THE American Surveyor

A FOOT IN THE PAS[illegible] EYE TO THE FUTURE

December 2007

Lost Treasure

Silvio Bedini — 1917–2007
A giant in surveying history passes

Laser Scanning
Woolpert shares best practices

GLO Survey Nightmare
Did surveyors lie to avoid alligators and snakes?

David Rittenhouse

Telescopic Theodolite

>> By Jeffrey D. Lock

Telescopic Theodolite

Figure 1

David Rittenhouse

As a researcher and restorer of 18th century Colonial surveying instruments, I deal primarily with the artistically crafted surveying compass. These instruments often have beautifully executed engraving, combined with technologically advanced workmanship for their generation. They stand out from the later instruments of the mid-19th century where mechanical repetition produced functional instruments devoid of the spark of artistic creativity.

While visiting a collector with whom I had corresponded, I inspected an instrument which appeared to be beautifully engraved but also, at first glance, gave the impression of having the ends of the main arms cut off in a most unceremonious manner. How could one do this to such an artistic instrument? To make matters more disconcerting, the instrument was signed, "Rittenhouse, Philadelphia." (**Figure 1**)

I was given the instrument to study and it became obvious by the level of engraving and craftsmanship that this was, as I had suspected, the work of David Rittenhouse, the elder. A complicating factor was that David's brother Benjamin, also an instrument and clock maker, had a son named David, and two compasses by the nephew have turned up signed "David Rittenhouse, Philadelphia." The difference in workmanship between the senior David, the elder, and his nephew's instruments is quite obvious when compared together.

