BACK FOCUS

Journal of the Australian Photographic Collectors' Society Inc
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Contents

The Australian Photographic Collectors' Society Inc.

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The Australian Photographic Collectors' Society Inc is incorporated in Victoria Australia, and has as its members, people with similar interests in photography. Its Rules of Association contain its aims and purposes as "To foster the collection, restoration and conservation of the apparatus, images and literature of photography from its beginning until recent times, and to encourage the exchange of information about such items."

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Meetings are held at Australian Model Railway Association Hall. 92 Wills Street, Glen Iris, VICTORIA - Details of meetings, markets, auctions and other event may be found on the APCS website: www.apcsociety.com.au

Society membership includes subscription to Back Focus: $50.00 per annum. See the APCS website for details.

BACK FOCUS No 120 CONTENTS

The Cover:

A feature of the history of the APCS is its publications. They started out as quasi-regular mail-outs of newsletters produced by the Gestetner ink process and are now monthly on-line newsletters and the annual Back Focus magazine. The cover image of this issue represents some milestones in that history - the last half century of how we collect, use and trade cameras. See the newsletters and the web pages for access to all the 1,000 or so articles that they contain.

The Australian Photographic Collectors' Society.

2025 marks the 50th year of the APCS. Much has changed over that time, not only in how the society runs and who are its members but also what we collect. A huge change has come over the whole art of photography - through the generation of electronic cameras to digital techniques and now cameras that we carry in our mobile phones. We now rely on computers and the internet in ways that were totally unknown back then.

In January 1976, a group of 10 people interested in collecting vintage cameras got together in Melbourne with the idea of becoming a club, and the Australian Photographic Collector's Society was born.

The idea grew and today the Society has a couple of hundred members throughout Australia and overseas. The Club is now an Incorporated Association that holds a dozen events each year, and has a wider audience of a couple of thousand people who go to the Box Hill markets and visit the APCS webpage downloading its publications etc., all focused on photography.

Over the years nearly 1,000 people have joined the Society for at least a year and probably 80 of those have served on committees. About 24 of those have shared executive positions. There have been something like 330 publications including newsletters and the magazine Back Focus, and the 'new' technologies of the World Wide Web dominate what we do.

The nature of the APCS – meetings – auctions – markets etc has not changed much over that time but there have been massive changes in photography. In 1976, film and printing, and the dark-room were still king and the idea of electronically controlled cameras was only just catching on. Digital photography was only to be found in laboratories and even the idea of scanning a photograph to form a digital image was a very new thing – and restricted to Black and White for nearly everyone.

Today, so much has changed. Photography is almost entirely digital and the "cameras" are being carried around by nearly everyone as devices hidden in their mobile phones. It seems that we are now in some sort of "transition" – the number of people that are collecting cameras has diminished, but selected old cameras are now seen as financial commodities and the business is mostly about "trading cameras", and the effect of that on international economies is enough to influence national balance sheets. Currently the APCS does not have accurate statistics on the level of trading at its events but an estimate of the order of $350,000 each year changes hands. Just how much trading is done on eBay etc by APCS members and those of the public that attend the markets is larger than that.

2025 is the APCS 50th year, and coming as it does right on the end of the COVID event, is likely to mark a new chapter in what the Society and its members do.

The history of the APCS

THe APCS started as a club - run by a small group of dedicated individuals who largely made up the committee. For "dedicated" you might substitute "strong minded" as the history is littered with times of conflict, and it was not always entirely harmonious. An inspection of the list of officers and committee shows that every now and again there was a complete spill and reorganising of the deck-chairs - in fact that happened 4 times over the 50 years. The personal reasons should probably be forgotten but there are a few underlying phases in the history of the APCS that also maps into technology change and what was seen as being important in the subject of collecting cameras.

In retrospect, 1976 was the end of the mechanical camera era as electronics took over adding new features to cameras that aided the professional and amateur alike and the emerging world of "tourist photographers". We also recall that this was also the time that colour photography became the normal medium - and it was also happening fairly quickly. For many the darkroom disappeared from the scene as photographers relied on laboratories. This was especially true for most colour work. It is not surprising that some members found those transitions undesirable.

Around 1990, digital photography was starting to emerge as a viable technology, and this rapidly became the "normal approach" for a great many photographers, and within 10 years, digital was the norm. This created more division as there were those who were still hankering over B&W and even plate photography. There were special attempts to create specialist groups - large format - cine - etc - but they usually only survived for a few months.

But there were a few functions of the APCS that were established very early and survive to the present day. Public markets were held in several venues over the years and are currently being held at the Box Hill Town Hall, and have occasionally been held in other cities - Adelaide and Ballarat. Members-only auctions were also held from the beginning and there is no sign of them ceasing any time soon. Around a dozen events have been held each year and about half of those have been simple presentations on specialist subjects to members - although as time has gone on the markets and auctions have dominated. The average age of the members has risen as time passes and that has reflected in a significant reduction in the social interaction between members and their families.

On a technical organisational matter, the APCS changed from a unsecured club to an Incorporated Association under Victorian Law shortly after the Incorporated Associations Act 1980, and then in response to the Reform Act in 2012.

The Meetings

The society has always met on a monthly schedule - with a holiday break for Christmas. The early meetings were at the home of John Minnis in Elwood. Some time before 1990 the meetings moved to the Melbourne Camera Club in Ferras Street, and in 2001 they moved to the Australian Model Railway Hall in Glen Iris where they remain today.

Many of the meetings were social with a lot of swap and sell going on, but the opportunity was taken for mini-markets, special auctions, photographic displays etc.

About half of the meetings had technical presentations as their main event and this was often a prompt for individuals to do special research to put additional value around what they said and showed to enthusiastic audiences. That opportunity may well be the reason why we have so many experts in selected fields today. Many of those presentations were to appear in the pages of the APCS publications in the months that followed.

The Markets

A major feature of the APCS is the public photographic markets - called flea markets in the earlier days. These are open to non-members as both table holders and buyers. At their peak in the late 1900s, more than 1,500 people would attend these that occurred twice each year.

The very early markets were relatively private affairs but by the late 1980s moved to the Melbourne Camera Club. Then in 1990 the first major market was held at the St Kilda Town Hall where it stayed until 1995 with a move to the Camberwell Civic Centre. Members recall - not so fondly - the task of setting up tables before the start and then the huge cleanup at the end! In 2015, a much more convenient location was found at the Box Hill Town Hall, where all that work was done for us as part of the hire package.

But there have been changes in the market environment. In the beginning virtually “anything” could be sold including items that had nothing to do with photography, but today the offerings have become more restricted and the whole world has become “risk averse” meaning that electrical goods and photographic chemicals are restricted, and that additional insurance has also been demanded by the venue operators.

The Auctions

The APCS auctions have been very popular events through the APCS history. There have always been legal restrictions on how auctions are run but the APCS adopted a “members-only” stance to get around the issues. A slight twist to that is that the public is able to submit items for auction and that unfortunately raises the necessity of assisting the Executors of the Estates of past members - becoming rather common in modern times. The auctions are held in the same location as normal monthly meetings.

Managing the auctions has always taken a lot of effort, but has settled down with special software written by member Keith Head (who, readers may have heard, passed away earlier this year). The auction software is also linked to the membership database. The very early auctions were close to spontaneous with very little planning but as time progressed, the methods also improved and now feature interactive catalogues with every item linked to photographs on the internet. Modern telephone communications assists as well with significant levels of sales going to absentee bidders and phone bidders.

The Social Outings

A few years ago, probably while the average member ages were a lot lower, organised outings and social events were common. The society held dinners on the evening before each market (usually at a venue that featured Pokies), and specialist trips and events were held that allowed members to try out their cameras and photographic techniques.

Competitions in photography were also held but even though significant prizes were offered, the number of submissions was lower than was viable and several competition events had to be cancelled through lack of interest.

Technology Change

The history of photography has been a study in technology change from the beginning - and usually at the highest level. Each technology group had a very limited lifetime and only lasted until the next major invention or practice. Technologies also overlapped and this has been an ongoing issue for the APCS.

Who would have imagined back in 1976 that we would be carrying cameras in our phones capable of photographs and videos that technically exceeded the standards needed for the move film industry and television - linked to the cloud with automated location identification etc etc? And all that at a cost that today is less than the cost of a roll of film at the time? Yes, there are expensive stand-alone cameras but they are only essential for specialist needs - and those who hanker after “photography that feels like the old days”.

The Publications

Right at the beginning there were newsletters, laboriously assembled and printed out using Gestetner ink printers - this was an ecconomically viable method as the break even point for the higher quality offset printing would have needed at least 500 members - significantly more than twice the number that we had. A downside to that was that after the initial drive for regularity passed, there were long periods when nothing happened. The early newsletters included both news and technical presentations, and there were even two “starts” to them - in 1976 and in 1985.

After another hiatus, in 1992, Ian Carron and John Keesing put a program together to produce a quarterly magazine called “Back Focus” - abandoning the old Gestetner approach and using more modern printing based on typesetting using a desktop computer, printing out using an inkjet or laser printer and then using commercial photocopying processes. Back then it was all black and white and the printing processes had to borrow from the newsprint techniques of the day using “screen printing “ to get some sense of grey-scale in photographs. Over the following years there were snippets of colour - mostly on the front page and in 2016 there was a decision to make the whole issue a colour opportunity and by then printing had matured to the point that mass digital printing from PDF files generated in Microsoft Word was the norm.

It was logical to change to desk top publishing software but old habits die hard and it was only in 2019 that Ian Carron agreed to make the change, but unfortunately Ian’s death in 2019 only allowed him to sketch an outline of a DTP issue for Number 114. With his passing, a complete change to DTP using Adobe InDesign marked another significant change. The cost of posting Back Focus became untenable and at the same time a fundamental move away from a news platform towards a more attractive “coffee table” look resulted in a change from a quarterly publication to the annual, significantly larger, publication that we have today.

The cover of this issue of Back Focus pictures a few of the milestones in the history of this magazine. This is issue No. 120 of Back Focus and its predecessors which together contain over a thousand articles. However prior to the formal counting of Back Focus from 1992 there were another 44 issues of the newsletter which should also be counted as they also contained extensive technical articles that would now be included in Back Focus - and indeed are included in the Back Focus on-line archive.

But in the background there had been another change. Publishing news quarterly was not sufficient and monthly newsletters were introduced again from late 2007 - and continue to the present day. Also affected by economics, the distribution of the newsletters became entirely on-line after 2018, as use of the internet became nearly universal.

Also around 2007, the APCS presence on the internet strengthened and became the public face of the society. Those techniques now allow the full archive of the APCS publications to be available to all and provides an instant method of getting information to members and the public alike. But times change and on-line publishing is becoming the norm. The future will include more access and convenience in finding what the APCS has published over the years as new approaches to indexing etc are developed.

The John Minnis Memorial Library

John Minnis was one of the founders of the APCS and served as its first President and was the force that drove the early issues on the society newsletter. He was an avid researcher known around the world for his efforts to discover details of early photography and equipment. The APCS had amassed a significant quantity of books on photography and a formal library was established in his memory. That library is now partially in transition to being on-line as the publications from other organisations are added to the resource.

Finances - the business case for the APCS

Financially the APCS is a success story. Moderate membership fees, a moderate vendors fee for the auctions and reasonable table and attendance fees at the public markets have allowed the APCS to be in a sound financial condition. There have been significant increases in costs in venue hire, insurance etc but the reserves remain at a level that ensured the survival of the APCS for many years to come.

Membership

Membership is open to all but there have been changes over the years. Originally the members were those interested in collecting photographic equipment but as the years have passed the membership seems to be more interested in photographic items as investments and as the source of a level of income. This has been a trend around the world and there have been some very significant increases in the value of certain items.

The advent of on-line trading through facilities like eBay have assisted that trend and the camera market place is now global. There was a day when the values of cameras were stable from year to year and you could look up a value in a book that was probably valid for at least a few years. In 2025 that is not the case and the marketplace is highly volatile in both upwards and downwards pricing as certain items are perceived to be more valuable than others. There have been plenty of examples of major shifts in perceived values based on one or two competitive sales, and an feature of “cultism” has also emerged as certain types of lenses for example have become more “desirable”.

The initial membership of the APCS was moderate - an initial 22 members - which built up to over 250 members by the turn of the Century, but that has steadily reduced and now rests at about 175. More than half the membership is in Victoria with the rest of the States evenly represented and a few members overseas. A statistic of interest is that members that joined prior to about 2003 are largely still with the society but since then the average retention period is only a couple of years. However it has emerged that other associations who “collect things” are having similar experiences.

But a new trend is emerging as there are at least a thousand people who regularly attend the Box Hill markets and in some ways they are also members of the community.

Membership fees were initially $2 per year and have been revised about once every decade and is currently sitting at $50.

Life members

In 1998 the APCS resolved to keep a register of those who have contributed to the society and its aims to an extend that warrants recognition. A scan on the following names reveals those who were the workers in the society - running the events, contributing to the knowledge, and as of a recent decision, serving for at least a decade on the committee. An honour board has been established in memory of long serving President, Secretary, Auction Manager and Newsletter Editor - Margaret Mason.

TED BEDGGOOD	**1998**
JOHN KEESING	**2008**
IAN CARRON	**2009**
MARGARET MASON	**2009**
MAX AMOS	**2010**
THOMAS HELLWEGE	**2013**
BRIAN HATFIELD	**2015**
ALAN KING	**2015**
KEITH HEAD	**2016**
DON PITKETHLY	**2016**
LEIGH HARRIS	**2018**
JOHN MILLAR	**2018**
JOHN FLEMING	**2019**
ANDREW KORLAKI	**2019**
STEPHEN MILLS	**2019**
STEFAN SZTROMAJER	**2019**
JOHN YOUNG	**2024**
KEVIN SAUNDERS	**2024**
KEN ANDERSON	**2024**
ROD REYNOLDS	**2024**

The APCS has existed for half a century and it is remarkable that there are still founding members with us:

STEPHEN MILLS
DON PITKETHLY

The COVID years

The history of the APCS has to include a commentary on what happened in the COVID years when the idea of face to face meetings, major public events and little attention to the possibility of cross infection were not part of our life - especially as the APCS was a group of people in an age-group that was very much at risk.

The pandemic affected us severely in 2020, and then less as the next 4 years passed. All APCS events ceased in their traditional way, to be replaced by social meetings using the ZOOM technique where virtual face to face could be achieved with computers fitted with microphones and cameras - The APCS was good at that and this became an opportunity to meet people in other States. Other features of the APCS like the newsletters and Back Focus continued - maybe with more importance as the only regular contacts with others.

Today, COVID is not much more than a memory although there is still a threat out there and officials tell us that most people are now vaccinated. A surviving practice is that we are now relying more on ZOOM for committee meetings and that has encouraged members from other than Victoria to become part of the Committee.

However the APCS survived and is not aware of any members that lost their lives as a result of COVID infection.

The APCS Management

The APCS has always been managed by a committee considting of a President, Vice-President, Secretary, Treasurer, and a committee that varies in number. These are all elected annually by popular vote at the annual general meetings. There have also been some appointed people who in many cases are aslo on the committee. These do the special jobs - Market Manager, Auction Manager, Back Focus Editor, Newsletter Editor, and more recently Web Guru. The roles of the committee are specified in the Victorian Incorporated Associations Reform Act 2012 at the present time - which assures that the APCS is managed in accordance with public expectations. The APCS reports publicly to the national ACNC body which is a Commonwealth Government entity.

The APCS Logos

It may not come as a surprise that the subject of APCS logos has been a matter of considerable controversy. The original logo adopted right at the beginning was in a couple of shades of grey and that proved difficult to print. Then in the 1990s there were two logos that involved only black line art on a white background - easier to print back then. If there was a problem with those it was that they were too complex and "busy" and what writing there was became unreadable when a small version of the logo was needed.

With the major shift to colour in the printing industry and on the internet, a new logo was needed, and a dozen options were considered in 2015, with the subliminal aim of a very clear message around what the society was. The adopted logo was a stylised image of a Kodak Volenda folding camera from the 1930s surrounded by a circle with the name of the society in as big a font as could be achieved. The overall image involved only spot colours avoiding issues when printed in uncontrolled colour spaces.

The historical logos
The original (top left),
1990 (top centre)
1997 (top right)
Current- 2015 (bottom left)

The challenge for the future

For a specialist society like the APCS, and noting in particular that after half a century of operations in an environment that is complicated by technology change, that there should be some sort of planning for the future. To add to the uncertainties, it is evident that photographic collector societies around the world are struggling to stay relevant and hence viable - especially those that concentrate on a specific type of photography or a specific manufacturer.

If there is a specific feature of the APCS that is seen as a major risk factor it is that the average age of its current membership is increasing. The statistics show that half the current members joined before 2008 - that is a retention rate of greater than 17 years. A more complex analysis shows that the retention rate in the period from 2000 to about 2015 was very poor - commonly only one or two years, but that has improved significantly over the last decade and particularly in the COVID years. We might only guess why this is so but it may be that the APCS is respooonding to emerging needs, and the interests of the newer members.

A common thought is that members are changing their focus from "collecting items" to "trading items", and this is also evident in the public initerest in the Box Hill Markets and the number of people who join specifically so that they can take part in the members-only auctions, and members-only markets.

Another significant change in the way the society operates is that old ideas of restricting access to archival material created by the society is being made openly public. Not so long ago you had to be a member to get a copy of Back Focus and the only part of the magazine that was on-line was a picture of the front page. That then changed to a low resolution copy of the current issue that could be downloaded from the website, and now the whole archive is accessible on-linie from a link on the public newsletter. Shortly that will be more directly accessible from a ling on the webpage proper. More generally, hard copies of Back Focus used to be sent to the National LIbrary in Canberra and to the Victorian State Library. A few years ago that changed to the submission of electronic copies that could then be viewed remotely from the libraries themselves.

What the APCS does is becoming more accessible to the whole community and not just the members.

It is easy to claim that the society is developing in accordance with the wishes of its members but the society has to go further than that - it has to move with the times and cater for what the future members want - and therein lies the challenge for the future. While the committee of the APCS may react to what they percieve as necessary there must be an element of luck - or fortunate judgement.

The APCS has significant financial reserves - mostly the result of market and auction activities, and specifically enough to make a few mistakes and inicorrect judgements over the next decade. It would be nice to have a few younger people willing to take over from the old team that have been holding the reins for the last decade.

Rod Reynolds - President 2025.

Interchangeable Lenses - 1900-style

Rod Reynolds

We change the angle of view in modern cameras by changing lenses or using zoom lenses, but more than a century ago it was more complicated than that as lenses were very costly, and mechanicaly it was not convenient. This item looks at the older options - some of which have been forgotten.

At the dawn of photography and indeed for its first 60 years, the lens was the most expensive component. The best of these were 4-element devices with high levels of correction, and the most successful were the fast Petzval invented in the 1840s with its limiting angle of about 30°, and eventually the double anastigmats with anything up to 6 elements but with fields up around 60°. Ranges of each of these were designed for specific image sizes, and it was normal to assemble a camera with a specific image size and choose a lens that just filled the image space – usually aiming for the widest angle of view. The idea of buying lenses to achieve even wider views and telephoto views was yet to come and when those features were demanded then the more usual path was to buy or make a new camera.

By the late 1800s, it was common to buy cameras with interchangeable lens boards that would allow other lenses to be used and of course the idea of using a lens designed for half-plate could be used as a reasonable weak telephoto on a quarter-plate camera, but it was a hobby for the affluent.

For those with restricted finances there were a couple of well-known options. Maybe at the top of the list was the idea of "making your own lens" by taking different groups – single elements or at best cemented achromatic doublets – and putting one each side of an aperture. That copied the idea of the rapid rectilinear lenses that were common and eventually the double anastigmats. Makers like Emil Busch made it easy to experiment by packaging half a dozen lens cells with common threads and a central aperture – sometimes with a shutter – and selling the kit as a "Casket Set" – including a chart of the cell combinations and the associated focal lengths. For those who purchased a symmetrical lens, it turned out that it could be converted to an instant telephoto lens by removing one of the main elements – the so-called "convertible lens" – and that idea was to continue into the 1950s with Schneider lenses made for Linhof etc that went one step further where the main lens was a double with different focal lengths on each side – creating a lens with three different focal lengths when the cells were used in isolation or together. The English firm of Dallmeyer had another idea and sold a more complicated unit that clipped or screwed onto the front – the ADON device – producing a moderate telephoto with decent performance – or at least so it was claimed. (Typical ADON below)

One of the casket sets made by Emil Busch - these allowed the user to pick and choose the focal length - and included tables of the element combinations.

Typical Schneider convertible lens from the 1950s allowing a change from 210mm to 370mm by removing the rear element, but losing a couple of f-stops.

All of these experimental lenses had one thing in common – they needed to be on cameras that had significantly adjustable lens positions and almost always the ability to focus on a ground glass in the image field. The conventional plate camera did that well, and there were a few reflex cameras that made that a bit easier.

Most of those lenses were experimental with significant chromatic aberration, but worked acceptably well with the orthochromatic plates and films of the day. The main driver for this experimentation was probably cost. A typical quality lens at the end of the 1800s cost about $3,500, and even a cheap lens was about $500 – all in today's equivalent Australian dollars.

As an aside, those cost levels also encouraged less scrupulous dealers to sell inferior lenses often with premium names on them. Forgery was rampant in the late 1800s and is still a problem today. We know about those lens options as we collect them and those variants turn up regularly in old collections.

There are many opinions about when modern approach to variable focal length photography started – was it George Eastman's roll film and mass-produced box cameras, or the various folding cameras that became popular as they were compact? Or was it the emergence of cameras that utilised 35mm cine film and enlargements to produce decent-sized prints. The latter proved to be extremely popular and experimental lenses did not achieve the quality necessary to be successful. So a whole new approach of interchangeable lenses became the norm. With popularity came mass production and the costs dropped very significantly. When you purchased a camera after about 1930 you had many lenses to choose from and such a set might include standard, tele and wide-angle lenses.

Later, additional lenses became very big business and many firms made lenses that would fit on the cameras of the day with adapters etc. The catalogues grew and the shortest lenses got shorter and the longer lenses got longer, and in general you could get lenses at any chosen quality for a relative price. There were a few makers who added tele converters by putting a group between the lens and the camera, and others who made add-on tele and wide converters that went on the front of the lens. Another approach was to replace the front element of the camera's standard lens with a device that rendered it tele or wide. Those approaches satisfied the amateur and even the advanced amateur but were hardly acceptable to the professionals who went for the dedicated and more expensive units. Today, digital is king and along with it all sorts of techniques that provide a very wide range of effective focal lengths at exceptionally good quality levels. There were zoom lenses in the mid 1950s but they were inferior performers compared with single focal length lenses. By the end of the 20th Century, zoom lenses had improved significantly and new digital techniques provided more flexible framing and effectively became the "new zoom".

Carl Zeiss Distars and Proxars

An approach from the late 19th Century was to invest in a quality prime lens and then modify it – almost always creating a longer focal length, buy adding a negative unit on the front = sometimes with variable value and the Dallmeyer ADON was probably the most common. However it needed a system with a wide control over the distance from the lens to the film – and of course that was easy with most plate cameras, and some allowed extreme variations. Most plate camera makers had models including double and triple extension bellows. A practical detail was that as the lens moved away from the film the effective aperture also reduced, but as most long focus work was done outdoors, there would normally be better light. Further, the smaller aperture also ensured better resolution. Early units like the ADON etc may have been fairly primitive and the smaller apertures were probably essential.

Around 1900, Carl Zeiss Jena made such focal length extenders too. The lens lists for Zeiss include quite a few called "Negativlinse" with focal lengths from 27mm to 120mm or so. Quite a few batches seem to have been made but the actual numbers are not recorded, and very few seem to have survived. Around 1901 the name changed to "Tele-negative" and although longer focal lengths – greater than 45mm – are listed the common earlier shorter length of 27mm does not appear. However an example of a 27mm Tele-negative is in this writer's collection with a serial number from 1905. The lens itself has a small diameter and applying a bit of reverse design, it would only have been useful on prime lenses having very short focal lengths.

