Development of Optical Rangefinders

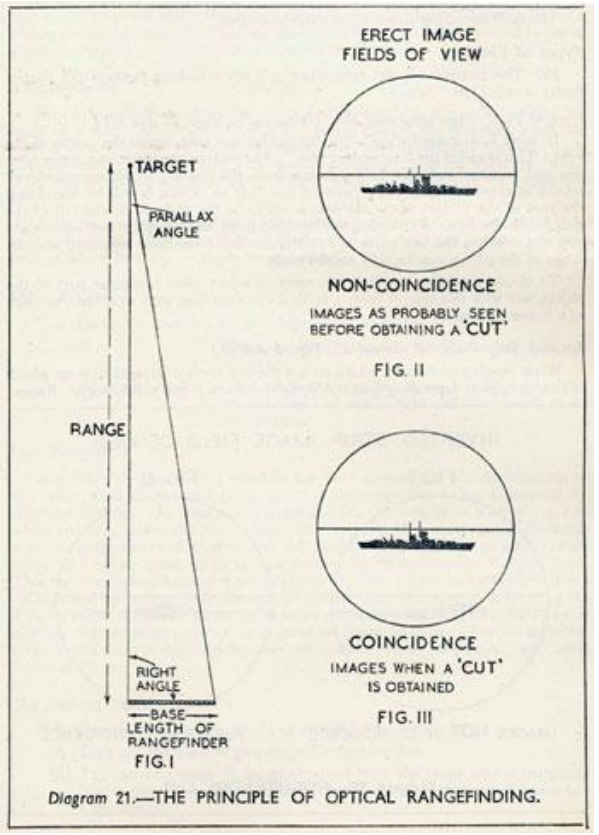
Christopher P. Carlson

Fall In 2024

Admiralty Trilogy Seminar

Outline

- Naval Gunnery in the 1890s
  - Why did range finding become necessary?
- Range Finding Techniques
  - Two-observer
  - Single-observer
- Coincidence Rangefinder
- Stereoscopic Rangefinder
- Optical Rangefinder Error
- Survey of World War I Optical Rangefinders
  - Whose were better? Barr & Stroud or Zeiss?
- Questions



Naval Gunnery in the 1890s

- Naval gunfire in the 1890s was a close-range affair.
  - Royal Navy gun layer trials early 1890s: 1,000 – 1,500 yards.
  - Royal Navy gun layer trials mid-1890s: 1,400 – 2,000 yards.
  - Fisher Mediterranean Fleet 1899-1901: 3,000 – 4,000 yards.
  - French Navy mid 1890s: 2,500 – 3,000 yards.
  - French Navy late 1890s: 3,000 – 4,200 yards.
  - Battle of the Yalu River 1894: 2,000 yards – 3,000 yards.
  - Battle of Santiago de Cuba 1898: 2,000 – 3,000 yards.
    - Americans open fire at 6,000 yards.
    - Battle of Manila Bay was similar.
- Exercise gunnery trials and wartime experience, for the most part, occurred at about the same range: 1,500 – 3,000 yards.
- Hit rates at these ranges, however, were very different.
  - Exercises: 20% – 33%
  - Wartime: <5%

