

they are sorted for straightness. A portion are then sent to the consumer, but a large portion are first coated with copper.

The process of forcing is proximately the same as that of moulding until the material is ready for the moulds; then, instead of being moulded, it is heated and made into cylindrical plugs, which are placed in a heavy iron cylinder, and, by means of a plunger driven by hydraulic pressure, the plastic material is forced through a steel-bushed orifice and comes out in the shape of a continuous cylinder, which is cut to the lengths desired. The carbons are then sent to the furnaces, and from this point the process is the same as for the moulded.

The forcing process permits of a wide range of shapes, as by changing the size of the steel-bushed orifice, cylindrical carbons can be forced having a diameter of  $\frac{1}{8}$  in., and from this size up to or even above 4 in. in diameter. Many other shapes besides cylindrical can also be made, such as plates that are not much over 4 in. wide and of a thickness of from  $\frac{1}{8}$  to 1 in. or over. These are cut into short lengths and used for dynamo or motor brushes. Plates as small as  $\frac{1}{4} \times \frac{1}{8}$  in. are also forced for small generator or motor brushes.

There is a great difference in density and structure between moulded and forced carbon. The pressure under which moulded carbon is made is about 8,300 lb. per square inch, while by the forcing process the pressure required is double or three times as great. By the method of forcing, the material is crowded together as it is pressed toward the small end of a conical chamber and is finally forced out at the vertex, thus giving a combination of lateral and end pressure.

By the method of moulding, the carbons receive side pressure only. Under the side pressure, the material tends to laminate in planes parallel to the axis of the carbon; while under end pressure, the planes of lamination are at right angles to the axis. As usually made, the pressure is not sufficient to produce distinct lamination; but it is evident that the structure of the material is inclined toward this class of formation, as in the case of slate rock, which is laminated in planes at right angles to the lines of pressure. Under certain conditions, lamination may be observed both in moulded and forced carbon.

Carbons as they are usually made for arc lamps are about  $\frac{1}{8}$ ,  $\frac{1}{4}$  or  $\frac{3}{8}$  in. in diameter, by about 12 in. in length. In some cases pairs are used, a carbon 7 in. and one 12 in. usually constituting a pair. Besides these there are several other sizes in use; for searchlights and for many of the large lighthouses, carbons as large as  $1\frac{1}{2}$  in. in diameter and often larger are employed.

In addition to the ordinary pencils, many other forms may be moulded, such as cups or crucibles, or almost any design where the material can be retained in moulds and submitted to great pressure. Plates are made 12 to 14 in. square, and in thickness from  $\frac{1}{8}$  in. to over 1 in.; and even larger sizes are often made.

In its physical properties carbon varies greatly, the variation depending upon its composition and treatment in the process of manufacture. The hardness may be from that of chalk to that of crockery, and its specific gravity may vary to about the same extent. It is quite brittle, and this property is retained through all its stages of hardness. The tensile strength and resistance to crushing increase with the hardness.

For cutting carbon the emery wheel is generally employed; it can be drilled or cut in the lathe with steel tools, but its effect is to wear them away very rapidly; even diamonds can be used as cutting tools but a short time. On the hardest specimens these operations are performed with difficulty even with the best of tools.

As applied to electrical engineering, the most important and interesting use of carbon is in the arc lamp; here we find phenomena that are wonderful even in the light of the most advanced science. If two  $\frac{1}{4}$  in. carbon pencils be placed with their points in contact and are included in an electric circuit having a current of 10 amperes, a slight amount of heat will be developed in the body of the pencils, which will be greatest at the point of contact; if, while the current is still passing, the pencils be separated a few millimeters, an arc of great luminosity and heat will be formed. If the poles of a voltmeter be connected with the pencils, the voltage due to the resistance of the arc will be seen to vary directly as its length, or nearly so; at about 20 volts the arc will be scarcely visible, and will increase in brilliancy and heat as the points are separated until the voltage reaches about 50, when the light will appear to be the most brilliant. At a point somewhere above this voltage, possibly 70 or higher, the arc will go out with a snap.

In the above case, if the current be maintained constant, of course the watts required will vary as the voltage, and this variation of the total watts is employed by all makers of arc lamps as a means of moving the feeding mechanism. This, in some lamps, may be so delicately adjusted as to move the carbons toward each other when the distance between the points has increased an amount corresponding to 1 volt, while many lamps require an increment of 5 volts to cause the feeding device to respond.

One of the most notable points in regard to the burning of the carbon arc is that the temperature in the positive carbon rises much higher than in the negative. It is noticed that when we extinguish the arc by turning off the current, the point of the positive carbon remains incandescent after the negative point has become black; the intensely heated crater formed on the positive carbon radiates far more light than the incandescent point which is formed at the end of the negative. The consumption of the positive is about twice as great as that of the negative when burned in the air; if burned in a vacuum, then the positive only is consumed. These facts seem to indicate that the larger part of the energy of the current is expended upon the positive carbon. A large part of the energy expended upon the arc is doubtless used in maintaining a counter electro-motive force, and another portion is absorbed in the conversion of solid carbon into vapor.

The arc may be colored by the introduction into the carbon of almost any foreign substance, and the color is characteristic of the substance employed, as in the case of the Bunsen flame; and as there are but few substances which are not volatile in the electric arc, the

range of color is very large. The intensity of temperature is, without question, highest in the center or inner portion of the flame and lowest toward the outer circumference; for this reason the vapors of substances arrange themselves in concentric envelopes—those which volatilize at the highest temperature taking positions nearest the center, those which volatilize at the lowest temperature becoming the outer envelope.

