ALVAN CLARK (1804-1887), GEORGE BASSETT CLARK (1827-1891) AND ALVAN GRAHAM CLARK (1832-1897), AMERICAN MAKERS OF TELESCOPE OPTICS.

PEDRO RÉ
http://astrosurf.com/re

Alvan Clark and his sons, George Bassett Clark and Alvan Graham Clark (Figure 1), were the main makers of large refracting telescopes in the late ninetieth century. The firm Alvan Clark & Sons was founded in 1846 in Cambridgeport, Massachusetts. For five times the Clarks made the objectives for the largest refracting telescopes in the world: (i) The 18.5-inch (470 mm) Dearborn telescope was commissioned in 1856 by the University of Mississippi; (ii) In 1873 they built the 26-inch (660 mm) objective lens for the United States Naval Observatory; (iii) In 1883, they finished the 30-inch (760 mm) telescope for the Pulkovo Observatory in Russia; (iv) The 36-inch (910 mm) objective for the Lick Observatory refractor was made in 1887 and finally (v) The 40-inch (102 cm) lens for the Yerkes Observatory refractor, in 1897, the largest ever built still in operation (Figure 2 and 3).

Figure 1- Alvan Clark (center) and his sons, Alvan Graham Clark (left) and George Basset Clark (right). Lick Observatories photograph.

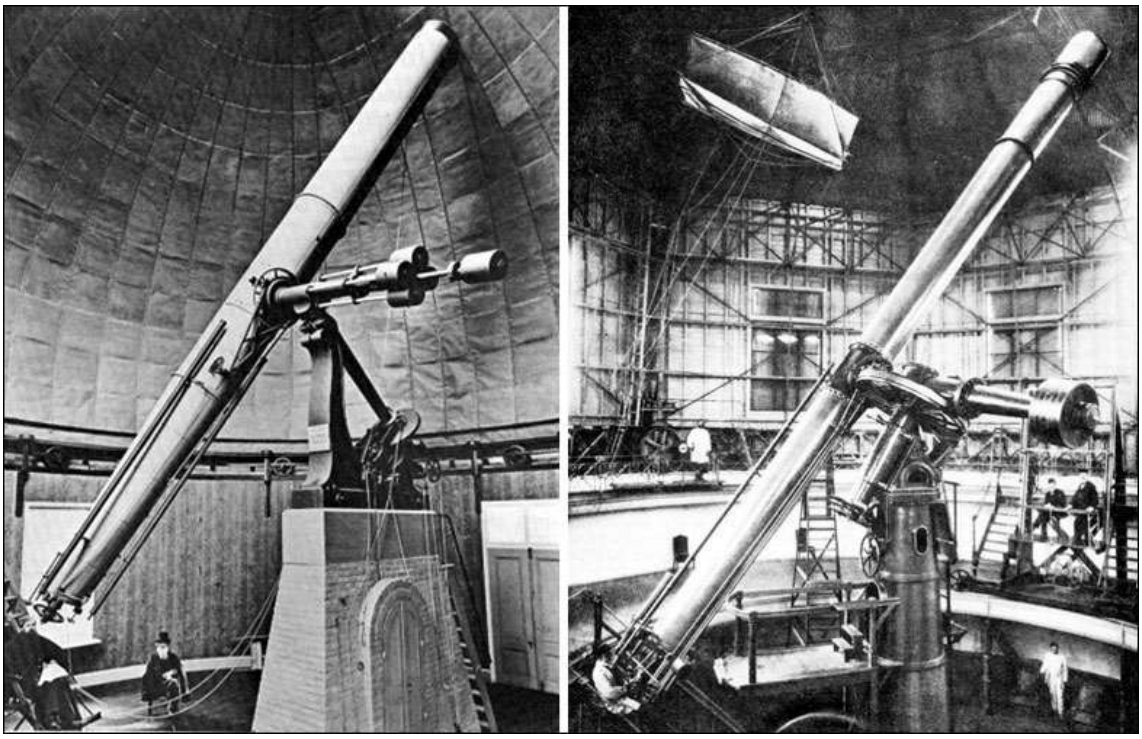

Figure 2- The 26-inch U.S. Naval Observatory refractor (left) and the 30-inch Pulkovo Observatory refractor (right).

