2. "Gunter's Scale" in Rees (ed.), *The Cyclopaedia; or Universal Dictionary of Arts, Sciences, and Literature* (London, 1819), vol. 17 (not paginated). Florian Cajori, "A History of the Logarithmic Slide Rule and Allied Instruments" in *String Figures and Other Monographs* (New York, 1960). On planimeters and other integrating devices see Henry S. H. Shaw, *Mechanical Integrators* (New York, 1886).

3. Additional Improvement #280, dated May 15, 1860, in "Additional Improvements," vol. 2, pp. 90-4. Records of the Patent Office, Record Group 241, National Archives and Records Administration.

4. Josiah Lyman to Commissioner of Patents, April 6, 1862. This letter is part of the Examiner's Report, dated May 3, 1872, on an extension allowed on patent #20,356. It is in the Records of the Patent Office, *op. cit.*

5. "Lyman's Improved Protracting Trigonometer," *Scientific American* 5 (1860): 341.

6. "Digest of Assignments, January 23, 1837 to June 30, 1864," L, No. 1, p. 229. Patent Office Records, *op. cit.*

7. "A Valuable Drafting Instrument," *Scientific American* 29 (1873): 264.

8. W. & L. E. Gurley, *Civil Engineers' and Surveyors' Instruments* (Troy, 1890), p. 59.

THE SOLAR SURVEYING INSTRUMENTS OF THE W. & L. E. GURLEY COMPANY

William H. Skerritt
with William E. Fitzgerald III and John Stickelmyer III

The history of the Gurley Company of Troy, N.Y. is rooted in the local instrument making tradition. In 1808 Col. Benjamin Hanks set up a bell, clock, and surveying instrument manufactory in Gibbonsville (now Watervliet), across the Hudson River from Troy. Already successful in his native Mansfield, Conn., Hanks sought to establish his son, Julius, in business in this "Industrial Gateway to the West."[1]

In 1845 Jonas H. Phelps and William Gurley, both having apprenticed in Hanks' shop, entered into partnership as Phelps & Gurley. The business became Phelps & Gurleys in 1851, when Lewis E. Gurley was taken into partnership. In 1852 the Gurley brothers bought out Phelps' interest, and began trading as W. & L. E. Gurley.[2] The Gurleys envisioned a manufactory very different from the small shops in which they had learned their trade.[3] Both men, having earned degrees in civil engineering, appreciated the practical applications of technology, and aimed to set their company at the cutting edge of instrument technology.[4] The Gurleys pioneered in mass marketing as well as mass production of instruments. Their annual *Manual of the Principal Instruments Used in American Engineering and Surveying* presented detailed engravings of their products, with lengthy discussions of how they should be used.

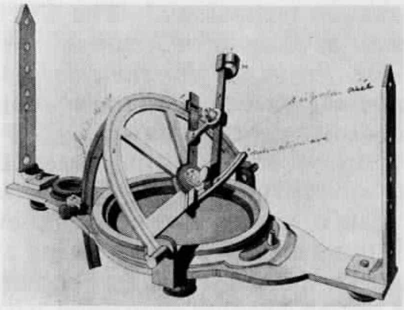
In 1908 the Gurleys began putting serial numbers on their principal instruments--the first two digits of the serial number are the last two digits of the date of manufacture. Assigning dates to earlier Gurley instruments is done mainly by considering changes in design, especially as reflected in the engravings published in the *Manual*. The assumption that design changes coincided with engravings has been confirmed in every case where corroboration is possible. Gurley instruments changed radically, not gradually.

Although Gurley was neither the inventor nor the earliest producer of solar instruments, when it finally got into the game it became a major player. The completeness of their line, the diversity of their designs, and the sheer numbers made, justify a study of Gurley's solar instruments.

Surveyors often need to determine the precise meridian without reference to a magnetic needle. Solar determination is particularly useful where there are no established control points or where there may be local magnetic variation. For the important early surveys, an astronomical transit instrument was used to determine the north-south line, and then theodolites, compasses, and/or levels were used to complete the survey. It wasn't until the second quarter of the 19th century that a solar apparatus was incorporated into a surveying instrument.