Zeiss Tele-Negative from 1905. Note that this is not a low-cost finish, and is clearly a premium item compared with the later Distar family.

Also around 1901, Carl Zeiss made another change with larger diameter negative lenses that they initially called "Distarlinse", and shortly afterwards "Distar" and from the surviving documentation they were targeted to the Tessar lenses only with 135 and 150mm Tessar lenses the most common, and these were being made in large quantities. Sometimes a chart of values etc is included with the Distar package and that seems to be related to the size of the Distar concerned.

Proxarlinse (top left) Distarlinse (top right) Distar (bottom left) and Proxar (bottom right). The top lenses are from 1903-04 and the bottom lenses are from about 1916 – from their serial numbers.

Tessar 1:4,5 f = 16,5 cm

Distar	1 VI	1,5 VI	2 VI	2,5 VI	3 VI
V	1,2	1,3	1,5	1,6	1,9
V²	1,4	1,7	2,1	2,7	3,5
fD (cm)	20	22	24,5	27,5	31,5
K∞ (cm)	20	22	24,5	28	32
K2m (cm)	22	24,5	28	32,5	38
Rel. Apert. Tessar 1/9 – Rel. Apert. Comb.	1/11	1/12	1/13	1/15	1/17
Rel. Apert. Tessar 1/12,5 – Rel. Apert. Comb.	1/15	1/16	1/18	1/21	1/23
Rel. Apert. Tessar 1/18 – Rel. Apert. Comb.	1/22	1/24	1/26	1/30	1/34
Rel. Apert. Tessar 1/36 – Rel. Apert. Comb.	1/43	1/47	1/52	1/59	1/67

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Tessar 1:4,5 f = 18 cm

Distar	1 VI	1,5 VI	2 VI	2,5 VI	3 VI
V	1,2	1,4	1,5	1,7	2
V²	1,5	1,9	2,3	3	4,1
fD (cm)	22,5	25	28	32	37,5
K∞ (cm)	22	25	28	32,5	38,5
K2m (cm)	25	28,5	32,5	38,5	47
Rel. Apert. Tessar 1/9 – Rel. Apert. Comb.	1/11	1/12	1/14	1/15	1/18
Rel. Apert. Tessar 1/12,5 – Rel. Apert. Comb.	1/15	1/17	1/19	1/22	1/25
Rel. Apert. Tessar 1/18 – Rel. Apert. Comb.	1/22	1/24	1/27	1/31	1/37
Rel. Apert. Tessar 1/36 – Rel. Apert. Comb.	1/44	1/49	1/55	1/63	1/73

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The Distar chart for a large diameter lens – in this case for 165 and 180mm Tessars

While earlier ideas were about producing longer focal lengths, adding a weak positive lens would reduce the focal length producing a reasonable wide angle lens when used with the Tessars. Zeiss called these "Proxar". The camera makers that used these devices produced documentation with other names and as late as the 1920s there were references to Distarlinse, Proxarlinse and in German as Distare and Proxare.

But there are complications as the story covers a long period from 1900 to the present day and there is evidence that those that wrote about the technique in the 1920s had largely "lost the plot" and one of those lens types – the Distar had been forgotten until very recent discoveries and research. But one type – Proxar – survived for a very different application.

Carl Zeiss Proxar supplementary lenses, and copies by other manufacturers are well known in modern photography as a common method for taking close-up photographs – usually in the range of 0.5 to about 3 diopters – that is focal lengths from 2 metres down to about 33 cm – and it is common practice to compound these together to get even shorter focal lengths. Note that a “Diopter” is a unit of lens strength and is defined today as “a lens of strength 1 Diopter has a focal length of 1 metre”. So a lens of +2 Diopters will have a focal length of 50cm. (The spelling “Diopter”(US) and “Dioptre” (UK) are both acceptable.) With the normal 50mm lens focused at infinity, the add-on lens allows the object being photographed to be at the add-on focal length distance. The Proxar name is associated with the Zeiss organisation, and while most Proxars are simple single element devices, there are a couple of examples made for a couple of the Zeiss cameras in the late 1950s to the early 1970s that are as strong as 5 dioptres and are multi-element.

At a recent APCS auction there was a bag of Zeiss filters etc which got little attention. When purchased and sorted, the pile included a couple of Proxars and a couple of negative focal length items marked Distar. But there was something else – these were marked “Carl Zeiss Jena” and they had serial numbers that belonged to the era of the first World War up to the late 1920s. Modern Proxars don’t have serial numbers.

So forgetting the very early devices, we might concentrate on these later single element lenses. While the documentation seems to be from the 1920s, these Proxars and Distars in particular had numbers from a much earlier period – mostly WW1 and earlier. This was confusing as the serial numbers seemed far too early to fit in with a 1926 pamphlet that provided some of the story, where the idea was that when added to a standard lens, these units effectively changed the overall focal length – Proxars creating a moderate wide angle lens typically 80% of the nominal focal length of the prime objective and the negative Distars creating a significant telephoto lens of up around double the nominal focal length. The pamphlet included typical photographs demonstrating the effect and range when used in conjunction with the f:4.5/135mm and 150mm Tessar lenses.

The documentation on the use of these Distars and Proxars is also somewhat confusing indicating that those who wrote the pamphlets were also confused. A USA catalogue for ICA cameras dated 1925 provides a lot of mixed information for Distars – but not for Proxars, and while there is no pricing for ICA cameras etc, there is a price column for the various Distars from about $60 each in todays terms. The corresponding German catalogue does not include any prices, nor does it mention Proxars. But we must note that these are ICA catalogues and not Zeiss papers. Proxars don’t seem to get a mention until Zeiss took over a large proportion of the German industry in 1926 – and then they became more prominent. It is very curious that all the documentation refers to the use of Distars and Proxars with Zeiss Tessar lenses and maybe these are optimised for the Tessars. A further curiosity is that even when Zeiss was making cameras in the 1900-1912 era, and were also making Proxars and Distars, there is no mention of them in the Zeiss catalogues that are to hand. (1902, 1904 and 1907) Is it possible that Zeiss considered the idea to be significantly inferior to using complete lenses and only produced them to satisfy the dependent manufacturers like Contessa and ICA? However the 1907 catalogue (USA) is particularly enlightening as it provides details of the Telenegative lens – a compound version of the Distar, but used rather differently, along with details of a Zeiss approach to Casket Sets – or “Satz” made of Protar cells in various groups. A detailed read of that document also shows that Zeiss components were very expensive with a couple of the top value lenses costing upwards of $30,000 in today’s dollars for a lens suitable for 3-colour work covering 24” square. The price of a 12-inch Planar Series 1a – the lowest performer of that group was of the order of $6,000 in today’s dollars.

Small and large Proxar and Distar lenses from about 1914 covering a wide range of prime lens fittings

However close examination suggests a bit more of a mystery, as these Proxars and Distars with their old serial numbers have the appearance and sizes of lenses that looked like they belonged to the early Contax era – around 1930 – or did they? Maybe there is another explanation that the adoption of 42mm flanges for the early Contax cameras may have been determined by Zeiss practices from a much earlier era. Indeed I did not have to look too hard to find older Zeiss lenses with front element diameters that were the same as the Contax as well as the common 37mm of early lenses.

Modern Zeiss Proxars were manufactured for specific camera models – Contax R/F, Contaflex SLR, Contarex SLR, Contax RTS, Hasselblad etc etc all aimed at close-up work, coated and sold as quality products, and none of those have serial numbers. But it seems that the original usage – and the associated Distars – have been largely forgotten except when something like these Century-plus-old devices turn up and someone finds an old pamphlet. But are these auction items as old as the serial numbers suggest? It is more likely that the use of Distars was not common and there might have been a lot of stock in storage for the period from 1913 to about 1929 when the catalogues stopped listing them.

To complicate issues and add to the confusion, the earliest pamphlet describing these lenses appears to be dated around 1922 and possibly as a reprint in 1937 by which time the Distar ideas were probably well and truly out of date. The “wide-angle” Proxars are easy to explain for use as a close-up device, but not so the Distars as they cannot be used with ANY lens on a modern camera that does not have the ability to be extended on bellows etc. What is more, the resulting telephoto lens is a long way further from the film plane than a typical telephoto lens, as the resulting prime lens plus negative “front element” is a simple calculation producing a new prime lens and not the trickery that results in a physically short tele-lens.

While some internet sources hold that the Distars and Proxars appeared first in a catalogue in 1926, others have suggested that they appeared as products much earlier – around WW1. Comparing serial numbers found on early Distar and Proxar lenses with data published in the relatively new books on Zeiss serial numbers by Thiele show that those lenses fall into groups shown in Thiele as "Protarlinse", "Negative-Linse" and actual "Distarlise" – definitely from 1903 (with examples held by this writer) and maybe from a year or two earlier. The period – 1920-1926 was also a period of considerable instability in German optical production and earlier written material may well have been lost. We need to be wary of published statements that may not have the benefit of recent research. New documentation is turning up all the time and a very recent analysis of the history of the Tessar lens published in January 2025 by Zeiss also shows that "Distarlinse" and "Proxarlinse" names belonged to about 1903. A modern commentary on the effectiveness of these lenses is also included. The records of Zeiss serial numbers show that these lenses were probably made in significant quantities.

Lists of serial numbers do exist (see the article on serial number publications elsewhere in this issue of Back Focus) but in the case of Carl Zeiss, while a lot of the records were destroyed in WW2, detailed records from 1890 to about the beginning of WW1 have survived although there are lots of gaps. When this author started looking at Zeiss serial numbers in the early 1970s, very little was known and it was commonly believed that many of the numbers were out of order. We now know differently and there are two series – one starting in 1890 as Carl Zeiss Jena (East Germany) and another starting in 1948 as Carl Zeiss Oberkochen (West Germany), and from that date the Jena series runs in parallel. There are lenses on Zeiss products, usually on cheaper cameras, like the Pantar lenses on some Contaflexes etc. These have some odd numbers not related to the main streams. Those lenses were not made by Zeiss but by external contractors like Rodenstock and others. So do the numbers on the Distars and early Proxars fit? Indeed they do and the reconstructed lists in the volumes by Hartmut Thiele sometimes show them as "Proxar" and sometimes as "Negative-satz", "Protarsatz", or "Protarlinse" with the dozen or so such early lenses in the author's possession being from 1903 to 1913 fitting into those groups but with the Distar and Proxar names on the units.

The 1926 pamphlet says more about what you can't do with these lenses than about what you can do and it is left to the reader to realise that the instructions are only relevant for plate cameras with a wide range of bellows positions. Further, the pamphlet lists lens diameters with much wider ranges that never seem to turn up in collections. There is of course a chance that the pamphlet includes a Zeiss habit of advertising items that are projected for future production. Both Proxars and Distars are listed in 11 different diameters from 21mm to 60mm. Strengths are listed from -1 to -4.5 dioptres in the case of the Distars and +0.5 to +2 dioptres in the case of the Proxars. All seem to be clip-on types – screw and bayonet Proxars were to come much, much later – and of course Distars were to disappear entirely.

Now the pamphlets do include some photographs demonstrating the wide and tele effects that can be obtained – done with a 9x12cm plate camera of the day fitted with a f:4.5/150mm Tessar for all examples in the 1926 document and with a f:4.5/135mm Tessar on a quarter-plate Ideal B in the case of the ICA document. It is logical that we might have a look at how well the idea works and that is quite easy to do with the aid of a modern digital camera, some bellows and a couple of adapters – and whatever Proxars and Distars can be found. A rummage through the odd-lenses box found a couple of candidates – a f3.5/135mm Tessar from a Contessa Nettel with a serial number that places it around 1925 and a f:2.8/75mm Tessar that came from a Reflex-Korelle from 1936 – contemporary with the pamphlets – both reasonably clean – no coatings of course. Checking revealed that Distars with strengths of -2.5 and -3.5 dioptres and a wide range of Proxars all with serial numbers from the early period (~1914) were available for testing. The test camera would be a Sony A7R – full frame 35mm format. While the 135mm lens is a more logical choice matching the power of the printed example, trying the 75mm lens is a closer emulation of the acceptance angle when used on a 24x36mm format. Of course we will be testing with colour and not B&W which was all that is in the 1930s documentation.

A test setup with a 135mm Tessar from the 1920s fitted to a Sony A7R using a Novoflex bellows unit and a couple of fabricated adapters

Adapting the f:4.5/135mm lens to a set of bellows revealed a surprise. The lens was mounted in a common Dial-set Compur shutter of a type made from 1912 to at least the end of the 1920s. However the thread on the back of the shutter that would normally be placed in a hole in the front of the camera bellows and secured in place with a threaded ring was none other than a 39mm Leica thread! Are the commentaries and beliefs that the 39mm lens thread was invented by Leitz valid? Or was that decision a direct re-use of the shutter thread from an earlier era, and maybe from as far back as the late 19th Century as a Compound shutter? The 39mm size does not line up with any of the modern shutter hole sizes, but in those early days anything was possible. The shutter thread pitch seems to be 0.75mm whereas the Leica pitch is 1mm, but for this test rig a conventional Leica adapter was used.

On the next page are some of the results of trying Distar and Proxar lenses on these Zeiss Tessars from the 1920s and 1930s. When 135 and 75 mm lenses are used on full frame 35mm format cameras, only the central part of the image is seen, so the following images are rather better than would be the case if the original larger formats were covered.

Image produced by the 135mm Tessar on a full frame 35mm format camera.

Image produced by the 75mm Tessar on a full frame 35mm format camera

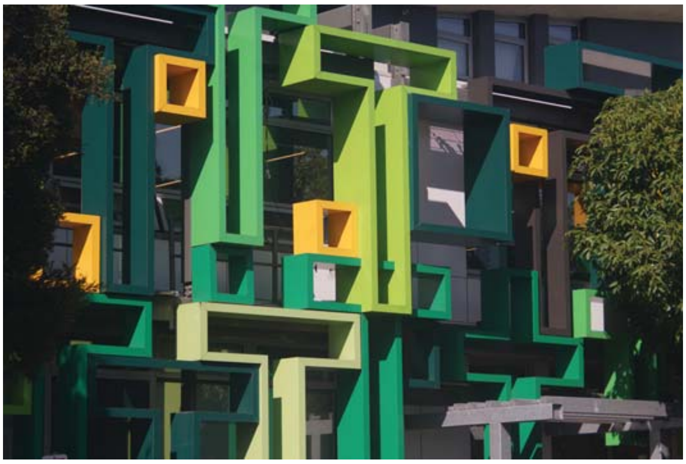


Image produced by the 135mm Tessar - but fitted with a 2 diopter Proxar lens - on a full frame 35mm format camera

Image produced by the 75mm Tessar - but fitted with a 3 diopter Distar lens - on a full frame 35mm format camera. The lesser effect compared with the 135mm lens is obvious

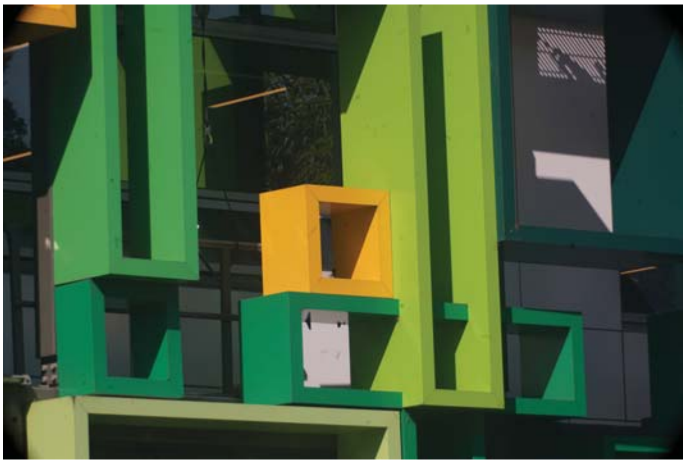


Image produced by the 135mm Tessar - but fitted with a 3 diopter Distar lens - on a full frame 35mm format camera

Some fundamental optical calculations show that the effect of each of these also depends on the focal length of the prime lens - ie the shorter the prime lens the less the effect of the additional element. Using the test setup shown on the previous page, coupling the 75mm Tessar to a Proxar resulted in being unable to achieve a focus as the whole lens assembly would have hod to be closer to the image plane than the setup allowed. Holding the lens in place by hand without the security etc of the bellows unit worked but the image was not worth presenting.

The lenses used in these tests - both Tessars with 37mm front mounts - along with the Distar and Proxar 37mm clip-on elements chosen for the exercise. The serial numbers on those belong to the WW1 era.

The image qualities achieved using these accessory lenses is pleasingly good, and a lot of magnification is needed to find aberrations that would be unacceptable for most photographic needs. The Zeiss documentation restricts the use of these Distars and Proxars to the longer lenses that were common for plate photography up around 9x12am ie around 5x4 inch, but the the above testing with the 75mm Tessar is just as acceptable. These tests were all done with the prime lenses set to f:5.6, allowing the automatic exposure control in the Sony camera to make the exposure adjustment. A couple of tests were also done wide open - with similarly pleasing results.

The Brownie Holiday Camera

Leigh Harris

In the world that promotes exotic cameras that are beyond the resources of most people, there are also cameras at the other end of the scale, often pretending to be quality items capable of "perfect shots". The Kodak organisation designed cameras for the masses and in the case of the Brownie Holiday Camera, it was so cheap that other organisations gave them away as promotions.

The Brownie Holiday is an endearing small bakelite camera that holds all the hall marks of what is a humble 'Brownie' camera. It features only the essentials; a simple meniscus lens, an easy-to-use tubular eye-level optical viewfinder, a shutter button for instantaneous exposures, and a winding knob. It utilizes a rear red window to locate the frame number, and a curved film plane to help counteract the limitations of 'curvature of field' of the simple meniscus lens. There's no auto-stop, double exposure prevention or any of the niceties that we expect on better cameras.

Designed to take eight pictures on 127 roll film, the image size is 2½" x 1⅝" for Imperialists, or in today's metric world, 65mm x 42mm. The creator was Arthur J. Crapsey, an industrial designer who was also commissioned by Kodak to design other mass market cameras such as the Brownie Bull's-Eye, Hawkeye, and Starlet to name a few. (United States Patent Office has Arthur J. Crapsey name on the patent of July 15, 1952; Des. 167,256.)

The Brownie Holiday Flash with the "Kodet" lens released in Canada.

This camera is seldom seen in Australia as it was primarily sold in North America and Canada. Countless numbers were produced and because of the economy of scale, were relatively inexpensive. And this is just what Kodak intended with the Brownie; a mass market, easy to use camera to encourage the sale of their film, and it did just that. This made it ideal for promotional purposes, and was used as 'bait' to sell other goods such as petrol, tea, cigarettes and some mail-order promotions. In its promotional guise, it was mostly labelled as a 'Brownie Bullet', and it is not uncommon today to find it with its original postal package, in unused condition, as many people were enticed by the lure of 'something-for-nothing', and had no real interest in using it.

An adverisement for the Holiday Camera sold at Chevron petrol stations - is the approach genuine or is there is an underlying sense of sarcasm?

It has a typical 50's appearance as one might expect from a 1950's design; a hint of art-deco and a streamlined body. Rugged and simple, there was not much to go wrong with it, the durable bakelite has stood the test of time. For today's collector, there's a feast in store, these little gems will keep you 'rivet-counters' out there very happy and busy for quite some time as there are no less than 30 different variations! Let's take a look at what some of these are:-

The Name: Holiday, Bullet and Chiquita; the latter being an export model for Spanish speaking countries; Chiquita means a few things in Spanish including 'small'.

The Origin: The faceplates reveal either Canadian or USA, all the Chiquita versions were of USA origin.

The Body: A lovely chocolate brown bakelite with coffee coloured shutter and winder (very apt for a Brownie don't you think?). It is also found in smart black bakelite with contrasting white fittings. Whilst the Holiday and Chiquita are seen in the two colours, the Bullet appears to be found only with a black body.

Both the Holiday and Chiquita can be found with and without flash contacts, while the Bullet exists only without flash. They have a plaited strap-handle, and a longer plaited neck-strap appears synonymous with cameras equipped with flash contacts.

Kodak claim that…despite its low price, it is as thoroughly engineered as a Kodak Signet or Chevron camera, providing top-quality performance in its class. It is engineered from front to back like a top-price precision camera. Clearly this is promotional material!

The Brownie Holiday Flash - an unusual green and red outfit box.

The Rivets: Here we go; either two flat faced rivets or two Phillips head self-tappers hold the faceplate firmly in place – a special for those looking for variants.

The Lens: A single element meniscus. Models up to July 1955 have a glass 'Kodet' lens, and after that date, they were supplied with a plastic 'Dakon' lens. (note that all Bullets have Dakon's.) Whether there is any noticeable difference in the lens quality between the glass Kodet and the plastic Dakon, is yet to be verified. Also, does the Dakon with the clear lens flange create more lens flare than the brown lens flange.

The Viewfinder: An easy to use clear plastic eye-level finder which Kodak states "is aspheric, and free of pincushion or barrel distortion" – something special on a low-priced camera.

Accessories: Well, yes - they are not often seen with a carrying case, but one was available. To increase the versatility and achieve nice portraits of your family or pets, the Kodet lens bezel accepts the Kodak No. 13 close-up or cloud attachment, and the Dakon lens bezel accepts the Kodak No. 6A close-up or cloud attachment. Those cameras with flash contacts accept the Kodak Midget flash unit.

Outfits: Kodak offered only the flash versions of the Holiday and Chiquita in an outfit form. One enterprising toy manufacturer, Fairchild Corporation, created their own outfit for the Bullet. There was no flash attachment, however they included a pocket photo album and a roll of Kodak film. These were then sold through retail toy stores.

Advertising: The Holiday and the Chiquita were well advertised by Kodak, both wholesale and retail, in numerous magazines and papers of the day. The Bullets, used as a premium, are liberally advertised for the promotion of a broad range of products and services, and were often exchanged for coupons and labels. These are all worth searching for and create an interesting historic dimension to the collection.

Review: An in-house Canadian Kodak publication 'Kodak' of December 1954 announced the introduction of the 'Brownie Holiday Flash camera'.

Novelties: Because of their popularity and iconic design, there have been at least two items produced that fit this category. One, a cast resin paper weight, and a glass Christmas tree ornament.

Manufacturing Dates: The Brownie Holiday was introduced in October 1953, with the Kodet lens until about 1955, and from then on with the Dakon lens. From 1954, it was available with flash contacts. Production ceased in the early 1960s. According to the Collectiblend, the Holiday was made until 1957, and the Flash version until 1962.

The 'ornament' with its box - note the reference to "Hand-crafted in Germany" - mabe an attempt to elevate a pretence of quality?

Conclusion: There are no serial or patent numbers indicated, however there are moulding or part numbers inside such as 125480 or 125481. The 'Kodak Parts List No. 5502' verifies these. The 'Holiday' models have 'Camerosity' date codes corresponding to George Eastman's 13 month calendar, i.e., YRRE is May 1954, though these are absent with the Bullets and Chiquitas.

Along with the 'Baby Brownie', the 'Brownie Hawkeye', and the 'Brownie Bull's Eye', these were the last really solid bakelite cameras that Kodak produced. After this came the 'Brownie Star' series, made of thinner less substantial materials and were more 'toy like' in their use and feel.

The Chiquita, just to make it interesting, are a little elusive and somewhat scarce, but they exist in at least 9 versions. When they do turn up on eBay etc they are sometimes described as 'Camera' or the 'Spanish Camara'.

