

# BUILDING LARGE TELESCOPES.

## I- REFRACTORS

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The second half of the nineteenth century was the age of the refractor. During this period we saw the growth of the refracting telescope to the greatest size attained to date (Figure 1). In the twentieth century the reflector surpassed the refractor.

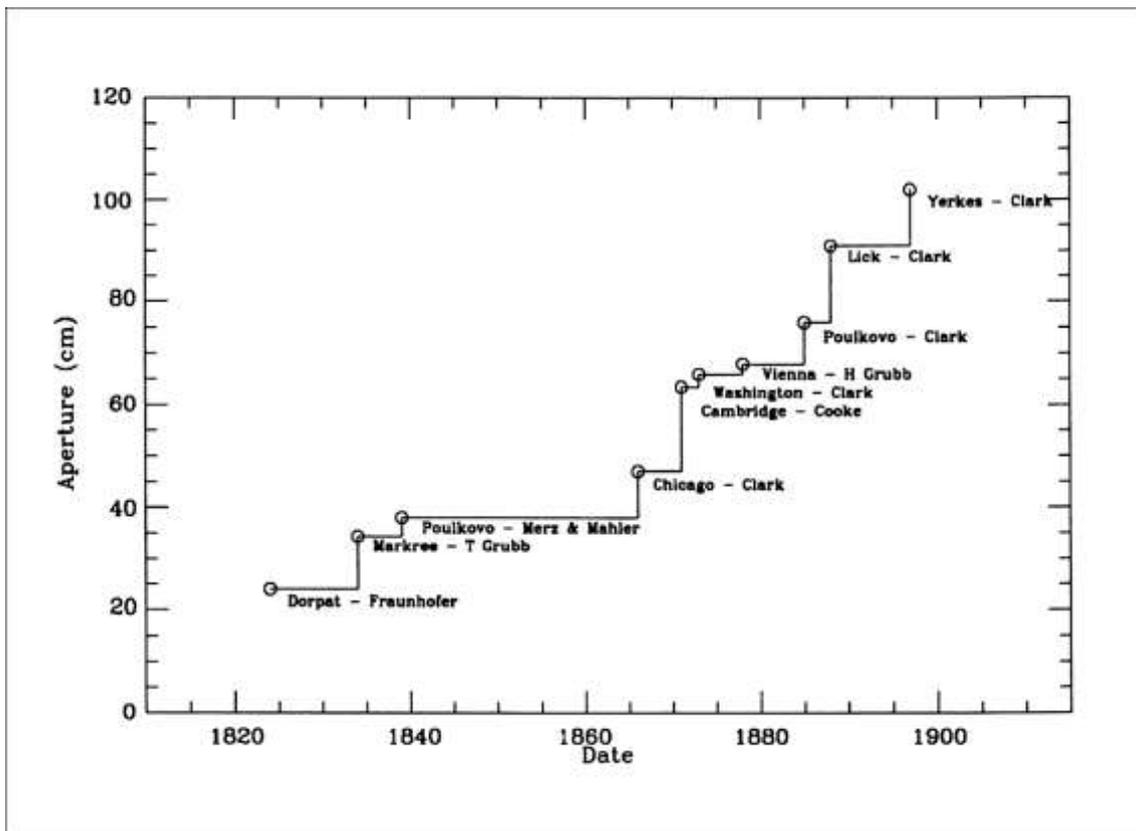


Figure 1- Growth in size of refracting telescopes during the second half of the nineteenth century.

Adapted from Danjon & Couder (1935).

The first modern refractor was built in 1824 by Joseph von Fraunhofer (1787-1826). The great Dorpat refractor with a 9.5-inch lens (14 foot focal length) was noted for his high quality optics but also for its mounting, the first example of what became known as the "German equatorial mount" (Figure 2).

The 13.3-inch Markee Observatory refractor was built by Thomas Grubb (1800-1878). This was T. Grubb first big contract as a telescope maker. The lens was built in 1831 by the French optician R.A. Cauchoix (1776-1845). The equatorial mount built by Grubb in 1832 was very solid compared to the equatorial of the great Dorpat refractor. The refractor was erected in 1834 on a triangular pier made of black marble (Figure 3). This telescope was not housed

under a dome. The instrument was exposed to the weather with only the lens covered when not in use. Circular walls build around the mount protected the observer from the wind.



Figure 2- The great Dorpat refractor (left) was installed at Dorpat Observatory (center) under the rotatory cupola (right).

