The picture of the combination of the various scientific and engineering societies of this country into one unit with an editor as "practical dictator" is a flight of fancy too great for us to take. Certainly the editors of the American Chemical Society are by no means "practical dictators." They are, in the first place, elected annually by a council of the society consisting of sixty or more representative chemists. Any attempt on the part of the editors to follow a course which was distasteful to a majority of the chemists of the country would be quickly followed by the appointment of other persons in their places. In addition to this, each editor has associated with him a number of associate editors, to some of whom every paper is submitted before publication and in case of any difference of opinion between the editor and associate editor to whom the paper is submitted, the question may be referred to the president of the society for decision. In some cases a doubtful paper has been submitted to nearly or quite the whole board of associate editors, and a practically unanimous opinion was secured before the paper was rejected. A democratic organization of the character of the American Chemical Society would seem to secure the rights of authors at least as well as they can be secured under the plan of a journal conducted as a private enterprise.

All the funds of the American Chemical Society go to the furtherance of chemistry in America. If the funds are increased as by an increase in membership or by advertising, all chemists will be the gainers. The work of its editors is largely a labor of love.

In the days when chemistry was little honored in this country, when chemists were few, salaries low, and support meagre, a few unselfish self-sacrificing men gave their time and money to the cause of the organization now known as the American Chemical Society, that all chemical research might be advanced and that the standing of all chemists in the community might be raised. In the days when there was no profit in publishing chemical journals, they published the *Journal of Analytical Chemistry* and later the *Journal of the American Chemical Society*. Their offense, if offense they committed, lay in publishing too much rather than too little; in printing the work of uncertain value rather than in excluding it.

The American Chemical Society favors and will always favor any movement among chemists which will advance the interests of chemistry and chemists

in the best possible way. In the matter of publication, it believes the best interests of chemists are conserved by a large organization. This is not an hypothesis but a matter of simple calculation. The society supports all movements looking to the benefit of chemistry. Its friends are the friends of chemistry in America.

W. D. RICHARDSON.

ORIGINAL PAPERS.

THE RARE EARTHS—THEIR PRODUCTION AND APPLICATION.¹

By H. S. MINER AND M. C. WHITAKER.

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The term "Rare Earths" was given originally to a group of earths of which but little was known and which we were accustomed to think was very sparsely appropriated throughout the mineral kingdom. At the present time, however, it is conceded that while not the most abundant of the elements which Nature has provided, yet they are of wide distribution; and when we consider that many of these elements are now dealt in by tons and the minerals containing them are dealt in by hundreds of tons, the term "Rare Earths" appears to be a misnomer. Instead, therefore, of conveying the original idea of scarcity, this term now conveys the idea of a fairly definite chemical classification, just as does the term the "Alkaline Earths" or the "Iron Group."

The late Prof. Mendeléeff has described this group of elements as one "which in their sesquioxides, present basic characteristics of a more energetic nature than those shown by alumina." The elements of this group as recognized by the International Committee on Atomic Weights, both by their chemical reactions, and by natural occurrence, fall into the following general classifications:

Cerite Group.—Cerium, Lanthanum, Neodymium, Praseodymium, Samarium, Gadolinium.

Ytterite Group.—Yttrium, Erbium, Terbium, Ytterbium, Scandium, Thulium, Dysprosium.

Thorium.

Zirconium.

The beginning of the study of this group of elements is traceable back about one hundred and twenty years and probably begins with the discovery of zirconium by Klaproth in 1788. He also

¹ A paper read before the New York Section of the American Chemical Society, Friday evening, December 11, 1908.

discovered cerium in 1803, while Berzelius just ninety years ago made the still more important discovery of the element thorium. From these beginnings the work was followed up all through the last century, and who shall say that the end of the chapter has been reached?

Dr. Carl Freiherr Auer von Welsbach.

Claims have been recently made that some of these supposed elements are not elementary in their character after all, but are mixtures of two or more elements. This claim is certainly supported by

precedent, notably the work of Dr. Auer when, after forty-three years, from the didymium of Mosander he produced neodymium and praseodymium. In view of these results and other work of a similar nature, it is not too much to believe that others of these supposed elements, and not improbably even the two just mentioned, are complex in their nature.

