Risley Prisms: 125 Years of New Applications

PAGES 273, 276

Nearly everyone today is familiar with at least one use for optical scanners, the laser bar code scanners found at the checkout counters in virtually every retail store.

What many people may not know is that optical scanners are essential components of many modern scientific instruments. In astronomy, for example, scanning spectrometers have been widely used for many years, and more recently optical scanning technology has been used to build motion compensators for large aperture astronomical telescopes (See for example, http://www.noao.edu/noao/noaonews/dec92/art29.html).

Geodetic laser scanning (GLS) instruments developed within the past decade, and designed to operate from satellites, aircraft, and the ground, make it possible to determine the coordinates of hundreds of millions of points on the surface of the terrain, in observing sessions as short as a few hours. The digital elevation models, contour maps, and other products derived from these GLS observations are revolutionizing the study of geomorphology, surface hydrology, fault systems, and beach erosion, as well as such related activities as forestry and the management of ecological systems [*Carter, et. al.*, 2001].

Some optical scanners use moving mirrors to steer light rays, or pulses of laser light, in a precise pattern. Others use moving refracting elements, including pairs of rotating prisms, generally referred to as 'Risley prisms.'

A quick search of the Internet returns a listing of dozens of papers and reports describing instruments developed by researchers in private industry, academia, and government laboratories that incorporate Risley prisms. However, most if not all share a common shortcoming: They contain not a single reference to a publication authored by Samuel Doty Risley. The reader is left to ponder when, where, and why Risley did the work that merits the credit so freely given, and without so much as a clue as to where to start searching for that information.

When, Where, and Why Did Risley Develop His Rotary Prism?

The classic optics textbook *Fundamentals of Optics* [*Jenkins and White,* 1957] contains a sketch of a "Risley prism of variable power" (Figure 1), and in a section headed "Combinations of thin prisms" states, "In measuring binocular accommodation, ophthalmologists make use of two thin prisms of equal power which can be rotated in opposite directions in their own plane. Such a device, known as the Risley or Herschel prism, is equivalent to a single prism of variable power." However, as with the more recent publications mentioned above, Jenkins and White give no references to publications authored by either Risley or Herschel.

Herschel is, of course, a familiar name in science. William Herschel (1738–1822) and Caroline Herschel (1750–1848), German-born brother and sister who practiced astronomy in England, discovered the planet Uranus, built large-aperture astronomical telescopes, studied and catalogued double stars, and pioneered the use of spectrophotometry in astrophysics. But it turns out that the Herschel alluded to by Jenkins and White is John Herschel (1792–1871), son of William Herschel and internationally renowned in his own right for charting the southern celestial hemisphere and for early measurements of the solar constant. Herschel used prisms in his astronomical work to measure the spectra of stars and later developed a handheld instrument that contained a pair of prisms that could be rotated with respect to one another to deflect light passing through them by a selected angle. A picture of Herschel's device may be found at http://www.eyeantiques.com/images/cd/Dia9x.jpg

The Risley alluded to by Jenkins and White is Samuel Doty Risley (1845–1920), a well-respected American ophthalmologist who practiced medicine for nearly 50 years in Philadelphia. Even with that information in hand, it proved difficult to find a reference to a publication authored by Risley concerning his variable power prism assembly. Persistence proved successful, though, when Raghavendra Kumar Vemula, a University of Florida (UF) graduate student, tracked down a reference to a paper by Risley titled "A new rotary prism" and obtained a copy at the UF Shands Medical Library. The paper, which is only a page and a half long, was first presented orally at the Twenty-Fifth Annual Meeting of the American Ophthalmological Society, in New London, Conn., and was subsequently published in the transactions of the society [*Risley,* 1889a].

