curve. Indeed, this was just the point upon which Mr. Ives had deemed Stolze to be in error. Nor is the variance an inconsiderable one. The question at issue was whether the fundamental red sensation is excited by the wave lengths in the blue-green and those beyond, and similarly whether the violet sensation is excited only by green-blue violet rays. Now, it appears very certain—as appears from the reasons given by Abney—that the red and violet sensations are not confined to opposite ends of the spectrum. If this were so, a green blind person would see two spectra separated by a region of darkness, where both violet and red just failed to excite vision in him. As a fact, he sees what to him is white light, due evidently to compound blue and red sensations. The curve of König's measurements, which we have upon the screen, also supports this view. Now, Ives worked upon Maxwell's curves which you see before you, and in spite of the great discrepancy, obtained excellent results. From this, and from some experiments of my own, it does not appear to me as if very accurate reproduction of the curves was requisite in the practice of this method. This is fortunate, for to get the correct densities is a matter of much difficulty.

The great charm of this method is that it allows of optical projection. The colors are pigment color. Again, the registering positives can be freely copied.

And here I must break off. I have only ventured to say what I thought might be useful in enabling those present who have given less time than I have to color photography to follow the remarks of members of the convention far more experienced in those methods than I am.

It had been my hope that I would have been able to lay before you some results obtained by a procedure of my own, which I had been working at in the spring of last year. I had put this aside, thinking the difficulties greater than they actually proved to be, when I set about preparing to bring the matter before the convention. The inexpediency of bringing a publication before patents are completed has barred me from seeking your criticism as I would have wished to have done. It must be my hope that at a future assembling of this convention I may be allowed to submit my work to your judgment.

Dr. Joly then exhibited and described

THE PHOTOGRAPHIC SEXTANT.

If it is not too much to expect that navigators should know how to develop a negative, in these days of reliable plates and ready mixed developers, the snapshot camera may be made of real value in the determination of solar altitude at sea. Not only might the accuracy of observation be greatly increased, but the risk of a false reading reduced to a minimum. What is perhaps of more importance, a moment too brief to afford a reliable eye observation might be completely availed of by the use of a photographic sextant. Lastly, and of not least importance, a permanent record of the observation remains for reference subsequently in case it be called in question.

The photographic sextant is not, in its optical principles, different from Newton's sextant (or, as it is called, the Hadley's sextant); that is, the fundamental principle is retained, viz., that the angle between the first and last directions of a ray which has undergone two reflections in the same plane is equal to twice the inclination of the reflecting surfaces to each other. There is, as in the ordinary sextant, a movable limb carrying a vernier, which travels over a divided half quadrant. This limb carries also a mirror at its axis of rotation in the usual manner, reflecting the image of the sun on to a second fixed half silvered mirror. This last mirror is situated at a little distance in front of a lens, which forms an image of the twice reflected solar disk as well as an image of the distant horizon which the lens commands through the clear half of the fixed mirror. In fact, the camera takes the place of the telescope or the ordinary sextant.

To enable the observer to point the instrument, matters are so arranged that the image formed by the lens is, before exposure, reflected out by a movable mirror forming part of the shutter, and inclined at 45° to the axis of the camera. This image is again reflected by a second mirror, and the image of sun and horizon either directly brought to the eye of the observer by the intervention of an eyepiece, or cast upon a small screen in the manner of some viewfinders. The mode of using the sextant is as follows: As the observer will know most generally his position, within certain small limits, he conveniently sets the vernier of the limb to read a whole number of degrees near the reading expected. He is now ready to take his snapshot when any opportunity offers; if the sky be clouded, simply sighting the sun through the viewfinder, and noting the time immediately upon releasing the shutter. The position of the sun in reference to the horizon, measured upon the negative, will now give him, in conjunction with the reading to which the limb is set, and when corrected for dip and refraction in the usual manner, the altitude of the sun observed. If he knows the local time, he has all the data required for calculating latitude. If he does not know the local time, a second snapshot will be requisite; or he may make one at, or very close to, the hour of noon, the last two methods being most generally useful.

In computing the angular separation of the sun and horizon by measurements upon the negative, it is requisite, of course, to know the constant of the instrument he is using. This may be found by photographing, at a known distance, a linear measurement of known dimensions. I may remind the reader that astronomers, measuring upon photographic plates, can estimate the separation of stellar images to the one-sixtieth part of a second.

To prevent solarization, dark glasses are used in the usual manner. These will not, of course, interfere with the light coming from the sky line.