Figure 2

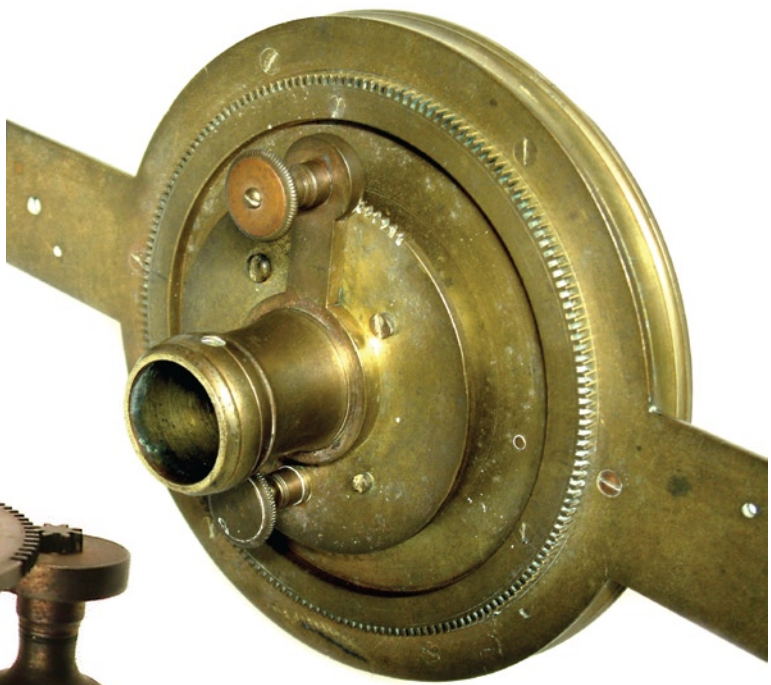

Figure 3

Figure 4

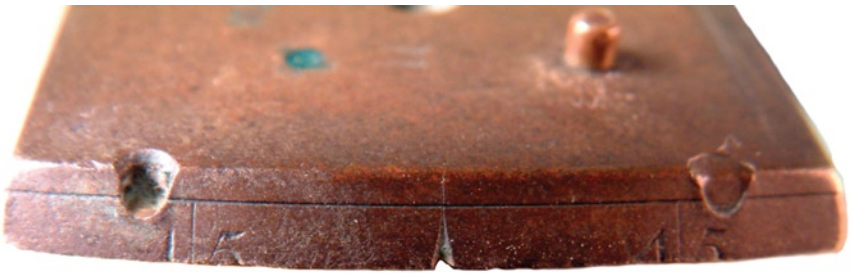

Figure 5

(**Figure 2**). David, the elder, was the accomplished astronomer who, in documenting the Transit of Venus in 1769, established his reputation as a world-class astronomer, mathematician, clock maker, and instrument maker. The fact that this instrument was indeed the work of the master, David Rittenhouse, made the cut-off arms even more of a travesty. After the shock wore off and I began the initial study of this seemingly defaced masterpiece, I was able to identify characteristics that made it clear this was no ordinary surveyor's compass. Underneath the compass box there was a large, full-circle ring gear (**Figure 3**) as well as a second gear-drive assembly on the socket that would permit the entire unit to be precisely rotated up to 45 degrees (**Figure 4**). I was quite relieved to find, after closer inspection, that the apparent cut-off ends of the main horizontal arms were in fact remnants of opposing verniers that were originally pinned to the ends of the fiducial North/South arms of the compass (**Figure 5**). The remnants of these arms carried the partial engraving of the vernier scale that made it obvious this was no typical surveyor's compass (although even an ordinary surveyor's compass by David Rittenhouse, the elder, is quite rare; at this date only seven examples have been recorded). It became clear this was in fact the central compass and arms of a theodolite and is the only one known to have been built by this esteemed maker. As I sat there, astonished at the historical importance of exactly what it was that I had in my hands, the most amazing fact was yet to come. As I explained to the collectors what they had in their collection, going through all the mechanical details of its construction, one of the owners made the casual comment "…wait, we also received a small telescope when we purchased it years ago." Envisioning a small, hand-held telescope that might have been included as part of the transaction, I really was not expecting to be any more impressed than I already was. To my amazement the owner reappeared with a small telescope mounted on a semi-circular vertical arc, with a scale obviously engraved by the hand of David Rittenhouse. This telescope and vertical arc assembly fit precisely into pinned holes in the North/South arms of the compass. (**Figure 6**) Not only did I have in my hands the only gear-driven theodolite by the

Figure 6

Figure 7

Figure 9

Figure 8

esteemed maker, David Rittenhouse, but with the introduction of the telescope assembly it was now elevated to one of the most important historical finds of this field in recent memory.

The owners agreed to let me take the compass and telescope for further study. I would propose a mock-up of what the finished instrument would have looked like, allowing them to consider the reconstruction of the missing pieces and returning the theodolite to its original configuration.

To properly return the instrument to its original design, it was necessary to produce the following:

1) Horizontal circle divided and engraved in the correct David Rittenhouse style with an integral pinion drive assembly to engage the existing horizontal ring gear on the compass body.

2) Reconstruction and division of the missing vernier ends which surprisingly had each of the opposing verniers divided to a different scale, 20 divisions on the vernier to 19 degrees on the horizontal circle on one end and 20 divisions to 21 degrees on the other.

3) Construction of four sight vanes, two on the horizontal circle and two for the alidade when the telescope was not used. I would like to thank Steve Turner at the Smithsonian for his help in photographing and measuring the sight vanes from an identically signed compass in that institution's collection.

4) Construction of a fully articulating, rack and pinion drive Jacob's Staff Adapter to fit the original socket and for future use with an 18th century tripod.

By studying the only other similar Colonial instrument of which I was aware, one produced by Benjamin Chandlee (father of Goldsmith Chandlee) that is located at the American Philosophical Society in Philadelphia, it was obvious that the Chandlee instrument would be helpful for proportions and dimensions. During the 18th century, English

