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But it says in the book...

All textbook writers inevitably begin by digesting the works of their predecessors (perhaps when students themselves) and then synthesize this knowledge, along with contemporary developments, into their own books. It is well known that this process sometimes leads to mistakes and anomalies being perpetuated through the generations, for no author can be expected to be expert in every field, or to question the antecedents of every statement he makes.

Thus, school texts and schoolchildren (and university students come to that) still trot out the ‘colours of the spectrum’ as:

red-orange-yellow-green-blue-indigo-violet

when any unbiased observation of a solar spectrum will disclose a ribbon of continuously-varying hue. Yet a few pages later it is taught that the spectrum represents a range encompassing an infinite number of different wavelengths of light, and that the human eye can distinguish some 2000 distinct tints! The ‘indigo’ also causes trouble: ask someone who has named it to put their finger on this colour, and they will usually be very unhappy! Newton originally named 5 colours, but many years later (in the Opticks) added orange and indigo, perhaps seeking a relationship with the octave in music.

It's the same with the ‘blue sky’ phenomenon. Textbooks happily quote Lord Rayleigh as proving that the scattering of light is inversely proportional to the fourth power of the wavelength, and then claim that this relationship gives rise to the blue sky. It does not - one would see a violet sky! The fact is that we must also take into account two further curves varying with wavelength: the emission of the Sun and the sensitivity of the human eye. Compounding these three curves together does give a resultant peaking in the blue.

It is therefore a good thing that established textbook wisdom should be queried from time to time. Two decades ago the ‘inert’ character of the noble gases was shown to be a fallacy, and this has led to important developments in krypton, xenon and (particularly) fluorine chemistry. This issue of the Bulletin contains a report of a discussion where the generally accepted story of the invention of the refracting telescope in the Netherlands in 1608 was challenged. It was also (quite rightly) ably defended. Readers must make up their own minds on the result, but I am sure none will question the value of the exercise.

The Editor

Gerard Turner awarded the Caird Medal

In March of this year Professor Gerard L'E. Turner (History of Science and Technology, Imperial College, London) was awarded the Caird Medal by the Trustees of the National Maritime Museum, Greenwich, “in recognition of the outstanding work he has done in promoting the study of scientific instruments.”

NOTICE OF ANNUAL GENERAL MEETING

The 9th Annual General Meeting of the Scientific Instrument Society will be held at The Society of Antiquaries, Burlington House, London W1 on Thursday, 8th July, 1993 at 2.00 p.m.

In accordance with the constitution all Officers and Ordinary members of the Committee resign at the Annual General Meeting.

All members of the Scientific Instrument Society are invited to submit nominations for any post as Officer or Ordinary member of the Committee. Each candidate requires a nominator and two seconders, and the nominator should seek permission of the candidate prior to nomination.

Nominations should reach the Secretary at P.O. Box 15, Pershore WR10 2RD, Worcestershire, England, as soon as possible.

Back Cover Illustration

IRON CLOCKS

'The iron wheel turns regularly, and thereby measures the passage of time.'

This print of a clockmaker's workshop comes from the New Discoveries drawn by Johannes Stradanus, and issued as a set of engravings by Galleus of Antwerp in 1638.
Meeting Report
Was there an Elizabethan Telescope?

The discussion meeting entitled "Was there an Elizabethan Telescope?" organized by the Scientific Instrument Society was held 26 March 1993 at the Society of Antiquaries in Burlington House, Piccadilly, under the chairmanship of Robert Fox, Professor of the History of Science at Oxford University. He welcomed the two invited speakers, Colin Ronan and Gerard Turner, adding that there would be some additional short contributions as well as a general discussion. He was pleased to see in the audience a broad cross-section of the astronomical and historical communities, not all of them members of the SIS.

Colin Ronan spoke to the proposal
There was an Elizabethan Telescope

Colin Ronan outlined the case for the existence of the first practical telescope in Elizabethan England. Referring briefly to the work of Leonard Digges (c. 1520-c.1559) as recorded by his son Thomas Digges (c. 1546-1595) in his 1571 edition of his father's book Panometria (about which Mr Ronan had previously published a paper) he expressed the view that Thomas Digges' report contained therein about his father's experimental and mathematical work on 'perspective glasses' seemed to be in two parts. The first described the use of lenses and mirrors, about which Thomas himself claimed to be writing a book. This included what may well be a reference to a reflecting telescope, possibly of Herschelian type. The second described what such 'glasses' could achieve in the way of seeing distant objects. It was this second section that contained the exaggerations - for instance about reading an open letter in a distant room - that have led some historians to discredit Thomas Digges' whole account. However, such exaggerations could be an integral part of the attitudes taken at that time towards new inventions and discoveries by people to whom science was still inextricably mixed with magic. This might be expected particularly from those who accepted the hermetic philosophy, such as Thomas Digges and his guardian John Dee; they expressed hopes of what the invention might achieve, not just its actual performance.

Though no trace of Thomas Digges' promised text about perspective glasses has ever been found, this does not mean that he did not write it. Indeed, Anthony a Wood in his Athenae Oxonienses claims that several 'mathematical' works ready for the press which, by reason of "...law-suits and other avocations, he was hindered from publishing". Possibly a legal restriction on publication had been made by the Elizabethan government in view of the possible military and naval use of such an invention.

It is however to be noted that Thomas Digges was a good astronomer - Tycho Brahe used his observations on the supernova of 1572 - and that it seems possible that he tried a telescope out on the sky, this leading him to the concept of an infinite universe.

Certainly there can be no claim that Digges was trying to get on a bandwagon; he was reporting something new which was not to be claimed again as an invention for nearly forty years. Yet the position of the Digges is not completely satisfactory, and independent confirmation is required. The evidence of William Bourne (fl. 1567-1580), a noted writer on military and naval matters, turns out to be significant in this respect. In 1578 Bourne published in London his Inventions or Devises, where in 'The 110. Devise', Bourne wrote "For to see any small thing a great distance from you, it requireth the ayde of two glasses...." This, surely, Mr Ronan claimed, is a clear definition of the principle of the telescope, and seemingly the first ever to be published. The rest of Bourne's text is concerned with a design of a 'perspective glass' of which some modern reconstructions have been made.

Again, at some unspecified date (but which from internal evidence appears to have been 1585, seven years after the publication of Inventions or Devises) Bourne was invited by Lord Burleigh to prepare a report on the matter of perspective glasses. Clearly, at a time when England was under threat of an invasion from Spain, such a device might prove useful in military and naval warfare. Bourne's report still exists, and contains much vital information. In the first place he makes evident that his information came from a visit or visits to John Dee and Thomas Digges. Second, he describes the properties of lenses and mirrors, as well as the preparation of a reflecting surface on the rear of those which are of glass rather than metal. Finally, Bourne then makes a remark which is crucial to the question of whether such a device existed, and this is the comment that "...the greatest impediment ys, that you can not beholde, and see, but the smaller quantity at a tyme". The significance of this statement is that it describes the small field of view observed through a telescope, something which indicates that Bourne himself had looked through such an instrument. It is very doubtful indeed that even Thomas Digges, for all his mathematical ability, could have calculated this effect from purely theoretical considerations.

As for models of what seems to have become called the "Digges/Bourne telescope", Mr Ronan explained that after the preparation of his original paper in August 1991 he had continued his research, and by early November that year had made a mock-up of the design given by Bourne using a convex lens as objective and a concave mirror as eyepiece. Unfortunately, the only materials he had to hand were a small objective with a focal length shorter than that of his concave shaving mirror. The result was that the telescope gave a diminished and inverted image. A better reconstruction, preferably built on an optical bench, was clearly desirable to test Bourne's crucial comments. On 23 November 1991 he therefore accepted with alacrity an invitation from the Optics Department of Imperial

On 6 February 1992 he had been delighted to receive a letter from Joachim Rienitz in Tübingen who wrote..."Accidentally I hit upon Leonard Digges' telescope nearly at the same time as you...", for this contained details of an experiment Rienitz had made totally independently, also using a shaving mirror and an objective lens, but this time of suitable focal lengths to give an image magnified by 5.4 times. This seems to be the first modern successful working model of the design. A second model was constructed by Ronan and Satterthwaite on an optical bench at Imperial College during July 1992 while, quite independently, Ewan Whitaker, lately of the Lunar and Planetary Laboratory at Tucson, Arizona, built his own Digges/Bourne design during the summer of 1992. Allan Mills (of the Astronomy Department at Leicester University) and Howard Dawes have done likewise.

Gerard Turner then spoke against the proposal that the telescope was known in Elizabethan times
There was no Elizabethan Telescope

G.L'E. Turner

We must be quite clear in today's discussion that the refracting telescope, the one with lenses, was invented by a Dutchman, Janssen of Middelburg, in 1608, while the reflecting telescope, the one with mirrors, was invented in 1669 by Newton. There is a great deal of evidence to support these dates, and knowing these dates helps in assessing false starts and false trails. Nothing has been newly discovered. The history of the development of both types through the 18th century clearly reveals the enormous technical difficulties there were in producing optical glass, which was not perfected until the mid-nineteenth century, and in designing lens and mirror systems. By looking at the broader context of the Elizabethan period and especially its technology, and words used for technical description, together with the most recent scholarship, one will see the latest reports to be seriously flawed.

Colin Ronan's Presidential Address to the British Astronomical Association was on 30 October 1991. At the top of the front page, the Daily Telegraph for 31 October has a headline: "Now it can be told: British Scientists beat Galileo by 33 Years". On 16 August 1992, in the Patrick Moore TV programme, "The Sky at Night", Colin showed his version of an Elizabethan telescope (which he dubbed a reflector) that combines a convex objective lens with a secondary concave mirror. Scientifically, this optical arrangement is not a reflecting telescope. In his Address, Colin claimed "the reflector in a truly practical form was first invented in England by Leonard Digges, probably sometime between 1540 and 1559". This would be fifty or more years before Galileo's use of a refracting telescope.

So far as I know, the first person to credit the invention of the telescope to the Elizabethan, Leonard Digges, was J.E. Drinkwater. His article "Curious extracts from old English books, with remarks which prove that the telescope, &c were known in England much earlier than in any other country" was published in 1814 in the Philosophical Magazine. Here he quoted passages from the 1571 posthumous publication of Leonard Digges, passages that regularly resurface. A prestigious sighting is in the Dictionary of National Biography (1885-1900), in the entry for Leonard Digges, while R.T. Gunther, in his Early Science in Oxford (1923), said there was: "no reasonable doubt that Leonard Digges was the real inventor of telescopes both refracting and reflecting, and that he thus forestalled Galileo by many years". The book on English scientific writings published in 1937 by Francis Johnson postulates that English scientists in the 16th century were
familiar with some form of telescope, and that the first terrestrial use of a telescope was made by Thomas Harriot in Virginia, since the instruments he showed to the natives included a "perspective glass". David Waters, writing in 1598 of Elizabethan navigation, follows the same path, and believes "it is equality certain that as early as the 1590s, Leonard Digges had made reflecting telescopes". Joseph Needham, in 1967, considered Leonard Digges had made a bi-lenticular system. One had thought this simplistic story had been killed by Professor van Helden in 1957, with his review monograph that included a wide selection of texts, with the well-known ones from Dee and Digges as well as those by William Bourne and Thomas Harriot.

Many writers during the past 200 years who are familiar with telescopes have found it easy to read into the language of the 16th century descriptions of instruments they wish to find in that period. To correct this, it is necessary to look at the wider context of military and civil surveying, the text-books of optics, the economic needs, and the technical capacity. The correct sense of the technical terms is vital for understanding what was going on. William Bourne's 1586 manuscript in the British Library called "A Treatise on the Properties and Qualities of Glasses for Optical Purposes, according to the Making, Polishing, and Graining of them" has been published several times from 1898. It was a letter to Lord Burghleigh, the Lord High Treasurer of England, where a favour was hoped for. Bourne has given us some definitions: "looking glasses...are those sorts of Glasses, that have a foil laid on the back side thereof, that causes the same glass to cast from it a beam". Then comes a surprise: "There is some sorts of looking glasses that are made of metals, which are commonly called 'steel glasses'". Perspective is a word used in English from the 14th century. For example, Chaucer writes: "Of quaint mirrors and of perspectives". The Oxford Dictionary says that: "in early usage, the word means mirrors for producing some special or fantastic effect, e.g., by distortion of images". The meaning of the words glass, mirror, steel glass, perspective, is vital to the interpretation of the works of Dee, Digges, Harriot, and so on. Colin Ronan has said of a passage in a text by John Dee, where there is a reference to perspective glasses, that: "From this it appears evident that telescopes of a kind were known". This shows a misunderstanding of the meaning of the word "perspective". It is just as if one claimed that the camera is a 16th century device because there is talk of the "camera obscura".

I shall have to delve still further into the 'perspective glass'. Leonard Digges, who died in 1559, wrote a treatise on surveying, A Geometrical Practise named Pantometria, and it was finished and published in 1571 by his son. Thomas. If the whole of chapter 21 in Pantometria be considered, one sees that a flat reflector made of steel is arranged overhead to provide a sightline to a ship or other object that would otherwise be out of direct sight by observation from a parapet or hillside. The simple geometry enables the range to be found provided the mirror is horizontal. After giving a worked example, Digges goes on to tell how you can move in a circle around the mirror, and thus draw what he called: "the true plain and proposition of a whole Country, with all the Towns, Coasts, Harbours, etc." Later comes the often quoted passage about "glasses concave and convex of Circular and parabolic forms". Again, the use of these to draw towns and villages, and a future book is promised on: "the miraculous effects of perspective glasses". Interpersed in this account are some flights of fancy, such as the ability to read a letter being open in a house "although it be distant from you as far as eye can descry"; and that the "reflection of glasses" could set fire to gunpowder half a mile distant. Digges also mentioned parabolic mirrors, which could not have been made: it was Euclidean geometrical talk. The promised book to explain all was never published.

One further remark has to be made about the Digges book. Commentaries select the words to do with "perspective glasses" for their speculation about an actualised telescope. They ignore adjacent words and sentences of the following sort: "Glasses not only discovered things far off, read letters, numbered pieces of money with the very coin and superscription thereof cast by some of his friends upon the Downs, in open fields, but also seven miles off declared what had been done at that instant in private places", and again: "He (that is Leonard Digges) had by the sun's beams fired powder and discharged ordnance half a mile and more distant". These are absurd statements; at seven miles the naked eye can discern an object 20 foot high; to see a small object such as a man's hand the telescope needs a magnification of over 200 times. Are we to accept parts of these accounts as pointing to an actual instrument while adjacent parts are to be dismissed as pure fantasy?

What exactly did Thomas Harriot take to Virginia in 1586? Most modern commentators simply quote: "a perspective glass". Professor van Helden says of this that it was "nothing more than a magnifying glass", and he disagrees quite specifically with Professor John Norrth who considered it to be a mirror. Van Helden is wrong, for the item next following in Harriot's list is: "burning glass". Let us read the passage at greater length: "Most things they saw with us...the virtue of the loadstone in drawing iron, a perspective glass whereby was shewed many strange sights, burning glasses, wildefire workes... spring clocks that seem to go of themselves...". Harriot showed a perspective glass and a burning glass. A burning glass can only be a convex lens or a concave mirror. Van Helden claims a perspective glass is a "magnifying glass", that is, yet another burn. From Harriot's wording this is impossible, so we can be sure that 'burning glass' is a concave mirror, and 'perspective glass' is a convex mirror. There is certainly no telescope here. It is hardly necessary to point out that both types of mirror are very ancient. The concave mirror features in the story of the burning of the boats at Saragossa, and convex mirrors were used domestically in Roman times, and may be seen in the British Museum and depicted in paintings such as those of Jan van Eyck before 1440. The convex mirror is infrequently to be found during the Elizabethan age as a symbol on title pages, such as The plantation of Virginia (1588). It draws a wide range of topics into a small compass brought straight in front of the reader-viewer.