The carbon flame affords one of the best subjects for spectrum analysis; it is therefore of great value for this purpose, and by its use the field of the spectroscopy has been greatly enlarged.

It is perhaps important to note that, aside from the color effect of foreign substances in the carbon pencil, there is in most cases a reduction of the light and generally a lengthening of the arc; this may be accounted for on the supposition that foreign substances usually volatilize at temperatures lower than carbon, and hence supply vapors which radiate less light, and, volatilizing more rapidly, the quantity of the vapor is increased and a corresponding reduction of voltage may also be noted. If the foreign substances are not homogeneously incorporated with the carbon, the arc will be unsteady and the light will be unsatisfactory.

In the burning of arc lamp carbons, there is always a quantity of carbon dust that falls from the burning points; this is not a product of combustion, but particles of carbon, which are detached and thrown off from the highly heated points by calcination. Many attempts have been made by inventors to reduce or prevent the loss of life of carbon; due to this cause. Some degree of success has been attained by introducing into the carbon ingredients which, fusing at a comparatively high temperature, become slag and mix with the detached particles and prevent them from falling off; and retaining them until they are consumed, the life of the carbon is prolonged to a very marked degree.

The hissing sound so frequently observed in the arc light carbons is a matter of importance. There seems to be a strong current of air and vapor moving between the highly heated points; when this current impinges in a certain manner against the point toward which it flows, hissing will be the result. To illustrate: if a jet of air be blown from a small tube, at high velocity, against a solid substance, a hissing sound will or will not be produced, depending upon the velocity of the air, the nearness of the solid and its configuration.

Many experimenters have endeavored to obtain a quiet, steady arc by the introduction into the carbon of foreign matter, which, by producing vapor more easily than carbon, will so modify the conditions as to prevent hissing; and, with a view of holding the arc in the center, a core is used. This core is simply a center, which may be  $\frac{1}{8}$  in. or more in diameter, of a material that is different from the body of the pencil and contains more or less of the foreign matter.

Some of the most quiet and steady-burning carbons that are in use have been obtained by the use of foreign matter and a core. Carbons are also made with hollow centers, through which solutions of salts are simply poured, a sufficient quantity being left therein to produce the desired result.

As early as 1867 M. Carre coated carbons with metals, such as zinc and tin; and about the same time Mr. Joseph Van Malderen experimented with carbons electroplated with copper. Carbons have, therefore, been electroplated almost from their first introduction, and copper has been the metal used. The only reason the writer has seen assigned for this use of copper is that it reduces the resistance, conveying the current to the end of the pencil with but little loss of energy. The life of the carbon is increased by coating with copper from 8 to 10 per cent.

The total resistance of an uncoated pair of  $\frac{1}{4}$  in. carbons, in a newly trimmed lamp, is about 0.20 ohm, while the total resistance of the lighted lamp is about 5 ohms. It is evident, therefore, that the resistance of the carbons is about 4 per cent. of the total resistance of the lighted lamp. The resistance of the lamp coils may be 2 per cent. The decrease of resistance due to copper coating will not account for the increase of the life; this is due, in the writer's opinion, to the fact that the copper tends to support and retain the particles of carbon that are detached from the points by calcination; to some extent, also, the fused copper forms in liquid beads, and, by absorbing the calcined carbon dust, tends to prevent its loss.

A comparatively new use for carbon is found in the carbon brush for dynamos and motors; here carbon is substituted for the copper brush, and hence retains the name, which appears like a misnomer. Carbon brushes reduce the cutting of the commutator and the sparking to almost nothing. The same commutator may be used for years with carbon brushes which, if copper were used, would be worn out in a few months. The quality of the carbon brush is of great importance; it must be of fine texture, sufficiently hard, and should act in some degree as a dry lubricant, and it should not give a squeaking noise. These are points that can be provided for by the manufacturer. Much difficulty is sometimes experienced by heating. This, of course, is a question of conductivity, and can usually be remedied by making the brush larger, or by coating it with copper, or by doing both.

The telephone is indebted for a large measure of its great success to artificial carbon. Here its value depends upon the principle that an increase of pressure produces a decrease of resistance. The writer is inclined to think, with Mr. S. P. Thompson and others, that the increase of pressure simply makes a more perfect contact. As the resistance of carbon is higher than that of metals, it is, in some cases, an excellent material for this purpose, and especially where moderate resistance is required.

Among the advantages of carbon for electrical resistances, we may note the fact that it can be heated almost to a red heat and held at this temperature, without undergoing any change whatever; and, being practically infusible, it will stand for a short time very high temperatures, even in the atmosphere, without suffering any deterioration. If held long at a red heat, however, in the air, it will calcine and sometimes oxidize. Carbon has also the remarkable property of showing a reduction of resistance as the temperature rises. At high temperatures this is very marked; for example: the decrease in resistance of an incandescent lamp filament at a white heat may be one-third of its resistance when cold. At temperatures below a red

heat, however, the change of resistance is of comparatively little importance.

Some of the difficulties that attend its use as a resistance material are as follows: the resistance of carbon varies between wide limits; two carbon pencils  $\frac{1}{2}$  in. in diameter and 9 in. in length could be selected, of which one would have a resistance of 0.20 ohm and the other 0.07 ohm. The forced carbon being more dense is always lower in resistance than the moulded, other conditions being the same. The resistance, however, may be largely controlled by variations in the manufacture.

The connection between carbon and a metal conductor often becomes a troublesome point, especially if high temperatures are to be used. For low temperatures the carbon may be electroplated with copper and the metal conductor may then be soldered; but for high temperatures the connection must be made by some form of clamping device.

