The "Mystery" of "The Warren Magnetic Clock", the first Synchronous Motor Powered Clock?

R. Hatch (CA)

Summary:

In the history of invention, it seems rare to see a device spring forth fully formed from the inventor's mind. It is rather through a series of experiments and the insights resulting from those experiments that inventions advance.

The following article examines the patents, early prototypes and existing battery powered clocks built by Henry Warren prior to the development of the highly successful A.C. synchronous motor (ca1916).

Prior to abandoning development on battery-powered timepieces Warren experimented with electrically impulsed clocks whose pendulums were initially mechanically coupled to the movement. These earlier prototype clocks later gave way to the production model "Mystery Clock" with a synchronous clock "motor" formed through a magnetic coupling to the pendulum. The development of this magnetic coupling clearly demonstrated the basic principle of synchronous motor operation (rotating magnetic field with a permanent magnet rotor) and strongly indicates that rather than a new departure, the synchronous motor of 1916 was instead an evolutionary outgrowth of the work on these earlier battery clock "motors".

Acknowledgements:

For the help of Mr. Rick Thomes, who was kind enough to share photographs from his collection along with encouragement and advice. Mr. John Anderson who also shared reference material and photographs he collected for his 1991 NAWCC bulletin article on Henry Warren. Thanks also to Mr. Chris H. Bailey the Curator of the American Clock & Watch Museum for the permission to use their photograph of Henry Warren's first electrified clock. In addition, Mr. Ted Bosschieter for allowing me to include a link to his fascinating website. Thanks also go out to Ms. Lori Lane, Executive Assistant at The Warren Conference Center & Inn in Ashland for answering my many questions and for allowing the use of the photo of Henry Warren.

After I had worked on this article for several years and submitted a draft to the NAWCC, Mr. Mackay Thurston furnished me with new information on the very earliest of Warren's clocks in the form of a surviving example and photographs of three other models, all of which were previously unknown. This led to extensive re-writing in 2009 but certainly provides more continuity to the story, thank you.

Photo used with permission of the Warren Conference Center & Inn

Photo 1, Henry Ellis Warren Ca. 1900

Introduction:

Henry Warren's contributions to the development of the synchronous motor, his popularization of mains-powered clocks as well as his development of Master Clocks (used to keep the frequency of the generation equipment powering these synchronous clocks accurate) has been well documented. **1** However, preceding these successes he initially pursued the development of a pendulum-controlled battery powered timepiece for domestic use. These efforts led Henry Warren first from a mechanically linked battery-powered escapement on to a magnetically coupled one and finally to the crowning achievement, the self-starting synchronous motor which was the culmination of that work.

The following article traces the development of Henry Warren's first production battery clock from the patent and prototype stage and early work on the synchronous motor concept until the development of his first mains-powered synchronous clock motor or roughly the years 1908-1916.

Personal History

Henry Ellis Warren was born in Boston on May 21, 1872 and this is where the 1880 census records him living with Rowland Ellis (his maternal Grandfather and head of the household) along with his Father Henry, Mother Addie, Sarah and Annie Ellis (his aunts) and his sister Olive. Additionally, three "domestics" lived along with the family, indicating that they enjoyed a comfortable financial status. His father's occupation is listed as "Wollen (sic) Merchant" while his Grandfather, at age 72, he had retired **2** from his position as the Customs Collector for the Port of Boston. **15** During this time, Henry learned the skills of the workshop as taught to him by Grandfather Ellis. **1** Through this experience he discovered his gift for invention.

In 1894, Henry Warren graduated from the Massachusetts Institute of Technology with a BS in Electrical Engineering. **3**

There is no clue from this early history to explain his later interest in clocks.

A 1991 article by John Anderson published in the NAWCC Bulletin, **1** gives a more complete account of his life and I would refer the reader there or to the "The National Cyclopaedia", **4,** or "American National Biography", **3,** articles.