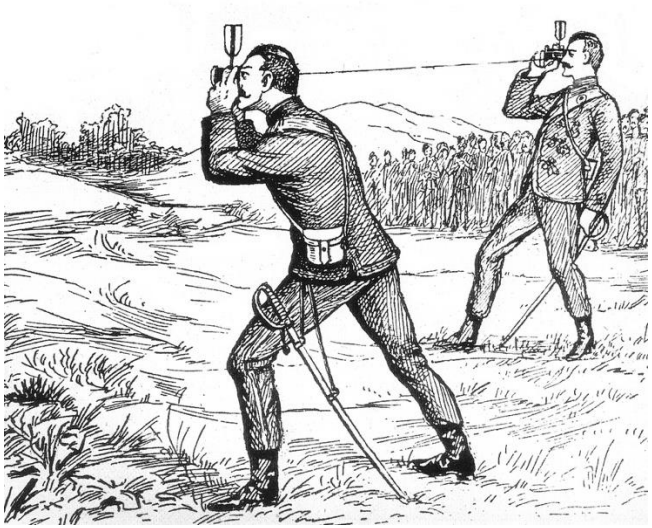
Naval Gunnery in the 1890s

- Problem: gunnery accuracy above ≈5,000 yards is very poor.
  - Probability of hit on the order of 2 – 4%.
- And yet, modern large caliber guns of the era have ballistic ranges that far exceed the range of accurate fire.
  - Royal Navy 13.5in/30 BL MkIII/IV has a range of 12.6 kyds at 13.5 deg elevation.
  - Royal Navy 12in/35 BL MkVIII has a range of 13.9 kyds at 13.5 deg elevation.
  - Upcoming 40-caliber guns will have ranges even greater.
- Forcing function: Torpedo range is already creeping over 1,500 yards and with expected improvements in propulsion, likely to reach ranges greater than 2,000 – 3,000 yards.
- Telescopic sight improves shooting out to 3,000 – 4,000 yards, but beyond that distance, range information is also required.
- How does one determine the range to a target?

Range Finding Techniques

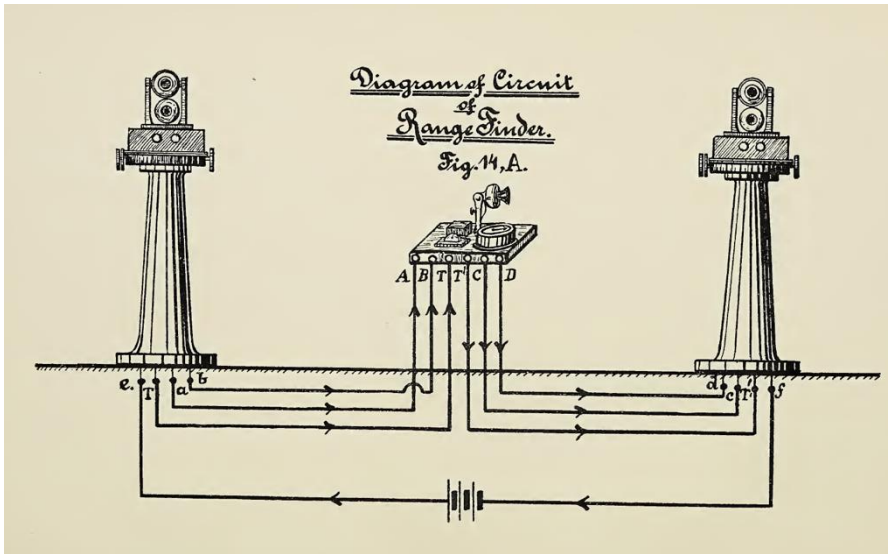
- Four different approaches were investigated from the late 1880s through the mid-1890s for shipboard use.
  - Three methods used some form of triangulation to determine range.
    - Target bearings were measured along with a known baseline to produce a right triangle.
  - One method relied on a two bearing cross-fix.
- Two-observer methods.
  - Fiske Range Finder
    - Developed in 1889.
  - Variation of the Watkin Mekometer
    - Developed in the late 1870s for the Royal Artillery.