Carbon is not used as a resistance where calibrated resistances are required, owing to the difficulty of determining its exact resistance. For resistance purposes, carbon is used in the form of pencils as small as  $\frac{1}{8}$  in. in diameter; larger sizes are also used; it has also been used in the granular form and as a powder.

As a contact piece, where contacts must be made and broken frequently, carbon has a great advantage in many places over metals; and frequently, where metals are used in switches for contacts for large currents, carbon blocks are successfully used as a last point of contact. In such places as these last mentioned, carbon often gives a long arc, but even where one pole is metal, instead of burning the metal the current seems to expend its energy on the carbon, which suffers but little and is renewable.

Carbon is almost universally used in primary open-circuit batteries for the positive pole, and for this purpose it is made in the form of cylinders or plates. It is not acted upon at ordinary temperatures by any acid or other liquid known to chemistry, and in batteries it is easily depolarized. Carbon is also used, to a limited extent, for crucibles; and when mixed with clay, stands very high heats without oxidization.

It is remarkable that while carbon is made in variety of forms, its uses are almost entirely confined to electrical engineering; and as we note the rapid advancement of this new department of scientific work, we may also note, as one of the changes it has brought to our century, this new industry—the manufacture of carbon.

A slight idea of its growing magnitude in the United States may be gained from the fact that it claims an investment of over \$1,500,000.

## THE DISPOSAL OF THE GARBAGE AND WASTE OF THE WORLD'S COLUMBIAN EXPOSITION.\*

By W. F. MORSE, New York City.

Two years since the report presented by the Committee of the American Public Health Association on the Disposal of Garbage and Refuse gave a clear idea of all the methods then in use for the disposal of city waste. Since that time the progress of destruction by fire has been by far greater than has been the employment of other devices. It is the purpose of this paper to briefly state what has been added to our knowledge on the subject, with special reference to the disposal by fire of the organic waste and garbage of the World's Columbian Exposition.

Total destruction by fire of city waste has been proved by six years' experience to be of great service to this country. So far as reports can be obtained, none of the garbage furnaces in use two years ago have been abandoned, but, on the contrary, the number has nearly doubled. New forms of destructors have been brought forward for experiment; novel ways of employing fuels are on trial; the utilization of the heat produced for obtaining power is found to be practicable; more convenient means for handling the material are used; the cost of operation is considerably reduced, and a general survey of the whole field shows a decided advantage both in number of furnaces constructed and their ability to perform the work required.

In Great Britain a still more rapid advance has been observed. From an exhaustive report to the City Council of Edinburgh made by a special committee, a paragraph may be quoted:

"There are now more than 310 cell destructors in use throughout the principal English towns, consuming 2,000 tons of refuse per day, at a cost varying from two and a half pence per ton at Bolton to three and a half pence at Southampton; nine pence at Ealing and Leicester, to one shilling at Derby, and one shilling three pence at Winchester."

It has been stated by competent authority that the present year there would be built in England 100 more cell-destructors, dealing with 250,000 tons of refuse per year. Thus, in Great Britain the process of destruction or disposal of town waste by fire has become a necessary part of the municipal sanitary work. No other new methods or devices appear to have been brought into use. There is a notable absence of the mention of any form of utilization of waste until the purification by fire has been first made.

Here at home there has been manifested a deep interest in this question; many cities and towns have sent out commissions for inquiry and examinations at places where various furnaces and process methods are employed, resulting in reports and recommendations for the erection of garbage furnaces. The individual yearly official reports of health officers have in a great number of instances included a concise description of garbage cremators, with estimates of cost of construction and operation, urging upon the attention of the city authorities the adoption of this form of waste disposal.

Perhaps the most instructive example of the disposal of waste by fire has been the work done for the past five months at the World's Columbian Exposition, and which is daily going on, affording an opportunity for a personal inspection of the value and sanitary usefulness of this means of getting rid of the "sins of the people."

When the plans for the World's Columbian Exposi-

\* A paper read at the International Congress of Public Health, Chicago, October 11, 1893.—From the *Sanitarian*.

tion were completed and it was known that 600 acres of ground would be occupied, that a considerable part would be used as the permanent residence of persons who would be constantly on the grounds, and that for six months the buildings would be thronged by a vast multitude, it became evident that the sanitary care of this extent of ground and its inhabitants was one of the most serious questions before the administration.

Given a residential population of 30,000 to 40,000 and a daily average of 150,000 to 300,000 additional visitors, it was estimated that the excreta, garbage, refuse and waste of every kind that must result from their presence would be nearly 100 tons per day, all of which must be collected and disposed of within the bounds of the Exposition, there being no legitimate outlet on land or water for such a purpose.

It is doubtful, in the history of this or any other country, whether there has ever been a sanitary problem of equal magnitude which must be solved in the short time allowed, or which demanded a more safe and scientific solution, than was the one here presented. To make a failure was to imperil the fortunes of the great enterprise, while a success meant not only protection for health, but the comfort and convenience of a great multitude of people.

After the adoption by the Exposition of the Shone hydropneumatic system of sewerage, the question of the final disposal of the product of the sewage sludge and the collection and disposition of the waste and garbage was considered. An exhaustive examination of all methods in use was made by the engineer in charge of the sewerage and water supply of the Exposition, Mr. W. S. MacHarg, of Chicago, resulting in the adoption of the Engle system of destruction by fire.

