

in this direction, for light consists entirely of vibrations transverse to the direction of propagation.

In any direction at right angles to the magnetic force, on the other hand, these oscillating electrons emit plane-polarized light which, as its wave length is not altered by the magnetic force, appears in the spectroscopy as a line which has the position of the normal cadmium line, but only one-third of its intensity. When viewed in this direction the revolving electrons present the edges of their orbits to the observer so that, if they could be seen, they would appear to move in straight lines, perpendicular to the line of

sight, as well as to the magnetic force. Hence the two groups of electrons, revolving in different periods, produce two spectrum lines, which are slightly displaced from the normal position toward the red and violet ends of the spectrum, respectively, and both of these lateral lines are plane-polarized in a plane at right angles to the plane of polarization of the middle line.

The appearances presented and the character of the luminous vibrations in the two cases are illustrated by Fig. 5.

Extraordinary apparatus is required for the ob-

servation of the Zeeman effect in this clear and distinctive form. The spectroscopy must have very high resolving power. Diffraction grating and interference spectroscopes are the most effective. The electromagnet must also be very powerful, for the separation of the lines increases with the strength of the magnetic field. Faraday, in 1862, sought vainly for some such effect, and Zeeman, in his first experiments, obtained only a broadening, and not a division, of the sodium lines.—Adapted for the SCIENTIFIC AMERICAN SUPPLEMENT from Prometheus.

THE BRIQUETTING OF COAL DUST.

A NOVEL BELGIAN PROCESS.

BY LINDON BATES, JR.

THE increasing consumption of coal, coincident with the exhaustion of certain veins, has for some time made economic the utilization of coal dust throughout Europe; and a considerable industry in the manufacture of this dust and coal debris into briquettes has sprung up in Germany, France, England, and more especially in Belgium, where the use of this fuel has become for some purposes universal. The Belgian government railways use this sort of fuel exclusively, and any one who has traveled on the Brussels and Ostend express will notice the carefully ranked piles of black 5-kilo (11.02 pound) bricks stacked up in the tenders. The coastwise steamers plying to Ant-

werp so as to be soft and sticky, mixed with the coal dust, and the compound strongly compressed into solid bricks.

The tar residue, called "brai" in the Belgian terminology, comes usually from gas plants or coking furnaces. The coal tar resulting from these processes distills into benzoates, C_6H_6 , and C_7H_8 , naphthas, etc., leaving as residue this brai, of varying chemical proportions of C, H, and O, and amounting to about 50 per cent of the original tar volume.

There are several tests for the utility of this residue for fuel making, for the wrong variety may give poor results in crumbling or cracking briquettes. The

thoroughly ground, mixed in the proper proportion, and carried on to a warming oven. Here the mixture is heated to the melting point of the brai, about 70

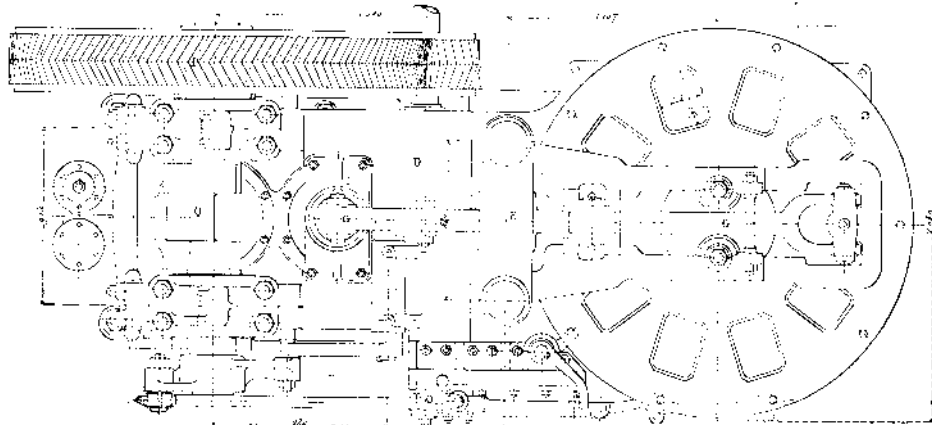


FIG. 2.—VIEW OF MACHINE PLAN.

werp largely use a larger size. In the households 1-kilo (2.20 pound) blocks heat the kitchen ovens. On the street corners the coal "eggs" are sold at a few centimes apiece for the braziers of the poor.

