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The 28-inch Refractor at Greenwich: A History of Two Telescopes

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SUMMARY

The history of the world's seventh largest refracting telescope is traced from its beginnings in 1855 as Airy's 'Great Equatoreal' of 12·8 inches aperture to its present-day role as a showpiece of the Old Royal Observatory, Greenwich.

1 HISTORICAL BACKGROUND

One of the important features of nineteenth century astronomy was binary star observation and measurement (1). Very close double stars (0·5–2·0 arc sec separation) require good seeing and high magnification for their study (2). Herein lay the antecedents of the 28-inch telescope, which began its career as a 12·8-inch refractor. The significance of double star measures is that stellar masses can be derived from the calculated orbits (3). A reliable set of measures made over a period of years may provide these data. As this account concerns two different telescopes used on the same mounting, the reasons for building each will be considered first.

2 THE DECISION TO BUILD

In 1846, public opinion in Great Britain was critical of George Airy's handling of the 'Neptune affair'. The controversy had blown up when J.Galle and H.d'Arrest, working in Berlin, had identified the planet Neptune visually in the position indicated by U.J.J.Le Verrier's calculations. Parallel mathematical investigations had been undertaken at an earlier date in England by John Couch Adams. His results were made available to the Astronomer Royal, George Airy, but it was some time before a search was started. The irony of the situation was that Adams had used the Greenwich observations of two earlier Astronomers Royal, J.Bradley and N.Maskelyne. He was also assisted by Airy's own reduction of planetary observations for the period 1750–1830 (a work which appeared in 1845) (4).

Allan Chapman (5) has recently given a remarkable insight into Airy's conduct during this period. Nevertheless, the 'Neptune Scandal' as it has been dubbed (6), left indelible marks upon British astronomy.

Nine years later in 1855, Airy was outlining the drawbacks in equatorial telescopes then at Greenwich (7): 'we required an Equatorial with a telescope far superior to those which we possessed on a better mounting and in a better position.' Possibly the memories of the Neptune business were still in his mind. The new telescope was to be a 12·8-inch refractor on a mounting of massive proportions (**8**). When, in 1893, the next telescope (the 28-inch refractor) was brought into service to replace the 12·8-inch, the same mounting was used to support it. Since the mount bore both refractors in succession, it merits close attention.

3 THE MOUNTING

George Airy's engineering genius (**9**) was nowhere better exemplified than in his planning of the English style equatorial. This was based upon an earlier telescope, the Great Northumberland Refractor at Cambridge (**10, 11**). This has been described by the present author elsewhere (**12**), and consists essentially of two piers of different size, with a framework between, parallel to the axis of the Earth's rotation. Inside this structure, the telescope tube itself is carried. Figure 1 presents a detailed view of the 12·8-inch ready for use.

The new mount was built with a lattice or 'cage' 26 feet in length. This comprised six iron tubes, braced with rods (the Cambridge version used Norwegian fir poles instead). The polar pillars of this cage were 'procurable in ordinary commerce' as Airy wrote (**13**), and corresponded to the four points of attachment nearest to the minor and major axes. Two of the tubes had holes drilled in them, and leaden shot was poured in, until equilibrium was achieved. The two piers which carried this substantial edifice are also noteworthy. The huge North pier was the largest complete casting up to that time, measuring 24 feet in height, and weighing $5\frac{1}{2}$ tons. The great Southern pier was formed of an iron base-plate, which ensured a firm bearing of the iron upon the pier. Liquid cement was poured through holes which ran the entire length of the mounting. Figure 2 shows drawings of the north end and south end of the polar-axis frame, which appeared in Airy's own description of the mounting in 1869.

The declination axis, being eccentric to the polar axis, allowed objects in the vicinity of the pole to be observed, so there was no 'blind spot' to the mounting. A 5-foot declination circle and a 6-foot hour circle were fitted. The R.A. setting circle (or flat band) was engraved on silver, this being a common practice on many first rate commercial instruments at that time. The hour circle was read by two microscopes and, when in operation, one showed the R.A. and the other, the R.A. + 12 h of the object under scrutiny. Originally a complex system of gas illumination was installed, but today the mount (which is still largely as described above) uses a red electric lamp by which to read the microscope.

The engineering work was commissioned from Ransomes & Simms in Ipswich, a firm with whom Airy enjoyed a close and creative relationship. Dent in the Strand, one of the most renowned clock makers of that century, contributed a water clock which supplied motion to the polar axis. This was a reaction engine, or Barker's Mill, and performed its work in the manner of a turbine. Sixty feet of water pressure were required to work the clock properly, and the pressure sometimes exceeded 100 feet. The Siemen's Chronometric Governor regulated this inequality, as the water from the mains pipe of the Kent Waterworks passed through the self-regulating tap. This system bore remarkable similarities to Airy's mechanism on the

