The Tale of the Great Theodolites

Jane INSLEY, United Kingdom

Key words: history of surveying, scientific instruments, theodolites, trigonometrical survey

SUMMARY

This paper traces eight large theodolites built during the 18th and 19th centuries. It is an up-date of a similar paper of ten years ago but which only recorded five such instruments as being known of at that time.

The Tale of the Great Theodolites

Jane INSLEY, United Kingdom

1. INTRODUCTION

In the surveying collection at the Science Museum, London, is the largest theodolite in Europe. In an earlier version of this paper ten years ago It was claimed to be one of only five to have been constructed; now that number has increased to six completed, with another two under construction before events overtook them.

2. THEODOLITE No1

The story begins in 1783, when the Royal Society of London received a memoir from their French equivalent in Paris, suggesting that it would be extremely advantageous to astronomy to fix the relative positions of the Observatories of Greenwich and Paris. Political, scientific and practical reasons led to the decision that this work would proceed, and the Royal Society chose General William Roy to conduct the English work on its behalf. The field work fell into two parts - the choice and measurement of a base line as the foundation, followed by the measurement and calculation of a series of triangles across Southern England towards the French coast.

These triangles would then be connected by sightings across the Channel to French triangles on the other side. For these angle measurements Roy wanted to be able to take a bearing on a mark over 70 miles distant, with an error in angle of less than 1/80th of a degree. The instrument to do this had a three foot horizontal circle, and as it turned out, took three years to make, from 1784 to 1787. In the meantime, Hounslow Heath was selected as a convenient flat landscape for the initial base. One end of the line chosen was marked with an upturned cannon, which is now a listed monument within the perimeter fence of Heathrow Airport.

Roy's soldiers had to clear furze bushes and anthills away from a line some 5 miles long, conveniently passing the corner of the property belonging to Sir Joseph Banks, the President of the Royal Society, and then make their measurements using specially constructed chains.
This work was completed in 1784, but the second part - the angle measurement - could not begin until 1787. The reason for the delay was the very slow progress of the instrument maker Jesse Ramsden in making the instrument.

"... the contrivance and construction of an instrument new of its kind proposed to be made use of, and more particularly the nicety of its division, whereby it is hoped the angles may be determined to a degree of precision hitherto unexampled, have required much more time than Mr RAMSDEN himself at first imagined. Without meaning to disappoint, this ingenious artist was perhaps in the outset too remiss and dilatory, and accidents having happened when

the workmanship was already far advanced, which he could not foresee or prevent, the execution has thereby been greatly retarded. "

Reporting on progress to the Royal Society in a series of lectures in 1790, General Roy was quite blunt about the causes of the delay.

"For several months of the spring and summer of 1787, Mr Ramsden had been seriously at work in endeavouring to finish the instrument. Not having employed a sufficient number of workmen upon it at the outset, it was now evident, that he had even deceived himself, by leaving too much to be done at the latter end. At length, however, the instrument was produced..."

What is not shown in the printed record, and thanks are due to Dr Anita McConnell for this, is that Ramsden, who was himself a Fellow of the Royal Society, was in the audience when Roy delivered his paper, and was aghast at what Roy said. He submitted a nine page refutation which is in the archives of the Society, but the committee basically sat on it, and the matter blew over. Ramsden did not really have a leg to stand on - there is copious documentary evidence that he was often extremely late with deliveries, but alas little truth in the story that, summoned to meet King George III, he turned up on the day and time specified, but late by a year.

In the same lecture, Roy produced the first published account of the great theodolite. The printed version went on for some 25 pages, despite his desire to confine himself to the principal parts only, and their method of use.

It is a brass circle, three feet in diameter, and may be called a great theodolet, rendered extremely perfect; having this advantage in particular, which common theodolets have not, that its transit telescope can be nicely adjusted by inversion on its supports; that is to say, it can be turned upside down, in the same manner that transit-instruments are, in fixed observatories.