In Germany, where the statistics of the industry have been carefully kept, there were by the last figures 52 briquette factories producing 1,550,000 tons. The consumption is given as 635,625 tons for the government railways, 192,110 sold for domestic consumption by dealers, 525,863 consumed by factories and industrial works, 119,400 used on steamers or exported, and 13,132 used on the canals—a total of 1,486,130 tons.

The manufacture of coal tar into briquettes is thus a very considerable industry.

The fundamental principle of the manufacture of briquettes consists in the use of residue tar, warmed

usual empirical test is to chew a piece of it, and if it melts and becomes soft, it is usable. More scientifically, it should soften at 60 deg. to 70 deg. C. (140 deg. to 158 deg. F.), and melt at 90 deg. to 100 deg. C. (194 deg. to 212 deg. F.).

This residue, which sells from \$8 to \$10 a long ton, is the most expensive constituent. The evolution of briquette manufacture has been toward a type of machine which, by its great compression, will compensate for and allow a low percentage of this relatively expensive agglomerating material. By the most modern system, only 5 to 7 per cent of brai is necessary to make a solid brick out of coal dust.

In preparing for the process, the coal dust is first washed; then thoroughly dried, for any moisture spoils the product. The coal and the brai are now

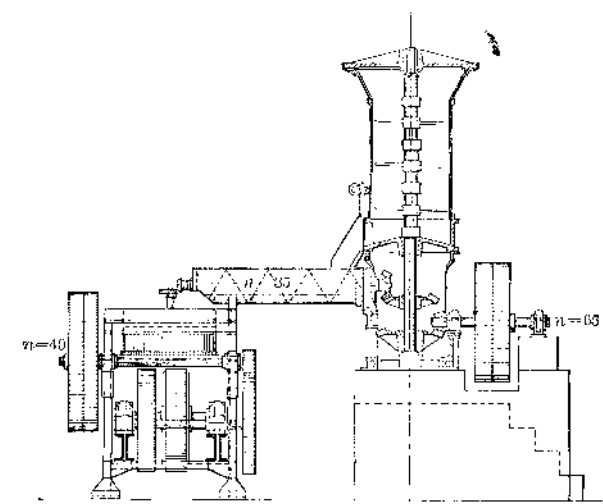


FIG. 5.—ARRANGEMENT OF BRIQUETTING PRESS PROVIDED WITH KNEADING MECHANISM. LONGITUDINAL SECTION.

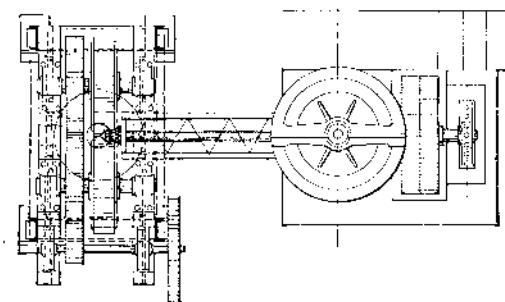


FIG. 5A.—TOP PLAN VIEW OF MACHINE IN FIG. 5.

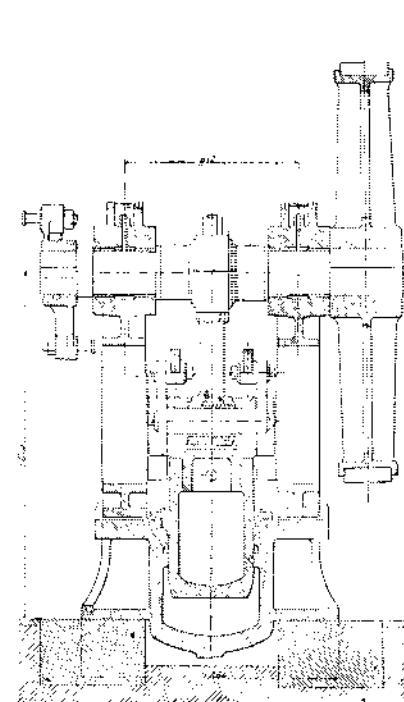


FIG. 3.—VERTICAL SECTION THROUGH a b (FIG. 1).