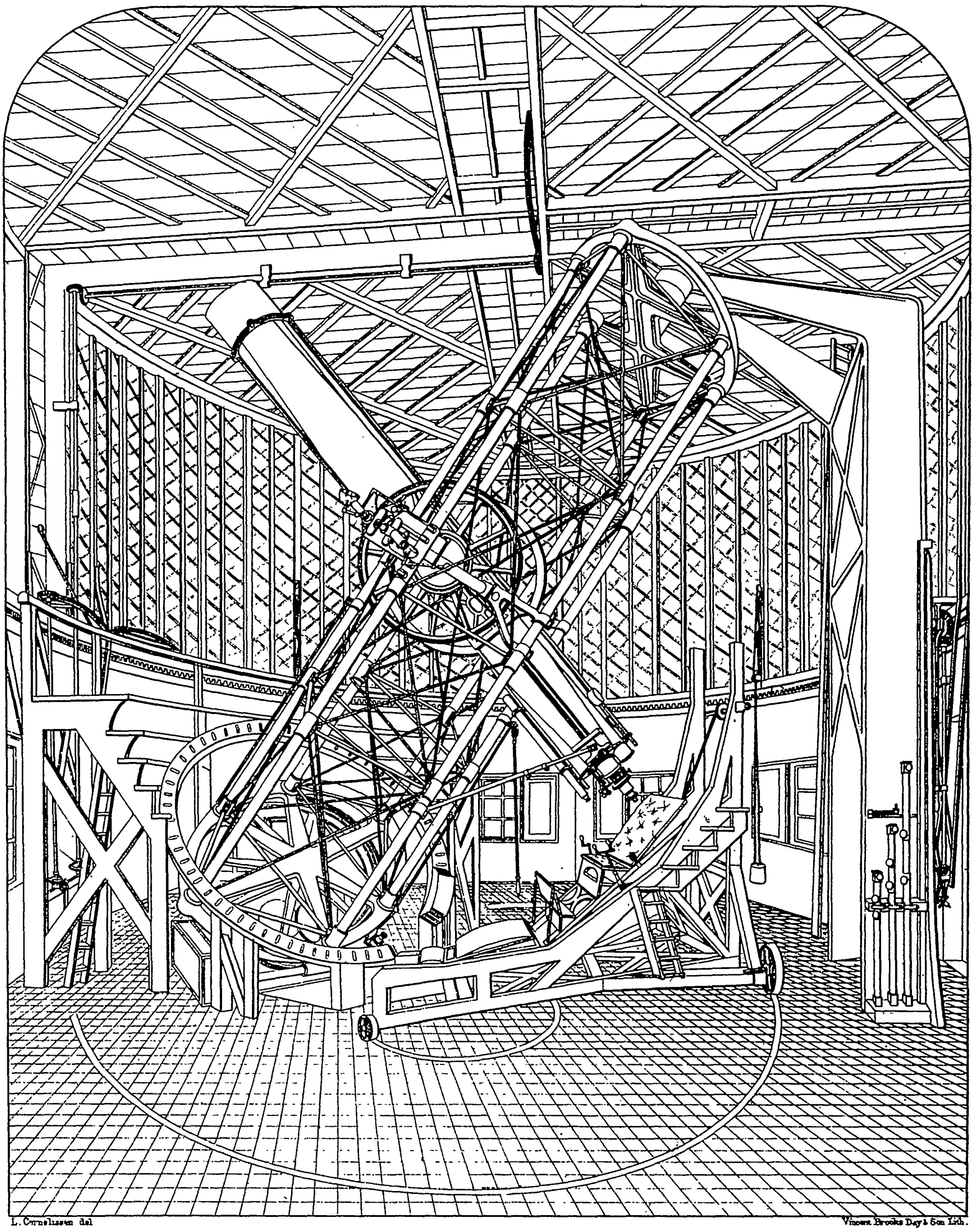

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FIG. 1. The Great Equatoreal. Reproduced by Courtesy of the National Maritime Museum.

Liverpool equatorial. The subject of clockwork regulation of telescope drives was explored by Airy in three papers (**14, 15, 16**). The Greenwich movement may be inspected by visitors to the Observatory, where it is preserved in a display.

With this mounting, tremendous rigidity was secured, and careful micrometric measurements could be undertaken. With the exchange of telescopes in 1893, certain modifications inevitably followed. Between 1929 and 1947, the water drive was replaced by a Gerrish-type electric drive. The

