THE HISTORICAL DEVELOPMENT OF THE INDUCTION COIL AND TRANSFORMER.*

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The induction coil and the transformer are no exceptions to the general law that improvements in experimental appliances advance along definite lines by a process of evolution in which rudimentary forms are subsequently replaced by more and more completely developed machines. We are able by careful scrutiny of existing and pre-existing modifications to detect that which has already been set in motion, and to follow it forward, and also to examine the prototypes in their relation to the final and fully developed idea. Most readers would probably consider that the proto-typical form of all modern induction coils and transformers was the iron ring with which Faraday made the initial discovery in electro-magnetic induction; and in one sense this is of course correct, but a careful examination of the early stages of the development of the induction coil as we now possess it seems to show that it is descended in the direct line not from Faraday's ring so much as from Henry's flat spirals, and that it is these latter which are the chief of the clan and true ancestors of our modern coil.

Henry's claim to be an independent discoverer of the fundamental fact of electro-magnetic induction is not now disputed. In the July number of *Silliman's American Journal of Science* for 1832, Joseph Henry, then a young teacher in the Albany Academy, gave an account of the manner in which he had independently, and before receiving an account of Faraday's work performed in the previous autumn, elicited from his own great electro-magnet an induced current by wrapping round the soft iron armature certain coils of insulated wire! In the same Paper in which he thus discloses his anticipated discovery he rendered an account of that in which he had anticipated this illustrious result by the discovery of the fact of self-induction of a spiral conductor, and denoted the phenomenon by the name by which it has since been known. Simply confining himself to the bare statement of the new fact that if the poles of a small battery are joined by a wire a foot long no spark will be found on breaking the circuit, whereas if the wire be thirty or forty feet long, and particularly if it be coiled into a spiral, it gives a bright spark when so employed, Henry noted the discovery and correctly attributed the phenomenon to the induction of the circuit upon itself. Finding, however, that Faraday was following on the same line of discovery he published in the *Journal of the Franklin Institute*, in March, 1835 (Vol. XV., pp. 169-170), a brief epitome of the facts he had collected, and made mention, for the first time, of the use of the spirals of flat copper tape or ribbon, insulated and closely wound together, with which he subsequently conducted his brilliant train of discoveries on the mutual induction of circuits.

A few months later, in the July number of *Silliman's American Journal of Science*, 1835 (Vol. XXVIII., pp. 329-331), he followed up this with a more explicit account of his investigations on the action of a spiral conductor, especially a flat tape spiral, in increasing the spark and the shock from a single cell of a galvanic battery. Using a very large single cell of very high potential, and more known as Dr. Here's Car. he sent the current from this through a spiral conductor formed of copper ribbon about one inch wide and from sixty to one hundred feet long, well covered with silk, and the several spires closely wound on each other. One end of the conductor being attached to one pole of the battery and the other through a spring to the rough edge of a plate of metal attached to the other end, he obtained vivid sparks at the place of contact. Moreover he noted that if copper cylinders two inches in diameter and about five inches long were attached as handles to the ends of the spiral by supplementary wires, and if these cylinders were grasped by moistened hands, a series of sharp shocks was experienced at the end of the spiral, and a motor was drawn along the rough edge of one plate of the calomelator. This preliminary investigation on the production of a spark and a shock from a single cell of a battery led him to make a thorough investigation of the phenomenon, and in which he most fully explored the whole of the facts. The experiments he described in the *Transactions of the American Philosophical Society* for February, 1835, (Vol. V., pp. 223-231); and in *Silliman's American Journal of Science*, for July, 1835, covering in these pages a recital of the independent investigations he made in going over the same ground as that occupied by Faraday in his Ninth series of "Electrical Researches" *On the Influences by Induction of an Electric Current on Itself,*, sent to the Royal Society in December, 1834, and read in January, 1835, Henry's removal from Albany Academy to Princeton College created an interruption in his researches, but the news of them travelled to England, and in turn created a further wave of discovery. The subject was taken up by William Sturgeon, the inventor of the electro-magnet, and on one day a Mr. Peabody, lately from the United States, in the Adelaide Gallery of Practical Science,* and this gentleman informed him of Henry's experiments on the production of a shock and spark from a single pair of plates in a galvanic cell. Sturgeon was at that time just engaged in launching a new journal devoted especially to electrical science; and in the first volume of this publication, he led off with a paper "On the Electric Shock from a Single Pair of Plates," in which he gave an account of Henry's work and of his own repetition of the experiments (Sturgeon's *Annals*, Vol. I., pp. 67). This was published in October, 1835. Sturgeon was at this time to have been acquainted with Faraday's Ninth series of Electrical Researches; but after repeating most of Henry's experiments, and adding some of his own, he arrived at the conclusion that the action of the spiral conductor in creating a shock was due to the collision of the magnetic lines of force

