Ground vs. Grid

**American Theodolite**
A failed attempt

**Biggert-Waters 2012**
Impact on surveyors

**Velocipedes**
Early-day mechanization
In 1939, the European continent was in the midst of a second major conflict after the passage of just two decades. There existed little doubt that the United States would be drawn into the war despite the nation’s desire not to be involved in the world conflict. Preparing for a prolonged war involved many different aspects beyond manufacturing bullets and bombs. Surveying instruments, such as levels and transits, were immediately and abundantly necessary for construction projects both at home and abroad. For the most part, American instrument manufacturers would supply these needs through increased production, but the greatest weakness was a shortage of theodolites, required nearest to the battlefield for mapping and directing artillery fire. Wild-Heerbrugg, the world’s leading manufacturer of optical instruments, was located in Switzerland. The Axis powers surrounded Switzerland and thus prevented the exportation of these instruments to the United States despite Switzerland’s neutrality.

After involvement in only the latter years of the first World War, the American instrument companies did not recognize a need to alter instrument design because most modifications would primarily be used by the military not the average engineering company. Both the instrument makers and users seemed content with the status quo.

The theodolites in use in the United States prior to World War II were mainly those used for the precise triangulation networks by the U. S. Coast & Geodetic Survey or other government agencies. A bulky instrument was generally...
After 5 years of intense effort to create the “American Theodolite,” Gurley produced this model to unsuccessfully fulfill a government contract.
not considered burdensome since the surveyed terrain was typically accessible and the amount of time to accomplish a project was generally not a factor. The use of this type of theodolite on an unpredictable battlefield, however, would be cumbersome due to changing landscape and the necessity for speed.

Heinrich Wild, born in 1877, is considered the mastermind behind the invention of the theodolite. This Swiss inventor had struggled with high mountain triangulation while using the bulky conventional design, so in 1905 he sought to develop a new theodolite to replace the unwieldy, awkwardly read, transit-type theodolite. When Wild patented his design on January 5, 1907 (38603), a new era began for theodolite construction.

That same year, Wild moved to Germany where he teamed with Carl Zeiss to develop new levels and a new theodolite. Wild’s new theodolite design allowed the user to simultaneously observe both sides of the horizontal circle by means of an optical micrometer. It was the first theodolite to be equipped with glass circles and a parallel coincidence mechanism. Wild filed for an American patent on this design on May 13, 1921, and it was granted on September 16, 1924 (1508585). This theodolite became known as the Th-1 and was first produced by Carl Zeiss in 1924.

Heinrich Wild returned to Heerbrugg, Switzerland in 1921 and, with the help of Swiss financiers, established Heinrich Wild Werstätte für Feinmechanik und Optik which eventually became Wild Heerbrugg in 1937. In 1926, the famous Wild T-2 theodolite became available through Wild’s company.

Among Heinrich Wild’s early associates was Albert Einstein, one of the world’s most brilliant physicists. Einstein and Wild enrolled at the Swiss Federal Institute of Technology in Zurich (ETH Zürich) at the same time and shared many common interests, including engineering.

Leading up to WWII, there had been little or no research and development of radically new surveying instruments within the United States. Years of maintaining the same design within instrument manufacturers finally caught up with the United States when involvement in WWII loomed ahead. The critical wartime need...
for advanced surveying instruments reached a desperate situation. The manufacturers claimed that surveyors and engineers had not come to them with additional needs so there had been no urgency to make design changes. Surveyors adapted to whatever instruments were available from the manufacturers instead of suggesting what would better suit their needs. It had become a situation of being reactive instead of proactive with neither side taking the lead.

In September of 1939, the official report of the Military Mapping Service Test held in southern California concluded that the standard American field surveying instruments were antiquated, unruly, and heavy. It recommended that they be replaced by modern, lightweight, and more finely graduated instruments that would permit field work to be accomplished more rapidly.

Recognizing the need to solve the American theodolite problem at the onset of WWII, the United States Army Engineers circulated a proposal among American instrument manufacturers for the development of a light and compact, precise, universal theodolite especially suited for military purposes. On October 6, 1939, it was recommended that an American theodolite be developed. After nine months of

The telescope on this instrument is another story all by itself. The short, “Wild style” telescope was another wartime development effort.

GURLEY THEODOLITE
BY DAVID LEE INGRAM

As an avid collector of antique surveying equipment, I am always looking to add to my collection. When I find a unique item, my curiosity level goes up. Recently, I spotted a Gurley theodolite. I had never even seen one and I was not aware that Gurley had ever produced a theodolite. So, out came the credit card.

After receiving the theodolite, an examination revealed it was a one-second theodolite with many similarities to the Wild instruments. My interest level continued to rise. Contacts with serious collectors of Gurley instruments revealed they had no knowledge of this product of the Gurley line.

Serious research then commenced with the emerging details telling a very interesting story.

This particular instrument is special because it is the first instrument made by Gurley in fulfillment of the government contract issued in 1942. This may be the only surviving example of the 15 manufactured toward the end of World War II.

The instrument appears to be in good condition with no missing parts or external damage. The optical path for reading the angles may need cleaning, aligning, and prism repair, but that work is for the future. For the moment, it is great to have an obscure piece of both surveying and WWII history.
As mentioned, the American manufacturers had an extremely difficult time trying to produce the horizontal and vertical glass circles in an optical theodolite. Aluminum, brass, or steel circles were produced in the early American prototype theodolites because of the difficulty of making the graduations and numbers upon a glass surface, a highly guarded secret. The glass circles were coated with a wax resist. Then the dividing engine cut through the wax resist whereupon acid (liquid or gas) was used to etch the glass where the wax had been etched. The circle was then coated with a black substance, lead sulphide, which filled the etching. The wax was then removed to reveal the black-colored graduations and numbers. One cannot see the etchings on a glass circle with the unaided eye, only with a microscope. The longest line of graduation on a glass circle is but 0.3mm in length with a width that is nearly impossible to measure. Instrument dealers who cleaned the glass circles of the optical theodolites knew that the tiniest speck left on the glass would look like a boulder when later viewed through the microscope eye piece.