The circle is attached by ten conical tubes, as so many radii, to a large vertical, conical hollow axis of twenty four inches in height, which may be called the exterior axis. Within the base of this hollow axis, a collar of cast steel is strongly driven; and on its top there is inserted a thick bell metal plate with sloping cheeks, which by means of five screws, can be raised or depressed a little.

Roy was quite explicit that the instrument represented an attempt to create an instrument of observatory quality to go into the field. It is also possible that this is the first description of a transit theodolite, where the telescope could be reversed without taking it out of its mounting, a feature which subsequently became widespread.

He detailed the structure of the base of the instrument, which had to combine strength to take the weight of the telescope, and steadiness for the rotation of the telescope mounting. The use of the instrument also involved a considerable amount of ancillary equipment.

The instrument.....weighed in the whole about 200 lbs. It is contained in two deal boxes;one of a circular form for the body of the instrument; and the other of an oblong square figure, for the transit telescope. Within this last box there is one of mahogany, that holds all the smaller parts of the apparatus. The stand, steps, stools, pullies, ropes, tent and canopy for the scaffold, &c,&c, weighed at least as much more. The whole attiral was transported from place to place, in a four-wheeled spring carriage, drawn by two, and sometimes by four, horses. The carriage part, originally that of a crane-necked phaeton, was presented, with his usual liberality, by Sir Joseph Banks; and upon it was built a kind of caravan, covered with painted oil-cloth, whereby every thing within was kept dry and secure.

The triangle series was completed by measuring a baseline at Dunkirk which was then calculated from both sides. The results were within 15 inches of each other over a distance of 39,800 English feet. Roy regarded this as validation of the technique, and the accuracy attainable with the finest instruments used with great care. He went on to recommend that the trigonometrical operation should be continued and gradually extended over the whole island.

"Compared with the greatness of the object, the annual expence to the publick would be a mere trifle not worthy of being mentioned. In reality, a chief part of the expence, namely, that of fine instruments, has already been incurred; and it would be a pity indeed to suffer them to be laid up and remain useless. The honour of the nation is concerned in having at least as good a map of this as there is of any other country."

He also suggested that the East India Company might consider using such an instrument for the Trigonometrical Survey of India. James Rennell, the first Surveyor General of India, was also a member of the Royal Society, was familiar with Roy's work, and his support led to another order being placed with Jesse Ramsden.

3. THEODOLITES No2, 3 and 4.

So the second of the great theodolites was commissioned for India. The instrument was finished in 1791, but Ramsden incorporated several improvements to the design, based on Roy's experience with the first one. He demanded a higher price, which to his astonishment the East India Company refused to pay. His misfortune came to the attention of the Duke of Richmond, former Master of Ordnance, who saw the opportunity to further Roy's idea for a national survey, but under his own control rather than that of the Royal Society. So he sanctioned the purchase of the second theodolite by the Board of Ordnance. The entry in the Expence Ledger of the Board of Ordnance recording the payment of £373.14s. to Jesse Ramsden is now regarded as the founding action of the Ordnance Survey.

In 1798, William Mudge, the superintendent of the Survey, applied to the Royal Society for the loan of the first theodolite, which had been lying unused at their apartments for some time. Permission was granted, and after some adjustments to bring it up to date with the second, both theodolites were used to progress the Primary Triangulation of Great Britain up to the middle of the century.

The ...difference between these instruments is, that the horizontal circle of the[second] is divided to ten minutes, and read by three microscopes; while in the [first] the circle is divided to quarter degrees, or parts of fifteen minutes, and is read by five microscopes: the respective advantage in each case being counterbalanced by the corresponding comparative disadvantage. Each instrument has an extra microscope not generally used, being one of the original pair at 180 [degrees] from one another.

The total weight of each instrument without its stand was about 200lbs.