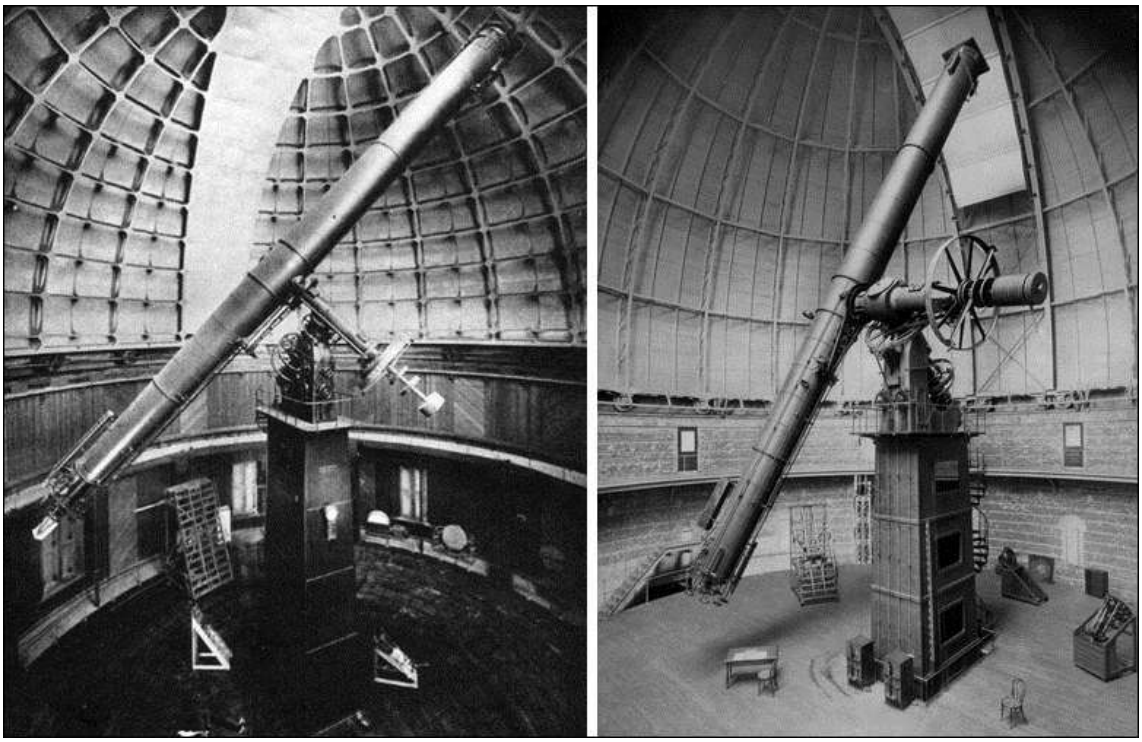

Figure 3- The 36-inch Lick Observatory refractor (left) and the 40-inch Yerkes Observatory refractor (right).

Alvan Clark was born in Ashfield, Massachusetts on March 8, 1804. He was the fifth of ten children of Abram (a descendant of Thomas Clark, one of the early pilgrims of the Mayflower) and Mary (Pease) Clark. Before turning to astronomy, Alvan was noted for his work in other fields, namely drawing and engraving. Towards the end of his life Alvan wrote an autobiography that is often quoted. This is the reason why the life and work of Alvan Clark is better known than that of his two sons.

Both Alvan Graham Clark and George Graham Clark devoted their entire careers to building fine astronomical telescopes. Alvan Graham did the optical work and George did the mechanical work. It is very difficult to identify who was responsible for a particular telescope built by the Clarks. Taking this into account all three Clarks are responsible for the achievements of the firm Alvan Clark & Sons that later became simply Alvan Clark.

Abram Clark (Alvan Clarks father) owned and operated a rocky farm, a sawmill and a gristmill in Ashfield leaving his son a patrimony of fifty dollars. Alvan received a formal education at a local small grammar school and began to work with his older brother in a wagon maker's shop. Soon he turned to other interests. On March 25, 1826 Alvan married Maria Pease and they became parents of four children (Maria Louisa and Caroline Amelia, as well as George Bassett and Alvan Graham). Alvan earned his living as an engraver and later by painting small portraits of exceptional quality in ink and watercolor (Figure 4). Sometimes he used a prism and a camera lucida to outline the main features of the people in his portraits and miniatures.