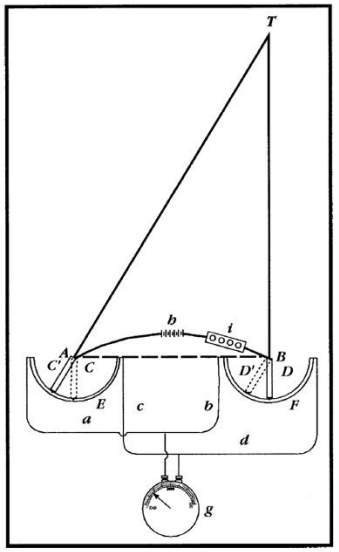
Watkin Mekometer MkI



Steward Telemeter

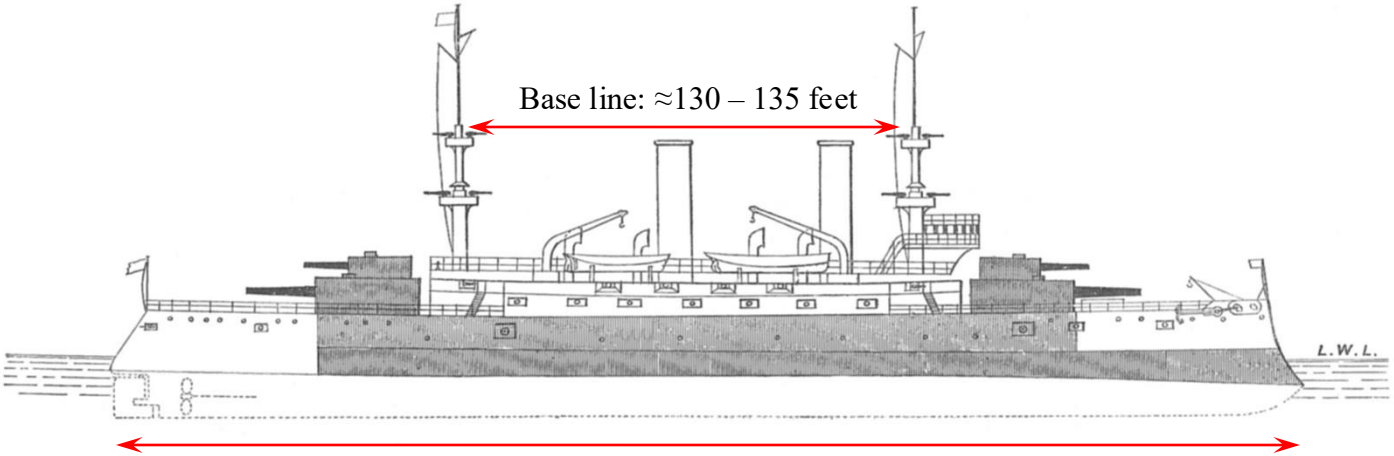
Fiske Range Finder





- Lieutenant Bradley Fiske, USN devised a rangefinder that used cross bearings taken from two separated stations on a ship's superstructure.
- Bearing stations each fed an electrical signal to a Wheatstone bridge.
  - Generated a voltage sent to a galvanometer whose scale was calibrated for range.
- Underwent at sea testing with both the U.S. and French navies.
  - Neither navy adopted Fiske's invention, and the Royal Navy didn't even test it.

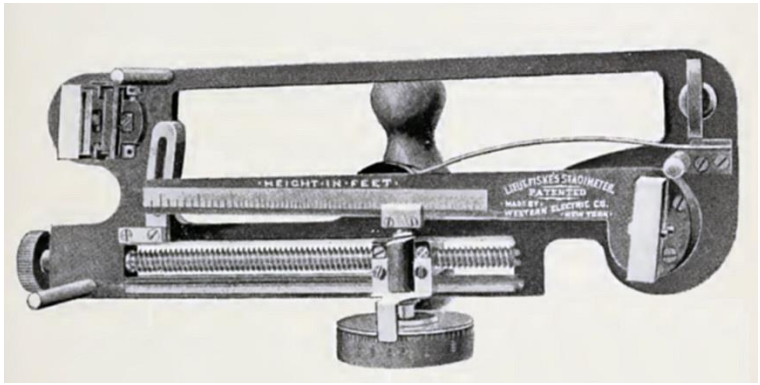
Fundamental Weakness



USS *Kentucky*

- Both the Watkin and Fiske rangefinders had short base lines.
  - Range accuracy was poor beyond ≈3,000 – 4,000 yards.
- Multiple bearings from a moving ship made operation difficult.
  - Roll, pitch, and yaw degraded the accuracy of the bearing information.
  - A Fiske rangefinder was used during the Spanish-American War; the range information was found to be unreliable.