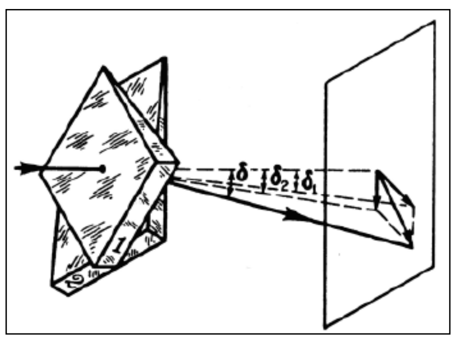

*Fig. 1. Sketch showing how two prisms can be used to deflect a light ray by an angle equal to the vector sum of the deflection of each prism. The deflection may be measured in degrees or diopters (one diopter results in the deflection of a light ray by one centimeter at a distance of one meter) [*Jenkins and White, *1957].*

Surprisingly, Risley never made any pretense of having invented the prisms, or even to having been the first to think of using them to detect and measure "anomalies in the ocular muscles." In fact, his paper began with the statement, "I present herewith…a new, and I think more convenient, form of revolving prisms than those heretofore in use. Adopting the principle first put in practice by Volkmann [German ophthalmologist Alfred Wilhelm Volkmann, 1801–1877]…two prisms…are mounted in a delicately milled-edge cell….The prisms are caused to rotate in opposite directions by means of a milled-head screw….The strength of the successive prisms, resulting from the rotation, is read off on the graduated scale engraved on the front plate of the containing cell" (Figure 2).

Samuel D. Risley: Student, Soldier, Physician

In 1888, when Samuel Risley presented his paper at the meeting of the American Ophthalmological Society, he was 43 years old and a well-known physician in Philadelphia. But he was not a native of Pennsylvania. He was born on 16 January 1845 in Cincinnati, Ohio. His education began in the Cincinnati public school system, but his family later moved to Iowa, and he graduated from high

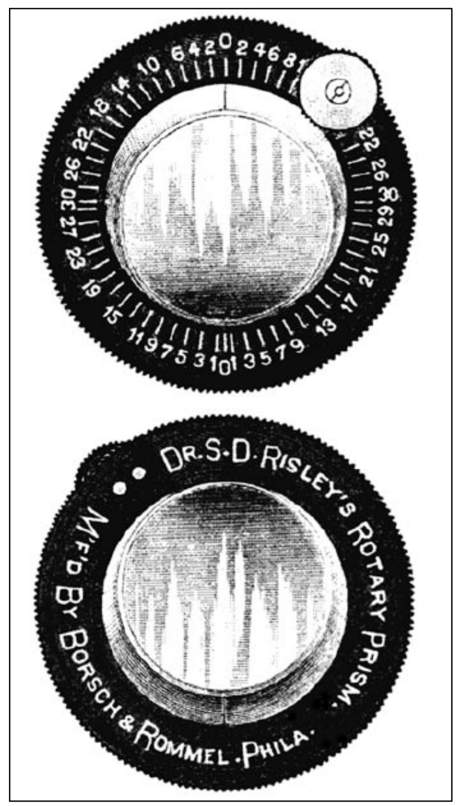

Fig. 2. Sketch, reproduced from Risley *[1889], showing front (top) and rear (bottom) views of the "rotary prism" assembly. The prisms were rotated in opposite directions by the thumbwheel located on the upper right of the front side of the assembly, which resulted in a nearly linear change in the effective power of the prism.*

BY W. E. CARTER AND M. S. CARTER

school in Davenport. The nation was embroiled in the Civil War, and he enlisted in the Twentieth Regiment of the Iowa Volunteers (infantry). Risley was assigned to Company D, under the command of Captain Dolphus Torrey. Company D suffered combat casualties, but during his three years of service, Risley saw more of his colleagues die from sickness than from wounds suffered in battle. Pneumonia was particularly dangerous for the enlisted men because they lived and performed their duties outdoors, in all seasons and weather conditions.

When he was discharged from military service, Risley enrolled at the University of Iowa. After two years of academic studies, he began to study medicine, working in the office of Dr. Lucius French, in Davenport. A year later he moved to Philadelphia and enrolled at the University of Pennsylvania (Penn). He graduated from Penn in 1870 with a degree in medicine. His thesis, entitled "Phenomena and signs of death," was almost certainly inspired by the deaths of a number of his colleagues during his military service.