Beginning of the Warren Clock Company

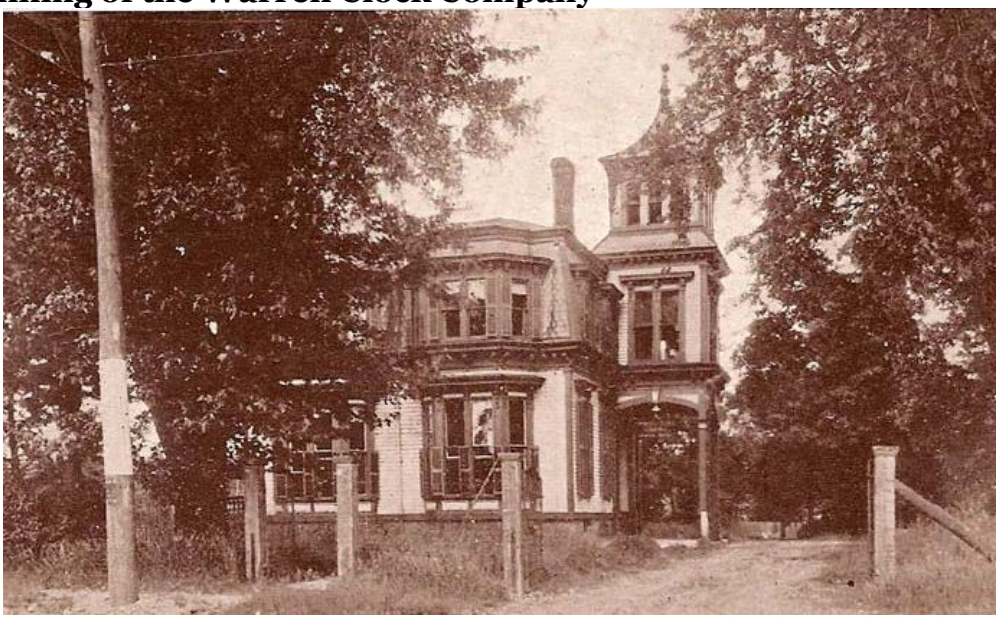


Photo from Author's collection

Photo 3, Warren Clock Company Office ca 1912-14

(Note: this building was still standing off of Hwy 135 East Bound near the intersection of Chestnut St. in Ashland, MA as of 2006 **6**)

To quote Henry Warren from a 1937 address to the *"Boston Clock Club"*. *"Like most of the other electric clock inventors I had dreams of various methods whereby electricity from batteries could be used to drive clocks. As far back as 1908 I filed a patent application on a rather crude form of electrically driven clock which represented the result of several years of desultory experimenting during my spare time…. Eventually I engaged assistance and organized a small independent company for the purpose of making further developments in electric clocks which were still of the battery type. This was done without severing my regular job of superintending the work of a manufacturing company"* (Lombard Governor Company– Author's note). **5**

During his time with the Lombard Governor Company, Henry Warren also became interested in improving the process and equipment used to cut gears. Eventually these interests led to setting up shop as The Warren Gear Works on his home property in a "Red Barn". In 1912 The Warren Clock Company of Ashland MA was formed, and incorporated in 1914, to commercialize his ideas for a battery driven timepiece and in the next few years there were a small number of clocks placed on the market. **7**. Later the company was moved into a building at the Lombard Governor Company where commercial production of battery clocks was begun. **4** Existing clocks and patents would indicate that this production

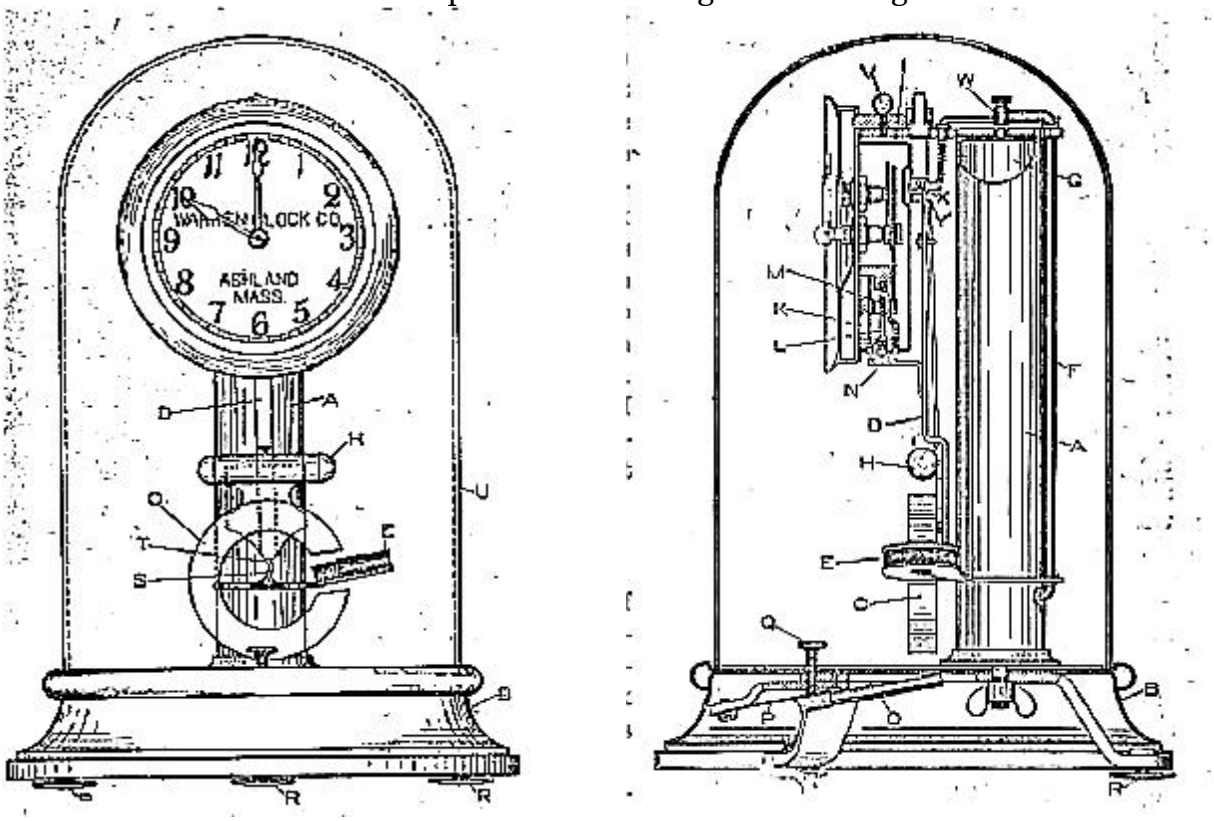
phase was underway by mid 1915 with earlier "prototype" clocks produced in his barn until sometime in mid 1914 or early 1915.