Digges, the surveyor, dealt with mirrors: flat, concave, and convex. In common with many, he allowed his knowledge of Euclid to run away, with him. William Bourne, author of Inventions or Devices
congratulations of Kepler, most strongly couple of weeks, using his ‘trunk’ of camera obscura, the eye, and and suggest that the telescope did not exist sunspots and the moons of Jupiter. A Dutch eyeglass maker tried to patent a standing, who had links throughout correct explanation of the Kepler was in correspondence with Thomas Harriot, who was at Syon Europe. Kepler was in correspondence with Thomas Harriot, who was at Syon with Thomas Harriot, who was at Syon Harriot led Galileo by a Harriot led Galileo by a Harriot led Galileo by a 26 July 1609 to view sunspots and the moons of Jupiter. Kepler’s congratulatory text to Galileo was published in 1610. The speed with which Harriot and Galileo made and used telescopes in 1609, and the swift congratulations of Kepler, most strongly suggest that the telescope did not exist before 1608. Kepler, quite carried away, wrote of the new telescopic research by Galileo:

“O perspicillum of great knowledge, more valuable anywhere than a sceptre! For is not he, who holds you in his right hand, made King, Lord of the works of God?”

Silvio Bedini has published a paper called “The Tube of Long Vision”, where he dealt with paintings with telescopes. The earliest known is in the Prado Museum of Madrid, and is The Five Senses - Vision by Jan Brueghel, dated circa 1610. This is yet another indicator to the crucial date.

What sort of glass was available for making lenses?

The earliest use for optical glass was in eyeglasses, which were first made in about 1286. Requirements are not stringent, as a lens just in front of the eye can be of moderate quality and not affect the user. Unless extremely hot furnaces are available, with covers for the pots, glass contains bubbles and lumps of impurities. It is coloured to some extent green or brown, and inhomogeneity produces wavy striations – particularly bad in optical glass. The market is tiny compared with the glass industry as a whole, and there was no profit or incentive to make better glass just for instruments. The first efforts to make optical glass were by Galileo’s friend, Sagredo. By 1618 he had undertaken research into making glass of optical quality. He was well aware of the bad effects of striations, causing the light to follow a zig-zag course through the lens and make images double and foggy. He said that out of a batch of 300 lenses only 22 were good enough to use in instruments. He ordered 200 pounds of finely powdered ashes, and these he passed through finer and finer sieves until there were only 16 pounds of very fine powder left. The same fining process took place with 200 pounds of rock crystal (quartz), which was reduced to 15 pounds. The mixed powders were then put in the glass furnace. Failures occurred through the fire going out and the pan breaking, and then the glass broke during grinding because it had been cooled too quickly. By May, 1619, Sagredo had made one plano-convex lens with a diameter of 9 inches. Unfortunately it proved no better than a similar lens of ordinary glass, and took twice the time to grind. Sagredo was bitterly disappointed, and since he died the following year no further research into optical glass was made at that time in Italy.

In Holland, the Huygens brothers tried to make lenses for telescopes. Those of the 1660s in the Leiden museum are surprisingly bad, being richly coloured and full of bubbles, inclusions and striations. Those lenses made in 1668 are better, but not by much. Three now with the Royal Society have been examined and published in Annals of Science by Dr Allan Mills; the largest has a diameter of 9 inches. Of them he says: “All are made from very poor glass, a heterogeneous and discoloured potash-rich "forest glass"”. A smaller lens in the Whipple Museum signed and dated: “Christopher Cock London 1668” is barely any better. When one finds that Josiah Wedgwood and Michael Faraday both failed to make really good optical glass, one realizes that the task in 1650 would have been beyond even the conception. Similarly with concave mirrors. James Gregory could not have one made in London. Newton had to make his own in speculum metal for the 1669 reflector, and he said it soon tarnished. The first really effective reflecting telescope was the one shown to the Royal Society in January 1721 by John Hadley, with an aperture of 6 inches.

So with rotten glass what are the earliest telescopes like? The best known are at Florence. I have looked at the lenses; they are coloured and spotty, and quite small. The field does not allow more than a quarter of the Moon to be seen at one go. As Professor North has written so graphically: “To look down Galileo’s mirror, for instance, is to see as much light as one sees darkness inside the barrel of a Colt 45 revolver at a distance of two feet”. If the overheated claims for the Elizabethans were half true, there would have had to be a most remarkable regression in technology over some 70 years.

To sum up: however romantic Colin’s model is, with its perfectly formed large lens and perfectly formed concave mirror, it is quite removed from the reality of the 16th, 17th, and 18th centuries. It fails on the meanings of words. It fails on the historical record.

And, most importantly of all, it completely fails on the technical capacity of the Elizabethans.
Report of Discussion

Jon Darius

The instrument constructed by Gilbert Satterthwaite at Colin Ronan’s behest was demonstrated to the audience (Fig.1). Satterthwaite was the first to admit that it incorporated a modern plano-convex lens and, for the mirror, an equally modern back-aluminized meniscus. Slides of images obtained with the telescope, including the Moon in broad daylight, were shown.

The first question expressed the nub of the doubters of the canonical view: if the telescope could be invented by Janssen in 1608 in Middelburg, then why not four decades earlier in England? Gerard Turner replied that for a full answer we should read van Helden on the subject, but that in any case it should be borne in mind that even if the techniques had been known they would have been internally difficult to apply, granting the current state of optical technology.


Charles Wynne, Emeritus Professor at Imperial College, remarked that there was a long history of lenses, and their use in combination may well have been tried. But once spectacles had appeared even their optically inferior glass could have given results which would have demonstrated that such a device as Ronan had described was satisfactory, at least in principle.

He stressed that from the time of Galileo’s discoveries glass had gradually improved, and explained that whereas small bubbles and small opaque inclusions might be a trouble in spectacles because their areas would be comparable with that of the pupil of the eye, they would be much less important in the context of a telescope objective.

Any unevenness of surface in lenses made from selected pieces of glass would have been ground and polished away. He then remarked that even good twentieth century optical glass, which was highly valued, still contained bubbles. Nevertheless, it worked extremely well in photographic lenses and telescope objectives.

Alan Chapman, Fellow of Wadham College Oxford, agreed with Gerard Turner that claims for an Elizabethan telescope run into serious historical problems. At the same time he questioned whether Bourne could be so easily dismissed as ignorant and plagiaristic. Bourne would have had the leisure to experiment like others of the period who toyed with the generation of optical images for their intrinsic interest, with no practical application in view.

At this point, the Chairman invited Allan Mills to contribute. Noting that “nature got there first” by endowing scallop eyes with telescope-like properties, Allan went on to define what is meant by a telescope, refracting and reflecting, and to describe a variety of lens-shaped antecedents from the quartz cabochon found in the ruins of Nimroud [alt. spelling Nimrud] through archaic Greek ornaments to round glass flasks filled with water. He also reviewed enigmatic references in the writings of Leonardo da Vinci and Girolamo Fracastoro, but concluded that in no case could a working telescope be safely inferred.

Allan Mills commented that invention could be as much a matter of semantics as of any historical event; after all, it could be argued in some sense that C.V. Boys “invented” fibre optics in 1890. Finally, he noted that the (re)construction of a reputedly early telescope using modern optics could not be taken as proof of anything at all.

Adding fuel to the fire, Gerard Turner observed that if we all get with 20th-century elements is a fuzzy image, how much worse it would have been with 16th-century optics. Among several shorter contributions, Howard Dawes reported that he too had constructed a model along the lines of Ronan and Satterthwaite. Jim Hysom, Director of Hytel Optics, commented on Galileo’s telescopes. Stephen Johnston of the Science Museum noted that at no point anywhere in his work did Digges claim to have seen or used the instrument which Colin Ronan would interpret as a primitive telescope.

Trevor Waterman wondered whether glass could “go off”, so giving us the impression that old lenses must have been worse than they actually were. Gerard Turner replied that although glass can devitrify Galileo’s lenses would be much the same now as when first used. He went on to emphasise that it would have been quite out of the question with 16th-century techniques to grind a lens 12 inches in diameter to a thickness of ¾ inch. Answering Colin Ronan’s query how Bourne could have known about the small field of view if he had been a mere “propounder” and not an actual user of an early telescope, Gerard Turner pointed out that a small field of view did not of itself imply a telescope.

Jon Darius thought that the Ronan/Satterthwaite model and its cousins by Howard Dawes, Allan Mills, Joachim Rienitz and Ewan Whitaker represented commendable attempts to demonstrate practically what could be achieved with relatively primitive optical technology – even though the use of modern optical elements rather weakened the case. Patrick Moore had said in his August 1992 television programme that building a model of an “Elizabethan” telescope needed a knowledge of optics and a degree of faith, qualities which protagonists of a telescope prior to 1608 generally shared.

But to construct a telescope today which could in principle have been assembled from existing components in the 16th century does not add up to an Elizabethan telescope, which might just as well be claimed to have been Venetian or Flemish. First of all, none of the latter-day reconstructors has been able to obtain optical glass sufficiently poor to emulate that available to a 16th-century experimenter. Second, it has been demonstrated that judicious selection from early texts, in particular Elizabethan (although it is no less true of da Vinci and Fracastoro), can lead the modern reader astray and inspire overheated claims of an earlier paternity.

In conclusion, the modern construction remains a valid historical speculation. No one has yet made a new historical discovery – which is not to rule out the possibility that from some unplumbed archive or manuscript evidence might some day emerge to push back the invention of the telescope by several years or even decades.

Closing the meeting, Robert Fox thanked all the participants, and especially the two main speakers, adding that this meeting had itself been an historical event.
'Make Glasses to See the Moon Large'  
An Attempt to Outline the Early History of the Telescope

Joachim Rienitz

This paper discusses Leonard Digges' telescope in the context of historical development and tries to explain why he chose an uncommon optical scheme. It also attempts to find a more reliable route to the early history of the telescope than the former speculations on the sources. Space allows no more than the fundamental ideas to be outlined here, dispensing with many details, quotations and references. A considerably more extensive treatment will be found in a book the author is preparing.

Let us first suppose we have supported a biconvex spectacle glass of, say, 2 m focal length (0.5 dioptres) within the opened window of a room with a wide view. If we approach the lens from more than 2 m distance, always observing with one eye only, we see an inverted image of the vicinity, it seems to be located at the lens, but we know that it is actually formed at 2 m distance from the latter. Approaching this image as far as the accommodation power of our eye enables us, we perceive, irrespective of the aberrations of the lens, much more detail than with the naked eye, e.g. a street number, or the clock of a steeple we could not read before. The single lens works here as a true telescope, but with only one step of image formation as against two in modern instruments. Assuming the conventional visual distance of 25 cm and substituting in the formula:

$$\text{Magnification} = \frac{\text{Focal length objective}}{\text{Focal length of eyepiece}}$$

We find $m = \frac{200}{25} = 8 \times$

With a concave mirror of the same focal length we would get a somewhat better image owing to the absence of chromatic aberration.

In our time this telescopic effect of a convex lens or concave mirror of considerable focal length is known only to a few people concerned with practical optics, and has hardly been noticed in the history of the telescope. Some historians of science have therefore dismissed the old accounts which seem to allude to telescopic observations as 'old myths' or, like van Helden, as 'fanciful notions about miraculous devices for seeing far away'. This appears to be at the least incomconsiderate, for in the old days some people were concerned with very substantial things too. However, following the spirit and customs of the time, the material content of the early reports is often disguised for various reasons: lack of expert knowledge by the writers, lack of general terminology, fear of charge with black magic by incompetent authorities, or secrecy for military or professional reasons. What matters in early history is to search for the material content - or at least to arrive at an estimate of the degree of truth.

Hitherto historians of optics have almost exclusively concerned themselves with the writings of ancient and medieval scientists. There exists, however, a second inconspicuous level of practical optical knowledge. As an example we might mention a descriptive representation of the path of light through a convex lens or in a concave mirror dispensing with the ray concept.

The burning mirror had already been used in the ancient world (but not for burning the Roman ships at Syracuse!). The burning effect is, indeed, much more obvious than the telescopic effect, but it cannot be excluded that a few attentive people may have become aware of, and perhaps profited from, the latter.

In his Opus Maius (1268) Roger Bacon alleges that Caesar had looked at the English coast by means of mirrors before deciding to cross the Channel. (One of the editors remarks dryly at the margin: 'Application to political problems of the laws of reflection'). There is, however, no evidence of this.
story in Roman times. Aaron J. Gurjewitsch, in his well-known work The World View of Medieval Man points to the fact that in those days people had no idea of a development of the world. All was a gift of God and therefore extant from the very beginning. It is this attitude which induced, for example, painters to represent apostles and saints with spectacles on their noses, and the telescopic effect of the mirror may have the same authenticity as the latter as evidence of contemporary knowledge.

There is likewise evidence for observations of the telescopic effect by means of a lens. Leonardo da Vinci (1452-1519) noted, without any further comment, in the Codice atlantico: 'Make glasses for the eyes [occhiali] to see the moon large'. Nevertheless, V. Ronchi held that Leonardo used concave metal mirrors, which he tried to make up to 6 m focal length. That Leonard Digges too was conversant with this application of a lens will be demonstrated later.

Fig. 1 is taken from Duodecem Specula by P. Joanne David SJ (Amsterdam 1610), a theological treatise. The man B observes the moon E by means of a biconvex lens in his outstretched arm. We do not take his motley for ignominy since ignorance had dressed Galileo as well as others with it too. Assuming the conventional visual distance of 25 cm and a focal length of 45 cm (2.2 dioptres, a frequently used spectacle glass) we get a magnification of 1.8 times. This is about the weakest magnification of the old spy-glasses, sufficient for attentive people to perceive a little more detail than with the naked eye.

An interesting hint on how the telescopic effect could have been discovered has been given by Johann Georg Krinitz in his Oekonomisch-technologische Encyclopaide (1786). He points to the fact that window-panes occasionally show more-or-less spherical elevations acting as burning glasses, and suggests this prompted some curious people to fix a convex lens on a flat window-pane to enlarge a distant object.

Soon or later the idea must have arisen to magnify the image generated by the lens or the mirror, thus adding a second step of image formation: in other words to create the modern telescope composed of an objective and an ocular. We will examine the telescope ascribed to Leonard Digges (ca 1563). The documents relating to this instrument, especially the much more informative paper by William Bourne, may be found in an appendix to the work by van Helden.

To the present author these suggested an uncommon construction: a lens of great diameter as well as great focal length as an objective, and a concave mirror, likewise of great diameter, as an ocular (Fig.2). The great diameters of the optical components had been chosen for good reasons. Bourne stresses that the lens 'must be very large, of a foot or 14 or 16 inches broade, and the broader the better', and 'yt must be grounde untill that the myddle thereof be not above a quarter of an ynche in thickness'.