Availability: You will have to compete with this writer to procure all the variations, but there's plenty out there as they were made in large quantities. Pricing has been varied but recently there have been some high prices, presumably for some versions. According to Collectiblend, Flash versions are now in the range A$15 to A$75 and the non-flash versions range from A$30 to A$90 depending on condition and the inclusion or otherwise of packaging etc. In today's volatile collectors markets it is likely that some rare variants could be highly desirable and hence costly. While some eBay prices are around A$10 plus postage, some hopeful sellers are pricing them up around A$250, and of course postage from the USA is very high at present.

Lens Calculations

Rod Reynolds

There are very few books that go into the art of calculating the performance of lenses and the art of designing them in the first place, probably because of proprietary protection and maybe because the methods were only in the minds of those who actually did the work. There is no doubt that those processes are complex and difficult to understand. It does not help that a lot of work was done in Germany prior to WW2 and for much of the time after WW2 it seems to have been assumed that the records were lost as a result of war activity. Those that wrote material for academic purposes and/or the interest of photographers took a simplistic approach and maybe even trivialised what was done historically.

Behind the scenes those who were the real experts seem to have largely ignored the national and company boundaries, and it is only very recently that those interactions and what was actually happening have come to light as there has been a quite recent move to understand not only what happened but how it all became "private knowledge" to those who were at the forefront. In some cases all we have is the results of the calculations, but there are clues there and a bit of "reverse calculating" can discover how they did it.

This article is a reprint of a presentation to the APCS in February 2025 and contains material from presentations in 1999 and 2019. It is primarily the work of other people, and credit is given as part of the text. This is not an academic paper so references are mostly not included.

Introduction

In this article I am attempting to summarise the overall subject of optical system analysis and design, and this story will inevitably be a mixture of the evolution of those methods and some level of increasing complexity. What follows is in no way an instruction on how to do everything that is necessary although there will be a couple of examples to indicate how it has been done. In some discussion towards the end I will outline some issues that are evident by observation and a level of theoretical approach but are a long way from being achieved practically.

What might be called "popular optics" is misleadingly simple in approach to the extent that it is of little use, and for some readers it might have more apparent importance than it deserves. Photographers who read lens reviews etc are used to seeing statements that rely on qualitative assessment but there is a lot more to it than that. This is an introduction only – no more – but it is an attempt to explain why we are now relying on parameters like MTF to make optical comparisons.

This is not an attempt at a learned paper and does not contain a detailed list of references. Indeed, some of the observations are the result of looking at what is reported and a level of guess-work about how those reports came to be stated.

I started writing this summary with the idea that I was going to base it on a similar paper that I wrote in 1999 but updating it to cover the lens computation methods from the last 25 years. But in January this year, information emerved on the history of the Tessar lens that included information from before WW2 that had been considered lost in WW2. I find that I have to revise my understanding from that earlier position very substantially – especially on historic matters that were well known by optics people before WW2, not only relative to calculations that were done on the Tessars and the related lenses during their development but also some specific details on substantially different lenses going back to the 16th Century. A key issue is that it seems that much of the theoretical work that was done in the period before WW2 occurred in Germany, and seems centered on the Zeiss organization. I am indebted to the author of that treatise – Marco Kröger who I understand lives in Berlin and seems to have access to a lot of material that we all thought was lost.

I have arrived at a realization of my own – maybe to be disputed by others – but there is considerable evidence that there has been an extraordinary level of "information sharing" especially in the last couple of centuries. One does not have to look too far to discover that the optical community was a very close one, and key people skipped from company to company and information was certainly shared from country to country. A few examples are well known and have been throughout the history of optics, but recent revelations suggest that it was much wider, and very much overcame partisan boundaries. Names keep swapping companies – Zeiss one day and Schneider the next – Germany one day and the UK the next – and even in the middle of wartime (WW1 and WW2) there was a huge level of optical trade between the UK and Germany in optical products and primary material for local manufacture for example. Some of those details have only emerged very recently after the release of previously restricted documents in the UK showing that not only was there significant trade between German and UK optical firms but the exchanges were managed by the UK Department of War in that country – sometimes there was a pretense of dealing through Switzerland, but often it was quite blatant. You don't have to look too far to discover that research work in one area turns up in another almost immediately – and even before patent applications in some cases! It was not only information that was swapped, and very considerable quantities of optical instruments and even primary material like glass changed hands during WW1 in particular.

Lenses have been used for a very long time – so much so that the first use of them has been lost in history, and any specific claims are almost certain to be wrong. Archeological evidence goes back at least 8,000 years and probably more and while the primary use of such devices was probably to produce "burning glasses" and "magnifying glasses" there is also use of them and even simple pin-hole devices to aid those with faulty vision. But along with their use, there is evidence that the theory of the lens and, for at least a couple of thousand years, mathematical approaches to understanding how they worked were well known. Concave and convex mirrors of course are a special case of lenses, and seems always to have been included in mathematical studies.

What can pass as "modern approaches" to analysis probably dates back to Mesopotamia, but certainly to the Greek mathematicians of 2,000 years ago, and, based on the mathematics of "Conic Sections" was probably more accurate than the methods that are often attributed to the likes of Newton in the 17th Century. However even before that the likes of Galileo must have had their own approaches to the subject. Unfortunately, so much of what has been written in the last century on the subject dates everything back to Newton, but while he formalised some of the arithmetic using cartesian mathematics, the principles and the quantitative theory behind it all was very well known a lot earlier.

But Newton did contribute to the ease with which we can analyse a simple lens and even extend it to some classes of thick or multi-element lenses. Subsequent work refined that early primitive approach and it is clear that virtually everyone that contributed to lens development approached the issues with a very solid basis in the mathematics that was involved. As the years passed, the mathematical methods were refined and was not until just after WW2 that the treatise by Buchdahl (1948 see below) produced a concise approach that stands today as the definitive way to analyse a lens subjectively which in turn permits modern measurement methods and accepted parameters to be stated. With what is emerging from Germany now relative to the period before WW2, we cannot avoid the observation that Buchdahl worked in optical mathematics in Germany before WW2 and almost certainly brought that knowledge with him when he was working on his 1948 treatise. However it is probably only the experts who have the motivation to understand and perform the very complex mathematics involved. Fortunately, there are some relatively elementary approaches that do give some insight into the design of complex lenses. One of those methods is applicable to the paraxial performance of a lens assembly – limited to the simple images on the main axis of a correctly aligned lens. Before diving too deeply into mathematical methods there are a few observations…

Lens/image Faults

Lenses and systems demonstrate faults of various kinds and those that worked in the area had a language to describe various deviations from perfection, and some of the technical terms were related to what was observed and not necessarily to the output of numerical calculation. Most lenses have been used to generate images which have faults, and those faults have been expressed in both qualitative and quantitative terms. Common ones include:

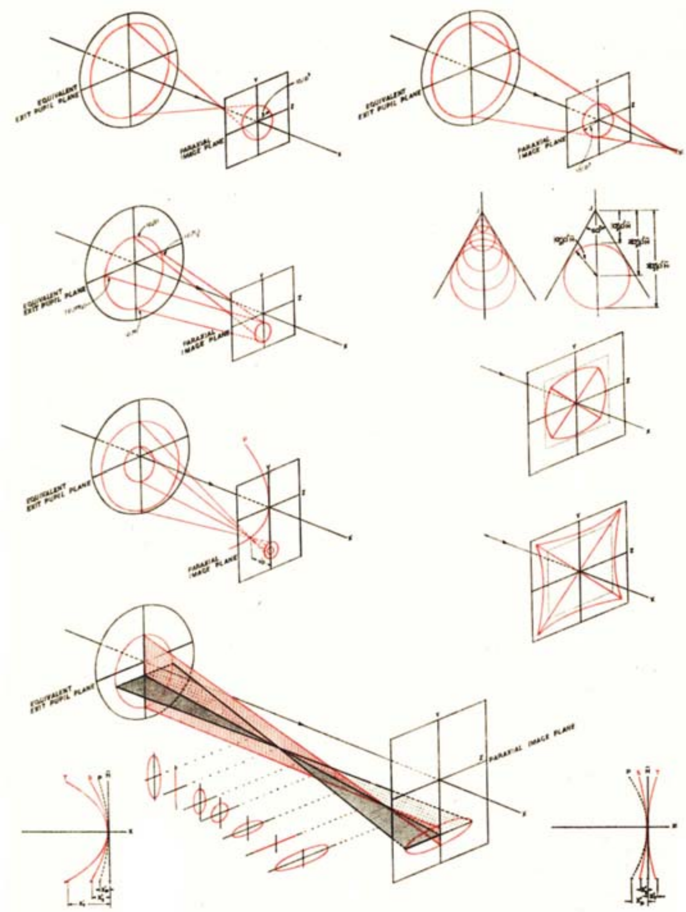
Astigmatism: where a focus point at the edges of the image field can be stretched in tangential or sagittal directions. (Note that this form of astigmatism assumes that lenses are manufactured and assembled correctly – and particularly on axis – but that is not always the case and other forms of astigmatism creep in – looking like one of the types usually considered for eye-correction lenses extending over the whole image plane, and often in more than one evident direction – that is a study all of its own, but occurs when an otherwise spherical lens has some cylinder characteristics.)

Coma: where a focus point usually at the edge of the image field is stretched in one or more directions – like the tail of a Comet – hence the name – and is sometimes referred to as flare.

Spherical aberration: where an image that is supposed to be square is stretched outwards at the corners (pincushion) or compressed inwards (barrel).

Chromatic aberration: where rays of different wavelengths (colours) focus at different points – usually resulting in colour fringing.

Field flatness: where the optimum focus is on a curved surface rather than a flat field that would be desirable for most optical applications.



Sketches of various distortions that appear in images generated by real lenses (Cruickshank and Hills 1960)

And of course for real lenses, many of these faults occur in combination. As lens designs have improved, many of these faults have been overcome but that only leads to looking closer and discovering other degradations that emerge. In modern optics a parameter known as MTF (Modulation Transfer Function) is commonly used to quantify image quality, and without being too exact can be thought of as a mixture of absolute focus and absolute contrast at micro definitions. Sometimes, MTF is averaged as a simple term like "resolution" which might be stated at the centre and corners of the image field. We return to that subject after considering non-paraxial calculations.

But simple observations of these parameters on an existing lens is a job to be done in the laboratory most of the time. Calculation of them from the physical arrangement of the lens elements is a vastly complex matter and becomes highly specialised for each lens type and the job that it is designed to do.

It can be quickly observed that these degradations are a strong function of the field of view, and hence the function of the lens concerned. The corners of the "standard lens" in most cameras is about 45-55 degrees from the axis, but for an astronomical telescope the field of view is more like 1 degree, and the limiting factors will be very different which in turn will determine how each of those lens families are designed. Another major issue is the resolution that different applications demand. A photograph taken with the idea that a human is going to view the result does not need to be any better than the human eye (with its own limitations) can observe, but a lens used to do the lithography for an electronic integrated circuit today needs to be able to resolve down to atomic levels – about 50,000 times better than a human eye. Over those ranges we run into another limiting factor… Light is an electromagnetic wave and the images that form are governed by the limitations of wave mechanics in the extreme. But that extreme is just evident in the performance of the human eye and is usually dealt with when we consider a "system" as being the combination of source, illumination, lenses, and the eye and cognitive processes that are involved. In the micro-lithography world those wave limitations dominate and lead to lenses, illumination etc that are quite different from those that we might use for general photography.

As devices and lens system were invented, specialist mathematical approaches evolved to describe and measure the degradations that were observed. So even centuries before Buchdahl, methods were emerging that permitted quite accurate calculations to be done, usually based on geometry and refraction in the case of glass etc. From about 1850, issues like chromatic aberration became important enough to include and written evidence shows that there were a few people who understood enough to analyse any lens, and also enough to make modifications to lenses to achieve improved results. Those people described and calculated lens performance in matters of coma and astigmatism and discovered ways of minimizing those effects.

Today a lot is said about "computer design" as if it were a new thing. But there have been calculating machines used to assist analysis for as long as they have existed – about 150 years in many cases. Longhand calculations are very laborious and almost impossible in most cases. From about 1900, optical designers used logarithmic tables to assist as most calculations involved only multiplication and division, although trigonometric tables are very useful in the case of "ray-tracing" but more of that later. A huge advantage of modern computers is that they are fast, and for a given optical layout, changes to design can be made and analysed very quickly. In some cases, what has been called "algorithmic computation" will have been used to create new designs or at least correct old designs.

However even the word "Computer" raises questions, because the term evokes what we think a computer is today and what we might guess that a programmer can do with it. Back in 1960, I was "computing" lens analysis using either a Marchant ACT-10 electric calculator that was limited to addition, subtraction, multiplication and division, or what was known as a "coffee grinder" which did the same calculations but was driven by a hand crank. Each of those machines had decadic input and output and each was accurate to 10-digits. However neither was programmable so were only an assistance to what was written on paper – and it took time…. Zeiss and presumably others already had access to what are now called computers but there were also probably limited to simple calculations but probably extended to chain sequences in the same way that a modern hand-held calculator is limited. They may even have had trigonometric variables – essential in ray-tracing. With my work back in 1960, we had to read them from books of tables. As computers grew in capability, more could be done and today parameter optimization is almost certainly done using techniques like predictor-corrector algorithms and ultimately integration with mechanical Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) – put them together and you get the modern term CADCAM.

Zeiss Jena had an electromechanical computer OPREMA as early as 1954, but in the 1960s Zeiss produced the specialised Rechenautomat ZRA1 computer based on 12,000 diodes and 770 valves – relying very heavily on magnetic storage. This would have reduced computation times dramatically. In the history of computing, the ZRA1 was also released in a different form for general computing.

But there is a new world that has emerged with the advent of digital cameras – where a computer becomes part of the camera and corrects the image taking into account the known parameters of the lens. Quite specifically, issues like chromatic and spherical aberration in an ordinary lens can now be corrected in the camera to produce images that are so close to perfect as to be indistinguishable from an uncorrected image taken using a "perfect lens'. Again, more about that later in this article. That level of computer assistance is now so commonplace that it probably exists in every camera made in the last couple of years although maybe only the better camera – including those in mobile phones – get close to a "perfectly corrected image".

This article does not set out to show how to analyse and design a lens or optical system. That would require something approaching a whole University course over several years – and would probably be out of date by the time the course was completed – such is the rate that technology change has allowed newer and faster approaches to be developed and adopted. The reality is that the only people capable of achieving a design at the leading edge are in the business of doing so for commercial purposes – and is initially a costly path that only becomes economically viable when economy of scale allows dedicated processing devices etc. Even as I write this, I am aware of theoretical approaches to image formation are still emerging – often on an image-by-image basis as we are seeing coming from the James Webb Telescope, and it may be years before elements of such design make their way into a camera that we can buy. If you doubt that, consider that it took a camera worth thousands of dollars in today's terms to take an image on Kodachrome film that has an equivalent digital resolution of about 10Mpixels – and that camera only needed a lens with that level of resolution, but today you can get an image of 200Mpixels on a phone camera that only costs $10 as part of the phone – a fairly simple lens but a significantly complex computer program – and that in only 30 or so years. What will the next 30 years demonstrate?

So the following format will start out simply with early calculation techniques and build that up to the more modern approaches. Actual calculation techniques won't be included but some of the results will be shown. A lot of what follows is taken from lecture notes that I took while at the University of Tasmania over 60 years ago, and the publications by Cruickshank, Buchdahl and others that are now out of print. More modern techniques, including discussions on computerization and image equalisation are taken from more general textbooks and similar resources, and in many cases have to be considered as qualitative rather than quantitative – ie the effect of the methods will be indicated rather than the actual values etc. However all of that has to be qualified by the revelations in the recent papers by researchers like Marco Kröger and his paper on the development of the Tessar lens – nearly 200 pages of very complex reading!

Early Optical Calculations

In early philosophies most primary entities were light and darkness, and amongst the earliest concept would have been well defined shadows, and the only images that might have been observed would have been the result of pinholes. Simple straight lines are enough to describe what is happening and even if loss of definition was considered, a bunch of straight lines is enough to quantify the results. We don't need to dwell much on this until we run into diffraction etc which became the subject of a lot of attention in the middle of the 19th Century when light was understood as a form of electromagnetic radiation opening up a whole new world of often complex mathematics. But the moment astronomers etc started playing with image-forming mirrors, new issues arose as images could be focused. The mathematics for that found a general approach in the form of a largely forgotten branch of mathematics called "Conic Sections" where the intersection of flat planes on cones – and even the intersection between a couple of cones provided solutions on how finite mirror surfaces could focus exactly. Conics was the language of philosophers in the civilized world from a about 4,000 years ago and was perhaps most highly developed by the Greeks and in Arabic countries. Some of the features of Conic Sections fitted very well with the optics of reflectors – and the labels "Parabola", "Ellipse", "Hyperbola" and "Circle" all feature in the design of devices that form focused images. Today however, we rely on Cartesian formulae etc to describe these surfaces, and that approach was the result of the new approaches by Sir Issac Newton. Solutions in Conic Sections are not surprising as so many features are linked to what is called the "focus" of the chosen curves. (In conic sections the focus has names in historical form. The name that we use "focus" is a 17th century scientific term that literally comes from the Latin meaning "fireplace" or "hearth" likely as an interpretation of the origin of energy, and is used in areas other than optics.)

So how did Conic Sections aid the development of optical systems? Conics was a discipline all of its own but application to optics would have relied on the characteristics of the various curves in much the same way that school studies of Geometry applied to shape and form.

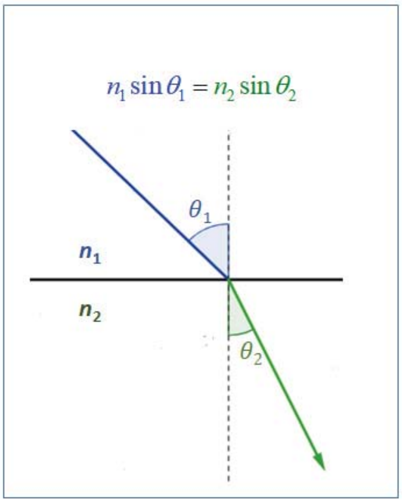
While the early consideration of Conic Sections was to do with form and features, modern calculations are entirely in the cartesian mathematics of Newton and it is emerging that Newton was almost certainly repeating the work of others. Everything can be expressed in numerical terms that allow calculation to the level of accuracy that is desired. A key result is that classical Conic Sections has been virtually forgotten although it did appear in school textbooks in a descriptive sense as recently as a century ago. Today it is little more than a classical curiosity although the generated curves still feature prominently.

But here we must digress. Conic Sections does not help with lenses where diffraction is involved. The phenomenon is that light bends when passing from one optical media to another when those media have different refractive indices – known today as "Snell's Law" after Willebrord Snellius (1580-1626). But it was suspected by Ptolemy of Alexandria (c.100-c.170 CE) and realized in its modern form by Ibn Sahl in Baghdad in 984 CE who even designed lenses with no (or at least reduced) aberrations!

Many others are now remembered for using and enlarging on that early work and by the 17th Century the trigonometric SINE relationship of Snell's Law was well established – but not necessarily the theoretical reason behind it. That had to wait until the physics of the speed of light was determined and how light was propagated became understood – and believe it or not, that was still being argued about into the 20th Century as old ideas take a lot of erasing – as late as 1920 there was even a text book that held that light was transferred through space via a medium called the Luminiferous Aether (also spelled 'Ether'). Complicating early understanding was the concept of the wavelength of light and that the refractive index of glass media was a function of the wavelength. But even that was understood practically and compound (Achromat) lenses were being made in the middle of the 18th Century by making groups of two elements with different dispersions and it was only a few years before Peter Dolland produced an even better corrected Apochromat (1763). Both those designs are still in use today in binoculars and telescopes as the main objectives.

A more detailed understanding of Snell's Law came in the latter half of the 19th Century – attributed to Ernst Abbe (1840-1905) working at Zeiss – and the realization that for each type of glass there were two physical parameters – Refractive Index which was itself a function of wavelength and Dispersion which was a measure of the strength of that function, sometimes known as the "Abbe Number".

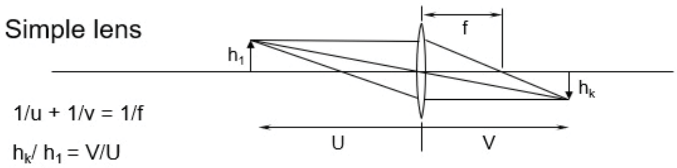
The observance of Snell's Law and conventional geometry is all you need to plot light through a multi-element lens and thus for the whole of the era of photography, it has always been possible to calculate each and every distortion that is produced by a lens – but it is fiendishly complex work understood by many but performed by only a few. While there have been developments, it comes under the general title "Ray Tracing".



Snell's Law in its simplest form. The direction of the resultant wave and hence Θ_2 depends on the wavelength of the incident light and he dispersion of the medium – known as the Abbe Number which causes many aberrations in an image – n_1 and n_2 are the refractive indices of the media on each side of the interface

Newton's Optical equations for a lens

The almost trivial equations for the formation of an image or a virtual image created by a lens relates the inverse of the object and image distances to the inverse of the focal length of the lens. It is often erroneously stated that it applies only to a "thin lens" but it can be extended to a general lens provided that a few extra terms are included to determine measurement points. For some classes of compound lenses – like telescopes and compound microscopes – Newton's equation has to be repeated for each stage and the image plane for the first stage becomes the object stage for the second stage. A useful tool to determine magnifications but of no use whatsoever when it comes to determining distortion in a practical sense. When applied off-axis, it can be used to determine a "virtual focal length" but only for the specific ray axis and maybe for only a specific object distance. As a concept that can be observed, it works, and is probably the simplest form of optical mathematics.



A diagram showing the Newtonian optical model determining the size and position of an image formed by a simple thin positive lens of focal length f – with this simple model there is no way of determining aberrations – the construction is based on simple geometry and straight lines – the value for the focal length f is determined by measurement of the image position for an infinite object – ie when V = f

Ray Tracing

The idea of understanding how lenses and optical systems in general work by tracing a number of rays through the system fits well with Newtonian mathematics, and ultimately allows "cones of light" or "pencils" through a system to define where the focus is and how it might be degraded by various factors like dispersion, diffraction etc. The measurable effects like spherical and chromatic aberration can be linked in similar terms, and for design purposes can be used to correct the performance of the system. Done manually, the process is a geometrical nightmare taking a lot of effort, with many opportunities to make mistakes. Ray models are possible through the use of modern computers and leads to even better results when modern digital sensors are then used. Image correction by this means becomes the norm.