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*The building, which was formerly the Adelaide Gallery of Practical Science, now survives as Gatti's restaurant in the Strand. It has many interesting electrical reminiscences connected with it. In the Adelaide Gallery Wheatstone performed his celebrated experiments on the 'Velocity of Electricity' in 1834 (see *Wheatstone's Scientific Papers*, p. 99). In it also Faraday performed the experiments on the Electrical Fish or Gymnotus, and established the physiological nature of its shock in 1835 (see *Electrical Researches*, Vol. II., p. 5).

The following extract from *Edward Walford's* 'Old and New London' may be of interest.

"Adjoining the Lowther Arcade, with its entrance in Adelaide-street, is the Adelaide Gallery, originally intended as a place of amusement and instruction combined. It was first opened in the year 1830, and named after Queen Adelaide, the consort of William IV. Its varied fortunes from the day when it was opened as a temple of science down to its transformation into a casino, are thus cleverly sketched by the late Mr. Albert Smith in his little book on 'London Life and Character':—'Some time back—dates are very dry things, so we need not care about the precise year—there existed in the neighbourhood of the Lowther Arcade an establishment called the Adelaide Gallery. It was at first devoted to the diffusion of knowledge. Clever professors were there, teaching elaborate sciences in lectures of twenty minutes each; fearful lectures were delivered, and lapsed and the fees paid. The students were required to point out the chairs in which they had grumbled sullenly in their bondage; mice led gasping sub-aqueous lives in diving bells; clock-work steamers ticked round and round a basin provided for proving the efficiency of washable clothes. There were clever machines which stray visitors were posed to class either as coffee-mills, water wheels, rotating jacks, or musical instruments. There were artistic scenes laid for giving galvanic shocks to the unwary onooma guns that turned bullets into lead sines against the target; and dark microscopic rooms for shaking the principles of teetotallers, by showing the wriggling microbe which wore the habit of a wriggling gas and ran up and down. Then came a transition stage in the existence of the Adelaide Gallery, at first steadfastly brought about. The oxy-hydrogen light was dully applied to the public magic lantern, and the end was the continual decay of the place. And last all the steam-engines and waterworks were cleared away, and the Adelaide Gallery was devoted entirely to the goddess of the horseless cab, and called a casino. It was altered into the Marlborough Theatre in 1856, and is now one of the refreshment rooms of Messrs. Gatti."
when the current in the coil was interrupted, and that this
gave rise to a momentary self-induced current in the coil set in
motion by a greater electromotive force than that of the exci-
ting cell. Subsequently he became acquainted with Faraday's
prior work on self-induction, and in a critical paper (Sturgeon's
*Annals of Electricity*, Vol. i., p. 193) he discusses Faraday's
results, and with great skill experiments with a number of coils
with and without iron cores, with the object of finding out how
much of the "shock" was due to the iron, and how much to the
wire coils. On page 283, Vol. I., of the *Annals* there is a
full reprint of Henry's Paper read before the American Phi-
losophical Society in February, 1835.

The next important fact seems to have been added by Prof. C.
G. Page, of Washington, in the United States, who published an
account in *Silliman's American Journal of Science* for October,
1836 (Vol. xxxi., p. 157), of his researches on the self-induction
of spiral conductors. Sturgeon abstracted an account of Page's
work in his *Annals* (Vol. I., p. 290), and made it available for
English readers. Prof. C. G. Page constructed in 1835 a spiral
copper strip coil, of which the strip was one inch wide and
220ft. long, carefully insulated, and having terminal wires
soldered at intervals of 55ft. This strip was rolled up into a
flat spiral, and mercury cups attached to the six terminal
wires.

A single cell of a Hare's calorimeter, or large copper-zinc
cell, was then attached to an adjacent pair of terminals, and
it was found that on breaking the battery contact sparks and
shocks could be procured by touching any of the other termi-
nals in pairs.

The difference between Henry's and Page's arrangements
may be indicated by a diagram, in which for clearness the
copper strip is represented as unravelled.

Let E & F (Fig. 1) be Henry's copper strip coil unravelled, and
let B be a galvanic cell, and H H the handles for taking the
inductive shock, when the battery circuit is broken at C. In
Henry's experiments the arrangement of the coil was such that
the self-induction of the whole of it was employed in producing
the shock when a person held the handles H H.