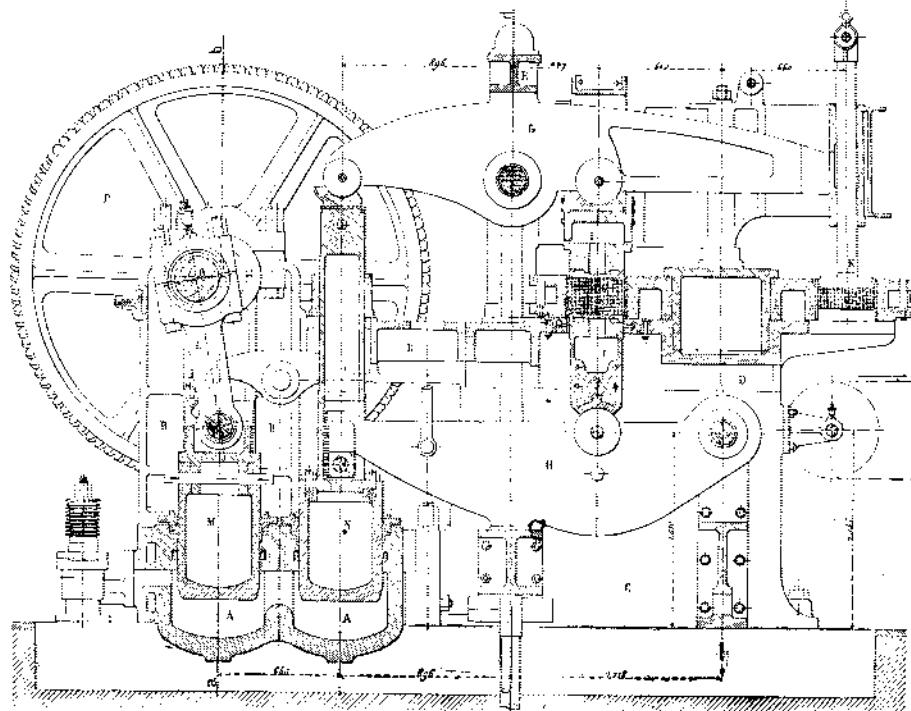


FIG. 1.—THE VEILLON SYSTEM OF MANUFACTURING BRIQUETTES. MACHINE FOR COHERING COAL DUST AND BRAI INTO MASS.

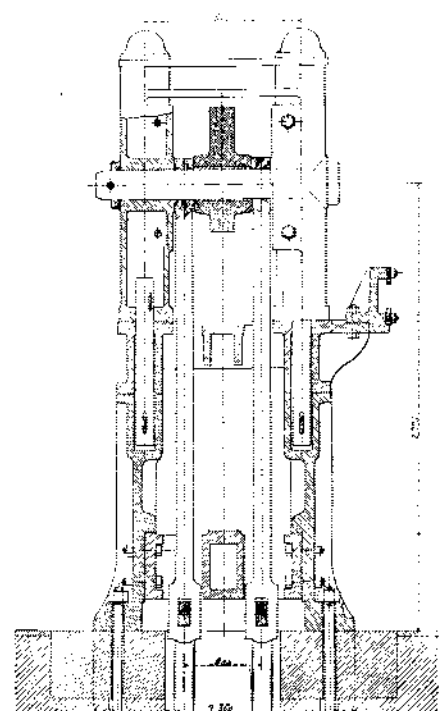


FIG. 4.—VERTICAL SECTION THROUGH c d (FIG. 1).

deg. C. (158 deg. F.). Next the mixture is dropped down a series of shaking tables, and brought into contact with superheated steam at 275 deg. C. (527

(deg. F.) to take out any moisture that might remain. Another mixing and kneading process takes place, and the mixture is ready to enter the mill. In the latest type of mill, two arms close together, catching between them the material for the brick, very much as a coin is stamped in the mint, compressing the brick with upward of 100 to 200 atmospheres pressure.

