Apo-Grandagon, Grandagon-N

Wide Angle Lenses: Large Format Photography in Small Spaces

Especially when photographing buildings, industrial shots or even landscapes, lenses with very large image angles are required in order to get the whole object in the picture when the choice of taking locations is small. For example, room interiors which have to be shown as completely as possible, building views which can only be taken from short distances or widescreen scenic panoramas. Converging lines which have such an annoying effect in wide angle shots can only be avoided by parallel shifts which require abundant image circle reserves, i. e. even larger image angles. But as the image angle increases, so it becomes more difficult for the optical designer to guarantee high image reproduction quality. This applies not only to the definition, but also and particularly for the equal illumination of the image field and the avoidance of distortion. As a result, good wide angle lenses become very complex.

With three wide angle lens types for large format photography, Rodenstock sets standards for image reproduction performance. In addition, these lenses are very fast so that focusing is substantially easier.

Apo-Grandagon – the Wide Angle Lens With Apochromatic Correction

By using innovative glass combinations – including ED glasses – the 8-element Rodenstock Apo-Grandagon has been apochromatically corrected. In practice this means that possible color fringes in the corners at high-contrast edges (e. g. building silhouettes against a bright sky) are reduced to such an extent that they are no longer visible. Even with back-lit building shots there no longer is any color fringe at fine details.

With an image angle – 120° the Rodenstock Apo-Grandagon offers sufficient movement reserves when the roll film sizes 6×6 cm to 6×12 cm are used. The Apo-Grandagon 55 mm f/4.5 even allows the use of sheet film sizes 9×12 cm and 4×5". This makes the Apo-Grandagon an ideal lens for building, industry and landscape photography.

Distortion values of less than 0.5 % in the whole scale range ensure that curvature of straight lines in the corners is restricted to such a low minimum that it is no longer a problem. This feature is decisive for quality – particularly for building shots, but also for wide angle product shots with a "dramatic" effect.

The excellent image error correction allows f/8 to be used as the working stop, shorter exposure times can be used for outdoor shots for better sharpness, and less light is required for indoor shooting.

Apo-Grandagon 55 mm f/4.5 in Compur 0 shutter

Grandagon-N f/4.5 – the Fast "Space Expander" for the Highest Quality Demands

The 8-element Rodenstock Grandagon-N f/4.5 is characterized by an image angle of 105° and with its three focal lengths of 65, 75 and 90 mm is the ideal wide angle lens for the highest quality demands in the film formats 9×12 cm/4×5" or 13×18 cm/5×7".

The high maximum aperture of f/4.5 makes point-sharp focusing easy and also allows comfortable image evaluation on the screen despite the light fall-off in the corners due to the wide angle. The exceptional image error correction allows a working stop of 16 which, in turn, allows relatively short exposure times for difficult lighting situations and for moving subjects.

The image quality is equally high right into the corners; even high-contrast edges in the corners are reproduced with sharp contours and with practically no color fringes. The distortion is less than 1% and is not critical for building shots.

Grandagon-N f/6.8 – the Very Compact Wide Angle Lens for Large Taking Formats

While possessing a slightly lower maximum aperture, the 6-element Rodenstock Grandagon-N f/6.8 appeals thanks to its compact design. With an image angle of 102° it is available in focal lengths from 75 to 200 mm (104° with focal length 115 mm) for taking formats of 9×12 cm/4×5" to 18×24 cm/8×10". All models allow more than sufficient movement within their respective taking formats.

High sharpness which is very uniform over the complete image field and the relatively low light fall-off to the corners also guarantee good results with this Grandagon version. Distortion values of less than 1.5% over the whole scale range will meet even the highest demands in building photography.

Focus-Mount for Apo-Grandagon/Grandagon-N

The helical Focus-Mount is available as an accessory and allows focusing down to close-up range on cameras without bellows.

Grandagon-N 90 mm f/4.5 in Copal 1 shutter

Grandagon-N 90 mm f/6.8 in Copal 0 with Focus-Mount

Apo-Grandagon

Formats, Shutters and Lens Dimensions

Apo-Grandagon	Recommended maximum film format	Shutter size	Smallest aperture with shutter*			Push-on mount diameter	Filter thread	Rear lens barrel diameter	Flange focal distance	Overall length	Shutter thread
			Copal	Compur	Prontor prof.						
						a	b	c	d	e	f
35 mm f/4.5	6×9 cm / 6×12 cm	0 01 S	22 –	– –	– 22	70 mm	M 67×0.75	60 mm	43.2 mm 41.1 mm	55.7 mm	M 32.5×0.5 M 39×1
45 mm f/4.5	6×9 cm / 6×12 cm	0 01 S	32 –	– –	– 32	70 mm	M 67×0.75	60 mm	55.5 mm 53.4 mm	65,3 mm	M 32.5×0.5 M 39×0.75
55 mm f/4.5	9×12 cm/4×5"	0 01 S	45 –	45 –	– 45	70 mm	M 67×0.75	60 mm	67.6 mm 65.5 mm	69,8 mm	M 32.5×0.5 M 39×0.75

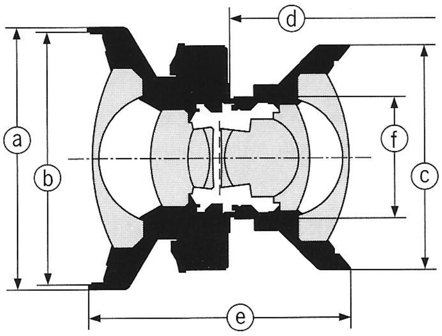
* Other shutters on request

Notes on the Recommended Working Aperture

In the table, the range given for the recommended working aperture is that in which the highest sharpness is achieved over the whole format with the depth of field being neglected.

The larger aperture applies to unmoved lenses, i.e. when the "format range" is used. The smaller aperture is recommended for shifted and/or tilted lens, i.e. for the "movement range".

Depending on the reproduction ratio and the depth of the motif, the required depth of field may make further stopping down necessary. In such cases, the sharpness may be reduced due to diffraction – particularly in the center of the image circle.



Lens section: 8 elements in 4 groups

Working Aperture, Angle of View, Image Circle and Shift Limits

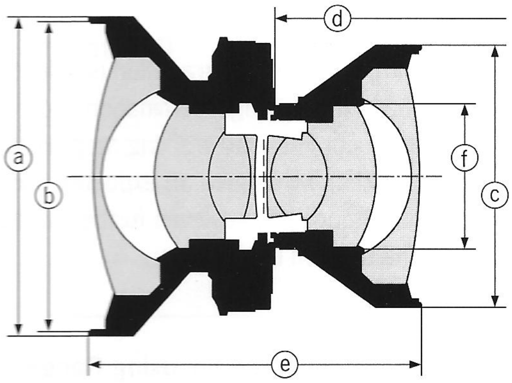
Apo-Grandagon	Recomm. working aperture	Angle of view at f/11	Image circle ∅ at 1:∞ and f/11	Shift limits in mm (with horizontal format, magnification ratio 1:∞ and f/16)								
				24×36 cm	3×3 cm	4.5×6 cm	6×6 cm	6×7 cm	6×9 cm	6×12 cm	9×12 cm	4"×5"
35 mm f/4.5	8 - 11	120°	125 mm	↑49 →44	↑47 →47	↑35 →31	↑29 →29	↑24 →22	↑20 →15	↑1 →1		
45 mm f/4.5	8 - 11	110°	131 mm	↑52 →47	↑50 →50	↑38 →34	↑31 →31	↑28 →25	↑24 →19	↑4 →2		
55 mm f/4.5	8 - 11	110°	163 mm	↑68 →63	↑66 →66	↑56 →51	↑49 →49	↑46 →42	↑40 →32	↑30 →19	↑16 →13	↑7 →5

Grandagon-N

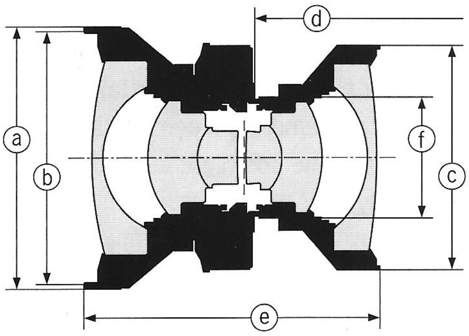
Formats, Shutters and Lens Dimensions

Apo-Grandagon	Recommended maximum film format	Shutter size	Smallest aperture with shutter* Copal	Compur	Prontor prof.	Push-on mount diameter	Filter thread	Rear lens barrel diameter	Flange focal distance	Overall length	Shutter thread
						a	b	c	d	e	f
65 mm f/4.5	9×12 cm / 4×5"	0 01 S	45 –	45 –	– 45	60 mm	M 58×0.75	51 mm	70.1 mm 68.0 mm	63.5 mm	M 32.5×0.5 M 39×0.75
75 mm f/4.5	9×12 cm / 4×5"	0 01 S	45 –	45 –	– 45	70 mm	M 67×0.75	60 mm	81.9 mm 79.8 mm	73.5 mm	M 32.5×0.5 M 39×0.75
75 mm f/6.8	9×12 cm / 4×5"	0 01 S	45 –	45 –	– 45	60 mm	M 58×0.75	54 mm	78.5 mm 76.4 mm	65 mm	M 32.5×0.5 M 39×0.75
90 mm f/4.5	13×18 cm / 5×7"	1 / 1 S	45	45	45	85 mm	M 82×0.75	70 mm	98 mm	88.5 mm	M 39×0.75
90 mm f/6.8	9×12 cm / 4×5"	0 01 S	45 –	45 –	– 45	70 mm	M 67×0.75	60 mm	93.6 mm 91.5 mm	78.5 mm	M 32.5×0.5 M 39×0.75
115 mm f/6.8	13×18 cm / 5×7"	1 / 1 S	45	45	45	85 mm	M 82×0.75	70 mm	121 mm	93 mm	M 39×0.75
155 mm f/6.8	18×24 cm / 8×10"	1 / 1 S	45	45	64	110 mm	M 105×1	90 mm	169 mm	133.5 mm	M 39×0.75
200 mm f/6.8	18×24 cm / 8×10"	3	64	64	64	140 mm	M 135×1	115 mm	215 mm	172 mm	M 62×0.75