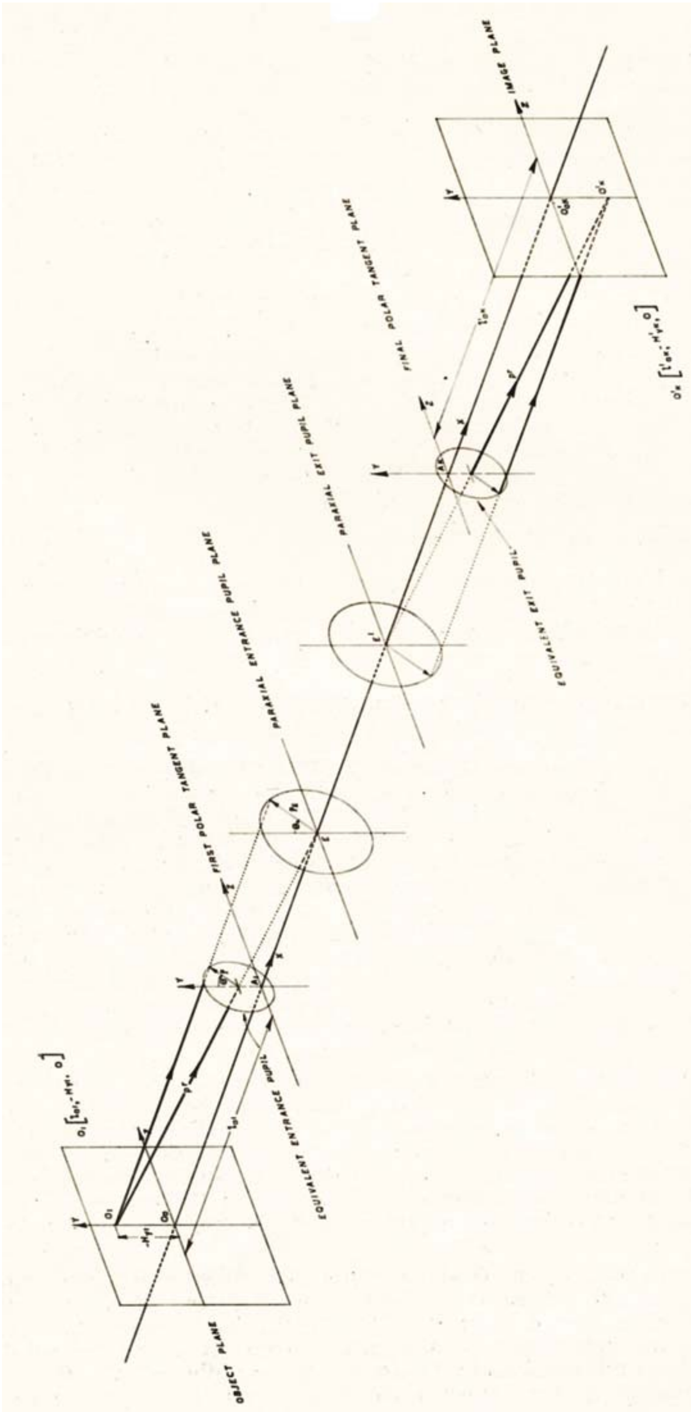
A lot of lens parameters that are seen in patent applications, particularly in the first half of the 20th century, include image-plane plots which were produced by ray-tracing. Usually, the results are only an indication of how the lens performs, but are very useful when it comes to selecting a lens for a particular job. But it also shows that the people who produced those image field drawings had access to the mathematics to draw them – and the variations that arise from dispersion.

While absolute calculations based on geometry are the most likely method to plot ray patterns, practical tracing must be much easier today compared with the methods this author used back in the days of non-coherent object sources and micro image analysis on an optical bench using a special microscope to locate the focal point. Today we could grab a couple of lasers on known wavelengths and use them as sources, and rig up a colour digital sensor connected to a computer screen to do the image analysis. In fact that is so obvious that it is probably the normal method today especially for testing in production. Yet even a decade ago, collimators made in about 1950 were still being used in one of the major lens manufacturing houses in the UK to centre the assemblies.

Paraxial Optics

In its simplest form, the optical lens equations of Newton for a thin lens are an example of paraxial optics, where the relationship between object and image distances and the virtual focal length are simply connected. But even a "thin lens" does have some thickness that makes focusing an image a matter of trial and error. As the name implies, paraxial optics only deals with the image that is on the optical axis – right through the centre of the system, where ray tracing is at its simplest. By the time that a few additional elements are added to address various degradations, a host of problems arise including elements that are not perfectly centered, and significant difficulty in working out where the focal distance should be measured from. The latter issue was of such a problem in the middle of the 19th century that many lenses were specified in terms of the distance from the back of the rear element to the focal plane and not the actual focal length. So we find lenses like Petzvals marked "6-inch" but when tested, the focal length proves to be 8-inch. Of course the thickness of the lens in that case might be as much as 4 inches so it is not surprising that confusion arose. Practically, the focus of a system defined using paraxial calculations might only apply when the elements have a small diameter with respect to the object and image distances and of course the focal length, and also only when the glass dispersion is not significant.

Mathematicians at the University of Tasmania developed a highly structured approach to the paraxial performance of multi-element thick lenses in the 1930s leading to a 4-parameter approach that allowed the geometrical properties of each element and its position in the lens to be used to generate a similarly structured set of 4 parameters for the whole assembly. Accompanying equations then related those parameters to physical measurements from the centre of the front and back elements of the assembly and allowed exact values for the elements like the focal length to be determined. Some new concepts emerged along the way – like principal planes etc that made a lot of sense and assisted in lens design and analysis in general. While the inventor of this approach may not be known with accuracy, F D Cruickshank was a student at UniTas in the 1930s and lectured using this model from about 1941 until he retired in the 1960s. The method is fully explained in a University of Tasmania monograph printed in 1959, and in various printed lecture notes that were issued to students.



Explanatory diagram of terms and symbols used for a ray pencil through a multi-element lens (and mirror) system which will have a solution when expanded up to and including 3rd order aberration products for a defined lens system (after Buchdahl 1948) – see also Non-Paraxial Optics. Extension of this diagram to higher order analysis can be achieved by inspection and assigning additiional variables, and where necessary, drawing additional image planes.

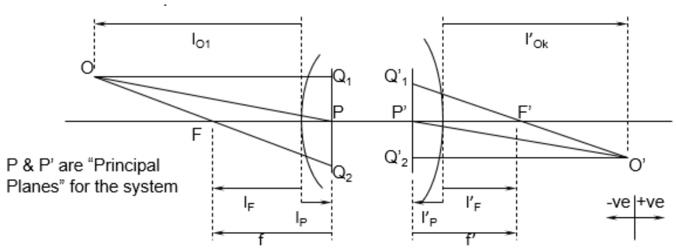


Diagram of a simplified ray pencil through a compound lens system including terms used in a paraxial model which does not take aberrations into account

There is a strong resemblance to electrical network theory and the computer approach to network theory has since been applied to the paraxial optical theory. So the Cruickshank sets of equations can now be considered as sets of 2x2 matrices and allow very convenient computer processes to be performed. However this parametric approach is of limited value and maybe not much more than a teaching aid that introduces the idea of what happens. However if the paraxial coefficients are known for a lens assembly then physical parameters such as the distances from lens to image can be calculated very easily. It follows that the paraxial coefficients of a real lens can be computed from a few physical measurements when it is set up on an optical bench and used in practical devices – at least for images at the centre of the image field and for reasonable approximations on image height.

We introduce 4 parameters for paraxial optics from ray tracing:
"C" defined as the reciprocal of the focal length 1/f'
"A" defined by $l'_{0k} = l'_F = A/C$ for an object O at $-\infty$
"D" defined by $l_{01} = l_F = -D/C$ for an object 0' at $+\infty$
"B" defined as the "optical thickness" for a single element and a little more complex for a multi-element. In words:
A relates the back focal distance and the focal length
B is a sort of measure of the thickness of the lens
C is the inverse of the focal length
D relates the front focal distance and the focal length

We can compute the parameters for a multi-element lens from its geometry with ease. We start at the first surface, and surface by surface build up a model for the whole lens.

At the first surface: $A_1 = 1$, $B_1 = 0$, $C_1 = \varphi_1$ and $D_1 = 1$

Then, written out in full for each surface:

$A_{j+1} = A_j - \tau'_j C_j$ where: τ'_j = element thickness / RI

$B_{j+1} = B_j - \tau'_j D_j$

$C_{j+1} = C_j + \varphi_{j+1} A_{j+1}$ where: φ_{j+1} = (RI' - RI) / radius of curvature

$D_{j+1} = Dj + \varphi_{j+1} B_{j+1}$ and overall, $AD - BC = 1$

All the data is known during manufacture or from measurement, and the paraxial coefficients can be calculated EXACTLY. We may need to include inter-element cement and coatings.

Remember to observe sign conventions.

Forget the arithmetic, but it can be shown that the position of a focussed image can be calculated from:

$l'_{Ok} = (Al_{O1} + B)/(Cl_{O1} + D)$

and its height from:

$h'_k = h_1/(Cl_{O1} + D)$ (other equations as well)

The above shows the equations and assumptions to calculate the position and height in an image formed by a complex lens system for paraxial performance – terms are from the ray diagram in the previous column – to repeat – it does not include aberrations.

Thick Positive				Thick Negative			
r	N	N'	t'	r	N	N'	t'
5.0000	1.0000	1.5235	2.344	-5.000	1.0000	1.5235	2.100
20.00	1.5235	1.0000		-20.00	1.5235	1.0000	

Tessar Lens				Human eye			
r	N	N'	t'	r	N	N'	t'
1.628	1.0000	1.6116	0.357	0.770	1.0000	1.376	0.0500
-27.57	1.6116	1.0000	0.189	0.680	1.376	1.336	0.3100
-3.457	1.0000	1.6053	0.081	1.000	1.336	1.386	0.0546
1.582	1.6053	1.0000	0.325	0.791	1.386	1.406	0.2419
inf.	1.0000	1.5123	0.217	-0.576	1.406	1.386	0.0635
1.920	1.5123	1.6116	0.396	-0.600	1.386	1.336	
-2.400	1.6116	1.0000					

all dimensions in cm

The paraxial calculations do need data for the lens systems and that is found from mechanical measurements of the elements, and knowledge of the glass types that are used – typical figures are shown above for 4 quite different lens systems

Non-Paraxial Optics

Unlike paraxial optics that are relatively straight forward and are easy to follow, what happens at an angle to the simple axis of the lens and what happens if the elements are not exactly in line is far from easy to analyse and the mathematics disappear into a lot of equations which are far from being classed as linear first order. While ray tracing techniques do work, there are some very significant limitations in the results especially when spectral and intensity distributions around the notional focus are considered. This is an issue in paraxial optics but becomes exceptionally difficult to describe – let alone calculate – in the non-paraxial case. Consider for example even describing the distribution pattern from a point source in the object field subject to Coma – the pattern is hard to describe and the energy densities are very complex especially when other issues like edge diffraction due to lens diameter are included. Ultimately, other branches of mathematics come into play and are probably still the subject of new research. Techniques like Scattering Matrices and Statistical distributions emerge as methods but are the stuff of research and of little practical use in the presence of manufacturing errors, quality control, etc. Clearly for a major project like a space telescope, the designers will do whatever is necessary to design the mechanics but what they do is unlikely to be used when designing your "snapshot camera". As to the fundamental theory of off axis imaging, the scope and solution was formulated in the monograph by Dr H A Buchdahl on "Optical Aberration Coefficients" [Buchdahl H A (1948): J. Opt. Soc. Amer, 38, 14] and [Buchdahl H A (1954): "Optical Aberration Coefficients" (OUP and a 1968 reprint by Dover)] , and an introduction to the idea was the subject of another University of Tasmania monograph by Cruickshank and Hills on "Third Order Aberrations" in 1960 that included the quaint observation that "once the idea of 3rd order aberrations have been mastered then the idea of extension to 5th and 7th order might follow". My personal experience is that both those writers had an odd sense of humour, and I rather suspect that only a very rare reader of that monograph gained more than a very shallow understanding of the ideas involved.

The question arises on why it was not until 1948 that this "polynomial approach" emerged. Earlier computation was probably good enough for the photography etc of the day and it is probable that the demands of super-accuracy needed during WW2 forced mathematicians to discover more accurate techniques. Buchdahl was primarily a mathematician but working in this optical area that had substantial contracts with various defense organisation from well before WW2 so had years to develop the approach. Certainly there were examples in patent applications in the UK and USA in particular that refined image plane performance of that family of lenses that were based on Rudolph's work at the turn of the Century, and recent information emerging in Germany demonstrates that the mathematicians there had access to "modern" plots of Refractive Index vs the Abbe Number for a very wide range of experimental glasses that was published internally in 1937. All that work can be achieved by adjusting elements in existing lenses. The Buchdahl approach allows a fundamental evaluation of an arbitrary lens system – on paper – without having to make it. This is an almost impossible task manually, but funding at the University of Tasmania meant that they had the best and latest computing devices at their disposal.

That 1948 treatise by Buchdahl remains as the key reference point in the understanding and computation of non-paraxial optics and can describe what happens in the images generated by real lenses. The derivation of the terms and expressions used in that work is complex and even in the 1960 summary it takes about 25 pages to get from formulation to results for the restricted 3rd order alone. (Buchdahl's book is over 370 pages!) A descriptive account is as follows:

1. Based on a geometric representation of a real lens as shown in the paraxial approach above, but expanded slightly to include details like adjustment to the entrance and exit pupil planes when the restriction aperture is considered, equations can be written for pencils of monochromatic light through the system, but unlike the paraxial case, the convergence in the image field is resolved in a 3-dimensional set XYZ.

2. If those XYZ parameters are then replaced by differential parameters (simple [Z=0] at the object plane) then complex products appear at the image plane, for which the simplest case restricting to values in cubic (third order) polynomials give rise to sets of equations that can describe Tangential and Sagittal Astigmatism and Coma. (This is done by simply making the 5th and 7th order, and higher order coefficients equal to zero for the 3rd order solution.) Evaluation of the polynomials can then be plotted as results in the image plane, and deviations from it. For a reasonably simple lens of say 4 elements, this level of result can be done long-hand but a mechanical or electronic calculator certainly saves time.

3. Parts 1 and 2 are then repeated for a range of illumination wavelengths, and for that, extensive data on the refractive indices for each of the glass types used is essential (eg RI-Abbe maps). While it may be possible to write equations for the results over the optical wavelengths, it is only necessary to choose two or three wavelengths corresponding to R, G and B for example when a digital sensor is used. The mathematical problem for broadband light and a sensor that is sensitive to the whole spectrum is immense and would probably be done by interpolation, with the output being written as

distribution functions rather than exact values. These results can then be plotted giving values for Chromatic Aberrations, with the possibility of arriving at CA shapes. The mathematics for that level of analysis is quite different and can be found in studies in the fields of Stochastic Processes that often use similar approaches with results that are often found in Rayleigh, Fourier and Henkel functions..

In modern digital cameras the evaluation of all this becomes a primary input into the correction algorithms that are being built in with the data for each lens being stored in the Camera BIOS. The overall result is that a digitally corrected “ordinary lens” is a lot cheaper than a “perfect lens” with no digital correction.

A practical approach starts with an approximation of the rays through the system (whose parameters can be physically measured) and constructing the likely results leading to the image plane for the results that are required.

The equations for those rays expressed as power series to the level of analysis (3rd, 5th etc.) are previously determined from the fundamental theory, and the arithmetic for those rays is then determined to produce charts of results for the necessary parameters that arise from the diagrams for specific aberrations.

Sometimes useful modifications to the lens assembly can be predicted – for example a simple modification to the position of the aperture control may be enough to control and even zero the Coma in the image plane. These are not issues or results that can be stated as part of the theory but are part of the art practiced by those who work in the environment, and it has a lot to do with experience. That level of computation or optimization appears in many approaches to optical design throughout history.

Special note: Variation of the aperture position with the aperture diameter is a practical way of some lens optimization and was used by Leitz (spherical aperture) and Zeiss (double aperture) in their higher performance lenses in the 1950s.

But if only it were than simple! By the time that all forms of resolution loss in a photographic image are considered, the combination can’t be written down in those fundamental terms of angles, dispersions, lens positions, etc etc, mainly because the light energy distribution functions are exceptionally complex and are rarely understood. But they can be measured in terms that are meaningful as “loss of resolution” when choosing a lens for a camera – and that introduces an entirely different approach to the statement of performance of a real lens – the “Modulation Transfer Function”.

Modulation Transfer Function

MTF deserves an article all of its own and is just one form of a rather larger subject that had its origins in what is known as the Rayleigh limitation of an optical system (late 19th Century). It has had several “definitions” and “approaches” over the years and is now considered to be defined as the “Fourier Transform of the Point-Spread Function”. In new work it is getting attention in the idea of “Phase Transfer Function” which has practical meaning when the source is a coherent laser – a complexity that is unlikely to be significant when you are taking a snapshot.

			1	2	3	Σ
	c	1	—1·7184	0·63992	—3·8098	
	t'	2	0·01047	0·03142		
	N	3	1·00000	1·63487	1·54712	
	N'	4	1·63487	1·54712	1·00000	
t_3/t_4	k	5	0·61167	1·05672	1·54712	
	cy_0	6	—1·7184	0·64439	—3·9252	
	v_0	7	0·0000	—0·6673	—0·7417	
$t_6 - t_7$	i_0	8	—1·7184	1·3117	—3·1835	
$t_5\, t_8$	i'_0	9	—1·0511	1·3861	—4·9252	
$t_6 - t_9$	v'_0	10	—0·6673	—0·7417	1·0000	
	y_0	11	1·0000	1·0070	1·0303	
$t_{11} - t_2\, t_{10}$	y_{0+}	12	1·0070	1·0303		
	cy	13	0·0000	—0·00410	0·10180	
	v	14	1·0000	0·61167	0·64660	
	i	15	—1·0000	—0·61577	—0·54480	
	i'	16	—0·61167	—0·65070	—0·84287	
	v'	17	0·61167	0·64660	0·94467	
	y	18	0·0000	—0·00640	—0·02672	
	y_+	19	—0·00640	—0·02672		
t_{15}/t_8	q	20	0·58194	—0·46945	0·17113	
	$2Ni_0$	21	—3·4368	4·2889	—9·8504	
	$(i_0 - i'_0)$	22	—0·6673	—0·0744	1·7417	
	$(i'_0 - v_0)$	23	—1·0511	2·0534	—4·1835	
$\frac{1}{2}t_3t_8t_{11}t_{22}t_{23}$	S_0	24	—0·6026	—0·165	18·487	17·719
	qS_0	25	—0·3507	0·0774	3·1637	2·8904
	q^2S_0	26	—0·2041	—0·0364	0·5414	0·3009
t_1t_{22}/t_{21}	$-\frac{1}{2}\lambda^2\omega$	27	—0·3336	—0·0111	0·6736	0·3289
	$q(q^2S_0 - \frac{1}{2}\lambda^2\omega)$	28	—0·3129	0·0223	0·2079	—0·0827

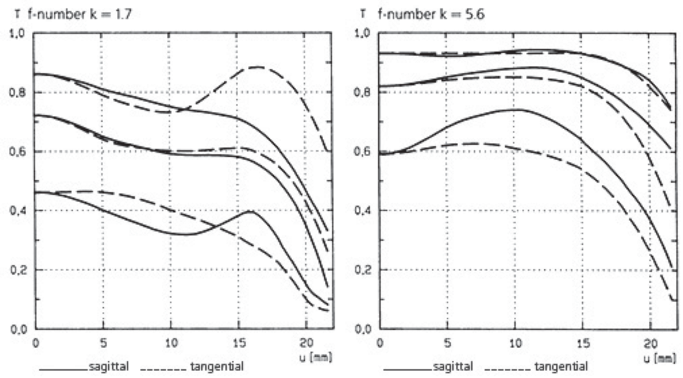
Example of 3rd order equation set - this does not show how the computation is done but does show that it can be done provided that enough effort is applied. All of the individual traditional aberrations (astigmatism, coma etc) can be determined from the process utilizing subsidiary equations that are part of the fundamental theory. The lens system is described in lines 1-4 and the remaining lines are computed.

For a photographer, the MTF diagrams that have been around for the last 60 years or so have been the data that has been relied on to describe the ultimate performance of a lens. For practical purposes, those diagrams have been determined by the observation of test patterns under laboratory test conditions, and there are international standards and even computer analysis programs that facilitate the generation of the plots that we see today. Observers of old data may note that the curves are all hand drawn from live observations on an optical bench. Today, once certain specific parameters are established for a given lens, computer programs like MATLAB can do most of the hard work. But are these MTF diagrams enough? Probably not – as while they can deal with the images produced by a specific lens, they usually do not take into account other image deterioration like edge reflections in the body of a lens, and incident light that we might avoid through the use of a lens hood, or by painting the element edges mat-black during manufacture. Often those distractions are more important than the pure optical path and show up as loss of contrast, sometimes design issues, sometimes manufacturing shortfall, and sometimes deterioration due to age and contamination. Sometimes other lens design features like the nature of antireflection coatings become important and may be the key issue when selecting a lens.

We might consider the advent of aspherical optics and how that affects computation in a lens. Not as much as one might think and not seriously different from the calculation changes that occurred centuries ago when telescope makers changed from spherical reflectors to parabolic reflectors. If there is an issue about aspheric optics is much more likely to be the major issue of translating fully corrected designs into the aspheric surfaces that are manufactured, and a complexity that seems to cause deterioration in MTF values at points in the image that were not so affected in a similar lens designed with spherical optics only – usually at the centre of the image. Are aspheric diffractive optics new? No – Zeiss made an Aspheric Tessar prototype in about 1920.

The evolution of MTF diagrams spans more than half a century and diagrams are used for different purposes. The type that is most common for a camera lens plots the tangential and sagittal contrast figures as a function of distance on the image plane from the centre for a range of apertures, and commonly for a set of resolutions. This is largely a historical use of MTF diagrams but serves well in the selection of lenses.

Maybe the easiest way to understand MTF diagrams it to take them for what they are and use them as tools for comparison, and even make the assumption that the lens is nearly perfect and only consider loss of resolution as the worst parameter.



A set of MTF diagrams for a Zeiss f:1.7/50mm Planar lens for 20, 40, and 80 l/mm at f:1.7 and f:5.6 showing contrast at distances from the centre for tangential and sagittal directions

Post Processing – The Digital Revolution

This author wrote a version of this article back in 1999 and concluded with a summary that lens design was unlikely to develop much further but that computerization would certainly make computation a lot easier. In the last 25 years, that certainly came to pass but there was another development that has overtaken the whole subject of getting perfect images. Digital images in a conventional camera are now up in the region of 100-200Mpixels and the data that is represented in a single image is larger than was contemplated.

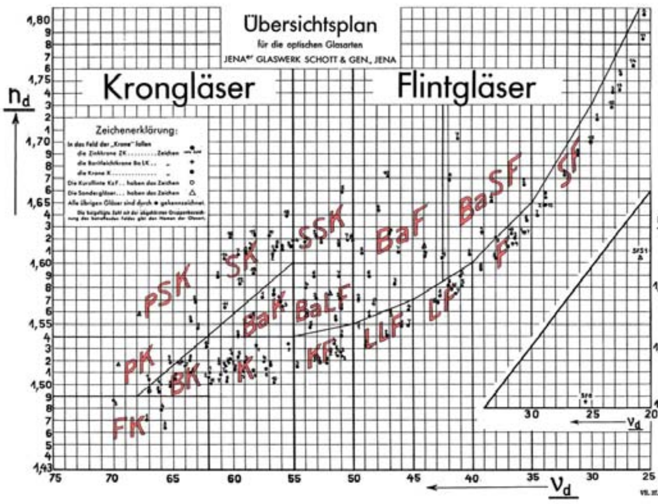
However such is the power of a modern computer that can be incorporated in a camera, that if the degradations in a lens are known then the image can be corrected as part of the storage process around what is “seen” by the sensor. The technique is known as one of the forms of Transversal Equalisation and the software is hidden in proprietary names like “The BIONZ Engine” (SONY). Effectively, an image can be corrected to remove spherical and chromatic aberration – bringing both those to zero. But is also allows the lens designers to optimise an otherwise complex lens to produce a simpler device but with known degradations that can be corrected in the software. For years, some of those ideas have been part of corrections in Photoshop etc but today they are integral with the camera. That has changed a lot about the way that we store images and while the idea may change in the future, at least for the moment the best images are probably stored as JPG images rather than RAW as the correction processes are integrated with the JPG conversions – resulting in significantly reduced data storage limitations at the same time.