At this point we diverge from the earlier paper to insert a third Ramsden Theodolite. Recent work by Thomas Glatthard, Alfred Bollinger, and Martin Rickenbacher in Switzerland, and Anita McConnell in her work on Ramsden, has revealed that Ferdinand Rudolph Hassler (1770-1843) was working with the geodesist Professor Georg Tralles in a survey of part of Switzerland, and following a tour of European cities and scientists, placed an order with Ramsden in 1794 for an instrument with a three foot azimuth. As Glatthard put it, "Unfortunately it did not reach Berne until 1797. In March 1798 was the French invasion to Switzerland; Switzerland became the Republic of Helvetien (1798-1804). The Ranmsden theodolite was only saved by Tralles cunningly taking it to pieces and the French general Schauenberg considered the single parts to be worthless".

Anita added that it was used subsequently as a transit, then gradually cannibalised. No image is known of this instrument.

The East India Company, having refused to pay Ramsden's bill, turned to another London instrument maker, William Cary, and commissioned him to build another theodolite like the first one. This was done, and the instrument arrived in India in 1802, when it was put immediately to use by Colonel Lambton, the new Surveyor General. However, in 1808 there was a catastrophic accident, described by Lambton's deputy and later successor George Everest in 1830.

"In raising it in its case to the top of one of the pagodas, the bearing rope which kept the weight from striking against the side of the building snapped when it was half way up,and the instrument, case and all, struck with a violent crash on the sidewall.
The blow was received on the tangent screw and its clamp. The case being insufficient to protect it, was broken, and the limb instead of being a beautiful circle was so distorted as to render it to all appearances , worthless.

Any person but my predecessor would, on witnessing such a disaster, have given the matter up as utterly desperate; but Colonel Lambton was not a man to be overawed by rifles"...."He proceeded to Bangalore, where there was a large establishment of ordnance artificers" .. ."Here he shut himself up in a tent, into which no person was allowed to penetrate save the *head artificers. He then took the instrument entirely to pieces, and having cut on a large flat plank a circle of the exact size that he wanted, he gradually, by means of wedges and screws and pulleys, drew the limb out, so as to fit into the circumference, and thus in the course of six weeks, he had brought it back nearly to its original form. The radii which had been bent, were restored to the proper shape and length by beating them with small wooden hammers, and this is the instrument with which I had to conduct the Western Series."*

This theodolite seems to have been accident -prone. In February 1825, Everest reported "a sudden storm accompanied by hail and rain", which blew all his tents down, including the one containing the large theodolite . Fortunately it received no unrepairable injury.

4. THEODOLITES 5 and 6.

After Ramsden's death in 1805, his business was taken over by Matthew Berge (former apprentice, son-in-law, and incidentally responsible for burning a hole in Ramsden's will by hanging it too close to the fire after noticing it had been spilt on). As Anita has discovered, two more three footers were commissioned from Berge for Palermo, for a survey of Sicily, but these despite being described as "almost ready" were never delivered, and their ultimate fate remains a mystery. The lesser instruments ordered at the same time are at Palermo Obeservatory.- See McConnell, chapter 9.

5. THEODOLITE no 7

Shortly after the1825 accident to the Cary/Barrow theodolite, Everest became very ill, and was invalided home, there being some doubt whether he would survive. It took him five years to recover, and he filled this time usefully by ordering new instruments for the Indian Survey to bring it more in line with the Ordnance Survey, and persuading the Honourable Court of Directors of the East India Company that it would be much more effective to set up a Mathematical Instrument Maker in India, so repairs could be carried out with far greater dispatch and technical skill.

He returned to India in 1830, with the instrument maker Henry Barrow, whose first task was to sort out the problems of the Cary theodolite, and with a selection of instruments including another three foot theodolite, this time with flying microscopes. Writing in 1847, Everest commented

"The large theodolite by Troughton was constructed to the order of the East-India Company between the years 1827 and 1830 by that celebrated artist, who was left to follow his own judgement subject only to such supervision as I might venture to exercise."....it was the first large theodolite constructed for this department in which the principle of flying-microscopes and a fixed limb was illustrated; in addition to other improvements"....

In 1874 Col Walker remarked that

"This is probably the best of all the instruments appertaining to the Survey, and it has been most extensively employed.

However, this had not been completely straightforward either.