* Other shutters on request



Lens section (f/4.5): 8 elements in 4 groups



Lens section (f/6.8): 6 elements in 4 groups

Working Aperture, Angle of View, Image Circle and Shift Limits

Apo-Grandagon	Recomm. working aperture	Angle of view at f/22	Image circle ∅ at 1:∞ and f/22	Shift limits in mm (with horizontal format, magnification ratio 1:∞ and f/22) 6×7 cm	6×9 cm	6×12 cm	9×12 cm	4×5"	13×18 cm	5×7"	18×24 cm	8×10"
65 mm f/4.5	16 - 22	105°	170 mm	↑50 →46	↑45 →36	↑35 →23	↑22 →17	↑12 →10				
75 mm f/4.5	16 - 22	105°	195 mm	↑63 →59	↑59 →49	↑51 →36	↑38 →31	↑29 →25				
75 mm f/6.8	16 - 22	102°	187 mm	↑59 →55	↑55 →45	↑46 →32	↑33 →27	↑24 →20				
90 mm f/4.5	16 - 22	105°	236 mm	↑85 →80	↑81 →71	↑75 →58	↑62 →53	↑54 →48	↑20 →16	↑21 →16		
90 mm f/6.8	22 - 32	102°	221 mm	↑77 →73	↑73 →63	↑67 →50	↑53 →45	↑45 →40	↑9 →7	↑10 →7		
115 mm f/6.8	22 - 32	104°	291 mm	↑113 →109	↑111 →99	↑106 →86	↑92 →82	↑85 →77	↑57 →47	↑58 →47	↑3 →2	
155 mm f/6.8	22 - 32	102°	382 mm			↑154 →132	↑141 →129	↑133 →125	↑110 →95	↑111 →96	↑67 →55	↑50 →42
200 mm f/6.8	22 - 32	102°	495 mm						↑171 →154	↑172 →155	↑133 →117	↑118 →105

Accessories: Center Filter and Focus-Mount

Neutral Gray Center Filter to Compensate for Physically Induced Light Fall-off

Exept for fish-eye designs, all lenses will, in principle, show a light fall-off towards the edges of the image circle. This will increase over-proportionally as the image angle grows so that it becomes visible with wide angle lenses on critical motifs, e. g. with a sky of exactly uniform shade. At 100° image angle this light fall-off already reaches more than two aperture stops in accordance with the "cos^4 law". With an open diaphragm, the light drop-off due to mount vignetting also comes into play. This may be of similar value and will reduce the screen brightness in the corners. But from the recommended working stop onward it plays no role and does not need to be compensated in the shot.

If wide angle lenses are used up to the edge of the image circle for the largest possible taking formats or due to camera movements, a center filter should then be used to reduce the cos^4 light fall-off. A center filter is a neutral gray filter with a density which is high at the center and which falls off to complete translucence at the rim. The density gradation is selected to ensure that a uniform image illumination is produced from the recommended working stop. However, the center filter will require an exposure correction (see table). Stopping down even further will have no effect on the uniform illumination.

Which Center Filter for Which Grandagon Lens?

Apo-Grandagon or Grandagon-N	Filter thread size	Exposure correction alternatively f-stops / shutter speed		Order number of center filters
35 mm f/4.5	E 67/86	+2	4×	1094.2403.143
45 mm f/4.5	E 67/86	+2	4×	1094.2403.143
55 mm f/4.5	E 67/86	+2	4×	1094.2403.143
65 mm f/4.5	E 58/77	+1.5	3×	1094.2403.138
75 mm f/4.5	E 67/86	+1.5	3×	1094.2403.139
75 mm f/6.8	E 58/77	+1.5	3×	1094.2403.138
90 mm f/4.5	E 82/112	+1.5	3×	1094.2403.140
90 mm f/6.8	E 67/86	+1.5	3×	1094.2403.139
115 mm f/6.8	E 82/112	+1.5	3×	1094.2403.140
155 mm f/6.8	E 105/127	+1.5	3×	1094.2403.141
200 mm f/6.8	E 135/–	+2	4×	1094.2403.134

Focus-Mount for Focusing on Cameras Without Bellows, e. g. Shift Cameras

The lenses Apo-Grandagon and Grandagon-N with focal lengths up to 90 mm and shutters of the size 0 or 01 S are also available in a version with a helical "Focus-Mount". This allows them to be used on cameras which do not possess a focusing device.

The Focus-Mount has a distance scale coordinated to the focal length of the corresponding lens so that, for example with hand-held shots with shift cameras, precise focusing is also possible without screen observation. Existing Rodenstock lenses of the types named can be equipped with the Focus-Mount too. The Focus-Mount has a straight-line focusing so that the lens it is connected to will not turn when the distance ring is turned. The time and f/stop setting of the shutter can therefore be adjusted or read regardless of the focusing position.

Information on the adaptation can be obtained from the camera manufacturer or from Rodenstock Photo-Optics.

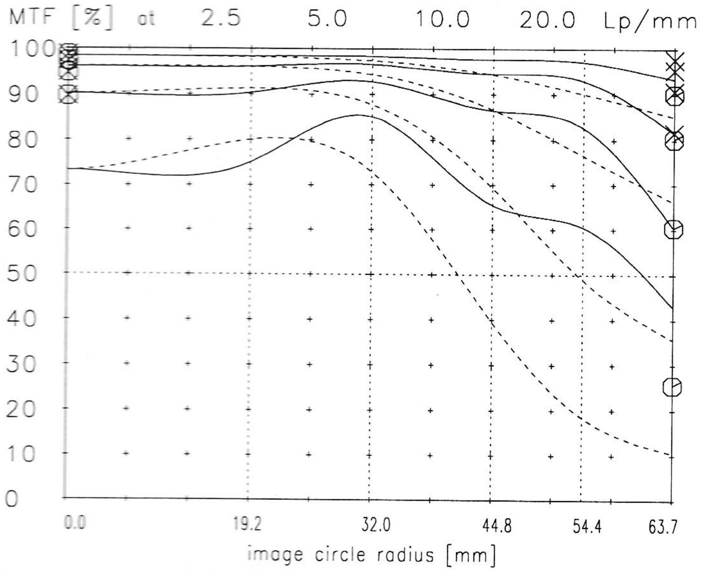
Flange Focal Distance and Focusing Range

Apo-Grandagon or Grandagon-N	Helical mount flange focal distance at 1:∞ with Copal/Compur	Focusing range of the lens withhelical mount
35 mm f/4.5	25.2 mm*	∞ ... ≈ 0.30 m
45 mm f/4.5	37.5 mm*	∞ ... ≈ 0.40 m
55 mm f/4.5	49.6 mm	∞ ... ≈ 0.60 m
65 mm f/4.5	52.1 mm	∞ ... ≈ 0.70 m
75 mm f/4.5	63.9 mm	∞ ... ≈ 0.90 m
75 mm f/6.8	60.5 mm	∞ ... ≈ 0.90 m
90 mm f/6.8	75.6 mm	∞ ... ≈ 1.30 m

