THE MEDICAL INDUCTION COIL

by Lloyd Butler VK5BR

The Induction Coil circuit will be well known to old time members as a basic signal source for the early spark transmitter and a high voltage spark generator for some early motor cars. Perhaps lesser known is that in the 1800's and the early 1900's, it was also made as a generator for medical purposes to feed electric shocks to the human body.

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Introduction

I was motivated to write about the Medical Induction Coil because one of these gadgets was stored away in my parents' home at Murray Bridge. I never heard how my parents obtained this device nor whether they had used it for any useful purpose. It might have been handed down from my grandfather who was interested in all sorts of engineering things. For example, he had a complete blacksmith's forge in his shed complete with large bellows and anvil. He installed pipes throughout his house to distribute home generated gas for gas lighting. At some stage he worked as the engineer on steam powered paddle steamers running in the Murray River. I was really too young to connect with my grandfather before he died, but apparently he told my older brothers: "Electricity is the coming thing boys - get into electricity". And they did!

Anyway, as a boy I used to experiment with this Medical Induction Coil device to generate high voltages and make sparks. I have often wondered how as youths we all managed to live through to adulthood with this electrical experimentation. You may see further on in the article why I added that sentence.

I will lead up to the medical example of the device by first discussing operation of the basic circuit and then some examples of its application.The induction coil has been a classic device for demonstrating magnetic induction and generating high voltages in the class room laboratory. With its automatic contact interrupter, it was also used to continuously generate the high ignition voltage in early Ford motor cars. The early Ford Coil is a legend. Other car engines have been similar except that the interrupter contacts (and later electronic switches) were actuated at a critical point in the rotation cycle of the engine, such that the spark in the combustion chambers ignited at the right time.
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A further use of the induction coil has been to generate electric wave trains to feed the radio transmitting aerial and form the spark transmitter.

One could also consider the vibrator power supply as being related to the basic induction coil. These were used to generate high tension for the early radio receiver from a low voltage DC source. They differed in principle in that the transformer primary current was switched or interrupted by electro-mechanical resonance of the detached vibrator rather than the magnetic field of the transformer or induction coil itself.

Operation of the Induction Coil

The basic circuit diagram of the induction coil is shown in figure 1. A typical assembly is shown in figure 2. The coil unit is a transformer with many more turns on the secondary than on the primary. The windings are wound over an iron core which concentrates the magnetic field passing through the windings and increases the inductance of the primary winding.

The primary winding is connected to a battery (typically 6 to 12 volts) via normally made interrupter contacts mounted on the coil assembly at the end of the iron core. Attached to the moving contact is a soft iron armature which is under the influence of the magnetic field projected out of the end of the iron core. With no field, the contacts are held closed by a spring or the spring tension of the moving contact itself. When the field is developed in the iron core, the contacts are opened to interrupt current flow. Current through the primary winding is repetitively turned on and off as the contacts are opened under the influence of the magnetic field and closed when the field collapses

Connected across the contacts is a capacitor (or condenser in the old nomenclature). Its value is quite critical as is forms a resonant circuit with the coil primary inductance. Each time the circuit is opened, the magnetic field collapses, generating current in the primary winding which charges the capacitor in the form of a single half cycle (or pulse) at the resonant frequency. Through magnetic induction, the pulse is coupled into the secondary winding to produced the high voltage.

The capacitor charging also slows the rate of build up of voltage across the interrupter contacts when they are immediately opened. This minimises the arcing of the contacts at the point of opening. This is the same reason as why the value of capacitance across the interrupter points in the motor car is carefully chosen.

In the process of the pulse decay, the current through the primary winding falls to a value where the field it creates can no longer hold the soft iron armature and the interrupter contacts close.

The process as described is repeated for the next cycle and all further cycles.

A high voltage is clearly created because of the high turns ratio between the primary to secondary windings. However, I think that the voltage magnification factor (or Q factor) of the primary winding resonance also contributes to generation of the high voltage of the secondary output pulse..