At that time lenses were sometimes ground from the plate glass normally used for mirrors. The round 'Mirror of the Sirenes' in the Ca' d'Oro at Venice (early 16th century) has a diameter of 43 cm. Nevertheless, a lens of the kind mentioned must have required much skill and experience. Moreover, the hint that it should be handled with care and always kept in a frame on account of its fragility would also seem to result from experience.

A lens of a diameter of one foot and a centre thickness of a quarter of an inch has a focal length of some metres. This renders it plausible that Digges started with the one-step telescope: the great focal length brings about a high magnification and the great diameter a wide field of view.

In order to transform the one-step telescope into a two-step instrument we hold a magnifier of great diameter directly before our eye. Approaching as before our 2 m lens at the window the object is hardly more magnified. We perceive the lens indistinctly, and the field of view is not greater than the diameter of the latter. Then we enlarge the distance between the eye and the magnifier, and perhaps changing the distance to the lens a little, try to find a position at which the whole diameter of the magnifier is filled with the image of the object. In other words the field of view becomes much greater than before.

In this position the magnifier forms an image of the objective lens, the entrance pupil of the instrument, in the pupil of our eye, the exit pupil. This is the path of the pupil rays, which is less well-known than the path of the image rays. In a correctly constructed instrument it has to be matched to the latter in order to get a wide field of view.

If we fasten a sheet of white paper at the place where the image is formed by the objective lens, we will notice that this image is much larger than that which we perceive with the one-step telescope. With the latter, on the other hand, we can explore this extension by moving our head around. The magnifier, here acting as the ocular, makes a part of this larger image accessible to us.

But why did Digges choose a concave mirror instead of a lens as an ocular? The answer is once more given by William Bourne. We remember that he claimed that the objective should have a central thickness of not more than a quarter of an inch, and he specifies the reason: 'if the glasse be very thick, then yt will hynder the sichte'.

In Digges' time the transparency of glass was moderate, and it was common practice to make the glass of (rear-surface) mirrors as thin as possible. The 'Mirror of the Sirenes' mentioned above has a thickness of 3 to 3.3 mm. A magnifier with a great diameter and a not-too-small magnification would have a central thickness of a multiple of a quarter of an inch, and therefore be of poor transparency. I believe that Digges chose a concave mirror in order to avoid this problem.

The present author tried his shaving mirror, being conscious of the imperfection of the components of earlier times. The image was of astonishingly good quality, and more brilliant than with the magnifying lens. Moreover, he chose a very acute angle between the optical axes of the lens and the mirror because the aberrations are thereby minimized. He looked with the shaving mirror over his shoulder at the
lens, so that the image remained inverted. One could get an apparently upright image by holding the mirror before the chest and bending the head downwards. In this case, however, the angle between the axes is much greater downwards. In this case, however, the view does not make sense because the aberrations increase towards the margin and too high a magnification is also detrimental. Moreover, since the magnification is given by the ratio of focal length of objective: focal length of ocular, a given magnification can be attained by means of shorter focal lengths of both components, too. Experiment and experience would have rendered it possible to reduce the length of the instrument and therefore to use a tube, and to apply a smaller and therefore thinner lens as an ocular. The instrument would become more manageable.

The considerable enlargement of the field of view might, at first sight, have given rise to naive expectations which cannot be fulfilled. If one promises to show a child a fly under the microscope he or she will be amazed by the fact that the insect cannot be seen as a whole. This idea may likewise be the meaning of Bourne's words: 'the greatest impediment ye, that you can not beholde, and see, but the smaller quantity at a tyme'.

With increasing experience one would have learned a lot. Too wide a field of view does not make sense because the aberrations increase towards the margin and too high a magnification is also detrimental. Moreover, since the magnification is given by the ratio of focal length of objective: focal length of ocular, a given magnification can be attained by means of shorter focal lengths of both components, too. Experiment and experience would have rendered it possible to reduce the length of the instrument and therefore to use a tube, and to apply a smaller and therefore thinner lens as an ocular. The instrument would become more manageable.

We do not know when and where these steps were taken. Since Leonard Digges' telescope would have had a positive ocular (it makes no difference whether this is a positive lens or a concave mirror) it is optically equivalent to the astronomical telescope Johannes Kepler published in 1611 in his *Dioptrice*, which was later named after him. The telescope which in 1608 became known to the public had a negative ocular: the Dutch or Galilean telescope. We are ignorant whether reasoning or trial and error led to this instrument, but it is an interesting fact first mentioned by Ronan that Thomas Digges, Leonard's son, was probably in touch with the Dutch scene from which this telescope originated.

Our results do not however mean that Digges was the inventor of the two-step telescope. The time was ripe, and there are still other hints at similar developments, unfortunately not as detailed as the sources of Digges' instrument. Nevertheless, it is to be hoped that future research will throw more light upon the early history of the telescope.

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From Derek Howse

Whilst it was still fresh in my mind, I thought it worthwhile to record my own conclusions following the most stimulating debate at the Society of Antiquaries on Friday. Gerard himself once argued that absence of evidence was not evidence of absence. I think that precept applies here. There is no positive evidence that there was an Elizabthan telescope; but, equally, there is no evidence that there was not. One must therefore look at it statistically in terms of probabilities. On the evidence presented, I think that the odds are better than even that there was an Elizabethan telescope, even though we have no direct evidence as such. Of course, if the question had been 'Was there an Elizabethan telescope that really worked?', I might have come to a different conclusion.

The astronomer David Gill, in his article 'Telescope' in the 9th edition of the *Encyclopaedia Britannica* (1888), started his History section with the words: 'The credit of the discovery of the telescope has been a fruitful subject for discussion'. He then cited pretty well all the early sources mentioned by Colin except the two important Bourne ones, concluding the first part of his discussion thus:

> It is impossible to discredit the significance of these quotations, for the works in which they occur were published more than twenty years before the original date claimed for the discovery of the telescope in Holland.

But it is quite certain that previous to 1600 the telescope was unknown, except possibly to individuals who failed to see its practical importance, and who confined its use to 'curious practices' or to demonstrations of 'natural magic'. The practical [my italics] discovery of the instrument was certainly made in Holland about 1608...

Plus ça change...! My sentiments exactly, except that the Bourne evidence, particularly *Inventions or Devises* #110, greatly strengthens the pro-Digges case in actually describing an instrument that could work, even though it might not have been terribly 'practical'.

It was splendid that the SIS should organize this discussion. Let's have more like it!

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From S.D. Ringwood

I was present at the meeting of 26th March at Burlington House which discussed Colin Ronan's proposal of an Elizabethan telescope. I feel I must write to express thoughts for which there was insufficient time at the meeting because of the many issues raised.

I have to express disappointment at the basis for Professor Turner's reply to Colin Ronan's paper. His opposition appeared to be based more on ideological grounds than on any hard scientific evidence to the contrary.

Professor Turner first treated us to a rather evangelical rendition of the classical story of the telescope's invention by Dutch opticians. But quoting from the history books is not a sound refutation in itself. One might just as well confront Darwin's evolution with chapter and verse from Genesis. The narrative concerning Janssen...
and Lipperhey is no doubt that of the development of a telescope; but by no means does this obviate an earlier version for which the history is less well documented. Arguing on this point is not science but dogmatism.

The labourious dismissal on the use of the term 'perspective' is disingenuous. True, it was used generically for all instruments used for sighting (and not necessarily those employing lenses). But it was still used even for the optic tubes that Galileo built until well after he and his discoveries had become famous. In fact, the word telescope was not coined until proposed by John Desmiani at a banquet hosted by Prince Frederich Cesi (Marquis of Montecello) at the occasion of Galileo's admittance into the Accademia dei Lyncei on April 14 1611. Before this, any optical instrument, lensed or otherwise, was called a perspicillum or instrumentum. There are no grounds for dismissing an Elizabethan 'telescope' because it was known by one of these other terms.

I do not consider that Professor Turner addressed fully the passages alluded to by Colin Ronan describing the instrument as providing close-up views of distant objects, albeit with a small field. It may be true that some of these descriptions are exaggerated, but Professor Turner misses the point if he dismisses the principle which is being described merely on this basis. The concept of using an optic tube to see far objects near needs to have been experienced before such exaggeration can occur, surely.

I confess to being rather puzzled that Gerard Turner should use a model of Galileo I to demonstrate the difficulty of using a primitive telescope. Of course it is difficult to use, but only compared to modern instruments. No doubt, at the time, Galileo thought it was truly miraculous (not having a Schmidt-Cassegrain to compare it with). Galileo used this instrument to good effect, it serving to spur him on to better things. I cannot see him tossing it in the bin because its performance was bad! I cannot see the Digges doing so either. In any case, it is the existence of the Elizabethan telescope which is at issue, not its abilities.

In preparing a paper describing my construction and use of a copy of Galileo III I feel I should add that, although the optical performance of this is poor compared to current designs, I still find it very able. Despite the very small field of view it takes only a little practice to use it to good effect. The original was certainly good enough to cause the downfall of a cosmology which had held sway for over a thousand years. Although the instrument I have copied was built a few decades after the proposed Digges telescope, the nature of the Elizabethan observations are very much akin to my own; apart from the strong documentary evidence presented by Colin Ronan, I feel that the similarity of these observations also lends credence to his claim.

Postscript – Nature Got There First!

Professor Michael Land of the University of Sussex has shown that – as is so often the case – nature has triumphed with the invention of the telescope. The humble scallop demonstrates not only her invention of the reflecting film based on multi-layer interference, but also its incorporation into an all-organic Schmidt telescope!


Fig.1 The common scallop (Pecten).

Fig.2 The scallop has several eyes distributed around the edge of the mantle.

Fig.3 Sectional and diagrammatic views of one of the eyes of the scallop. Incoming rays pass through a correcting lens before being reflected at a concave hemispherical reflecting film towards distal photoreceptor cells embedded in the upper layer of the retina. This optical path characterises the Schmidt wide-field telescope.
An Experimental Generator with a Gramme Ring Armature

H Jaspers

In 1860 Pacinotti invented the ring armature used in his electric motor. Not until 9 years later did Gramme patent his ring armature generator – which means he cannot really be called the inventor of this very important breakthrough. Nevertheless, all writers recognise the importance of Gramme: making use of the ring armature he invented, developed and manufactured the first really practical dc generators. Previous dynamos produced very variable currents. A fairly constant direct current was needed for electroplating, and to produce it only very large and inefficient machines (e.g. the Alliance) were previously available.

Zénobe Théophile Gramme was a Belgian working in Paris for Ruhmkorff and the Société de l’Alliance. During the 1860s he patented many improvements for generators. In 1869 he patented the invention for which he became famous, a combination of the ring armature (with many more coils than Pacinotti’s) and the self-exciting principle invented/discovered by Siemens in 1867. He was the first to construct the core of the ring armature of iron wire to suppress eddy currents. Most writers consider that Gramme probably constructed the ring armature without any prior knowledge of Pacinotti’s invention.

Descriptions and illustrations of five different generators with ring armatures are given in the patent of 1869: “Le cylindre ‘a’ est d’une seule pièce, ou forme par un grand nombre de spires de fil de fer ...; les conducteurs qui l’enveloppent sont enroulés de manière à faire trente-six petites bobines ...” (Fig. 1). A description was also given in Comptes Rendus LXXIII (1871), p. 175 et seq., a report by Gramme presented by M. Jamin. It describes the theory of the ring armature and gives some details of a generator that was demonstrated. This machine had two field electromagnets, each wound with 7 kg of copper wire 3mm in diameter so there were four poles influencing the ring. There were four brushes; two of them delivered half the current generated to the field magnets, the other pair delivered the output. The ring was wound with 200m of copper wire 2mm in diameter, again weighing approximately 7 kg. It is remarkable that the core of iron wire is not mentioned here. The commutator described is of a primitive construction (Fig.2).

In the Comptes Rendus of the same year a letter by M. Pacinotti was published. Written approximately one month after the above publication, he claimed that by 1860 he had constructed a ring armature machine that generated a continuous current. It could also be used as a motor.

In the Comptes Rendus LXXV (1872) Gramme reports on the development of his generators. He describes his ring armature made of a plain ring of soft iron (une couronne en fer doux, ne présentant aucune saillie) again not mentioning the important improvement of an armature made of soft iron wire. He remarks that the most important part of his invention is that any desired number of poles can be applied. This makes it possible to generate – with only one machine – a series of different currents and to split it up between various circuits, as required for example by the electric light. He briefly describes the construction of a commutator made of strips of metal, and mentions that it is very important that these are very close to each other yet well isolated; only in this way can the sparks be prevented which significantly diminish the current. He also claims another invention – the replacement of solid metal springs by brushes made of many copper wires braided together to form a mat, with the aim of preventing sparks between commutator and brushes and to reduce wear and tear. He describes two generators, one for electroplating (low voltage, heavy current) constructed by Breguet, and one for lighting. He mentions that the initial supply of current to the fixed electromagnets was due to the influence of the Earth’s magnetic field, and that this made superfluous the Daniel cells he was preparing for this purpose. This is a strange claim, as in his account of 1871 he mentions remanent magnetism. Finally, it should be noted that in his French patents he describes a condenser to eliminate sparks, and the possibility of using his generators as motors.

Now let us study in more detail the generator illustrated in Fig. 3. It is 30cm high and of rather crude construction. Its fixed field magnet appears to have the many separate coils found in ac generators, but in fact there are only two windings, left and right, covered by paper held together by two sets of 9 bindings looking like coils. The ring armature consists of a flat ring (of iron wire?) on which the copper wire is wound, it being divided into 20 separate

Fig.1 Part of illustration belonging to the patent of 1869

Fig.2 Diagram from Comptes Rendus 1871

*Many writers mention 1870 as the year of Gramme’s invention; this is not correct.
The electrical connections are quite complicated; there are 6 switches, one of them a reversing arrangement (Fig. 5). Obviously the purpose of this is to experiment with different ways of feeding the field magnets. A provision for an external supply to the field magnets seems to have been removed later. The underside of the wooden platform on which the generator is mounted is covered with decorated (wall?) paper on which the electrical connections are described thus: "Inducteur fil supérieur (2x), Inducteur fil inférieur (2x), Balai super.; Balai inter.; Borne extérieur; Borne droit du commutat.; Demi cercle du commutat.; Centre commutat." (Fig. 6). The construction, particularly of the commutator and ring armature, is the same as that in the Gramme generators described by Walmsley and Schellen.

All this suggests that the present generator is an experimental machine used by Gramme to investigate the result of various connections of the fixed field coils and rotating armature. This must have been important information, very necessary for the design of his large machines, as at that time not much knowledge could have been available on the self-excitation of generators. Perhaps an analysis of the handwriting on the underside of the wooden base (Fig. 7) could confirm the hypothesis that this is Gramme's own machine?

The ring armature had disadvantages, particularly the fact that only that part of the winding on the outside of the ring participates in the generation of current. This disadvantage was overcome by the drum armature, invented by Von Hefner Alteneck (Siemens) in 1872. Nevertheless the Gramme machines performed very well, and did their duty for many years. An example of a late 19th century industrial Gramme generator is illustrated in Fig. 8. It bears
a plate "MACHINE GRAMME BREVETEE SGDG, 20 Rue d’Hautpoul, Paris 188 ".