The negative may be preserved for future reference. It must be labeled with the fixed reading of the limb and the time and date of observation. This is all that is required to render it an absolutely permanent record, or it would not be difficult to contrive that the setting of the limb be photographically recorded upon the plate when taking the snapshot.

To render the construction of the instrument more clear to you, I have had the wooden model constructed which is upon the table. It was hardly accurate enough to serve to determine the latitude of Dublin,

but a photograph of sun and horizon taken by it may be of interest.

RECENT PROGRESS IN ASTRONOMICAL PHOTOGRAPHY.*

By Mr. A. TAYLOR, F.R.A.S.

ASTRONOMICAL photography has been dealt with before the convention on two previous occasions: by the late Father Perry, at Birmingham, and by myself at Bath. To-night I desire to give an account of some of the new methods of work, and the results which have been obtained during the last three or four years—in fact, since the meeting of the convention at Bath. It will be well, perhaps, that I should first call your attention to the remarkable way in which the introduction of photography to astronomy has not only opened out new and unexpected fields of research, but has necessitated an entire revolution in the instrumental equipment of the modern observatory. As our president recently pointed out in a discourse to the Royal Institution, it was necessary to entirely rebuild the telescope in order to fit it for photography. In visual observations irregularities in the movements of the telescope were comparatively unimportant, so easy was it for the observer to correct them as they occurred, and to suspend his measurements until the celestial objects he was measuring were accurately placed on the cross wires of his micrometer. In a photograph, however, the record is not that of any selected moment, but is an accumulation of impressions made throughout the whole of the exposure; and any irregularities of movement of the instrument would cause the star images to appear as lines, instead of round dots. A general strengthening of the instrument was, therefore, the first necessity, and the stand, moving parts and tube are much stronger in modern than in the old instruments. A much greater accuracy of movement being required, special attention had to be paid to the bearings, and the driving arrangements were considerably improved. In an instrument like that made by Sir Howard Grubb for Dr. Gill, at the Cape, a photograph of which I now show you, special attention has been paid to all these points; and the new electrical control (from an invariable pendulum), invented by Sir Howard, so regulates the movement that it is impossible for the error of the pointing of the telescope to amount to more than one-fortieth of a second of time during the whole exposure given. As some exposures have extended to twelve hours, given in three successive periods of four hours each on successive days, and the resulting photographs have shown perfectly round star images, I think there can be little doubt that the required delicacy and accuracy have been completely attained.

Eighteen of the principal observatories of the world are co-operating to produce an international photographic catalogue and a photographic chart of the stars, using object glasses of 13 inches aperture and 11 feet 3 inches focus. No less than 22,000 plates are required for each series, the catalogue plates, with five minutes' exposure each, giving all stars to the eleventh magnitude, while the chart plates, with forty-five minutes, will include all stars to the fourteenth magnitude. The samples of these I show you are from negatives by Dr. Gill, at the Cape.

In the study of the details of nebulae much valuable work has recently been done, but none are so remarkable as those of Dr. Gill with the nebula near η Argus. Here, with three hours twelve minutes' exposure, you will see the remarkable character of this object; but the next slides, which show Herschel's drawing of the nebula, and a photograph taken with twelve hours' exposure at the Cape, are still more striking. This S-shaped structure in the drawing is entirely absent in the photograph, and there is considerable doubt as to whether this is a case of real change in the nebula or inaccuracy in the drawing. It will give some idea of the number of stars shown by this photograph to mention that the space of sky that would be covered by a shilling held at arm's length from the eye contains 200,000 stars, scarcely one of which would be visible to the unaided eye.

With star clusters equally good results have been obtained. In the cluster ω Centauri a field glass will not show any individual stars. Gould's catalogue of southern stars gives seven as reaching the tenth magnitude, while this photograph with two hours' exposure gives no less than 6,389 stars.

Very much valuable work has been done with ordinary portrait lenses mounted on equatorial telescopes. The whole of the Milky Way in the Northern hemisphere has been photographed by Professor Barnard, at the Lick Observatory, and by Dr. Max Wolf, at Heidelberg; while Mr. Russell, at Sydney, has used his portrait lens for the same work in the Southern hemisphere. We have thus a complete photographic picture of the Milky Way, and the study of star distribution as shown on these photographs is yielding extremely valuable results. You will notice the bright cloud-like distribution of stars on these photographs by Professor Barnard, and the extraordinary dark lanes edged by bright stars that are characteristic of all these pictures, great similarity of which to the curves and other structures found in the solar corona are strong presumptive evidence of the existence of streams of dark matter ejected into a resisting medium in space. The connection between nebulous matter and stars shown by Dr. Max Wolf's photograph of the α Cygni region have a very important bearing on the question of the method of formation of stars; and, without entering into any technical discussion of these phenomena, I may say that many theories previously held will have to be abandoned, as a consequence of the new light thrown by photography on star distribution. As incidents in this photographic work, I will also point out meteor trails, such as are shown on this photograph of Dr. Wolf, and the discovery of minor planets, which is now almost entirely effected by the use of portrait lenses. Mr. Russell has turned his lens to the study of the dark patches in the Milky Way, and he shows that the dark rifts, and even the well known "Coal Sack," which was hitherto supposed to be quite devoid of stars, are really full of faint stellar forms. So far as we have gone at present in astronomical photography, we have not yet sounded the depths of the stellar universe; every increase of ex-