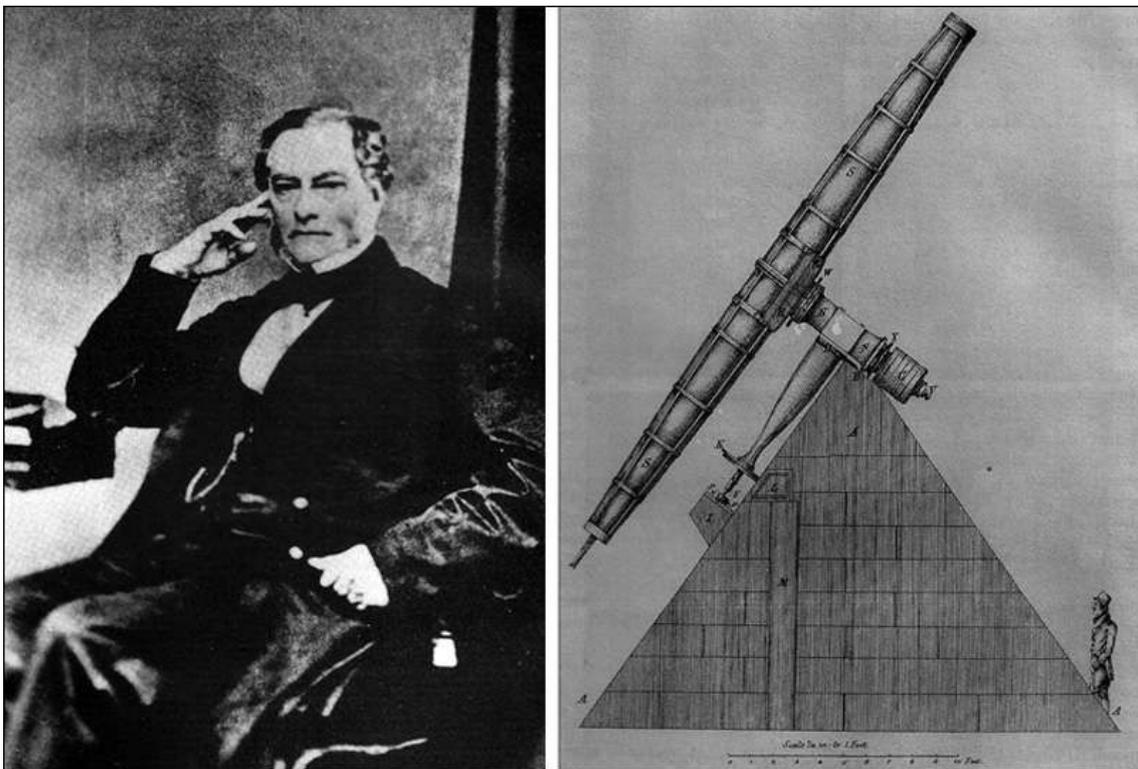


Figure 3- Thomas Grubb (1800-1878) and the 13.3-inch Markee Observatory refractor (1834).

In 1850 the largest refractors were the 15-inch (38 cm) instruments at Pulkovo and Harvard (Figure 4). These two telescopes were built by Merz & Mahler (Munich). In the middle of the nineteenth century the largest reflector was the Leviathan of Parsonstown built in 1845 by William Parsons, third Earl of Rosse (Birr Castle, Ireland). During this period refractors were largely preferred by astronomers for precision work at the observatory. Apart from periodical cleaning, the optical system of refractors needed no further attention. These instruments had several drawbacks: residual chromatic aberration, high cost and size limitations (lens plus mount). Reflectors do not exhibit chromatic aberration. The first mirrors were made of a

copper-tin alloy that tarnished and had to be frequently re-polished. Only after the introduction silver-glass mirrors the reflector was able to compete with the refractor as far as precision work at the observatory is concerned.

