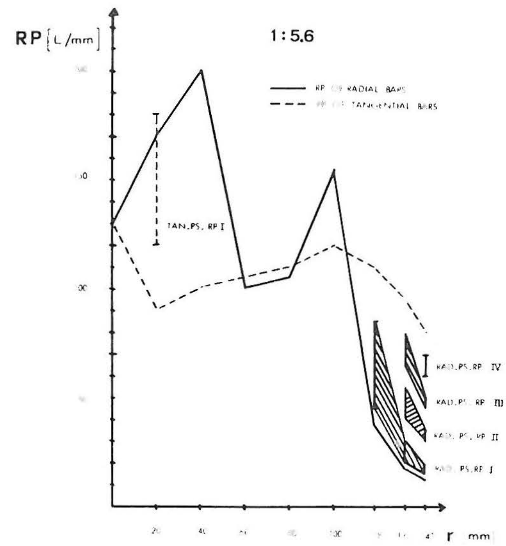

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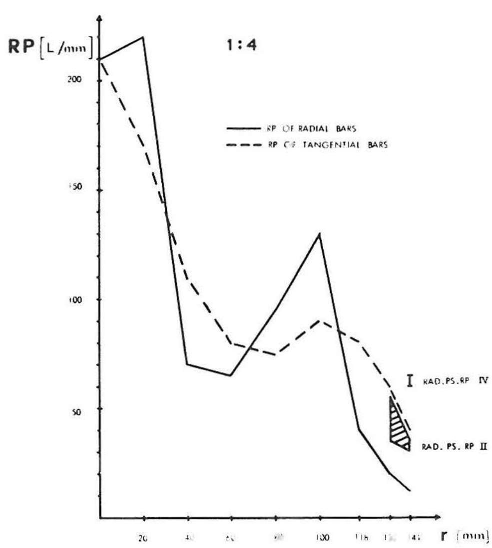
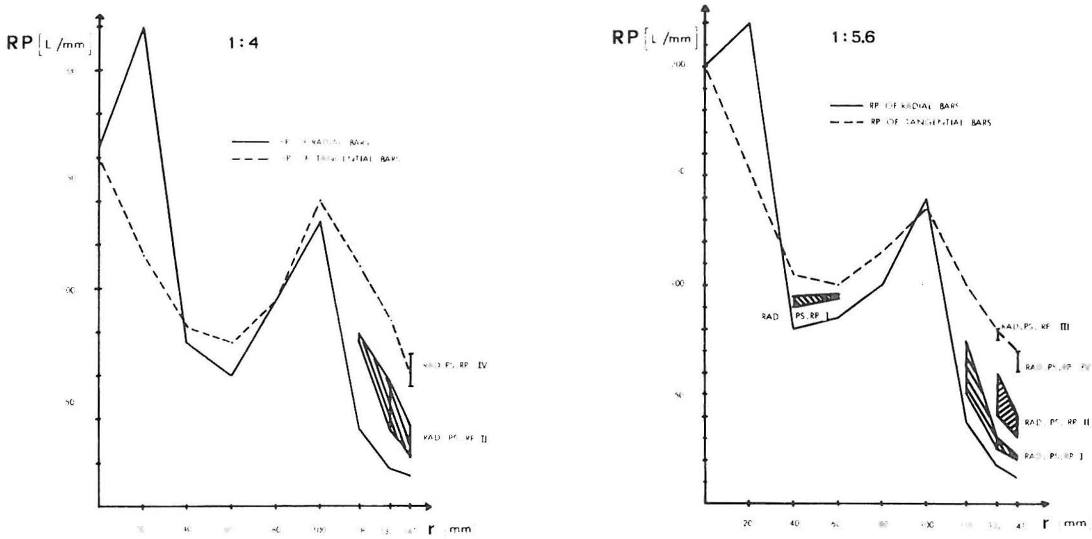


15UAg II No. 3058

Fig. 4. Resolving power.