In 1834 William Austin Burt, a U.S. Deputy Surveyor, surveyed an area north of Milwaukee in the Wisconsin Territory, and found his "intersections varied as much as 100 links." Rechecking his chaining, Burt determined that the variations were due to fluctuations of the magnetic needle of his compass instruments. He had, in fact, traversed a major iron and copper ore body.

During the summer of 1835 Burt devised a solar apparatus which determined the meridian by using the sun's position as a reference. His instrument employed a latitude arc, a declination arc, and an hour circle, and mechanically solved the equation for the celestial triangle. Burt took his idea to the Philadelphia instrument maker, William J. Young, who, for $25, built a prototype solar compass which won the Scott Medal of the Franklin Institute. On February 25, 1836 Burt was granted a patent for his invention. The solar compass was gradually improved, and eventually gained widespread acceptance, particularly in the western surveys. In 1850 the U.S. Land Office recommended its use. In 1851 it won a prize medal at the London Crystal Palace Exhibition.[5]

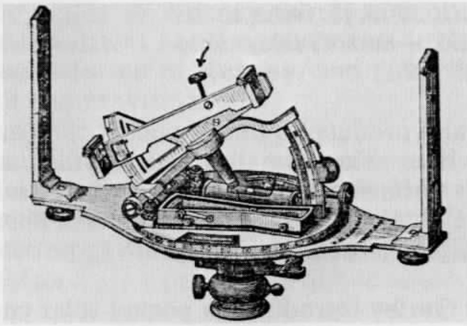


Patent Drawing of Burt's original Solar Compass

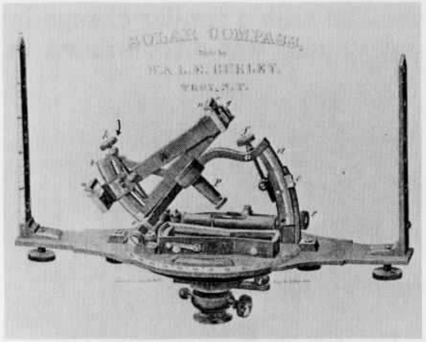
The Gurleys introduced three solar instruments in 1858. Burt's solar compass, they noted:

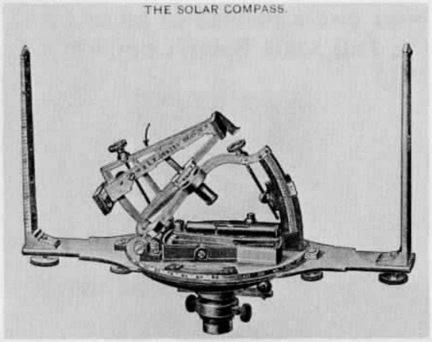
> "has...come into general use in the surveys of U.S. public lands, the principal lines of which are required to be run with reference to the true meridian....The invention having long since become the property of the public, we have given our attention to the manufacture of these instruments, and are now prepared furnish them, with important improvements of our own devising, at greatly reduced prices."[6]

Gurley's original Solar Compass was similar to Burt's improved solar compass. A second form, in which the tangent screws were moved close to their arcs, was introduced in the 1860s. A third form, with modified declination arc, was introduced in 1895. The fourth and final design appeared in 1911, and was discontinued in 1915. This form incorporated redesigned declination and latitude arcs, and the solar apparatus was mounted over a full compass.



Gurley Solar Compass (1858)

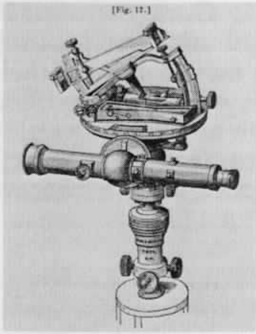




Gurley Solar Compass (1868) Gurley Solar Compass (1896)

Gurley's Solar and Rail Road Compass was a transitional piece, introduced in 1858 and retired in the 1860s. This was a conversion of Gurley's standard Rail Road Compass in which the brass ring, glass cover, magnetic needle, and center pin were replaced with the solar apparatus mounted on a circular brass plate. This conversion did not require machining.