**Literature**

Brevet no. 61275, 1863, # avec addition 1865;

Brevet no. 75172, 1865, # avec additions 1868, 1869;

Brevet no. 87938, 1869, # avec additions 1870, 1872;

British Patent no. 1668, 1870, to Gramme and D’Invernois.

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Z T Gramme, *Comptes Rendus* 1872, LXXV, p. 1497 et seq.


S P Thompson, *Die Dynamo-elektrischen Maschinen*, 1893, pp. 16, 17, 48, 49.


**Referee’s note**

Another valuable work in this subject is:


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**Fig.6** The underside of the base of the generator.

**Fig.7** Close-up of a label, to show the handwriting. Is it Gramme’s?

**Fig.8** Small industrial generator, signed Gramme. Private collection.
Commander A B Becher of the Hydrographical Office devised an artificial horizon for the sextant. The original instrument is said to have been tested in 1834 by Captain Hewett, in the Thames Estuary.1 By 1844 Becher had numerous testimonials to its efficacy in service, and a sale to H I H Grand Duke Constantine of Russia, the accessory being made by 'that excellent artist Carey and fitted by him to one of Simms' favourite sextants.2

Becher, a member of the Royal Astronomical Society, also described the horizon in their journal.1 The horizon consisted of a mirror kept level by a small pendulum hanging in an oil pot. R B Bate was commissioned to make it up, but seems to have had some difficulty with it, writing to Becher in May 1843: 'I charged the East India Company 20gns for the sextant with your horizon - I will do them for the Admiralty at 15gns. The future one shall be better made. I am going to try iron limbs and index bars.3

Bate's involvement with the horizon was short-lived. Although the title of Becher's handbook describing the horizon mentioned Bate as its manufacturer,4 a second edition, published the same year, shows that J C Dennis had the contract and was supplying the horizon fitted to his own sextants. Likewise Dennis was 'the only manufacturer' named in the description published in the Nautical Magazine of 1844.5 (Figs 1 & 2)

Dennis also experienced problems - though of a different kind, for in 1845 he came to the High Court seeking to recover the costs of two sextants fitted with Becher's horizons which he had made to order for Edward Dent, and Becher appeared as a witness in the matter. The court transcript has not survived, but The Times reporter captured the argument in full:6

Court of Queen's Bench, Guildhall, February 20.

(Sittings of Nisi Prius, before Lord Denman and Common Juries.)

Mr Crowder and Mr M Chambers appeared as counsel, and Mr T D Taylor as attorney for the plaintiff; and Mr M D Hill and Mr P Pickering as counsel, and Mr Pickering as attorney for the defendant.

This action was brought to recover the price and value of two sextants, which the plaintiff, who is a mathematical instrument maker in the Strand, and the glass heads of the blank tube does not fit into its place. The centre of the radius is not perpendicular to the plane of the arc.

Mr Crowder proceeded to reply, but the jury, who heard the whole defence with impatience, returned a verdict for the plaintiff, for the amount of his demand.

Mr Crowder, astronomical instrument-maker, stated that the articles were of a different kind, and that the price demanded, 40 guineas, was a fair and reasonable price.

Mr Hill, having addressed the jury for the defendants, called a person of the name of Messenger, from the establishment of Messrs. Dollond, and he deposed that the sextants in question were very inferior instruments. There could not be a more important defect in the manufacture of a sextant than the fact of the centering not being perpendicular to the plane of the arc. The square glasses ought to fit close, and the glass heads of the blank tube ought to be better adjusted.

Thomas Smith, in the employment of Mr Dent, described the sextants as inaccurate and imperfect.

Mr Crowder proceeded to reply, but the jury, who heard the whole defence with impatience from the beginning, interrupted him, and returned a verdict for the plaintiff, for the amount of his demand.

The case lasted until 7 o'clock.
Notes

1. ‘The pendulum artificial horizon - invented by A B Becher, Commander RN’, Nautical Magazine (1844); 291-7 and 349-359. In a letter published in Nautical Magazine (1844); 551-2, J H Bass expressed annoyance at Becher’s claiming as his own an invention discussed in confidence.

2. ‘Becher’s artificial horizon’, Nautical Magazine (1844); 187-9 and 235-236.

3. RAS Monthly Notices 4 (1844); 81-2.


6. ‘Description of an artificial horizon to be used at sea when the natural horizon is obscured…’, Nautical Magazine 23 (1844); 502.

7. The Times, Friday, February 21 1845, page 7 d-e.

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Conference review
Instrument Seminar in Stockholm

Hemming Andersen

On 14th December 1992 a seminar was held in Stockholm on Artifacts as sources for technical and scientific research. It was arranged by Olov Amelin of the Royal Swedish Academy of Sciences, and was attended by some 50 enthusiasts.

Opening remarks were by Professor Tore Frängsmyr, Director of the Centre for History of Science.

The first speaker was Jim Bennett of the Whipple Museum, Cambridge. His presentation was entitled: Making instruments count: the opportunities for scientific instrument collections, their curators and historians. By giving his views on the general importance of making use of known collections and bringing to light the unknown, and illustrating his points by specific examples, (e.g. comparing astronomical instruments as tools for observations and as works of art) he brought much inspiration to the Scandinavian area.

From Denmark, Claus Thykier of the Ole Romer Museum and Søren Andersen, clockmaker and conservator of scientific instruments, gave an illustrated talk: To reconstruct history. Plans for reconstruction of Habrecht clocks were described, and copies of the Romer planetary machines (see SIS Bulletin no.25) were brought along for all to operate. Hemming Andersen described his work on the Danish National Inventory.

Naturally, local Swedish matters were an important part of the programme, and the following contributions were presented: -

Curt Roslund: Ales stones, a stone circle in Scania, as a pre-historic instrument.

Elizabeth Hidemark: Research at Nordiska Museet.

Per Dahl: The invisible techniques.

Matts Ramberg: About the Tekniska Museet’s policy on collecting artifacts.

Each talk was followed by lively discussion, and at the end of the sessions Olle Amelin rounded off.

The setting was superb. The morning sessions took place in the Vetenskabsakademien (Swedish Royal Academy), which also houses Berzelius’ old chemical laboratory. The afternoon was spent at the Old Observatory, which now has modern conference facilities. Lunch was provided, and an evening meal was served in the old vaults under the observatory. An especially moving and poetic feature was a Lucia-Procession by 15 girls and boys singing traditional Swedish Christmas carols; this was arranged by Mrs Amelin, who is teacher of music. We were uplifted in body and soul.

This was the first time an event of this nature has taken place in Scandinavia, but it was such a success that another seminar in Denmark is already being considered. Salute to Olle Amelin for a great initiative!
100 Years of Prismatic Binoculars

Hans Seeger

100 years ago the patent for the prismatic binocular - the "Feldstecher" was applied for by the Carl Zeiss Company, Jena. The title of patent No. 77086 (issued 1. Oktober 1894) was "Doppelfernrohr mit vergrößertem Objectivabstand, Patentirt im Deutschen Reiche vom 9. Juli 1893 ab" (Fig 1), translatable as "Binocular with increased objective spacing. Patented in the German Reich from July 9 1893". An instrument that is today commonplace and an indispensable tool had found its shape, and this outward form is still employed in current products. No inventor's name is given in the patent, but it is certain that Ernst Abbe had carried out the development. At the time of issue of the patent Carl Zeiss was deceased (1888); he had founded the company in Jena in 1846.

It would not be justifiable to claim that this patent represented a completely new invention, because the telescope was already well-known in both astronomical and terrestrial forms. However, the Galilean, Kepler, and terrestrial systems all have disadvantages limiting their general application.

The demand for a handy optical aid for both eyes, with a magnification of 6-10 x and an erect three-dimensional image of sufficient luminosity, had been recognised in the last century, and the first prismatic binoculars were constructed long before the patent issued to Ernst Abbe. The main operative element of these was a prismatic image-inverting system. An assembly of this nature, replacing the lens inverting system used in long terrestrial telescopes, was invented by the Italian engineer Porro (patent issued 1853), but the prismatic binoculars produced by Porro did not succeed. At that time there was no appropriate optical glass, and the technology of prism grinding had not been mastered. Others too produced prototypes of prismatic binoculars but without success - an example of the fact that invention alone does not guarantee improvement if the necessary production technology is unavailable.

The ingenious optician, manufacturer (and subsequently social reformer) Ernst Abbe was concerned with the construction of an improved hand-held prismatic telescope as early as 1873, but was not successful at that time. After his first patent application Abbe was surprised to learn that the prismatic binocular could not be patented. He was informed that the binocular was known, and had been described and depicted in a textbook on physics. What was he to do? The prismatic binocular was known, but had been regarded as a curiosity and produced only in small quantities. Not known however, was the optimum form of the prismatic binocular - and this form he proceeded to discover and protect by patent.

Fig.2 Three "Feldstecher" from the first series of the Carl Zeiss Company, Jena. Characterised by enhanced separation of the objectives.

Fig.3 Prismatic binoculars circa 1900. Constructions not infringing the Zeiss patent. (Geerz, Berlin)

From CARL ZEISS in JENA. Doppelfernrohr mit vergrößertem Objectivabstand.

Fig.1 Illustrations from the patent of 1893 "Doppelfernrohr mit vergrößertem Objectivabstand"
behind a protective shield or from a allowed the observation of a target from artillery commander's telescope, which application thus saw the birth of the prisms, binoculars can he built in company and the typical form of their objective diameter in millimetres.

The first prismatic binoculars were called "Feldstecher" - translated "field-piercer". At the first attempt Ernst Abbe found a binocular shape that was timeless and appropriate. Today the first series models of the Feldstecher are not regarded as antiques - in contrast to some of the efforts of their competitors at the time. Due to the Zeiss patent the latter were forced to produce binoculars with impractical shapes (Fig 3). The designation of the first Feldstecher reaching the market (Jan. 1894) were 4 x 11, 6 x 15 and 8 x 20: the first figure gave the magnification, the second the objective diameter in millimetres.

The patented form of the prismatic binocular was such that the objectives - the front lenses directed to the object - were positioned wider apart than the oculars, the eye lenses. (Fig 2). This design gave an enhanced stereoscopic effect, i.e. in the instrument objects could not only be seen with higher magnification but also with an obvious three-dimensional appearance.

Abbe’s merit, and the success of his binocular, generated a lot of imitation by other optical companies, and the large variety of different constructions made before 1908 has never been repeated. All models of that period not originating from Jena are easily recognised: their objectives are not farther apart than the oculars, in order that they should not infringe the Zeiss patent. This development, however, leads naturally into another direction: opticians looked for other prismatic systems to circumvent the Zeiss patent.

During the further development of the binocular in a few words? Depending on one’s point of view one will either see a succession of detailed improvements or alternatively a variety of significant inventions. It is a fact that a 90 year old prismatic binocular in good condition (or overhauled by an expert) can still cause surprise by its excellent optical quality, and certainly cannot be regarded as obsolete.

In the years following the expiration of the Zeiss Feldstecher relate primarily to the optics. Models with larger objectives were built to give a higher luminosity. About 1905 the first 6 x 30 model was produced: a popular design giving a good combination of magnification and objective diameter. The first 7 x 50 Porro I model was sold in 1910, a typical nightglass, still essential for the modern mariner or hunter. In nearly unchanged shape this model has been built for more than 80 years.

During the further development of the binocular special attention was directed to the field of view - every observer was interested in obtaining a wider area. From the first models with a subjective viewing angle of 36 degrees this angle was increased to more than 80 degrees (Model Deltar, 1923). The demand for a wide-angle binocular originated from the military, for in World War I binoculars of this kind were urgently needed to detect attacking aircraft. Additional developments were directed to the design of binoculars that could be used while wearing a gas mask. When using binoculars today few are aware that the intentions which led to the development of the binocular in a few words? Depending on one’s point of view one will either see a succession of detailed improvements or alternatively a variety of significant inventions. It is a fact that a 90 year old prismatic binocular in good condition (or overhauled by an expert) can still cause surprise by its excellent optical quality, and certainly cannot be regarded as obsolete.

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important improvements in the optics were by no means for peaceful purposes!

In Great Britain a new development for binoculars was invented and introduced. By cementing together the prisms and one of the ocular lenses, models with only three optical elements in each side were produced: objective, prism unit with field lens, and ocular lens. In comparison with the usual models these have a higher luminosity because less light is lost by reflection. In Germany too, this concept was also used, but meanwhile a completely different principle to enhance image luminosity was being developed in Jena.

In 1936 "coating" was invented, an anti-reflection layer that covered the surface of the optical elements. With this invention the luminosity of optical instruments was greatly enhanced, and initially the new development was treated as a military secret. However, the invention was neither secret nor restricted to Jena or Germany: some years later in World War II the Allies were in possession of (military) coated optics too.

With the introduction of wide-angle oculars and coated optics the standard binocular had achieved its most important improvements.

As early as World War I special naval binoculars were introduced, characterised by a typical form containing a prism system described by Abbe and before that by Porro. It is known today as the Porro II prism system (Fig. 6). These navy binoculars were in production until World War II, and even today are regarded as superb in form and performance. For a small circle of interested people they are valuable collectors items. It is, however, not the rarity which is fascinating - it is the superior optical quality. In Germany, with its highly developed optical industry, models like these were produced on the principle: "cost irrelevant". In connection with high class binoculars one thinks automatically of the U-boat night glasses of the last World War, which can be regarded, correctly, as outstanding even today (Fig.7).

With the marine glasses of the 1930s and 40s binoculars reached a summit in their long development, for they can no longer compete in some military areas. Radar, with its inherent advantages, replaces visual techniques more and more. In WWII infrared viewers could observe in complete darkness. A new pathway had been started, leading to image amplifiers and thermal viewers, which remains in active development. Ordinary optics, with their restriction to the visible part of the spectrum, are being more and more replaced by electronic images and computer processing. Nevertheless, binoculars in the form created by Ernst Abbe 100 years ago are still irreplaceable for many military applications.

The value of use and the sum of all the benefits, however, cannot explain the fascination of a good binocular, as clear today as 100 years ago. In an old catalogue there is a statement to be found - and nothing needs to be added: "A binocular cannot only become part of the eyes, it can become a part of the heart too".

References


Acknowledgments

I should like to dedicate this paper to my friend Arthur Frank of Jersey (formerly Glasgow) who, over many years, has done so much for the collection and preservation of optical instruments of all kinds.

I must also thank Kevin Crowley and Peter Lamb for their assistance with the English text.

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A couple of years ago my friend Fausto Casi of Arezzo, a well-known Italian dealer and collector of scientific instruments and wireless apparatus, showed me a very strange device. I studied it carefully, but was unable to make an identification although I had a vague idea that it could have been an uncommon railroad surveying apparatus. I was given a few photographs, but then forgot about it. However, a few months ago I was looking for an article and purely by chance (this happens quite often!) I found a description of the strange device.

The 'macchina iconografica e ortografica' is in fact a surveying instrument to be used in catacombs. Its inventor was the Roman meteorologist, mineralogist and geologist Michele Stefano De Rossi (1834–1898). De Rossi, who was a university professor in Rome, wrote several scientific articles and invented a few seismic instruments (seismograph, tremitoscope, seismic microphone). With his brother Giovanni Battista De Rossi (1822–1894), a famous archaeologist, he studied the geology and architecture of the Roman catacombs. During these explorations underground M.G. De Rossi experienced considerable problems in surveying, and he wrote:

"I desired to overcome all the above-mentioned difficulties by means of a machine which, if not more precise than the usual methods, could at least accelerate them and reduce the long uncomfortable periods required in these dark, humid, narrow places full of litter. I therefore tried to devise a mechanical system so that, during the measurement of the dimensions and angles of the underground passages, all these would automatically be drawn in a desired reduced proportion on a sheet of paper, simultaneously with the vertical profile of the ground."