posure has given a corresponding increase in the number of stars, and many eminent authorities believe that, with sufficient exposure, we shall find that the whole of the heavens is full of stars, and it will be possible to get plates in which the star images will be so numerous and so close together that they will overlap, and the plate will appear simply a blaze of light.

Turning to the spectroscopic work, we find that photography has almost entirely replaced visual observations. Professor Pickering, at Harvard, developed Fraunhofer's original design of the spectroscope, and showed the possibilities of the object glass prism in the study of stellar spectra. As an object glass will photograph a large number of stars in one field, it follows of necessity that, if we place a prism in front of and completely covering that object glass, we can simultaneously photograph, on the same plate, the spectra of all the stars in that field. Using this method, he has made a complete spectroscopic survey of all the stars visible from Harvard, and has extended the work by the establishment of observatories in Peru, so as to include all the southern stars. We thus have for the first time a complete spectroscopic catalogue of the stars; and the various stages of evolution from a cool to the hottest stage, and the regular cooling down to extinction, are readily recognized. This work has been further extended by Professor Lockyer at South Kensington, and I am able, by his kindness, to show you some of these photographs, in which you will see that the number of lines found in some stellar spectra will favorably compare with the number shown on our best solar spectrum obtained some years ago.

Dr. Vogel, of Potsdam, has adapted photography to the spectroscopic study of the motion of stars in the line of sight. Just as the steam whistle of an approaching train sounds shriller than that of a stationary one, while the whistle of a receding train is lower in pitch, so the wave length of the light of an approaching star is shortened, and that of a receding star is lengthened. It follows, therefore, that a photograph of the spectrum of an approaching star will have its lines displaced toward the blue, and that of a receding star will be displaced toward the red; and we can measure the amount of the displacement by photographing on the same plate a line from the spectrum of a terrestrial element for comparison. These photographs of the spectrum of α Aurigæ taken by Dr. Vogel at six months' interval show this displacement, and it is possible to measure, not only the rate of movement of the star itself in the line of sight, but also in this way to measure the rate of movement of the earth in its orbit round the sun. Photography is peculiarly fitted to this work, since it is quite independent of atmospheric irregularities, and the results obtained are far more accordant and accurate than any visual observations could possibly be.

A new kind of binary star has also been discovered by this photographic spectroscopic work. Some stars, photographed by Professor Pickering, in America, and by Dr. Vogel, in Germany, showed a periodic doubling of the lines, and this was clearly due to the fact that in these cases we were dealing, not with single stars, but with two stars which were revolving round a common center of gravity, the spectra of these being exactly superposed when they were moving at right angles to the line of sight, while, when moving in opposite directions, one spectrum was displaced toward the red and the other toward the blue. By measuring the amount of this displacement as shown on the photographs it is possible to determine the rate of revolution of each component; combining this with the period of revolution, it is possible to determine their distance from each other and the dimensions of their orbits, and also to calculate their combined and relative masses. The photographs of β Aurigæ, taken on successive days, show this doubling, and from a detailed examination of many plates it has been determined that the period of revolution is four days, the rate of movement 150 miles per second, their distance from each other 8,000,000 miles, and their combined mass 2.3 times that of the sun. No telescope that we can hope to construct will show this star as a double, and yet we have indubitable proof that it is one.

Time will not allow me to deal at all fully with the new star which was discovered in the constellation Aurigæ in February, 1892, but some points connected with it so clearly demonstrate the value of photography to the astronomer that I must briefly mention them. It was discovered visually on February 1, 1892, but previous to this the camera had secured many records. Professor Pickering has invented an automatic apparatus for photographing the whole of the heavens visible at Harvard on every clear night. This automatic camera had picked up this new star on December 10, 1891, and a photograph of the same region taken by Dr. Max Wolf on December 8 does not show it; its time of appearance is therefore fixed by photography to within forty-eight hours, and many valuable records of its varying magnitude were secured between the time of its photographic first appearance and its visual discovery. Unfortunately, the great and rapid accumulation of plates at a modern photographic observatory does not allow their very rapid examination, and the appearance of the Nova remained unknown until the visual discovery by Mr. Anderson, of Edinburgh.