FIG. 1.—Henry's Coil.

In Page's arrangement the strip with its six or seven contacts is
represented by S S (Fig. 2), and the cell or battery was
applied to the terminals 1 and 2. Page found that severe
shocks could be obtained by taking hold of metal handles
attached to the terminals 7 and 3, or 6 and 5, or 7 and 6,
when the battery circuit was broken at C. By making the
break and make of contact by rapidly revolving spur wheel he
got a succession of sparks from a portion of the strip not in-
cluded between the battery terminals. In place of a spur
wheel he also made and broke contact rapidly by dragging one
end of the battery wire over a file or rasp in contact with the
plate of the battery.

On page 294 of Vol. I. of the *Annals* Sturgeon explained
Page's experiment correctly as due to the induction of one part
of the coil on the other. For the first time he made the dis-
covery of *induction* and showed that different parts of the
same conductor might act as primary and secondary circuits to
each other if in contiguity.

We then come to an important contribution by the Rev. N.
J. Callan, of Maynooth College. This investigator followed up
with great interest and success the researches of Faraday,
Henry, Page, and W. Sturgeon, and on page 295 of Sturgeon's
*Annals of Electricity*, Vol. I., we have a Paper by him, written
in 1836, "On the best method of making an electro-magnet"
"for electrical purposes, and on the vast superiority of the"
"inductive power of the electro-magnet over the electric power of"
"the common magneto-electric machine."

In this Paper Callan describes the construction of an electro-
magnet with two separate insulated wires, *one thick and the other
thin*, wound on the iron core together. He first coiled on a
long and thick horsehoe-shaped bar of iron a very thick copper
wire covered with silk or cotton, and successively over this a very
long *thin iron wire*, also insulated with cotton, and once
end, viz., the inner end, of the iron wire was joined to the outer end
of the copper circuit. In his first magnet the copper wire con-
sisted of a wire 50ft. long and one-twelfth of an inch in
diameter, and the iron wire was 1,300ft. long and one-fortieth of
an inch in diameter.

He sent a current from a battery of one or two pairs of
plates through the thick copper wire, and attached metallic
handles to the ends of the iron wire for the purpose of taking a
shock, and then on making and breaking the circuit of the
battery rapidly he got severe shocks from the iron wire circuit.
Here we have the first description that exists of an induction
coil with a short thick and a long thin wire upon it; but the
peculiarity of it is that the end of the secondary or thin wire is
joined to the end of the thick wire, so that they form one circuit
wound all in the same direction upon the magnet. Callan's
experiment was, therefore, an extension of Page's, and this last,
again, was an improvement on Henry's apparatus. Callan
followed up this Paper by another dated June 14, 1836, pub-
lished in Sturgeon's *Annals*, Vol. I., p. 376, being "A descrip-
tion of the most powerful electro-magnet yet constructed."
He had forged an iron bar 2½ inches in diameter, 13 feet long,
and bent into a horseshoe. It weighed 15 stone. Four
hundred and ninety feet of insulated copper wire, one
inch in diameter, were wound round it in one layer, and
over this a thin insulated copper wire 10,000 feet long
and one-fortieth of an inch in diameter; and one end of
the thin wire was soldered to one end of the thick wire, so that
the whole length of the two wires formed a single circuit, wound
all in the same direction on the big horseshoe. The current from
20 large Callau cells (iron cells), or from a Woolaston battery
of 280 pairs of plates, was passed through the thick copper wire
circuit alone, and rapidly interrupted by an apparatus Callan
called a repeater. Wires were soldered to the extremities of
the fine wire circuit to receive the induced current. Provided
with this formidable apparatus, the inventor proceeded to per-
form striking experiments with the induced current.

When by means of an electro-magnetic repeater a rapid succession
of secondary currents was induced in the fine wire, and passed
between charcoal points attached to the ends of the secondary
circuit, they were slightly ignited. "The shock, as can be
imagined, was excessively severe, and the ardent experimen-
talist proceeded to pass from this experimental in the produc-
tion of an arc light by means of a transformer to an experi-
ment in *electrocution*. For he adds: "Although the"
"igniting power of the electric current produced in the long"
"coil of thin wire was very feeble, its intensity was exceedingly"
"great. When it (the secondary current) was passed through"
"the body of a large man, it caused death. With this magnet,
or one like it, was sent by Callan to Mr. Sturgeon, and the
by him exhibited to the London *Electrical Society* at a
meeting held on August 5, 1837, and members and visitors
enjoyed powerful shocks from the secondary wire of this elec-
tromagnetic apparatus."