A NEW DESIGN OF ELECTROMAGNET ENERGIZED WITH THERMOELECTRIC CURRENT.

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Electromotive forces and currents produced by thermocouples are as a matter of common experience very small. They are measured in microvolts or millivolts, and milliamperes, respectively. That the current is small is, of course, the result of resistance which, in most thermocouple circuits used in practice, is relatively large. A circuit having a resistance of an ohm allows a current of one milliampere to flow for each millivolt of electromotive force, and currents of this order of magnitude produce no pronounced mechanical effects. To enhance the effects of thermoelectric currents, thermopiles of large dimensions, such as that of Noë, have been on the market in Germany for many years. With a thermopile of this type a gas burner could be made to ring an electric bell or even charge a storage cell. To the student there is nothing of the unusual or spectacular in such a demonstration.

Wunder[1] describes an arrangement consisting of an electromagnet winding of a few turns of copper rod 1 cm. in diameter, the winding being made to fit a U-shaped iron core of the usual type. The current through this winding is produced by an iron-nickel thermocouple secured to the two ends of the copper circuit. Wunder states that the magnet is capable of supporting a heavy latchkey. Compared with earlier demonstrations this one is striking and may be expected to stimulate the student's interest. Another demonstration piece described by Merkelbach[2] employs a bismuth-antimony junction with a copper circuit in the form of an elongated loop. This loop is mounted with its plane vertical and a magnetic needle is mounted within the loop so that it responds to the current flowing through the circuit. Various other similar pieces have been described both in the literature and in the catalogs of German apparatus firms.

Volkmann[3], struck by the possibilities revealed in the earlier demonstrations, designed an electromagnet to be energized by thermoelectric current which should exert greater pull than that of Merkelbach. He succeeded in producing a magnet which, when the thermocouple was heated with a blast burner, was

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[1]Wunder, ZS. f. phys. u. chem. Unterr., XXIV, 1911, 224.
[2]Merkelbach, ZS, f. phys. u. chem. Unterr., XXVI, 1913, 299.
[3]Volkmann, ZS. f. phys. u. chem. Unterr., XXVIII, 1915, 25.

capable of lifting somewhere between 10 and 20 kg. The manufacturers of the Volkmann apparatus supply it with a 5 kg. weight attached to the armature.

In studying the demonstrations of Wunder, Markelbach and Volkmann the writer became convinced of the possibility of a really spectacular demonstration with thermoelectric current. He first constructed a magnet of Volkmann's design and found 10 kg. to be the maximum load which it could sustain when one junction was immersed in tap water and the other heated with a Meker burner. He then designed a lifting magnet with particular attention to securing correct shapes and relative dimensions, and proper relative placement of the magnetic and electric circuits, to develop maximum pull for the quantity of iron and copper used.

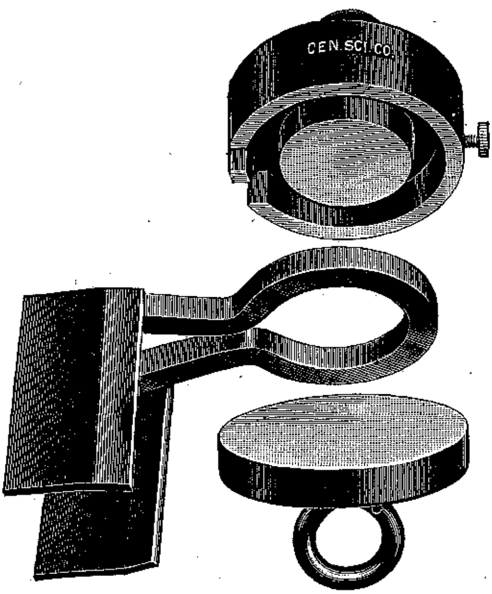

FIG. 1.

In the form which proved highly successful the electric circuit consists of a single turn of square copper bar of large cross sectional area, formed into a circular turn. The ends of the turn extend outward a few centimeters. Between these ends is silver-soldered a copper-nickel alloy bar. Thick copper plates are silver-soldered to the outer sides of the ends of the copper bar. The general arrangement of the electric circuit as well as the body of the magnet and armature are shown in Fig. 1. (In the figure the alloy bar is hidden by one of the plates.) The copper plates serve as heat transfer means which have large thermal conductivity, large area to receive or dissipate heat and large area of thermal contact through which heat can be delivered to or withdrawn from the junctions of the thermocouple.

Both magnet and armature are machined from soft iron of high permeability. In order that the magnet may exert maximum pull it is essential that the contact surfaces of magnet and armature be ground plane and that the two surfaces be in close contact over their entire area. This makes necessary the avoidance of nicks around the peripheral corners of the contact surfaces of the magnet and armature which would cause slight separation of these two surfaces.

A groove of rectangular section is machined in the face of the magnet against which the armature fits, and this groove receives the circular turn of copper. The latter is firmly clamped in place with two screws. Although the inside surfaces of the groove are coated with baked japan for insulation there is no great need for the precaution of insulating the copper bar because of the very low potential differences in the copper circuit. Magnet and armature are provided with stout hooks.

Fig. 2 represents the apparatus as used in a demonstration. One of the copper plates is immersed in a beaker of water and the flame of a burner is played on the other. After perhaps 15 seconds the armature is tightly held. When the heating has been continued long enough to establish a sufficient temperature difference between the junctions a weight hanger may be suspended from the armature, and the load applied.