It was not the instruments of an inferior class only that required to be modified, but even the best of all were found to need certain alterations before their performances could be made thoroughly satisfactory.....Thus even the great theodolite which was constructed by Messrs Troughton and Simms in 1830, and of which a Committee of Scientific Officers, convened to report on the several instruments brought out to India by Colonel Everest, had expressed unqualified approbation - pronouncing it 'a model of perfection', and recommending "to the Hon'ble the Court, the employment of Messrs Troughton and Simms, on any and every future occasion, for the construction of instruments [for the Survey], in preference to any other artists" - was found on trial to be seriously defective in the arrangements for relieving the pressure of the revolving portion of the instrument on the vertical axis, and of the telescope on its pivots, and until these defects were remedied the instrument could not be made use of.

But after that, Everest reported "the instrument not only gave no further uneasiness, but was as perfect in performance as beautiful in appearance." The two theodolites presented the same problem for carriage, but the Indian solution was slightly different.

All three packages are invariably carried by men, and are never taken about in carts, for the two-fold reason that good cart roads, crossing the country in all directions, do not exist, and that the instruments can be transported by men, over difficult ground and up to the summits of high hills, with much less risk of injury than they would incur if carried in carts over good roads. The box containing the body of the instrument is the largest and heaviest of the three packages; two bamboo poles are usually fastened to it, one on each side, with ropes, and eight men carry it simultaneously, four in front and four behind, on their shoulders. As packed for travelling the heaviest instrument of all is the Cary-Barrow 36-inch theodolite, the weight of the body of the instrument is 649lbs, the telescope 130lbs, and the stand 232lbs, total 1011lbs; ....

The corresponding figure for the Troughton and Simms instrument were: stand 238lbs, body 559lbs and telescope 254lbs, giving a total of 1051 lbs; this in fact made it slightly heavier than the Cary/Barrow one, probably as a result of small adjustments.

The Troughton and Simms instrument remained in active service up to 1873, when it was described as being in store in Calcutta.

6. THEODOLITE No 8.

However, the Cary/Barrow one had begun to show signs of age by the mid 1850s, and moves were initiated to replace it. The problem was given to Col Strange, a former surveyor who had retired to England, but was still active; he was given the task of designing and superintending new instruments, and also of testing and examining all instruments ordered for India. Sir Andrew Scott Waugh, then Surveyor- General of India, drew up a "*Specification of a New Great Theodolite"* in 1855

It took a spell of sick leave in 1857 for Strange to be able to find the time to prepare the drawings, which he took home to England in 1859. At the Great Exhibition of 1862, he became acquainted with aluminium bronze, an alloy of 90 parts copper with 10 parts of aluminium, with three times the rigidity of ordinary gun metal, and included its use to lessen the total weight of the instrument. Presenting the new theodolite to the Royal Society in 1867, he explained

It is now ten years since the work was placed in the hands of Messrs Troughton and Simms - a long period certainly. The delay has arisen from several causes - from the removal of the factory of that firm to Charlton, from the necessity for various modifications and some experiments, particularly on aluminium bronze as the material for some portions of the instrument, from the time occupied in the designing, supervising, and testing the other numerous and important instruments...and finally, from the time which my duty of superintending the whole scientific instrument supply of India necessarily occupies.

In enumerating the various parts, Strange specifically mentions his certainty that the flying micrometer arrangement was preferred and is superior for instruments of this sort. He described a new method of supporting the weight:

The moving parts of the instrument... constitute a very ponderous mass, weighing 284 lbs. If the whole of this weight were allowed to bear on the flange of the vertical axis, the friction would be so great as almost to cause cohesion....
The arrangement adopted for the present instrument is.... three rollers, of larger diameter than before... of steel,.... supporting the weight on their circumferences precisely as is now customary with heavy revolving observatory domes. The friction is therefore no longer of the rubbing, but of the rolling kind.

So here we have a field instrument incorporating features taken from the observatory building, as well as the optical instruments within!

In a supplementary note, he added that the total weight of the instrument in its field cases was 1455 lbs, with a heaviest package containing the instrument and case at 392 lbs, lighter by some 100 lbs from the earlier Troughton instrument.