I have alluded to the fact that the elements once noted for their rarity are very widely disseminated throughout the mineral world. It has been claimed that the fifteen elements which I would include in the classification of the "Rare Elements" are found in over one hundred different minerals. These minerals have been found scattered over the whole globe. Lines of several of these elements have also been found in the solar spectrum.

The wonderful discovery made by Dr. Auer transformed the group of elements which had been long known as the "Rare Earths" from scientific curiosities into materials having a very practical value. Minerals containing certain of these elements had been known to scientists for more than one hundred and fifty years; but beyond a very limited use in the preparation of a few medicinal compounds no practical value had been developed for any of them.

The first Welsbach mantles required principally lanthanum, cerium and zirconium, elements which existed in large quantities in the Swedish mineral cerite and in zircon. An ample supply of both of these minerals was found and large quantities of cerite were mined in Sweden, and soon sufficient zircon was produced in Norway and in North Carolina to meet the demands of the incandescent gas lighting industry. This type of Welsbach mantle also developed a demand for the mineral allanite and a large deposit of this rare earth mineral was discovered in Virginia.

The invention of the thoria-ceria mantle, composed of practically 99 per cent. of thoria, produced an immediate and urgent demand for minerals rich in that element. At that time the Norwegian mineral thorite, containing about 50 per cent. of thoria, seemed to be the most hopeful source of supply. Diligent search, however, failed to discover a sufficient quantity to supply more than a small fraction of the thoria needed. Many other minerals, of course, were known which contained thoria, most of them in much smaller percentages than thorite, but none of these, with the exception of monazite, had been found to exist in commercial

quantities. Deposits of monazite sand had been discovered in North Carolina and in Brazil, and considerable quantities had been mined for use in the manufacture of the lanthanum-cerium-zirconium mantle. Lanthanum and cerium were the ingredients which had at first made the monazite of value and the thoria content had been practically overlooked and discarded. Finding that minerals rich in thoria were not commercially available more careful attention was directed towards the deposits of monazite already developed, with the result that large deposits were found in both of these localities. Though by no means an ideal mineral, yet being the only one found in paying quantities, it soon became recognized as the commercial source of thoria.

Monazite had been known since early in the nineteenth century and the fact that its name signifies "to be solitary" indicates that at the time of its discovery, at least, it was considered to be one of the very rare minerals. Since its first discovery monazite has been identified in the rocks over a large part of the earth's surface. Usually, however, it is found to compose but a minute portion of the rock and in many instances its presence can only be detected by the use of the microscope. The monazite deposits of commercial importance are those occurring in the placer sands of the streams and the adjoining bottom lands, and in certain beach sands along the seashore. Geologists tell us that such deposits can only be formed in countries which have not been subjected to the tremendous eroding influences of prehistoric glaciers during the ice age.

Monazite, in its original formation, occurs in rocks of the granite class and in many places these rocks have been decomposed by the action of weathering, and the grains or crystals of monazite thus liberated are collected in the stream-beds or bottom-lands below. As the monazite moves to its bed, by the action of running water, it undergoes a process of sorting and concentration, the lighter minerals being washed away, leaving the heavy monazite in a pocket with other heavy minerals, forming a "placer" deposit.

Monazite crystallizes in monoclinic crystals and has a hardness of from 5 to 5.5 and a specific gravity from 4.8 to 5.3. It is generally found in small grains or crystals; in fact, the grains are so fine that the mineral is commercially known as "monazite sand." Large masses and crystals have been found in Norway, though in this form the mineral is a very great rarity. Monazite is found in a variety of colors, such as light yellow, red, brown, green, buff and a great variety of intermediate shades. Chemically speaking, monazite is essentially a phosphate of the rare earths of the cerium group, and though its various components may vary considerably in different samples, a fairly typical analysis would be as follows:

Kuitting mantle fabric.

