THE JOURNAL OF NAVIGATION (2003), **56**, 315–321. © The Royal Institute of Navigation
DOI: 10.1017/S0373463303002236 Printed in the United Kingdom

Finding Distance – The Barr & Stroud Rangefinders

Peter Ifland

KEY WORDS

1. Rangefinder. 2. Range. 3. Distance. 4. Navigation.

This article is the fourth in a series dealing with the techniques and instruments used to find distance for navigation and gunnery. The Barr & Stroud rangefinders, first introduced in the 1890's, were based on refracting prisms at each end of a horizontal tube. This design became the universal standard ashore and afloat for almost 100 years.

The last decades of the nineteenth century and the early part of the twentieth century leading up to World War I were times of war and the threat of war. England and the Boer War, Japan's wars with China and Russia, and the Spanish American War all involved major commitments of military forces both afloat and ashore. Potentially hostile alliances brought additional diplomatic tension to national interests across the globe from Chile to Russia and many points between. Simultaneously, the technology for waging war advanced rapidly and the debate within governments as to how much to spend and on which tactical and strategic options was the subject of hot and frequently divisive debate.

Advancements in artillery and naval gunnery technology were particularly impactful during this era. Guns were no longer smooth-bore, muzzle loading, ball firing cannons but now were rifled, breach-loading with aerodynamic projectiles. The range of effective fire increased as the bore of guns increased from 4 to 6 inches and eventually to the wide use of 16-inch guns for coastal artillery and battleships. Concurrently, the maximum range increased from 2,500 yards to 20,000 yards.

The markedly increased range of guns put new demands on the techniques and instruments for fire control. Naval engagements no longer were fought with broadsides at close range but the newer, faster armored steel ships of the early 1900's could now stand off and fire at the moving target at great range. The higher trajectories required for greater range led to longer time of flight of the projectile and thus the need to calculate the position of the target when the projectile was timed to arrive at the target taking account of the target's computed course and speed.

Naval fire control was managed by each gun captain using visual sighting of the fall of the shot well into the 1890's. Navies of the major sea powers, particularly of the United States and Great Britain were acutely aware of the need for improved range finding and actively encouraged the invention and development of more accurate instruments. Lieutenant, later Admiral, Bradley A. Fiske and the companies with whom he associated, were particularly active and influential in the United States Navy (Ifland, 2002). Concurrently, the Scottish firm of Barr & Stroud was highly successful in developing and supplying the Royal Navy as well as many foreign navies with improved range finding instruments.

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

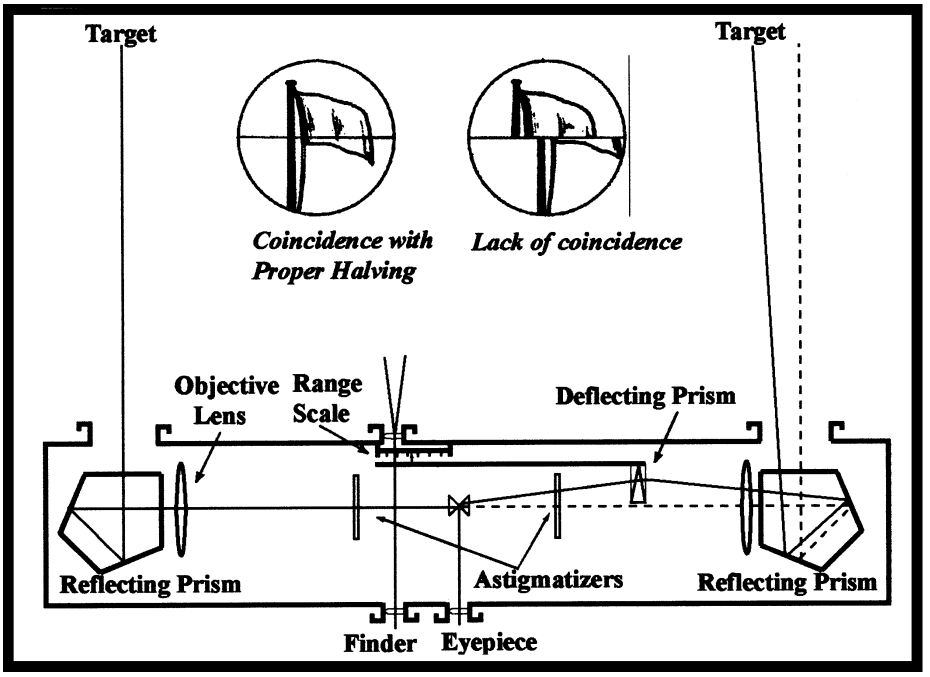


Figure 1. Diagrammatic of a Barr and Stroud rangefinder. Redrawn from Moss and Russell, 1988 and Anonymous, 1917.