After compression in the mill the bricks fall out onto a moving platform, and are stacked.

The process is therefore one of great simplicity. A plant of two presses with the necessary equipment capable of turning out together 100 long tons per day of ten hours, requires as the laboring force only one engineer, two men to feed in the coal and the briar, and three boys to stack the briquettes.

In general, these briquettes are preferred to coal, except where the latter is so easily available as to give it the advantage of accessibility. They can be more easily and conveniently handled, and are cleaner because they do not break up readily. A 10 to 15 per cent less quantity of briquettes will give the same heat as coal, and leave less slag, less ash, and less smoke. At Wilhelmshaven some briquettes were left exposed to all weather for three years, and showed no deterioration when used, the tar employed in their manufacture having protected them, so that it is a very serviceable fuel indeed.

Although America has still such an abundance of coal for all purposes, it is by no means sure that the increasing price will not make it economic for us as well to utilize a considerable portion of the coal dust and screenings now wasted, for making briquettes. The cost of manufacturing this fuel, counting everything save the coal dust, is roughly \$1.60 per ton. If the product could be sold for \$5 a ton, it would probably compete successfully with the best anthracite even at present prices, for the margin of \$3.40 should leave a very fair profit, after deducting the cost of the coal dust. So that it is not at all unlikely that the manufacture of coal briquettes is destined ultimately to be a very large American industry as well.

THE STUDY OF ANIMAL MOTION.

PREFACING his more impertinent remarks by a brief historical sketch of the three centuries since the birth of Borelli, the author of the study of animal movements at Naples, Prof. William Stirling, in his discourse before the British Association for the Advancement of Science, said: Nothing was more remarkable than the variety and apparent simplicity of both animal and plant movement. The motor organs that produced them had been more carefully studied than the movements produced. The harmony between the form and functions of a muscle, the co-operation of groups of muscles to produce specific movements were revealed everywhere in animals as well as in the human frame itself. The co-ordination took place in the higher animals in the central nervous system, a system characterized by autonomy as well as centralization. Animal movements might be classified according to the media on or in which the animal moved. In terrestrial progression the ground was a more or less fixed or rigid point of support or fulcrum. The action of the moving limb tended to repel the fulcrum in one direction, and the body itself in the opposite direction. The more solid and resistant the ground, the greater would be the amount of energy available to propel the body forward. The energy, however, was generated by the animal itself. As air was 800 times lighter than water, aerial motion presented the most interesting of all problems. It had been solved by insects and birds alike, and both these flying motors were heavier than air. The air fulcrum was far more mobile than the aquatic or terrestrial support, yet in spite of this the greatest velocities were obtained in aerial progression.

Giovanni Alfonso Borelli was born in Naples in 1608, the son of a Spanish soldier and a Neapolitan mother whose name was Borelli. He became professor of mathematics in Messina about 1640, and in 1656 he was called by Ferdinand Duke of Tuscany to Pisa, where he taught the results of his investigations, and wrote a large part of his work, "De Motu Animalium." Twelve years later he returned to Messina, which he left as an exile in 1674, and went to Rome, where he lived for a time under the patronage of Queen Christina of Sweden. The decennium passed in Pisa was the most brilliant period of his scientific life. Borelli applied to living beings the laws of mechanics, and reduced to its simplest form the theory of animal locomotion, and dealt both with external visible movements and movements of internal organs with voluntary and involuntary movements.