Single-observer Rangefinders



Fiske Stadimeter

Liuzhol-Maikishev Micrometer

Self-contained Optical Rangefinder

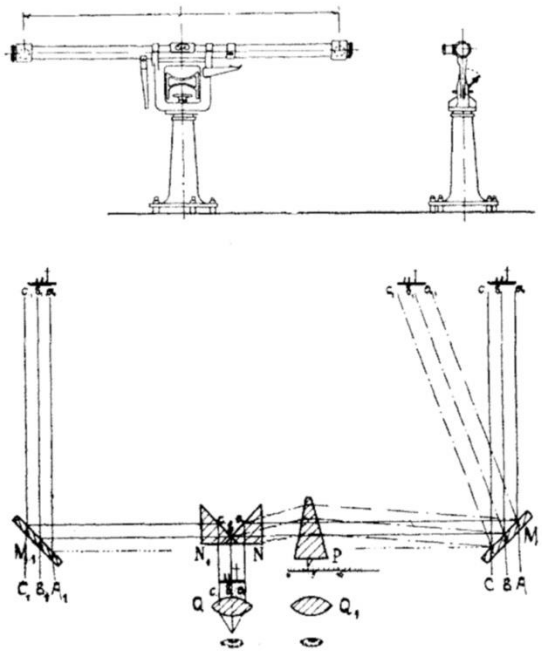
- Single-observer rangefinders fall into two categories, both use triangulation to determine range.
- Depression rangefinders and self-contained optical rangefinders.

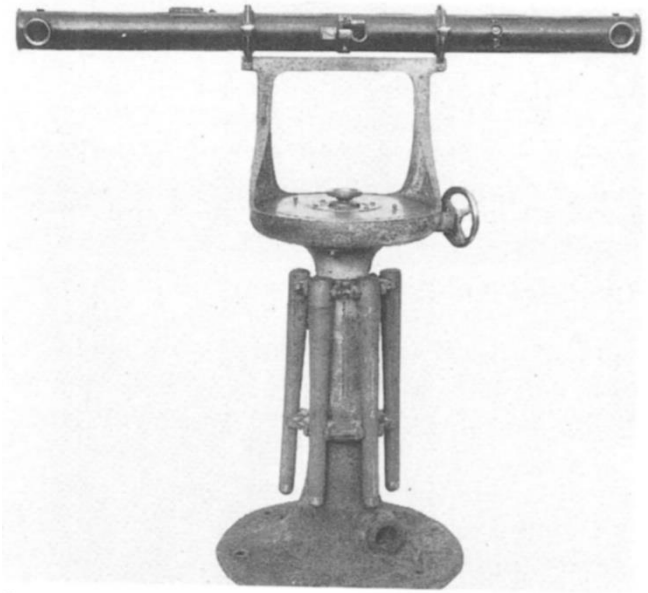
Depression Rangefinders

Fiske Stadimeter

- Depression rangefinders measure the vertical angle of the target and use the target's height as the base line.
  - First proposed in 1855 by naval gunnery aficionado Sir Howard Douglas.
  - Big issue: The target had to be correctly identified to get the proper height.
  - Ship's movement often made it difficult to measure the angle accurately.
  - Effective range limited to about 4,000 – 5,000 yards.
- Many versions manufactured and employed by several navies.
  - Liuzhol (1882), Fiske (1892), Handgërat (1893), Liuzhol-Maikishev (1894)