De Rossi was quite ambitious, and only thanks to a series of complicatissimi esperimenti carried out with the Roman instrument maker Ermanno Brassart was he able to realise the desired equipment. Ermanno Brassart was one of the most important Italian instrument makers of the time. He specialized in meteorological and seismic instruments, and constructed Secchi's famous 'meteorograph'.

De Rossi successfully presented his instrument at the 1862 Universal Exhibition in London. At the 1865 Dublin Exhibition he won an award for his map of the 'Callisto' catacomb obtained with its aid. In 1867 he received a silver medal at the Paris Universal Exhibition. A detailed description would be too long for this paper (De Rossi required 15 printed pages!) so I will simply attempt to summarise the construction and application of the instrument.

a) Basic mechanics (Fig.1)

The apparatus is built around a box-like brass frame (340 x 115 x 250 mm) bearing on its upper face a wooden table (partially covered with sandpaper) sliding on two guide-rails. Above this table a long curved arm attached to the frame supports a magnetic compass, an alidade, and a rolling carriage with two steel writing stylus. Beneath it, a fine-thread screw rotates along the long axis of the box-frame, and is fixed to a triple-grooved pulley at one end. A continuous loop of silk ribbon is led over any chosen groove, thereby rotating the pulley as it is pulled through. The wooden table is connected to the screw by a protruding threaded bracket, so that any rotation of the former produces a horizontal displacement in the direction of the rails. A folding metal arm, fixed to the frame, allows the instrument to be maintained at a fixed distance from the wall of the catacomb when held by the wooden handle shown in Fig.1. (This handle is missing from the instrument owned by Casi: the wooden stand in Fig.2 is a modern replacement.)

b) Mapping the catacombs

A sheet of lined paper is put on the table after raising the carriage with a special lever. The lines of the paper have to be oriented parallel with the magnetic needle of the compass. The paper is held in place by the pressure of the rollers when the carriage is released.

The handle of the instrument is then held by the surveyor in his right hand, whilst with his left he takes hold of the loop of silk. Finally, after having determined a reference point in the underground corridor, he begins to walk slowly forward, pulling through the ribbon as he does so. This operation has to be done in such a way that the length of ribbon drawn through the apparatus exactly corresponds to the distance covered. The rotation of the pulley and screw will then traverse the table between the guide-rails by a proportional amount. Because of the friction with the sandpaper the sheet of paper will move with it beneath the rollers of the carriage, whilst the two stylus draw a double line. The separation between these two points may be adjusted to correspond in scale with the width of the passage in the catacomb.

When the surveyor has to turn because of an angle in the passage a special mechanism allows the paper to be rotated through the same angle without translation. The reference direction is maintained by the compass needle after rotation, the grid lines on the paper must again be parallel with the needle. The operator then proceeds in the new direction, drawing through the ribbon
as before, until a suitable length of passage has been delineated. The reference point designated by a weight incorporating a loop through which the ribbon runs is then transferred, and the survey continued until the map of the catacomb is complete.

c) Levelling

This operation can be conducted simultaneously with the previous technique, which produces a plan. To do this, a special alidade is fitted to the side of the instrument with two screws. A slider moves freely along a longitudinal slit on this component, but is constrained in a vertical direction by a column connected to the fine screw mentioned above. The slider holds a pen which can trace a line on a piece of paper fixed vertically on this side of the instrument.

The apparatus is supported on a small table or tripod at a position A (Fig.1), and adjusted to the horizontal with a built-in plumb line. A target is set at a convenient distance away and at the same height from the floor of the tunnel (position B). The alidade is then sighted and fixed along the imaginary line connecting the instrument and the target. Subsequently, when moving from A to B in the manner outlined above, the pen traces a line on the paper with an inclination corresponding to the angle existing between the horizontal and the line A-B. This operation is then repeated with the target set in a new position C.

When it was not necessary to map a catacomb, but only to level it, then the procedure described in (b) could also be adapted for this purpose. The instrument had to be rotated through 90° in such a way that the sheet of paper beneath the carriage was set in a vertical plane and the axis of the micrometer screw was parallel to the imaginary line connecting the two points to be levelled. Subsequent operations were then analogous to (b), but instead of rotating the paper to align its grid lines with the magnetic compass they would be adjusted to be parallel with the direction indicated by the plumb bob.

d) Practicability

The instrument belonging to Fausto Casi is (apart from its handle) in perfect condition, and fits in a beautiful leather case lined with red velvet. It is slightly different from the drawings in De Rossi's article, and is not signed. It probably represents an improved version of the original.

A few times I held the instrument in my hand: it was very solidly made and quite heavy. I have not yet tried to use it according to the instructions of the inventor, but he seems to me to have been over-optimistic when claiming that it was very easy and practicable to use. I suggest that, because of its weight and the complicated manipulation required, it was never popular. (Otherwise it would have become better known for surveying in mines or towns – possible applications suggested by De Rossi.) And, even if it could have been operated fast and efficiently, surveyors tend to be very orthodox and conservative in their choice of instruments. De Rossi's machine was probably considered as nothing more than a curious contraption invented by an 'academic'. In fact, the instrument in the possession of Signor Casi is the only one I have ever seen, and I am curious to know if any SIS member has ever heard of it before.

Notes and references

1. M.S De Rossi, 'Dell 'ampiezza delle romane catacombe e d'una macchina iconografica e ortografica per rilevarne le piane e i livelli', Atti dell'Accademia Pontificia de' Nuovi Lincei, 13 (1859-1860) 373-411.


4. In fact, De Rossi used a sheet of paper covered by a second sheet of carbon paper. With this system it was possible to use steel points as styli: they traced finer lines than a pencil, and did not need continual resharpeming.

5. Each groove of the pulley produces a different rate of rotation of the 0.25 mm pitch screw. With the largest pulley the drawing scale is 1:500, 1 metre of unrolled ribbon producing a line 2 mm long on the paper.

6. It is also possible to use only one tracing point when, for example, it is required to plot only the middle axis of the passage or only one of its walls.

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A Panoramic Teleidoscope

David L. Hirsch

Can an engineer schooled in the disciplines of contemporary technology 'retreat' to the time of Sir David Brewster? To that end, an exercise in historical technology was proposed. The objective was to design and construct a version of an early scientific instrument with some specific function. The task would be daunting save for one concession: the use of modern hand and power tools for working the wood and metal parts. After consulting books and catalogues on scientific antiquaria, the subject selected was the kaleidoscope. Essentially a recreational curiosity in Brewster's time, the kaleidoscope serves the same purpose today, although practical applications have appeared. Textile designers, for example, have created cloth patterns inspired by the diversity of images that can be generated by the instrument.

Much to the credit of Sir David Brewster and his early nineteenth century work with the generation of multiple images, there is today a resurgence in the popularity of kaleidoscopes. Contemporary makers still follow the basic rules laid down by Brewster while adding their own innovative enhancements. Such is the case discussed here.

The instrument described in this article is a variation of the kaleidoscope referred to as a teleidoscope. Both instruments are similar in the configuration and arrangement of the mirrors. The principal distinction is based on the type of element used at the 'object' end of the instrument. The teleidoscope may use a rotatable cell containing a mix of colored glass fragments or other items. In place of the cell, another system uses one or more transparent rotating discs with various fragments embedded in them. Additional forms of object systems are limited only by the ingenuity of the maker.

In contrast, the 'object' end of the teleidoscope is fitted with either a sphere or a hemisphere. The element must be transparent and can be clear, colored, or interspersed with various inclusions. The sphere or hemisphere is fixed and cannot be rotated relative to the mirrors. The teleidoscope shown here contains a clear glass hemispheric lens with its plane surface adjacent to the mirror array.

The configuration of the teleidoscope shown in Fig.1. was inspired by microscopes of the eighteenth century. The three turned legs suggest those used on Culpeper or Nuremberg stands, and the base compartment design is based on the work of John Cuff.

The teleidoscope was built mainly of brass and mahogany, two of the materials frequently used in early scientific instruments. The basic kaleidoscope assembly was derived from a kit which consisted of vinyl tubing and end caps, a set of three second-surface mirrors, and an object cell. A plano-convex lens was included for the eyepiece. After discarding the object cell and its contents, the remaining kaleidoscope parts, the plano-convex lens and the hemispheric lens were assembled within a 2" diameter brass body tube. The removable eyepiece cap fitted over the top of the tube gave access to the mirror array, thereby allowing the kaleidoscopic images to be recorded with a camera or camcorder.

A detent ring held to the body tube by three thumb screws serves to limit travel of the tube. A flanged mahogany ring supported by three turned brass legs retains the body tube assembly. Three additional thumb screws bearing against three spring loaded nylon plugs provide smooth, non-slip translation of the body tube assembly within the flanged ring.

The massive pivoted stage turns freely on a sleeve bearing embedded in the top of the base. A cavity in the stage accommodates either a lucite disc or a tiltable double mirror. In the first application, various objects are placed on the disc which is then rotated to produce the kaleidoscopic images. In the second application the lucite disc is removed and replaced with the double mirror. Rotation of the stage then results in a changing panoramic view of objects within sight and in focus, regardless of distance from the hemispheric lens. The stage is rotated by means of a crank and pulley coupled by a belt.

A fitted drawer in the base of the teleidoscope is shown in Fig.2. It is used to store removable stage parts, forceps and other paraphernalia. With the exception of the kaleidoscope kit parts, lenses, brass drawer hardware and screws, all of the wood and metal parts were hand made.

Completion of this project gave a dramatic insight into the problems of construction and function encountered and overcome by the early makers of scientific instruments. Fortunately, the products of their incredible skills and acumen may still be found in museums, private collections and elsewhere as fitting reminders of how and where today's high technology began.

References

2. T Boswell ed., The Kaleidoscope Book (Sterling/Lark, 1992), pp. 1-23

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Fig.1. The panoramic teleidoscope.

Fig.2. Drawer with accessories.
A correspondent in the Netherlands recently acquired the object shown here, which has so far defied all attempts at identification.

The tubular metal body is 183 mm long by 21 mm outside diameter, and may be closed by two screwcaps. One bears a small central hole, the other a hole and radial slit. A square aperture enables the main body to be mounted (as shown) upon a smaller stainless steel tube provided with a 'corkscrew' thread at the other end. A rod, calibrated non-linearly from 7 - 66, may be passed through a spring-loaded matching hole in a scale fixed to the side of the main body. This scale is graduated linearly from the hole as the origin, up to 18 on the left and 48 on the right. An associated component resembling a tent-peg has been placed on the supporting plinth.

The correspondent notes that when the side tube has been fitted (as here) it is no longer possible to see along the axis of the main tube via the holes in the screwcaps.

Mystery Object Identified

The mystery instrument illustrated in Bulletin 36 is a trocheameter or carriage waywiser. It was attached to the wheel of a carriage to indicate the number of revolutions during a journey. The distance travelled was then determined by calculation, as can be seen from the instruction leaflet published by Francis West (fl.1829-48) who was at this address from 1844.

Peter Delehar

Editor's Note

The same identification has been made by David Coffeen.
The History Of The 'Avometer'

Based on material prepared by R P Hawes, AVO International, Archcliffe Road, Dover, Kent CT17 9EN

Introduction

The 'Avometer' has been in continuous production since 1923 and, in its various models and types, is regarded with affection and nostalgia by several generations of scientists and engineers. This provides a remarkable opportunity to study the evolution of a scientific instrument through 70 years of commercial development.

Invention

The Avometer was invented by Donald Macadie, a Scot born in Edinburgh in the 1880s. Early in 1900 he joined the GPO as an engineer, and remained with them throughout his working life, retiring in 1946. He died in 1952, secure in the knowledge of the mark he had left upon the world of electrical measurement.

Macadie devised the Avometer because he grew tired of carrying around a variety of test meters for use in his work. He felt that, with careful design, a single meter could be made to serve the bulk of everyday measurements of current, voltage and resistance, and yet be portable, rugged, and essentially foolproof. Approaching this aim in the early 1920s, he patented the resulting multi-range instrument under the trade mark 'Avometer' (Amps, Volts, Ohms meter). He had previously designed and patented a very successful automatic coil winder, and was permitted to licence both inventions for commercial production whilst remaining a member of the Post Office engineering staff.

The first Avometer (1923)

The Automatic Coil Winder Company of Rochester Row, London, was making the Macadie/Douglas coil winding machines, so it was natural that they should also take up the new multimeter. The first commercial AVOMETER was produced in 1923 (Figs. 1 and 2) and was a simple dc instrument. (See Table 1 for characteristics of this and succeeding models.) The prototype incorporated a high-quality well-damped moving-coil meter and a knife-edge pointer moving over a 5 inch scale with anti-parallax mirror, all protected by a kidney-shaped window set in a robust rectangular case. Interlocked click-stop rotary switches enabled function and range to be changed without disturbance of the live test leads. These characteristics have remained distinguishing features of all 'Avos' ever since.

The instrument soon became very popular, creating a large demand. The Automatic Coilwinder and Electrical Equipment Co. Ltd., as it then became, expanded into larger premises in Douglas Street, London SW1.

The DC Avometer (1927)

With increasing sales and widening applications in the growing electrical industry some design changes and improvements were made: from these sprung the DC AVOMETER as it came to be called. The meter sensitivity was doubled to 6 mA full scale deflection (fsd), and a fuse was included to protect the meter winding. A + 2 button was introduced in 1931; this device enabled the voltage and current ranges to be doubled.

At about this period the Company acquired additional premises in Vauxhall Bridge Road.

The Universal Avometer (1933)

By this time a need had developed for a multimeter that could make ac measurements, and in 1933 the 20 range UNIVERSAL AVOMETER was announced.

34 and 36 range Universal Avometers (1934 and 1935)

These appeared in successive years, and enjoyed considerable success, but their replacement proved even better.

The Model 7 Avometer (1936)

The Model 7 UNIVERSAL AVOMETER came on the market in 1936, and rapidly established itself as a leader in its field. It was scaled differently to previous models: all the early Avometers had been scaled 0 - 120 as the basic scale, but the new instrument used a scale of 100 with decimal range-changing. A 0 - 400 scale was also provided. The basic meter movement was upgraded to 1 mA fsd, achieved with an improved jewel suspension (Fig.3). To accommodate the + 2 feature its sensitivity was shunted to 2 mA fsd. Another advance was an

Fig.1 The first Avometer, 1923. It retailed for £12.12.0.

Fig.2 Cover of instruction booklet provided with the first Avometer.

Fig.3 Diagram of construction of the spring-loaded jewelled pivots for the moving coil of the analogue meter.