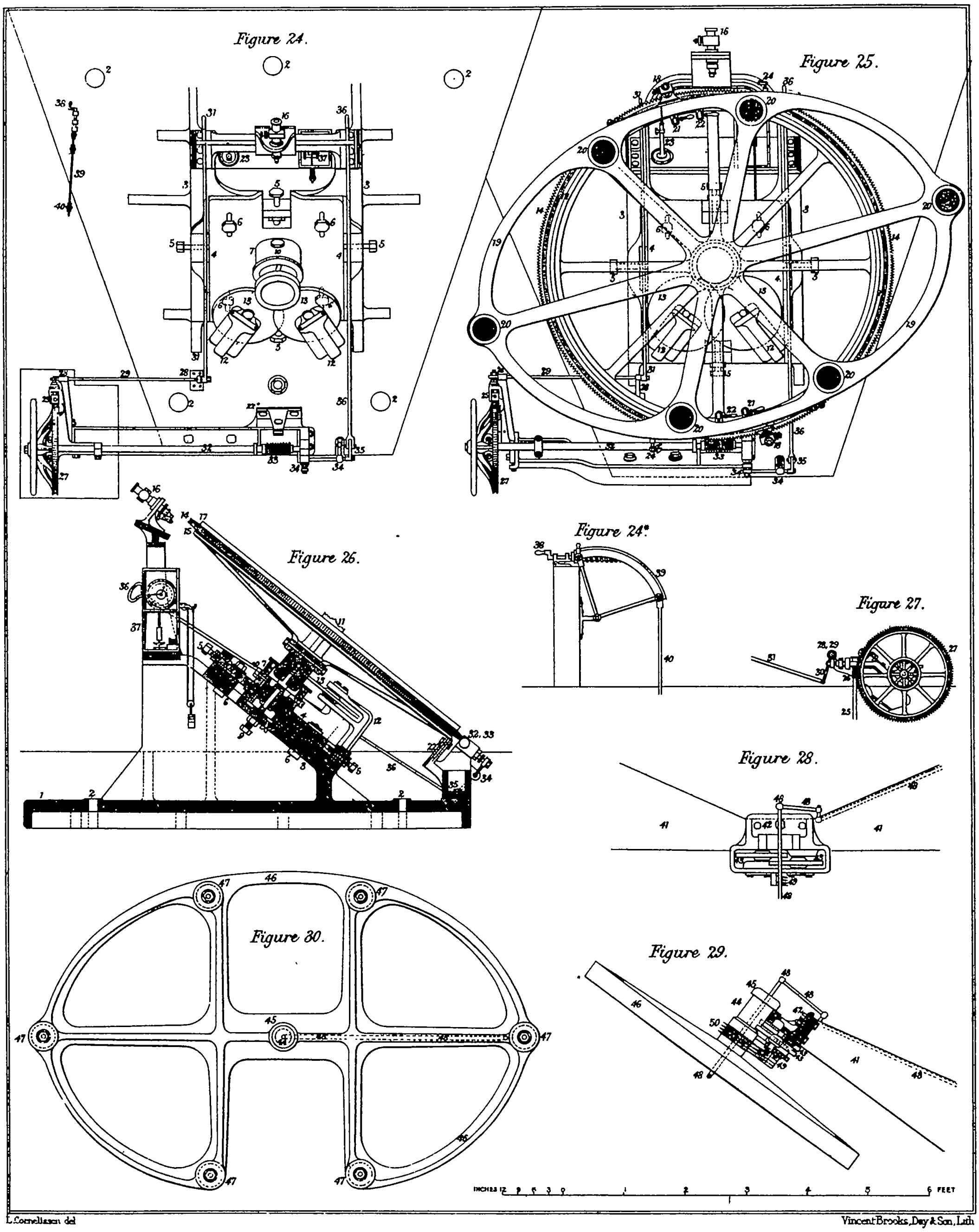

FIG. 2. The upper or north end and the lower or south end of the polar-axis-frame. Reproduced by Courtesy of the National Maritime Museum.

late George Hole, the renowned mirror maker and telescope engineer, described the Gerrish system (17): 'The most general form is some variety of the Gerrish system. In this, the motor speed is constantly monitored by a pendulum operating a switch. The motor also operates a second switch in time with the pendulum, and receives current during a part only of the swing. A fly-wheel preserves its rotation during the dead period. Should the motor get out of step with the pendulum, the switching ensures that the motor receives current for the required part of each swing until it has again attained the correct speed: a device so excellent that it became almost universal, and it also added a new verb to the language, 'to Gerrish', i.e. to function correctly.'

From 1957 to 1971, a synchronous motor was substituted, and as Hole commented: 'With suitable gear reduction the synchronous motor is a simple, compact drive' (**17**). At the time of writing (1989), a stepper motor has been installed, the specification of this being: MINIANGLE MOTA Type 24 PM-C-007 1·8 degrees per step by Astrosyn Co. Ltd, Japan. A variable frequency control unit by P.K.S. Designs Ltd, Bournemouth, England, adjusts the rate from a hand paddle, hung at the breach end of the telescope tube. The Declination circle is located high up, and is therefore read through a sighting telescope. Sidereal time is found by reference to a long case clock by Horne & Thornthwaite situated conveniently near the sidereal time circle. This timepiece contains a German movement, and accompanied the telescope from Dome F at Herstmonceux; it is meticulously maintained.

4 TWO TELESCOPES

Optically the two telescopes share a common denominator: both are refractors primarily intended for visual observation. There are essential differences however. The 12·8-inch was enclosed in a tube constructed from four planks of mahogany, forming as Airy described it: 'a square, towards both ends the angles are cut off by inclined nuts by which operation the square is reduced to an octagon, well adapted to the reception of the brass work of object glass and eyepieces' (**13**). Mahogany was a widely favoured material for refractor tubes at that time, both amateur and professional. George F.Chambers, the well-known nineteenth century amateur, echoed this preference: 'For telescopes up to 5 ft or so in length, the tubes are generally made of brass, but for sizes larger than that, in consequence of the expense of brass, other materials are frequently employed, such as sheet-iron, zinc or wood.' (**18**). A detailed description of the process of making a mahogany tube was given by F.Brodie in 1856 (**19**). To quote an extract is to glimpse the care and cost that was expended upon their fashioning: 'Every successive veneer, prior to being laid on, was lined with a piece of thin calico, to prevent the veneer from splitting while being turned round the core. This calico was removed when the veneer was dry; after which the surface was prepared for another veneer, by being levelled over and freed from inequalities by the veneer plane. Each veneer was in a single piece, the joints being placed at alternate sides of the tube, and the grain of the wood reversed at every layer. A tube was thus formed of 8 thicknesses, the 7 inner ones being of Spanish mahogany, having stains or other faults which rendered them unfit for fine cabinet-work, and therefore of moderate cost (about 9d. per foot super.). The 8th was of the finest Spanish mahogany, and cost (on account of its great size) about 1s 8d. per foot super. The thickness of the tube when finished was three eighth of an inch. It was French polished on the outside.' It was thought that wood improved the thermal balance of the telescope too. However, when the 12·8-inch was finally removed and used as a guide scope for the 26-inch Thompson refractor, the telescope was given its present stout tube of steel. The 12·8-inch object glass was crafted by the

FIG. 3. The 28-inch Refractor in use in dome F Herstmonceux (L.S.T.Symms is at the eyepiece) NMM Neg. No. B619.

celebrated firm of Merz of Munich, and was made with a focal length of 17 feet 10 inches. Optical work was commissioned from Troughton & Simms, London. A starfinder of 3-inches aperture was also affixed. The observer when using the refractor would have faced the dial-plate of the sidereal chronometer. This was located on the end plate of the telescope, and this arrangement was practically identical to that on the Cambridge instrument. The comparison of the technical drawings of each instrument will show the similarity clearly (**13, 20**). By contrast, the 28-inch object glass was ground and figured by Alfred Grubb, with glass supplied by Chance. The Grubb–Chance partnership was forged at this time, and was to become a familiar feature in the subsequent history of the Observatory.