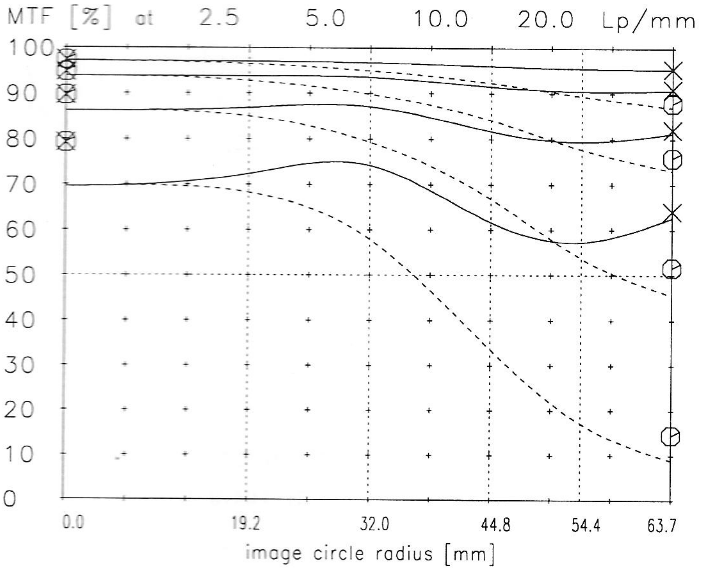
* Copal only

Apo-Grandagon 35 mm f/4.5

MTF at ratio 0.03x f/ 8



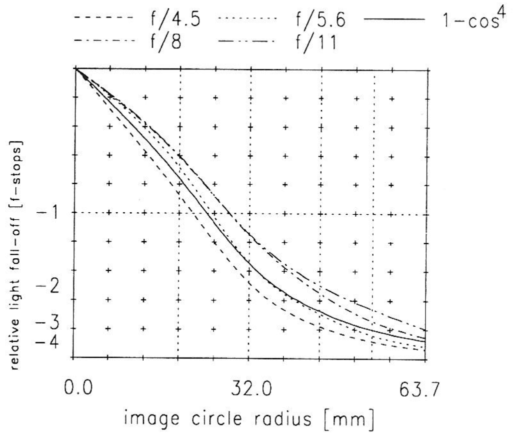
MTF at ratio 0.03x f/ 16



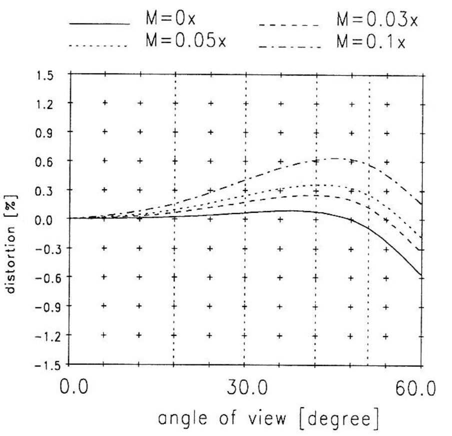
——— sagittal, × Diffraction limited value
- - - - - meridional, ⊖ Diffraction limited value

Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

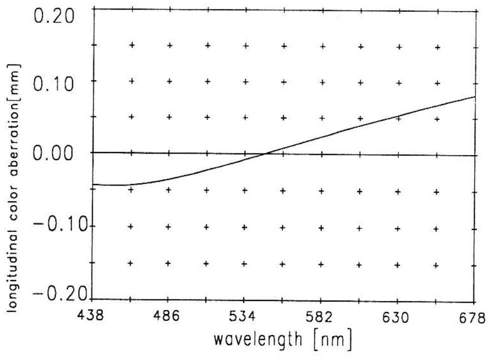
relative light fall-off at ratio 0.03x



Distortion at ratio 0x to 0.1x

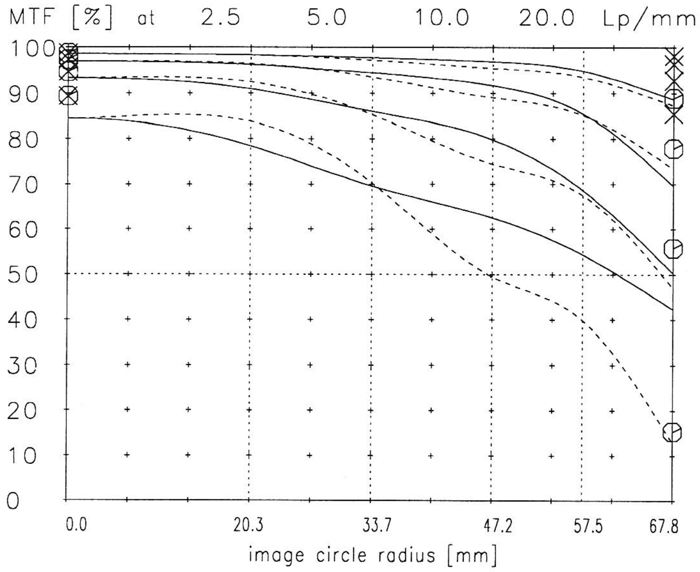


Longitudinal color aberration at ratio 0.03x

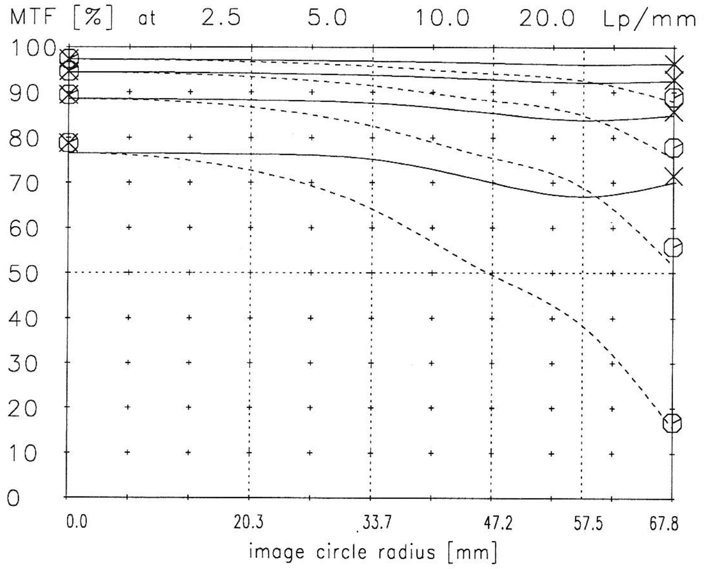


Apo-Grandagon 45 mm f/4.5

MTF at ratio 0.03x f/ 8



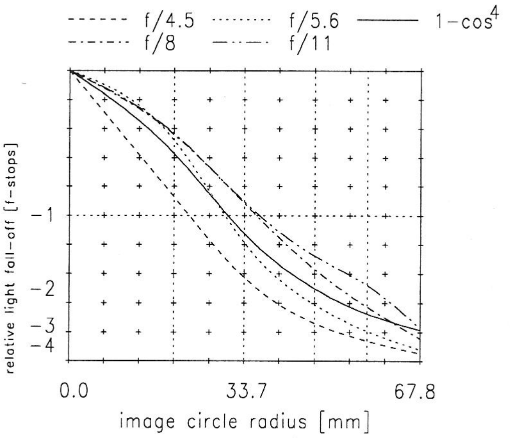
MTF at ratio 0.03x f/ 16



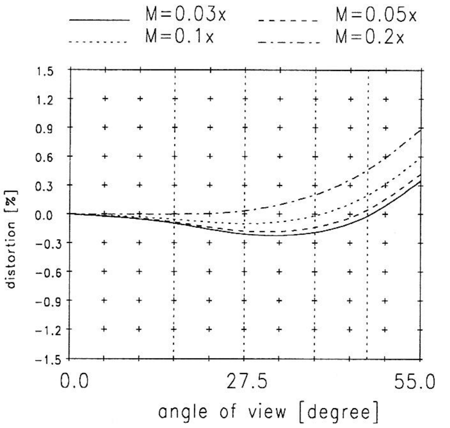
——— sagittal, × Diffraction limited value

------ meridional, ⊖ Diffraction limited value

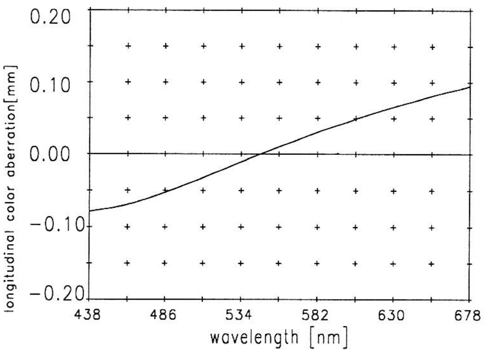
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x



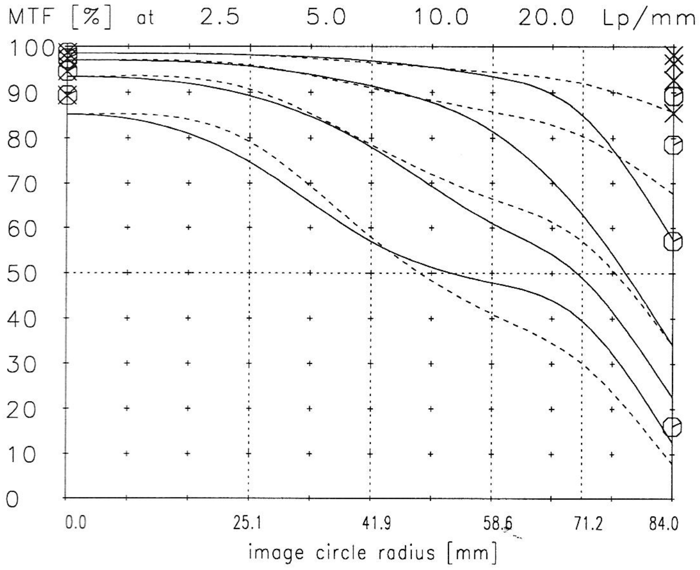
Longitudinal color aberration
at ratio 0.03x