* This is a rather confusing nomenclature. When depressed, the sensitivity of the meter was temporarily halved to 12 mA by a shunt, so any figure indicated by the needle against the scale had to be doubled. Such a button would probably be labelled 'x2' nowadays.
Fig. 4 The overload cut-out mechanism.

automatic cut-out fitted in place of the fuse. Shown diagrammatically in Fig. 4, this mechanism was actuated by the acceleration of the pointer, not by its going off the end of the scale. On excessive overloads it was claimed the circuit could be broken before the needle had traversed even a third of that distance. When the fault had been corrected connection could be quickly restored (again without disturbing the test leads or exposing the interior of the instrument) by simply pressing the released reset button down to its normal position. The ac scale was reasonably accurate up to 10 kHz.

Capacity, power and decibel scales for ac measurements were added in the Mark II version (Fig. 5).

**Avominor models (1934 and 1936)**

These smaller instruments were aimed at the thriving amateur radio constructor market. The DC AVOMINOR came first in 1934, but was replaced by a universal ac/dc version in 1936. Unique in design, both were accurate, but were more restricted in range than the standard Avometers. Ranges were selected by plugging the test leads into appropriate sockets.

**Model 40 Avometer (1940)**

However, the electrical power industry required a capability of 480 and 1200 volts full scale; ranges not available on the Model 7. To meet this need the 36 range multimeter was upgraded. It was ideally suited to measuring three-phase voltages, and the lower sensitivity was not a disadvantage. It was marketed in 1940 (Fig. 6).

**The war years**

This period saw large production of Avometers, mainly the Model 7, Model 40 and Universal Avominor, with many going to the Forces. These came from the factory in Douglas Street as well as a smaller factory in Islington, with a warehouse at Stansted in Essex.

**Avometers HRM and HR2 (1946)**

These were introduced to make use of the new alloys then becoming available for the construction of permanent magnets, such as ‘Alnico’ (an alloy of aluminium, nickel and cobalt). The instruments retained a basic resemblance to their predecessors, but the + 2 button was replaced by a REV.M.C. switch, this spring-loaded push-button simply reversed the connections to the moving coil movement, and hence its direction of deflection. The objective was to save the time and hazard involved in changing over the test lead clips on a live circuit. These instruments had the 20 kΩ/V sensitivity on dc required for electronic work, but unfortunately had little sensitivity on ac. AC current ranges were therefore not provided. This soon led to the introduction of the Model 8.

**Model 8, mark I (1948)**

This new multimeter created a profound impression among technicians concerned with the electrical, television and radio service trade as well as in manufacturing, and soon replaced the HRM and HR2 models.

The much-missed ac current ranges were restored, and an ac sensitivity of 1 kΩ/V achieved - at that time an extremely good figure. The dc sensitivity remained at 20 kΩ/V, an artificially aged Alnico magnet being used in the movement. Scales of 0-100 and 0-25 were provided. Accuracy was 2%, using cracked carbon resistors. Every meter was individually hand calibrated, when an accuracy of 1% could be obtained, but this figure could not be held over long periods of heavy use so a lower accuracy was claimed.

In the absence of a + 2 button the maximum measurable current was 10 A; the maximum switched voltage was 1000 V. However, by transferring the negative test lead to an alternative socket, up to 2500 V ac or dc could be measured. Like the Model 7, the Model 8 used the automatic cut-out to protect the movement against overload.

**Models 7 mark II and 40 mark II (1956)**

Making use of improved magnetic materials, mark II versions of the Model 7 and Model 40 were introduced. The new Model 7 retained the + 2 facility, but now had sockets for power factor and wattage measurements on ac. Both instruments had 500 Ω/V sensitivity on ac.

**Model 8, marks II, III and IV (1956 - 1972)**

The excellent design and reputation of the Model 8 meant that only comparatively small improvements were possible as new components became available. In the mark II (Fig. 7) a thermistor aided temperature correction under arduous conditions, and diodes improved the frequency response and incorrect polarity protection in marks III and IV. A fuse was added to the ohms circuit in addition to the mechanical cut-out.

The millionth AVO was produced in 1965, and a new factory built in Dover around the same time. The first digital multimeter was produced there in 1968.
sub-assembly that could be removed for repairs. A new method of making printed shunts was employed, originally conceived in Russia and developed by H W Sullivan Ltd of Dover. This involved the resistor pattern being bonded to a heat-dispersing aluminium substrate, resulting in higher stability, increased ability to withstand overload, and a considerable saving of space. Use was made of flexible printed wiring for interconnecting the sub- assemblies. Both switch knobs had a bar pattern moulded into them to make operation easier with gloved hands, and all the labelling used international symbols. The accuracy claimed was 1% on dc and 2% on ac, both at full scale deflection, and 100 mV drop at 50 μA dc for use with external shunts.

Model 8, mark VII (1992)

Comparison of Fig. 9 with Fig. 8 will show that the only external changes after 20 years are deletion of the 3 kV terminals, but addition of fuse protection on all ranges. Sensitivity is 20 kΩ/V dc and 2 kΩ/V ac.

This minimum of change, but continuing sales, are true testimonials to the sound and timeless design of the Model 8. Of course, the parent company now produces a very wide range of test equipment, much of it based on printed and integrated circuits coupled to liquid-crystal digital displays.

Acknowledgements

The assistance given by AVO International through their Publicity Manager, Mrs Valerie Sawers, is gratefully acknowledged. The words AVO, AVOMETER and MULTIMINOR are registered trademarks of AVO International.

References


Editor's comments

1. The phases of invention, commercialisation, acceptance, improvement, mass production and consolidation are clearly evident in the story of the Avometer, as is the competition arising from the emergence of new technologies leading to retrenchment and decline. The name has become synonymous with the multirange meter measuring amps, volts and ohms; and the manufacturers have, quite rightly, done their best to guard and promote it over the years. However, recent decades have seen a struggle to maintain standards, prices and sales in the face of fierce foreign competition and escalating labour costs. It would nowadays be quite impractical to expect individual calibration of every meter on every range. Modern design practice is assembly of a number of prefabricated circuits manufactured to be as identical as possible, with elimination of mechanical components wherever feasible. Thus, the liquid crystal digital display has generally replaced the moving coil meter and, with appropriate range changing, is inherently capable of much greater accuracy and precision.

2. I am very attached to my Model 8 mark II AVO, but must concede that its inability (shared by the latest 1992 model) to check ac currents up to the 13 A nominal limit of the modern square pin outlet is really annoying. I am advised that 'cost and demand' have prevented restoration of the useful + 2 button, but would argue that a limit of 10 A is against the design philosophy that made the instrument such a success, and a symptom of its decline.

3. Some of the data listed in Table 1 are uncertain, for the original manufacturers have been absorbed into multi-national organisations over the years, and the current makers no longer possess the relevant records. We should, therefore, be interested to hear from anyone in possession of a working Avometer dating from before 1936 – especially an owner of the 1923 ancestor.
Fig. 8  Model 8 mark V Ammeter (1972).

Fig. 9  Model 8 mark VII Ammeter (1992). It retails for £286.
<table>
<thead>
<tr>
<th>Model</th>
<th>Year</th>
<th>Sensitivity (fSD)</th>
<th>Switched ranges</th>
<th>Notes</th>
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<td>34 range</td>
<td>1934</td>
<td>6 mA</td>
<td>dc volts: 1200, 120, 12, 1.2 V, 120 mV</td>
<td>+ 2 button added.</td>
</tr>
<tr>
<td>Universal</td>
<td></td>
<td></td>
<td>doubled volts and amps ranges</td>
<td></td>
</tr>
<tr>
<td>36 range</td>
<td>1935</td>
<td></td>
<td>as above, plus 480 V dc</td>
<td></td>
</tr>
<tr>
<td>Avominor (dc)</td>
<td>1934</td>
<td>1.67 mA</td>
<td>dc volts: 500, 250, 100, 25, 5</td>
<td></td>
</tr>
<tr>
<td>Model 7</td>
<td>1936</td>
<td>1 mA</td>
<td>dc volts: 1000, 400, 100, 10, 1 V, 100 mV</td>
<td>Decimalised, with scales of 0-100 and 0-400</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>doubled when + 2 button pressed</td>
<td>Auto cut-out replaces fuse</td>
</tr>
<tr>
<td>Mark II</td>
<td></td>
<td></td>
<td>capacitance: 0.01 to 20 μF</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>decibels: -10 to +15 dB</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>power: 1mW to 4W</td>
<td></td>
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<tr>
<td>Model 40</td>
<td>1940</td>
<td>6 mA</td>
<td>dc volts: 1200, 480, 120, 12, 1.2V, 120 mV</td>
<td>Based on 36 range model</td>
</tr>
<tr>
<td>HRM HR2</td>
<td>1946</td>
<td>20kΩ/V dc (50μA fSD)</td>
<td>dc volts: 2500, 1000, 250, 100, 25, 10, 2.5 V</td>
<td></td>
</tr>
<tr>
<td>Model 8</td>
<td></td>
<td></td>
<td>doubled with + 2 button replaced by meter reverse press button</td>
<td></td>
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<tr>
<td>Mark II</td>
<td>1956</td>
<td></td>
<td>decibel scale added</td>
<td></td>
</tr>
<tr>
<td>Mark III</td>
<td>1965</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mark IV</td>
<td>1970</td>
<td>20kΩ/V dc</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mark V</td>
<td>1972</td>
<td>2kΩ/V ac</td>
<td></td>
<td></td>
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<tr>
<td>Mark VI</td>
<td>1984</td>
<td></td>
<td>as mark V, except 3 kV omitted and 100 mV dc added</td>
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<tr>
<td>Mark VII</td>
<td>1992</td>
<td></td>
<td>as mark VI</td>
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Compasses and Colophons

David J Boullin

The article by Bernard Edwards entitled Scientific Bookplates reminds me of the importance of early printed books in the portrayal of scientific instruments. Particularly in sixteenth and seventeenth century books the textual illustrations and publishers colophons or 'printers marks' sometimes show scientific instruments even when the subject matter of the books is not scientific.

The prime example of the scientific colophon comes from the printing house founded in Antwerp by Christopher Plantin and known as Plantin-Moretus. This firm was founded in about 1553, and produced printed books continuously until the late eighteenth century. The premises remained within the family and were purchased by the City of Antwerp in 1576, subsequently being turned into a printing-house museum that should be visited by anyone interested in the history of scientific printing and bookbinding. (In the Friday-Market, Antwerp; open daily except Mondays).

My illustration (Fig.1) shows the firm's colophon of a pair of compasses, first used in 1557. The design of the compasses varied with the years; in 1564/5 simple compasses were shown with a hand scribing a circle, (Fig.1, left); in 1573 the compasses were more decorated and interesting backgrounds appeared, notably of Antwerp, the home of Plantin-Moretus, (Fig.1, top). Finally we come to the compass colophon designed by Peter Paul Rubens (Fig.1, bottom). Rubens made 2253 works of art plus 484 drawings, and some of these include scientific instruments.

It is little known that the painter Peter Paul Rubens (1577-1640) worked as a book engraver for the house of Plantin-Moretus from 1605 until 1640, the year of his death. The first engraving he made of the compass colophon was for his brother Philip's book Electorum Libri published in 1608, three years before the latter's death. This colophon is the one illustrated in Fig.1, top. Of course, the compass was a popular symbol in the sixteenth century and was used by many artists, including Albrecht Dürer, but the magnificent colophon designed by the master artist formed the basis for all subsequent compass colophons used by the Plantin-Moretus printing house, and became world renowned.

No illustration of compasses links printing and illustrations of scientific instruments instruments better than my Fig.2, which shows Gerard Mercator holding a pair of compasses on what must undoubtedly be one of his own globes. Although this engraving appeared in a book by J. J. Boissardus (Iconum Viror Virtute atque Eruditione Illustris Repraesent), engraved by Bry Leod and published in Frankfurt in 1599) Mercator was intimately associated with Christopher Plantin and Antwerp.

Plantin was not only a master printer but continued his business in the retail trade which had sustained him in his early years when times were hard. This trade linked him closely with some of the most noted scientists, including Gerard Mercator. He sold all kinds of things from ladies gloves to maps,
The upper part of the frontispiece to an atlas published by Ioannes Jansson, Amsterdam, 1653: globes, armillary and a cross-staff are to be seen.

Fig. 4

Between 1559 and 1573 Plantin supplied Mercator with the paper for his maps and globes. Interestingly, astrolabes in Antwerp at that time (viz 1568) were only about one third of the price commanded in Spain. Christopher Plantin published Mercator’s map of Europe in 1572, but never printed any of Mercator’s atlases. The English edition of Mercator’s atlas, published in 1612, shows compasses, an armillary and two cross staffs, one in use (Fig. 3.). Christopher Plantin printed 1887 books between 1553 and 1589. Although the majority were theological 147 were scientific, including 55 relating to geography, 33 to astronomy and astrology, 28 to the natural sciences, and 22 to botany plus a smaller number of medical works. Thus the works published by the Plantin-Moretus printing house may serve as a fruitful source of illustrations of scientific instruments.

However, I should not like to give the impression that illustrations of scientific instruments are confined to scientific books, or that Plantin-Moretus was the only (or even the major) printer who used engravings of scientific instruments in their productions.

I have searched many 16th and 17th century books for illustrations of scientific instruments and, apart from being rather extensively found in geographical atlases, they are quite rare, even when the text is scientific. Indeed they are just as likely to be found in religious works. Due to shortage of space I can only give some isolated examples here.

The illustrations of scientific instruments in early atlases may be found in the publisher’s colophon as well as in cartouches on the maps themselves. Thus, Ioannes Jansson, Amsterdam, was a prolific cartographer and published many maps and atlases. Fig. 4 shows the upper part of the frontispiece to an atlas published in 1653; we see an armillary in the centre, globes to left and right, and a figure...
using a cross-staff to the left of the right hand globe.

Other examples from the same publishing house are from cartouches: Fig. 5, top, is from a map of the Loire Valley with putti holding a surveyor's chain, compasses and cross-staff, with an armillary in the centre.

Fig. 5, lower, is from a map of Gascony. I do not know the nature of the instrument which the man on the left is aligning with the sun's rays. This cartouche also illustrates a Holland circle, surveyor's chain, mariner's astrolabe, celestial globe (on the far left) and another armillary. In Fig. 6, from a map of Bermuda by Joannes Jansson, we have navigator's equipment including dividers, lead lines and a sandglass.

Probably the book with the most comprehensive representations of scientific instruments is Lucas Janszoon Wagenaer van Enckhuysen's maritime atlas *Eerste van de Spiegel de Zeearant*, published by Christopher Plantin from Leiden in 1584. This was one of the most important mariner's sea-manuals ever printed: a Privy Council-approved English edition appeared in 1588. My Fig. 7 shows the title page to the original Dutch edition; nine (or possibly ten) navigational instruments are shown as follows: (starting top left), 1, quadrant; 2, celestial globe; 3, centre, possibly a burning glass or lens; 4, terrestrial globe; 5, mariner's astrolabe; 6, sandglass; 7, cross-staff; 8, plumb line; 9, dividing compass; 10, mariner's compass.

Finally, I have some illustrations from non-scientific publications. The following are all from a history of the Jesuits, published by Plantin-Moretus in 1640: each instrument is set in the highly decorative surround that is typical of the highest standards of printing exercised in the sixteenth and seventeenth centuries.

In Fig. 8 are two timekeepers: a weight-driven wall clock with verge and a vertical sundial. The Roman numerals on the horns or antlers surrounding the dial appear to indicate the time at places distant from the meridian for which the dial is calibrated (probably Antwerp).