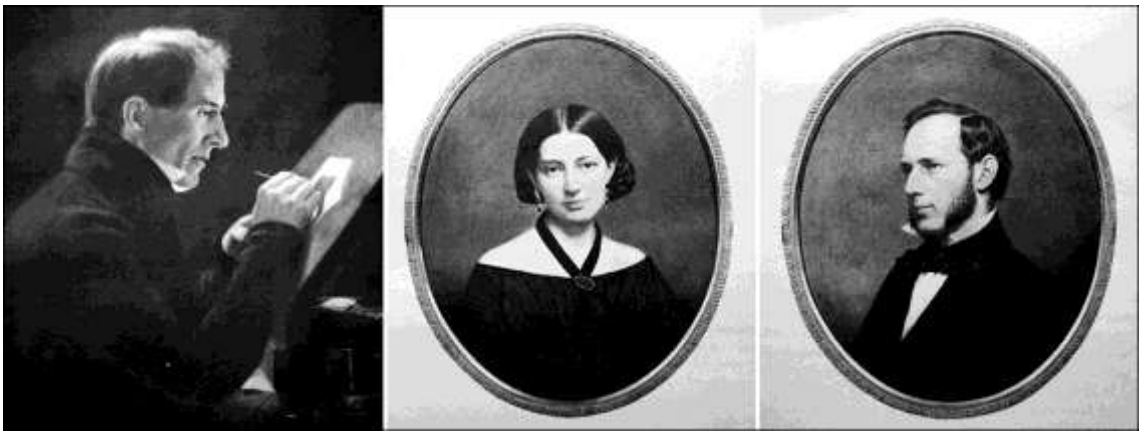

Figure 4- Alvan Clark portrait as an artist in his studio (left), center and right two of A.Clark paitings (Mrs. And Mr. Charles Henry Cummings).

Clark maintained the studio until 1860 when the firm Alvan Clark & Sons became lucrative. It seems that Alvan Clark turned to telescope making almost by accident. His eldest son, George Basset, while a student at Andover (Phillips Academy), melted down a metal bell in order to make a reflecting telescope. Alvan attention was caught and by 1850 the firm Alvan Clark & Sons was founded. The firm grew out of a small shop in East Cambridge used by George Basset to repair optical instruments.

In 1850 the largest refractors were the 15-inch (38 cm) instruments at Pulkovo and Harvard Observatories both made by the Merz & Mahler in Munich (Germany). The largest reflector was the 72-inch (182 cm) "Levithan" erected in 1845 by the Third Earl of Rosse, William Parsons, at the Birr Castle in Ireland. In the middle of the nineteen century refractors were regarded as precision instruments while reflectors were considered much more crude and difficult to use. For this reason refractors were the preferred instruments for astronomical work at observatories worldwide.

Alvan Clark started by building metal reflectors with aperture as large as 8-inch. In 1847-48 Alvan using a 7.5 inch reflector build by himself made a drawing of the Orion nebula. William Cranch Bond, director of the Harvard Observatory, was very impressed with this sketch (the drawing was more complete than the sketch made by William Herschel using his 20-foot reflector).

Clark soon realized that refractors had better light gathering power and definition than metal reflectors and started building objective lenses around 1846. The first lenses he made were similar to ones built by the only contemporary American lens maker, Henry Fitz (1808-1863).

William Rutter Dawes (1799-1868) an English amateur bought several Clark objectives, one of which was used from 1869 to 1869 by William Huggins (1824-1910) for his monumental work in spectroscopy. A trip to England in 1859 (the only time Alvan Clark left the United States) was very important for establishing Clark's reputation as a maker of telescope optics both abroad and in the U.S. Soon after, Clark was asked to make a refractor with an aperture of 19 inches (48 cm) for the University of Mississippi. The firm Alvan Clark & Sons had only built objectives of apertures up to 8 inches. After examining the 15-inch lens of the Harvard Observatory and recognizing its imperfections, Clark offered to make a 15-inch. The University wanted the largest telescope of the world and Clark agreed to make an 18.5-inch (47 cm) objective.