The introduction of exact physical and chemical methods revolutionized physiology, especially from the period of Johannes Müller onward. On the physical side no method contributed more to this advance than the "Graphic Method." A more exact analysis and interpretation of animal movements was not possible until the graphic method had been applied to the study of movements which were either too rapid

or of too short duration to be followed by the unaided eye. In physiology the impulse toward the application of the graphic method came through Carl Ludwig in 1847, when he invented the "Kymographion," or wave-writer. Thus for the first time was recorded the beat of the heart as expressed in the variations of pressure within the arteries. The graphic method was rapidly extended to the study of all kinds of physiological and other phenomena. New apparatus in the form of "myographs" and other recording instruments were invented. Time was accurately recorded by vibrating tuning-forks and by chronographs. Problems deemed insoluble a few years before, thanks to the labors and investigations of Helmholtz, Du Bois Reymond, and Prof. Marey, of Paris, were brought within the range of the experimental method. Photography soon lent its aid, and there was a great future for the application of the cinematograph to physiological problems. Lantern slides were shown indicating the changes of form of *Amoeba*, its mode of feeding, movements and reactions to stimuli, as described by Jennings. The observations of Bohn on Atlantic *Actina* that lived between high and low water mark were next summarized, and the problems

no fracture in dry stones, so metallic joints have been formed of $\frac{1}{8}$ inch thick. The increase in cost is about 10s. per square foot of the bridge's horizontal surface.

SELENIUM.

SOME new phenomena in connection with selenium cells are brought out by H. Pelabon in a paper read before the Académie des Sciences. These cells are of the electrolytic type, but act differently from the ordinary electrolytic selenium cell. The type with which we are familiar consists of two selenium-covered plates in a liquid and we light one plate, keeping the second in the dark. We thus obtain variations in the electromotive force of the cell owing to the action of the light. M. Pelabon uses a cell in which the solution is of trichloride of antimony and the electrodes are two rods, one of pure antimony and the other of an antimony-selenium alloy. The former is the negative pole. Such cells have different properties from the usual kind. When left in the dark, the electromotive force on open circuit reaches a constant value in a few days, when the temperature