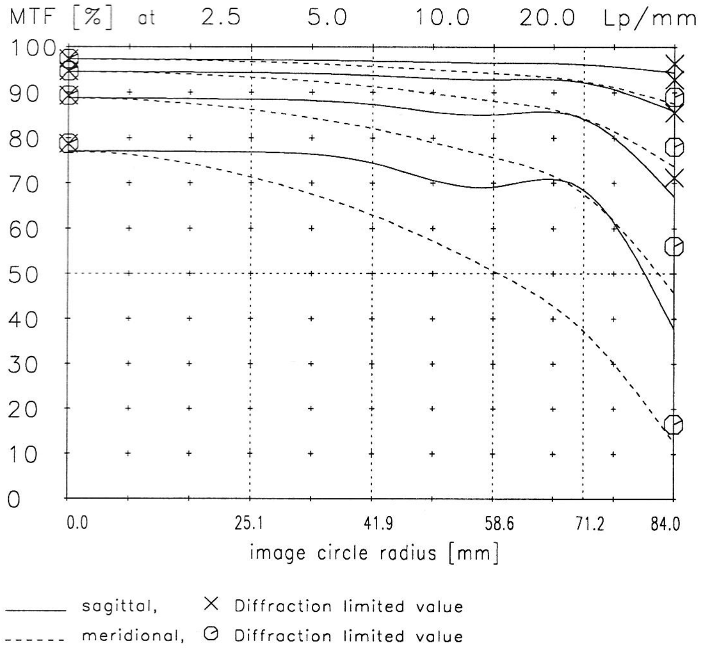
Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

Apo-Grandagon 55 mm f/4.5

MTF at ratio 0.03x f/ 8

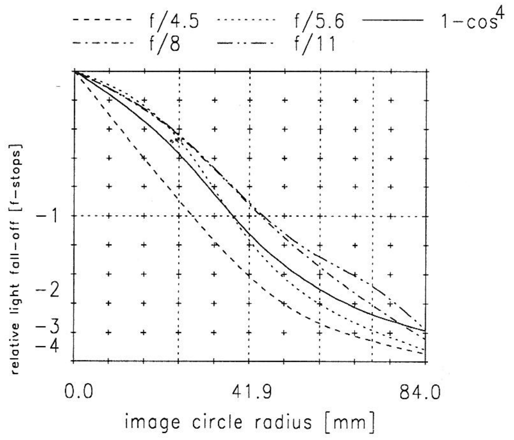


MTF at ratio 0.03x f/ 16

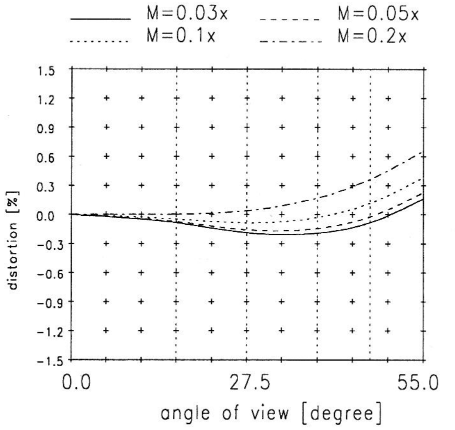


Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

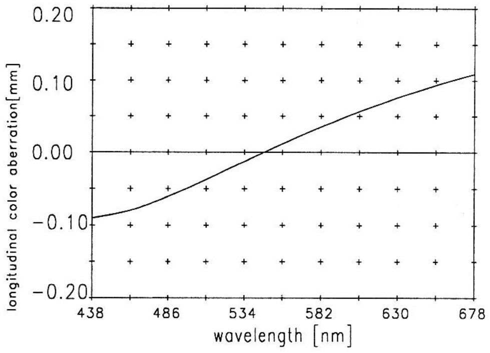
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x

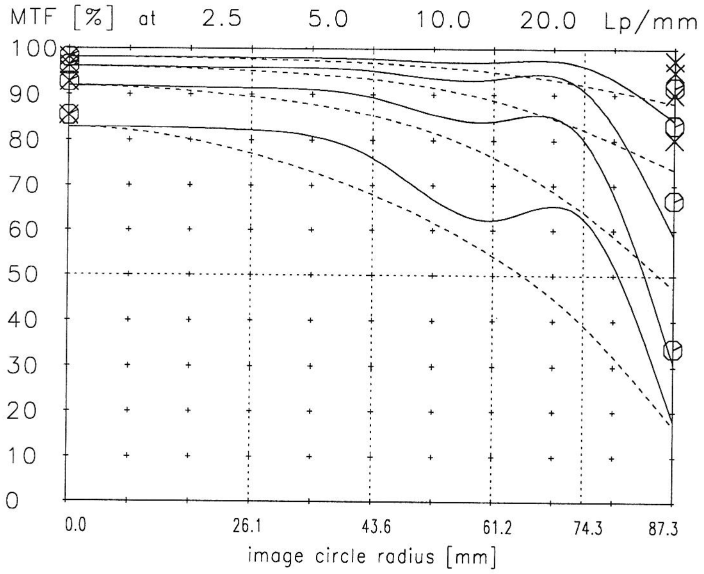


Longitudinal color aberration
at ratio 0.03x

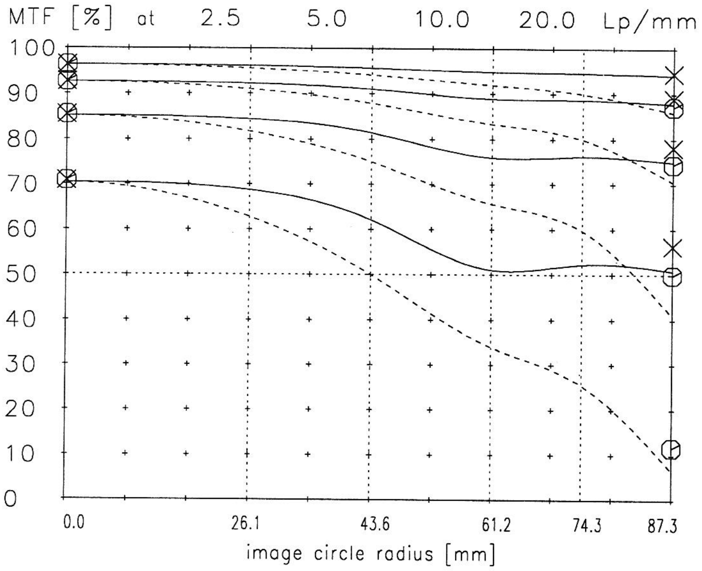


Grandagon-N 65 mm f/4.5

MTF at ratio 0.03x f/ 11



MTF at ratio 0.03x f/ 22

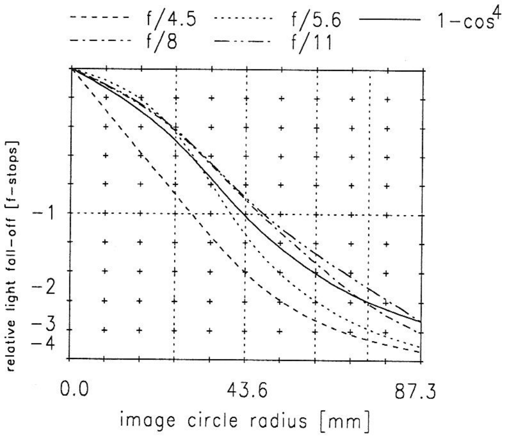


———— sagittal, × Diffraction limited value

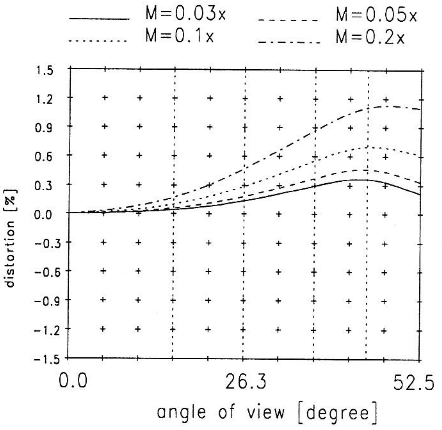
------ meridional, ⊖ Diffraction limited value

Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

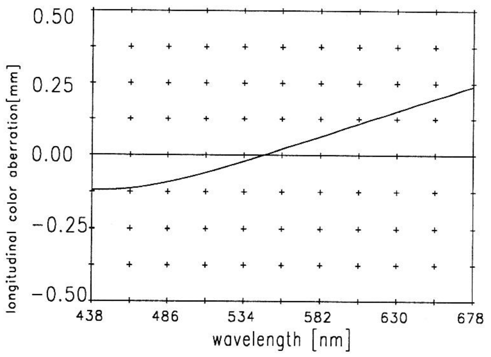
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x