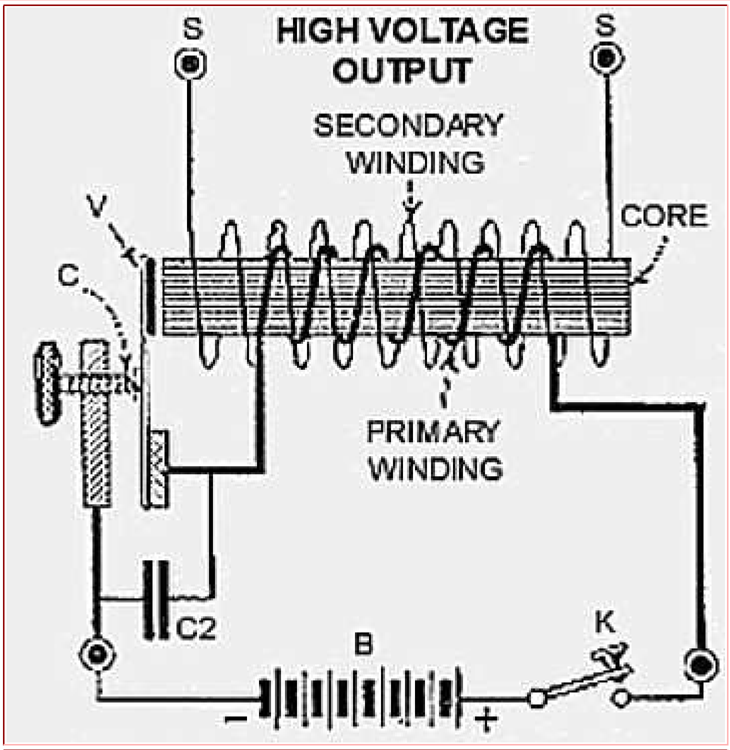

Figure 1
The Induction Coil
Typical Circuit

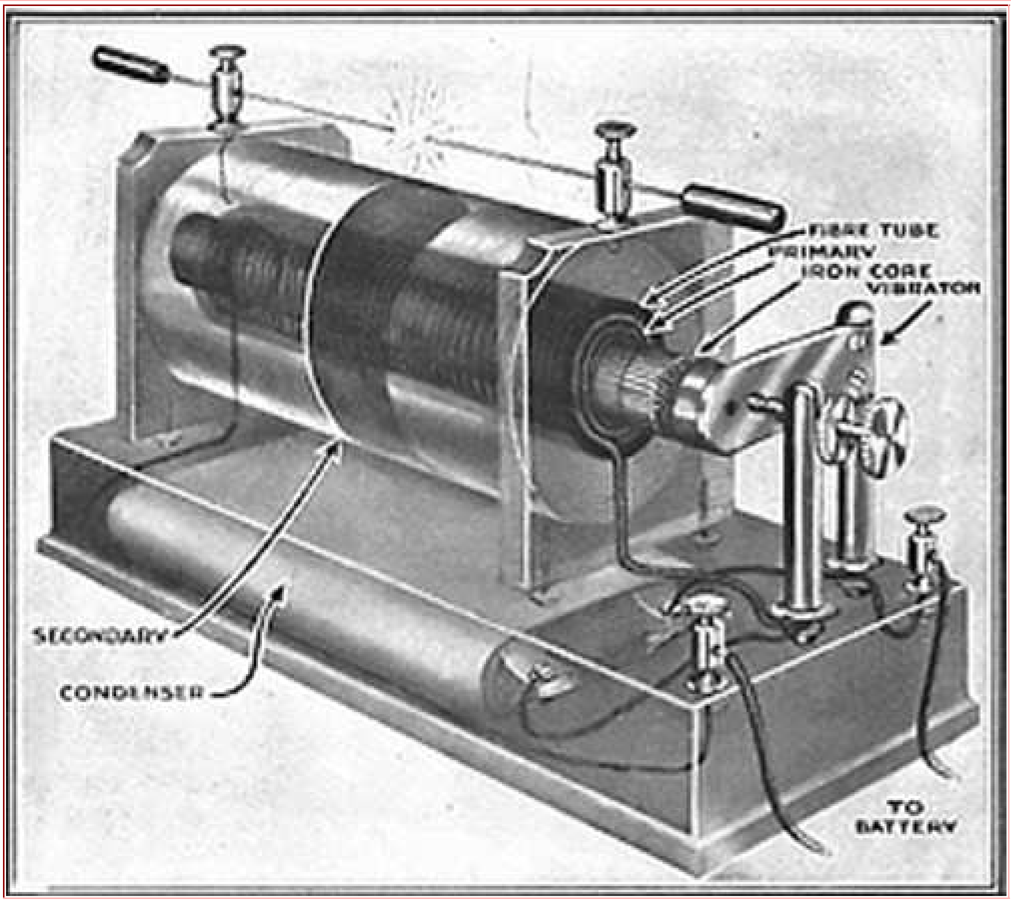

Figure 2
The Induction Coil
Typical Assembly

The Spark Transmitter

Figure 3 is a circuit for a Spark Radio Transmitter, using the basic induction coil system previously described. Connected across the secondary winding of the Induction Coil is a spark gap, capacitor C and a coupled aerial. The capacitance of C is set for resonance with the coupled aerial circuit at the transmitting frequency.

Prior to an induction coil secondary pulse, capacitor C is in a charged state. The air gap between the spark gap electrodes breaks down when the pulse is initiated and voltage across the gap rises to a critical value. At that point there is conduction through the spark gap and current from C flows into the reflected aerial inductance commencing resonance within the aerial circuit. A damped wave train is radiated from the aerial as power is absorbed at each cycle, diminishing the amplitude of the following one. The cycle train ceases when the pulse voltage falls to a value where the spark gap ceases to arc and the gap stops conducting. Resonance ceases and C is left in a charged state ready to discharge current and restart resonance on the next spark gap breakdown.

A new damped wave train is generated from the next pulse from the induction coil and of course at every pulse.

So there are two resonant functions here. Firstly, the periodicity of the wave trains is set by the inductive and capacitive constants in the induction coil, or in other words, the periodicity of the induction coil pulse. Secondly, the periodicity of wave cycle (or cycle frequency) within the wave train, is set by the inductive and capacitive constants in the aerial circuit. I guess that is quite a mouthful, but when you think about it, the circuit operation is quite complex.

A limitation with the damped wave train generated by the spark transmitter (and similar systems), was that it occupied a very wide frequency spectrum.. Use of spark transmitters started around 1887. They were eventually phased right out around 1930 when narrower bandwidth systems were well established using the electron tube.