Phosphoric anhydride.....	28 per cent.
Cerium oxide.....	30 "
Lanthanum oxide.....	14 "
Neodymium oxide }	16 "
Praseodymium oxide }	
Thorium oxide.....	5 "
Yttrium oxide.....	2 "
Iron oxide }	5 "
Calcium oxide }	
Etc.	100 "

The discovery of the application of monazite to the incandescent gas lighting industry was a great incentive to the search for this mineral, but even after nearly twenty-five years, the only deposits of commercial importance are those originally known in the Carolinas and in Brazil. It is true that the borders of the deposits as originally known in both these localities have been very much extended, and far richer beds have been uncovered

than were originally known to exist; yet until this date all the monazite sand used in the manufacture of incandescent gas mantles comes from either the Carolinas or from Brazil.

The monazite district in the Carolinas comprises approximately 3500 square miles of the border region of both North and South Carolina, and lies chiefly in Burke, McDowell, Rutherford, Cleveland and Polk Counties of North Carolina, and in Spartanburg and Greenville Counties of South Carolina, though many of the counties bordering on these mentioned contain deposits of this mineral. The monazite is found in the sand carried down by the rivers and "branches" of this district, and in the gravels underlying the "bottom" land bordering on these streams. Many of these streams and

zite, to settle and remain in the bottom of the boxes.

Stream beds are now so far exhausted that attention has to be paid to the adjoining "bottoms." The monazite is found in the gravel and there is usually a heavy "overburden" to be removed before this gravel can be reached. Here again the operation of placer gold mining is followed, except that in many cases the work has to be conducted methodically, since much of this bottom land has a value for tillage purposes. The purification of the washed sand is continued by various concentration devices, such as Wilfley tables or magnetic separators, by which most of the other impurities are removed, and the final product contains from 90 to 95 per cent. pure monazite, in which form it is ready for the market.

The largest known deposits of monazite sand are those which are found in Brazil, and these deposits supply practically all the monazite that is used in the European thorium factories. The principal Brazilian deposits are found on the coast of the provinces of Minas Geraes, Sao Paulo, Rio de Janeiro, Bahia and Espirito Santo. The monazite here is really a beach sand, being found either on the shore of the ocean, or in the lowlands immediately bordering the shore. The method of mining the Brazilian sand is very similar to

Saturating mantle fabric with lighting fluid.

"branches" had been originally worked for gold, and the "tailings" of these placer operations were early found to contain monazite in paying quantities. The natural concentrates of the stream-beds were about the first deposits to be worked commercially in this region, the plan of operation being similar to that of gold placer-mining with the well-known "Long Tom" or rocker apparatus. By this process, the water from the "branches" is temporarily deflected from its channel, and is used to wash and concentrate these deposits in sluice-boxes before it returns to the original channel farther on. The sand and gravel are shoveled on to a perforated plate, and washed in the streams of water, allowing the lighter and finer impurities to float away, and permitting the heavier particles, principally mona-

that in vogue in North Carolina.

The annual production of monazite sand has very rapidly increased since the introduction of the Welsbach light. From the very small quantity of sand which was mined in the year 1888, the output has increased, until at present the annual transactions in this mineral are rated by the thousands of tons. Thus the day has passed when monazite sand can be spoken of as a "rare" mineral.

A new mineral was discovered a few years ago in the island of Ceylon, which has a composition rendering it an almost ideal source of supply for incandescent mantle chemicals, could it be procured in sufficient quantities. This mineral is thorianite and it is composed essentially of uranium and thorium, the latter comprising from 60 to 75

per cent. of its composition. As in this mineral the element sought is its essential constituent, it is to be regretted that as yet it has been found only in this one locality, and there only in small quantities.

As the chief use of the rare earths is found in the manufacture of incandescent gas lights, it might not be inappropriate for us to consider, at least, some of the salient points in the development of this system of illumination which has such a broad application.

Without any attempt to give a complete history of gas illumination,¹ or even to fully describe the very interesting development of incandescent gas lighting, I would say, that the discovery by Goldsworthy Gurney in 1826, that a lime cylinder could be raised to incandescence by the flame of an oxyhydrogen blowpipe first called attention to the fact, that certain refractory substances, when heated to a high temperature, possessed light-giving qualities. Thomas Drummond was supposed to be the first to make practical application of this discovery, which he did in the survey of Ireland, by the lamp which bears his name, which was used in connection with the heliostat for locating distant stations, and which has been in continuous use ever since as the "lime" or "calcium" light. Developments along this particular line have been confined to varying the size, shape and composition of the incandescent body, the lime being replaced by magnesia and later by zirconia.