In the first experiment the magnet sustained a load of 48 pounds with no sign of detachment of the armature. The writer then found that he could suspend his own weight (190 pounds) without pulling the armature off. The next experiment was to measure the breaking pull with an electromagnet tester of standard design. It was found that a load in excess of 400 pounds was needed to detach the armature.

It is interesting to determine how much current flows in the copper bar to produce a magnetic pull of this magnitude. The first method of finding this current is to compute the electromotive forces from estimated temperature differences, and the resistance from the dimensions of the circuit. Assuming a

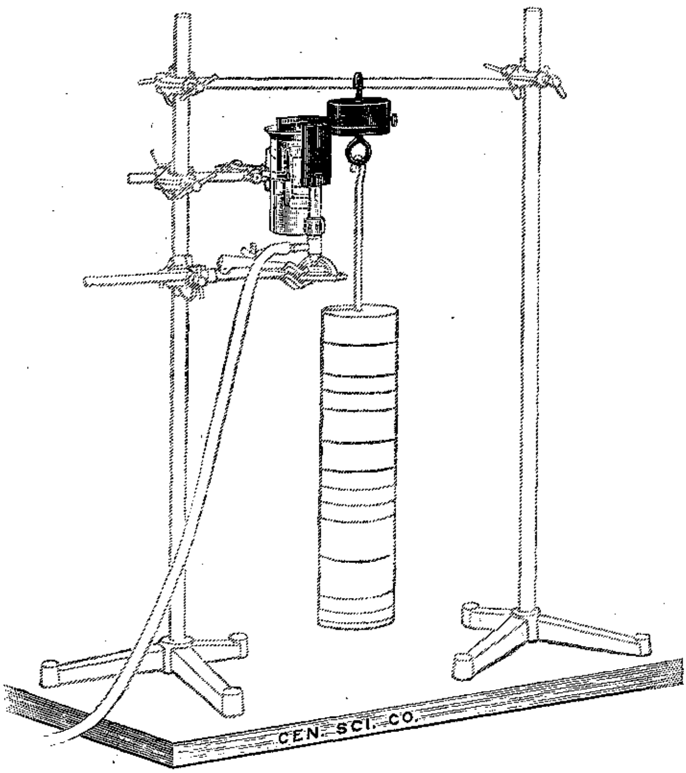

FIG. 2.

temperature difference of 350°C the e.m.f. is in the neighborhood of 14 millivolts. Taking the resistivity of the copper turn, at a temperature of about 40°C as 2×10^{-6} microhms per centimeter cube, we find that its resistance is 4.9×10^{-5} ohm. That of the copper-nickel alloy is 6.5×10^{-5} ohm. The total resistance in the circuit is thus 10.4×10^{-5} ohm. Applying Ohm's Law to the above mentioned electromotive force and resistance we find that the current is approximately 135 amperes.

This value seems so astonishingly large for the current developed by a single thermocouple that an indirect check measurement was made. A coil of 100 turns was wound to fit the groove in the magnet body. Direct current, measured with an ammeter, was supplied to this coil. It was found that a current of 1.4 amperes (i. e., 140 ampere-turns) sustained a load in excess of 485 pounds, showing that the computed value of the current was approximately correct.

The result of the test with the 100-turn coil, no less than the first, was astonishing. The resistance of the coil is slightly larger than 1 ohm. When this is connected across a single dry cell a current of 1.4 amperes flows. Thus, the magnet with a 100-turn winding, with a single dry cell supplying the magnetizing current, is capable of sustaining the weight of three men of 160 pounds each.

There comes to mind the showmanship of Otto von Guericke and his Magdeburg hemispheres, which two teams of eight horses each, pulling in opposite directions, could not pull apart—a great extravagance in horses! As a spectacular demonstration, ropes might be attached to magnet and armature, and, having energized the coil with a dry cell, let six boys have a tug of war—three on each side—with the magnet between them.

The experiment with the 100-turn coil shows the correctness of design of the magnet. It shows further that the design of the magnet, no less than the design of the electrical circuit[4], is responsible for the surprisingly large pull produced by the current from a single thermocouple.

[4]Patent application has been filed to cover the features which are responsible for the exceptional performance described in this article.

THE DISPUTED CHACO.

The Paraguayan Chaco area in dispute between Bolivia and Paraguay comprises a region larger than the States of New York and Pennsylvania combined. It is a vast territory inhabited largely by primitive Indians, and it is not to be confused with the better known Argentine region commonly called "Chaco."

Describing a journey up the Parana and the Paraguay to this vast and little known region, which so long has been a subject of disagreement, William R. Barbour wrote to the National Geographic Society:

"The Chaco was once a shallow inland sea, with its eastern border about where the river now flows. This sea eventually dried up, leaving vast swamps, with a salty or alkaline grayish sandy soil devoid of rocks. The river is to-day the dividing line, even the plant and animal life differing on its two sides.

"I was told that a few miles east of the river the country consists of high rolling hills clad with open forests of cedar and other valuable cabinet woods, and with running streams of clear water in the valleys.

"Our destination was Puerto Casado, some three hundred miles north of Asuncion and only a few miles below the Brazilian frontier. We reached it the next noon, leaving our ship to plow on several hundred miles farther, to its final stopping place at Corumba, Brazil, and catching it again on its return trip.

"Puerto Casado is the site of an old extract plant, small sawmill, and town of employees. The entire establishment, with seven million acres of wild land, extending across the Chaco to the Bolivian frontier, belongs to one Argentine family."—*Geographic News Bulletin.*