In 1888, Archibald Barr was Professor of Engineering and William Stroud was Professor of Physics at the Yorkshire College of Science in Leeds. They were good friends and next-door neighbours. They had worked together for several years on developing and patenting a lantern slide camera. When the British War Office advertised for an improved single operator artillery range finder with 4% accuracy, i.e., 40 yards at 1000 yards, to replace the widely used two-operator Watkin Mekometer, the two professors decided to respond. (Ifland, 2002, Moss and Russell, 1988).

The design Professors Barr and Stroud submitted was based on the idea of two reflectors at the end of a tube. This was not a new idea – Patrick Adie, a scientific instrument maker, had patented it in 1860. In Adie's model, one mirror was fixed to reflect the image of the target at 90 degrees into the eyepiece while the mirror at the other end of the tube could be rotated proportional to the distance also to reflect the image of the target into the eyepiece. One problem with range finders of the Adie design is that the second mirror had to be rotated very precisely. For example, the difference in angles for an error in range of 40 yards at 1000 yards, as required by the War Office, is about 20 arcseconds for a nine-foot base!

The design the two professors submitted to the War Office drew heavily on their academic knowledge of physics and engineering – Stroud to come up with creative, problem-solving designs and Barr to execute these designs in simple, reliable instruments. They were able to solve many of the problems of the Adie and other single operator design instruments in the model they submitted for the War Office field tests (Figure 1).

The instrument Barr and Stroud submitted for the 1888 War Office field trials embodied a number of major improvements over previous designs and established the

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

basic design concepts of military range finders through World War II. An eyepiece for the left eye, the "Finder", used a small, wide field Galileo telescope to permit the operator to locate the target and centre it in the eyepiece. They used pentagonal prisms rather than mirrors for the reflectors at the end of the base as a way of getting around the distortions with temperature inherent in flat reflectors and the difficulty in clamping them firmly in place. The mirrors at the centre of the eyepiece were arranged so that the images from the reflectors were cut in half horizontally. Thus, the operator could easily bring the two images to precise coincidence (Figure 1). The most critical innovation was to place a "Deflecting Prism" in the path of the reflection from the right prism. The "Deflecting Prism" slid along the axis of the tube proportional to the range, as far as needed to refract the image into coincidence in the central eyepiece. The range was indicated on a scale superimposed in the Finder eyepiece. The optics were placed in a carefully mounted inner tube to protect them from vibrations and mechanical damage and to minimize the effect of changes in temperature. These features were protected in Barr and Stroud's British Patent number 9520 of June 30, 1888. The instrument used in the field trials first conducted in 1889 had a three-foot base and performed well enough to be considered for further trials. Barr and Stroud modified their design for the second trials to use plane parallel reflectors as a cost saving step. Unfortunately, the new design proved unacceptably vulnerable to temperature changes and the War Office rejected it in favor of the old Watkin Mekometer.

By 1891, the British Admiralty was forced to the conclusion that the effectiveness of the Navy's gunfire urgently needed modernization. The Admiralty solicited inventors to submit candidate rangefinders with a specified accuracy of 3%, 90 yards at 3,000 yards. Barr and Stroud, who had continued to improve their rangefinder designs, responded with an instrument specifically designed for sea duty. The professors clearly recognized that their instrument should be useful for inshore navigation and station keeping. For this purpose, they provided astigmatizers that could be inserted into or removed from the sight paths. (Figure 1). The astigmatizers converted a point of light from a running light, a masthead light or a distant lighthouse into a sharp vertical line so the two images could be brought to coincidence precisely. The tubes were made of copper and brass to avoid interference with the ships' magnetic compasses. A 5-foot instrument, designated FA Mark 1 and mounted on a tripod was first tried in April 1892 on HMS *Aretusa* and then on the gunnery school ship *Excellent* in June. The tests were successful and they received their first order for five rangefinders early in 1893. The production model has a base length of 4 feet 6 inches that was to become the standard. It featured a sturdy base made by James White & Co. that could be bolted securely to the deck (Figure 2).