In about 1830 we find that the municipality of Paris was attempting to light their streets by using little buttons of zirconia, heated to incandescence by the combustion of gas and oxygen conveyed to the burners in separate pipes. The excessive cost made the early abandonment of this system a foregone conclusion.

In 1839 Cruickshank took out a patent in England for a cage or mantle of fine woven platinum wire, which was of the proper shape and size to thoroughly envelop the outer portion of the flame, and

be just enough smaller than the flame to be thoroughly immersed in it. Cruickshank soon realized that platinum was not the ideal material for light-giving purposes, for he says "although the light emitted by platina at a high temperature is very bright, it is inferior to that of lime and other earths at the same temperature." He tried to combine the strength of his platinum with the light-emitting properties of these earths, but found it was impossible to make his paste adhere to the surface of the platinum for any length of time.

The introduction of non-carburetted water-gas by Gillard in 1848, furnished a new incentive for invention, for though this gas which Gillard used in connection with his iron foundries at Narbonne, would be adapted for heating purposes it would

Sewing and tying mantles.

have no application as a source of illumination. The inventor of this process of gas manufacture would naturally be expected to have the greatest interest in this development, and we are not surprised to find Gillard himself, devising a cap or mantle of fine platinum wire which he suspended in the flame of his "blue gas," and it is said that for some months this method of lighting was used at Passay and at Narbonne, but the rapid deterioration of the platinum mantle made this experiment very short-lived. The mantles not only lost their light-giving power, but finally became so brittle that they fell to pieces, and we are not surprised that Gillard's experiment should eventually fail as did that of his forerunner, Cruickshank, nine years before.

¹ See information given by Dr. Doremus in the discussion that follows.

Until the early 50's, the only non-luminous flames that could be produced were these of the spirit lamp and of uncarburetted water-gas, but at about this time Prof. Robert W. Bunsen, while planning and fitting out his great laboratories at Heidelberg, incidentally developed the burner that now bears his name, an invention which has done more for the gas industry than almost any other discovery or invention connected with it. While considering the methods of heating that should be adopted on the working benches of his new laboratory, it is said, that one of Bunsen's assistants pointed out to his chief that a non-luminous flame could be produced by passing coal-gas a short distance through the air, and then taking it through a piece of wire gauze. Seeing at once the impor-

Gillard, whom we noted as using a platinum mantle on the "blue" water-gas which he invented in 1848, continued to use it as late as 1865 in Paris and in Narbonne. He was followed by Lewis, Sellon, Moreau and others, but their lamps all met the same fate as did the first invention of Cruickshank.

Clamond, who had been working on this problem for a number of years, brought out a lamp in the early 80's in which the illuminant consisted of an earthy basket. His first lamp was of the inverted type, and the basket was held in position by a platinum skeleton, but he soon changed this lamp to the erect type, and made his earthy basket of a conical shape. The Clamond basket was made from a pasty mixture of magnesia, the fibers being wrought into the desired form while in the flexible

condition before ignition. Various modifications in the composition of the basket were made, in some of which zirconia was used, but the system was destined to be soon supplanted.

Other experimenters attempted to manufacture a mantle, by spreading an earthy paste in a thin layer over a form, and then perforating the dried sheet, which, after ignition, was suspended in any non-luminous flame, but this system was soon found to be impracticable.

The next form of an incandescent lamp to receive a practical test, especially in the fuel-

Modeling and hardening mantles.

tance of this suggestion, Bunsen brought his marvelous manipulative skill to bear on the problem, and in a few weeks produced the "Bunsen" burner. It is of interest to know that the assistant who made this suggestion, was later known as Sir Henry Roscoe.

It is not the purpose of this article to describe in detail the work done by the multitude of investigators, who from time to time entered this new field of research, but only to mention some of the characteristic steps leading up to the incandescent gas light of to-day.