In the 1950's, the National Bureau of Standards finally obtained a dividing engine from the Swiss to use for the etching of the glass circles. In order for the engine to be completely free from serious vibration, it was mounted on a thick block of concrete one meter square with the top surface flush with the room floor, but separate from it. The block was insulated from the surrounding ground and concrete by a 2-inch layer of cork board. The temperature had to be between 68° and 77° when the circles were ruled and could not vary by more than 0.5° once the process began. The ruling points were made from high-grade commercial diamonds mounted to the tip of a steel shank. The WWII-era glass circles typically measured 3.5 inches for the horizontal circle and 2.7 inches for the vertical circle.

“The entirety of 1943 was plagued with additional delays and only a few milestones were gained in developing a theodolite.”

likewise found to be defective, so it too was returned. It took an additional three months for the second model to be resubmitted, an eternity of time during wartime conditions.

When the National Bureau of Standards initiated work on the glass circles in December of 1941, they desired them to work exactly like those on the European theodolites. Development of these circles was stalled under pressing conditions with only some success reported by mid 1942. Due to mounting frustration in late summer of 1942, the Gurley design was reclassified as a substitute standard, to be procured only to meet the most urgent requirements. At this same time, a second contract was awarded to the Keuffel and Esser Company (K&E) for an additional source to produce a wartime theodolite.

Finally, by October of 1942, an order was placed with Gurley for 25 instruments, but production was delayed pending the fabrication of an improved experimental model. By this time, the United States was fully engaged with the war in Europe and in the Pacific. The entire year of 1943 was plagued with additional delays and only a few milestones were gained in developing a theodolite. Combat engineers were making do with the existing theodolites from pre-war stock. An acceptable

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pamlonged discussion, Project SP321 was finally approved and assigned on July 25, 1940. The project was plagued with difficulties and exasperating delays from the beginning. The W. & L. E. Gurley Company (Gurley), with a long reputation of manufacturing quality surveying instruments dating back to the 1840’s, accepted the challenge to design two experimental models in September of that year.

The initial objective was a five-second theodolite, but as development continued, the goal became a one-second instrument like the Europeans used. The project was broken into two parts, (1) the preparation of the miniature, precise, graduated circles, and (2) the actual design and manufacture of the model theodolites. The glass circle aspect was handled by the National Bureau of Standards. A short telescope design was undertaken by the National Defense Research Committee. Gurley was to manufacture the rest of the instrument.

The development of the glass circles immediately proved to be beyond what the Americans could easily achieve. The first experimental theodolite, without glass circles, was not completed and shipped until November of 1941 when war for the United States was imminent. Upon testing, the military found this instrument to be non-satisfactory in both its optical reading and viewing systems, so it was returned to Gurley. The second experimental model was equipped with steel circles in lieu of the aluminum ones on the first model. This second model was inspected in June of 1942 and was

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GLASS CIRCLES

The WWII-era glass circles typically measured 3.5 inches for the horizontal circle and 2.7 inches for the vertical circle.
model was finally completed in March of 1944 just months before the Allies’ invasion of the European continent at Normandy. A lightweight and modern theodolite was essential when the ground forces pressed toward Germany. The latest model had incorporated the newly designed short telescope, but still had steel rather than the elusive glass circles. Despite this continued problem with developing the glass circles, the theodolite manufacturers were instructed to proceed with production.

On November 28, 1944, Harold R. Larsen and John B. Sonderman, assignors to the W. & L. E. Gurley Company of Troy, New York, received United States Patent No. 2,363,877 for their theodolite. The filing date was nearly 22 months earlier on February 11, 1943.

By the summer of 1945, the war with Germany had ended. The United States had developed many highly technical instruments such as the Norden bombsight, encryption machines, advances in weaponry and aircraft and naval vessels. Even with the atomic bomb in its final stages of development, America’s best scientists and engineers still could not produce the glass circles for a theodolite like the Europeans had done many years earlier. In some respects, it should have been a simple issue of reverse engineering the glass circles by taking apart a Wild theodolite.

By the end of the war, only 15 theodolites had been delivered by Gurley. K&E had not delivered even their first experimental model under its development contract. Post war inspections and tests were made on the Gurley theodolite and the K&E theodolite which had finally come under production. The Gurley instruments were generally found to be unsatisfactory, but the K&E instruments met the basic requirements. However, because of the many difficulties encountered and the expense involved, K&E was no longer interested in producing the one-second theodolite. Therefore, in 1947, Gurley was contracted to produce an additional experimental model and five service test models in accordance with revised specifications. The National Bureau of Standards was once again engaged to attempt to produce the graduated glass circles.

Again progress was slow and with difficulties, so the experimental theodolites were not completed until September of 1950. Another patent for the Gurley theodolite was issued for the trunnion bearing from which the telescope rotated. This patent came on July 8, 1952, after having been filed with the U. S. Patent Office five years earlier. Cold weather tests for the American one-second theodolite were conducted from 1951 to 1953 at Fort Churchill, Canada. The American theodolite was finally considered a success, but the cost of production in the United States could not compete with that of the European manufacturers which by some estimates was only one-sixth of the cost.

Therefore, on July 2, 1954, after nearly 14 years from the beginning of the project to the end, the American one-second theodolite project was officially cancelled by the Corps of Engineers Technical Committee.

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