A contract was entered into with the Exposition authorities by the Engle Sanitary and Cremation Company, of Des Moines, Ia., and New York City, by which the construction of two garbage furnaces to destroy the sewage sludge, garbage, stable refuse, and miscellaneous combustible waste, was guaranteed by the company. The location assigned was a lot 150 × 75 feet in the extreme southeastern part of the grounds, near gate No. 6, and within a short distance of the Anthropological Building, the Forestry Exhibit, and near to the Sewage Cleansing Works, and here were built two Engle garbage cremators, placed together longitudinally, with a brick stack 50 feet high.

The details of construction of the Engle furnaces have been printed at length in the Proceedings of the American Public Health Association, and it will at this time be sufficient to summarize this for the benefit of those who may not have seen or do not recall the description. The cremators, including the stack and brickwork connecting with the furnaces, are 45½ feet long, 17½ feet wide, and 12½ feet high, exterior dimensions. On each side are platforms 21½ feet wide by 57 feet long, reached by an inclined approach of 100 feet. The covering house is 35 feet square, of corrugated iron. There are large sliding doors on two sides, through which the garbage carts discharge their loads upon iron slopes leading from the platform down to the feeding holes of the furnaces. There are two of these slopes, which are 20 × 10 feet, and have a storage capacity of ten tons each. The garbage dumped from the carts passes down the slopes into the feeding holes, of which there are four for each furnace, one being large enough to receive the carcass of a horse. It falls upon the transverse grate bars in the upper or main combustion chamber. These bars are made of interlocked fire clay moulded blocks, firmly keyed together, with spaces through which the ashes fall into the lower chamber. The fires are at each end of the upper chamber, one being above and the other below the level of the grates. The main or primary fire is by the action of the draught brought directly over and through the material on the grates, driving the smoke, odors, and gases the length of the chamber and downward into the flame from the second fire. This perfected and complete combustion fills the lower chamber and space beneath the grate, and passes on its way over bridge walls to a second combustion chamber, and finally into the base of the chimney. Every particle of carbon, vapors, gases, and smoke is annihilated or transformed into carbonic acid gas, that is discharged at a temperature of 1,000° at the top of the chimney—a thin, colorless, invisible gas, which is immediately dissipated. Of all the chimneys and smokestacks within the grounds there is none which shows so little signs of burning fuel as does this one. Connected with the interior of the combustion chambers are inlets which bring hot air from small chambers over the fire boxes, to which the oxygen is admitted from the outside and heated to a high temperature. Hollow arches over the top, air spaces in the sides, and hot air pipes from the chimney also assist in furnishing heated air for the combustion of the garbage.

The distinguishing feature of the Engle system is the use of the second fire, destroying the products of combustion from the material burned and utilizing the heat thus obtained within the furnace. In the destructors employed in England this is accomplished by a secondary fire called a "fume cremator," placed near the base of the chimney, the heat from which cannot be utilized. Before the introduction of this device their chimneys emitted smoke and offensive odors.

The fuel used at the Exposition furnace is crude petroleum. This is brought by pipe lines directly from the oil fields in Indiana to tanks within the grounds, from which it is pumped into a stand pipe 30 feet high supplying all the power plants of the Exposition. To atomize the oil, power is obtained by a 12 kilowatt electric motor which drives a Root blower, giving an average pressure of 12 ounces of air per square inch of opening. The form of burner used is the S. C. T. burner, atomizing by air alone, using no steam. This burner, a late invention of Messrs. Squire, Cobb & Towl, is largely employed by the Standard Oil Company in its pumping stations and is the only example of its type in use at the Exposition. By an accurate test made by weight and measure of the oil, it is determined that under usual conditions there is used from 5 to 7 gallons of oil per hour by each burner; three burners being usually run in each furnace, the maximum amount of oil required would be from 30 to 42 gallons per hour, but this is greatly reduced during the latter part of the work, when, the radiated heat of the furnace being very great, less fuel is required.

There is brought to the cremators at 10 a. m. from 8 to 15 tons, the average quantity being about 10 tons of sewage cake from the Sewerage Cleaning Station. By the Shone system all the sewage from the grounds is forced by compressed air into large receiving tanks at the cleansing station, being about 2,500,000 gallons daily. After treatment with chemicals and the precipitation of solids to the bottom of the receiving tanks, the effluent is run off into the lake and the residuum pumped into sewage presses and formed into sludge cakes 2½ feet in diameter and 1 to 1½ inches thick.

These cakes come directly from the presses to the furnaces, being broken up into fragments in their transfer by carts. An analysis of this sludge gives moisture 58 per cent. and dry matter 42 per cent. Of this dry matter there is about 18 per cent. of combustible material, being 6 to 8 parts of oily or soapy material and 10 to 12 of paper pulp and fecal waste, the remainder being ash, lime, earth and chemical and mineral products. Thus only 18 per cent. of the original sewage bulk can be actually burned. When exposed to high temperatures in this semi-fluid, viscous condition, the liquids slowly evaporate and the residuum falls in a yellow powdery ash. It does not burn, as there is so small a percentage which fire can take hold of, but transforms to a condition like burned clay or earth. The ash remaining is far greater in quantity than from an equal amount of garbage, the process is slower, actual results showing that 24 tons of garbage can be burned at a lower temperature in the time required by 8 tons of sludge at a far higher heat.

The daily collection of garbage begins at 11 o'clock at night and continues until morning. The carts used are those known as the Hill garbage wagon, a light, water-tight iron body on two wheels, holding 45 cubic feet, with a projecting tailboard allowing the discharge of the contents free from the wheels. They are drawn by one horse and attended by one man.