The defining power of the 28-inch, proved to be a valuable attribute when the study of very close binaries was undertaken. Two stars whose angle was 0·2 arc sec could be separated, as the refractor's resolution was found to be 0·17 arc sec (**21**). In view of the progress of astrophotography, the 28-inch was designed as a photo visual refractor. Although rarely done, the crown glass component of the object glass could be reversed; and the separation increased to alter the correction for chromatic aberration. This would make the telescope suitable for photography with blue sensitive plates. The focal length would be reduced by 23 inches by this procedure. Thomas Lewis, one of the great figures of double star astronomy, whose work will be discussed later, noted that photographs were taken of double stars with the 28-inch in 1897 (**22**). The dry collodion plates yielded 'good results'. In fact each plate had a number of images of the double star on it, each resulting from exposures lasting 1–30 sec. Lewis derived a formula for these plates, 'It would seem therefore that with these particular plates, and an exposure of 5 s or 6 s, we should obtain photographs of pairs separated 1″·25, in which the images shall just touch, provided the photographic action did not spread when the two images approached.' 1″·25 was equivalent to 0·0021 inch on the plates.

Today the refractor has a zero magnification finder, together with a 6-inch starfinder, and a 7 × 50 elbow telescope to assist in centring objects. A Crayford eyepiece mounting, by John Wall, is to be found at the eye end of the telescope.

Since all the work of the two telescopes would be carried out by an observer with his eye to the glass as it were, Airy improvised an ingenious set of observing chairs. The principal chair resembled somewhat the Dawes type chair (**2**). A rectangular frame of substantial dimensions ran on two tram lines which are still to be seen embedded in the tiled floor of the observing room. Operated on a winch basis, it could be raised or lowered to a considerable extent. It was also possible to bring the chair forward with great delicacy. A small polar observing chair was also constructed; although nowadays a more conventional chair has replaced the earlier model. A thorough account of the 12·8-inch equatorial was written by Airy (**13**), and is a typically clear and concise description. A beautiful document, it is complemented by a fine set of technical plates. Figure 3 shows the 28-inch being used in Dome F at Herstmonceux.

5 DRUM AND ONION DOMES

The Great Equatorial Building was constructed in 1859 to accommodate the 12·8-inch refractor. It possesses a 'muscular' quality, but as M.Girouard (**23**) has commented in *Spirit of the Age*: 'the mid Victorians didn't want things pretty, they wanted them tough, solid and masculine'. Originally, a

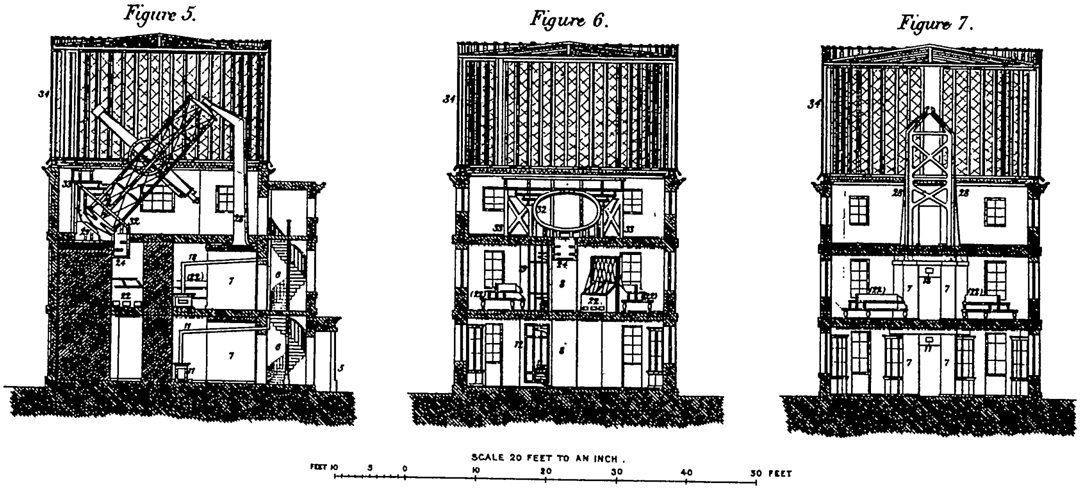

FIG. 4. Vertical sections of the south-east 'drum' type dome. Reproduced by Courtesy of the National Maritime Museum.