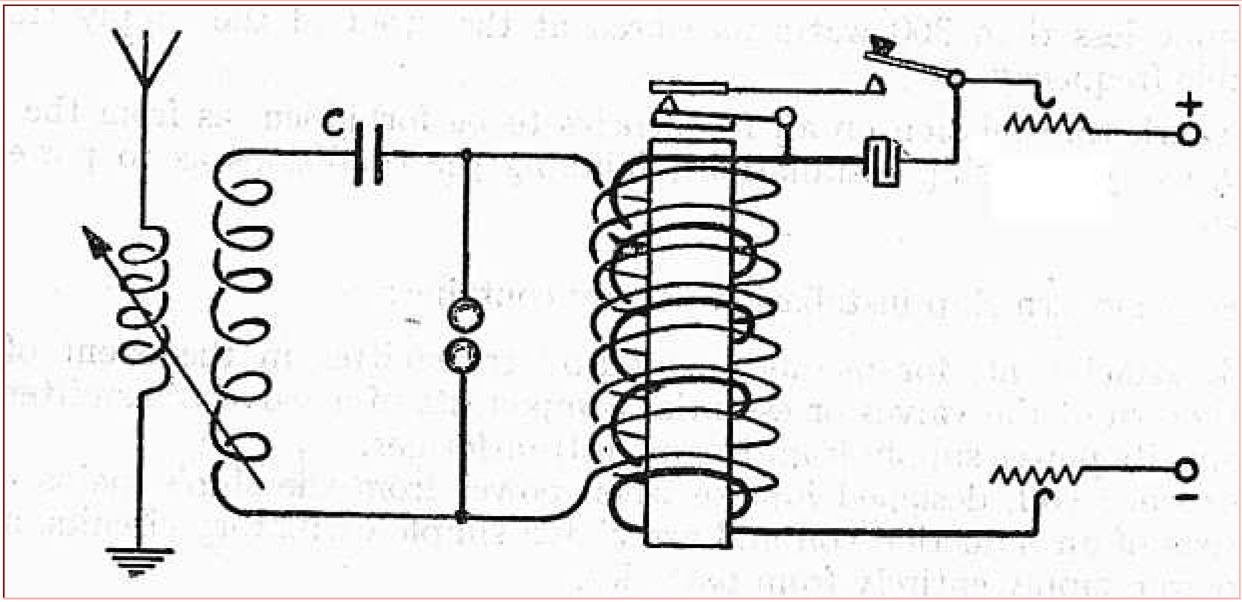

Figure 3
Spark Transmitter
From the Admiralty Handbook

The Medical Induction Coil

If there ever was any documentation for the Medical Induction Coil , I certainly don't have it now. So I have had to rely on my memory to describe what the device was like and try to find reference to the unit (or something similar) on the Internet. I found the unit Type AO133 (shown as figure 4) which is very close to what I remember. Like the AO133, our induction coil assembly was fitted in a neat wooden case with accessories. Such accessories included the two metal hand held probes to feed electric shock via the hands and padded plates which could be wetted to stroke the skin. These can be seen in Figure 4, but our unit also had a plate which could be dropped into the bath water for an electric bath.

The induction coils arrangement was similar to figure 1 with a centre core of bunched soft iron wires and primary and secondary windings which provided the step-up voltage. One addition was a metal tubular sleeve between the primary and secondary which could be slid in and out between the two windings. The tube was nickel plated on a base metal which I think might have been brass alloy. I assume that the sleeve acted as a shorted turn to reduce the magnetic coupling between the two windings. The more the sleeve was pulled out from between the windings, the greater the coupled field and the greater the developed secondary voltage. So the setting of the sleeve was the means to control the intensity of the electric shock.

Looking at the centre of the coil assembly in the AO133 unit, an insulated finger knob can be seen which is probably joined to a similar tubular metal sleeve. In our unit, the end of the tubular metal sleeve was formed into a knurled knob which could be grasped with the fingers.

I can't remember whether any source voltage was shown on the unit case. To test the device, I probably used the commonly available 9V torch battery or a radio C bias battery.