This latest monster arrived in India in April 1874, when it was made over to Colonel Tennant to use during the observations of the Transit of Venus. However, in the note published after the transit was completed, Colonel Tennant described his instrument as a 6" telescope by Messrs Cooke and Sons, equatoreally [sic] mounted, and supplied with a double image micrometer of Sir G B Airy's pattern, made by Troughton and Simms. So what was the story?

In 1879, David Gill was appointed astronomer to the Cape, and given the task of building up the Observatory, its instruments and its scientific reputation. In his History of the Cape Observatory of 1913, Gill wrote that the Survey of India theodolite

...."proved to be too heavy for transport to the tops of mountains.[surprise!] It remained therefore unused in India until 1882, when, on the representation of General Walker, .. it was permanently lent to the Cape Observatory......The instrument, almost immediately on its arrival from India, was employed in making daylight observations of difference of azimuth and altitude between the Sun and the Great Comet of that year. Subsequently the errors of graduation of the circle, of the screws, and of the pivots were accurately investigated, and during 1885 and 1887 a large number of observations were made by Captains method for the determination of fundamental declinations. The instrument is particularly well adapted for this research, but the loss of the only available observer in 1887, and the necessity for making the corresponding zenith telescope observations compelled limitation of the use of the instrument. The pressure of other work has, until the present time, prevented the completion of this interesting investigation."

7. WHERE ARE THEY NOW?

- The first Ramsden Theodolite survived until 1940, when the headquarters of the Ordnance Survey at Southampton received a direct hit from a German bomb. The instrument had been stored in the basement, and was believed to have melted.

- The Cary theodolite has a revered place with the Survey of India, in Dehra Dun; there is a museum there with a considerable number of the other instruments from the Great Trigonometrical Survey.

- The second Ramsden theodolite is preserved at the Science Museum in London, where it currently forms part of the display of the King George III collection of instruments of natural Philosophy and eighteenth century science.

- Scraps from the third Ramsden theodolite were rescued recently from a Berne metal company and are in private hands. The Swiss topographic survey (Bundesamt fur Landestopographie Swiss Topo) has a display about Hassler's work, and there is a Ramsden Corner showing two microscopes and a telescope lens. The Swiss also found the instrument too cumbersome for their terrain. The smaller reflecting and repeating circles were far more handy.

- Office in Cape Town by the Director of the Royal Observatory, Cape of Good Hope, in 1947. It now lives in the Museum of the Department of Land Affairs, Chief Directorate: Surveys and Land Information.

- The author's grateful thanks are due to Jim Smith, for the Everest connection, to Dr

Anita McConnell for sharing her work on Ramsden over more than a decade, to Martin Rickenbacher, for information from rainy Switzerland, and to Thomas Allen in South Africa for helping with information and photos of the last great theodolite.

REFERENCES

Insley, J, 1997, "From London to South Africa", South African Journal of Survey and Mapping,vol 24, pp83-89, Gonubie, South African Council for Professional and Technical Surveyors

McConnell, A, 2007, Jesse Ramsden (1735 - 1800): London's Leading Scientific Instrument Maker, [city], Aldershot, Ashgate.

BIOGRAPHICAL NOTES

Jane Insley has been a curator at the Science Museum London since 1974, starting as a museum assistant for the Chemistry collections and currently the Senior Curator, Engineering Technologies. She has written extensively on matters to do with the history of scientific instruments, and to a lesser degree on environmental technologies, winning the Jehuda Neumann prize for the history of meteorology. Her current main research interest is the history of museum dioramas, and her recent professional work has focused on the museum's electricity supply collection. She likes writing about the history of science and technology because of the amazing things people got up to in the past.

CONTACTS

Ms Jane Insley
Science Museum
Exhibition Road,
London SW7 2DD
UNITED KINGDOM
Tel. +44 (0)207 942 4213
Fax. +44 (0)207 942 4103
E-mail: jane.insley@sciencemuseum.org.uk
Website: www.sciencemuseum.org