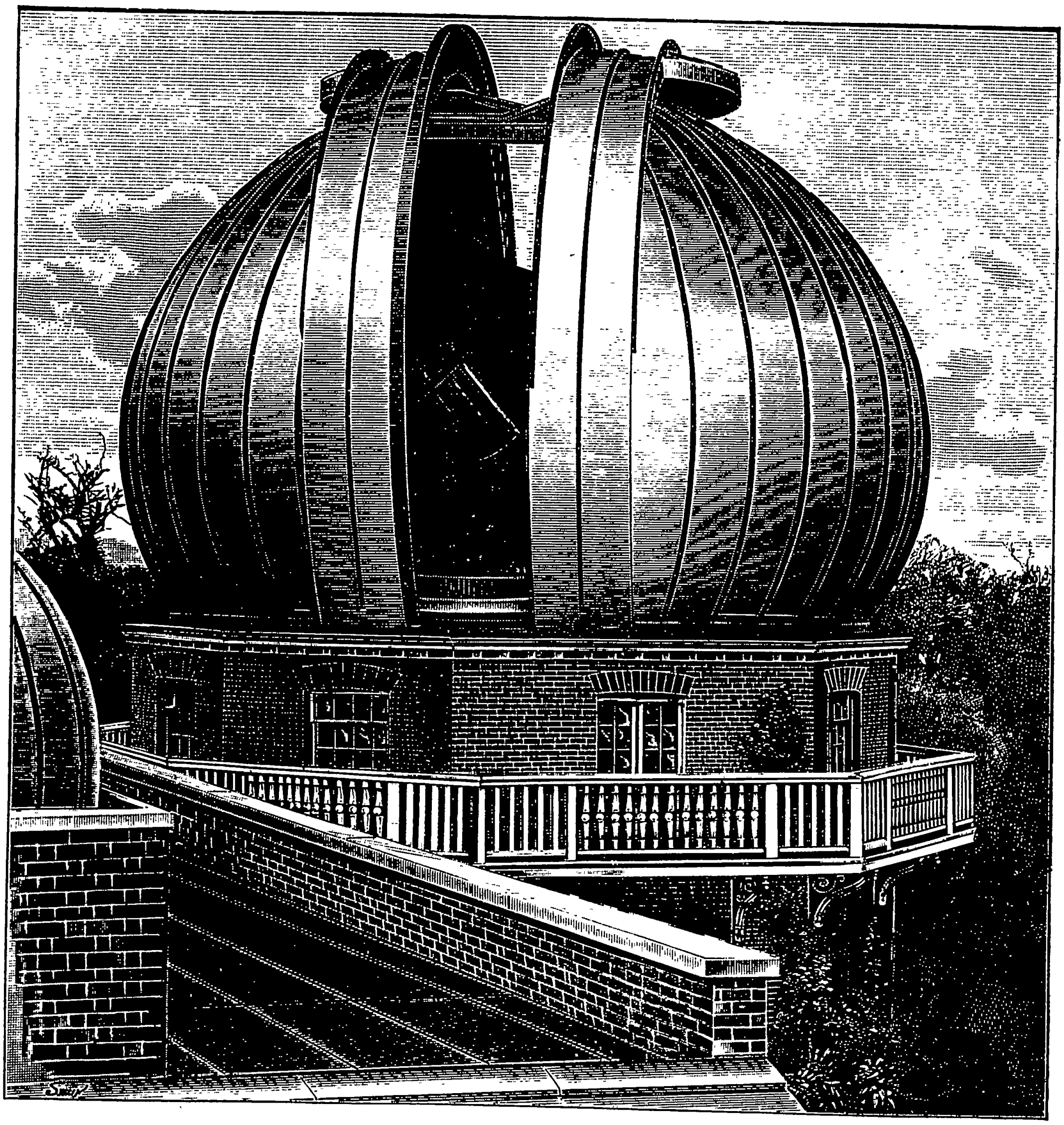

FIG. 5. Special dome by T.Cooke & Sons, at the Royal Observatory Greenwich. NMM Neg. No. B286(A).