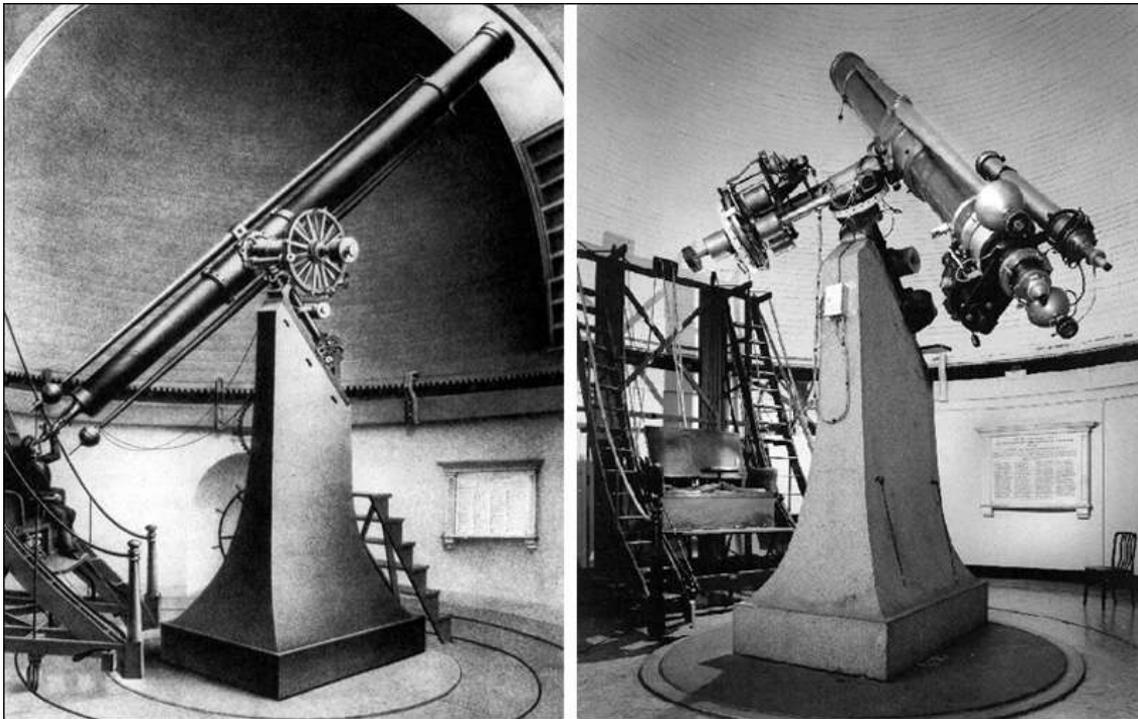


Figure 4- "The Great Refractor" of the Harvard observatory installed in 1847, was for twenty years the greatest refractor in the United States.

The next big refractor was built by Alvan Clark (1804-1887). Alvan Clark and his sons, George Bassett Clark and Alvan Graham Clark were the main makers of large refracting telescopes in the late nineteenth century. For five times the Clarks made the objectives for the largest refracting telescopes in the world. The first of these object glass was the 18.5-inch (470 mm), 8.2 m focal length Dearborn telescope, commissioned in 1856 by the University of Mississippi (Figure 5). When Alvan Graham Clark tested this objective for the first time in 31 January 1862, he discovered the companion of Sirius. The telescope was only erected after the end of the American Civil War in 1866, by the University of Chicago.

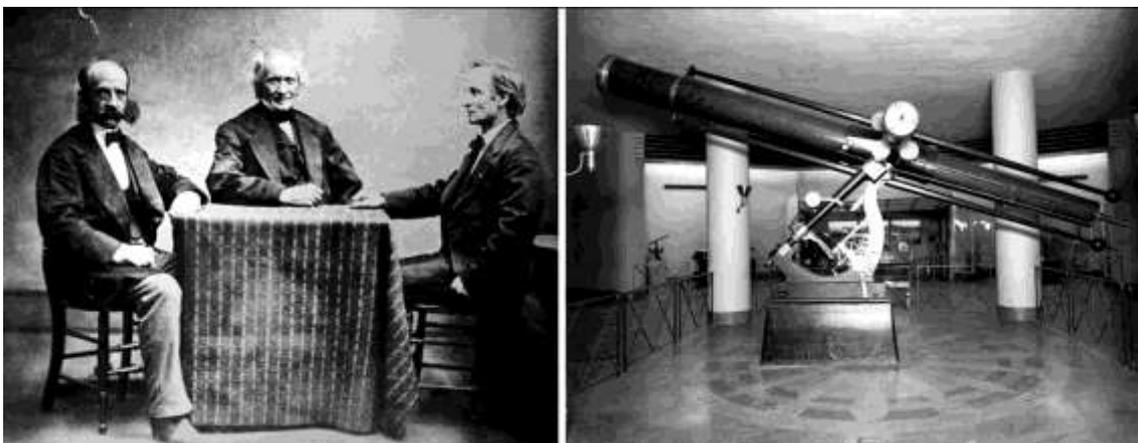


Figure 5- Alvan Clark & Sons (left) and the Dearborn refractor (right) erected in 1864.