Just how these processes work are largely proprietary but in general the idea is that if a pixel is in the wrong position as a result of pincushion distortion for example then a relatively simple algorithm can relocate it to where it should be. The same can be said when the chromatic errors for different colours (basically only 3 to consider) can all be aligned and put where they should be. Any effects due to such relocations can also be addressed via pixel interpolation to smooth out the effects of such changes. Interpolation requires some arithmetic between pixels and that is commonly done using established mathematics around “cubic splines” a quite old method for smoothing values. It is not a coincidence that Buchdahl et al simplified their mathematics to the 3rd order – which is the same polynomial form as used in cubic splines. And if you want to emulate a particular film type, or account for incident illumination errors, then that can also be accomplished by more software. Ultimately, the better the software – the better the image, which is exactly what we are seeing in the latest cameras – and even the low-cost devices that are in most if not all of the phones that we carry with us.

Analysis vs Design

A simple single element lens has drawbacks that are well understood. Key amongst them is what is known as Dispersion – simply the dependence of Refractive Index on the illumination wavelength and correspondingly the effect on Snell’s Law. We see that practically in light through prisms and rainbows – very useful if you want to make things artistically pretty or design a refractometer – but a nuisance if you are designing a lens. Inventors have exploited the ability of glass to have high and low refractive indices and different dispersions depending on the chemical makeup of the glass to produce useful designs – probably dating from the middle of the 18th Century when the first Achromats were made for telescopes. By mid-19th Century techniques for minimizing Astigmatism were also understood by a couple of individuals, and progressively more and more problems were addressed with some quite innovative approaches – often involving the “invention” of new types of glass. In fact, look at the specification for any modern lens and you will see that each element has a high specification on the glass to be used. Readers will be aware of the use of “radio-active glass” as a result of the adoption of some rare-earth elements to create glass with high RI and/or controlled dispersion. These issues however are likely to be the common reason for changing designs.

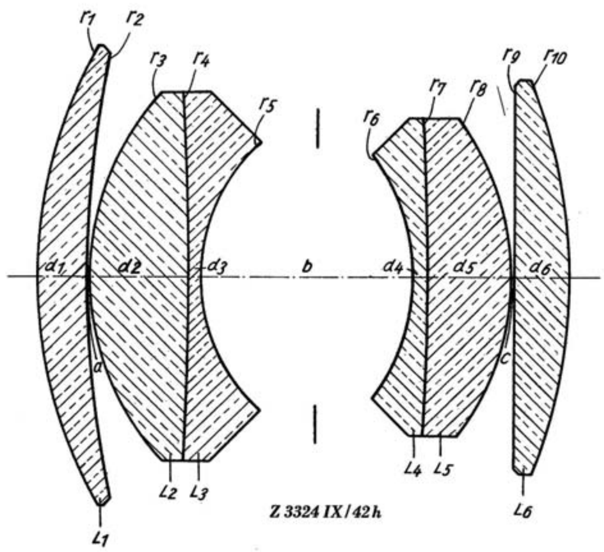
Technical note: A measure of dispersion is known by its “Abbe Number” and an inspection of the chart of dispersion against refractive index shows that there is a level of control achieved by changing the type of glass. Thus a high level of control allows at least two wavelengths – say blue and red – to be cancelled by the appropriate choice of glass chemistry. Add more elements and more control of dispersion is possible – hence Apochromats – essential when producing colour separations in the printing industry, or simply reducing fringing in a photograph. When the image plane is not exactly flat the whole issue becomes barely manageable as fringing can also occur due to defocusing. In a curiosity, lenses made using mirrors only are free of any dispersion effects as all reflections are specular and independent of wavelength. Aperture-based diffraction is another issue entirely - see the discussion at the end of this article.



Graph of refractive index against dispersion (Abbe Number) for a range of glass types – it is notable that this graph was produced in 1937 indicating the level of understanding in the subject at that time – the indications in RED are for various glass types (Crown Glass and Flint Glass shown as curves)

Zeiss Oberkochen Planar 2/50 mm
Berger/Lange 1953

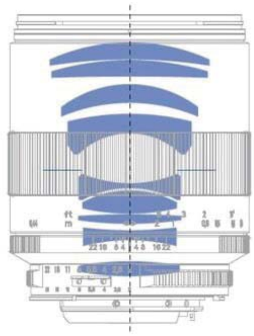
Linsen	Radien	Dicken und Abstände	n_d	ν		$\frac{\Delta n}{r}$
L_1	$r_1 = +0{,}612136 \cdot f$					$+1{,}128834/f$
		$d_1 = 0{,}06488 \cdot f$	1,69100	54,8	LaK9	
	$r_2 = +1{,}410420 \cdot f$					$-0{,}489925/f$
		$a = 0{,}00191 \cdot f$				
L_2	$r_3 = +0{,}359409 \cdot f$					$+1{,}693920/f$
		$d_2 = 0{,}12918 \cdot f$	1,60881	58,9	SK3	
L_3	$r_4 = -4{,}271650 \cdot f$					$+0{,}009713/f$
		$d_3 = 0{,}01717 \cdot f$	1,56732	42,8	LF6	
	$r_5 = +0{,}235077 \cdot f$					$-2{,}413337/f$
		$b = 0{,}27858 \cdot f$				
L_4	$r_6 = -0{,}265683 \cdot f$					$-2{,}531965/f$
		$d_4 = 0{,}01908 \cdot f$	1,67270	32,2	SF5	
L_5	$r_7 = -3{,}542760 \cdot f$					$+0{,}001688/f$
		$d_5 = 0{,}11067 \cdot f$	1,66672	48,4	BaF11	
	$r_8 = -0{,}344239 \cdot f$					$+1{,}936794/f$
		$c = 0{,}00191 \cdot f$				
L_6	$r_9 = +12{,}390800 \cdot f$					$+0{,}055767/f$
		$d_6 = 0{,}07060 \cdot f$	1,69100	54,8	LaK9	
	$r_{10} = -0{,}691799 \cdot f$					$+0{,}998845/f$



This chart of the design of the Zeiss f:2/50mm lens realised in 1953 was apparently not used until the release of the Contarex Camera in 1959. It is notable for the use of TWO elements involving the synthetic Lanthanide Boron chemistry LaK9 with a very high refractive index – no wonder those lenses gained such a high reputation as it meant that the lens could be dispersion limited only by the maximum aperture.

Of course, manufacturing changes and improvements have had a lot to do with the emergence of the lenses that we have today, as have the ways that we use them.

Long ago you moved the whole lens to focus it, but even in the middle of the 19th Century it was a practice for some lenses (Petzvals) to move the position of the rear element by a tiny bit to get better performance at close distances. The idea of focusing with the front element only is common and some of the latest precision lenses (eg Zeiss 2/50 and 2/100 Makro-Planars) move two rear elements independently (as well as the main body) for close focusing – so if you put the whole lens on bellows and try and focus that way you are bound to get poor performance as the back elements are in the wrong position. That sort of adjustment to the geometry certainly improves design but poses major issues when computation is attempted.



Brennweite/Focal length	100 mm
Blendenbereich/Aperture range	f/2 – f/22
Linsen / Gruppen/Lens elements / Groups	9/8
Fokussierbereich/Focusing range	0,44 m (17.32") – ∞
Arbeitsabstand/Free working distance	0,25 m (9.84") – ∞
Bildfeld*/Angular field* (diag. / horiz. / vert.)	25° / 21° / 14°
Bildkreisdurchmesser/Diameter of image field	43 mm (1.69")
Anlagemaß/Flange focal distance	ZF, ZF.2: 46,50 mm (1.83") ZE: 44,00 mm (1.73")
Objektfeld bei Naheinstellung* Coverage at close range (MOD)*	48 x 72 mm (1.89 x 2.83")
Abbildungsmaßstab bei Naheinstellung Image ratio at MOD	1:2
Filterdurchmesser/Filter thread	M67 x 0.75
Lage der Eintrittspupille (vor der Bildebene) Entrance pupil position (in front of image plane)	65,4 mm (2.57")
Drehwinkel des Fokussierrings (inf – MOD) Rotation angle of focusing ring (inf – MOD)	349°
Durchmesser max./Diameter max.	ZF, ZF.2, ZE: 76 mm (2.99")
Durchmesser des Fokussierrings Diameter of focusing ring	ZF, ZF.2, ZE: 76 mm (2.99")
Länge (ohne Objektivdeckel)/Length (without lens caps)	ZF, ZF.2: 89 mm (3.50") ZE: 91 mm (3.58")
Länge (mit Objektivdeckeln)/Length (with lens caps)	ZF, ZF.2: 113 mm (4.45") ZE: 115 mm (4.53")
Gewicht/Weight	ZF, ZF.2: 660 g (1.46 lbs) ZE: 680 g (1.50 lbs)

* bezugnehmend auf das 24x36mm Format/referring to 36 mm format

Outline and details of the Zeiss f:2/100 Makro-Planar featuring TWO floating rear elements that effectively produce zero chromatic and spherical aberration over a wide range of object distances – again there is extensive use of modern synthetic glasses

Considering the complexity of analysing a given lens, the idea of building a computer to "design a new lens" does not seem very realistic, and the "classical approach" to play with what exists seems more logical – hence Dr Rudolph's Tessar which came about by "putting the front group of a Protar and the back group of a Unar together" was a stroke of genius as it turned out. The continued development of the Tessar has very recently come to light as developments between the two World Wars is now emerging, and dozens of variants emerged. Even in today's super lenses, there are clear examples of surrounding an established double anastigmat with a bunch of correcting elements, field elements, collimators etc to achieve the desired result. New glass types and aspherics have certainly played a part, but the idea of arriving at those designs by some sort of computer program does not seem very likely.

However there is little doubt that a lot of computation was necessary to justify the expense of experimentation and to highlight the advantages of t he newer designs.

The Future – Perfect lenses and beyond

Lenses exist today that are near enough to perfect at high resolutions, but subject to some spectral limitations and of course the limitations that come with aperture, and maybe you have to be on some sort of a priority list to have access to them. There are still compromises and if you want resolution at 60,000Mpixel then you are restricted to a monochromatic wavelength that can only be achieved with very special lasers and filters, and have financial resources up in the tens of millions of dollars – those lenses being used for photolithography in the electronic integrated circuit industry. But if you want a perfect standard lens then it will be an f:2/50mm Macro-Planar and will only cost you a couple of thousand dollars – and maybe not look for anything finer than about 400Mpixel.

But this level of development means that I can take a photograph with my S24-Ultra mobile phone that has better resolution than I could achieve with a Linhof 5x4 with the best lens available 50 years ago, and we can only guess what military systems are resolving today.

But another technique is emerging that promises exceptional results for some imaging. It spans several disciplines controlled by what you can do with a computer, the mathematics of orthogonal arithmetic, and a fundamental law of optics that essentially says that the achievable resolution of an optical system is a function of the diameter of the optical system. For a real lens it is well known that provided the design of the lens is "perfect" then the best resolution is when it is wide open. Thus it is that those lithographic lenses have apertures like f:0.5, and rely on mirrors as much as lenses – but they are monochromatic and that concept apparently does not extend to wider bandwidths. But consider a "virtual lens" which consists of a couple of lens/sensor combinations that are a metre apart. In that case – assuming that we can combine the images – will have the effective aperture of a metre, and is able to create an image that is much finer than your f2/50 Macro-Planar by itself. I leave the details of the software to others. But take it a step further and consider the James Webb Telescope as it travels around the Sun and in that case images taken 6 months apart of a distant galaxy will be on an aperture base of twice the orbit of the earth around the Sun – ie 300 Million km – with an exceptional resolution. Put a telescope with that technology on Mars and the base becomes 440 Million km. The resulting resolution implies that we will one day be able to photograph the details on a planet that is travelling around a distant star.

That technology has already been achieved in a mobile phone with the sensors being in a ring of 7 elements with the diameter being the width of the phone, not very satisfactorily by all reports but the idea works. Reading about this today is easily confused with the idea of taking multiple images with a matrix of centres and compiling them to create an overall image with much higher resolution. That idea is already common-place and there are plenty of examples. Maybe we have to wait for the technology being employed in the JWT to make its way into our phones! But the idea does conjure the idea of lens-less cameras.

Further Reading

This article is of necessity a very brief overview of the history of optical calculations associated with systems of lenses. There are many publications on the subject but most of the general interest books on optical design only deal with things in a qualitative sense that does not require much computation. Books released as part of manufacturer's promotions are often written by marketing people rather than technical people and many of those "explanations" are a long way short of reality.

For example there was a revolutionary change to the design of the Zeiss Tessar that was used on the Rolleiflex-T in about 1960. The Rolleiflex marketing blurb only stated that the lens had undergone a "new calculation" but reality was that the Zeiss factory had completely redesigned it adopting Lanthanide glass for one of the elements. The same happened for the original f:3.5/40mm Tessar used in the German version of the Rollei 35 – explaining why that little camera did such a good job – Lanthanide glass again.

It is actually quite hard to discover books and references that enlarge on the principles that are included in this paper as most of that work has been close to research areas in tertiary institutions and in the back rooms of the manufacturers. However books on the manufacture of glass for example are readily available, along with books on manufacturing issues, coatings, grinding and polishing, and all those things that ultimately are needed to create a good lens.

Libraries and national information repositories should have copies of the fundamental work by Buchdahl:

Buchdahl H A (1948): J. Opt. Soc. Amer, 38, 14

Buchdahl H A (1954): "Optical Aberration Coefficients" (Oxford University Press) – (reprint 1968 Dover)

The latter book by Buchdahl is readily available secondhand as the Dover reprint, and includes the 1948 material.

The two monographs mentioned from the University of Tasmania do not show up in internet searches and may only be available from private collections. Similarly the student notes that were published around 1961 were only distributed to registered students.

The special case of telescope optics that is restricted to fields of view of around 1 degree does get attention in books on astronomical instruments but is nearly always limited to discussions around Achromatic Doublets used in refracting telescopes – the form of main objectives that have been the standard for the last 250 years. Similarly the discussions and computations around reflecting telescopes are almost all concerning parabolic reflectors – and they have been the standard for a much longer time, and indeed are still the technique used in monsters like the JWT. However the eyepieces used in telescopes have much wider pencil angles and calculations are just as involved as those we might like to use for camera objectives. Another area of interest is that of microscopy but most if not all written material is from the proprietors of those instruments.

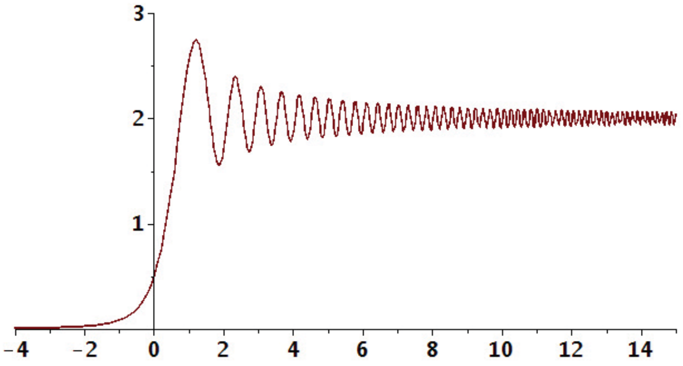
Even relatively simple lenses from the last two centuries are complex - and today it is not unusual to find lenses with a dozen or more elements. Sometimes even the idea of calculating what happens in a lens is not useful, but the knowledge of the calculation process does help explain why lenses are so complex. The literature is rich with books outlining the history and complexity of the lenses that the various manufacturers use.

Several manufacturers have published books highlighting their products and they make interesting reading. A massive resource is the Lens Vade Mecum that was written by Wilkinson and Glanfield in the very late 1900s with updates as late as 2001. Only a few copies were ever printed but it has been digitised and is now available as an on-line download of around a thousand pages - but without the illustrations. A full version assembled around 2003 can be purchased from on-line sources in 20 files containing something close to 2.000 pages. In reading any of these books, a lot of the detail has been derived from research and there are plenty of examples where the identification of a given lens is questionable or is simply wrong from later research.

Relatively brief books on the subject have been published by Focal Press with qualitative details on most important lenses but little detail on the manufacturers concerned and almost no detail on design history.

Addendum – Aperture diffraction

A resolution limitation that is not included in traditional computation methods is the diffraction that arises from the aperture of the lens system, but this can be calculated. In the case of a well designed and manufactured lens this source will dominate at all apertures, but in a lesser lens is only evident at smaller apertures. The effect is easily outlined starting from the wave diffraction at an edge shown in the following diagram.



Diffraction at an edge due to the electromagnetic nature of light. The actual curves depend on wavelength and for white light will be somewhat diffuse.

The diffraction also depends on the source and image distances and special names have been used for two classes – Fresnel and Fraunhofer diffraction. When this construction (sometimes called a "Cornu Spiral") is extended to a circular aperture then the resulting field in the image plane becomes a traditional Fresnel Disk which has a diameter that increases as the aperture reduces.

The resulting patterns limit the resolution that can be achieved with a lens of a given diameter - the lager the diameter the better the resolution but working against that , the larger the diameter then more likely that there will be aberration issues that cause the image to deteriorate. Further, the larger the diameter the smaller the depth of field. It turns out that these issues (diffraction, depth-of-field, and aberrations) all interact in the lenses that we use in our cameras. Even the very best lenses tend to be less than perfect when they are wide open and a typical photographer will stop it down to get the best images, achieving a good depth of field at the same time.

A resolution limit can be found for two point sources in the object field that are brought close together and the absolute resolution limit is achieved when the first maximum in the Fresnel field from one point coincides with the first minimum from the second point.

A "perfect" or "near perfect" lens may be said to be "diffraction limited" and this does not actually vary with the design of the lens with one very special exception. It can be shown that the limiting condition is given by:

$\theta = 1.22\ \lambda/d$

Where:

"θ" is the subtended angle in the image plane of the two points – a measure of the resolution limit.

"λ" is the wavelength of the light, and

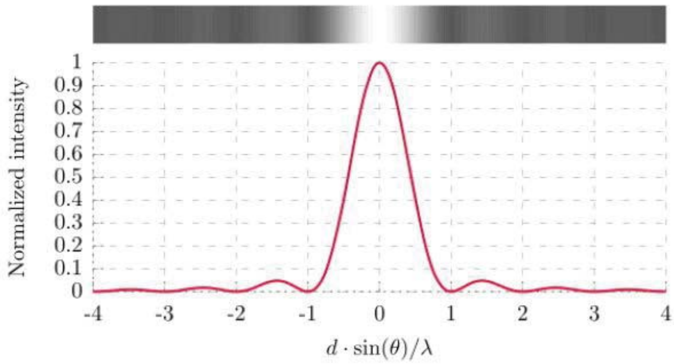
"d" is the diameter of the aperture.

(Remember to keep the measurement units the same.)

This condition is historically known as the "Rayleigh Criterion", and is commonly known as the "Diffraction limit" for an otherwise perfect lens system.

The excception to this rule can occur with certain mirror systems employing advanced aspherics, and an effective diameter can exceed the physical diameter - probably only in the field of advanced astronomy. It may also only be relevant to monochromatic observations.

However for a real lens trying to resolve a point of light - like a star for example - the reality of its diameter creates an image intensity pattern shown below - which is viewed as a slightly fuzzy point surrounded by rapidly decreasing rings. As this is wavelength dependent it only shows up clearly with monochromatic light - but white light results in just the central fuzziness.



Plot of the diffraction of a point source as a result of a lens with a given diameter.

For most photographic lenses designed for advanced amateur or for professional use, the maximum performance that is diffraction limited is achieved at around f:1.8 to f:2 but when the same generic design is extended to f:1.4 diffraction limitation cannot be achieved and other aberration limits apply.

A cute example is to consider a distant car's headlights that are a metre apart and to calculate how far from the car they can be observed as two lights by a human. If the viewer has "perfect eyes" then the distance deterimined by considering two of those point source diffractions plots on top of each other but separated by the value of "d" is about a kilometer.

Thornton-Pickard - the tale of a display

What started out as a request for the loan of a camera for a display in the Victorian Police Museum turned into a story about a common camera but with a few twists along the way that suggests that what appears in catalogues may be a bit different from what was available at the time. In this case a bit of research also shed some light on how cameras were used in Law Enforcement.

Thornton-Pickard

It would be a very rare camera collector that had not heard of a Thornton-Pickard camera – one of the most popular serious cameras at the beginning of the 20th Century in the British Commonwealth. At least one of those attractive cameras will be in many collections. There were many models but with so many parts being shared between them, mix and match became common, sometimes creating a "special version" that was not strictly made by the firm. This article looks at what seems to be one of them.

But before that story, the history of Thornton-Pickard itself. Probably the best read is "The Thornton-Pickard Story" by Douglas Rendell, published in 1992. This is available as a PDF on-line. The following is a brief summary relevant to the manufacture of cameras bearing the name. John Edward Thornton (1865-1940) came up with ideas for a roller blind shutter and even a camera while he was an apprentice to a printing company, and in 1886 went out on his own to sell cameras that were made by others. Within a year he was making new items at a company he established in partnership with a business manager, Edgar Pickard (1862-1897) – the "Thornton Manufacturing Company" and had even exhibited some at the Royal Jubilee Exhibition. As was common, he secured his trading future with a dozen patents from the beginning.

The manufacturing company started in Manchester but moved to their long-term home in Altrincham in 1891. They made shutters throughout that period but also released several cameras – focusing on the well-known premium "Ruby" and an economy "Amber". These were available in sizes from quarter plate to whole plate and were essentially compactable field cameras in Mahogany wood and brass supported by a range of lenses and double dark slides. Important features that made them popular were that they were priced in the middle to upper brackets – and they worked well. Those roller-blind shutters were highly popular as they could be fitted to many cameras as well as the Ruby etc.

The relationship between the inventor-engineer Thornton and the business manager Pickard family was reported to be tumultuous and that is evident in the large number of models that were produced – often with only minor variations. In 1898, Thornton left the company and George Pickard remained managing the company until his death (1919) when Arthur Gray Pickard took over, surviving the post-WW1 and depression decline until 1939, although a repair company existed for another couple of decades. (After leaving the group, J E Thornton went into business in the film design and manufacture business and after moving to America in 1913 he patented a 3-colour cine-film process which was manufactured by Kodak under license. Eventually Thornton would hold a huge number of patents. He died in England in 1940.)

The Thornton-Pickard name exists on nearly 60 distinct models over the 50 or so years of the company name, but it seems that there were variants that are not included in that number. In Australia for example, Thornton-Pickard was apparently represented officially by Harringtons in Australia and New Zealand, but surviving examples show that some Thornton-Pickard cameras are found with name plates by Baker and Rouse in Sydney. It seems that other outlets existed as well. For collectors here, that leads to difficulties in identifying some of those cameras. Although the Thornton Pickard business ceased in 1939 there are personal recollections that new cameras were still in stock and being sold as late as the early 1960s, although just what models were involved has been lost in time. And there is a further issue: The Thornton-Pickard name appeared on nearly all of the shutters and many of those were used on similar cameras from other manufacturers – leading to mis-identification.

The Thornton-Pickard Imperial Triple Extension Stereo Whole Plate Camera

A year ago, there was a call from the Victorian Police Museum to see if the APCS could find a special camera that would have been used for taking photographs in police work in the early 20th Century. It was needed for a display from that era. There had been a similar request from the New South Wales Police some years ago, which was apparently satisfied when they found an Eastman Camera that fitted the bill, and in that case there was evidence that NSW had used Eastman cameras. The Victorian request was a bit different. They had identified that they wanted "Carte de Visite" format images and they believed that the equipment was likely to be more like the multiple lens systems that they believed were used in the USA based on possibly erroneous search results on the Internet. Inspection of surviving images suggest that the camera was more likely to be a stereo camera – initially thought to be based on the British half plate format.

A request within the APCS for the loan of a stereo half-plate Ruby or the like did not uncover a candidate but a casual conversation with a member revealed that he had a Thornton-Pickard Imperial with a wide front that should be able to be added to an available shutter that had no body – found in a local collection. When they were brought together the shutter was found to match the camera exactly, and the interface panel on the back of the shutter was found to have a Thornton-Pickard serial number on it – suggesting – maybe fancifully – that this shutter was originally on this camera, maybe put together by Thornton-Pickard or an agent. That possibility was heightened a bit later when it was observed that another detail on that "mating" was different from other examples.