Notwithstanding the discouraging results obtained with platinum as an illuminant even as far back as 1839, we find that it was persistently tried for fully fifty years by a long line of inventors.

gas plants of this country, was that designed by Fahnejelm, which may be described as a bundle of needles of refractory earthy material, arranged in the form of a comb, and suspended in the non-luminous flame of the bats-wing type. Fahnejelm preferred magnesia for his base material, though he mentions a number of other possible oxides. He forms these oxides into a paste and at the same time incorporates a small quantity of flux to make them stronger and more pliable when heated in the flame. These lamps were given a thorough test in connection with the fuel-gas plants in the Hyde Park Plants at Chicago, at Jackson, Mich., and at other places, but were soon discarded.

Stewart devised a type of burner, which embodies the Fahnejelm idea of pencils or needles of refractory

earth. He reduced the mass in his pencils, however, by making them tubular in form so as to increase the lighting efficiency, and caused the gas to issue from a series of small orifices, so as to form a number of independent blue flames in close proximity to the incandescent tubes.

More than half a century has elapsed since the first incandescent gas light was invented, and during that time many interesting developments have been made, the most important of which we have attempted to enumerate. Important as these inventions were, however, none of them constituted a satisfactory incandescent gas light for the crux of the situation had so far eluded all investigators. It remained, therefore, for the young Austrian chemist, Dr. Karl Auer, to conceive the idea of impregnating a fabric with salts of the rare earths, burning out the organic material and so forming a skeleton or mantle of the rare earth oxides. About the year 1880, Dr. Auer was engaged in investigating the chemistry of the rare earths in Prof. Bunsen's laboratory in Heidelberg. In order to get the material in a more attenuated form, he says: "It just occurred to me, by chance, to impregnate a cotton webbing with a solution of these salts, and then to burn out the cotton. It was most probable that the experiment would fail, as the remaining earths were not liable to stick

together after the cotton was burned out, but after all, the experiment was a success, and the earths retained the form of the webbing."

In his further experiments he found that lanthanum oxide not only formed a coherent body, but gave a very intense white light, and it was this fact that inspired him with the idea of using the rare earths for lighting purposes on a large scale. A mantle made from this material, however, soon decomposed and crumbled to a powder. Realizing the necessity of combining the lanthanum oxide, with its demonstrated light-emitting qualities, with some other substances that might not so easily absorb water vapor or carbonic acid, he first experimented with magnesia, but finally adopted zirconia as the substance best adapted for this work;

and, based upon this composition, the commercial manufacture of incandescent mantles was begun. The mantles gave from 30-32 C. P., with a consumption of three cubic feet of gas per hour. Finding it necessary to improve this efficiency, Dr. Auer experimented with all possible material in nearly every conceivable combination, but with no essential improvement. Finally, in duplicating some of his earliest experiments, he noted that thorium oxide possessed desirable qualities.

In resuming these experiments with thorium it was necessary to prepare more material, and in doing so a very remarkable phenomenon appeared, the purer the thorium preparation, the less light emitted. Feeling convinced that his thorium had been increasing in purity as his candle-power had

Coating mantles.

been diminishing, he began to experiment with the portions that had been removed, by successive purification processes. Here he found evidence of a special light-giving body, which was demonstrated to be cerium. With this information, and a few synthetic experiments by the addition of pure cerium to pure thorium, the brilliant light which we have to-day, was obtained. The incandescence of the new mantles exceeded that of the old three-fold. The lasting qualities were also very much improved, and finally a satisfactory incandescent gas light was obtained.

The advent of the thorium-cerium mantle served to give the incandescent gas-lighting industry the greatest impetus that it had ever received throughout its history. The efficiency of the old lanthanum-

zirconium-cerium mantle was increased by this invention to fully 22 candles per cubic foot of gas consumed. A pure thoria mantle, as has been stated, gave but very little light, but strange to say only about 1 per cent. of ceria was sufficient to produce this marvelous efficiency. The addition of more than this amount resulted in a lowering of the candle power, but within certain limits this loss in light was fully compensated for by an increase in the yellow color of the light.

Trimming and inspecting mantles.