The garbage comes from the kitchens of the national and State buildings, restaurants, the native villages, and often contains large amounts of coal ashes. There is no paper, sweepings or combustible refuse, and but small quantity of excreta from earth closets and vaults. There have been burned the bodies of two camels, four horses, two cows, two deer, one elk, several dogs and smaller animals. These pass into the upper combustion chamber through the large feeding hole, no preliminary cutting being necessary. The body of the largest horse was consumed in an hour, the smaller animals in much less time. There was no visible discharge from the chimney during their combustion. The mixture of coal ashes with garbage, which has sometimes been as much as 25 per cent. of ash, delays the process of combustion, requiring more time and labor to pass it through the grates, but does not otherwise affect the operation of the furnaces. The quantity of liquids contained in the garbage is very large. After rains there is always a great increase in this; frequently the carts discharge one-third or more of their contents in water.

There are required three shifts of four men each for the 24 hours, which, with two engineers and superintendent, makes 15 persons employed in the management of the furnaces. Because of their peculiar situation and the fact that the furnaces must always be ready for public inspection, a larger force is employed than would otherwise be necessary for the work. The greater proportion of the work is done between the hours of 12 o'clock midnight and 12 o'clock noon. It could be all done in the six hours from 12 to 6 o'clock a. m. if the collection could be brought to the furnaces more promptly. The cost of operation and maintenance, including the cost of fuel, is, as nearly as can be reckoned, from 60 to 70 cents per ton. This is larger than has been done at some other of the Engle furnaces, because of the exceedingly refractory character of the sludge destroyed. As before stated, it takes much more heat and labor to destroy the sewage sludge than it does a quantity of garbage three times its bulk, and the product of ashes and consequent labor in handling these is very largely increased. If the ordinary and usual collection of garbage of a city, say, for instance, Chicago, was to be destroyed by this process and the work carried on by private contractors or by strict oversight on the part of city authorities, it is certain that the cost of operation would be considerably reduced. It is safe to say that 50 cents per ton would represent the cost for this class of garbage. Where the garbage includes the miscellaneous combustible refuse of the city the cost of combustion is still further lessened, as every particle of combustible matter aids in consuming the wet material. For instance, at the city of Savannah, Ga., where there have been two Engle garbage cremators in use for the past four years, the official report of the operation of these furnaces from January 1 to September 1, 1893, is as in the following table:

The cost for destroying the 37,955 cubic yards is \$4,457.21, at a net cost of 11½ cents per yard. This does not include horses, cows, etc., which are burned in the cremators—this is garbage only. It is difficult to estimate this quantity by weight, as it includes a large proportion of combustible refuse and a considerable amount of the contents of privy vaults.

During the year 1892 the average cost per cubic yard for fuel and labor at this city (Savannah) was 13 cents.

Garbage loads .....	14,922
Cubic yards .....	37,955
Cows .....	97
Horses .....	155
Goats .....	30
Dogs .....	1,650
Cats .....	2,768
Fish .....	55 bbl.
Meats .....	7,675 lb.
Poultry .....	10,643 hd.
Onions .....	23 bbl.
Oranges .....	36 ld.
Bananas .....	31 ld.
Apples .....	5 bbl.
Infected goods .....	651 pieces.
Average amount burned daily .....	158½ cub. yds.
Average loads hauled daily .....	62½.

As will be seen, the addition to the city garbage proper of combustible refuse tends not only to provide means for the disposal of worthless matter, but to di-

minish the cost of maintenance of the furnace which destroys the offensive kitchen offal. This record is still further strengthened by reports of a similar character from the cities of Norfolk, Va.; Richmond, Va.; Jacksonville; Panama; Salt Lake City and Ogden, Utah; Des Moines, Ia.; Findlay, O., and many other cities where these furnaces are in use.

The ashes from the destruction of garbage at the Exposition accumulate in a pile outside the house and are used by the authorities of the Exposition in filling such parts of the grounds as had to be brought up to grade. No effort has been made to utilize them for any purpose of fertilization, but they possess undoubted value, as they contain from at least 4 to 6 per cent. of potash and a small percentage of phosphoric acid. Repeated analyses of the products of garbage combustion have shown that there is enough value in these ashes, if properly separated from the debris, to very nearly pay for the fuel used in the operation of burning. When used for filling low grounds or making streets they are more valuable than the same amount of earth or gravel. On sandy roads these ashes pack solid, do not break up under the wheels, and make an elastic and firm track.

The destruction of the garbage of the Exposition has been continuously performed since May 9, when one furnace went into operation. There has been no cessation; the daily collection being delivered and disposed of with the utmost rapidity consistent with the sanitary performance of the work, the object being to keep the grounds free from waste and to care for the sewage sludge as fast as produced, so that no offense shall arise, and there need be no large accumulation on hand. This has been perfectly accomplished; and had it been possible to secure a perfectly trained body of men to operate the furnaces, so that experienced help would be sure of being had at all times, the work of operation would have been much simplified. Taking the work of these garbage cremators as a whole, considering the difficulties under which they were constructed, the limited extent of time for which they would be employed, the exceedingly refractory character of the waste to be consumed, and the difficulties incident to the construction, management, and superintendence of the work, the results accomplished have certainly been remarkably successful.