But there was a major oddity – the Thornton-Pickard Imperial was a Triple Extension version – clearly marked on the common white inset disk on the camera, but it was a full-plate camera – not listed as a stereo option in the catalogues of the era or in more recent identification lists. There were other features too that made this a bit different and maybe the result of experimentation at the manufacturing stage – in particular the clips that hold the back in place and a curious device that allowed a small amount of movement of the back – again different from other versions of that adjustment. The base of the camera carries a serial number – 389-C – using stamps that are quite different from other cameras. This is not an early camera as it has many of the features of the "Improved Imperial" first advertised in 1907, but might have been experimental leading up to that. But we also have to note difficulties in dating these cameras accurately – see the later comments.

An unusual swing back adjustment on the candidate full plate camera.

The fabricated half-plate back based on an Eastman back from around 1905 that was fitted to the candidate full plate camera.

And there was another odd matter. The body of the camera came with an alternative back converting it to a half plate format using the back from what we presume was one of the early Eastman Cameras – a "spring-back" that takes standard DD plate holders made by Eastman for 5x7inch and half-plate formats. This is almost certainly a later addition as TP would have used their half-plate holders that are quite different if this was a factory modification.

Police Photography

The photographic needs in the Police world included a couple of details – they wanted face-on and profile images of inmates, they wanted to keep them together and there was a matter of confirming that the images were of a particular person. They eventually solved that by putting the two images on the same plate using a stereo camera arrangement, but with a portrait format rather than the common stereo square pair – with those portrait dimensions being more typical of "Carte-de-Visite" as the Victorian Police Museum had identified. This can be done easily on a stereo camera by capping one lens at a time. Some photos were "signe" using a stylus on the exposed plate, usually along an edge, mechanically exposing the plate which then appeared as white writing on the reversal. Kodak used that signing idea on their "Autographic" cameras – via a panel on the back of the camera through the roll-film paper backing. Assuming that this Thornton-Pickard was used for Police work, further issues are lost in time – but it all seems logical, and the final arrangement satisfied those running the display. Police work was not restricted to "mug-shots" and a lot of general photography was done as well – often maintaining the Carte-de-Visite format.

A fairly typical mug-shot showing face and profile photos on the same plate (USA example) along with identification in white which would have resulted from scribed characters on the undeveloped negative.

Among the many models of cameras bearing the company name, logic is hard to find and some names probably had more to do with marketing than design. A full analysis could take a lot of research and it could be hard to work out what was in the minds of those who determined what would be made and sold. Details based on advertising often have to be based on the British Journal Photographic Almanac – an annual publication with a very extensive advertising section – and in the most relevant period around 1907, there were 35-40 pages of Thornton-Pickard advertising with some pages marked "new" in 1906 still being marked that way in 1909. This poses a fairly major problem in dating Thornton-Pickard models as the same advertising pages were used time and time again over sometimes a long period. For example, the "Imperial Triple Extension" is stated in one web reference as being introduced in 1913, but it is clearly listed as such in the Catalogue for 1907 as an improved version, so presumably it existed without such improvements prior to that! The web-reference "Collectiblend" suggests ~1904 as the earliest date.

One of the most celebrated Victorian photographs - that of Edward (Ned) Kelly - in this case with identification on the left hand side. This is of a young Ned so some time before 1880.

But dating the various models based on advertising is not quite so simple as looking for the first time or period that a model appears. Many of the descriptions need to be interpreted. For example, what we mean by "movements" today may not be quite what was meant back then. But after looking at the illustrations for interpretation we discover that not all is well there either. Typical of most of the Thornton-Pickard advertising, page 235 of the BJA for 1907 clearly shows a Royal Ruby Triple Extension by description but the illustration is a drawing and not a photograph, and anyone familiar with the form of the front shutters can see that what is there is an artist's impression – quite wrong in a couple of details, and it simply was not made in that arrangement of control etc. This example is maybe typical of a lot of advertising back then when it seems to be been common or acceptable to advertise emerging features under the belief that product would be produced later, or maybe when orders started coming in.

Across most of the product categories, the name "Ruby" was reserved for premium models, and included the "Ruby" and "Royal Ruby" both being field cameras from quarter plate to whole plate, but also lots of totally unrelated cameras – "Ruby roll film" that used standard 120 roll-film, "Ruby Bijou", "Ruby Reflex" (both of which were quarter-plate reflex cameras), "Ruby Speed" which took 4.5 x 6cm plates and included an f2 Taylor Hobson Cooke Anastigmat lens, and "Ruby Focal" a small strut-type 1930s camera.

And there were a lot of field cameras that looked like the original Ruby. The "Amber", "College", "Crown Stereo", "Patent Tourist", "Praetor", "Royal Favourite", "Tribune" and of course the "Imperial" and its variants were all very similar, often with differences that are hard to understand. In the early days there was a "Royal Ruby Triple Stereo" a half plate camera that looked very much like the "Imperial Triple Expansion Stereo" detailed above but on a smaller scale. This raises a question around why the "Imperial" was introduced – it was a bit cheaper than the Ruby, and in some ways was more desirable. Indeed the "Imperial Perfecta" (1907) was promoted as a new direction with new features that probably made it more useful than the premium "Ruby". A few were only in a restricted range of sizes, eg the "Tribune" was only available in quarter-plate, and some had a restricted range of lenses. All had the same shutter design, but there were a couple with back as well as front shutters. In some cases, there was a marketing play so the "Guinea model" of course had to be priced at 21 shillings. So was it named to the price or priced to match the name?

The triple extension is commonly pictured in the extended form - 600mm ie 3 times the length of the base. This view is in the extreme wide angle position. Adjusting those struts takes a bit of care.

Analysis suggests that some variations in pricing possibly had to do with what lenses were fitted, with some of the lens options being available only on the top model. Lenses were made by other people including Beck, Dallmeyer, Ross, Aldis, Ross (their own and under licence from Zeiss), Goerz, and as mentioned above, Taylor Hobson. Volumes were so high that some lenses were marked "Thornton-Pickard Beck" for example. The advertisements in the BJA for 1909 and some later issues list a few lenses as being made by Thornton-Pickard, but in the wonderful volumes on lens makers – the Vade Mecum by Wilkinson and Glanfield – they state that it is most unlikely that they ever made lenses, and suggest the alternative that they simply sourced lenses from others or the common practice of getting un-named lenses from France and adding their own name. They also observe that there were differences between lenses of the same name, possibly the result of sourcing from different manufacturers. A clue to the price variations between camera models with the "same" lenses is also provided in the Vade Mecum – simply that premium lenses were provided with a Ruby compared with a lesser grade in the Amber. That immediately waves a warning flag when looking at lenses that are not with their original cameras – one would have to test lenses to determine their actual performance. It is also notable that for an additional cost, some lenses could be tested and verified by Greenwich – implying that some selection might have been made with the additional cost for even better examples.

Of course, with so many parts being common to a lot of these cameras, a modern restoration could quite easily assemble a camera that Thornton-Pickard did not actually make and market! Cameras do turn up with the identification disk missing – maybe a swap was done to make a lesser camera look like a "Ruby" – there is a rather rough Ruby in this writer's collection that is missing its identification label!

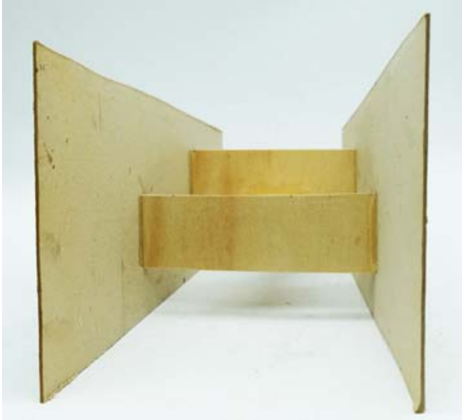
Thornton-Pickard did not just stick to the cameras and shutters that we see most commonly today. Typical of a lot of the British industry, special efforts were made when items were needed for the war efforts and the firm was there for both WW1 and the leadup to WW2, although the latter was during the decline of the firm.

From a collectable point of view the Thornton Pickard name covers a wide range of desirability and hence prices – from a few dollars for a 1911 "Weenie" up to maybe $10,000 for a WW1 Aerial camera, "Hythe" gun camera or that "Ruby Speed". However very attractive and relatively common "Ruby" or "Imperial" cameras – particularly half plate models – can be found for typically $250 to $500 depending on the lens and condition, and if the shutter is not working then you can see how to restore it in the article in Back Focus No 119.

The Display Camera

The camera that would eventually be part of the Victorian Police Museum display needed a level of restoration. It needed to be cleaned, a couple of the geared racks needed to be removed and straightened, and a couple of missing bits needed to be salvaged from donor cameras. Thornton-Pickard shared items amongst many cameras so bits could come from anywhere. Remarkably, the shutter only required cosmetic work as the blinds were quite supple. Now this is a Triple Extension model and the bellows are about two feet long when extended. So in the standard position only extended by a few inches, the bellows would sag – and that goes for most bellows cameras if stored or displayed open. This camera was going to be open for a year or more, so an internal supporting frame was assembled from stiff card and a couple of bits of thin 3-ply to ensure that permanent damage was not done.

It is fairly evident that the camera has been modified as it does not fit with any catalogue description exactly, and it is more than likely that some of those modifications make it look like a camera that was made rather later in the history of Thornton-Pickard. Details that confuse the issue include the inversion of the plate holding the shutter and lens assembly – it is certainly inverted compared with advertising photographs, but a locating notch on the shutter only works when the mounting plate is inverted. Clips on the top that hold the back in place are not original and while they seem to be Thornton-Pickard parts that might date from around 1910, the top also has screw-holes that would match much earlier clips prior to 1907. All those cameras included a rotating base and there were many variations. But for some reason the rotating base on this example had been replaced by a more solid non-rotating arrangement that was definitely not made by Thornton-Pickard.



The 3-ply support for the bellows in the display camera to avoid the otherwise inevitable sag over the year that it was to be on display.

For the display a new tripod head was fabricated and attached in a way that does not mark the unit which will suffice until a donor camera is found with a serviceable base. The original full plate ground glass was still intact, so in order to minimise the risk of damage, a back from a full plate Ruby donor was fitted with the ground glass replaced by a suitably sized ply sheet. Another measure to reduce risk was to remove and store the shutter release cable which was special to Thornton-Pickard shutters on one end and embossed "Watson Bowdon – ANTINOUS – patent" on the press button – almost certainly an early one – the patent was 1896 but they were used in that form for quite a while. At 24 inches long, this example is double the usual length, and being in perfect condition is worth keeping that way. There must be another story about the Watson-Bowden cable as there was a significant Law Case about it in 1904 that ran for about a week with many seeking to modify or overturn the patent of 1894. This cable release differs from modern units as the outer moves and the inner is fixed, rather than the other way around on the modern cable release – which also has a simple straight or tapered thread on the camera end. In describing those cables, the name Watson has been lost in time and they are now known as "Bowden Cables". The patent of course has long since expired.

The Thornton Pickard Imperial full plate camera in a stereo configuration provided by this writer for the Cardomania display of historic photographic techniques and images at the Victorian Police Museum in Melbourne.

(Photograph - Victorian Police Museum)

Lens Serial Numbers - Clues to Identification

Maybe starting with the industrial revolution, many manufacturers put sequential numbers on what they made, but a century later as the volume of product went up, those numbers went up to astronomical levels and new companies arrived at differing approaches to identifying what they made. This article attempts to unravel some of the mystery around the numbers and markings on camera lenses and even cameras.

For at least a couple of hundred years it has been the practice to put serial numbers on manufactured devices. For collectors of photographic equipment, the fact that those numbers do exist is extremely helpful in organising what they have and in a great many cases identifying exactly what is in their hands. The older lens makers – Voigtlander, Dallmeyer, Zeiss etc started counting from a low number – maybe 101 or 1001 – and kept counting with the result today that current production has maybe 8 digits for those companies still in business, and in many cases in-house records hold more information about the items. But if you only have a number there are a couple of issues:

- The numbers do not identify what the item is and when it was made unless there is a cross-reference.
- Manufacturers with multiple product and build sources seem unable to retain a unified sequential system.

Thus a multiplicity of approaches has emerged often based on what was logical when that decision was adopted with the obvious result that the adopted recording methods were based on the available tools – manual recording – computerised recording etc. Once a company chooses a method, it appears to stick with it – one of the "features" of legacy systems.

Considering only photographic lenses, what are the key details that identify the item?

- What the item is (speed, focal length and what camera it fits).
- When it was made.
- A unique number in that product identity.

Some of that information is almost always printed on the item or is evident from what the interface connection is. Thus Leitz will print data on a lens – "50mm f:2 Summicron Canada" and by inspection it may have a M-bayonet to connect to the camera. But you need a related database AND a serial number to find out any more and some of that information may be proprietary to the company and not available to collectors. But a maker that evolved in the computer world might put a single product name on it – thus Fuji might only put "Fujinon XF 35mm f:2" on the lens and a number that is hard to find, and you might have to take a photo with the lens on a digital camera and check the EXIF data on the photo to discover the number which is written into the software inside the lens!

Sometimes the method (if that is what we call it!) is evolutionary and changes over the years. Further, different companies have adopted different systems and practices meaning that there is no single approach that can apply to all camera lenses. The current fount of all knowledge – the Internet – can help but for in-depth understanding of each manufacturer we have to rely on experts who sometimes have access to company records but sometimes have to "reverse engineer" the method from the surviving examples made over the years – linking them to advertising and general understanding of the industry. A parameter that keeps cropping up is that numbering systems also have been known to change depending on the country that the item was made for.

Some manufacturers have hidden codes inside the serial numbers that are printed on the items – sometimes as obvious as a letter code or number that identifies the year of manufacturer or the factory concerned.

Maybe 50 years ago little notice was taken of those numbers as they often seemed to be rather random but collectors in particular were starting to pull databases together and exposing patterns connecting serial numbers with the date of manufacture in particular. Then those patterns became definitive databases and were being handed around between collectors and some were even published in the various magazines that were printed at that time. In a few cases, manufacturers delved into their records and produced much more reliable supporting data. In many cases individuals made detailed studies of what they could find from anything from pictures of lenses to lists that they had compiled.

Then along came the internet and common platforms for people to bring their private number collections together. In a few cases, manufacturing databases had become lost as a result of destruction in war, or simply lost in the archives that were sitting in back rooms. Some collectors started assembling databases from "associated data' like matching lens numbers with particular cameras and when those cameras appeared in advertising. Once patterns started to emerge then a simple step was to estimate production numbers with time and use a bit of arithmetic to determine the age of a particular lens for example where only the serial number was known. Sometimes those methods failed when it emerged that some manufactures did not have a progressive numbering system in place, or number ranges started with different lenses or cameras.

Today there are lots of manufacturers who responded to the huge demand for cameras during the last Century, and to understand their "systems" a collector needs to discover who has done the research and published the results as printed books or as information on the internet. Early on, as data built, some lens manufacturers and their numbering systems became rather obvious and even definitive when actual stock books etc came to light. Most collectors of certain photographic products are well aware of data that is usually considered to be exact and reliable:

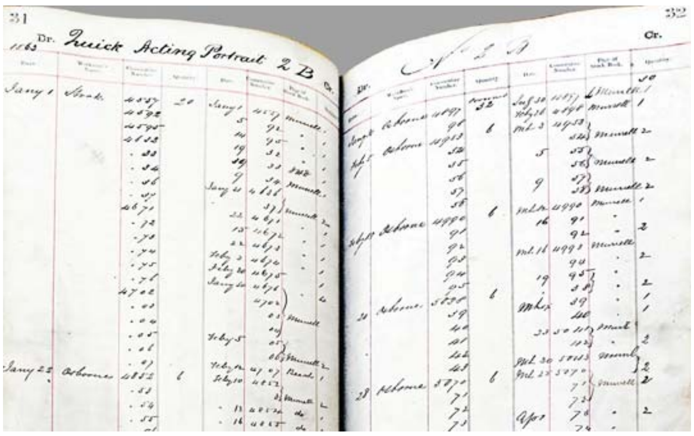
- The Leitz organisation established rigorous numbering for camera bodies and lenses.
- Dallmeyer kept exact records and details for lenses from the very beginning up to the early 20th Century – which became very useful as there are a lot of lenses on the market that are marked "Dallmeyer" but were fraudulently made by others, and the serial numbers help in identification.
- The Schneider Kreuznach organisation ran a single list even when lenses were made for other organisations.

- Carl Zeiss ran two main lens lists – Carl Zeiss Jena and after partition of Germany as a result of WW2, a second list from 1948 based on West production. However camera lists were by model, version, and date runs often supported by model numbers that were not necessarily numerical.
- A few manufacturers use date codes and conventions to identify manufacture. A couple of those are easy to understand and are well documented. For example, serial numbers are supported by codes like “VHPICTURES” (Hasselblad) and “CAMEROSITY” (Kodak) to keep some people guessing.

While most of those lists are fairly straight forward, there are some quirks when organisations like Zeiss were manufacturing in multiple countries and allowing others to manufacture under license – assigning ranges of numbers for those oddities. Sometimes the oddities are easy to negotiate but for some cases a bit of sleuthing is necessary to uncover reality.

A lot of people have put a lot of effort into unscrambling the numerical mysteries and you only have to go to the internet and search of for “MAKER lens serial number” and you will be presented with some sort of pattern – but there are MAKERS out there like Pentax for example where you will be presented with a statement like “there is not much sense around the numbers that Pentax used”, but find someone who has studied Pentax in details and a real structure does emerge, even if it is unique to Pentax.

On the other hand databases are emerging that go much further than just the serial number and the date that it was issued. Some of that data can be found on the internet but for some makers you need very substantial books to find what is available. There is a lot of serial number detail on very early lenses in the “Vade Mecum” by M. Wilkinson and C. Glanfield. That general reference on lenses and their makers is dated 2001 in its final edition but is now a major PDF document extending to 19 files, and was produced before some of the number range refinements emerged – so is approximate at best. More recent publications are probably more useful but in general each publication will be specific to a particular manufacturer.



A page (1863) from one of several volumes of manufacturing and stock data for Dallmeyer lenses covering from about 1860 to 1901 that can be seen on the internet. They do take some searching to discover all the detail that is available, but some knowledge of lens types will speed the process.

A relatively new writer/publisher in the last 20 years on the identification of cameras and lenses is Hartmut Thiele who has published an extraordinary 38 volumes covering just about every aspect of the German industry, and several of those have more than half a dozen updates. Some double up on the work of others but a few are the result of extensive research and a level of interpolation to fill in details that had been considered lost.

As well as summary books, the big names in the industry are present - Voigtlander, Leitz, Rodenstock, Steinheil, Angenieux, Kodak (Nagel), and a lot of camera makers are featured titles. A problem for those interested in these specialist subjects is that no sooner is a print run released but it is instantly sold-out and getting copies is a matter of luck, and in some cases a buyer may have to rely on secondary sources like eBay to find copies. And to add to the issue, all volumes are in German and the only “sellers” are German traders. In one case, a volume had been “out-of-print” for several years and suddenly became available with the printing of a new edition. A fortunate internet search found a copy which was purchased but a couple of days later the book was “out-of-print” again.

Leitz and Leica

There are many publications that cover the collectable era. But Leitz is a continuing organisation and the knowledge base has to be kept up to date. The list of database publishers is long but a new one has come to the attention of collectors. Erwin Puts is a prolific writer and self publisher of data on many manufacturers and his last edition (He died in 2021) is available on-line if you look for it – “Leica Compendium – Third edition” – goes into a lot of detail including the history of the Leitz lens development- some 610 pages of solid reading. However there is already indication that others are simplifying his book and adding new information as it emerges.

Hartmut Thiele also authored wrote a few volumes on the Leitz organisaion and its numbering system.

There is a special problem that arises with some lenses that are marked “Leitz” when the company resorted to other manufacturers. Some Leitz “Focotar” lenses were made by Schneider around 1970 (often called “LFE” versions [Large Front Element]) and if you check the serial number on them they can be identified as “Xenotar” enlarging lenses using the numbers on the lenses from the Schneider lists.

Voigtlander

One of the very first lens makers that survived was the 18th Century organisation Voigtlander and they had a simple sequential system that is well documented – a simple list that has been analysed into blocks by year of manufacture and interpolation will allow anyone interested to approximate the month as well.

Schneider-Kreuznach: Paul Ewins writes

There are 4 volumes by Hartmut Thiele, a three book set “Grosses Fabrokationsbuch Schneider Kreuznach” published in 2008 and 2009 (the latest edition of those was released in 2017) and a special 2020 book on lenses made for OEM camera manufacturers. The original 3-volume set covers the period from March 1918 through to March 1976 at both the old and new Kreuznach factories, but not the Gottingen factory as this was a separate enterprise.

It is arranged like a large paper based spreadsheet or database. Each row represents a completed batch, with the batch date, lens name, max aperture, focal length, number in batch, first number in batch, last number in batch, who it was made for (i.e. Schneider or OEM for the likes of Kodak, Rollei etc.), which camera or mount, and finally further remarks/ clarifications. It is sorted by the first number in the batch which is usually sequential by date as well, except for a period between 1929 and 1935 where one factory has one range of numbers continuing on from 241,996 and the other (presumably the new factory given the much larger batch sizes) starts afresh at 300,000.

Since this is the entire production record from that period it features not just camera lenses but enlarging and projection lenses, reproduction lenses, collimators, industrial lenses and some that are just plain mysteries. Amongst all of these are many marked “Muster” which roughly translates as sample or prototype. While many of these obviously went nowhere, sometimes with a careful investigation of subsequent production over the next year or two you can, for instance, find that a batch labelled Tele-Xenar probably became the Tele-Arton.

A deep dive unearths all sorts of oddities, like a 1000mm/f8 Tele-Xenar in July 1964 or a 460mm/f4.5 Aero-Xenotar in March 1964, that are intriguing but give no context. The most frustrating thing is that it is a very laborious and error prone task to search for lenses based on anything other than the serial number. I would happily pay the purchase price again for a searchable electronic version.

The front covers of the four volumes on the Schneider-Kreuznach lenses by Hartmut Thiele.

In 2020 a companion volume was released “Schneider-Optik fur Kameras” which features only those lenses made for cameras of OEM customers and is sorted by manufacturer, then camera type, then lens type, then serial number. This is a great help for anyone with an interest in one particular brand or even one particular camera. For example there are just two entries for the Rolleimagic, each for a batch of 25,000 lenses and then two entries for the Rolleimagic II, each of 12,140 lenses. Unfortunately a lot of the interesting early lenses weren’t necessarily identified by customer, so the Wallace-Heaton Zodellar appears in the earlier books as a Schneider Zodellar, and thus doesn’t feature in this book. This isn’t a criticism of the author as he has taken the approach of reproducing the data without interpreting it. I believe this to be the correct method as it reduces the errors to ones present in the source documents or errors of transcription which are probably unavoidable entirely in a project this size and leaves the reader free to make their own interpretations.

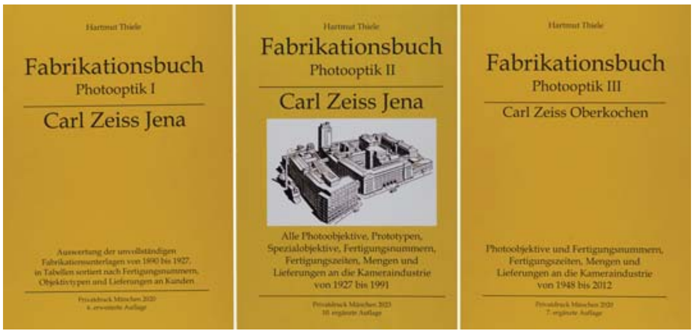
Carl Zeiss: Rod Reynolds writes

While simple charts of Zeiss serial number ranges and their relation to the estimated dates have been available for some time, a lot of that information was sparse and approximated at best and only a few lists went so far as to relate the lens types to the numbers. Very similar to the above books on the Schneider lenses, Hartmut Thiele undertook an entirely new approach gaining what information was available from East and West German Zeis records, and interpolating a lot more from varioous sources. Three books also entitled “Fabrikationsbuch” provide as good a list a can be achieved but as one of those is already up to the 9th edition, it is likely that there will be more as additional information comes to hand. Modern data is essentially complete and accurate but the actual data prior to WW2 suffered during that war and only some ranges are exact.