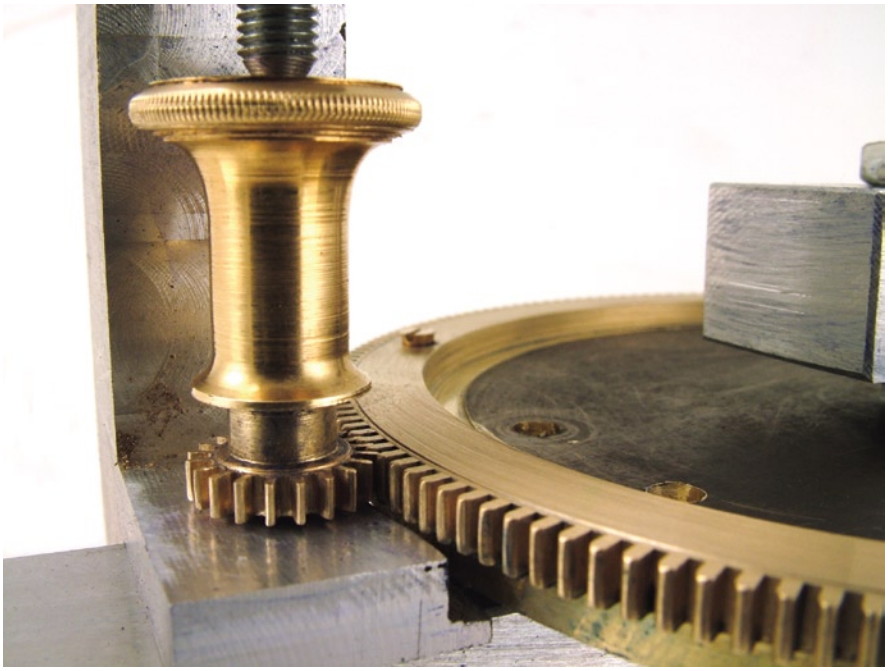

Figure 10

makers constructed theodolites of this configuration and an English example was perhaps studied by David Rittenhouse as an initial concept for this particular theodolite. Some of the English instruments had replaceable telescopes, as well as sight vanes for the moveable limbs. The telescope would be used to read vertical angles. When only horizontal angles were to be read, the telescope would be removed and two sight vanes were put in its place on the horizontal arms (**Figure 7**). Due to the scarcity of brass in the colonies, most Colonial theodolites of the 18th century were much smaller, having horizontal circles in the 6"–7" range (**Figure 8**) unlike this David Rittenhouse and the Benjamin Chandlee discussed earlier, which are in the 11"–12" range, similar to the English examples.

The telescope was an amazing example of optical work. At a diminutive length of 9", it had incredible clarity and a focusing range from 8 feet to infinity. The image was non-erecting and upon disassembly revealed the provision for internal, adjustable cross hairs (**Figure 9**).

I began fabrication of the horizontal circle by constructing a mock-up plate out of aluminum, which was chosen over the much harder brass. Once the proportions of the aluminum horizontal plate "looked" right, *e.g.,* the relationship of the number of spokes, their width, as well as the width of the outer circumference allowing for the eventual dividing and engraving of numbers, I began to cut the final plate out of brass. By fabricating a depthing tool specifically for this project, I was able to measure the correct dimensions for the distance between the new pinion gear and the original ring gear on the underside of the compass (**Figure 10**). With helpful advice from David Todd, a clock specialist from the Smithsonian's National Museum of American History, I was able to accurately space and shape the pinion teeth to obtain the proper

"mesh" and, therefore, the smooth rotation of the compass body over the horizontal circle (**Figure 11**).

The placement for the graduated scale was computed from the angle of the compass alidade ends. Once established, the circle was divided in a manner commensurate with 18th century techniques. The numbers on the horizontal plate were engraved in the same David Rittenhouse style as found on the needle ring of the original compass (**Figure 12**). New thumbscrews were fabricated using the original threaded holes in the compass body to duplicate the original diameter and threads per inch.

The aspect of fabrication that proved to be the most challenging was the construction of the vernier ends and division of the scales that were to be located at each end of the North/South arms of the compass body. This task of fabrication and division was aided by the fact that there remained portions of the engraved vernier divisions on the original alidade ends. By projecting the 15-0-45 scale divisions at the ends, the layout of the individual marks was possible. Once completed, the new vernier ends were re-pinned to the ends of the original alidade (**Figure 13**). This step of the restoration was more complicated than first expected because, under no circumstances, could I allow my restoration work to disturb the beautiful, original patina of the compass body. I had to devise a method of drilling the new vernier ends using the original holes in the compass arms, installing pins, and peening them over in preparation for a final filing as close to flush with the original surface as possible, being always careful not to scratch or mar the original surface in any way. **Figure 14** shows the final result.

The accuracy and longevity of any theodolite is directly proportional to the size and construction of the bearing surface between the rotating compass, alidade assembly, and the horizontal circle. The bearing on this particular instrument by David Rittenhouse is the largest I have ever come across, measuring a little more than 2.5" in diameter,