The most recent work in solar photographic spectroscopy is due to Professor Hale, of Chicago, with his new instrument, the spectro-heliograph. This instrument, as you will see, differs very slightly in appearance from an ordinary spectroscope, the essential difference being that, instead of allowing the whole spectrum to fall on the photographic plate, Professor Hale arranges for the spectrum to be stopped by a metallic plate with a fine slit in it, which only allows monochromatic light to reach the sensitive surface. He then moves his spectroscope slit across the image of the sun, and, keeping his photographic plate fixed, the selecting slit moves at the same rate in front of the plate. When the instrument is arranged so that only the bright line, K, of the solar spectrum reaches his plate, he is able to photograph the solar prominences round the edge of the sun and the solar faculae on the disk. A visual examination of the prominences would require at least two hours; the photographs can be obtained in as many minutes. Many faculae, quite unobtainable by other means, are photographed by his instrument, and the results of the last two years' work have entirely revolutionized the study of solar physics.

* Read before the Photographic Convention, Dublin, July, 1894.

The beautiful character of his spectro-heliograms is sufficiently evident from the slides which his kindness enables me to show you.

At the total solar eclipse of 1893, April 15 and 16, the method of work was entirely photographic, and the results are far more important than any previously obtained. Time will not allow any discussion of these photographic results, but I thought you would be interested in seeing them, and I would particularly call your attention to the slide showing Bailey's beads, in which the solar corona is shown, and the edge of the sun breaking out at the end of totality. I have included the spectroscopic work in the slides brought down to-night.

STEAMER FOR PRESSED HAY.

IN Fyfe's system here illustrated the object is to compress the uncut hay as tightly as possible into

arm shown when not in use, is provided with substantial steel lugs which engage with hinged bolts secured to the cylinder, and the rim is faced up to form an airtight joint with the cylinder when the material is placed inside. Inside the cylinder is provided a heating coil and a floor plate. By means of suitable valves and pipes the pump may be employed to create a vacuum in the cylinder, after which steam is admitted, then blown off, and the vacuum pump is again brought into action to exhaust the remaining steam. The process is described by the Engineer as follows: The hay being closely pressed into bales to a density of 20 lb. per cubic foot, is now packed inside the cylinder, and the door being closed, the pump connected with the cylinder is set going to produce a vacuum. Steam under high pressure is then admitted and allowed to permeate the hay for fifteen to thirty minutes' duration, when it is blown off, and what remains is exhausted by means of the vacuum pump. For ordinary

out in a finished state. Besides possessing the advantage of great economy as regards fuel consumption and labor, this process, it is said, renders feasible the use of new hay for feeding cattle. Moreover, the hay being supplied in the form of bales, a railway truck is capable of holding more than twice as much as in the old truss form, thereby reducing proportionately the cost of transit. With the chemical features of this new process we shall not pretend to deal; but we may state that the result of analyses made by Mr. J. Barker Smith, L.R.C.P., Lond., upon different qualities of hay—treated and untreated—serve to show that the indigestible wood fiber is diminished, while the digestible fiber and carbohydrates are increased.

THE MANUFACTURE OF SMOKELESS POWDER.*

By OSCAR GUTTMANN, Assoc. M. Inst. C.E., F.I.C.

THE general interest created by the appearance of the so-called smokeless powders for military use, and their adoption by nearly every army in the world, together with the comparative ignorance in which the civilian public finds itself with regard to the nature and production of these powders, made me think that a brief summary of the most striking peculiarities of this rapidly increasing industry would be of interest.

Most of you will be aware that in 1888 the world was first startled by the appearance of newspaper reports about a new and smokeless powder invented by a chemist of the French government, and that very soon after this the German army had a similar one. It has since been stated that the first experiments in connection with the discovery of smokeless powders were made in 1884, by Mr. Vieille, the well known chemist of the French government gunpowder factories. What this powder at that stage was is not quite clear, but it is not improbable that it consisted of a mixture of collodion cotton and picric acid, similar to the original basis for the much talked of Melinite. This composition, however, seems to have been abandoned after a short period, and that kind of smokeless powder which is now very largely used in other countries as well as in France to have been adopted.