At the end of the nineteenth century British shipyards were producing warships not only for the British navy but for foreign navies as well. Acceptance of the new rangefinder by the British Admiralty immediately stimulated these foreign navies to buy the Barr and Stroud rangefinder for their ships. The Japanese were particularly good customers and the partners were informed that they were to supply rangefinders for the ten new Japanese warships then under construction. The Japanese practice was to fit as many as six rangefinders on their large ships, each placed in close support of a gun battery. The Barr and Stroud rangefinders served the Japanese particularly well in the battle of Tsushima in 1905 against the Russians who had bought and installed only a few of the rangefinders and had not yet learned to use them.

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

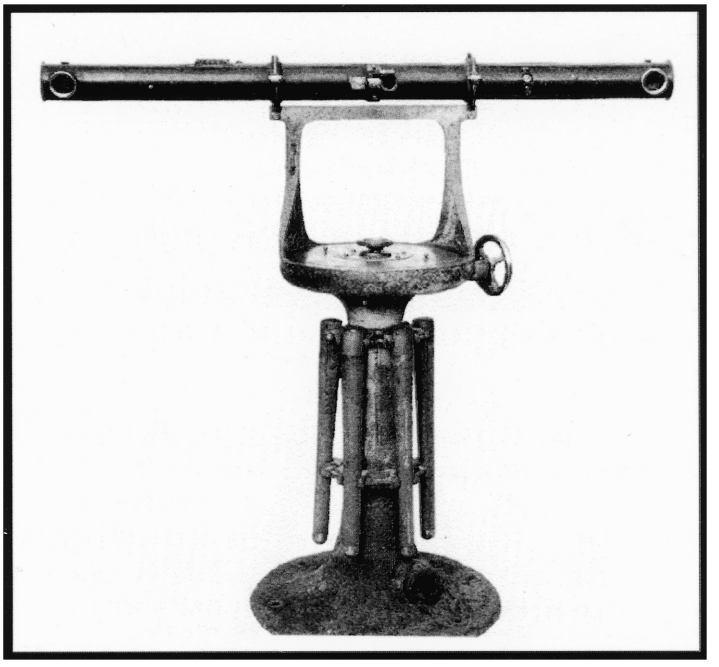


Figure 2. Barr and Stroud naval rangefinder number 3, 1893, viewed from the front showing the ports for the two reflectors at the ends of the tube, the "Finder" telescope in the center, and the mount by James White & Co. (Moss and Russell, 1988).

As the orders began to pile up, the two professors realized that they could no longer run the business as a sideline. They formed the company Barr & Stroud Patents in 1894, to become simply Barr & Stroud, Ltd in 1912. In 1893, they contracted with an established naval armament and construction firm, W. G. Armstrong, Mitchell & Co., to promote sale of their rangefinders abroad. The firm moved its operations to Glasgow in 1895 and markedly expanded their office and production facilities to meet their growing business needs. Production rose from six rangefinders in 1893 to 14 in 1894 and 29 in 1895. They introduced an improved model, the FA2, in 1896 and the Admiralty promptly ordered twenty at a price of £240 apiece. In 1899 the Admiralty ordered 100 range finders with the intention of fitting one fore and one aft on every capital ship. International sales, particularly to Japan, continued to grow with customers all over the world. Barr & Stroud sold 490 rangefinders in the ten years following their introduction in 1893.

The original request from the British Admiralty in 1891 indicated that the rangefinder should have the capability to pass its information to the guns through some system of instantaneous communication. In response, Barr & Stroud developed an electrical system of transmitters placed at the rangefinder station connected to receivers on the bridge and at each gun mount. The Japanese were the first to purchase the new "range and order" instruments and installed the system on every ship fitted with Barr & Stroud rangefinders. (Go to http://www.fido.sakhalin.ru/timurk/tsusima/togo01.jpg for a marvelous picture of Japanese Admiral Togo and two Barr and Stroud rangefinders, the one in the background fitted with the range and order equipment.)