The 18.5-inch refractor did not remain the largest refractor in the world for a long time. Robert Stirling Newall (1812-1889) a wealthy Scottish engineer and amateur astronomer, commissioned Thomas Cooke (1807-1868) to build a telescope for his private observatory at Ferndene. The discs for a 25-inch (64 cm) refractor were ordered from the Chance Brothers Company in 1863. The lens had a focal length of 9.1 m and a combined weight of 66 kg. The Newall refractor took seven years to build. It was for a few years the largest in the world. Newall erected this telescope in 1871 on his estate, a very unfavorable site: during a period of fifteen years he had only one night in which he could use its full aperture (Figure 6).

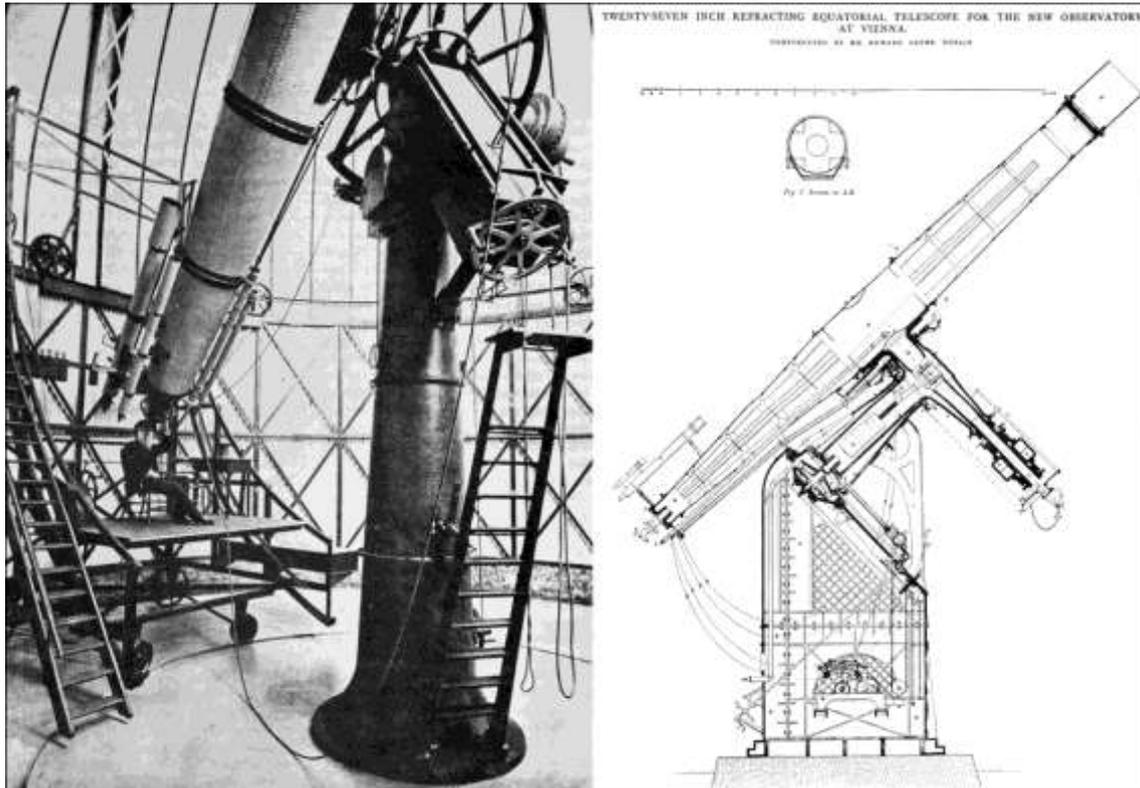


Figure 6- The 26-inch Newall refractor (left) and the 27-inch Grubb refractor of the Vienna Observatory (right). The 27-inch surpassed the 26-inch Clark of the U.S. Naval Observatory becoming the model of all mountings for subsequent large refractors.

The Clark firm also built in 1873 the 26-inch (660 mm) objective lens for the United States Naval Observatory. In 1883, they finished the 30-inch (760 mm) telescope for the Pulkovo Observatory in Russia (Figure 7). Asaph Hall (1829- 1907) discovered the two satellites of Mars (Phobos and Deimos) using the 26-inch lens in 1877. The mount of the United States Naval Observatory was modeled after the Newall refractor.