Fig. 9 (upper) shows an apothecary in his shop using a large pestle and mortar, with many fine jars in the background. The lower illustration is one of the many fanciful views of Archimedes using a concave mirror to set fire to the Roman ships at the siege of Syracuse.

The essential point I wish to make is that pictures of scientific instruments may be found disseminated in old books with apparently unconnected titles: there is much material for fruitful research.

**Acknowledgments**

It is a pleasure to thank Stephen Gregory, the Librarian of Sion College, John Carpenter Street, Victoria Embankment, London EC4Y 0DN, for provision of facilities and for permission to reproduce the illustrations shown here.

**References**


3. Christopher Plantin, Cassell: London, 1960. For general references concerning Rubens see chap. 13, in particular the following: 'The genius of Rubens was constrained to trans late in his frontispieces the content of heavy and arid theological treatises which have today lost all their interest, and whose only value now lies in the fact that the great master of Flemish Baroque deigned to illustrate them' (p 228).


Author's address: 19 Woodstock Road Witney Oxon OX8 6EB
Market Place

Arthur Middleton

Quatrain XXIII  "Ah, make the most of what we yet may spend.
Before we too into the Dust descend;
Dust into Dust, and under Dust, to lie,
Sans Wine, sans Song, sans Singer, and - sans End!"

Quatrain XXIV  "Alike for those who for To-day prepare,
And those that after a To-morrow stare.
A Muezzin from the Tower of Darkness cries
"Fools! your Reward is neither Here nor There!"


This time, the narrative begins in the Far East.

Did you know that there is no such person as a Japanese auctioneer? Or, until recently, no such thing there as a public auction sale? The whole idea and concept is completely unknown and alien to them. It was therefore with some trepidation that a major London auction house decided last year to mount a sale in Tokyo. To take it, they flew out one of their top men. As he climbed on to the rostrum he was greeted by a packed roomfull of 180 registered bidders, all talking to each other. As he announced Lot One. 180 paddles shot into the air. As he tried to sort them out, the hubbub started again and he rapped with his gavel for silence. 179 of the Japanese thought that he was actually selling the thing - it was, after all, the first time any of them had ever been to a sale - and pandemonium broke out as they believed they had missed it, and lots 2, 3, 4, 5, 6 and 7 as well. It took an interpreter a few minutes to calm everyone down.

It was not the first sale ever held there. One or two of the better Parisian auctioneers have tried, with a fair degree of success, holding a sale of Impressionist paintings at the Hotel Georges V with a satellite television link to another room in Tokyo, with bidding going on in both places. The time difference was convenient, 10.30am in Europe being 7.30pm in Japan. Two years ago Messrs. Ader, Picard and Tajan took an entire art nouveau sale to Japan, where they considered the market was strongest for such items. It was a runaway success and the best items made very high prices, one man buying them on behalf of a private and anonymous collector. The Frenchmen flew home feeling very satisfied. The euphoria evaporated as the weeks passed and no money arrived. Months went by and despite urgent faxes, still nothing. Eventually the buyer informed them that because his private collector had suffered a large loss on the Stock Exchange he was no longer interested in the goods and they would have to regard the sale as annulled. The auctioneers were increasingly concerned, for they knew that while there was no Japanese Law governing their activities, they were still operating under French Law, whether the sale was held in Tokyo or Timbuctoo. One clause makes them - and any French auctioneer - ultimately responsible for paying the vendor, and in this case they were two million pounds short, the vendor had already commenced legal proceedings, and they were going to lose. The eventual bill, counting two years interest and legal fees, was nearer £2½ million. They had only one recourse, and that was to hastily arrange the sale and lease-back of their pleasant 19th-century building in central Paris. Meanwhile, the unsold items had been returned and stored in a bank vault in Switzerland, where they remain to this day. Technically they now belong to Messrs. Ader and Tajan (M. Picard having moved off to start his own business) but during the elapsed time the market in such things has fallen drastically, and a resale now would show a large loss. They may have to wait some years for the market to rise again - if it ever does.

This is another law which will be binding on the English auction houses when they start selling in France. Has anyone told them about it? Apparently not. The lady in Sotheby's Press Office is getting a little weary of my telephone calls: "No, I don't know... and I really can't tell you when sales will begin there (and now passes the buck and rapidly signs off)... why don't you ask our office there? I'm sure they'll know more". Five minutes later the buck is returned equally fast: "Ah, non, Monsieur, il faut demander à Londres." Christies are content to play a waiting game, and so on this particular subject there is nothing further to report.

The Hotel Drouot, where practically all Parisian sales are held, is by now universally disliked: it is overcrowded, cramped and stuffy. Some of the major sales of expensive furniture and paintings are held in the more genteel atmosphere of the Hotel Georges V (where kitchens were described in such graphic and unhygienic detail by George Orwell in his 1920s classic Down and Out in Paris and London). There is sufficient demand for another sale-room in Paris, and now Bernhard Steinitz has come up with a proposal for one in St. Ouen. You will remember that I described in my last article (Bulletin no. 35, Dec. 1992) how his idea for a luxury hotel had run into a little local difficulty with the planning authorities, who preferred to see cheap housing for their impoverished immigrants. Mr. Steinitz, as an alternative, has plans for a "super-Drouot" where the auction rooms will be large and well supplied with natural daylight - markedly deficient in the present Drouot. This is not a bad idea: there are thousands of dealers in the flea market, and it would be easy to tempt some of the auctioneers from the city centre.

If you are unaware of the way the French do things, this is it: the Hotel Drouot is owned and run by the Compagnie des Commissaires-Priseurs, who rent out the rooms in the building to their members for the viewing and sale days. A small room for two days will cost FF6,000 (2900) but a large double room on the first floor for an important sale with a three day view will cost FF30,000 (4£,000). For this the auctioneer will get the services of some porters and a couple of floor-walkers during the sale itself. The building is thus self-financing, but of course an auctioneer is not bound to use it; he could just as well hold his sale at Mr. Steinitz's new building where the costs would be appreciably lower. I imagine there will be more horse trading before one or other of his schemes is given the go-ahead.

The world-wide operations of Sothebys, including its Bond St. and Billingshurst sale-rooms, has now
Fig.1  Front and rear faces of a nasaicula sundial sold at Sotheby's on 25th February 1993. It is slightly larger than the Greenwich example.

been taken over by an American lady, Diana Brooks. She flew into London in April to take charge of her new fief and was described at the time by Geraldine Norman in *The Independent* as “a sort of brainy Doris Day”. Before she arrived every departmental head was ordered to produce projected figures for the coming year. How absurd! How could they possibly predict in advance what and how much they are going to be given, and how much it will sell for? – it indeed it sells at all! It is quite normal these days for a greedy vendor to play one auction house against the other and to eventually arrive at a “no sale no fee” agreement despite an unrealistically high reserve, although this happens more with highly priced paintings and furniture than the pathetically cheap scientific instruments.

Sotheby's first sale of the year, on the 25th Feb, started with 98 lots of opera glasses and spy glasses, a single-owner collection of gilt brass, tortoiseshell and ivory fit for a boudoir. To the auctioneers relief virtually all these sold, although two hours before the sale there was not a single bid in the book. The rest of the sale was undistinguished except for the consistently high prices made by early 19th century pocket globes (over £2,000 each). The star piece at £36,000 was a rectilinear brass dial in the manner of the “little ships of the Venetians” (Fig.1). This had been catalogued carefully but guardedly as “English, possibly 18th century”. This it was clearly not. It was either 15th century, or an Italian bauble made for a Grand Tourist in the 19th, except that the positive results of the tests at Oxford did not come through until after the catalogue had gone to press. Mme Margharida Archinard flew in with the idea of buying it for the Geneva Science Museum, but was only the under-bidder. By chance Greenwich recently acquired another example, which Dr. Kristen Lippincott wrote up in this journal (No. 35 Dec. 1992).

Pocket globes continued to make news when a rare example by

Fig.2  Small worlds, as dispensed by Bonhams. The little Newton globe at the top is 2" in diameter.
Leonard Cushee sold for £3,200 in an otherwise modest country sale. Cushee only worked from 1759 to 1761, and the colours were so fresh it could hardly have been out of its case. Marked in Africa were the "Zaara Desart", "Abbassina", and "Negroland". In the 5th century BC all this would have been part of the Persian Empire of Xerxes, who, as the Book of Esther tells us, "reigned from India even unto Ethiopia, over an hundred and seven and twenty provinces".

Another pocket globe appeared at Bonhams on 12th March and duly made £2,600. This one was by Dudley Adams - normal enough, but he was using his father's engraved copper plates which he had inherited from his mother, and the geographical detail was long out of date. (Fig.2) This time we had "Barbary", the "Defart of Zara", and the "country of the Cafres". Trevor Phillips competed by telephone from the safety of his hotel bedroom in Switzerland. He was still the under-bidder and would have been better-off staying on the slopes.

Christie's major spring sale took place on the 6th May and attracted a large turnout, and not just because it was 3 days before the next Science Fair or because they held a most hospitable reception the evening beforehand. It was not a marathon, such as the Moscovitz dispersal where your correspondent nodded off and then bought the wrong lot; this was 189 lots of such variety and interest that several buyers commented that "it was the best sale since the 1980's". There were 34 Wheatstone-related items, a fine and rare 18th century concave mirror on a bronze stand, a mid-18th century Lahore astrolabe, (£10,000) a 17th century gunners sector in ivory giving details of shot and powder for Italian, French, Dutch, and English cannon, (£1,600) and a large Smith and Beck microscope with a handwritten note signed by F.H. Wenham himself stating that "...the original binocular arrangement made and fitted by him... these parts being necessarily Detachable having been the first ever adapted". (£9,500) (Fig.3) One of the cleanest examples ever seen of Edward Nairne's chest microscope made a total of £12,000 (Fig.4). The sale was odd in that it seemed to divide between inexpensive and reasonable, or very expensive. The unusually high prices commanded by the top ten items - only two of which could positively be
identified as late 18th century — was due to the determination of two telephone bidders, so much so that Jeremy Collins on his rostrum paid scant attention to the people standing or sitting in front of him. In this case we were superfluous.

The latest Science Fair, number 14, took place on Sunday 9th May. This time the queue at two minutes to ten was satisfactorily long, and by two minutes past ten Peter Delehar had sold his fine example of Wheatstone’s wave machine. He also showed an early electric lathe, of the type first introduced for instrument-making by the French engineer Gustave Froment around 1845. (Fig.5) Rob Robinson from Hamble showed a matching pair of sextant and reflecting circle by Gambey of Paris. The volume of business seemed steady but not dramatic, with an interesting variety of items on display.

I gather that some of my comments about a previous fair were not well received by some exhibitors. Well gentlemen, that’s too bad. I record my own impressions at the time, and afterwards talk to some of the people I know best — not just those with tables but buyers from England and overseas — to try to form an overall picture. If you sold something that you thought was rare and marvellous, then tell me; but don’t complain to Peter Delehar much later, as there is nothing he can then do and you are wasting his time. If the Editor considered my remarks to be unjust, inaccurate, or not in the public interest, then he has every right to delete them. So far he has found no reason to do so.

Finally, the verse from the Rubaiyat that you have been wondering about while reading this article:

"The Moving Finger writes: and, having writ,
Moves on: nor all thy Piety nor Wit
Shall lure it back to cancel half a Line,
Nor all thy Tears wash out a Word of it."

Fig.5  An early electrically-powered lathe, circa 1860, which appeared at the Scientific Instrument Fair on the 9th May.
Current and Future Events

Cambridge, England

Empires of Physics is an important special exhibition now open at the Whipple Museum, Free School Lane, Cambridge CB2 3RH. Arranged on two floors, it explores the relationship between instruments developed in English and German laboratories and their public presentation in international exhibitions at the end of the 19th century. The museum is open Monday to Friday 14:00 to 16:00, admission free.

The museum has also organized a programme of workshops for A level students based on the exhibition. Details from the curator.

Munich, Germany

The new Surveying Gallery is now open in the Deutsches Museum, Museuminsel 1, D-8000 Munich 22, Germany. Situated on the top floor opposite large windows, the astronomical editions to the East and the West are beautifully illuminated and well displayed.

Until 26 September 1993

Museum Boerhaave, Leiden

The travelling astronomer: Dutch astronomical expeditions to the East and the West

Dutch astronomers took their share in the international effort to observe the transits of Venus in 1874 and 1882. The first expedition to Réunion near Madagascar failed owing to weather conditions, but the second one in 1882 to Curaçao in the West Indies was a complete success.

Solar eclipses were another reason for astronomers to travel to distant parts of the globe. To observe these, nineteen Dutch expeditions were organized between 1901 and 1973. Some of the instruments used during these expeditions will be shown at the exhibition.

A touch of the exotic will be added through an evocation of the 1926 eclipse camp on Sumatra in the Dutch East Indies. Visitors may try their skills at a computer-simulated Venus transit. There is a 32-page booklet in Dutch to accompany the exhibition.

For details contact G. Kreeftmeijer, Presentation Department, Museum Boerhaave, PB 11280, 2301 Leiden, the Netherlands.

21–25 June 1993, Chicago

The XV International Conference on the History of Cartography will be organised by the Herman Dunlap Smith Center for the History of Cartography at the Newberry Library, Chicago and the International Society for the History of Cartography. Details from the Center, 60 West Walton Street, Chicago, Illinois 606010, U.S.A.


The Royal Society and the Fourth Dimension: The History of Timekeeping will be the theme of a one day meeting, jointly sponsored by The Royal Society and the Antiquarian Horological Society, to be held at the Royal Society on Friday 25th June 1993. The papers will reflect the role and influence of the Royal Society during the development of precision timekeeping in England from the 17th to the 19th century – from Huygens and Hooke, including the years of the Board of Longitude, through to the culmination of the full development of the marine chronometer by Arnold and Earnshaw. Speakers will include Redney Law, John Leopold, Jonathan Betts, Michael Wright, Andrew King and Derek Houwe.

1993 is also the tercentenary of the birth of John Harrison. Harrison will be the subject of one of the papers being presented. His achievements in the history of timekeeping and navigation will also be demonstrated in the context of several other papers.

It is hoped to mount a small exhibition of manuscripts and artifacts related to the meeting.

For further information, please contact Mrs Sheila Edwards at The Royal Society, 6 Carlton House Terrace, London SW1Y 5AG. Tel No. 071-839 5561, extn 261.

25 June – 10 October 1993, Antwerp

Within the scope of “Antwerp, Cultural Capital of Europe, 1993” an exhibition is to be held in the Hessenhuis entitled Antwerp, Story of a Metropolis (16th-17th centuries).

Eight Antwerp-made scientific instruments will be shown, together with other artifacts from the mid-16th to mid-17th centuries.

26 June 1993, Liverpool

The Newcomen Society is organizing a meeting on the theme Perceptions of Great Engineers: Fact and Fantasy at the Merseyside Maritime Museum. Further details from The Executive Secretary, The Newcomen Society, Science Museum, London SW7 2DD.

7 – 14 July 1993, La Jolla

The Fifth International Congress on the History of Oceanography will mark the founding of Scripps Institution of Oceanography. Details: ICHO V, University of California, San Diego, Office of Conference Manager, Mail Code 0513, 9500 Gilman Drive, La Jolla, CA 92037-0513, U.S.A.