Self-contained Optical Rangefinders

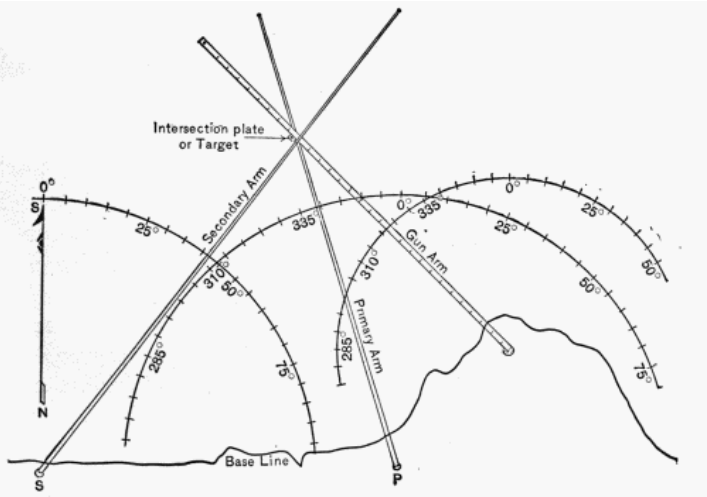




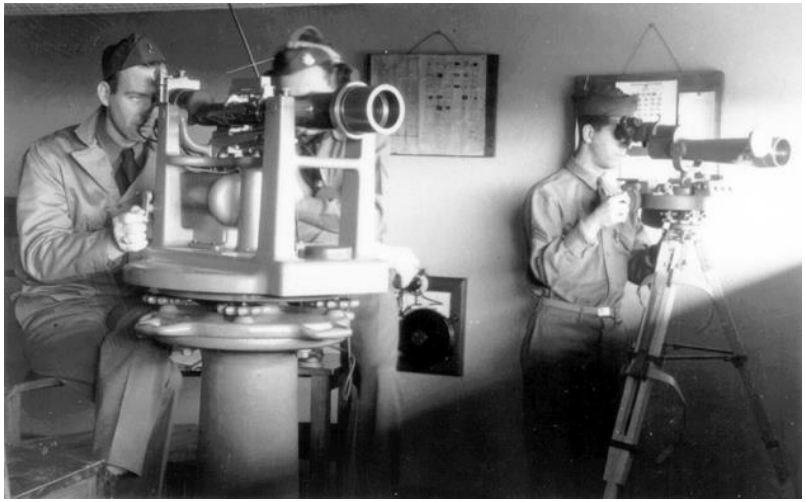
Barr & Stroud FA Mk 1 Coincidence Rangefinder

- Dr. Archibald Barr and Dr. William Stroud submitted a coincidence optical rangefinder in response to an Admiralty request for proposal.
  - The FA Mark 1 produced the most accurate range readings during a set of trials in April 1892 aboard HMS *Arethusa*.
  - Accepted into service with the Royal Navy in 1893.
- Significant improvement over the first coincidence rangefinder designed by Patrick Adie (1860).

Not Without Value



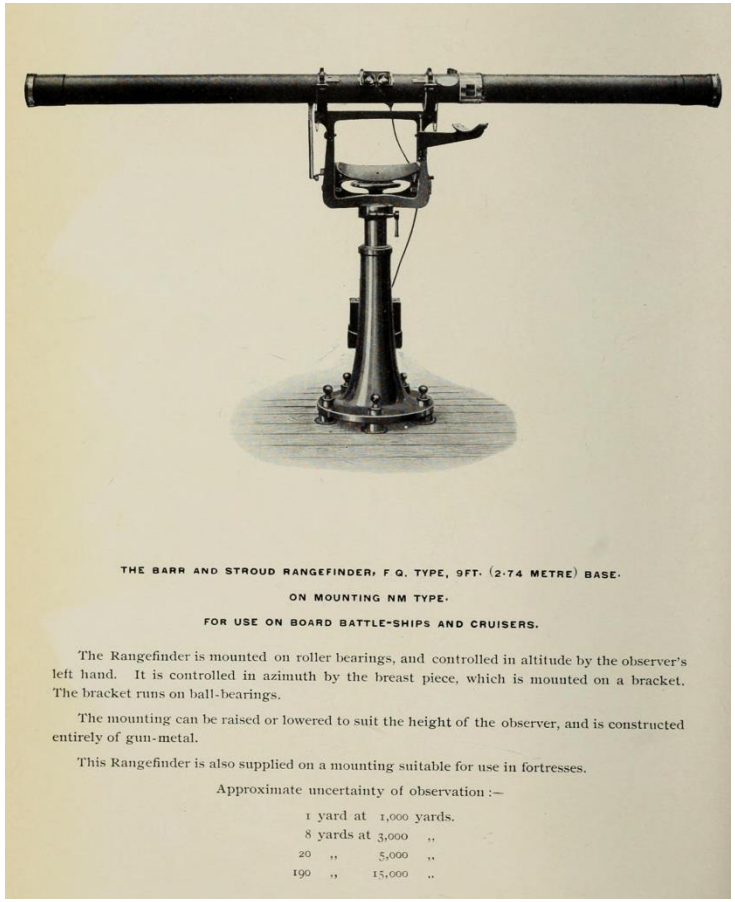
U.S. coastal artillery base station optical rangefinders



- Both the Fiske rangefinder and depression rangefinders were theoretically sound and found great utility with coastal artillery batteries.
- Fiske rangefinder concept was used in the Horizontal Base system with the base stations miles apart and precisely surveyed.
  - General rule was the base line had to be ≈1/3 the maximum range of the gun.
- Depression rangefinder became the Vertical Base system with the station precisely surveyed – exact height of the rangefinder became the base line.