The firm moved to a new location with larger facilities near Harvard to work on this lens. The two crown and flint discs (ordered from the Chance Brothers Company of Birmingham) were finished in 1862. Alvan Graham Clark while testing this lens discovered the companion of Sirius on January 31 1862. By this time the American Civil War had begun and the University of Mississippi was unable to fulfill the agreement with the Clark firm. The Chicago Astronomical Society bought the lens and the telescope was installed in the Dearborn Observatory of the University of Chicago in 1866.

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. Altogether 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 5).

In 1871, Clark agreed to make an instrument that surpassed the Newall refractor. By this time Alvan Clark & Sons had already refigured the lenses of several telescopes of the U.S. Naval Observatory with excellent results. The 26-inch (66 cm) crown and flint discs weighting 50 kg were again commissioned from the Chance Brothers Company. The lenses were finished in two years (1873). The objective was mounted on a metal tube (previous Clark instruments were provided with a wooden tube. With this instrument (installed by late 1873) Asaph Hall (1829-1907) discovered the two satellites of Mars (Phobos and Deimos) in 1877) (Figure 2).

In 1872 Karl Ludwig von Littrow (1811-1877), director of the Vienna Observatory, made plans for a large refractor and the contract went to Howard Grubb (1844-1931) of Dublin. The young Grubb together with his father Thomas Grubb (1800-1878) were mainly specialized in building reflectors with heavy equatorial mountings. For this project H. Grubb designed a German equatorial mounting that was a great improvement over the mountings supplied by the Clarks in such a way that it became a model for all future mountings of large refractors (Figure 5).

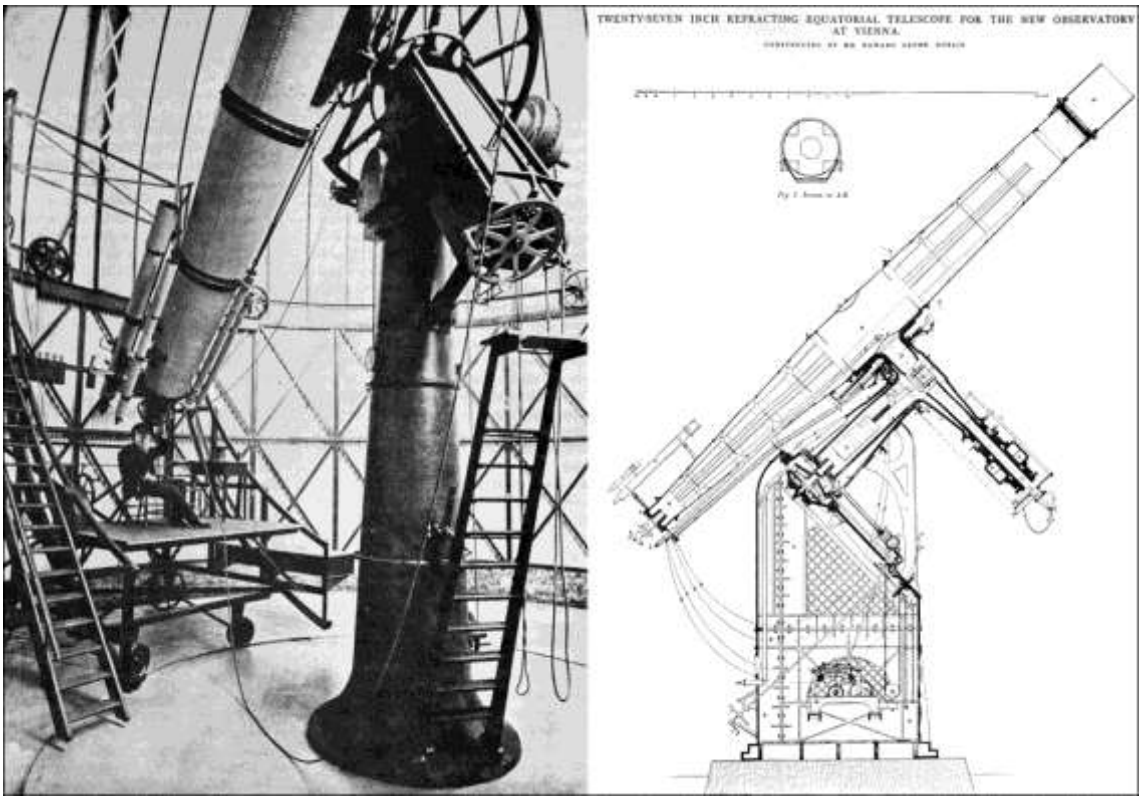

Figure 5- The 26-inch Newall refractor (left) and the 27-inch Grubb refractor of the Vienna Observatory (right). The 27-inch surpassed the 26-inch Clark of the U.S. Naval Observatory becoming the model of all mountings for subsequent large refractors.

