preceding list, as many as eight or ten sketches should be entered in the note-book in connection with the descriptions. No one should omit careful and repeated observation with the naked eye, although final tests will naturally be made, if possible, with an opera glass. If the glass magnifies three or four diameters, a genuine beginning can be made in selenography, and for that it would be hard to find a better guide than Chapter V, in *Astronomy with an Opera Glass*, by Serviss.

To be Continued.

GLASS FOR OPTICAL INSTRUMENTS WITH ESPECIAL REFERENCE TO TELESCOPE OBJECTIVES.

J. A. BRASHEAR.*

When the glass for the 36-inch objective of the Lick Observatory was under process of manufacture, and many failures had been made in obtaining the crown disc, a very successful glass maker in this country came to the writer and suggested that he could make such a disc without any difficulty. After a brief conversation with the gentleman as to his plans, it was clearly evident that the sum of his knowledge about optical glass was that it should be *transparent* and free from bubbles. Many persons, not conversant with the conditions demanded in a piece of glass suitable for making a high class telescope objective, consider that transparency and freedom from bubbles are the most important elements to consider, whereas a piece of glass may be as "clear as crystal" and without a bubble to mar its beauty, yet be worthless in an optical sense.

The history and development of the optical glass industry is indeed a very interesting story, but as its general facts have been written many times, it is best that we give our readers information of a kind that will be of practical value. They will, however, desire to know something of the methods of manufacture.

In making window glass, plate glass, table-ware glass, etc. the furnaces for melting the material are large enough to have from four to a dozen or more pots placed in them, and these pots are used until they break or are burned out, but in making optical glass but one pot is placed in a small furnace. Great care must be taken in the preparation of the pot as the oxide of iron and other impurities, often constituents of the clay used in the manufacture of pots for melting glass in, would ruin the finer grades of optical glass.

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After the pot is brought up to a pretty high temperature the "batch" or material for the glass is placed in the pot and allowed to subside by the softening of the more easily melted materials, and again filled up, three fillings being usually required.

While the "batch" is melting we will give the composition of a few of the various glasses used in optical work.

Guinand and Fraunhofer used for the flint glass for objectives for telescopes,

100 parts silica,
106 parts red oxide of lead,
43 parts carbonate of potash.

Bontemps used

100 parts silica,
100 parts red oxide of lead,
21.5 parts carbonate of potash,
5 parts nitrate of potash.

A standard "batch" used in France and England contains:

100 parts silica,
105 parts red oxide of lead,
20 parts carbonate of potash.
5 parts nitrate of potash.

For denser flints more oxide of lead is used and for lighter, less of the oxide, and there are very many variations, formulæ for which the writer has received from the younger Feil, but which need not be repeated here.

For the crown glass the "batch" is composed of

100 parts silica,
41.64 parts carbonate of potash,
9.46 parts red oxide of lead.
9.46 parts slacked lime,
1.90 parts nitrate of potash.

Another formula is,

100 parts silica,
42.66 parts carbonate of potash.
21.66 slacked lime,
2.22 parts nitrate of potash.

In this latter formula the lead is left out entirely.

The optical glass manufactory of Jena has added many new kinds of flint and crown glasses which are now at the command of the optician, and Mr. Mantois of Paris has also made a number of new kinds during the past few years, but the standard flint and crown glasses for telescope objectives are practically those whose formulæ have been given above. Ordinary optical crown glass has an index of refraction for the D line of the spectrum of 1.51, but by the addition of baryta, this index has been increased to as high as 1.587.

Boro silicate flint glass has been made with an index for the D line as low as 1.55, while the dense yellow flint glass known as Faraday glass has an index for D equal to. 1.9626. But we must return to our glass melting furnace, and will find the "batch" melted and quite limpid. A "gathering" of it is now taken out on a rod called a punty, although a small pipe is frequently used so that the trial piece may be made something like the shape of a pear with a slight hollow blown in it. If the trial piece is found transparent and free from "seeds" which are imperfectly melted particles of silex or minute air bubbles, it is good enough for ordinary purposes for which glass is used in the arts, but for optical purposes it must now be stirred by a peculiar stirrer made of pot clay which is sometimes heated before being inserted in the pot. Our French optical glass makers call this stirrer Le Guinand, after the celebrated Guinand who first used this method of thoroughly mixing the glass. An iron bar called a crochet, bent at the end to insert in the clay stirrer, but which does not come in contact with the melted glass is put in an opening made for it in the Guinand and the glass is stirred thoroughly until it becomes so stiff by gradual cooling that it cannot well be stirred longer. For ordinary optical glass this one stirring usually suffices, but a second and even a third stirring is resorted to after the glass has been made softer by additional heating, if the highest grades of glass are desired.

This careful and prolonged stirring is one of the most difficult parts of the manipulation, as it usually requires two workmen to stand before the intensely heated furnace for two or three hours. When the stirrer is first introduced and the glass is limpid it can be moved around inside of the pot once a second, but at the close of the operation it requires five or six times as long to move it.

The stirrer must not touch the pot or some of the clay may be incorporated with the glass, and thus ruin it.

The purpose of this stirring is, to so thoroughly mix the glass that it will be as nearly equal in density throughout the mass as possible, and be free from striæ and other impurities that are, in part at least, eliminated in this way. After the final stirring, the next step is to thoroughly lute or stop every open place in the furnace so as to prevent any air from gaining admittance to it, and then a slow process of cooling goes on for from four to eight days, according to the size of the pot and the amount of material contained in it. This slow cooling is not for the purpose of annealing the glass in a perfect manner, but to save the glass from being shattered into small fragments. With the slowest cooling, it is always very uncertain whether or not large pieces, unbroken, can be secured, for if a lump is *cracked* in any way it can never be reunited to make a perfect disc; hence it is that as the discs of optical glass increase in size their cost increases greatly, and justly so. The writer has seen some very odd looking shapes in the original blocks at the factory of Mr. Mantois in Paris, from which one would think it impossible to make a disc suitable for a large objective, but we all owe a debt of gratitude to Guinand for the beautiful process which takes hold of this rough and unshapely piece of glass and fits it for the optician's handiwork.

And now let us follow the block as it goes through the processes which make it suitable for a lens.

A superficial examination determines whether it has such serious defects as would make it useless to carry the manipulation further. This preliminary examination causes many pieces to be rejected or set aside to be utilized for plates good enough for some uses such as cheap photo lenses, opera glasses, etc. If however, on close examination, it is found suitable for a high class lens, any serious defects are either ground off on a mill or sawed off with a soft iron saw, using sand or emery, or with a diamond saw, *i. e.*, a soft iron saw with diamond dust hammered in its edge. Some times it is found necessary to grind more than half way through a block of glass to cut out an imperfection and this may be done with safety, and indeed it is possible to grind almost through a block of glass and save it, but if the cut goes entirely through, it will never reunite without a flaw, whereas, when the cut is not through, the opening, with its surrounding rough surfaces will slowly rise to the top when the piece is softened in its secondary heating, which we will presently notice.

To be Continued.

FAITH IN THE INTEGRITY OF THE INTERSTELLAR MEDIUM.

DE VOLSON WOOD.*

That space is not void is conceded. That it is filled with a medium capable of transmitting light and heat is not questioned. This medium is believed to be uniform in density and elasticity,

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