nomically in these cases, the torch holder was reduced to the wick as a means of transport for wax or oil.

The oil lamp, which was actually developed in prehistoric times, represented the highest form of lighting engineering progress for a very long time. The lamp itself – later to be joined by the candlestick – continued to be developed. All sorts of magnificent chandeliers and sconces were developed in a wide variety of styles, but the flame, and its luminous power, remained unchanged.

Compared to modern day light sources this luminous power was very poor, and artificial lighting remained a makeshift device. In contrast to daylight, which provided excellent and differentiated lighting for an entire space, the brightness of a flame was always restricted to its direct environment. People gathered around the element that provided light or positioned it directly next to the object to be lit. Light, albeit weak, began to mark man's night-time. To light interiors brightly after dark required large numbers of expensive lamps and fixtures, which were only conceivable for courtly gatherings. Up to the late 18th century architectural lighting as we know it today remained the exclusive domain of daylighting.

Paraffin lamp with Argand burner.

1.1.3 Science and lighting

The reason why the development of efficient artficial light sources experienced a period of stagnation at this point in time lies in man's inadequate knowledge in the field of science. In the case of the oil lamp, it was due to man's false conception of the combustion process. Until the birth of modern chemistry, the belief laid down by the ancient Greeks was taken to be true: during the burning process a substance called "phlogistos" was released. According to the Greeks, any material that could be burned therefore consisted of ash and phlogistos (the classical elements of earth and fire), which were separated during the burning process – phlogistos was released as a flame, earth remained in the form of ash.

It is clear that the burning process could not be optimised as long as beliefs were based on this theory. The role of oxidation had not yet been discovered. It was only through Lavoisier's experiments that it became clear that combustion was a form of chemical action and that the flame was dependent on the presence of air.

Lavoisier's experiments were carried out in the 1770s and in 1783 the new findings were applied in the field of lighting. Francois Argand constructed a lamp that was to be named after him, the Argand lamp. This was an oil lamp with a tubular wick, whereby air supply to the flame was effected from within the tube as well as from the outer surface of the wick. Improved oxygen supply together with an enlarged wick surface meant a huge and instantaneous improvement in luminous efficiency. The next step involved surrounding wick and flame with a glass cylinder, whereby the chimney effect resulted in an increased through-put of air and a further increase in efficiency. The Argand lamp became the epitome of the oil lamp. Even modern day paraffin lamps work according to this perfected principle.

Christiaan Huygens.

Isaac Newton.

Optical instruments have been recognised as aids to controlling light from very early times. Mirrors are known to have been used by ancient Greeks and Romans and the theory behind their application set down in writing. There is a tale about Archimedes setting fire to enemy ships off Syracuse using concave mirrors. And there are stories of burning glasses, in the form of water-filled glass spheres.

At the turn of the first millennium, there were a number of theoretical works in Arabia and China concerning the effect of optical lenses. There is in fact concrete evidence of these lenses dating from the 13th century. They were predominantly used in the form of magnifying glasses or spectacles as a vision aid. The material first used was ground beryl. This costly semi-precious stone was later replaced by glass, manufactured to a sufficiently clear quality. The German word for glasses is "Brille", demonstrating a clear semantic link to the original material used for the vision aid.

In the late 16th century the first telescopes were designed by Dutch lens grinders. In the 17th century these instruments were then perfected by Galileo, Kepler and Newton; microscopes and projector equipment were then constructed.

At the same time, some basic theories about the nature of light originated. Newton held the view that light was made up of numerous particles – a view that can be retraced to ancient time. Huygens, on the other hand, saw light as a phenomenon comprising waves. The two competing theories are substantiated by a series of optical phenomena and existed side by side. Today it is clear that light can neither be understood as a purely particle or wave-based phenomenon, but only through an understanding of the combination of both ideas.

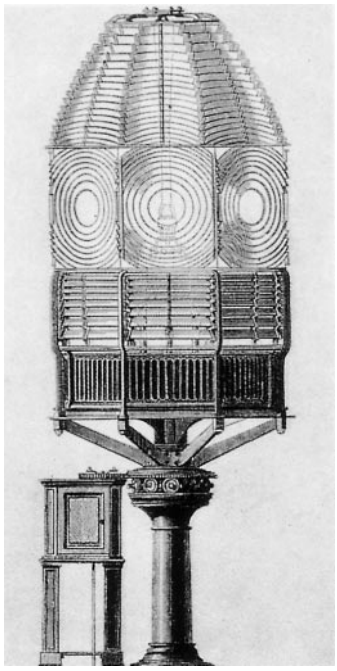
With the development of photometrics – the theory of how to measure light – and illuminances – through Boguer and Lambert in the 18th century, the most essential scientific principles for workable lighting engineering were established. The application of these various correlated findings was restricted practically exclusively to the construction of optical instruments such as the telescope and the microscope, to instruments therefore that allow man to observe, and are dependent on external light sources. The active control of light using reflectors and lenses, known to be theoretically possible and

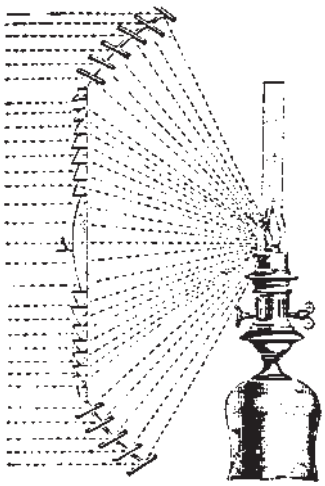
occasionally tested, was doomed to fail due to the shortcomings of the light sources available.

In the field of domestic lighting the fact that there was no controllable, centrally situated light available was not considered to be a concern. It was compensated for by family gatherings around the oil lamp in the evenings. This shortcoming gave rise to considerable problems in other areas, however. For example, in lighting situations where a considerable distance between the light source and the object to be lit was required, above all, therefore, in street lighting and stage lighting, and in the area of signalling, especially in the construction of lighthouses. It was therefore not surprising that the Argand lamp, with its considerably improved luminous intensity not only served to light living-rooms, but was welcomed in the above-mentioned critical areas and used to develop systems that control light.

This applied in the first place to street and stage lighting, where the Argand lamp found application shortly after its development. But the most important use was for lighthouses, which had previously been poorly lit by coal fires or by using a large number of oil lamps. The proposal to light lighthouses using systems comprising Argand lamps and parabolic mirrors was made in 1785; six years later the idea was used in France's most prominent lighthouse in Cordouan. In 1820 Augustin Jean Fresnel developed a composite system of stepped lens and prismatic rings which could be made large enough to concentrate the light from lighthouses; this construction was also first installed in Cordouan. Since then Fresnel lenses have been the basis for all lighthouse beacons and have also been applied in numerous types of projectors.

Beacon with Fresnel lenses and Argand burners.





Fresnel lenses and Argand burners. The inner section of the luminous beam is concentrated via a stepped lens, the outer section deflected by means of separate prismatic rings.

Augustin Jean Fresnel.

1.1.4 Modern light sources

The Argand lamp marked the climax of a development which lasted tens of thousands of years, perfecting the use of the flame as a light source. The oil lamp at its very best, so to speak. Scientific progress, which rendered this latter development possible, gave rise to the development of completely new light sources , which revolutionised lighting engineering at an increasingly faster pace.