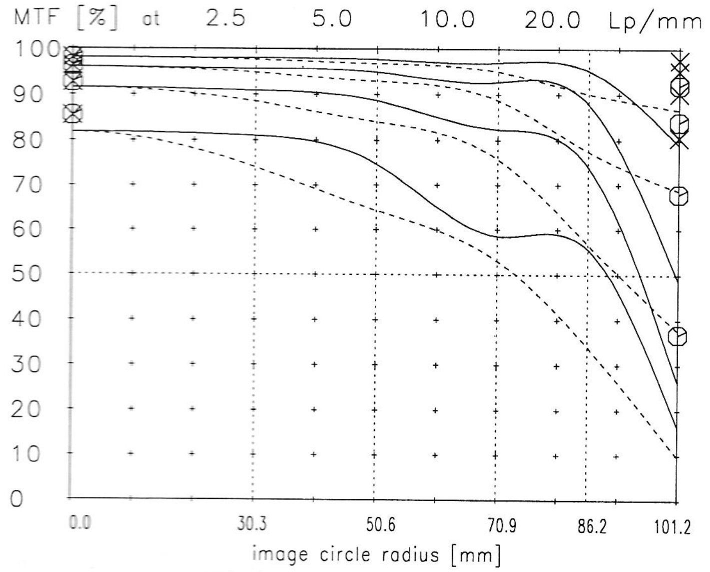


Longitudinal color aberration
at ratio 0.03x

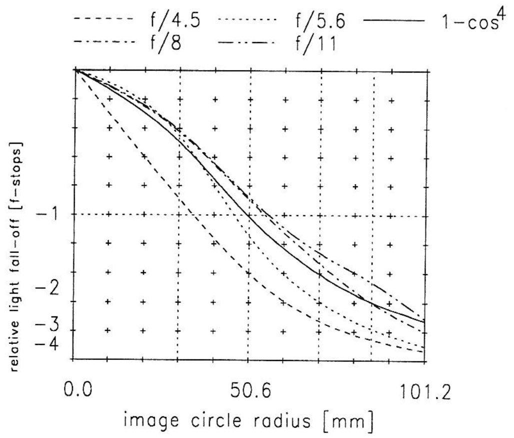


Grandagon-N 75 mm f/4.5

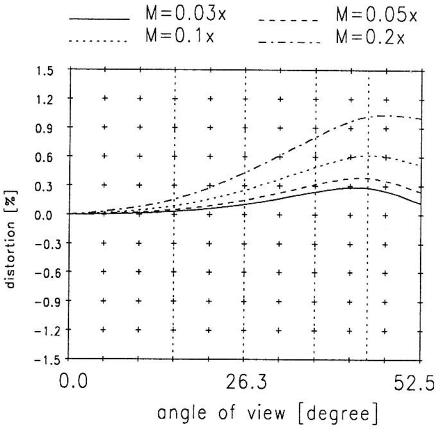
MTF at ratio 0.03x f/ 11



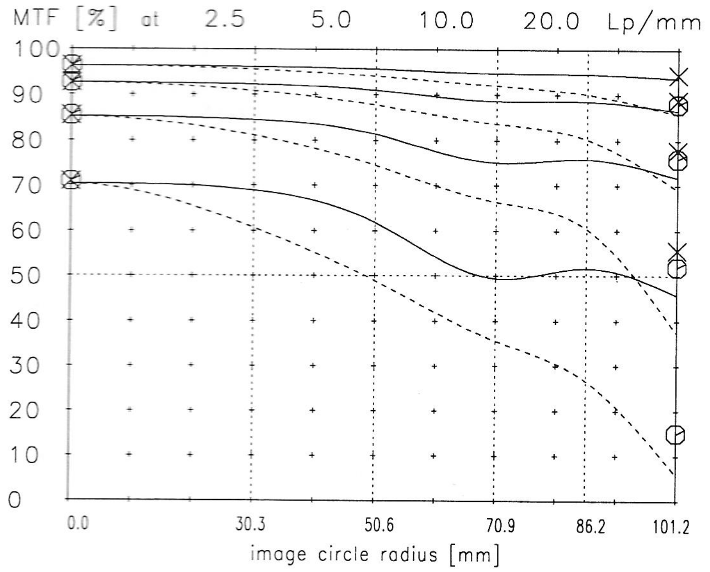
relative light fall-off at ratio 0.03x



Distortion at ratio 0.03x to 0.2x



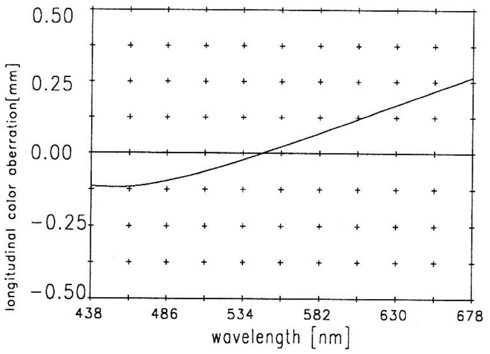
MTF at ratio 0.03x f/ 22



------ sagittal, × Diffraction limited value

------ meridional, ⊖ Diffraction limited value

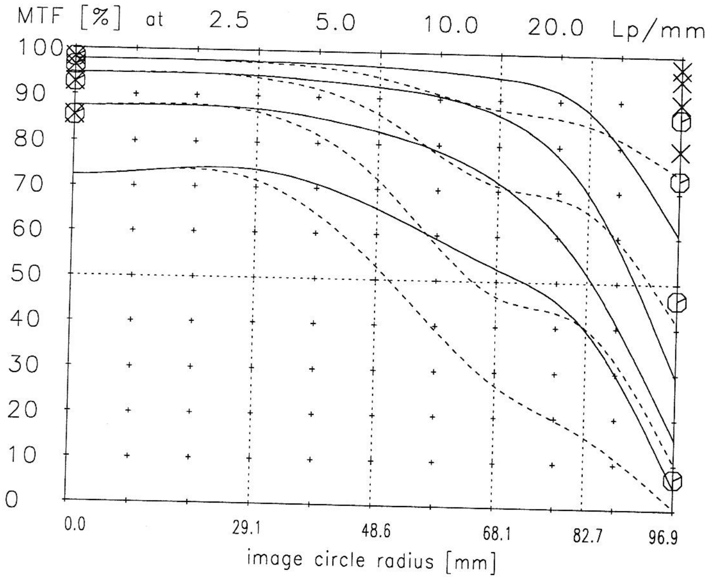
Longitudinal color aberration at ratio 0.03x



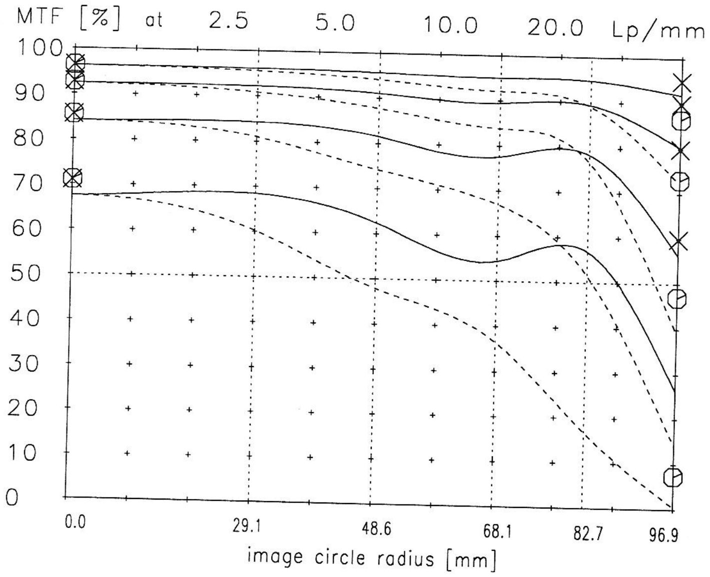
Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

Grandagon-N 75 mm f/6.8

MTF at ratio 0.03x f/ 11



MTF at ratio 0.03x f/ 22

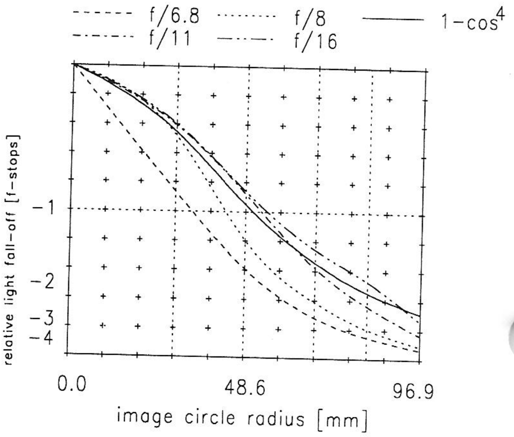


—— sagittal, × Diffraction limited value

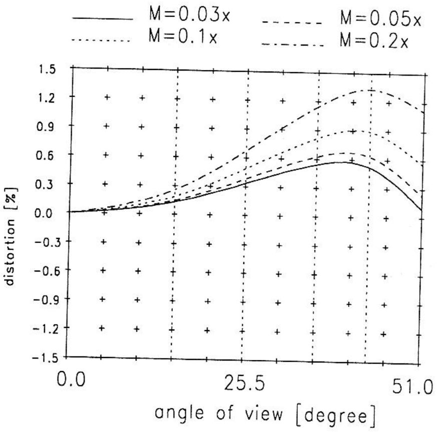
------ meridional, ⊖ Diffraction limited value

Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

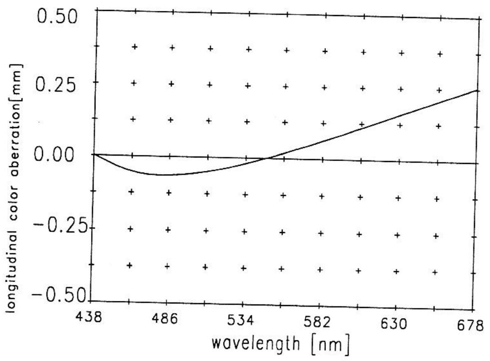
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x

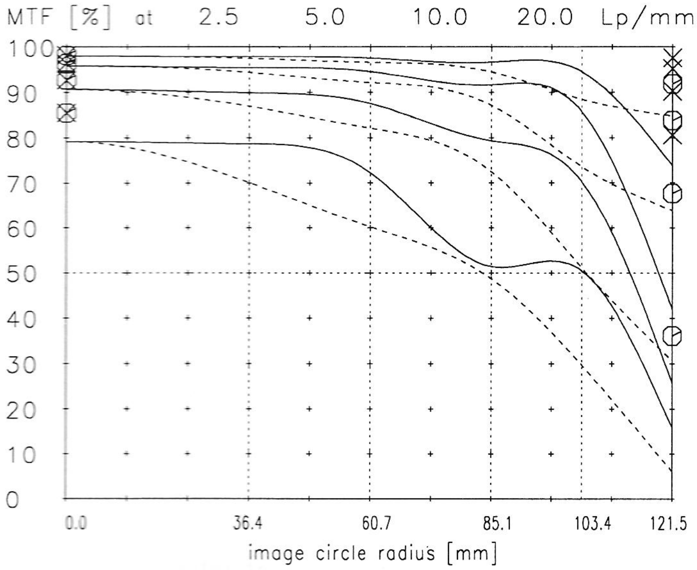


Longitudinal color aberration
at ratio 0.03x

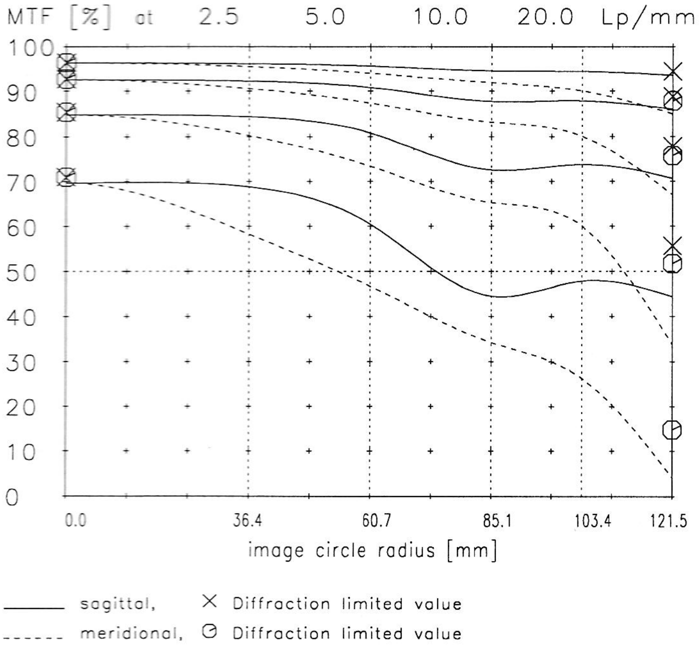


Grandagon-N 90 mm f/4.5

MTF at ratio 0.03x f/ 11

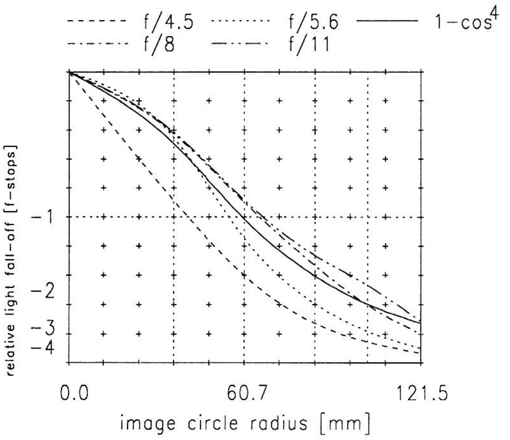


MTF at ratio 0.03x f/ 22

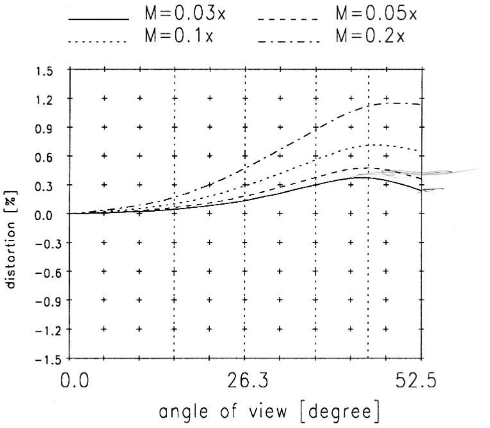


Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

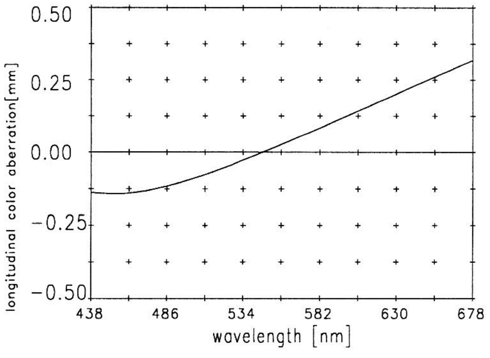
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x

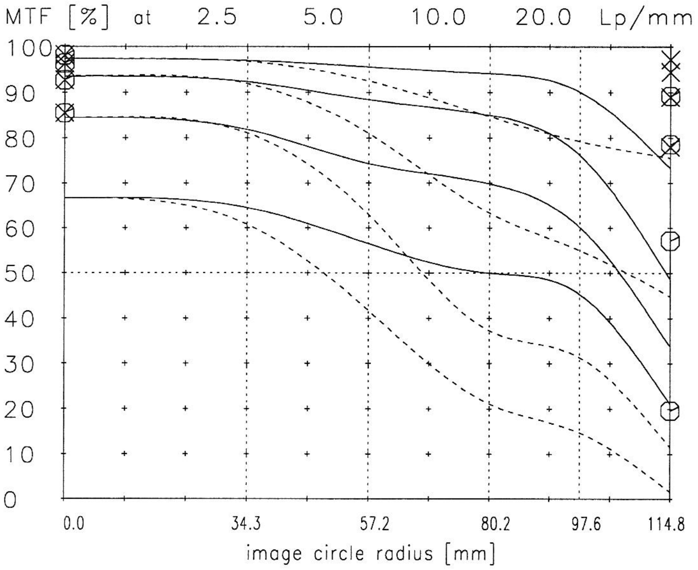


Longitudinal color aberration
at ratio 0.03x

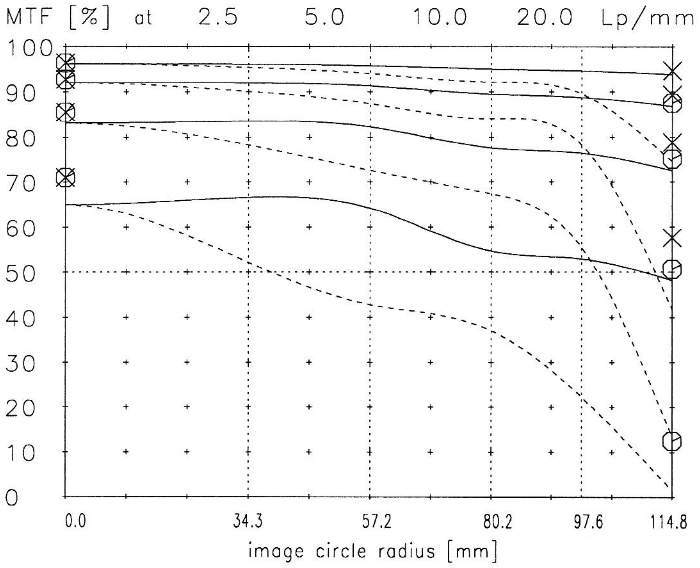


Grandagon-N 90 mm f/6.8

MTF at ratio 0.03x f/ 11



MTF at ratio 0.03x f/ 22

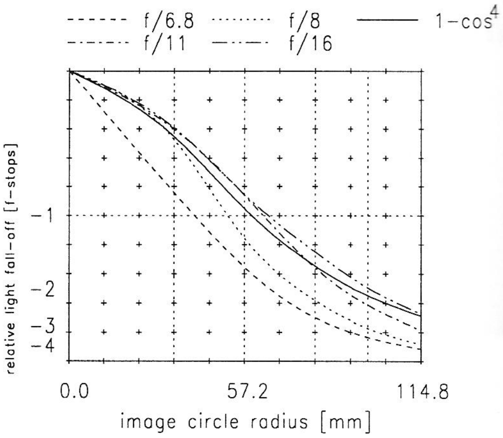


______ sagittal, × Diffraction limited value

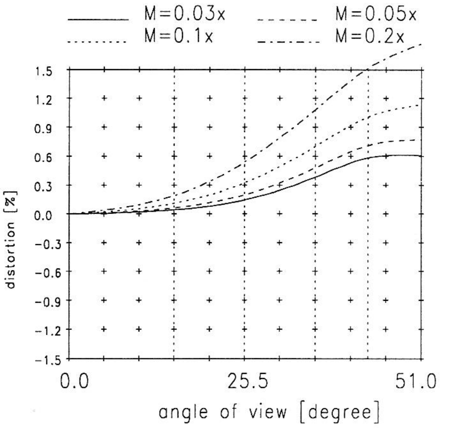
- - - - - - meridional, ⊘ Diffraction limited value

Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

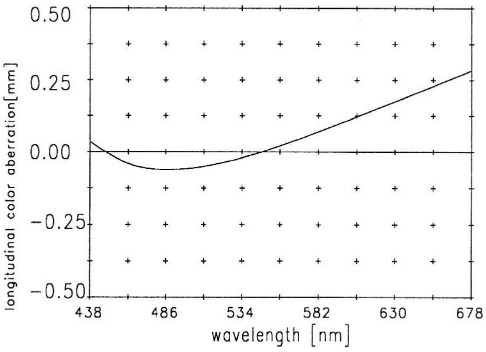
relative light fall-off at ratio 0.03x



Distortion at ratio 0.03x to 0.2x

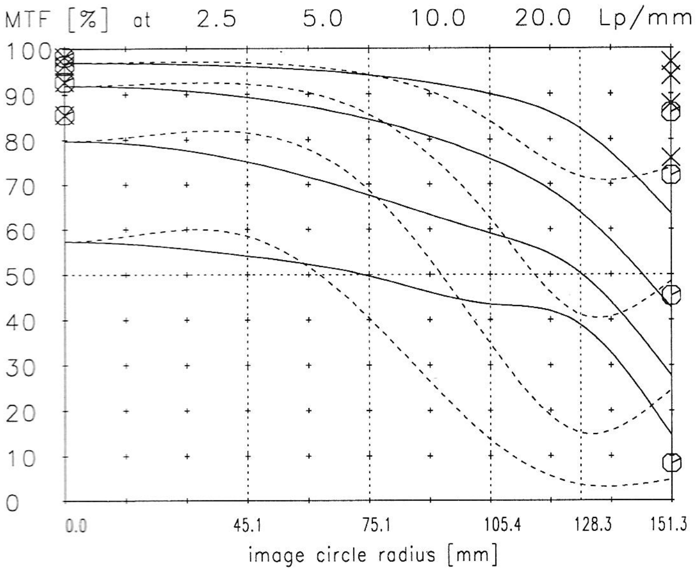


Longitudinal color aberration at ratio 0.03x

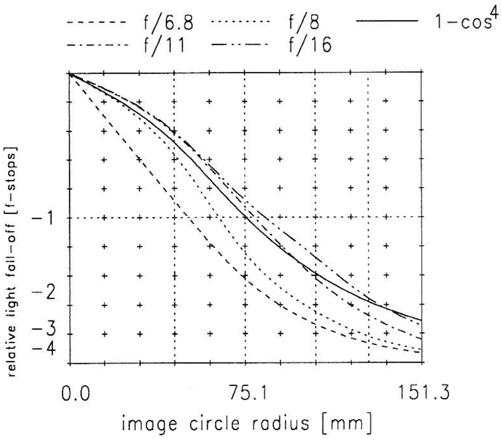


Grandagon-N 115 mm f/6.8

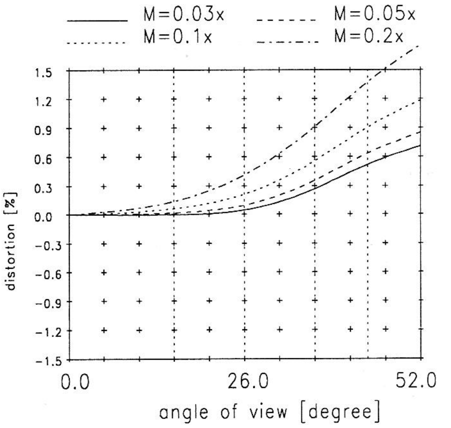
MTF at ratio 0.03x f/ 11



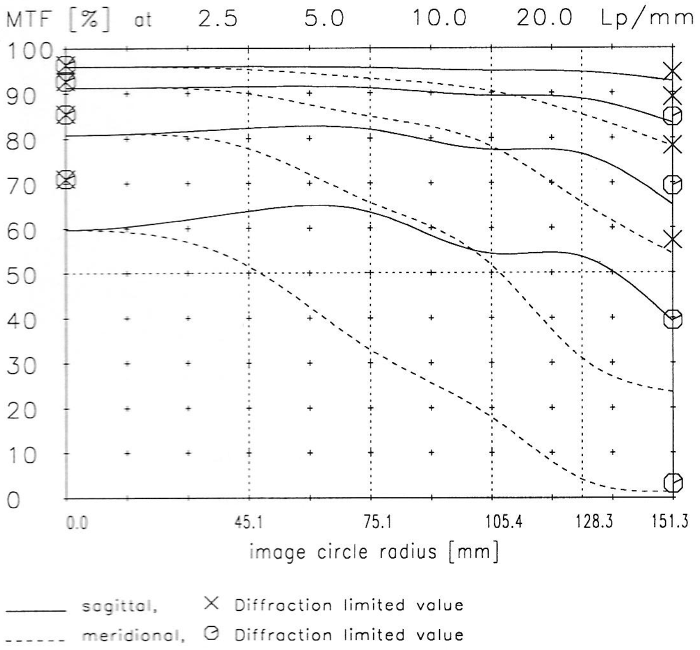
relative light fall-off at ratio 0.03x



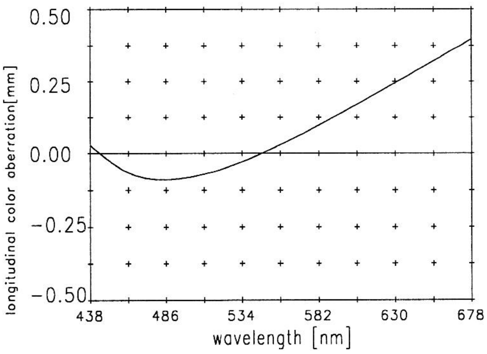
Distortion at ratio 0.03x to 0.2x



MTF at ratio 0.03x f/ 22



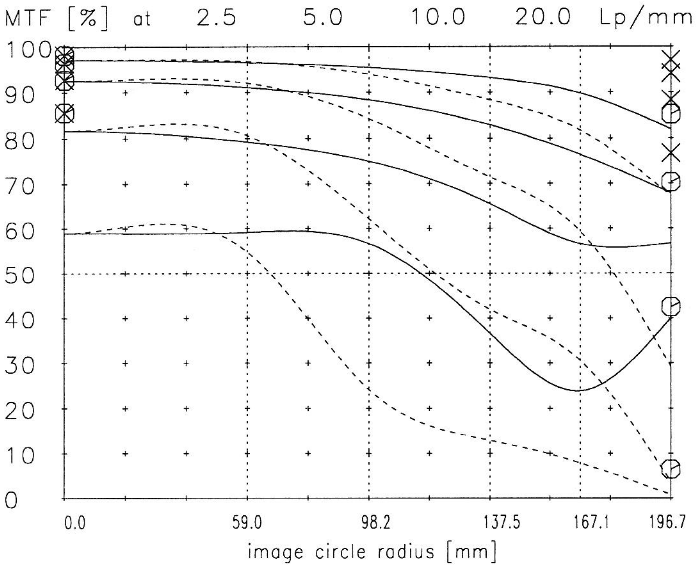
Longitudinal color aberration at ratio 0.03x



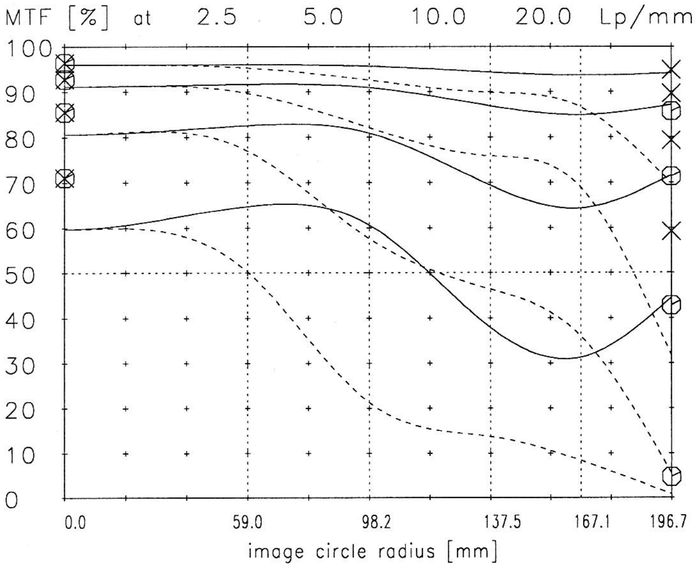
Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