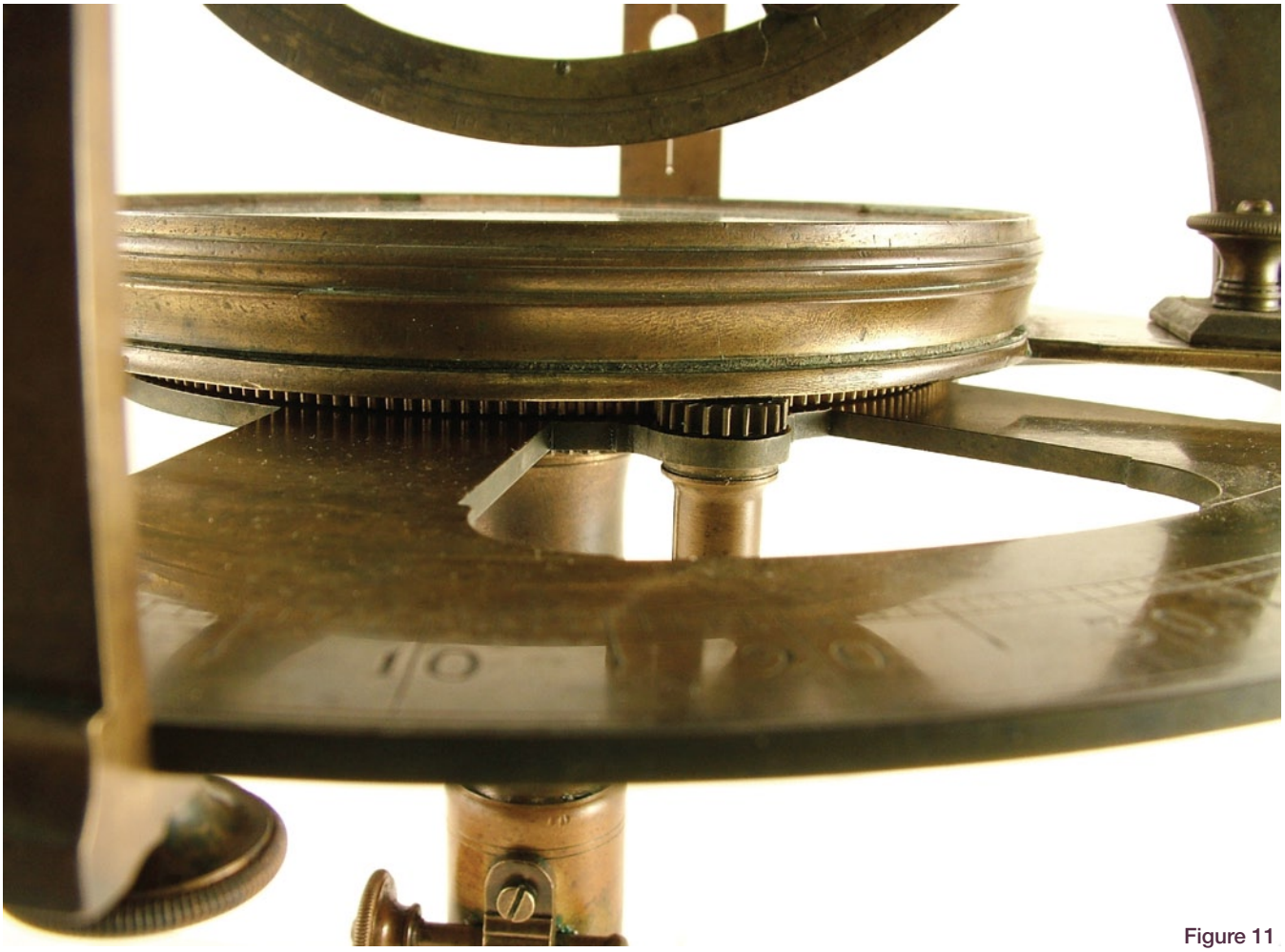

Figure 11

Figure 12

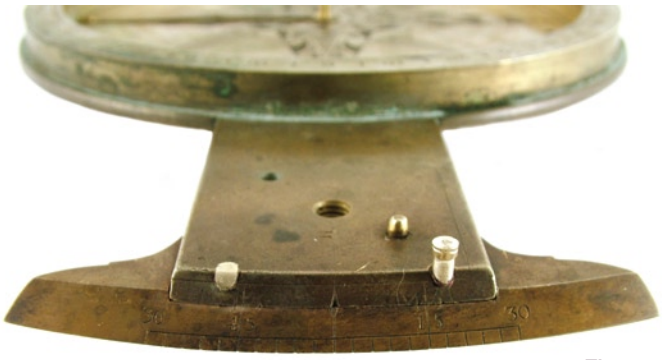

Figure 13

which is guaranteed to maintain the accuracy of this rotating assembly for generations. A great deal of time was spent lapping the internal tapered bearing surface of the new horizontal plate to the existing tapered bearing on the compass/alidade assembly. This assured parallel rotation to the compass/alidade assembly is absolutely necessary for the proper sliding clearance of the new vernier ends.

All of the replacement pieces that were fabricated, the four sight vanes and vernier ends, as well as the large horizontal circle, were signed and dated for historical documentation (**Figure 15**). Once all the mechanical fabrication had been completed, as well as the engraving and divisions, the new pieces were patinated to match the original brass as closely as possible (**Figure 16**).