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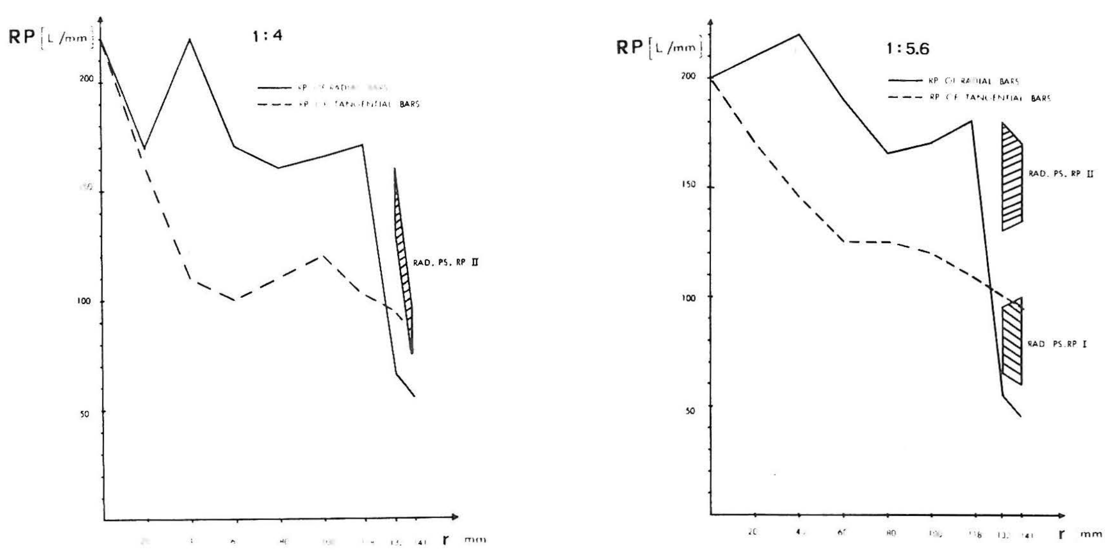
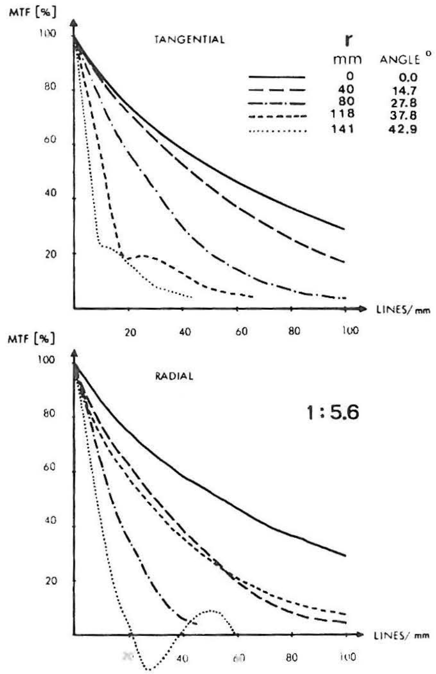


15/4 UAg No. 13001

Fig. 4. Resolving power.



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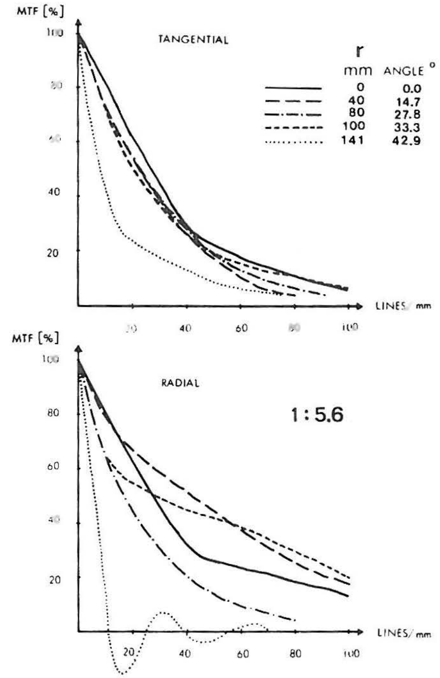