Types of Optical Rangefinders

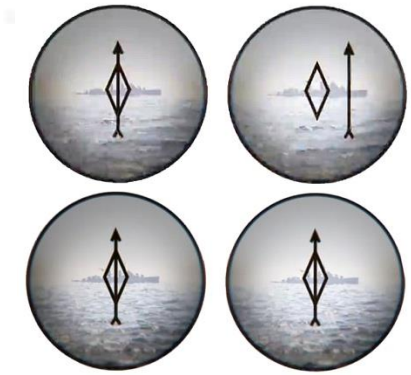
- There are two basic types of optical rangefinders: coincidence and stereoscopic.
- Mechanically, there is little difference in operation between the two design concepts.
- Barr & Stroud favored coincidence rangefinders.
  - Monocular, lighter, didn't require excellent stereo vision and had less eye strain with time.
  - A little faster in determining the initial range in good visibility.
- Zeiss favored stereoscopic rangefinders.
  - Binocular, heavier, and better at range finding on a "fuzzy" target.
  - Handled poor visibility conditions better, especially at long range.



Royal Navy FQ 2 coincidence rangefinder

Coincidence Rangefinders

Stereoscopic Rangefinders



VIEWS SEEN BY EYES BEFORE COMPENSATOR WEDGES ARE ADJUSTED

Optical Rangefinder Error

- What defines the measure of accuracy for optical rangefinders?
- Vast majority of rangefinder producers adhered to the accuracy standard that range error could not be greater than 1%.

Rangefinder Error Equation

Range Error = $(dq \times R^2)/(B \times M \times 206{,}265)$ yards

dq = Angular resolution limit (arc-seconds)

12 arc-seconds was the accepted standard

R = Target range (yards)

B = Rangefinder base length (yards)

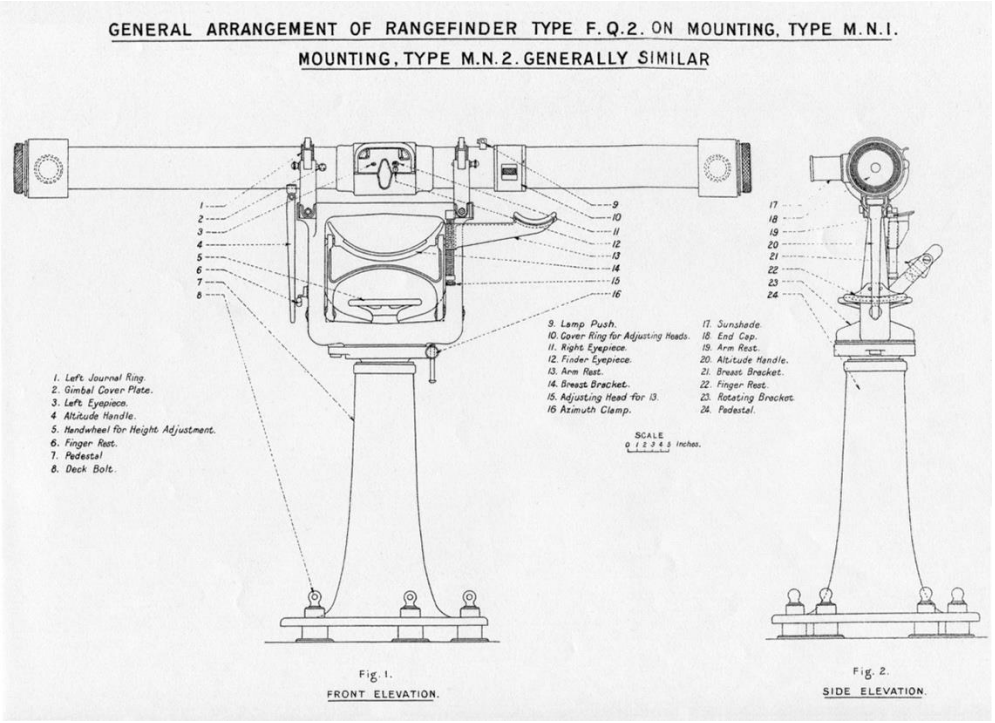
M = Rangefinder magnification (x power or diameters)