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

The period leading up to World War I saw demands for increasing rangefinder accuracy. Specifications escalated from 4% at 1000 yards in 1881; 3% at 3000 yards in 1891; to 3% at 6000 yards in 1901. Early in the war the modern battleships of Britain and Germany fought battles at 15,000 and 20,000 yards. The obvious response was to increase the base length of the rangefinders. The Admiralty's first purchases were 6 feet in length; then came models of 9 feet length, 15 feet, 20 feet, 25 feet, 30 feet, and even 42 feet. Accuracy increased proportionally – the 42-foot FX3 model of 1924 was accurate to 1·3 yards at 3000 yards or 0·043%. The ultimate execution of the concept of "length equals accuracy" was Barr & Stroud's 100-foot coastal defense rangefinder installed at Singapore harbour. It had an accuracy of 17 yards at a range of 31,000 yards, 0·055%.

The advent of the airplane as a weapon of war in WWI called for Barr & Stroud to modify their short artillery range finder to measure range and altitude of aircraft. They simply rotated the tube vertically around its axis and added a scale on the mount to read the angle of elevation of the aircraft – range and elevation gives altitude. Barr & Stroud also applied their expertise in optical instruments to produce a popular binocular stereoscopic rangefinder for submarine periscopes.

Throughout their history spanning more than 100 years, Barr & Stroud faced strong competition. During the 1890's, Carl Zeiss, the eminent German optical firm, marketed a competitive rangefinder based on the stereoscopic principle. With this system the operator had to align an arrow seen with his left eye with an image of the target seen with the right eye using his depth perception. The system was accurate to one yard at 1000 yards but operation was so delicate that German operators were forbidden to have alcohol or sex before getting underway. The German firm Herren Optische Anstalt C. P. Goerz used two prisms rotatable in opposite directions to bring the images to coincidence in proportion to range instead of a sliding prism as with Barr & Stroud. In the United States, Bosch & Lomb and Keuffel & Esser produced rangefinders of their own design but also produced instruments of Barr & Stroud's design during the war years. The accuracy of these competitive rangefinders was comparable to those of Barr & Stroud but the British instruments generally had the advantage for ease of operation with their simple coincidence optics.

Through the 1920's, ships were fitted with a number of rangefinders. Instruments of 30 to 40 feet were mounted directly on the main battery turrets and in a central director tower while shorter rangefinders were stationed alongside individual smaller batteries. By the start of World War II, naval rangefinders were mounted in trainable directors as part of a central fire control system (Figure 3). Data on range and bearing to the target was fed continuously to a central fire control computer located safely below decks. Even though radar became universally available to allied navies, optical rangefinders continued to be the preferred instrument for gunfire control.

Most warships built after about 1970 no longer carried an optical rangefinder. Deployment of missiles with different aiming and guidance requirements spelled the end for optical rangefinders and Barr & Stroud produced their last in March 1982. The firm's line of other optical instruments for military applications kept pace with new laser range finders, infrared sights for tanks, and sophisticated thermal imaging instruments. Attack and search periscopes developed for the new Trafalgar class hunter-killer subs were an important part of their supplies to the Admiralty during the 1980's. In 1987, Barr & Stroud became a subsidiary of Pilkington Brothers Ltd.,