These three volumes cover the Jena period from 1890 to 1926, the West German numbering from 1948 to the present, and the Jena period from 1926 to 1991. Together those books cover all lenses with serial numbers along with specific details identifying the lenses and who they were made for. Again like the Schneider books, the data is presented as paper spread-sheets but is presented in several ways, by sequential numbers and by lens names. Some 25 Million lenses are listed in the three volumes. There are two basic sequences - Jena numbering started around 1890 while West Germany started after WW2. After German unification (1990) Zeiss unified a year later and following numbers carried on from the Jena sequence,

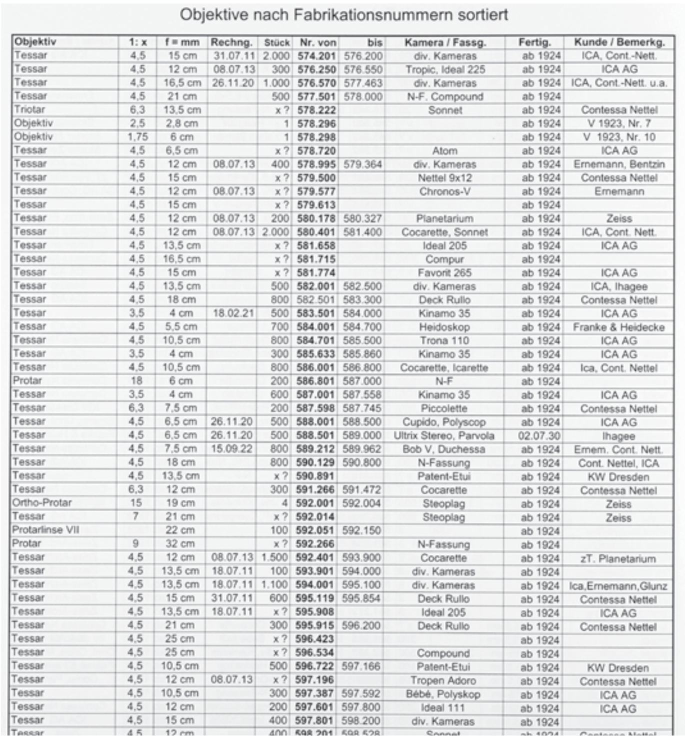
The combined Zeiss books amount to 750 pages – and it will help readers if they read German, although that is not essential as the numbers and headings are self-evident, although there is a lot of use of abbreviations that have explanations (in German!) at the back of each volume. Unfortunately these are not cheap and the combined price is up around A$200 plus postage from German book-sellers.

The Zeiss organisations ran their numbering across the whole lens lines so items from cameras, microscopes, and industrial products are all included in their number sequences. But there are issues that confuse things. Zeiss (East and West) set blocks of numbers for other organisations like Ross in the UK and Bausch and Lomb in the USA as well as Hasselblad where Zeiss lenses were made under license. The manufacturing dates in those cases are problematic and have been left undefined in these volumes. It is known that many of those dates overlap. Some lenses were made under license where the numbers make no sense at all - for example some Tessar lenses found on French stereo Verascope cameras by Jules Richard are the genuine article but have unaligned serial numbers.



The front covers of the three volumes on the Zeiss Jena and Oberkochen lenses by Hartmut Thiele, covering from the beginnings in 1890 to the most receent as new editions emerge.

When checking several industrial lenses in particular, their numbers were found to be in the middle of a batch of a totally differnt lens - so a single microscope lens (probably part of a batch) is in the middle of a big batch of common lenses used in cameras - eg 50mm Tessar. This calls into question the accuracy of the batch quantities and shows that a lot of the data is interpolated. This was particularly noted in production data prior to WW2, and in at least a couple of cases of uncommon lenses, raises the possibility that some numbers might have been duplicated.



Objektive nach Fabrikationsnummern sortiert

Objektiv	1: x	f = mm	Rechng.	Stück	Nr. von	bis	Kamera / Fassg.	Fertig.	Kunde / Bemerkg.
Tessar	4,5	15 cm	31.07.11	2.000	**574.201**	576.200	div. Kameras	ab 1924	ICA, Cont.-Nett.
Tessar	4,5	12 cm	08.07.13	300	**576.250**	576.550	Tropic, Ideal 225	ab 1924	ICA AG
Tessar	4,5	16,5 cm	26.11.20	1.000	**576.570**	577.463	div. Kameras	ab 1924	ICA, Cont.-Nett. u.a.
Tessar	4,5	21 cm		500	**577.501**	578.000	N-F. Compound	ab 1924	
Triotar	6,3	13,5 cm		x ?	**578.222**		Sonnet	ab 1924	Contessa Nettel
Objektiv	2,5	2,8 cm		1	**578.296**			ab 1924	V 1923, Nr. 7
Objektiv	1,75	6 cm		1	**578.298**			ab 1924	V 1923, Nr. 10
Tessar	4,5	6,5 cm		x ?	**578.720**		Atom	ab 1924	ICA AG
Tessar	4,5	12 cm	08.07.13	400	**578.995**	579.364	div. Kameras	ab 1924	Ernemann, Bentzin
Tessar	4,5	15 cm		x ?	**579.500**		Nettel 9x12	ab 1924	Contessa Nettel
Tessar	4,5	12 cm	08.07.13	x ?	**579.577**		Chronos-V	ab 1924	Ernemann
Tessar	4,5	15 cm		x ?	**579.613**			ab 1924	
Tessar	4,5	12 cm	08.07.13	200	**580.178**	580.327	Planetarium	ab 1924	Zeiss
Tessar	4,5	12 cm	08.07.13	2.000	**580.401**	581.400	Cocarette, Sonnet	ab 1924	ICA, Cont. Nett.
Tessar	4,5	13,5 cm		x ?	**581.658**		Ideal 205	ab 1924	ICA AG
Tessar	4,5	16,5 cm		x ?	**581.715**		Compur	ab 1924	
Tessar	4,5	15 cm		x ?	**581.774**		Favorit 265	ab 1924	ICA AG
Tessar	4,5	13,5 cm		500	**582.001**	582.500	div. Kameras	ab 1924	ICA, Ihagee
Tessar	4,5	18 cm		800	582.501	583.300	Deck Rullo	ab 1924	Contessa Nettel
Tessar	3,5	4 cm	18.02.21	500	**583.501**	584.000	Kinamo 35	ab 1924	ICA AG
Tessar	4,5	5,5 cm		700	**584.001**	584.700	Heidoskop	ab 1924	Franke & Heidecke
Tessar	4,5	10,5 cm		800	**584.701**	585.500	Trona 110	ab 1924	ICA AG
Tessar	3,5	4 cm		300	**585.633**	585.860	Kinamo 35	ab 1924	ICA AG
Tessar	4,5	10,5 cm		800	**586.001**	586.800	Cocarette, Icarette	ab 1924	Ica, Cont. Nettel
Protar	18	6 cm		200	**586.801**	587.000	N-F	ab 1924	
Tessar	3,5	4 cm		600	**587.001**	587.558	Kinamo 35	ab 1924	ICA AG
Tessar	6,3	7,5 cm		200	**587.598**	587.745	Piccolette	ab 1924	Contessa Nettel
Tessar	4,5	6,5 cm	26.11.20	500	**588.001**	588.500	Cupido, Polyscop	ab 1924	ICA AG
Tessar	4,5	6,5 cm	26.11.20	500	**588.501**	589.000	Ultrix Stereo, Parvola	02.07.30	Ihagee
Tessar	4,5	7,5 cm	15.09.22	800	**589.212**	589.962	Bob V, Duchessa	ab 1924	Ernem. Cont. Nett.
Tessar	4,5	18 cm		800	**590.129**	590.800	N-Fassung	ab 1924	Cont. Nettel, ICA
Tessar	4,5	13,5 cm		x ?	**590.891**		Patent-Etui	ab 1924	KW Dresden
Tessar	6,3	12 cm		300	**591.266**	591.472	Cocarette	ab 1924	Contessa Nettel
Ortho-Protar	15	19 cm		4	**592.001**	592.004	Steoplag	ab 1924	Zeiss
Tessar	7	21 cm		x ?	**592.014**		Steoplag	ab 1924	Zeiss
Protarlinse VII		22 cm		100	**592.051**	592.150		ab 1924	
Protar	9	32 cm		x ?	**592.266**		N-Fassung	ab 1924	
Tessar	4,5	12 cm	08.07.13	1.500	**592.401**	593.900	Cocarette	ab 1924	zT. Planetarium
Tessar	4,5	13,5 cm	18.07.11	100	**593.901**	594.000	div. Kameras	ab 1924	
Tessar	4,5	13,5 cm	18.07.11	1.100	**594.001**	595.100	div. Kameras	ab 1924	Ica,Ernemann,Glunz
Tessar	4,5	15 cm	31.07.11	600	**595.119**	595.854	Deck Rullo	ab 1924	Contessa Nettel
Tessar	4,5	13,5 cm	18.07.11	x ?	**595.908**		Ideal 205	ab 1924	ICA AG
Tessar	4,5	21 cm		300	**595.915**	596.200	Deck Rullo	ab 1924	Contessa Nettel
Tessar	4,5	25 cm		x ?	**596.423**			ab 1924	
Tessar	4,5	25 cm		x ?	**596.534**		Compound	ab 1924	
Tessar	4,5	10,5 cm		500	**596.722**	597.166	Patent-Etui	ab 1924	KW Dresden
Tessar	4,5	12 cm	08.07.13	x ?	**597.196**		Tropen Adoro	ab 1924	Contessa Nettel
Tessar	4,5	10,5 cm		300	**597.387**	597.592	Bébé, Polyskop	ab 1924	ICA AG
Tessar	4,5	12 cm		200	**597.601**	597.800	Ideal 111	ab 1924	ICA AG
Tessar	4,5	15 cm		400	**597.801**	598.200	div. Kameras	ab 1924	
Tessar	4,5	12 cm		400	**598.201**	598.528	Sonnet	ab 1924	Contessa Nettel

Part of a typical page from the early Zeiss Jena volume. This page is deductive as far as date is concerned - "ab 1924" simply implying "from 1924" - but in the middle there is an actual date where data was found from a user and in that case Ihagee. Most of these pages contain additional data like the camera that the lens was intended for, the customer where it was not Zeiss (if known) and the date of the order.

That issue has been noted previously in a different way - it has been long suspected that blocks of numbers were issued in the 1960s for exotic Contarex lenses which only existed as glass elements in storage which were assembled when orders were placed, and that some of those numbers did not get sold until years later - and in a mount that was specific to the Contax RTS caneras. Indeed some of those numbers may never have been used - but the whole range appears in these books. This can be misleading as while a block of say 20 lenses are shown, the actual number that were ever in circulation could be significantly less. But there can also be extras when prototypes were given obviously nul numbers - like "000001"

As in the case for Leitz lenses, some lenses are marked "Zeiss" or "Carl Zeiss" where numbers make no immediate sense at all. In the case of Zeiss, most if not all of the "Pantar" lenses used in the cheaper Contaflex and Contina cameras, and many of the lenses after WW2 marked "Anastigmat" and "Nova Anastigmat" are made by other lens makers like Rodenstock and those serial numbers belong to the lens maker and not Zeiss.

Japanese Lenses

Japanese manufacturers have adopted numbering systems that warrant individual attention and it is hard if not impossible to summarise them. Not only are the "systems" complex, there are significant variations over time and the various camera families. Each manufacturer warrants a full article on its own, and in some cases even group by group - for example the numbering system for rangefinder lenses might need a different treatment from that for SLR cameras, because of significant time difference in manufacture.

There are other oddities as well. Cosina and Yashica had their own lens families and later, both made lenses with Zeiss serial numbers on them. Today, many lenses are made "off-shore" in China etc and don't get their numbers until added by the parent company in Japan, and as in the case of Fuji mentioned earlier, the serial number is written into the firmware in the lens and you have to take a photo and look at the EXIF data to discover the details. We leave it to the specialists to describe how to make sense of most of those numbers.

However for many Japanese manufactures there is more to those serial numbers than just a "number" – they often contain codes that contain a lot of the information that collectors are looking for. When combined with other information that is printed on the lens, like its focal length and aperture and details that are also on the barrel or bezel, the date of manufacture, the factory where they were made, the quality of the item and even the country that they were made for can all be deduced. The actual sequential number of the lens is not as important when that other information is understood. The problem for collectors is discovering those codes and how to interpret them as the manufacturers have not been forthcoming in explaining them. But it also means that assumptions by researchers have not always been correct and as more information is gathered the "decoding" has to be updated – and in some cases corrected.

An example of one Japanese "system' is given in the next article by Peter Kitchingman on Canon Rangefinder lenses.

Canon range-finder lens numbers

Peter Kitchingman

Not all lens serial number systems are simple. APCS member Peter Kitchingman uncovers the complexity around the numbers that appear on range-finder lenses made for the Canon cameras.

Some years before I produced my "Canon Rangefinder M39 Lenses 1939-1971" book, one thing that had puzzled me for some time is the serial numbering system Canon uses with each new lens, which always seems to be a random number. After receiving a reply from a seller on eBay™ about a serial number on a lens he was selling, I finally decided to try to solve this mystery. The lens in question was a SERENAR 85mm f:2 lens (#59000), which is now in my collection.

All my data on the 85mm f:2 lenses pointed to a serial numbering sequence beginning with #50001. The lens was issued in February 1948, and I could find no possible reason why Canon chose to start the sequence with #50001. The next 85mm lens that Canon released was the SERENAR 85mm f/1.9 (issued in September 1951). The lowest serial number for this lens in my records was #59003 and I presumed that the 85mm f:1.9 would begin with #59001.

Based on the information at my disposal I devised an Excel datasheet starting with the earliest lens marked with "Seiki-Kogaku Serenar" (S-KS). Before I get into any further details, a little history with regards to S-KK and the lead-up to Canon's manufacturing its own lenses.

In 1935 S-KK started manufacturing its own cameras and N-KK began supplying the company with N-K marked finished optical lenses in metal tubes (barrels). S-KK then placed these tubes into lens mounts ready for mounting onto appropriate cameras.

Early in 1939, Seiki Kogaku purchased two lens generators, five lens polishing machines, and a lens checker or Vertometer. Ryozou Furukawa, who had worked under the company's chief lens designer, Kakuya Sunayama, was then transferred from N-KK to S-KK to help set up these optical machines in the Nakane-cho of Meguro ku factory. Once the machines were ready, Furukawa began designing and developing new lenses for S-KK.

S-KK's first usable lens was probably the 1940/41 Seiki-Kogaku 75mm f:4.5, which may have been supplied to the military during the Sino/Japanese conflict mounted in a Fingerprint Camera. The lens lacked the "SERENAR" name which was trademarked in December 1941 and added to all S-K lenses after that date. To date only two lenses are known #552 and #616 and it seems to me that Canon numbered the lenses according to production?

With the outbreak of Japanese hostilities in the Pacific in late 1941, almost all manufacturing by S-KKCo was directed towards the war effort. The only lenses that may have been produced by S-KKCo between 1941 and 1945 were for X-ray cameras and enlargers.

The S-K R-Serenar 5cm f:1.5 lens is one lens that may have been manufactured by S-KKCo's Meguro-ku factory. The recorded numbering sequence for these four digit lenses is #3xxx, #4xxx, #6xxx and #7xxx. A small number of lenses survived to date, which indicates that either not many of these lenses have been produced or many had been destroyed during the conflict.

The absence of lenses recorded in the #5xxx range could be the reason why this batch of serial numbers was assigned to the company's new enlarging lens. This lens was manufactured in early 1945 to replace the N-KK-supplied Hermes enlarging lens. The new enlarging lens was almost an exact replica of the N-KK Hermes lens, but with some slight variations. As far as I know, only four S-K enlarging lenses have ever been recorded. They are numbered #5002 (converted to a screw mount lens), #5108, #5114, and #5181.

The S-KS 5cm f:3.5 lens was the first commercially available camera lens that Canon produced in its factory. Production likely began in December 1945. As the serial numbers #3xxx, #4xxx,#6xxx and #7xxx had been used on the S-K R-Serenar 5cm f:1.5 lens and the #5xxx number for the enlarging lens. This could be the reason why Canon began the serial numbering sequence for the S-KS 5cm f:3.5 collapsible lens at #8xxx which can be found mounted on the model J-II and later camera bodies.

Early in 1947 S-KKCo produced a limited number of S-KS 20cm f:4 lenses. Whether S-KKCo went into serious production is doubtful - only one lens (#4015) has survived.

S-KKCo also released its second commercial lens, the S-KS 13.5cm f/4 telephoto lens. The serial numbering sequence for both lenses began with #4xxx. Whether the number was derived from "f/4" in 13.5cm f:4 is open to discussion. I think that S-KKCo did not choose #9xxx to begin the sequence because the S-KS 5cm f:3.5 lens had encroached into that serial number range.

The S-K Serenar 5cm f:2 was the third new lens to be released in February 1947. The five-digit serial number, #2xxxx, was used to start the sequence. Why Canon chose a five-digit serial number had me confused, as the four-digit #2xxx had never been used on any previous lens. It could well be that this four-digit number was assigned to the early R-Serenar 5cm f:1.5 X-ray lenses in 1942, even though none have been recorded in the #2xxx range. The number "2" might have been derived from f:2, for reasons which will be explained below.

In August 1947 the company changed the name "Seiki-Kogaku" on its lenses to "Canon Camera Co" (CCCo), and in January 1948 the company released their fourth new lens CCCo SERENAR 10cm f:4. The #1xxx batch of numbers had not been used previously, and the #4xxx sequence had been used for the S-K 13.5cm f:4 lens. Therefore, it was logical for Canon to begin the numbering sequence for the 10cm lens with #1xxx. These four-digit 10cm f:4 lenses are very difficult to find today, because they were produced in that configuration for only a short time.

In February 1948 Canon changed the serial numbering system of two of its existing lenses (13.5cm f:4 and 10cm f:4) and introduced the fifth new CCCo 8.5cm f:2 lens. I am not sure whether Canon could foresee that the serial numbers for the 13.5cm f:4 lenses would ultimately encroach onto the numbering system of 5cm f:3.5 lenses. Nevertheless, the company issued a new five-digit numbering system for its 13.5cm f:4 and 10cm f:4 lenses.

Again, I am not sure when the new numbering sequence began for the 13.5cm f:4 lens, but the lowest number recorded is #31547, while the last of the four-digit numbers recorded is #6900. The 10cm f:4 numbering system began with 4xxxx, possibly because this was the fourth lens Canon produced in a new focal length. As mentioned above, the production of the four-digit 10cm f:4 lens lasted for about one month. The 8.5cm f:2 lens was the only new lens to be introduced in February 1948, its serial number beginning with #50001. This was the fifth lens in a new focal length; hence Canon's decision to use number "5" to start the serial numbering sequence.

In April 1949 Canon introduced the model IIB camera to the market and changed the designated measurement on all items from centimetres to millimetres. All of Canon lenses, except the 5cm f:2 lens, changed to the new measurement format. The 5cm f:2 lens was sold until stock ran out.

The 50mm f:1.9 lens became the standard for most IIB cameras, but in reality, it was a re-calculated 5cm f:2 lens. The serial numbering system for the 50mm f:1.9 began at 2xxxx, the same sequence initially used by the 5cm f:2 lens. There were overlaps of the serial numbering range between the two focal lengths.

I did a small Excel exercise when I combined my database of S-K and CCCo 5cm f:2 lenses up to the highest number (#21956) I had recorded with the CCCo 50mm f:1.9 database up to that last f:2 serial number as I thought there maybe duplicates numbers. There were no duplicates numbers but there were three batches of consecutive serial numbers where one number was an f:2 and the other a f:1.9 number. Interesting as it seems that Canon avoided replicating serial numbers and may have filled in gaps where an early f:2 lens had been rejected?

In March 1950 Canon introduced its first wide-angle lens, the 35mm f:3.5. The serial numbers for this lens began at #60001. This was Canon's sixth lens in a new focal length; hence the use of number 6 to start the serial numbering sequence. Now we come to something that is particularly interesting. I did not realize this until I had processed the chart on the computer and printed it out. Studying the chart in detail, I noticed a pattern of events emerging. The

next lens Canon issued was another 35mm lens, but with a faster aperture of f:3.2. The serial numbers for this new lens began at #67001. The first two digits, “67,” are made up of the “6” from the earlier 35mm f:3.5 and the “7” indicating that the 35mm f:3.2 lens was the seventh new Canon lens. Then I realized that the highest number for the 35mm f:3.5 in my database was #65856. I doubt that Canon ever produced lenses up to or close to the serial number 67xxx.

This revelation opened up a bag of worms. I proceeded to check the 85mm, 100mm, and 135mm focal lengths, and everything finally fell into place. I have already explained the sequence of the 85mm f:1.9 lens issued in September 1951, following the demise of the 85mm f:2 lens. This is when I’ll pick up the story.

In October 1952 Canon released two faster lenses in the 100mm and 135mm formats. The 100mm f:3.5 serial numbers began at #49001, and the 135mm f:3.5 numbers began at #46001. These replaced the older 100mm f:4 and the almost ancient 135mm f:4 lenses. The highest serial number recorded for the 100mm f:4 is #48406, while for the 135mm f:4 it is #45306. Whether any of the 135mm f:4 lenses actually reached the 46xxx serial number range I am not sure, as I am yet to record any. The highest serial number recorded in the 100mm f:4 indicates that it is close to the 49xxx range of the 100mm f:3.5 lens.

Another lens with an odd serial number sequence is the standard SERENAR 50mm f:1.8 lens. Released in December 1951, along with the new models IIIA and IVF, it was the standard lens for contemporary Canon cameras. The sequence began with #58001. Why Canon chose number “58” to begin the sequence I can only guess. The previous standard lens was the 50mm f:1.9, and the highest lens ever recorded in that focal length is #56831. Canon probably continued the serial numbering sequence from the 50mm f:1.9 lens, but gave itself enough room should the f:1.9 lens still be required. The numbering system may have changed for the 50mm f:1.8 later on, when the Model VT was introduced along with the re-styled Canon 50mm f:1.8 lens. The sequence began with #20000. The highest serial number I have recorded on pre-VT era lenses is #167758.

All new lenses issued after October 1951 (excluding the 50mm f:1.8, 100mm f:3.5 and 135mm f:3.5) had their serial numbering sequence beginning with #10001. The first lens to be issued was the 28mm f:3.5, released in October 1951.

There was a change in the numbering sequence of the later 50mm f:0.95 lenses brought about by the introduction of TV industry lenses. None of these specialized lenses can be used on any Rangefinder camera but many have been converted to mount onto the M series Leica cameras.

On page 37 is a version of the spreadsheet mentioned earlier in this article - it summarises the lens numbers that have been discovered for each of the Canon Rangefinder lenses as well as a few others from that era. Later Canon lenses for other camera types have similar model-related numbering systems which probably have other twists to the methodology. It is left to others to describe and summarise those practices.