It must be remembered that this destruction is performed under the observation of men experienced in furnace construction—engineers perfectly familiar with all the details of application of heat and power, experts who are responsible for the cleanly condition of the grounds and the comfort of great multitudes of people—and is inspected by thousands of persons interested in examining, for sanitary reasons, the destruction of waste where the slightest sanitary annoyance would be instantly observed and commented upon. To have done this work five months to the entire satisfaction of the board of administration and the sanitary engineers of the Exposition is a most striking and conclusive evidence of the value of garbage cremation and of the usefulness of the Engle system when brought into use on a large scale. It is evident that the same work could be performed elsewhere under conditions which could hardly be more exacting with equal success.

There remains in this connection only one thing more to be noted: In most cities throughout the United States the collection service, whether by contract or by municipal work, collects and transports all the waste of the city in one receptacle. In but comparatively few places is the separation made of putrescible garbage, combustible waste and ashes. The result is an aggregation of material which cannot be destroyed in its original state, which is difficult to separate satisfactorily, and which is entirely worthless from the admixture of putrescible matter which permeates the whole.

The next step demands an apparatus which shall take this material and prepare it for cremation, separating the valuable parts and destroying the rest. It is entirely practical to so arrange a series of screens, sieves, or separative machinery which shall take the mixed garbage, ashes, etc., remove the finer portions of ash, separate the paper, leather, glass, iron, rags, and discharge the residuum into the mouth of the furnace, where it is destroyed. The material which is of value, and which is by this process sorted out, would then be disinfected by steam heat, cleaned and prepared for sale, and the revenue therefrom placed to the credit of the city. If the city of New York can receive \$93,000 each year for the privilege of picking over the garbage as it is discharged on the decks of the scows, and if the parties holding this contract can make a large sum of money by this crude, imperfect system of handling this material, it is quite certain that if the work were carried on in a systematic manner a great deal larger revenue would be produced. What is true of New York is true to a greater or less extent in every city of the country. There is to day hauled out and put upon the dumps, cast overboard, or discharged into garbage cremators, valuable material enough to defray 25 per cent. of the cost of the collection service in every place. Under the American system of wasteful living there is thrown out from households a large proportion of food products, which would be reckoned valuable abroad. Under the somewhat lax and irresponsible methods of municipal business conducted by committees and councilmen of this country, there is less attention paid to the economical operation of garbage disposal methods than should be done; the result is the destruction yearly of a great mass of valuable waste which should be saved at a profit to the city.

Another thing, the heat caused by the destruction of putrescible waste can be perfectly well applied for the production of power, which, in its turn, is used for municipal purposes. There goes up the chimney of every garbage cremator in the country heat enough to run a steam boiler of 15 to 40 horse power. When these garbage destroyers are built as they should be, in connection with other municipal plants where steam is employed, the cost of operation would be greatly diminished, and the necessity of doing the work cleanly and economically will become much more apparent. Our English brethren have made greater progress in this direction than has been done in this country. Their destructors in some cases are self-supporting, from the fact that everything of value is utilized and



the heat is turned into active power. The day will come in this country when this will be as much a part of the disposal system as is the construction of the furnaces themselves.

#### THE DISPOSAL OF EXCRETA

without the intervention of conveyance by sewers is accomplished by the operation of a small fire closet which has been constructed and is at work at the side of the garbage cremators at the World's Exposition. This shows by a small working model what might be done on a larger scale in every school house, public building, or manufacturing establishment where no drainage can be secured and where the necessity for the disposal of the organic waste is evident. Proceeding upon the same plan of employing two fires, the one disposing of the excreta and the other the products of that combustion, the excreta is received upon the grate bars, the liquid portion passing into the pan underneath, and at the proper time—usually twice each month—is destroyed by the application of fire in the two fire boxes. The amount of fuel is insignificant, the time required very short, and the operation of destruction inoffensive, unobjectionable and sanitary. This device has been employed in this country for six years, has been found to be a perfectly sanitary substitute for all privy vaults, system of water carriage or earth closets, and is susceptible of being applied at every place where the conditions do not warrant the conveyance of household excreta by drainage. This apparatus will repay a strict investigation and will demonstrate its usefulness under all conditions.

#### A RECAPITULATION

of the work done at the Exposition up to date may be of interest, though it is necessarily incomplete.

For the five months that the cremators have been used there was about 5,732 tons of sewage cake and garbage brought to the furnaces, also a considerable amount of stable refuse and damaged food products, besides the bodies of 12 large animals. The average weight of a load of sludge cake was found to be 2,700 pounds and of a load of garbage 2,035 pounds. In these calculations the weight of sludge is assumed at 2,400 pounds and of garbage at one ton, except in the middle of the summer, when this was slightly larger.

The largest quantity of oil burned in one hour was 71½ gallons, used by 6 burners, the average of eight days' test being 37½ gallons per hour, or 6½ gallons for one burner per hour.

One day's trial, during which time the oil, sludge, and garbage were accurately weighed, showed there was destroyed 8½ tons sludge cake, 27¼ tons of garbage mixed with large quantities of liquid, the time required being nine hours for the sewage cake and twelve hours for the garbage.

There were burned 895 gallons of oil for fuel. The labor employed extended over the twenty-four hours, the relative proportions of expense for fuel and labor being about 75½ cents for sludge, 67½ cents for garbage per ton.

Taking the cost for fuel and for labor during the time the furnaces were actually operating, the expenses would be considerably reduced, the increased cost being due to the peculiar conditions of night collection of garbage, the necessity for quickly destroying it, and the lapse of time before the sewage cakes are received.

The largest day's work done was the disposal of 21¼ tons of sewage cake and 38¼ tons of garbage, the time required being about eighteen hours, at a cost for fuel and labor of 60 cents per ton.