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

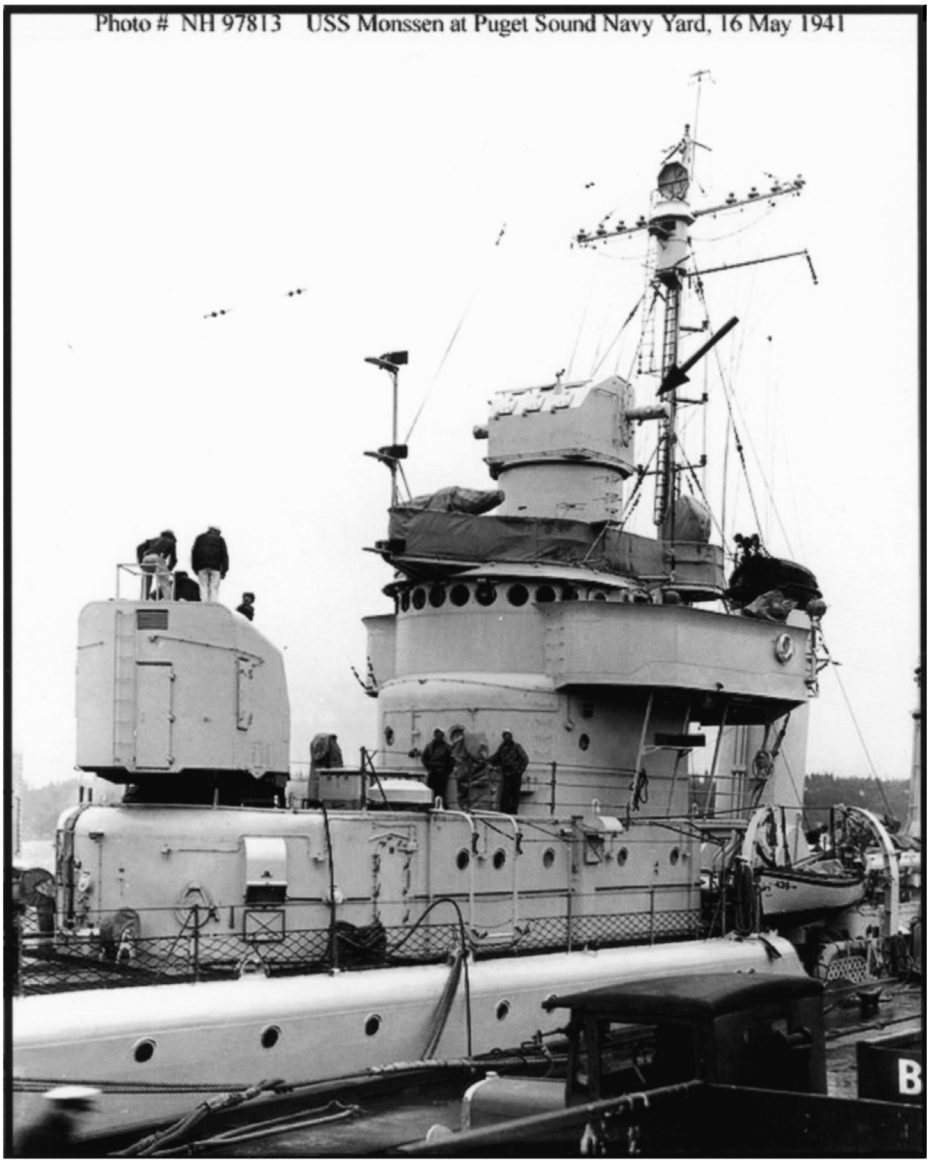


Figure 3. A U.S. destroyer showing a typical range finder installation in a director located high above the bridge. Official U.S. Navy photograph from the collection of the Naval Historical Center, Washington, D.C.

the world's leading producer of high quality glass, in a move to strengthen their civilian product development and marketing capability. The firm later became known as Pilkington Optronics (1988); for a brief period it was part of Thompson-CSF (1998); and ultimately was acquired by the Thales Group to become Thales Optronics, now Thales UK. They are still in the business of developing and marketing innovative optical equipment.

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press

ACKNOWLEDGEMENTS

This article draws heavily on *Range and Vision, The First Hundred Years of Barr & Stroud* by Michael Moss and Iain Russell, published by Mainstream Publishing, Glasgow, 1988. This material is used by the kind permission of Prof. Michael Moss, University of Glasgow, where the archives of the Barr & Stroud company now reside.

REFERENCES

Ifland, P. (2002). Finding Distance – The Fiske Rangefinders. This *Journal*. **55**, 147.

Ifland, P. (2002). Finding Distance – The Haecke Rangefinder. This *Journal*, **55**, 323.

Ifland, P. (2002). Finding Distance – Not Knowing Height. This *Journal* **55**, 495.

Moss, M., Russell, I. (1988). *Range and Vision – The First Hundred Years of Barr & Stroud*. ISBN 1-85158.128-6. Mainstream Publishing Company, Edinburgh.

Anonymous. (1917). *Description of the The Barr & Stroud 9-Foot Horizontal Base Self-Contained Rangefinder Type F. Q. 2*. No. 1905 of May 16, 1911, Government Printing Office, Washington, D.C.

Anonymous. (1917). *Handbook of Range-Finders, 70 CM. and 80 CM. Base For Use Of Infantry and Cavalry*. No. 1797 of December 9, 1915, Government Printing Office, Washington, D.C.

https://doi.org/10.1017/S0373463303002236 Published online by Cambridge University Press