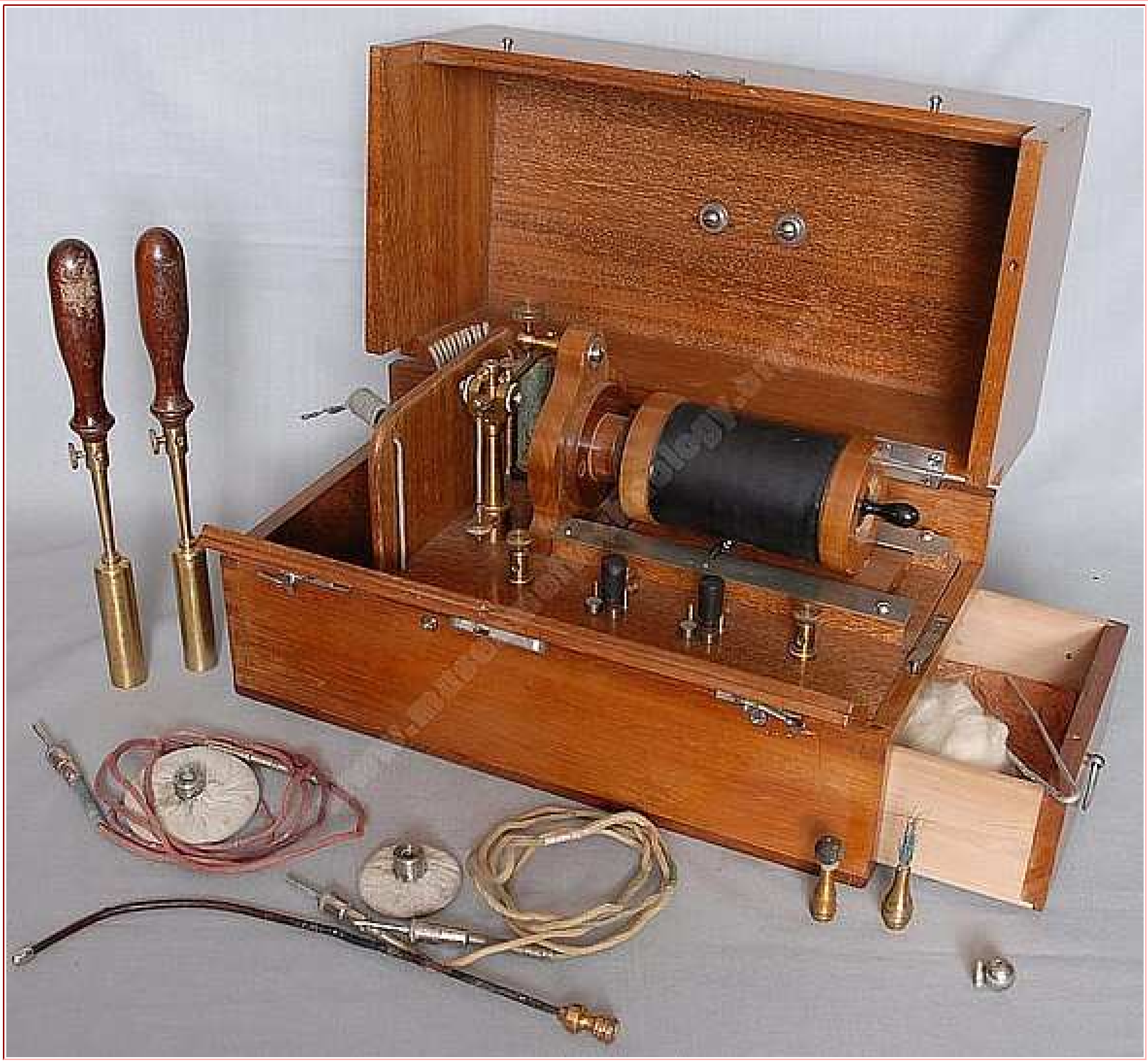

Figure 4
The A0133 Medical Induction Coil
(An exhibit of the Museum of Technology the Great War and WW2)

My Folly

Experimenting with electricity and electrical devices should be approached with plenty of fore-though and due care. I have to describe something I did with the Medical Induction Coil, which in retrospect, was very foolish. I wondered how intense the strength of the electric shock might be with the control sleeve pulled right out so that the magnetic field between primary and secondary was at maximum.

With the sleeve fully in, the shock level was tolerable but I pulled it right out and grasped the hand held probes. The problem with electric shock is that the electric current freezes the muscles in the body and in this case it acted on my wrists. I just couldn't let go. It is interesting that despite the electric current passing from one hand through my body to the other, I could still think. Even under electric shock, I wondered how I was going to turn things off to get out of this predicament.

Fortunately I had not pulled the sleeve right out of the coil assembly and the end of the sleeve was just sitting in the assembly end. I found I could still move my arms and I belted the sleeve with the back of one hand so that it was pushed right back into the assembly. The shock level abated and I was able to release the probes from my hands. It shook me up a bit quite a bit but I recovered.

So I will just add a message: Never assume that a device is harmless just because it operates from a low voltage such as a small battery. This Medical Induction Coil certainly wasn't harmless.

If something electrical must be touched which might turn out to be hazardous, use the back of the hand not the palm. Also avoid a second connection such as the other hand or another part of the body. I also refer to an article I prepared on Electrical Safety and had published in Amateur Radio January 1998. The copy is also the web at: http://users.tpg.com.au/ldbutler/ElectricalSafety.htm

Summary

The Medical Induction Coil is described as a device used in the 1800s and early 1900s to provide medical treatment by feeding electric shocks to the human body. To lead up to the medical version, the operation of the basic Induction Coil has been described. Attention is also drawn to other applications of the Induction Coil such as the Ford Coil and use as a spark source to generate damped wave trains in early Spark Radio Transmitters.

As I found out at an early age, the Medical Induction Coil could generate quite high voltage and needed to be operated with due care.

Now that I have written this article, I wonder what happened to that early device which I experimented with in my parent's home. It certainly didn't appear when my aged parent's possessions had to eventually be moved on. I also realised that I had never ever seen any documentation describing the Medical Induction Coil until I searched the Internet this year.

References

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