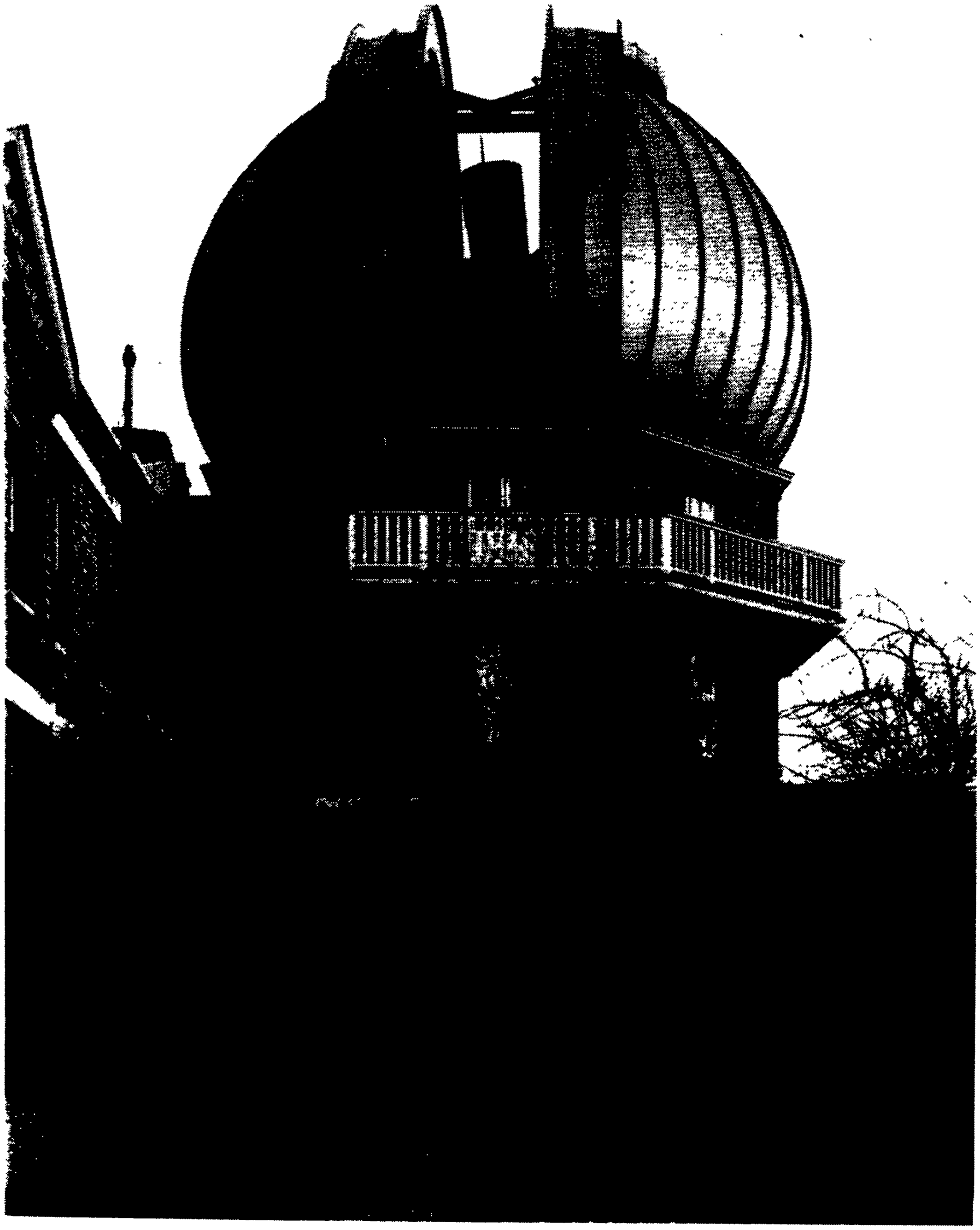

FIG. 6. The 'Onion' Dome. NMM Neg. No. B5698/B.

wooden drum-shaped dome (again a typical style of the period) topped the building (Fig. 4). Measuring 32 feet in diameter, it had a 4-foot wide pair of shutters, and the external covering was of sheet zinc. A mix of architectural styles (**24**) was quite familiar in the nineteenth century, so it was not unexpected when a dome 'oriental in appearance' replaced it (**25**). Popularly called the 'Onion' dome, for reasons which are apparent from Figs 5 and 6, its purpose was to house the extra tube-length of the 28-inch telescope. In Fig. 5 the dome can be seen as it was first constructed by T.Cooke & Sons in 1893. A riveted iron frame of 36 feet diameter ran along a 31-foot circular wall-plate, and the shutter-width had also been increased by 3 feet. The covering was of papier mache, and survived damage sustained during an air raid in October 1940. It was stripped by the fall of a V-1 bomb on 1945 July 15. The 28-inch was dismantled in 1947, and the dome in 1953.

With the removal to Herstmonceux, the telescope was sited in Dome F of the Equatorial Group (**26**), a building measuring 37 feet in diameter. It was finally returned to Greenwich in 1971; a 'complicated operation involving a huge crane, and a complete team of experts' as Patrick Moore described it on *The Sky at Night* (**27**). With the re-assembled telescope, it was accommodated in a temporary dome whilst adjustments were carried out. In addition a replica 'Onion' dome was fabricated out of modern materials, using the original plans. The 28-inch has now stood since 1974 in its first site. On 1975 May 20, in the tercentenary year of the Observatory, H.M. Queen Elizabeth II officially re-opened the telescope. The rejuvenated Observatory adds a not unpleasing aspect to the Greenwich sky line. The final alteration to the dome was made with the intention of inviting the public into the observing room itself. Previously a winding iron staircase had been the only means of access and egress from the telescope. This was unsuitable for the constant two-way traffic of people. The solution was to build a second staircase, and this was completed by Christmas 1987, when H.R.H. Duke of Edinburgh formally dedicated it. A typically Airy touch, which may be missed by visitors, is the door of the observing room itself. Although masquerading as an ordinary panelled door, it is in fact built of iron, exemplifying the philosophy of 'tough, solid and masculine'.

6 EARLY RESEARCH

In 1857, when the 12·8-inch object glass was ready, the anticipated research programmes were the examination of planetary disks, and micrometric observations. On 1860 May 24, the very first recorded observation was made (an occultation of Jupiter). As spectroscopy was making its presence increasingly felt, experiments were conducted in this field in 1862. A prismatic spectroscopic apparatus was used in 1863, and by 1874 a Browning spectroscope was added. E.Maunder (**28**) noted this about the work then in progress: 'However the 12·8-inch was not powerful enough to do much more than afford a general indication in which way the principal stars were moving, and to confirm in a general way the inference which various astronomers had found, from discussing the proper motion of stars, that the Sun, and the solar system were moving toward that part of the heavens, where the constellations Hercules and Lyra are placed'. In 1891 work was discontinued. Photography was better suited to this field, and with Thompson's gift of photographic equipment and the 26-inch refractor as well, the new 28-inch was to be reserved for double-star micrometry.