Finally, it will be seen that the disposal of city waste by fire can be carried on in the immediate vicinity of dwellings without nuisance or offense, provided the work be done by furnaces adapted to the purpose, and operated by men who are competent. It is demonstrated that not only garbage, refuse, and dead animals, but also sewage sludge and excreta can be perfectly destroyed when required. It has been shown that the cost of doing this work is as reasonable as can be expected, considering the difficulties which are to be encountered, and that this cost is steadily being reduced as the character of the work becomes better understood and the furnaces are constructed on more scientific plans. It must be evident that a great saving can be made by separating such valuable parts of city waste that can be sold, and thus diminish the cost of operation, and it is certain that the progress made in the direction of waste disposal by fire far outstrips and exceeds all other methods or means which have been developed since the meeting of this association held two years since.

Since the date of the foregoing paper (October 11, 1893) the record of work done has been brought down to the end of the Exposition. There have been burned in six months' continuous service the garbage and sewage sludge resulting from the presence of 27,250,000 persons. This work has been appreciated by the authorities and recognized by the award of medals of the highest class for the garbage cremators and the Engle fire closet.

#### THE MOON'S FACE—A STUDY OF THE ORIGIN OF ITS FEATURES.\*

By G. K. GILBERT.

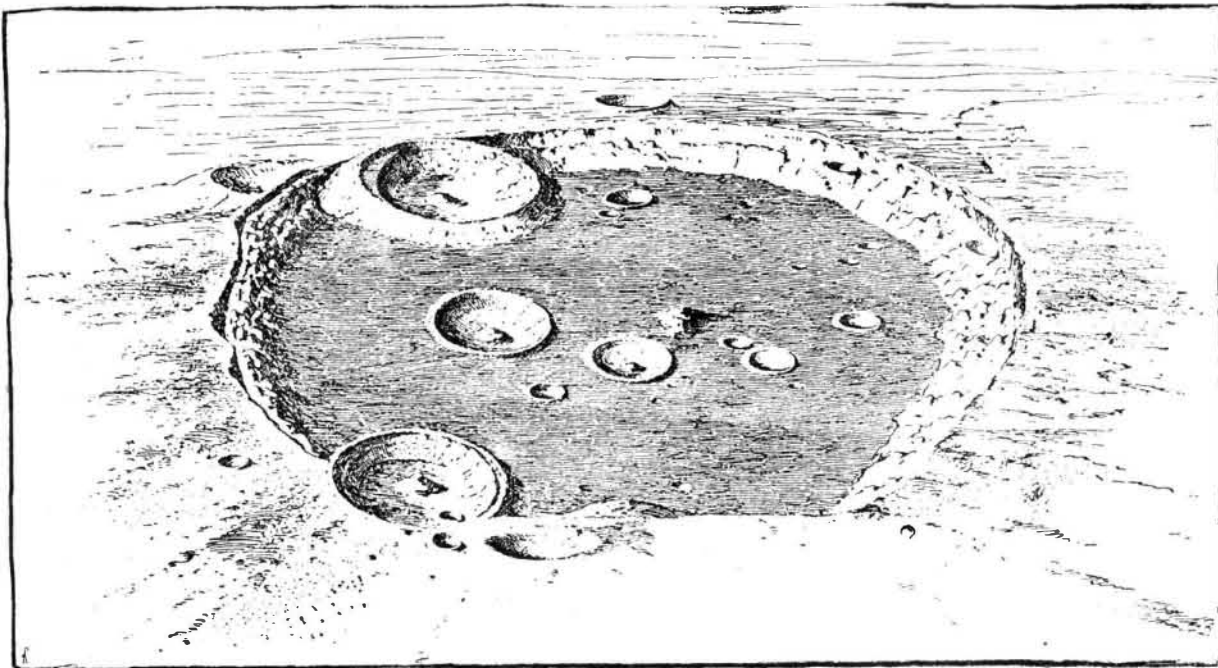
THE face which the moon turns ever toward us is a territory as large as North America, and, on the whole, it is perhaps better mapped. As its surveyor, even if armed with the most powerful telescopes, is still practically several hundred miles away, his map does not represent the smallest features; but as all parts are equally accessible, and as he has labored industriously these many years, there is no remaining space on which to write the legend "unexplored." Upon his map are a score of great plains with dark floors,

which he calls *maria*; there are a score of mountain chains; there are a few trough-like valleys remarkable for their straightness; there are many thousand circular valleys with raised rims, which it is convenient this evening to call craters,\* although for the purpose of detailed description he has found it convenient to give them many distinctive names;† there are thousands of bright streaks, which are neither ridges nor hollows, but mere bands of color; there are many hundred narrow linear depressions, which he calls rills.

Despite the persistent enthusiasm, the patience, and the industry with which he has studied his field, it

more or less correlated with size, but their intergradation is so perfect that they are all regarded as phases of a single type.\* Those of medium size will be first described.

Picture to yourself a circular plain ten, twenty, fifty or one hundred miles in diameter, surrounded by an acclivity which everywhere rises steeply but irregularly to a rude terrace, above which is a circular cliff likewise facing inward toward the plain. This cliff is the inner face of a rugged, compound, annular ridge, composed of shorter ridges which overlap one another, but all trend concentrically. Seen from above,



LUNAR CRATER CLAVIUS, SHOWING GROUPING OF CRATERS.