Grandagon-N 155 mm f/6.8

MTF at ratio 0.03x f/ 11



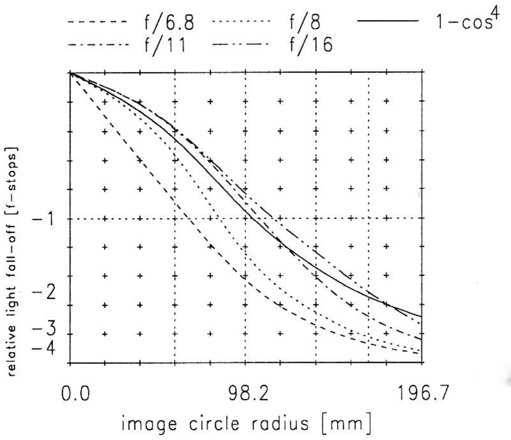
MTF at ratio 0.03x f/ 22



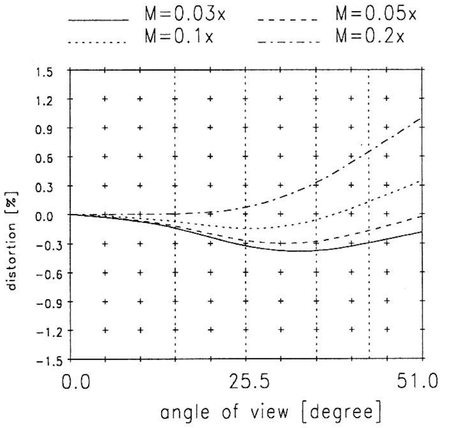
______ sagittal, × Diffraction limited value
------ meridional, ⊖ Diffraction limited value

Named frequencies [line pairs/mm] in modular transfer function (MTF) as well as diagrams of relative light fall-off, distortion and longitudinal color aberration refer to film plane.

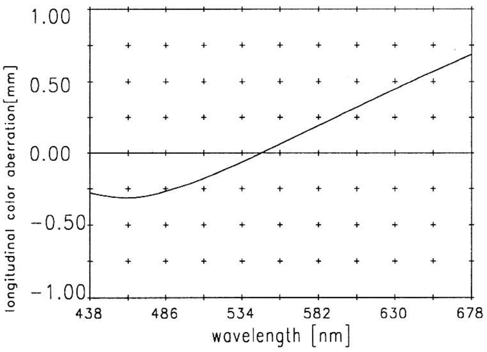
relative light fall-off
at ratio 0.03x



Distortion at ratio 0.03x to 0.2x



Longitudinal color aberration
at ratio 0.03x



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Center Filter Comparisons

Product Information

Reduction in light fall-off with wide-angle lenses.

Even when large format wide-angle lenses are stopped down to an aperture where vignetting no longer occurs, the $\cos^4$ law means that their extreme field angle will still lead to high light fall-off towards the edge of the image circle (up to 3 stops) which is particularly problematic with color prints. This light fall-off can be reduced by using a center filter if, for example, large camera movements result in the picture format extending into the periphery of the image circle.

A center filter is a neutral gray filter with decreasing density towards the rim – ideally right up to complete transparency. Although it is possible to select the difference in density between filter center and filter rim in such a way that the light fall-off of the lens is completely compensated, this is not normally done:

- Other lenses also show physically induced light fall-off which is no real problem even for critical motifs as long as the fall-off remains low.
- The density required in the filter center to provide "better" compensation also means greater light loss (consequence: longer exposure time or higher illumination/flash energy).
- The graduated grey shade of center filters is difficult to produce so that center filters are relatively expensive. A greater difference in density would make production more difficult and so further increase the price.
- There is no such thing as an absolutely neutral gray filter film. To ensure that image center and periphery are not reproduced in different colors, the density difference between filter center and rim may not be too great.

At the "photokina" 1994, the Rodenstock center filters with the engraving "Centerfilter 4x" were replaced by new ones with the engraving "Centerfilter ND 0.45" (exception: Centerfilter E135 for Grandagon-N 200 mm f/6.8).

Despite the slightly lower density in the center to reduce the brightness loss, the higher transparency in the periphery still allowed a greater density drop and so better compensation.

Center filters in comparison – Evaluation using practical prints (normal motif/grey field)

To demonstrate the improvement in quality, the old and the new Rodenstock center filters were compared with each other and two other popular center filters ("external center filters"). The test covered measurements and practical photography. The taking lens was the Apo-Grandagon 55 mm f/4.5 with a field angle of 110° and an E67 filter thread.

1. Measurements

The maximum density at the center and the peripheral density were measured directly at the border to vignetting with a measuring cell of 2.7 mm diameter – roughly the pupil diameter at f/number 22. The maximum density gives the longer exposure time, the density difference the compensation effect.

Center filter	Density at center (log value)	Longer exposure time (aperture stops)	Compensation effect (log value)	Compensation effect (aperture stops)
Rod.	0.44	1.46	0.41	1.37
Rod. 4× (old)	0.49	1.62	0.28	0.94
Ext. filter ND 0.45	0.59	1.95	0.35	1.16
Ext. filter ND 0.9	1.19	3.95	0.71	2.36

The table also shows the maximum density and the compensation in aperture stops because these values are more familiar to the photographer. The measuring values apply to only one sample so that they can only serve as general guidelines for practical photography and only serve to support the evaluations obtained from the practical results.

The measurements demonstrate that the new Rodenstock center filter ND 0.45 has the lowest brightness loss with less than 1.5 stops and the best efficiency thanks to an almost equally high compensation effect. The brightness loss of the old Rodenstock center filter 4x is insignificantly higher at 1.6 stops, but the compensation is much lower at less than 1 stop due to the lower transparency in the periphery.

The external center filter ND 0.45 is directly comparable as it has the same nominal value, but it also "swallows up" half a stop more light than the Rodenstock center filter ND 0.45 and its compensation is between that of the old and the new Rodenstock filters. So the photographer loses more light without quite reaching the good compensation effect of the new Rodenstock center filter ND 0.45.

The external filter ND 0.9 promises a much higher degree of compensation. Although it does not reach the nominal value of 3 stops (≙ ND 0.9) due to the low transparency in the periphery, its degree of compensation of almost 2.4 stops is exactly one stop higher than that of the new Rodenstock center filter. However, this higher compensation effect is purchased at the cost of an enormous light loss of 4 stops.

2. Practical photography
Architectural photographs of the aluminum front of a multi-storey building reaching from the image circle center to the periphery and of a grey concrete wall which also extends from the center to the periphery should show what degree of compensation is sufficient for critical motifs in practice and whether the center filters cause visible color shift in the picture center.

Pictures of a white surface with an exposure adjusted to medium gray in the image center show the properties described even more clearly; however, they also make incredibly high demands on the density gradation and on the color neutrality which are not practical and so must be evaluated with corresponding reservations.

The new Rodenstock center filter ND 0.45 also proved superior in the practical photography tests. The residual light fall-off is lower than with standard lenses (with no center filters) and is not a problem. At the center the color reproduction is slightly "warmer" than at the edge; however, this is only visible on critical surfaces (here: grey concrete area).

With the old Rodenstock center filter 4x the light fall-off is at the same level as with standard lenses and the area around the image circle center is reproduced with a slightly redder tone than the periphery.

The external center filter ND 0.45 approaches the effect of the new Rodenstock center filter as regards compensation and, like this, shows practically no color shift between center and periphery. However, it does have a cool, light green color tendency over the whole picture surface and "swallows" half a stop more light.

The external center filter ND 0.9 best compensates the light drop-off of the wide-angle lens. But this has to be paid for in the center with a light loss of 4 stops (still over 3 stops on average over the whole image field due to the brighter periphery) and a general green tendency over the whole image field. If motion blur makes it impossible to extend the exposure time sufficiently, the filter light loss has to be compensated by an opening of the aperture. But then the vignetting which occurs may well result in a higher light drop-off than with the other center filters and a "normal" working aperture.

The mount of both external center filters is, however, not designed for an angle of 110° so that vignetting occurs: With the Apo-Grandagon 55 mm f/4.5 around 3 mm is covered at the edge of the image circle due to the low free aperture of the front filter mount and a bright circle line appears around 4.5 mm inside the original image circle edge due to reflection at the inner mount edge. This reduces the available angle of the lens to 107° and the image circle diameter of the Apo-Grandagon 55 mm f/4.5 by 9 mm.