Approx Date of Issue	Lens	Possible SN beginning and lowest recorded	Highest SN recorded on database	Commercially issued lenses in sequence	Possible reason for SN beginning and reason for change
40/41	7.5m/f4.5 S-K	501/ 552	616	Special	1st lens S-K Canon made & supplied to the military in a fingerprint camera. Never sold commercially.
43/46	5cm/f1.5 S-KS	3001/ 3001 Nr*	4790	Special	1st # indicated the year of manufacture. 3xxx, 4xxx, 6xxx & 7xxx are known. Identified as R-Serenar. Never sold.
44/44	13.5cm/f4 SK	?	?	Prototypes	Two lenses reported in this focal length.
45-Jan	5cm/fl.5	5001/ 5002 Nr	5114	Special	SK allotted 5xxx - Seiki-Kogaku enlarging lens found in S-K or Hansa enlargers. Similar to Nikon's "Hermes" lens.
45-Dec	5cm/fl.5	8001/ 8011 Nr	9299	1	SK allotted the # 8xxx for this lens. SK's first commercially sold camera lens.
46-Sep/Oct	20cm/f4 SK	4001/ 4011 Nr	4011	Special	"4" from f4 Only one example known
46-Sep/Oct	13.5cm/14 SK	4001/ 4003 Nr	5123	2	"4" from f4
47-Feb	5cm/f2 S-KS	20001/ 20008 No*	20214	3	"2" from f2
47-Aug	5cm/f3.5 CCCo	?/ 9325	13721		Name change - Seiki Kogaku to Canon Camera Co (CCCo).
47-Aug	5cm/f2 CCCo	?/ 20232	21956		Ditto
47-Au g	13.5cm/f4 CCCo	?/ 5126	6900		Ditto
48-Jan	10cm/f4	1001/ 1026	1078	4	1xxx sequence not used previously. 4-digit SN
48-Feb	10cm/f4	40001/ 40143	41006		New 5-digit SN. The 4th lens in a new FL by Canon.
48-Feb	13.5cm/f4	?/ 31547	34700		New 5-digit SN. Old 13.5cmlf4 SNs would ultimately encroach into the 5cm/f3.5 range.
48-Feb	8.5cm/f2	50001/ 50013	50213	5	New Lens. 5th lens in a new FL by Canon.
49-April	100mm/f4	?/ 41223	48406		Change from "cm" to "mm" Model II B introduced
49-April	135mm/f4	?/ 34867	45306		Ditto
49-April	50mm/f1.9	20001/ 20059	56831		Re-calibrated 5cm/f2. Model II B introduced. SN overlaps but f1.9 is in 'mm' f2 is in 'cm'. No duplicates recorded.
49-April	50mm/f3.5	?/ 13760	23920		Change from "cm" to "mm" New Model II B
49-April	85mm/f2	?/ 50289	59000		Ditto. Lens 59000 in writer's collection
50-Mar	35mm/f3.5	60001/ 60008	65856	6	New lens. 6th lens produced in new focal length
51-June	35mm/f3.2	67001/ 67044	74626	7	New Lens. "67001" follow-on from 35/f3.5 7th lens produced but with larger aperture
51-Sep	85mm/f1.9	59001/ 59003	80627	8	New Lens 59001 following on from 85/f2
51-0ct	28mm/f3.5	10001/ 10038	21767	9	New Lens. First lens to have SN begin at 10001
51-0ct	35mm/f2.8	10001/ 10028	43907	10	New Lens
51-Nov/Dec	50mm/f1.8	58001/ 58006	167758	11	New Lens. 58xxx SN continues on from 50mm f1 .9 but leaves room for f1.9 SN to #57999
52-July	85mm/f1.5	10001/ 10018	12194	12	New Lens
52-0ct	50mm/f1.5	10001/ 10174	29131	13	New Lens
52-0ct	100mm/f3.5	49001/ 49069	98623	14	New Lens "49001" following on from 100/f4
52-0ct	135mm/f3.5	46001/ 46009	110715	15	New Lens
53 Mar	800mm/f8	10001/ 10032	10155	16	New Lens
55-Jan	50mm/f2.8	10001/ 10040	36607	17	New Lens
56-Jan	25mm/f3.5	10001/ 10020	17647	18	New Lens
56-Mar	28mm/f2.8	10001/ 10004	21454	19	New Lens
56-Mar	35mm/f1.8	10001/ 10002	25457	20	New Lens Introduction of model Vt
56-April	50mm/f1.8	200001/ 200002	348484	11a	Ditto - New SN starting at 200001.
56-April	50mmf1.2	10001/ 10050	56440	21	New Lens Introduction of model Vt
56-April	400mm/f4.5	10001/ 10210	10710	22	New Lens
57-Mar	200mm/f3.5	10001/ 10131	11182	23	New Lens
58-Aug	35mm/f1.5	10001/ 10035	15541	24	New Lens
58-Sep	600mm/f5.6	10001/ 10369	10369	25	New Lens
58-Sep	l 000mm/f11	10001/ 10073	10969	26	New Lens
59-lan	100rnm/f2	10001/ 10099	16562	27	New Lens
59-Aug	50mm/f1.4	10001/ 10032	120530	28	New Lens
61-Jan	50mm/f2.2	10001/ 10537	12696	29	New Lens
61-Mar	85mm/f1.8	10001/ 10276	13014	30	New Lens
61-June	135mm/f2.5M	10001/ 10036	19794	31	New Lens
61-June	200mm/f3.5M	10001/ 10175	11687	32	New Lens
61-June	50mm/f0.95	10001/ 10006	29462	33	New Lens Introduction of model 7
62-April	35mm/f2	10001/ 10051	43593	34	New Lens Introduction of model 7
64-Aug	19mm/f3.5	10001/ 10016	11255	35	New Lens

Nr - Old designation for "number", No- the new designation introduced around the time the S-KS-II camera was released in October 1946

S-K=Seiki-Kogaku. S-KS=Seiki-Kogaku Serenar (the "Serenar" name was patented in december 1941)

The APCS John Minnis Memorial Library

John Minnis was a founder member of the APCS and the Society more or less revolved around his home in Elwood for the first decade. He was renowned for documentation and after his passing the APCS inaugurated a library in his memory. This is a summary of the library today and its migration into the future.

Photography is full of publications relating to the art of photography, the cameras and equipment that have been used, the technology, the support of the equipment, and today the hobby of collecting.

Most collectors have a personal library that is likely to be centred on their own speciality, but would like to have access to more of the material that has been printed from time to time. Logically, the APCS sees the value of having a library for occasional use by members, and the John Minnis memorial library is such a collection in its own right.

The library is stored in a cabinet at the AMRA Hall in Glen Iris and is accessible at all APCS events that are held there. Members can refer to it at any time and books may be borrowed on an honour system - please respect it! There are a few sections which can be summarised:

1. The British Photographic Society published Journals and Almanacs from its inception in the 1850s and the APCS library includes a complete set of the Almanacs - although many of the early ones are reproductions. The Journal collection is far from complete but a recent acquisition has added a significant quantity from the 1980s onward. This part of the library is essentially a history of photography but focussed on the British perspective.

2. Camera and equipment manuals have been produced by their manufacturers and this part of the library falls into several distinct sections: (a) operation handbooks, (b) repair handbooks, and (c) third party summaries of systems - like the “Leica System”.

3. Books and directories focussed on collecting cameras - including various identification and valuation guides, outlines of major collections around the world and “coffee table books” all about collecting.

4. There is a pile of magazines and papers that have been added from time to time, some from the industry, some from initiatives to capitalise on the “collecting business” and some from organisations that have aims similar to those of the APCS. That pile is a physical one but many are now emerging as on-line access - see a bit later.

5. You would expect that a complete set of the publications produced by the APCS would also be there but for some reason that has not happened, and this part of the library is sparse at best.

Libraries have a habit of growing and space at the AMRA Hall is at a premium and we need to do something about it. A modern trend is to make libraries accessible electronically and on-line so that users can have access from anywhere that has an internet connection. A few years ago the absence of the complete set of APCS publications was addressed and the missing items were found and scanned to PDF where that was the only option but for the more recent material the original digital copies were all converted to interactive and searchable PDF – ie essentially everything for the last 25 years. Two lots of those publications are now available on-line.

All issues of Back Focus and its early newsletter predecessors have been converted - see the cover of this issue for images of some of the milestones! All copies are arranged using their original identification numbers in individual files. Eventually, access will be directly from the APCS webpages, but for the present users need to go to a specific web page using their favourite web browser - Safari, Edge, Chrome or what-ever: The web page is ***https://www.apcsociety.com.au/BackFocus/*** and that will bring up a page listing all the issues. In general, clicking on any one of those links should display the PDF in your browser - simply scroll down to view all the pages. “Right-Click” anywhere on a page will give you options to download the PDF if you wish.

You can return to the full index page using the back arrow on your browser. In the future, access will be from a menu button on the main APCS website and the resulting download page will be a bit prettier! The resolution of the stored PDF documents is a little lower than the full printed versions, but if high resolution images are required of any of the photographs, the APCS holds copies of the originals at or higher than the resolution used in the published issues.

An index of the individual items in Back Focus is held by the APCS in an Excel spreadsheet, currently covering from about 1992, and a work in progress will extend that to include articles back to the beginning in 1976. At some time in the future some sort of search process will be developed that will allow individual articles to be accessed by subject, author etc - a form of “Back Focus Wiki” if you like. There are something like a thousand individual articles in the history of Back Focus and its predecessors covering a very wide range of subjects, written by dozens of people who are experts in their subjects. Many of the articles are the result of extensive research.

Similarly all issues of the modern form of the monthly newsletter have also been stored electronically but access at present is by special permission.

But the APCS is not the only organisation to be producing their publications in an electronic form and many of those have similar access from their websites. From time to time these are mentioned in the APCS newsletters along with their internet references, and a temporary access to a lot of them can be found on the APCS system as local copies: ***https://www.apcsociety.com.au/Library.htm***l. Access is similar to that for the Back Focus magazines.

From time to time important documents become available and are acquired by the APCS and added to the library, but as time passes, more and more will be accessible online. While this is not to everyone’s idea of a library, it is the way of the future at a significantly lower cost to individuals.

And a final matter - recent publications by the APCS are also stored in the TROVE database at the National Library in Canberra, and should be available on-line through that system.

AUSTRALIAN PHOTOGRAPHIC COLLECTORS' SOCIETY Inc

A0016888V

(Founded 1976)

50th ANNUAL REPORT

Included with Back Focus No. 120 – June 2025

And to be presented at the

ANNUAL GENERAL MEETING

on

Sunday 20th July 2025 at 2pm Eastern Standard Time

AMRA Hall – 92 Wills Street, Glen Iris, Victoria

President's Report

2025 is the 50th year of the APCS with the actual anniversary of the first meeting being next January. COVID is essentially over and the Society returned to normal in 2024-2025 – but it is a new normal as the nature of what members are doing with their collections is changing. That is being observed around the world in similar collecting societies, and marks a new determination of what the future will be.

Most significantly, communication with members and the public via the internet, along with access to information via computing in general have become normal. The COVID years did a lot to accelerate those changes with some key changes like moving from physical meetings to ZOOM software. Sometimes these things creep up on us and a recuring theme today is that change is inevitable, and the APCS will have to change in order to support its present and future members.

While the membership of the APCS continued to decline, the number of people who attend the Box Hill markets has increased significantly, due to interest in older cameras and the use of film by younger people attending those markets.

The central thrust of what interests our members is changing from collecting cameras to trading in cameras, partly as a way of improving our personal finances and partly as some sort of investment process. That is evident not only from the market attendances but also from the level of advertising on such formats as eBay. There are also some significant shifts in perceived values – both upwards and downwards.

These trends and driving a general review of what the APCS provides for its members and others who are seen to be prospective future members. This is probably a slow process of change, but driven by immediate issues and a consideration of what the society might look like in the future and how its management might get there.

Nevertheless, the program for this last year followed the pattern of previous years, but with a further drift away from technical presentation meetings to marketing activities.

Membership: The membership level fell again in 2025 – a consequence of the age of many of the members. We currently have 135 full members of which 9 have been awarded Life Membership. There are currently 20 names on the Life Membership Honour board, but 7 of those are no longer with us.

During the year we lost Keith Head – Keith joined in 1988 and was a key contributor to the operation of the society – especially as its Treasurer for a decade during which time he designed the electronic database that we still use for membership and auction programs.

There were several resignations that came to our notice as members moved to care, and it was evident that many who did not renew membership during the year also lost their email and phone contact details, probably for the same reasons.

Finances: The Society is strong financially and improved in the 2024-2025 year. Full details are in the Treasurer's report but the thumbnail summary is that there was a $25,000 surplus for the year – a very good position to be in and one that will allow us to fund risks that might be associated with change looking forward.

Publications: Back Focus continues as a glossy annual, now accepted as a printed mailout sent to Australian members by post and made available to the rest of the World as an on-line PDF document from a link in emails and freely available on-line from the APCS website.

The monthly newsletter continues as an electronic document linked from emails to all members – nominally on the second Sunday of each month.

The APCS web-pages are taking an increasingly important role as they can be modified very quickly and get information to members just as quickly. The web is replacing surface mail as the main communication medium, with a major driving force being its very low cost.

Auctions: Three members-only auctions were held in 2024-25. These were generally successful but there is evidence that the hammer prices are falling as members seem to be transitioning from acquisition modes to reducing what they are keeping. Further, the migration from collecting to trading cameras means that members are looking to make profits on what they buy. This change is disturbing and changes the whole focus on what we may be doing in the future.

Markets: Public and members-only markets continue to be the main activities of the year. However venue hire costs and insurance are increasing and they will eventually have to be passed on to the table holders and buyers alike.

The Box Hill markets are becoming more attractive to buyers and sellers alike. For the last couple of years, the demand for tables in the main hall have increased and the attendance by buyers has increased by about 25% for each of the last two years – or maybe it is the 'Post-COVID' era. In fact, the increase is posing a problem for the Society as we need to manage the numbers at Box Hill to deal with the evident overcrowding at some times on the day. Increases in hall hire and in the necessary insurance detract from the bottom line but overall the markets are yielding increased profits.

Thanks: The APCS is a volunteer organisation. The duties fall to a few that put their hands up and we are sincerely thankful to those that do so. We thank the committee and all those that come to the auctions and markets in particular to do all those things that ensure successful events.

Rod Reynolds, President

Treasurer's Report

I now present the financial accounts for the year ending 31st May 2025

Financials: This financial year ended with an operating surplus of $25,050.72 compared to a deficit the previous year of $4783.23. The society conducted two public markets and three member's auctions which each generated a surplus for the society. The March market exceeded expectations with 1030 patrons. The highest previous number of patrons at any of our activities in recent years was 871 in September 2024. The market in Adelaide was discontinued this year due to unavailability of the site. Subscriptions received were similar to the previous year and represented 105 membership payments for the year.

Equity: The equity of the society increased from $84,064.93 to $109115.65. This was mostly the result of an increase in market revenue and the increase in members auctions from two to three.

Expenses: Expenses were generally the same as last year with the exception of the extraordinary payment made to the M Mason estate last year. This resulted in a lower level of expenses this year and a resulting surplus. Most costs have risen during the year, with postage, rental and insurance being the most significant. A low level of receipts for the April 2025 auction is due to a number of unpresented vendor's cheques. These are being processed now and will be reported in the next period.

Fixed Investments: Our fixed investments continue to be managed by UCA Funds Management. They are placed in the U Ethical Cash management Trust fund. We received four quarterly distribution payments. The interest rate was 4.5% which is above the present rate of inflation.

Outlook: With the improvement in surplus, the society may consider increasing their fixed investment and also consider a purpose for the fixed investment. With the decline in use and acceptance of cheques most members are using Electronic Funds Transfer for payments. Consequently, the society could improve membership transaction effectiveness by moving to an on-line membership and subscription program. Programs such as these are popular with clubs and societies with membership less than 200.

I would like to thank Kevin Saunders for his assistance in reviewing the accuracy of the reports.

John T Young, Honorary Treasurer

FINANCIAL STATEMENTS FOR THE YEAR ENDED 31 MAY 2025

2024	Profit and Loss statement	Notes	2025
	Income		
5,996.90	Subscriptions	3	5,333.00
2,615.57	Interest Income		2,236.80
29,110.60	Auction Receipts	4	42,102.10
8,278.40	Market Door Entry Fees	5	9,235.00
8,190.00	Market Table Fees and Sundry Sales	5	9,398.70
344.00	Adelaide Market	5	0.00
4,545.00	EFTPOS sales		2,933.50
20.00	Other income		0.00
59,100.47	**Total Income**		71,239.10
	Expenses		
25,944.10	Auction Vendor Payments	4	24,816.70
4,451.50	EFTPOS payments		3,498.65
22.00	Auction Expenses	4	0.00
9,013.50	Market Expenses Melbourne	5	6,492.50
680.00	Market Expenses Adelaide	5	0.00
4,755.00	Back Focus	6	4,338.82
167.90	Social and refreshments		356.50
168.00	Website/computer/software		235.50
0.00	Depreciation		0.00
2,368.70	Insurance		2,409.59
269.70	Meetings-AGM		0.00
197.70	Office Expenses, Stationary & Packaging		498.31
14,049.00	Other expenses (M Mason Estate)		0.00
714.55	Postage		373.60
0.00	Rental		1,720.00
50.00	Newsletter		779.25
547.05	Bank fees		668.96
500.00	Library Purchases		0.00
63,898.70	**Total Expenses**		46,188.38
-4,798.23	**Operating Surplus/Deficit for Year**		25,050.72

2024	Balance Sheet As At 31 May 2025	Notes	2025
	Assets		
	Current Assets		
76,682.93	Cash and Bank Accounts	7	101,633.65
76,682.93			101,633.65
	Non Current Assets		
7,882.00	Library at Cost		7,882.00
1,681.00	Equipment at Cost	8	1,681.00
1,681.00	Less Depreciation	8	1,681.00
7,882.00	**Total Non Current Assets at WDV**		7,882.00
84,564.93	**Total Assets**		109,515.65
	Liabilities		
	Current Liabilities		
500.00	Subscriptions in Advance		400.00
500.00			400.00
500.00	**Total Liabilities**		400.00
84,064.93	**Net Assets**		109,115.65
	Equity		
88,863.16	Retained Earnings		84,064.93
-4,798.23	Operating Surplus/Deficit for Year		25,050.72
84,064.93			109,115.65

Statement of Cash Flows

2024	Statement of Cash Flows	Notes	2025
	Cash Flows from Operating Activities		
5,746.90	Total Subscriptions Received		5,233.00
2,615.57	Interest Income Received		2,236.80
29,110.60	Proceeds from Auctions		42,102.10
16,812.40	Proceeds from Markets		18,633.70
4,545.00	EFTPOS Sales		2,933.50
20.00	Other income		0.00
-63,898.70	Payments to All Suppliers		-46,188.38
-5,048.23	**Net Cash Inflow/Outflow from Operating Activities**		24,950.72
-5,048.23	**Net Increase/Decrease in Cash Held**		24,950.72
81,731.16	Cash at the beginning of the financial year		76,682.93
76,682.93	**Cash at the end of the financial year**		101,633.65
	Reconciliation of Operating Surplus to Net Cash		
-4,798.23	Operating Surplus/Deficit		25,050.72
0.00	Depreciation		0.00
-250.00	Change in Subscriptions in Advance		-100.00
-5,048.23	**Net Cash Inflow/Outflow from Operating Activities**		24,950.72

Notes To and Forming Part of the 2025 Financial Statements

Note 1 Reporting

This special purpose financial report was prepared for distribution to the members to fulfill the committee's financial reporting requirements under the Australian Photographic Collectors Society's constitution and the *Association Incorporation Reform Act 2012* (Vic). The accounting policies used in preparation of this report, as described below, are in the opinion of the committee appropriate to meet the needs of the members:

(a) The financial report was prepared on a modified cash basis of accounting, including the historical cost convention and the going concern assumption.

(b) The requirements of accounting standards and other professional reporting requirements in Australia do not have mandatory application to Australian Photographic Collectors Society because it is not a 'reporting entity'. The committee has, however, prepared the financial report in accordance with all applicable Australian accounting standards.

(c) Property, Plant and Equipment is carried in the accounts at cost less, where applicable, any accumulated depreciation. The depreciable amount of Property, Plant and Equipment is depreciated over the useful life of the assets of the Society commencing from the date the assets are first held ready to use.

(d) Cash and Cash Equivalents. This includes cash on hand and deposits held with banks including trading accounts and term deposits. Interest earned is brought to account as it is received and credited to the account.

(e) Goods and Services Tax. Australian Photographic Collectors Society is not registered for GST. All amounts are recognised inclusive of the amount of GST where it applies.

Note 2 Trade Receivables

The Society trades on the cash basis of accounting. It does not bring sales to account when the sale is recorded but only when payment is received.

Note 3 Subscriptions

2024		2025
750.00	Prior Subscriptions in Advance	500.00
5,746.90	Subscriptions Received	5,233.00
-500.00	Subscriptions in Advance	-400.00
5,996.90		5,333.00

Note 4 Auctions

2024		2025
20,039.10	August receipts (08)	15,261.75
-	August Payments	-13,682.00
0.00	August refunds	0.00
-22.00	April/August Expenses	0.00
9,071.50	April receipts (04)	17,563.55
-8,048.20	April payment	-2,490.50
0.00	November receipts (11)	9,276.80
0.00	November payments	-8,644.20
3,144.50	Profit / (Loss)	17,285.40

Note 5 Markets

2024		2025
4,355.00	September Door Entry Fees	4,085.00
4,200.00	September Table Fees and Sundry	5,183.50
-6,268.50	September Expenses	-2,745.00
2,286.50	Profit / (Loss)	6,523.50
3,923.40	March Door Enty Fees	5,150.00
3,990.00	March Table Fees and Sundry Sales	4,215.20
-2,745.00	March Expenses/ Table refunds	-3,747.50
5,168.40	Profit / (Loss)	5,617.70
344.00	Adelaide market - result	0.00
-680.00	Other market expenses miscellaneous	0.00
-336.00	Total Adelaide market	0.00
16,812.40	Total market proceeds	18,633.70
-9,693.50	Total market expenses	-6,492.50
7,118.90	Market revenue	12,141.20

Note 6 Back Focus

2024		2025
200.00	Articles	0.00
4,555.00	Production	3,490.00
0.00	Distribution	848.82
4,755.00		4,338.82

Note 7 Cash and Bank Accounts

2024		2025
26,653.02	NAB Trading Account/Quicken balance	51,603.74
50,029.91	UCA Cash Management Account	50,029.91
76,682.93		101,633.65

Note 8 Equipment at Cost

2024		2025
798.00	Library Cabinets	798.00
475.00	Furniture	475.00
408.00	IC LCD Flat Screen	408.00
1,681.00		1,681.00

Depreciation

2024		2025
798.00	Library Cabinets	798.00
475.00	Furniture	475.00
408.00	IC LCD Flat Screen	408.00
1,681.00		1,681.00

Officials and Contacts

Office Bearers 2024-2025

PRESIDENT	Rod Reynolds – president@apcsociety.com.au
VICE PRESIDENT	Ken Anderson
SECRETARY	Kevin Saunders – secretary@apcsociety.com.au
TREASURER	John Young – treasurer@apcsociety.com.au
COMMITTEE	Paul Ewins Tom Marinov
NEWSLETTERS	email to web@apcsociety.com.au
BACK FOCUS	email to backfocus@apcsociety.com.au
AUCTIONS	email to auctions@apcsociety.com.au
MARKETS	email to market@apcsociety.com.au
WEBMASTER	Rod Reynolds – web@apcsociety.com.au

Clubrooms

MEETINGS	AMRA Hall 92 Wills Street, GLEN IRIS

Contacting the APCS

MAIL	THE APCS C/o The Secretary (See the web, newsletter & Back Focus for current details)
PHONE	(See the web, newsletter & Back Focus for current details)
WEBSITE	http://www.apcsociety.com.au

BACK FOCUS

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