Gurley's Solar Telescope Compass introduced in 1858 consisted of a solar apparatus mounted on a circular brass plate to which was affixed a telescopic sight. A second form, with the tangent screws moved close to their arcs as in the Solar Compass, was introduced in the 1860s. This instrument was not successful--"the position of the telescope to one side of the center, and the excess weight on that side have always been serious objections to its use in the field"--and Gurley sold their last one in 1870.


Gurley's Solar Telescope Compass (1858)

Gurley also produced a line of pocket compasses that mirrored their full scale line. These smaller instruments could be used on a tripod or jacob's staff, and could even be provided with leveling heads and telescopic sights. Establishing the date of these instruments is particularly difficult, because Gurley never put serial numbers on them.

In 1880 Gurley introduced a pocket solar compass, similar in many respects to Burt's original design. A second form, with tangent screws added to the declination and latitude arcs, was introduced in 1883. The third and final change, introduced in 1911-12, included an hour circle instead of an arc, and coincided with a similar change in the full scale Solar Compass. This instrument was discontinued in 1915.


Gurley Pocket Solar Compass (1880)

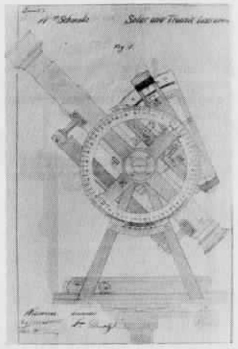

Gurley Pocket Solar Compass (1883)

By the mid 19th century the transit had become standard for topographic surveys and, in terms of sales, was probably the most important instrument. It was imperative that a solar transit be devised. By the late 1860s the rush was on. The first solar transit was invented by William Schmolz, a San Francisco instrument maker, and

patented by him on December 24, 1867. His solar consisted of an attachment, basically of Burt's 1850 configuration, mounted on top of the transit telescope at the axis. Schmolz's invention was quickly followed by F. R. Seibert's solar transit in 1869, Benjamin Lyman's solar compass patented in 1871, Harrison Pearson's solar attachment patented in 1875, Buff & Berger's Pearson's solar attachment in 1878, and J. W. Holmes' solar theodolite also in 1878.

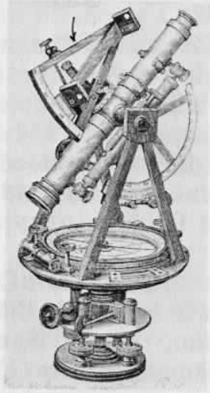
The Gurleys could not afford to be left out of the market in such a vital area. In mid-1874 William Gurley sent his brother-in-law, attorney Charles A. Kenney, to visit William Schmolz and to negotiate the purchase of his patent. On August 10, 1874 Schmolz agreed to sell the rights to Kenney for $1,000 in gold coin. On October 14, 1874 the patent for "Improvements in Solar and Transit Instrument" was transferred to Kenney, and from Kenney to W. & L.E. Gurley, with one provision:

> "But I, the said Schmolz, hereby reserve to myself the privilege of manufacturing at my shop in said San Francisco, and using the said improvement on one (1) of said instruments and no more, in each and every year hereafter."[7]

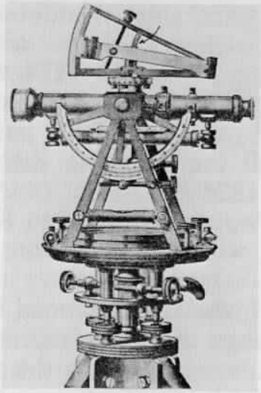

Solar Transit as Patented by William Schmolz, 1867.

Production of the Solar Attachments--which were always referred to as the Burt Solar Attachment--began right away.[8] Solar attachments were mounted onto Engineers' Transits with either 4" or 5" needles, and onto Surveyors' Transits with either 5" or $5\frac{1}{2}$" needles. In addition, older instruments could sent to the factory to be retrofitted with the new device. The solar attachment was particularly useful on the Light Mountain Transit introduced in 1876. In fact, of the approximately 500 Light Mountain Transits made from 1876 to 1885, nearly 40% were solar. During that same period, approximately 70% of all solar transits made were Light Mountain Solar Transits.[9]