8 July 1993, London

The Scientific Instrument Society will be holding its Annual General Meeting on Thursday 6 July 1993 at 14:00 in the Society of Antiquaries, Burlington House, Piccadilly, London W1. This will be held in conjunction with a meeting at which the following short research papers will be presented:

Alison Morrison-Low, Royal Museum of Scotland

Economies of Scale: Instrument Contracting in Early 19th Century England

John Burnett, Royal Museum of Scotland

How Common were Thermometers in the 18th Century?

Paolo Brenni, Istituto e Museo di Storia della Scienza, Florence

The Discovery and Conservation of Father Secchi’s Meteorografo of 1857

S.R Sarma, Aligarh Muslim University, Aligarh, India

A Survey of Indian Astronomical Instruments

There is no charge to attend this meeting or the AGM, which will follow at 16.30.

9–11 July 1993, Essex

William Gilbert and the Elizabethan World is the topic of a conference jointly organized by the University of Essex and the History Group of the Institute of Physics. Speakers will include Jim Bennett, J.V. Field and Patrick Collinson. Details from Prof. L.J. Jordanova, University of Essex, Wivenhoe Park, Colchester CO4 3AQ.

22–29 August 1993, Zaragoza, Spain

19th International Congress of the History of Science. It is the intention to hold a Scientific Instrument Symposium for one day, on a date to be decided,
during the course of this congress. Details from Mariano Hormigon, Facultad de Ciencias (Mathematicas), Cuidad Universitaria, E-50009, Zaragoza, Spain.


An international conference on the theme of Technological Change will be held at Rhodes House, Oxford, from 8-11 September 1993. The conference, which is organised by the University of Oxford in collaboration with a number of partners, will provide an opportunity for a fundamental re-examination of the state of the discipline of the history of technology in its widest sense. In this respect it deliberately resembles the conference on "Scientific Change" that was held in Oxford in 1961. Details from Professor Robert Fox, Modern History Faculty, Broad Street, Oxford OX1 3BD.

31 October 1993, London

The Fifteenth International Scientific & Medical Instrument Fair will be held on Sunday 31 October 1993 at the Portman Hotel, Portman Square, London W1, 10.00 - 16.30. Details: 081-866 8659.

4-6 November 1993, Cambridge, USA

The Longitude Symposium at Harvard University, Cambridge, Massachusetts, USA will celebrate the tercentenary of the birth of John Harrison. Speakers will include Alan Stimson "Development of instruments for determining direction and distance travelled: latitude, local time and lunar distances"; John Leopold "Christiaan Huygens", Owen Gingerich "Cranks and Opportunists: nutty solutions to the Longitude Problem"; William Andrews "Harrison's early marine timekeepers": Catherine Cardinal "LeRoy and Berthoud" and David Penney "Mudge" etc.

The meeting is being organised by the Collection of Historical Scientific Instruments, Harvard University, in association with the National Association of Watch and Clock Collectors.

For a brochure and registration form write to Will Andrews, The Longitude Symposium, Harvard University, Science Centre B6, Cambridge, Mass 02138, U.S.A.

13 November 1993, London

Science Lecturing in the Eighteenth Century is the subject of a meeting in conjunction with an exhibition at the Science Museum. Details from Dr. Alan Morton, The Science Museum, Exhibition Road, London SW7 2DD.

17 November 1993, London

The Society's first Invitation Lecture will be given by Dr. R.G.W. Anderson, Director of the British Museum, at the Society of Antiquaries, Burlington House, Piccadilly, London W1, 18:30 to 20:30. The title will be: People and Museums: Expectations and Responses. This is a public lecture, and admission is free. Details: Trevor Waterman, Meetings Secretary, 75a Jermyn Street, London SW1Y 6NP.

3 – 6 May 1994, Paris

A number of events have been planned to mark the bicentenary of the execution of Lavoisier on 8 May 1794. Details: Michele Goupil, Secretaire du Comite Bicentenaire Lavoisier, Academie des Sciences, 23 Quai Conti, 75006 Paris, France.

8 May 1994, London

The Sixteenth International Scientific & Medical Instrument Fair will be held on Sunday 8 May 1994 at the Portman Hotel, Portman Square, London W1, 10.00 - 16.30. Details: 081-866 8659.

7–9 Sept. 1994, Leiden

A conference Origins and Evolution of Collecting Scientific Instruments will be held at the Boerhaave Museum in Leiden. Early scientific instruments make up distinct parts of applied arts and science museums. They are objects of interest to collectors, archaeologists and historians alike. Instruments have been included in collections continuously since the Renaissance, but the reasons for their acquisition have changed in response to changing needs and inclinations of the collectors.

From 7 to 9 September 1994, the Museum Boerhaave, the Dutch National Museum of the History of Science and Medicine, will be the venue of a conference devoted to this theme. Some fourteen speakers will address this subject in the general context of collecting as a European phenomenon.

To coincide with the conference, the Museum Boerhaave will mount a special exhibition on collecting scientific instruments.

Offers of papers are being considered. Poster sessions may also be envisaged.
A History of Electric Light and Power
Brian Bowers.
Peter Peregrinus Ltd. in association with
The Science Museum, London. 1991 (soft
back reprint), illus. + 278 pp.

Reviewing this book provides a good
opportunity to take a brief look at the
Institute of Electrical Engineers (IEE)
History of Technology Series of which this
volume is number three, and which is
under the general editorialship of Brian
Bowers.

The series had a rather inauspicious
start in 1979 with P.H. Sydenham’s
Measuring Instruments: Tools of
Knowledge and Control, a fascinating
subject about which the author knows a
great deal, but which was not treated
very successfully. There have been
eighteen volumes to date covering a
wide selection of topics. There is V.J.
Phillips on early radio wave detectors
(no. 2, 1980) which is in many respects a
companion volume to his more recent
history of early oscillographs published
by Adam Hilger (1987); S.S. Swords on
the origins of radar (no. 6, 1986); R.W.
Burns on the formative years of British
television (no. 7, 1986); J.G. O’Hara
and D.W. Pricha on Hertz and the
Maxwellians (no. 8, 1987); P. Povey
and R.A.J. Earl on vintage telephones
(no. 9, 1988) E.B. Callick on wartime radar
magnetrons and other microwave
devices (no. 11, 1990); G. Bussey on
early wireless receivers (no. 13, 1990);
and Paul Tunbridge on Kelvin’s
influence on electrical measurements
and units (no. 18, 1992). R.J. Clayton
and J. Algar have been responsible for
two volumes, no. 14 (1991) on the history
of the GEC Research Laboratories, and
no. 19 (1992) which is a transcript of the
war diary of Sir Clifford Paterson, the first
Director of the same laboratories. Two
volumes were published in 1991 to
celebrate the bicentenary of Faraday’s
birth: nos. 36 and 17 being respectively
Faraday’s Electrician travel diary, edited
by Brian Bowers and L. Symons; and his
chemical notes of 1822, edited by R.D.
Tweezy and D. Gooding.

These topics indicate that the series is a
very mixed bag indeed. In general, it is
good to define the majority of these
varied and technical histories, in which
the authors have concentrated on
published primary technical sources.
For instance, Gordon Bussey’s almost
sole source for the development of early
radio sets was the magazine Wireless
World. Little attention is given to
archival and other documentary
material which would have allowed a
fuller historical assessment. Such
documents would be especially useful
when placing these technical histories in
their social context. The majority have
been written by engineers who have a
specialist interest in that field of the
air subject, and wish to emphasise the
development of the particular technology in
which they are interested. By contrast, most
historians make up in historical skills
what they may lack in technical
expertise. It is salutary to compare the
different perspectives in Paul
Tunbridge’s treatment of Kelvin’s
involvement in electrical measurements
in this series with that by Crosbie Smith
and M. Norton Wise, Energy and Empire.
A Biographical Study of Lord Kelvin

It is unfair to criticise this series for
something it is perhaps not intending to
be, and technical histories can certainly
be a very useful source of information.
In my opinion, the best works in this
series are those by Robert Clayton and
Joan Algar on the GEC Laboratories,
Russell Burns on early television, V.J.
Phillips on radio detectors and S.S.
Swords on the first radars. Several
volumes would be useful for SIS
members interested in identifying and
dating electrical devices, in particular
Vivian Phillip’s on radio detectors,
Brian Callicks on magnetrons and
related devices, and Peter Povey and
Reg Earl’s on vintage telephones.

It is in this context that Brian Bowers’ A
History of Electric Light & Power (the soft
back reprint of the 1982 publication)
should be judged. It is again a useful
technical history in the format
presumably established by him under
his editorialship – his own volume on the
origins of electrical science in the supply
industry and the development of the
main uses of electricity. The book is
divided into four sections: (1) ‘Origins’
The beginning of static and current
electricity, Faraday’s researches, early
telegraphs, electric motors [msprinted
‘meters’ in the Contents list], and
electrical science; (2) ‘Practical
possibilities’ (Early dynamos, arc and
filament lamps); (3) ‘Public supply’
(Early supply schemes, legislation,
power generating stations, metering of
the supply); and finally (4) ‘The
consumer’ (Domestic installations,
lighting, heating, electric motors and
traction). Most chapters are very brief
and to the point, and end with a list of
references. In line with the series
generally there is no separate
bibliography, but there is an index. The
author’s discussion of any possible
social consequences are compressed into
the final chapter of three pages.
Nevertheless, this is a most valuable
summary of the main technical trends
that have taken place in the
development of the electrical supply
industry.

Willem Hackmann,

Science Preserved: A Directory of
Scientific Instruments in
Collections in the United Kingdom
and Eire.
Mary Holbrook, with additions and
revisions by RGW Anderson and DJ Bryden
HMSO 1992, £35
ISBN 0 11 290060 7

This book is described by its publisher
as the Downaday Book of historical
scientific instruments in Britain. Well,
it’s not quite that old – but it has been 25
years in gestation! Also, William would
have grossly undervalued his kingdom
if his survey was as incomplete as this
one, for 6 major collections (the Science,
Wellcome and National Maritime
Museums in London, the National
Museum of Scotland in Edinburgh; and
the University Museums in Oxford and
Cambridge) are merely summarized.

The first 78 of the 271 pages in this long-
awaited production are occupied by a
glossary of instrument types. Clearly
annotated and lavishly illustrated, this
is certainly valuable in its own right –
but is this the place for it? No, it’s not –
but its presence betrays the underlying
problem that afflicts current studies in
this field. Any modern scientist knows
that it would be impossible to list every
type of scientific instrument in Britain
today, so implicitly recognizes that what
is meant are historical scientific
instruments. To most, this conjures up
images of brass and glass, mahogany
and microscopes; others are reminded
of obsolete apparatus quietly corroding
in a basement store. Either way, only a
few want to know more. But does ‘historical’
mean old, beautiful, or an invention
seminal to the progress of science?
Surely it should cover all these
criteria but (as we see here) in practice it
is the early instruments that tend to be
prized and collected. Many are in fact
far from unique, but the appeal (certainly
to private collectors) is, I think,
that the instrument is complete in
itself, represents a satisfying blend of
science, art and craftsmanship, and that
its working and function are understandable to the non-specialist.

After World War I science became
increasingly complex and specialized,
and this is reflected in the associated
instrumentation. An ever-widening
background is necessary to appreciate

Book Reviews
Opinions expressed by reviewers are their own, and do not necessarily reflect the views of the Editor or the Society.
Instruments in Spain

A useful additional reference to our article on scientific instruments in Spain (Bulletin 36, pp.22-24) has just come to my attention. This is:

El Observatorio de Cádiz 1753 - 1831
A. Lafuente and M. Selles

Jane Insley
Curator, Environmental Sciences
Science Museum
London SW7 2DD

Tachémètre Moinot-Richer

Referring to my letter in Bulletin 36 (p.37) I should like to inform members that, thanks to this English-language publication and the help of German and Dutch connoisseurs, my French theodolite can now be completely restored.

John B. de Pas
Jan Ligthartplein 36
3706 VD Zeist
Holland

Origin of the term 'scientific instrument'

Several years ago, in an essay review entitled 'What is a Scientific Instrument, When Did It Become One, and Why?' published in British Journal for the History of Science 23 (1990): 83-93, I suggested that the original meaning of the English term “scientific” instrument and/or apparatus pertained to devices intended for elementary education, and only later was it applied to devices for advanced training or research. The term was apparently introduced by the Department of Science and Art which, in 1853, reported to the Committee of Council Education, that it was “superintending the preparation of Scientific Diagrams and Apparatus suited to elementary schools.” Support for this etymological analysis appears in the Handlist of Scientific Instrument-Makers’ Trade Catalogues 1600-1914, prepared by R.G.W. Anderson, J. Burnett and B. Gee, and published in 1990 by the National Museums of Scotland in association with The Science Museum. Among the catalogues listed in that remarkable publication – known from single copies now in private hands – are Elliott Brothers, Committee of Council Education, Scientific Apparatus for the Use of Elementary Schools (London, [ca. 1856]), and John Griffin, Descriptive Catalogue of an Organized Set of Scientific Apparatus for use in Elementary Schools (London, 1856). We also learn that the one known example of Griffin’s Illustrated Catalogue of Scientific Apparatus for Use in Elementary Schools (London, 1856) is bound with the catalogues of the Department of Science and Art, and that the title page of the 1858 edition of Griffin’s Descriptive Catalogue refers to the list of apparatus appended to the “Special report on Apparatus for Elementary Instruction in Science” written by Frederick Temple, Her Majesty’s Inspector of Schools.

Deborah Jean Warner
Curator, History of Physical Sciences
Smithsonian Institution
Washington, D.C. 20560
STOP PRESS: £8 Million for Calculator

A RARE 19th-century mechanical calculator (Fig.1), expected to raise no more than £20,000 at auction, was sold for almost £8 million on 19th May in a bout of unprecedented competitive bidding which stunned staff at Christie's.

Two bidders were determined to secure the gilt and lacquered instrument, made by the German Johann Christoph Schuster. The sale ended when one of the telephone bidders, the Swiss collector Edgar Mannheimer, raised the price to £7,701,500 – an auction record for any scientific instrument.

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Further information and photographs: V. Burness, 2, Cross Keys Cottage, Ashgrove Road, Sevenoaks, Kent, TN13 1SX.

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The Scientific Instrument Society

Membership

The Scientific Instrument Society (SIS) was formed in April 1983 to bring together people with a specialist interest in scientific instruments, ranging from precious antiques to electronic devices only recently out of production. Collectors, the antiques trade, museum staff, professional historians and other enthusiasts will find the varied activities of SIS suited to their tastes. The Society has an international membership.

Activities

Regular evening meetings are held in London, as well as occasional one-day and week-end conferences in attractive provincial locations. Speakers are usually experts in their field, but all members are welcome to give talks. Special ‘behind-the-scenes’ visits to museums are a useful feature. Above all, the Society’s gatherings are enjoyable social occasions, providing opportunities to meet others with similar interests.

The SIS Bulletin

This is the Society’s journal, published four times a year and sent free to members. It is attractively produced and illustrated, and contains informative articles about a wide range of instruments as well as book and exhibition reviews, news of SIS activities, and meetings of related societies. There is a lively letters page, and ‘mystery objects’ are presented. Another feature is a classified advertisement column, and antique dealers and auction houses regularly take advertising space, so that collectors may find the Bulletin a means of adding to their collections.

How to join

The annual subscription is due on 1 January. New members are asked to pay a joining fee in addition to the annual subscription.

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