206,265 = Converts arc-seconds into radians

Contrary to many historical articles, base length is <u>not</u> the only driving performance characteristic of a rangefinder nor is it the one that exerts the greatest effect.

Optical Rangefinder Error

- Royal Navy FQ 2
  - Base length: 3 yards
  - Magnification: x28
  - Effective range: 14,500 yards
- Imperial German Navy Bg 3m
  - Bg = Basisgerät (Base Device)
  - Base length: 3.28 yards
  - Magnification: x25
  - Effective range: 14,300 yards



- Wait a minute! Didn't German rangefinders have superior performance?

Patience Grasshopper, all will be revealed in good time.

Survey of WWI Rangefinders

- For the most part, naval rangefinders on World War I surface combatants were either a Barr & Stroud or Zeiss instrument.
  - Several countries had license production.
  - Cooke-Pollen (Great Britain)
  - Bausch & Lomb (USA)
- At the start of the war:
  - FA 2: 1.5 yards, x24, 6,500 yards — Royal Navy
  - FQ 2: 3.0 yards, x28, 14,500 yards
  - FT 24: 5.0 yards, x28, >20,000 yards
  - Bg 1.5m: 1.6 yards, x25, 8,000 yards — Imperial Germany Navy
  - Bg 3m: 3.28 yards, x25, 17,500 yards
- Paul Schmalenbach wrote that the Bg 3m rangefinder had a range error of 165 meters (180 yards) at a range of 16,000 meters (17,490 yards). "The History of German Naval Artillery"

Whose were better? B&S or Zeiss?

- Experiments by U.S. and UK experts on German naval rangefinders found little difference between them and allied equipment.
  - "impossible to say which is best."
  - "there is little to choose between the two types of rangefinder, provided the operators observing are equally skilled in range-taking."
  - "Performance of coincidence and stereoscopic instruments was about the same when range errors were measured in yards."
- What was missing from the American and British test trials was a very critical element – the *German* rangefinder operator.
- German vision requirements for rangefinder operators were extremely strict – more so than Allied navies.
  - Excellent stereo vision (3D perception).
  - Visual capabilities a third better than a good sighted man.
  - Ability to resolve a minimum of 10 arc-seconds.
  - <5% of the population would meet such strict requirements.

Whose were better? B&S or Zeiss?

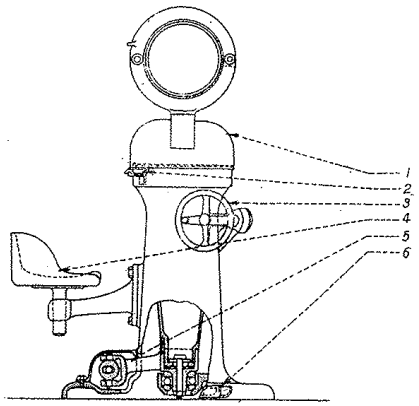
- US and UK assumed an angular resolution of 12 arc-seconds in the range error equation.
  - If one uses the German vision requirement of 10 arc-seconds, the range error equation matches the performance quoted by German naval officers.
- From a purely mechanical perspective there is very little difference in performance of the Barr & Stroud and Zeiss rangefinders.
  - Zeiss did have better optics.
  - The key difference was the operator.
    - Vision requirements.
    - Level of training.
    - Demonstrate no more than 400-meter error at 20,000 meters – 2% error.
- The best rangefinder at the Battle of Jutland was the Barr & Stroud FT 24 on the 15in gun battleships.