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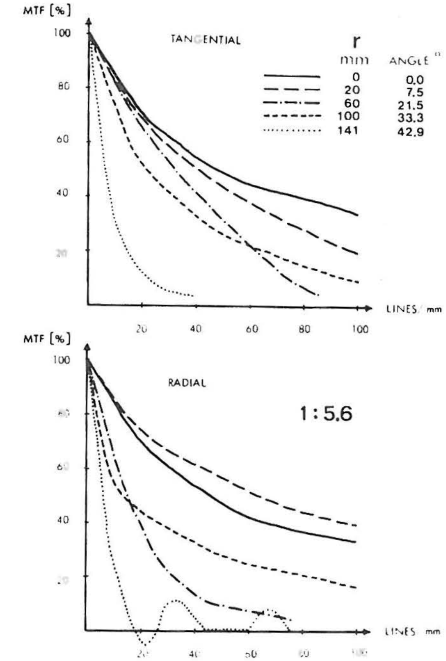
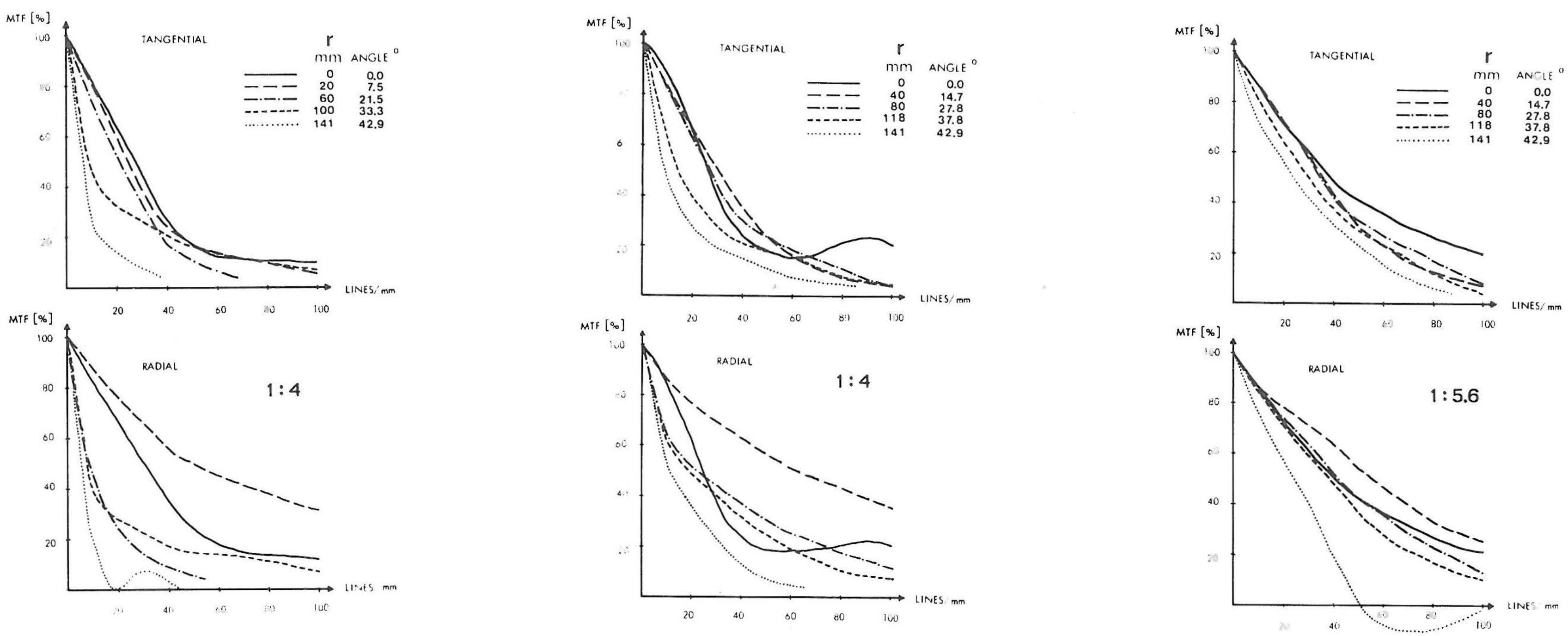


15UAg II No. 3014

Fig. 5. MTF.



15UAg II No. 3014

(15UAg II No. 3058 is about similar)

15/4 UAg No. 13001

Fig. 5. MTF.