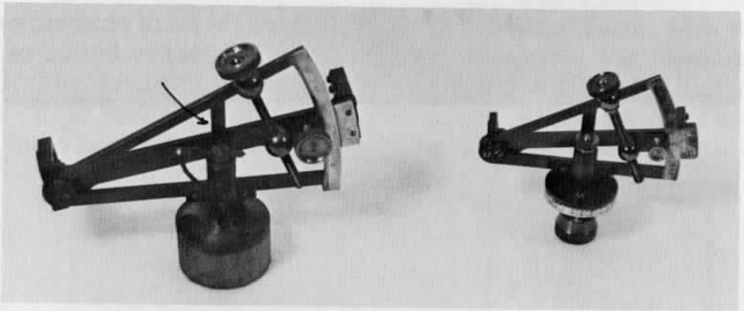
The Solar Attachments continued in production with only minor modifications until 1948. The original design had no cross support. The 1876 design includes an arcuate cross support. The 1883 version has a straight cross support. In the 1911-12 form the cross support is aligned with the spindle.



Gurley Solar Transit (1874)



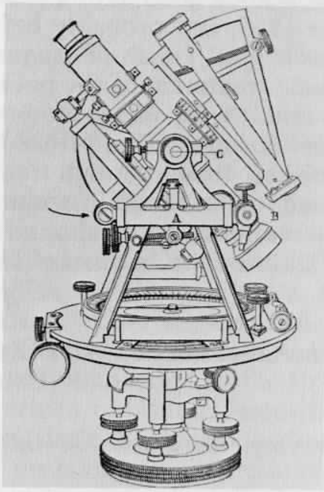
Gurley Solar Transit (1876)



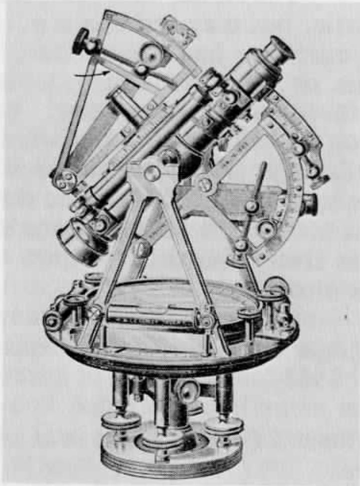
Gurley Solar Attachment (1911-12 form)
(Skerritt collection)

W. & L.E. Gurley patented a Latitude Level on September 2, 1884. Its purpose was to "recover the Latitude of a Solar Transit, without referring to the vertical arc; and generally for setting the telescope at any desired angle in running grades, etc." By 1885 this device had been redesigned to include two adjustment screws instead of one. The Latitude Level was first offered in 1885, and was furnished, at no charge, on all solar transits made thereafter.

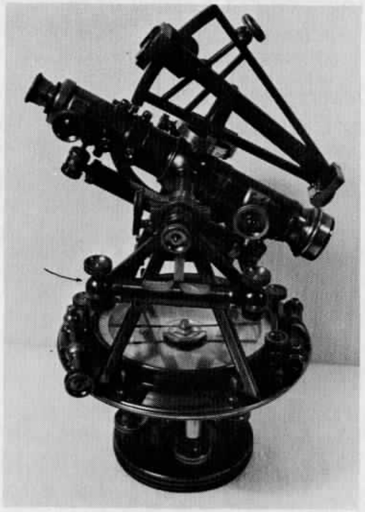
The R. M. Jones Latitude Arc was Patented on January 16, 1883. Gurley secured exclusive rights to its manufacture, and it first appeared in their 1884 *Manual*. This device had its own vertical arc and latitude level, and replaced the normal corresponding equipment.



Gurley Solar Transit with
Patent Latitude Level (1884)



Gurley Solar Transit with
Jones Patent Latitude Arc (1883)



Gurley Light Mountain Solar Transit with Patent Latitude Level (1885)
Note that the adjustment screws are at both ends of the bubble vial,
and its hanging supports are straight rather than curved.
(Skerritt collection)

In 1886 Gurley made a basic design modification to its transits. The two most obvious changes were the introduction of spring opposed tangent screws, and the replacement of the straight legged "A" form telescope supports with a bent leg design.