Conclusions

- The early 1890s saw gunnery firing ranges at <2,000 yards.
  - Gun laying with the naked eye.
- By the mid-to-late 1890s, the range had increased to 3,000 – 4,000 yards.
  - Telescopic sight.
- After 1900, wartime experience and a few gunnery champions pushed firing ranges out to about 6,000 yards.
  - Russo-Japanese War saw most of the fighting at 5,000 – 6,500 yards.
- The adoption of optical rangefinders increased the probability of hit, but modern guns were still being employed to about half their ballistic range.
- Accurate firing at 10,000+ yards would require the ability to predict a target's future position – fire control, Argo Clock and Dreyer Table.
- This marked the transition from firing on "track" quality data to "targeting" quality and enabled gunnery ranges out to 15,000 – 20,000 yards.

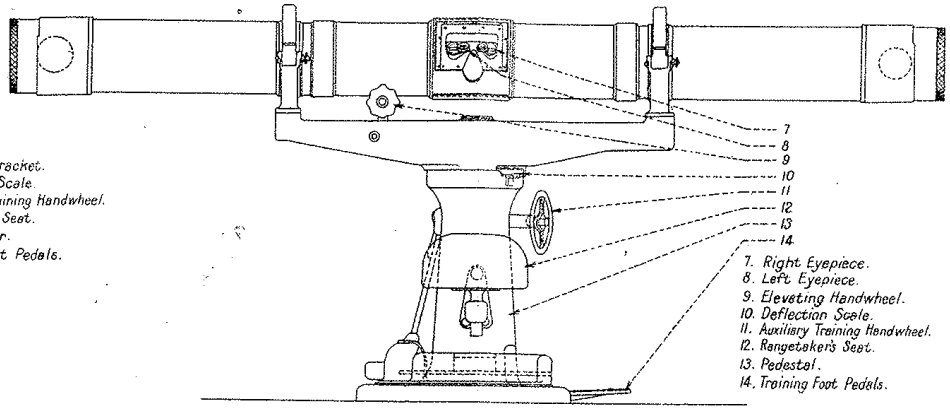
Questions?

GENERAL ARRANGEMENT OF RANGEFINDER, TYPE F.T. 25 ON GUN CONTROL TOWER MOUNTING, TYPE M.W.I.



1. Rotating Bracket.
2. Deflection Scale.
3. Auxiliary Training Handwheel.
4. Rangetaker's Seat.
5. Training Gear.
6. Training Foot Pedals.

Fig. 1.
SIDE ELEVATION.



7. Right Eyepiece.
8. Left Eyepiece.
9. Elevating Handwheel.
10. Deflection Scale.
11. Auxiliary Training Handwheel.
12. Rangetaker's Seat.
13. Pedestal.
14. Training Foot Pedals.

Fig. 2.
FRONT ELEVATION.

15. Training Foot Pedals.
16. Pedestal.
17. Range Working Head.
18. Faceplate.
19. Rangetaker's Seat.

SCALE
0 1 2 3 4 5 Inches.

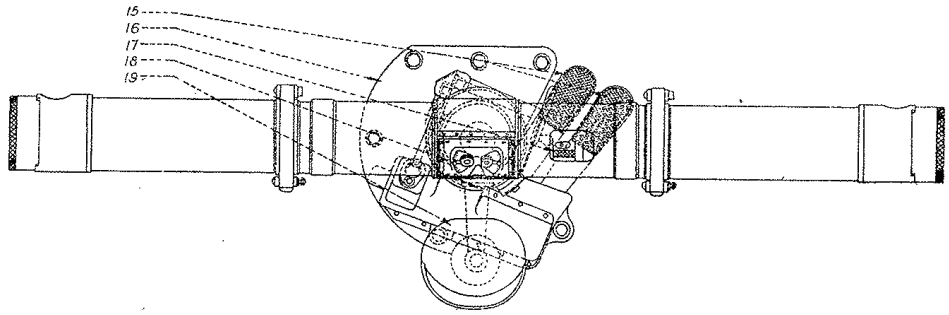


Fig. 3.
PLAN.