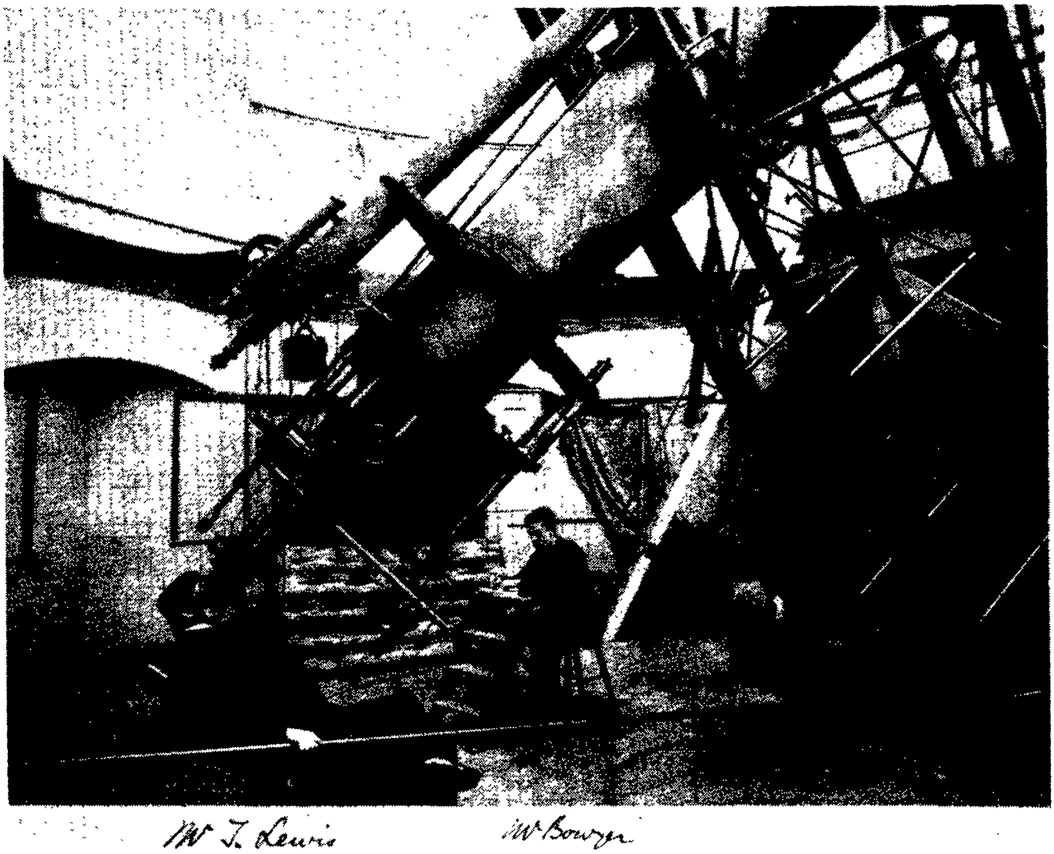

FIG. 7. T.Lewis (at the eyepiece) and W.Bowyer taking notes at the 28-inch *c.* 1899. NMM Neg. No. B5698/c. Reproduced by Courtesy of the National Maritime Museum and Royal Greenwich Observatory.

7 DOUBLE STAR OBSERVATION

The monumental Greenwich Observations (**29**), which cover the double star measures made between 1893 and 1919 at Greenwich, was published in 1921. During this period, the 28-inch had been used by such observers as T.Lewis, W.Bowyer (both of whom are seen in Fig. 7), W.Bryant, H.F.Furner, and Sir Frank Dyson. In a single year 645 pairs were measured. Thomas Lewis prepared an excellent summary of F.Struve's 'Mensuræ Micrometricæ' (**29**, **30**). This important work was a collection of measures stretching back to Sir William Herschel's day, and collated by Lewis between 1886 and its publication in 1906. In the preface, the author stated that Frank (later Sir Frank) Dyson, then Astronomer Royal for Scotland, insisted on bringing it before the R.A.S. Council, by whom it was printed as a Memoir. This mass of material was further enhanced by additional papers from the Senate of the University of Cambridge, and others who had learned of the imminent publication of this work. An excellent introduction is followed by a list of principal observers, numbering 105. Lewis himself measured 419 of the Struve pairs. Lewis also wrote a classic series of papers on double stars (**31**). Better known is his 1914 discussion on eyepieces and resolution (**32**), which is still a key reference for active double-star observers.

FIG. 8. Bifilar micrometer. NMM Neg. No. C2947.

Another observer of distinction to use the 28-inch was R.Jonckheere who began his career in France in 1909. During the Great War, he moved to Greenwich and continued his work. By 1917 he had published a catalogue (33) of all double stars under 5 arc sec discovered visually in the years 1905–16, in the sky area within 105° of the North Pole.

The final phase of observations encompasses the period at Herstmonceux and the resettling at Greenwich. Until September 1970, Sir Richard Woolley, Astronomer Royal, L.S.T.Symms (seen in Fig. 3), M.P.Candy, D.H.P.Jones and R.W.Argyle produced measures with this instrument. R.Argyle has