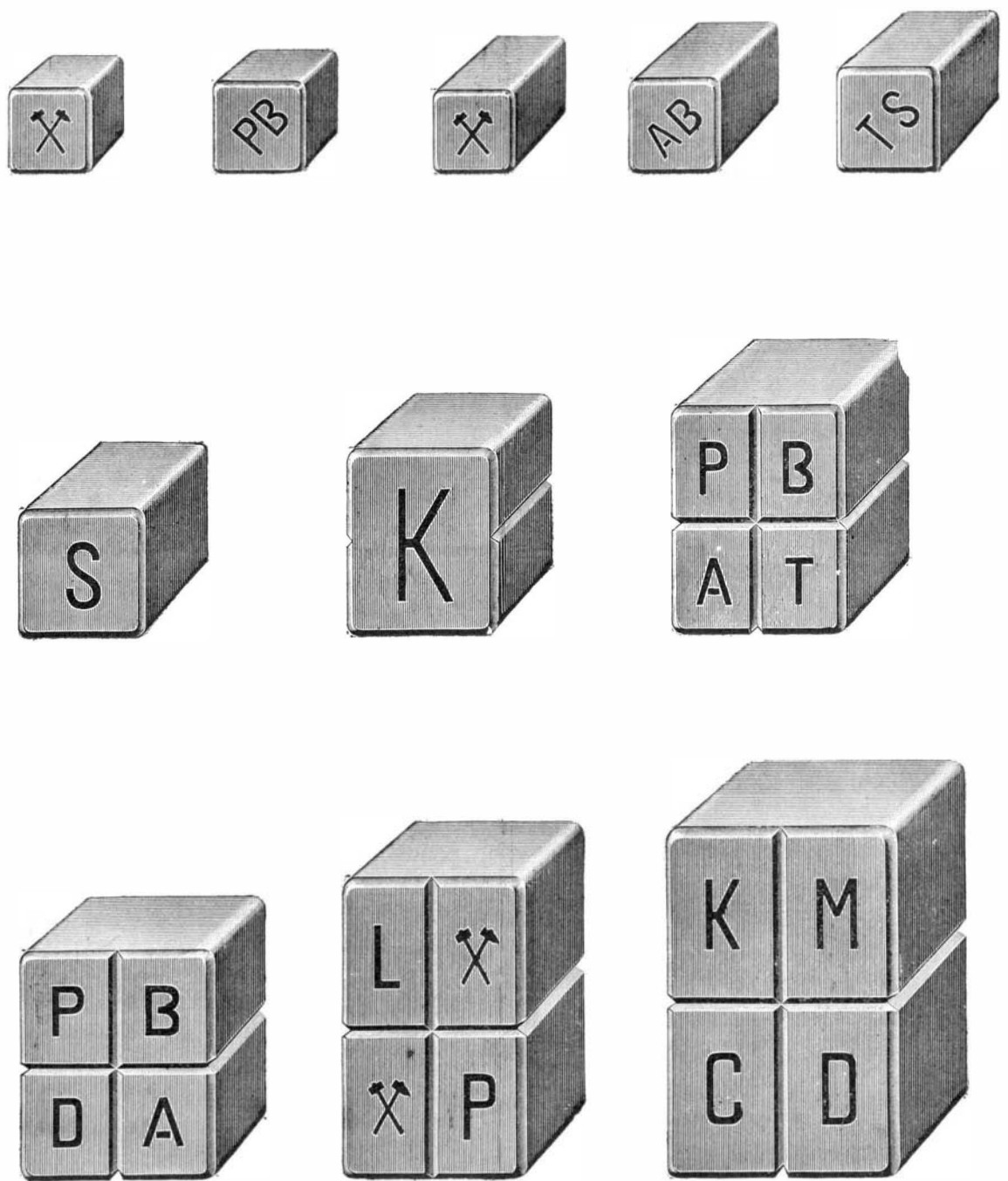


FIG. 6.—SAMPLES OF BRIQUETTES.

suggested by the rhythmically pulsating bells of the *Medusa* or jelly-fish illustrated by colored slides reproduced from the works of Allman and Haeckel. The Echinoderms represented by sea-urchins and starfish were also considered. The subject of flight was dealt with briefly, the observations of Da Vinci, Pettigrew, Marey, Lendenfeld, and M. L. Bull at the Marey Institute at Paris being touched on. The last part of the lecture dealt with reflex action as the physiological unit in the operations of the nervous system, the subject being illustrated by the reflex movements of a pithed brainless frog and by the protective reflexes of such animals as crabs, lizards, etc., which amputated a limb or the tail when violently seized. That animals could still execute well co-ordinated movements after certain injuries to the nervous system was made clear by a film showing a frog climbing an inclined plane and maintaining its equilibrium after removal of its cerebrum.

In a concrete bridge, recently completed near Lyons, France, zinc has been used instead of cement to join the stones of two elliptical arches, the span of which is 82 feet. Molten zinc at 800 deg. F. is said to cause

is kept fixed, and we may call this initial value *a*. Lighting the positive electrode, the electromotive force immediately rises and reaches a value *b*. Then while the light is still kept on, this value begins to diminish, and after about 20 minutes the electromotive force reaches the initial point *a*, which now remains constant. Suppressing the light, the electromotive force diminishes and takes a value *c*, then it rises slowly and in one hour it comes back to the initial point *a*. In an experiment made with a cell in which the electrode is composed of 4 parts antimony and 1 of selenium, the three values are respectively 0.0559 volt (initial); 0.0789 volt (*b*) and 0.359 volt (*c*). We thus have variations which are about half the original value. On closed circuit the results are analogous, but the values are now different, and we have a variation of 1 to 6, which is large. Any proportion of selenium can be used, but the most sensitive cells are those in which the amount of selenium is less. In the latter experiments it was 1 to 99. Sulphur or tellurium cannot be used to replace the selenium, and this latter is necessary. Other metals can be used instead of antimony. No effect is given by ultra-violet rays, and but little by blue rays.