While every conceivable substance has been experimented with, as an excitant upon a mantle with a thorium base, and many materials have been found that possess this quality to some degree, yet no substance equals that which was found to be the excitant in the original substance upon which Dr. Auer worked, cerium. The highest candle-power, on an average, is obtained with the addition of about 1 per cent. to 1.25 per cent. of ceria, though this amount is dependent upon the character of the fiber of the mantle itself. Manufacturers are often compelled, however, against their best

judgment, very frequently, to supply mantles of very much lower percentage of ceria than those indicated as giving the maximum initial efficiency. The increase in the proportion of ceria increases the yellow rays in the spectrum of the mantle, producing a better quality of light, and making a mantle of superior quality and more permanent and uniform light-giving power.

Many attempts have been made to improve upon the thoria-ceria mixture of Welsbach, and I presume that the end of these attempts is not yet. But thus far, pure thoria and pure ceria are the mainstay of the incandescent mantle business.

There is no more important constituent entering into the manufacture of mantles than the thread which forms the base from which the mantle is started. Various fibers are used in the spinning of these threads, but the only ones of any commercial importance are cotton and ramie. Artificial silk might be mentioned as of experimental importance. Furthermore, there are a number of kinds of thread made from the various different materials. For example, a thread may be a single twisted cord, or it may be two cords twisted together, in which case it is known as a two-cord thread; or it may be three cords twisted together in which case it is known as a three-cord thread; or you may have four-cord threads or six-cord threads. Threads of more than six cords are not made in the sizes used for mantle-making. The cost of the thread varies with the quality of the material from which it is made, and also with the number of strands twisted together to form it.

While extensive studies have been made of other fibers than those mentioned here, results have not been obtained which would justify their use in the manufacture of mantles. Of the three materials—cotton, ramie and artificial silk—cotton is used almost exclusively in the United States; both ramie and cotton are used abroad; artificial silk is only in the experimental stage. In view, therefore, of the importance of cotton as a base for the manufacture of the American mantles, we will confine the discussion to threads made from this substance.

Inasmuch as the texture of a finished mantle reflects every detail of the basic fabric from which it is made, the kind of a thread, the quality of the material used to make it up, and the uniformity of its size, have a direct bearing on the physical and candle-power life of the mantle. It is necessary to use a thread of uniform diameter with a maximum number of cords and made from a material with a

long staple in order to produce a mantle of the highest quality. In the manufacture of mantles of different qualities to be sold at different prices, the distinction starts in with the quality and kind of thread used. In the cheap mantles the three-cord and four-cord and in some cases six-cord threads are used which are made from the lower grades of cotton. The highest grades of mantles require the use of a carefully made six-cord thread of uniform size made from the best quality cotton.

One of the most important operations in connection with the manufacture of mantles from cotton or any of the other basic fabrics is the washing process. It can be taken as an axiom in mantle-making that anything which tends to introduce the slightest chemical impurity into the finished mantle will work great injury to the product. Starting with the thread, therefore, we remove every possible trace of mineral impurity. The purest cellulose fiber which you have ever seen is absorbent cotton, such as that on the market for medicinal and surgical uses. On analysis, this absorbent cotton shows a mineral impurity of from 0.05 to 0.06 per cent. Ordinary cotton threads, such as are used in sewing, will show a mineral impurity of practically 0.5 per cent.

The washing process used to produce these results must necessarily be very efficient, as there is a marked difference between washing loose cotton, like absorbent cotton, and the tightly twisted threads in the knitted fabric used in the manufacture of mantles. The method of washing is a carefully designed combination of a chemical and mechanical process. The work is done in a room or building especially constructed with a view to carrying out an operation requiring exceptional cleanliness. The chemicals used are the purest substances obtainable; the solutions are all made in distilled water, and all of the mechanical appliances are constructed from materials especially chosen to resist the action of the various chemical agents employed. This equipment must be of such a character as to produce not only the highest

attainable degree of purity in the fabric, but must produce it with absolute uniformity. It is obvious that perfect washing of some lots of fabric, with the imperfect washing of others, would materially affect the uniformity of the product.