One note of explanation regarding the standards adhered to on the restoration of this instrument: Nowhere was any modification made to any of the original parts of the instrument. In all cases the newly replicated pieces were either screwed to original holes maintaining the original thread pitch and diameter of the threaded holes or pinned to original tapered holes in the instrument. In the case where there was a chip at the end of the original alidade, the most expeditious repair would have been to braise additional brass to fill the chip and file the area back to its original taper and dimensions. Taking care not to disturb the original alidade, the new vernier end instead was braised and finished in such a manner to fill the chip on the original alidade by adding material to the new vernier end. The chip was then closed once the vernier end and the alidade were pinned together. Total photographic documentation was maintained throughout the entire restoration and the replicated pieces were signed and dated by bold engraving prior to patination.

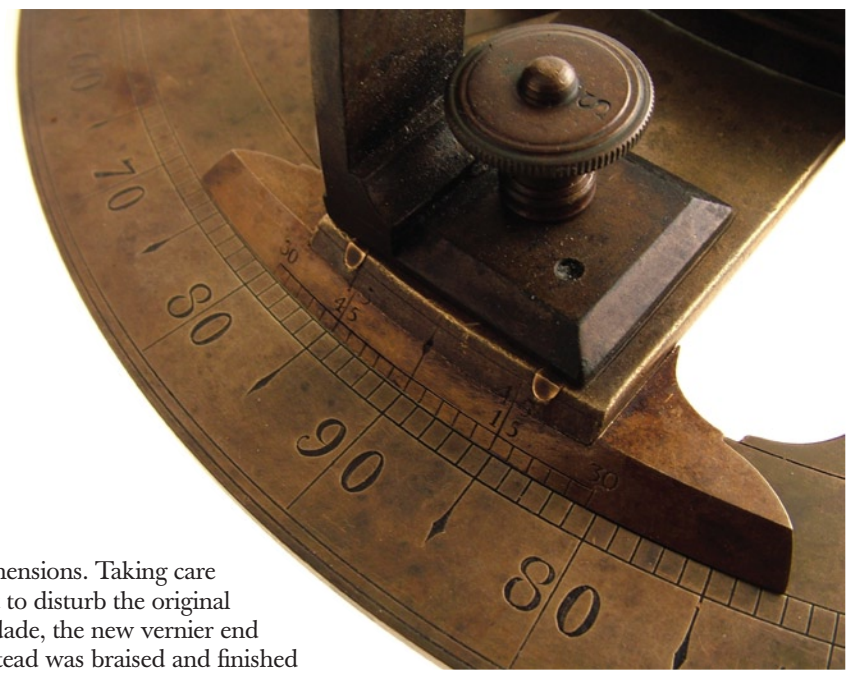

Figure 14

As the final assembly of the replicated pieces with the original sections began to dovetail together, the amazing intricacy and beauty of this once spectacular instrument began to unfold. Once again we may admire this impressive mechanical and artistic artifact by one of the colonies' finest craftsman and genius of the 18th century, whose name is not well known outside of the scientific community. My only hope is that David Rittenhouse would approve of my restoration.

Figure 15

Figure 16

The number of instruments documented as being constructed by David Rittenhouse in either Norriton or Philadelphia is very limited. If one studies his notes, it is clear that he was not interested in the repetitive construction of instruments based on the same design, instead he sought out the challenge of mastering difficult projects. It is a well-known fact that he was employed to help with the extension of the Mason Dixon Line, as well as establishing several other state boundaries. The sophistication that is inherent in the design and construction of this instrument obviously benefitted from the fact that David Rittenhouse was an exceptional surveyor as well as instrument maker. This rare combination of skills produced a consistent output of extraordinary instruments.

This instrument, along with others from the Colonial period, is currently on display at the Museum of the American Philosophical Society, Philadelphia, in an exhibition titled: "Undaunted: Five American Explorers, 1760-2006." The exhibition, which will run until December 2008, will include selective instruments, paintings and drawings, maps, charts, photographs, and ship models, presenting the explorers in the context of their discoveries and studying the methods of documentation of their important contributions.

Drawing on more than 30 years' experience in the restoration field, **Jeffrey Lock** has focused on colonial instruments from the 18th century and the techniques that were used for their construction. His continuing research has uncovered unusual instruments that will be discussed in future articles. Additional articles can be found on Jeff's website, colonialinstruments.com.