Otto W. Struve (1819-1905) director of the Pulkovo Observatory ordered a 30-inch (76 cm) objective from the Clarks in 1879. The lens was not completed until 1884. The mount was finished on the same year by Repsold (Hamburg) (Figure 2). This refractor (then the world largest) went into operation at Pulkovo in 1885. It was extensively used in the study of double and proper motion of stars.

In 1880 the Clark firm was again given a contract to build a 36-inch (91 cm) objective and photographic corrector. The blanks were ordered from the firm Field in Paris. 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 firm Warner & Swasey 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 3).

With the completion of this instrument the representatives of the University of Southern California asked the Clarks to make an objective for a larger telescope. In 1889 they agreed to build a 40-inch (102 cm) lens and the blanks were ordered from the firm Mantois in Paris. When the disks arrived the University was unable to pay the bill and the opportunity to obtain the largest refractor in the world went to another Institution. George Ellery Hale (1868-1938) that had just been appointed Associate Professor at the University of Chicago was able to raise the necessary sum to buy the lens by convincing the Magnate Charles Tyson Yerkes (1837-1905). Yerkes contributed with $300.000 to establish what would become known as the Yerkes Observatory, located in Williams Bay, Wisconsin.

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 (Figure 6). The 40-inch refractor (19.3 m focal length) went into operation only in 1897 after the foundation of the Yerkes Observatory in 1895 (Figure 3). 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 7). James Edward Keeler (1857-1900) that examined the lens in 1896 wrote in a paper published in the *Astrophysical Journal*:

"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 6- Mounting of the 40-inch Yerkes refractor on display at the Columbia Exposition in Chicago (1893).

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 (Figure 8). By this time reflectors were the main instruments used for spectroscopy and astrophotography.

Figure 7- Alvan Graham Clark and Carl Lundin with the 40-inch object glass.