Saturating is a comparatively simple process, where the thoroughly dried webbing is placed in a suitable vessel and covered with the lighting fluid. The fabric is allowed to remain in the lighting fluid until it is thoroughly saturated. The excess of fluid is then drawn off and the fabric is put through an equalizing machine piece by piece. The amount of substance to be used in the mantle is regulated at this point. In the inferior grades of mantles the quantity used is cut down to a minimum and is controlled only by the limit to which the manu-

Packing mantles.

facturer can go and produce a mantle which will hold together during the succeeding manufacturing operations. In the highest grades of mantles, the amount of lighting fluid used is based upon a careful consideration of the amount of material required to produce a mantle of the highest physical and candle-power life.

The next step in making a mantle is the formation of the head and loop. This operation is accomplished by folding-in one end of the tubular fabric and uniformly plaiting the folded portion and sewing an asbestos cord through the plaits. The asbestos cord used for this purpose must be made from a carefully selected long staple asbestos fiber, and must contain a minimum amount of cotton binder. In the manufacture, as well as in

the use of the mantle, the asbestos cord is subjected to an intense heat, and unless it has been made from a long staple asbestos fiber with a minimum amount of cotton binder, it will disintegrate and render the mantle useless. The American manufacturers of this asbestos cord obtain their supply of raw material from Canada.

The method of branding mantles is very simple. The principle on which it is based is governed by the fact that the oxide of thorium and cerium is white, and in order to form an indelible brand on the mantle it is only necessary to place over this white oxide some chemical which has a colored oxide, as, for example, iron, which gives a reddish brown oxide, or didymium, which gives a dark brown oxide. Didymium gives the most permanent brand and is the substance most generally used. The brand is put on the saturated fabric by using a rubber stamp in conjunction with a stamping pad which has been saturated with the branding fluid.

The mantle is now suspended in a suitable hood and a torch applied for the purpose of burning out the cotton. The ignition is usually made at the top near the asbestos cord, so that the burning out will be gradual and not subject the remaining ash fabric to any undue strain. After the cotton is completely consumed the ash of thorium and cerium oxides hangs in a soft, shapeless, flabby condition, and presents a very remote resemblance to a mantle. It is a remarkable phenomenon that this ash should have sufficient cohesive power to hold together after every vestige of the original cotton fabric has been burned away.

When Dr. Auer first explained his idea for making a mantle to Prof. Bunsen, that famous teacher replied: "It is extremely doubtful if the ash can be made to hold together." This opinion was based upon Prof. Bunsen's knowledge of the general characteristics of metallic oxides, but the combination of metals with which Dr. Auer was working were exceptions to the rule. The Incandescent Gas Lighting Industry rests upon this remarkable exception.

The operation also has some remarkable features. After the cotton is completely burned out in the process just described, the soft, flabby ash is carefully adjusted over a blowpipe. The operator of this device controls levers which raise and lower the mantle and which adjust the gas supply and the air supply to the blowpipes. In some cases the gas issues under a pressure of several pounds to

produce the intense flame required, but in either event the adjustment of the flame and the control of the position of the mantle is entirely in the hands of the operator. Under the influence of this intense blast flame, the flabby ash left when the cotton fabric was burned out is blown (by the proper control of the flame) into the shape of a finished mantle and is changed from its soft pliable state into a hard resilient form. This operation requires greater skill and experience than any other work connected with the manufacture of mantles.

The mantle is now "coated" to preserve the ash in the exact state in which it left the hardening operation while it is going through the inspecting, trimming, packing, transportation and installation stages. This coating or collodion, as it is usually called, is made from soluble cotton.

In the next step the mantles are taken out of the drying chambers and placed before inspectors, whose duty it is to trim them to uniform length and carefully inspect each individual mantle. This is an operation which is regarded as very important. It is an easy matter for people handling collodionized mantles to injure them, and yet the injury will not show until the coating is burned off. Furthermore, the inspection is not entrusted to irresponsible employees, and the greatest amount of care and supervision is devoted to this branch of the manufacture of mantles.

The mantles go to the Packing Department, where they are packed according to the desire of the consumer. The market is supplied with Loop mantles, Double Wire-Cap mantles, Centre-Support Cap mantles and Ring-Top mantles.