In 1889, Alfred Nobel took out a patent for the manufacture of "Ballistite," which is an ingenious modification of his blasting gelatine. This and the above mentioned French powder are the two types upon which most of modern smokeless powders are based.

The first approach to a powder giving no smoke on combustion, and which at the same time was not composed of the usual saltpeter, sulphur, and charcoal mixture, was, apart from the guncotton used over thirty years ago, the Schultze powder, which has been used as a sporting powder in this country for more than twenty years, and which consisted of nitrated wood, prepared by the treatment of wood with nitric acid, mixed with saltpeter or a similar substance. Although this powder has been brought to great perfection for sporting purposes, it has failed to be practicable for military use, since it can hardly be such a uniform material as is required for this purpose.

A much nearer approach to the modern smokeless powders, and, in fact, in some way indicative of them, was the E.C. powder, invented by Mr. Walter F. Reid, and patented in 1882 by Messrs. Reid & Johnson. Generally speaking, Reid formed grains of nitrocellulose by putting powdered nitrocellulose into a barrel, sprinkling it over with water and revolving the barrel, whereby, through agglomeration, grains of various sizes were formed. These were dried and then moistened with ether-alcohol, which had the effect of gelatinizing the surface of the grains. A small addition of aurine gave the powder an orange color. After being again dried, the grains were then put through a sieve in order to separate them, since they adhered slightly to each other through the gelatinizing process.

In a similar way Max. Von Forster made cubical guncotton powder by cutting cubes out of compressed guncotton, and dipping them into a solution of acetic ether, which coated them externally with a thin skin of collodion. This was only used for filling shells. Later on Messrs. Judson and Borland made a smokeless powder called the J.B. powder, by a process similar to the E.C. powder process, the only difference being that the guncotton grains were treated with a solution of camphor in benzoline, which, on being evaporated, left some camphor behind. This powder did not remain long in the market.

It is a pity that Mr. Reid stopped at this stage of the manufacture, because he was very near making that class of smokeless powders which are now known as pure guncotton powders; but in extenuation it may be said that at that time the want of such a powder had not been clearly expressed, since there was then neither rifle nor projectile in existence which would have been suitable for the use of powders whose pressures and velocities are so much higher than those of the ordinary black powder.

It is due to the success of the long continued experiments of two Swiss experts, Major Rubin and Professor Hebler, who have advocated for more than ten years the adoption of the small caliber rifle, that powder manufacturers have been forced to find powders suitable for the use of such weapons.

I remember very well how in the beginning of 1886, Professor Hebler showed me an experimental cartridge case made for his small caliber rifle, and asked me whether I could give him a pellet of compressed guncotton which could be loaded into such a cartridge case, and which would be likely to give to his long cylindrical projectile the required velocity. I then pointed out to him that such a charge would be impossible, on account of the sudden combustion and the very high pressure it would develop, and I offered to make him a small piece of blasting gelatine which would burn more in layers, and, therefore, probably suit his purpose better. The very suggestion of using blasting gelatine in a rifle was so much against all recognized ideas, that the matter was not further proceeded with; but after all, that rather hazardous suggestion of mine has turned out to be an idea in the

* Read before the London section of the Society of Chemical Industry, May 21, 1894.—From the Journal.

FIG. 1.—COVER REMOVED, SHOWING INTERIOR AND STEAM COILS.

FIG. 2.—FRONT END, SHOWING AIR COMPRESSOR.
APPARATUS FOR STEAMING PRESSED HAY

bales, with the object of retaining heat (for drying it more effectually, and then submitting it to a steam pressure of 60 lb. to 80 lb. Loose or exhaust steam would be useless, as it could not possibly permeate a hard pressed bale; any such attempt would be merely cooking the outside while leaving the inside. The apparatus shown consists of a strong steel cylinder, 6 ft. long by 4 ft. diameter, mounted on four wheels, and with a removable cover at one end for the introduction of the material to be cooked. The other end of the cylinder is cambered, and carries a Westinghouse combined vacuum pump and air compressor, supplied with high pressure steam. The cover, which is slung from the

requirements the cylinders are made 20 ft. long by 6 ft. diameter, and are capable of holding from 2½ to 3 tons of compressed baled hay at each operation. In dealing with wet hay under Fyfe's system, hot air under pressure and at temperature of 300° may be used instead of high pressure steam. One hour is said to be the time required to put hay through the entire process; fifteen minutes are required to fill the cylinder with hay and affix the door, while another fifteen minutes suffice to produce a vacuum and to get steam up to 80 lb. pressure. The cooking requires twenty minutes longer, a further ten minutes are needed to exhaust the steam, the bales are then ready to be turned