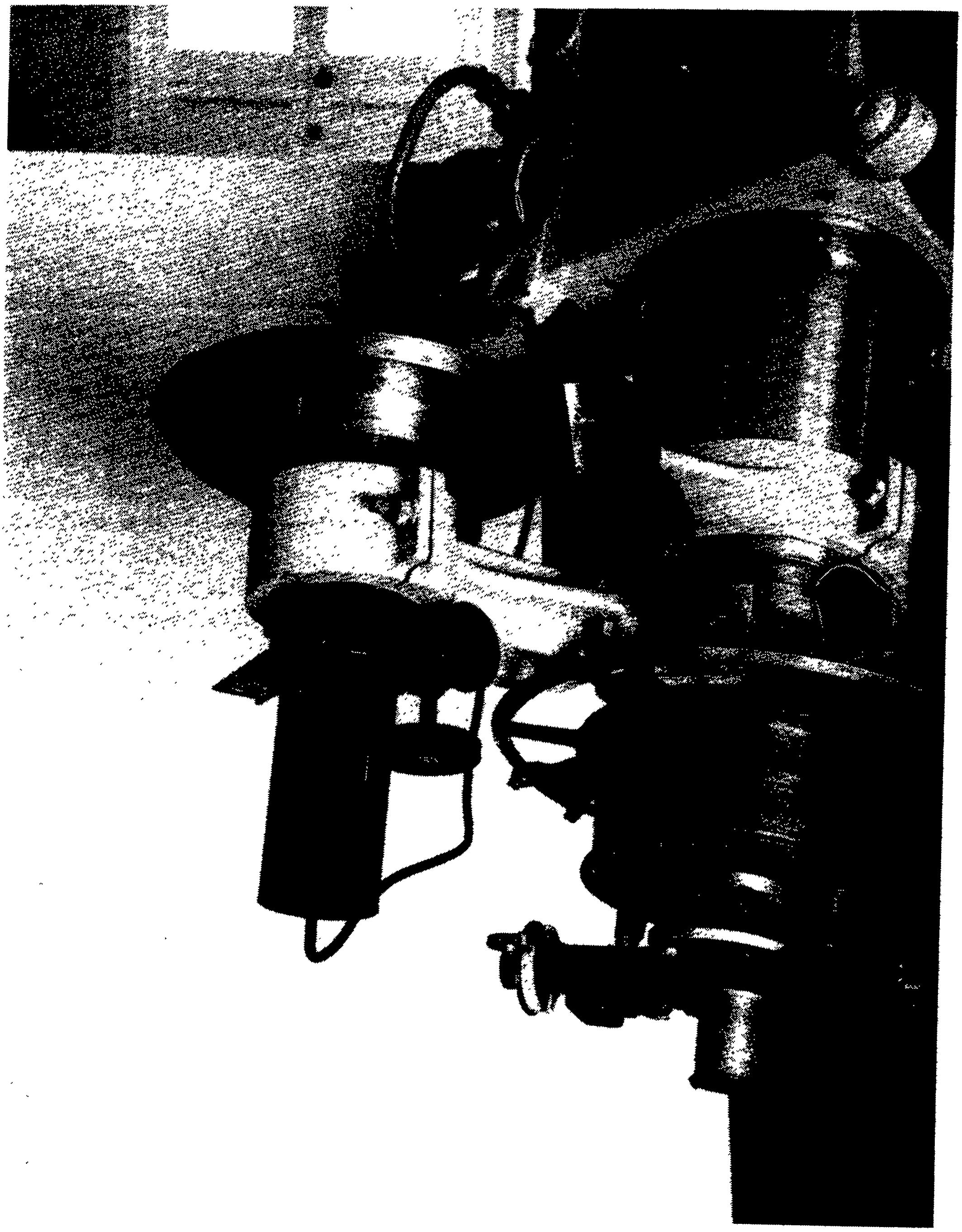

FIG. 9. Comparison Image Micrometer. NMM Neg. No. C2948.

maintained an active interest in double-star astronomy, and directs the Double-Star Section of the Webb Society. M.P.Candy, writing for prospective observers in this sphere (34), noted that with the 28-inch the Dawes Limit was 'satisfied exactly'. As to the resolving power discussed earlier, Candy remarked 'it has been possible to measure a few pairs as close as $0''.16$'. Magnifications of $\times 700$ were common, although the refractor could be used up to $\times 1300$ power.

The measuring tools of the telescope are shown in Figs 8 and 9. The Bifilar micrometer (Fig. 8) is a typical example of the classic form of instrument originally developed by Auzout in the seventeenth century (**35**). This type received great attention from the Victorian instrument-makers (**36**). As screw-technology improved, so did the technical performance. Very fine scales could be divided, and it was by no means uncommon to find micrometers with verniers reading to 1 arc sec in amateur hands. The wires used to measure the object under study were, and usually still are, spider's webs. Despite the fact that synthetic strands are used in the micrometers at many observatories, it is the opinion of many instrument makers that spider threads are superior. They possess characteristics of fineness and uniformity which are unique, and well suited for the work demanded of them. In 1920, the skilled craftsmen at Thomas Cooke's York factory could routinely split a single spider's thread in half, and fit them into micrometers and surveying instruments for a few pence. It is a clear advantage when measuring a double star to have access to the finest thread possible. The technique of dividing a web now appears to have become something of a lost art. The filar variety of micrometer suffers from the need to illuminate the wires, or the field, and this reduces the magnitude threshold of the telescope. The 12·8-inch refractor used an elaborate system of gas jets to provide the illumination, whereas an l.e.d. is employed today. Red is the preferred colour, and its intensity may be adjusted via a rheostat.

Spiders' webs especially can become contaminated by fine dust or simply break (F.Struve broke four in 11 years), and in this respect a synthetic web has a distinct advantage. Some of the disadvantages inherent in the filar design can, to an extent, be alleviated by the device shown in Fig. 9. This is the Comparison Image Micrometer (**37, 38, 39**) developed by F.J.Hargreaves in 1931 and modified by him in 1932. L.S.T.Symms and C.R.Davidson adapted it for service on the 28-inch. The micrometer produces, from an illuminated source, a pair of artificial stars which can be aligned with the real star images in the telescope field. A pair of crossed and rotatable Nicol prisms can be varied to match the illumination of the stars under observation. A blue filter allows the colour temperature of the micrometer's own lamp filament (2800 °K) to change to one of 5500 °K, which is the colour-temperature of a typical star-image in the 28-inch. On windy nights, pairs as close as 0·17 arc sec may still be measured, even though the telescope is oscillating by as much as 1 arc sec. Position angles were sometimes measured with the bifilar under normal circumstances, and the separations taken with the Comparison Image. Experienced observers such as M.P.Candy and R.W.Argyle commended the performance of the Comparison Image.

8 PUBLIC OPENING

The history of the Greenwich refractor is essentially a story of nineteenth century engineering design and technology, a period when Great Britain was the 'workshop of the world'. The general public who come to Greenwich are presented with a wonderful specimen of that age, a proof of man's enquiry into the Universe.

This educational status assumes even greater importance when it is remembered that this may be the only astronomical contact the average person makes. The visitor is made completely aware of astronomy's history and cultural significance on coming to Greenwich, and the 28-inch is an integral part of that process. In addition, accredited observers and groups may use the instrument on one of several dates that are assigned to them for research purposes.

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