Diameter 143 miles; depth about two miles.

must nevertheless be admitted that he has rarely satisfied himself and never satisfied his fellow-workers with the explanations he has suggested as to the origin of the features his map delineates. But selenographers are not the only students of the moon's face. There are also selenologists who use the telescope comparatively little but cogitate much, and who have evolved theories of great ingenuity and variety. Far be it from me to say aught to their disparagement, for this evening I join myself to their ranks; but, again, it must be confessed that the selenographers do not look upon the teachings of the selenologists with favor. So, despite all that has been

this ridge calls to mind a wreath, and it has been so named. From the outer edge of the wreath a gentle slope descends in all directions to the general surface of the moon, which it is convenient to call here the outer plain. The outer slope of the crater may be identical in surface character with the outer plain, or it may be radially and somewhat delicately ridged, as though by streams of lava. The inner slope, from the base of the cliff to the margin of the inner plain, is broken by uneven and discontinuous terraces, which have the peculiar habit of land slip terraces as one sees them about the flanks of a plateau capped by a heavy sheet of basalt. From the center of the inner

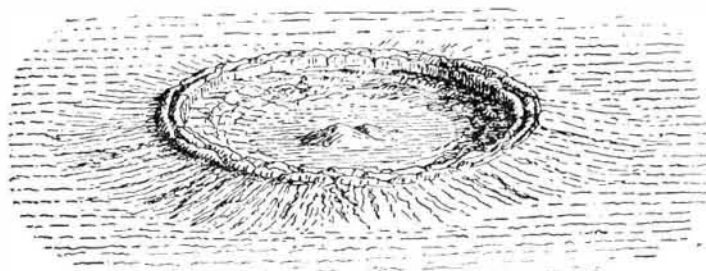


FIG. 1.—Type form of lunar crater.

done, the field of theory is still open, and this is my excuse for putting forth ideas founded neither on protracted observation nor on protracted study—this and the further plea that the problem is largely a problem of the interpretation of form, and is, therefore, not inappropriate to one who has given much thought to the origin of the forms of terrestrial topography.

**Crater Characters.**—In the study of lunar physiography—or physiognomy, if you prefer—interest naturally centers in the craters, for these are the dominant features. All theories begin with them; and, before examining the theories, it will be well to place

plain rises a hill or mountain, sometimes symmetric, but usually irregular and crowned by several peaks. From the outer plain to the base of the wreath the ascent is 1,000 or 2,000 feet, and the ascent thence to the top of the wreath may be as much more. The descent from the wreath to the inner plain is ordinarily from 5,000 to 10,000 feet, and the height of the central hill is 1,000 to 5,000 feet. With rare exceptions, the inner plain is several thousand feet lower than the outer plain.

The central hill is not universally present, but appears in rather more than half the craters of medium size. With craters more than 100 miles in diameter its

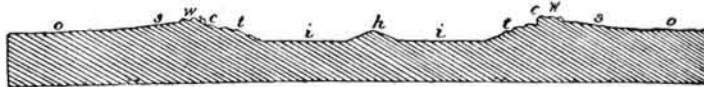


FIG. 2.—Cross-profile of lunar crater. *oo*, outer plan; *ss*, outer slope; *ww*, wreath; *cc*, inner cliff; *tt*, terraced inner slope; *ii*, inner plain; *h*, central hill.



FIG. 3.—View and section of margin of basaltic table, showing land slip terraces.

clearly in view the characteristics of the lunar craters. The range in size is great, extending from a maximum of about 800 miles diameter to a minimum of less than one mile. The size of the smallest ones is not known, as they are beyond the present power of the telescope. Within this range are several varieties,

occurrence is comparatively rare, and it disappears altogether before the maximum size is reached. Increase in size is also accompanied by atrophy of the wreath, but to this rule there is a conspicuous exception, in that the greatest of all the craters preserves the third part of its wreath. In the absence of the wreath there is no sharp line of demarcation between the craters and the maria, and several large plains of

\* Address as retiring president of the Philosophical Society of Washington, delivered December 10, 1892. A supplementary communication on the same subject was made to the society at the meeting of January 7, 1893. The substance of that communication, as well as the results of later studies and experiments, are included in this publication.

† An outline of the discussion was read to the National Academy of Science in November, 1892, and was reported in abstract in the *American Naturalist*, vol. 26 (1892), pp. 1056, 1057. A similar outline was presented to the New York Academy of Science in February, 1893, and is reported in abstract in vol. 12, pp. 93-95, of the *Transactions*. The same abstract appeared in *Astronomy and Astro-Physics* for March, 1893, No. 113, p. 236.

\* The word *crater*, derived from the Greek name of a kind of bowl, is used chiefly to designate the bowl-shaped cavities of volcanoes. In this paper, as in most selenographic writings, it designates a topographic form without implication as to the origin of the form.

† Nelson classified craters as crater cones, crater pits, craterlets, craters proper, crater plains, ring plains, mountain rings, and walled plains, recognizing gradation between them and also between walled plains and maria. *The Moon and the Condition and Configuration of its Surface*, by Edmund Nelson. London, 1876.

‡ My observations were practically limited to two lunations in August, September and October, 1892, a period affording eighteen nights available for work. My instrument was the 26¼ inch refractor of the United States Naval Observatory, and the power found most serviceable was 400.

\* The only exceptions to the type that I have noted are associated with certain of the rills. They are so small that I could not determine their characters with certainty, but they seemed to lack rims and to be hopper-shaped.

Nelson (op. cit., p. 66) describes "crater cones" as of different type, characterized by cups at the apices of cones, but these I did not succeed in discovering. On several occasions I saw at the terminator what appeared to be small craters perched on high pedestals, but when the same objects were observed at such distance from the terminator as to escape the exaggeration peculiar to that illumination, they were seen to be depressed craters of the usual type.