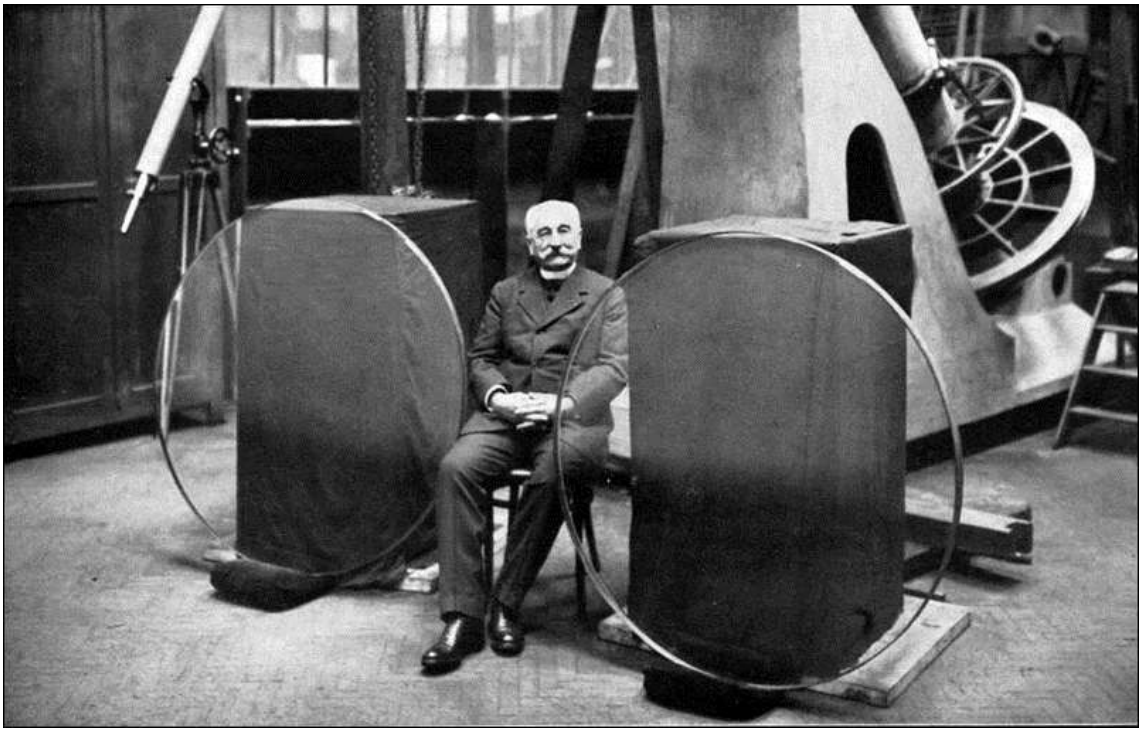

Figure 8- 50-inch optical disks made by the Mantoins firm (Paris).

Very little is known regarding the Clark methods for grinding lenses. The Clark left no records of these procedures. Many people visited the Clark factory and were shown every detail of the process. One visitor wrote that the methods employed were crude and inferior to those used by European optical makers. The success of Clark's lenses was attributed to skillful manipulation and supervision rather than the use of precise mechanisms. It seems that the techniques used were nothing extraordinaire. Great care was taken in the grinding and polishing of a lens. The blank disk was always tested for purity and evenness (glasses with evident striation were discarded). Grinding and preliminary polishing was done with rudimentary machines which consisted of horizontal tables rotated by a steam engine. Early Clark lenses were ground with emery, but later (1887) cast iron sand was used as an abrasive. When grinding was finished the metal lap used for this purpose was changed for one made of grooved pitch fed with water and rouge for polishing. The Clarks never used cloth polishers. The process of correcting and perfecting the lenses was always performed. Local correction was suggested to the Clarks Henry Fitz. Fitz only retouched one surface whilst the Clarks regularly retouched all four surfaces of each objective. This maybe the explanation for the superior quality of the Clarks object glasses.

Local corrections were used to remove small errors after grinding and polishing. To locate this errors the Clarks developed a test similar (but prior) to the one described as the Foucault knife-edge test for mirrors. This test was performed either on a star or on an artificial star (inside a horizontal tunnel with almost 70 m of length). Tests on photographic lenses involved photographing a star several times in focus and out of focus in order to examine the images obtained. A perfect lens would form even images.

Once the irregularities were found these were marked and the lens had to be retouched several times until a perfect shape was reached. Alvan Clark seemed to have a special sense of touch in such a way that he could detect irregularities with his fingers. He repeatedly used his bare thumbs to make local corrections.

Most of the Clarks objectives are similar to Fraunhofer lenses consisting of an equiconvex crown (R1 = R2) and a meniscus flint in which R3 is made a few percent shorter in radius than R2. R4 (closer to the eyepiece) becomes a long radius convex surface being almost flat. There are mainly two drawbacks in this type of lenses. It is an air spaced design, similar to the Fraunhofer, but with weaker curves. R1, R2, and R3 are all close in radius to one another. Spherical aberration can be canceled (corrected) just as in the Fraunhofer design. In addition, if R1 and R2 become reversed during cleaning, there is no apparent change in performance.

Most of the Clark objectives are corrected for visual use. However two methods were developed for adapting the lenses for photographic applications. The Lick refractor was provided with a third (smaller) photographic lens. In 1887, with the assistance of Edward C. Pickering (1846-1919) the Clarks developed a clever combination of two lenses that could be used for either visual or photographic observations. Is this design the Crown component is more convex on one side than the other. For visual applications the flatter side was put in contact with the flint and for photography the crown lens was reversed and separated from the flint.

The Clarks were great opticians, perhaps the most skillful ever. The excellence of their achromatic objectives is recognized even today in an era where apochromatic refractors are readily available.

Sources:

Gingerich, O. (ed) (1984). *The general History of Astronomy. Astrophysics and twentieth-century astronomy to 1950.* Cambridge University Press.

King, H.C. (1955). *The history of the telescope.* Diver Publications Inc.

Warner, D.J. (1968). *Alvan Clark & Sons, Artists in Optics*. Smithsonian Institution Press.