The contract for building the 27-inch refractor of the Vienna Observatory was given to Thomas Grubb in 1872. Grubb introduced many innovations in the equatorial mount. The mount was very sturdy as compared to the Clark mounts. This equatorial mount became the model for all future mounts of large refractors (Figure 6).

Georg Wilhelm Struve (1793-1864), director of the Pulkovo observatory contracted the Repsold firm in Hanover for building the mount of a large 30-inch (76 cm) refractor (14.1 m

focal length). The lens was made by Clark & Sons in 1884. The world largest refractor went into operation at the Pulkovo observatory in 1885 (Figure 7).

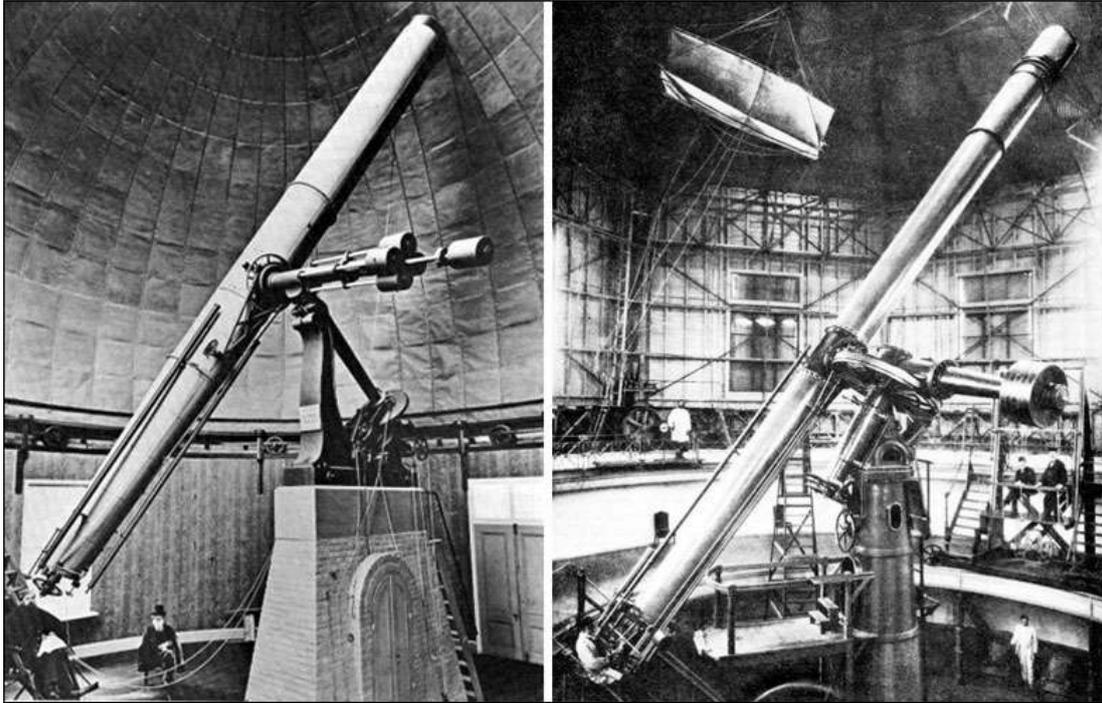


Figure 7- The 26-inch U.S. Naval Observatory refractor (left) and the 30-inch Pulkovo Observatory refractor (right) built by the Clark & Sons firm.

The next two big refractors were also built by the Clarks. In 1880 the Clark firm was given a contract to build a 36-inch (91 cm) objective and photographic corrector. The lens with a focal length of 17.6 m was finished in 1885 but the photographic corrector (33-inch, 84 cm) was only completed in 1887. The mount for this refractor was built by the Warner & Swasey firm and erected on Mount Hamilton (Lick Observatory) in 1887. The Lick refractor was one of the most productive instruments in the history of astronomy (Figure 8).

The Clarks agreed to make a 40-inch (102 cm) objective for the Yerkes observatory (Figure 8). Alvan Graham Clark, the last surviving member of the Clark family began figuring the lenses and Warner & Swasey were asked to supply the equatorial mount. The mount was finished in 1893 being displayed at the Columbia Exhibition in Chicago that same year. The 40-inch refractor (19.3 m focal length) went into operation only in 1897 after the foundation of the Yerkes Observatory in 1895. This refractor is still the largest in the world today. The combined weight of the two components of the 40-inch objective was 225 kg (Figure 9).