Also in 1870, Samuel Risley married Emma D. Thompson and accepted a position as a clinical clerk at Wills Eye Hospital, in Philadelphia. In the years that followed, he held several different positions, all in Philadelphia, including lecturer and assistant surgeon at the University of Pennsylvania Hospital, professor of diseases of the eye at the Philadelphia Polyclinic and College for Graduates in Medicine, and attending surgeon at Wills Eye Hospital. He devoted much energy and time to treating the children at the Pennsylvania Training School for Feeble-Minded Children. He also helped screen students in the public schools to identify those who had poor eyesight and needed glasses to function better in the classroom. His work in the public schools convinced him that the generally poor lighting was causing many students to develop myopic vision, and he lobbied state and local officials to provide adequate lighting in the classrooms.

Thoroughly examining the eyes of a large population of patients (such as all of the students in the Philadelphia public school system) was a laborious task, particularly with the ophthalmological instruments then commonly available. From his military service, Risley was familiar with precise mechanical assemblies, such as the trigger and firing mechanisms of weapons, and he soon suggested several improvements to the optometer and ophthalmoscope that enabled physicians to more quickly measure "the errors of refraction in the human eye." For example, he improved the ophthalmoscope by adding cylindrical lenses that could be switched into place to quickly determine and correct for astigmatism in patients' eyes.

'Inventing' the Rotary Prism

Risley's 'invention' of the rotary prism was driven by the need for a fast and accurate method to determine if a patient's ocular muscles were sufficiently out of balance to result in significant vertical or horizontal (lateral) displacements between the images formed in each eye and, if so, to measure the power of the wedge required to correct a patient's vision. It was common for physicians to perform this test by placing successively stronger or weaker prisms before one of the patient's eyes and testing to see if his or her vision improved—a tedious procedure that consumed the physician's time and caused the patient fatigue. The rotary prism assembly (Figure 2) replaced an entire set of prisms of differing powers with an assembly containing just two prisms but which could quickly and accurately be set to realize a wide range of 'effective' powers [*Risley,* 1889a].

The real genius of the Risley rotary prism was that the two prisms were mounted in a cell "with a diameter the same as those employed in the Nachet trial glasses, which therefore fits readily into the ordinary trial frame…." *Risley* [1889b] preferred to test his patients' eyes using a "short word… in the center of a white card…placed firmly at thirty centimeters from the eyes…." With any needed corrective lenses for nearsightedness or farsightedness and astigmatism in place, he could test the balance and ability of the patient's ocular muscles to accommodate for selected amounts of vertical and lateral refraction introduced before one eye. Risley arranged with Borsch & Rommel, of Philadelphia, to manufacturer the prism assembly, and it soon became standard equipment in most ophthalmology offices, at least most American ophthalmology offices.

Twist of History

Samuel Doty Risley (Figure 3) authored some 150 articles reporting the results of his surgeries, his treatments of eye diseases, his work with school children, and his improvements to ophthalmology instruments. Many of his original manuscripts, abstracts, speeches, lecture notes, and correspondence are preserved in the library of the College of Physicians of Philadelphia. It seems certain that Risley would have been surprised indeed to learn that nearly a century after his death his rotary prism would be credited as the basis of many modern optical scanners—including those in the most advanced geodetic laser scanning instruments, used to map the surface of the Earth with unprecedented precision and resolution [*Carter et al.,* 2004]. His goal was simply to make the day-to-day work of ophthalmologists more efficient and to minimize the discomfort of their patients, by providing a fast and convenient way to insert wedges of differing powers into the standard eye-testing apparatus. Samuel Doty Risley died on 1 April 1920, at age 75.

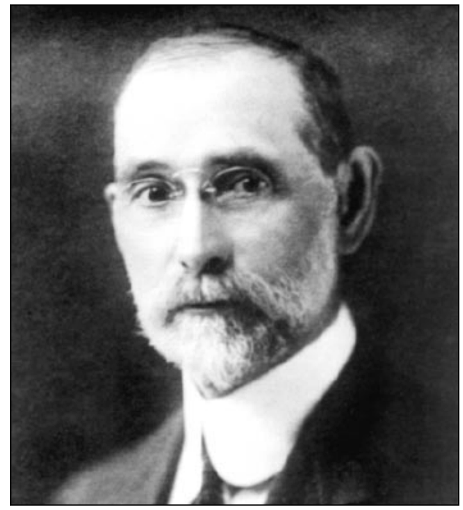

Fig. 3. Photograph of Samuel Doty Risley, taken circa 1910. Courtesy U.S. National Library of Medicine.

Acknowledgments

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