The finish on Gurley instruments is not a good dating characteristic, but may serve as a guide. Since 1855, and probably before, the customer had the option of either a "bright" finish of lacquered brass, or a "bronze" finish, achieved by acid treatment of the polished surfaces before lacquering. Until the mid 1870s, unless otherwise specified, all instruments were furnished "bright." From that time until about 1900 compasses were furnished "bright," and transits, levels, and solar instruments were "bronzed." Aluminum instruments, first offered in 1876 but not ostensibly marketed until about 1895, were always furnished with a "natural" finish. The "morocco" finish was introduced in 1916.

1. Edgar Freeman Hanks, *Hanks and Other Ancestors of Mine* (Essex, Ct., 1968).

2. Charles E. Smart, *The Makers of Surveying Instruments in America Since 1700* (Troy, N.Y., 1962).

3. *In Memoriam, William Gurley* (Troy, N.Y., 1890).

4. Henry B. Nason, *Biographical Record of the Officers and Graduates of the Rensselaer Polytechnic Institute, 1824-1886* (Troy, N.Y., 1887).

5. William A. Burt, *Description of the Solar Compass* (Detroit, 1844), and *A Key to the Solar Compass* (Philadelphia, 1855 and later). John Burt, *History of the Solar Compass* (Detroit, 1878). J. B. Davis, *History of Solar Surveying Instruments* (Cleveland, 1900).

6. W. & L. E. Gurley, *A Manual of the Principal Instruments used in American Engineering and Surveying*, 4th ed. (Troy, N.Y., 1858).

7. Charles E. Smart, Manuscript Notes and Correspondence, 1967-1972, from the estate of Charles E. Smart.

8. W. &. L. E. Gurley, *Civil Engineers' and Surveyors' Instruments* (Troy, N.Y., 1878-1952). W. &. L. E. Gurley, *Solar Ephemeris for Use With Solar Compass and Patent Solar Attachment for Transits* (Troy, N.Y., 1889-1955).

9. Charles E. Smart, Manuscript Notes, *op.cit.*

DAVIS' QUADRANTS IN AMERICA

Deborah Jean Warner

In 1627 Captain John Smith, "sometimes Gouvernour of VIRGINIA, and Admirall of NEW-ENGLAND" included "A backe staffe" among the equipment needed by navigators bound for America.[1] The backstaff was relatively new when Smith wrote, but it was soon to became the most popular instrument for determining latitude at sea. Continental Europeans referred to the backstaff as the "English quadrant," while the English usually termed it "Davis' quadrant" after the man who had invented it in the 1590s, and who had probably tested it in American waters. Davis' quadrant was particularly important to the British colonists in North America. Many American navigators used it, and several American craftsmen made them. Indeed, Davis' quadrant was the first navigational instrument, and probably the first mathematical instrument of any kind, produced in large numbers in America.

The first American historian to call attention to Davis' quadrants was Howard M. Chapin who, in a short article published in 1927, noted that these instruments were among the few objects made in colonial America which were usually marked with the maker's name and the date of manufacture. Having located eight of these instruments, Chapin called for a census, "with extensive consideration of their manufacturers."[2] M. V. Brewington published a list of 13 American Davis' quadrants in 1961.[3] Silvio Bedini located several more, as well as a great deal of information about their makers.[4]

A prototype quadrant appeared in Captain John Davis' navigational manual, *The Seamans Secrets* (London, 1594). By 1604, when illustrated in *The Jewell of Artes*, a manuscript treatise on ship building written by Captain George Waymouth, Davis' quadrant had reached its final English form. By 1680 Davis' quadrant was acknowledged "the best approved and most general Instrument that is in Use for Observing the Sun's Meridian Altitude at Sea."[5]

Davis' quadrant is a fairly simple instrument. It consists of a central limb about two feet long with a fixed horizon vane at one end, and a 30° arc with a sliding sight vane hanging down at the other end. (In the 18th century, this arc was often just 25°). Above the central limb at the horizon end is a 60° (or 65°) arc of smaller radius equipped with a sliding vane for throwing a shadow from the sun onto the horizon vane. The horizon vane has a horizontal slot in it. The sight vane has a small sighting hole. The traditional shadow vane has a straight edge and no holes. The one widely accepted modification was introduced around 1670 by John Flamsteed, soon to become the first Astronomer Royal, who equipped the shadow vane with a lens to produce a sharper image of the sun.[6] In the 1730s there were at least