Before his death in 1897, Alvan Graham Clark declared his intention to make a 60-inch (152 cm) lens. In the twentieth century several attempts were made to build larger refractors without any success. By this time reflectors were the main instruments used for spectroscopy and astrophotography.

The limit of refractors was reached with the 40-inch. According to James Edward Keeler (1857-1900) that examined the lens in 1896:

*“From these tests it appears that the character of the image varies with the position of the lenses relative to each other, and, to a less extent, with the position of the objective as a whole*

*relatively to its cell. It is probable that flexure of the lenses is the principal cause of the observed changes, and it is interesting to note that there is here evidence, for the first time, that we are approaching the limit of size in the construction of great objectives”.*

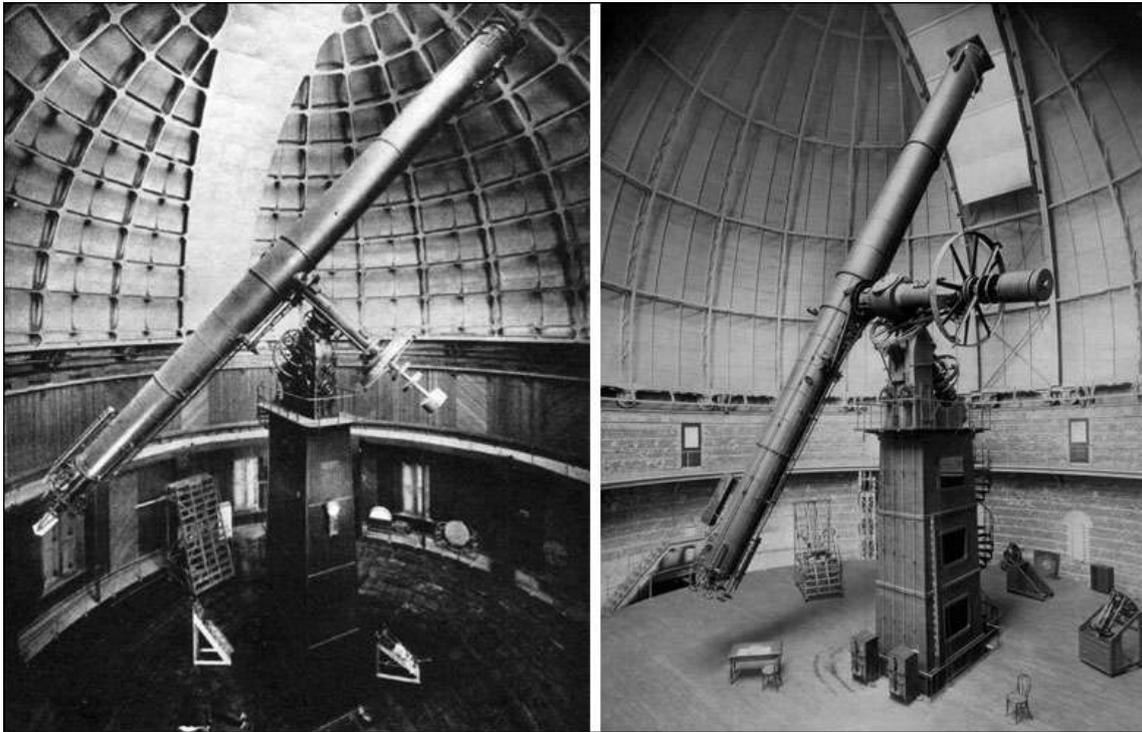


Figure 8- The 36-inch Lick Observatory refractor (left) and the 40-inch Yerkes Observatory refractor (right).



Figure 9- Alvan Graham Clark and Carl Lundin with the 40-inch object glass.

Sources:

- Danjon, A. & A. Couder (1935). *Lunettes et Télescopes*. Livrarie Scientifique et Technique, Paris.
- Glass, I.S. (1997). *Victorian Telescope Makers: The Lives & Letters of Thomas & Howard Grubb*. Institute of Physics Publishing, London
- King, H.C. (1955). *The History of the Telescope*. Dover Publications, Inc. New York.
- Warner, D.J. (1968). *Alvan Clark & Sons, Artists in Optics*. Smithsonian Institution Press.