In summing up this superficial outline of the process for making mantles, it must be apparent that it is a process of great complication. These complications are divided into two distinct classes:

First.—The chemical problems which have to be solved and controlled.

Second.—The problem of supervising and controlling the work of the employees in the various different operations.

The first of these problems is under the control of a chief chemist and staff, who supervise the manufacture and use of each one of the chemical constituents entering into the make-up of these goods. Every operation involving a problem in chemistry or physics is carefully studied out and conducted under their supervision and direction.

There is no chemical manufacturing industry which requires such a large staff of trained experts

as the manufacture of mantles and the raw materials for their production.

The second division of this subject is of no less importance than the first. There are many critical operations in the manufacture of a first-grade mantle. By a critical operation, I mean an operation which if not properly conducted will result in the production of an inferior piece of goods.

It is necessary, therefore, to have not only a carefully organized supervising staff of exceptionally efficient foremen, but also to have a high grade of intelligence in the working force and to teach them to appreciate the importance of the work entrusted to them.

The amount of skill required from the employees and the grade of intelligence demanded will exclude mantle-making from that class of manufacturing industries which use cheap and ignorant help. The proportion of pay-roll which goes to the supervising staff is greater in mantle-making than in any other manufacturing line. The greatest factors contributing to the success of the American mantle manufacturer are:

First.—A thorough study and understanding of the technical difficulties involved in the various different processes.

Second.—A carefully organized and intelligent supervision of every process.

Third.—The high intelligence, integrity and skill of his employees.

Furthermore, I laid down in the beginning the axiom that any impurity introduced into the mantle in any of the processes would seriously affect the finished product. This makes it apparent that absolute cleanliness of the entire plant, of every operation and of every operator is imperative. In addition to this, the raw materials in the process must be made under the direct technical supervision and control of the mantle manufacturer.

Discussion by Dr. Charles A. Doremus: Dr. Miner has referred to Drummond as the first one to obtain an incandescent light. He will pardon my reading from a memoir by Prof. Robert Hare. It is entitled "On the Supply and Application of the Blowpipe," published by order of the Philadelphia Chemical Society, 1802.

Hare made a report to the Society on December 10, 1801, and exhibited experiments with his new apparatus which consisted not only of a blowpipe but also of a hydrostatic reservoir for holding the hydrogen and oxygen in separate compartments to be delivered as required.

On page 29 of this pamphlet the following description of some of his experiments occurs:

"The cock of the pipe communicating with the hydrogen gas was then turned until as much was emitted from the orifice of the cylinder as when lighted formed a flame smaller in size than that of a candle. Under this flame was placed the body to be acted on, supported either by charcoal, or by some more solid, and incombustible substance. The cock retaining the oxygen gas was then turned until the light and heat appeared to have attained the greatest intensity. When this took place, the eyes could scarcely sustain the one, nor could the most refractory substances resist the other." Hare has in many places in his subsequent writings made full claim to the "lime light."

Discussion by Dr. Morris Loeb: In addition to the hypotheses mentioned by the first speaker, it has, at times, been suggested that the oxide of thorium forms a complex with the other oxides, and that luminosity accompanies isomeric changes in this larger molecule. It has occurred to me that the conversion of heat into luminescence might be well explained on a hypothesis similar to that which was, I believe, first advanced by Huggins, for the explanation of fluorescence by the existence of very large molecular masses. We all know how the presence of phosphoric pentoxide enables tungstic acid to form much larger complexes. Is it not possible that pure thoria does not form large molecules, but that the presence of small quantities of some of the other oxides leads to the formation of the big complex molecule, which transforms the heat waves, rather than transmitting them?

GUAYULE RUBBER. I.

By THEODORE WHITTELSEY.

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It has long been known that the natives of Mexico in some of their games use balls composed of an elastic substance which they obtain by chewing the bark of a shrub called Guayule. Attempts have been made from time to time to introduce this substance industrially, but without success until recently. The first practical experimentation on a commercial scale seems to have been made in 1903-4. In the following year the product, which has been found to be a true rubber, began to be put on the market. From this time on the industry developed with extraordinary rapidity, and the excitement in northern Mexico is said to have been