Warren Clock Design

The design goals for the development of Warren's battery clock were two-fold; first as stated in his "Clock Club" speech was that, *"My work has been wholly concerned with providing devices which would tell the time with the very greatest convenience and with a high degree of accuracy…"* **5**.

Secondly, as stated in Patent # 1,160,346 his intention was to make *" the works of the clock… capable of being removed from the clock when it is desired to move, ship, or transport the clock and can be replaced by unskilled labor without danger of disarrangement…"* . This "modular construction was to allow field service by the customer without the need of skilled clockmakers who were not versed in electric clock theory or practice and had, in the past, proven resistant to technological change.

A description of the Magnetic Clock's design principles and operation was furnished to the "*The Keystone Weekly"* by the Warren Clock Company. Published on June 6th, 1916 it detailed the clock's operation and design goals. **8**. Selections from this article are quoted below along with two original illustrations.



Illustrations furnished by the Warren Clock Company along with a description of its operation, appearing in the "*The Keystone Weekly*" June 6th, 1916. 8

"There has recently been placed upon the market a new kind of timekeeper known as the Warren Magnetic Clock, which the manufacturer claims embodies improvements in the mechanism, and especially the escapement, more radical than any made during the previous century." **8**

"Motion is transmitted from the pendulum to the movement as follows: The lower end of the needle (L) carries a curved extension projecting downward into a cup or depression filled with a fine quality of light mineral oil. Neither air nor dust can enter the case (K) and the oil which it contains cannot possibly escape. Mounted upon the pendulum rod (D) is a platform or bracket (N) and concealed upon the platform (N) are two very small horseshoe permanent magnets. The poles of the magnets on (N) strongly attract the curved extension at the lower end of the needle (L) across two thicknesses of metal and an air-space."

"According to a new principle broadly patented in the United States and foreign countries, the reciprocating or swinging motion of the pendulum which moves the bracket (N) to and fro across the axis of the magnetic needle (L) causes the latter to revolve once for every complete swing of the pendulum."

"The oscillating motion of the pendulum is thus converted into a continuous motion of rotation of the needle (L) and this needle by means of the screw thread (M) transmits motion at a greatly reduced rate to the first gear of the clock train. The remainder of the clock train is more or less conventional although the bearings are so designed as to run without lubrication. The entire works of the clock are protected by a dust-tight cover (I)."

After this long written description, it would be fun to see all this in motion! If you have a computer handy please refer to Ted Bosschieter's excellent website for an animation of the Warren clock at; http://electric-clocks.eu/div/zus/Warren.htm. You can click on the Dial area of the animation and see the magnetic "motor" in operation or the pendulum and watch the action of the mercury switch or "electric pulsator" as Henry Warren described it. **9**

Earliest Clocks

Henry Warren's first clock patent, #927,907, was applied for on October 22nd, 1908 and granted on July 13th, 1909. Entitled *"Electric Apparatus for Driving Clocks or Similar Mechanisms",* it describes an electromagnetically impulsed pendulum with oscillating contact system driving an otherwise conventional clock movement.

The first surviving experimental electric clock (a modified family banjo clock) was converted to electric drive prior to 1909, and is now in the collection of the American Clock & Watch Museum at Bristol, CT. Refer to **Photo 2**. It appears to closely follow the second clock Patent #1,089,886 applied for December 23rd, 1909 and granted on March 10th 1914 and is shown in **Figure 2**. However, rather than using an oscillating switch, like the first or second patent, this clock is reported to use a mercury switch (which Warren referred to as a "Pulsator"). This suggests that the clock may have been a "breadboard" that was updated as new ideas presented themselves. The patent containing the mercury

switch (Pulsator) concept was not applied for until July 27th1910. **Refer to Figure 5**.

No other examples of this design have come to light during the research of this paper, leading to the conclusion that this particular line led to a "dead end". What is clear from his work and his own statements is that clock making at this time was a still an amateur endeavor. **5**

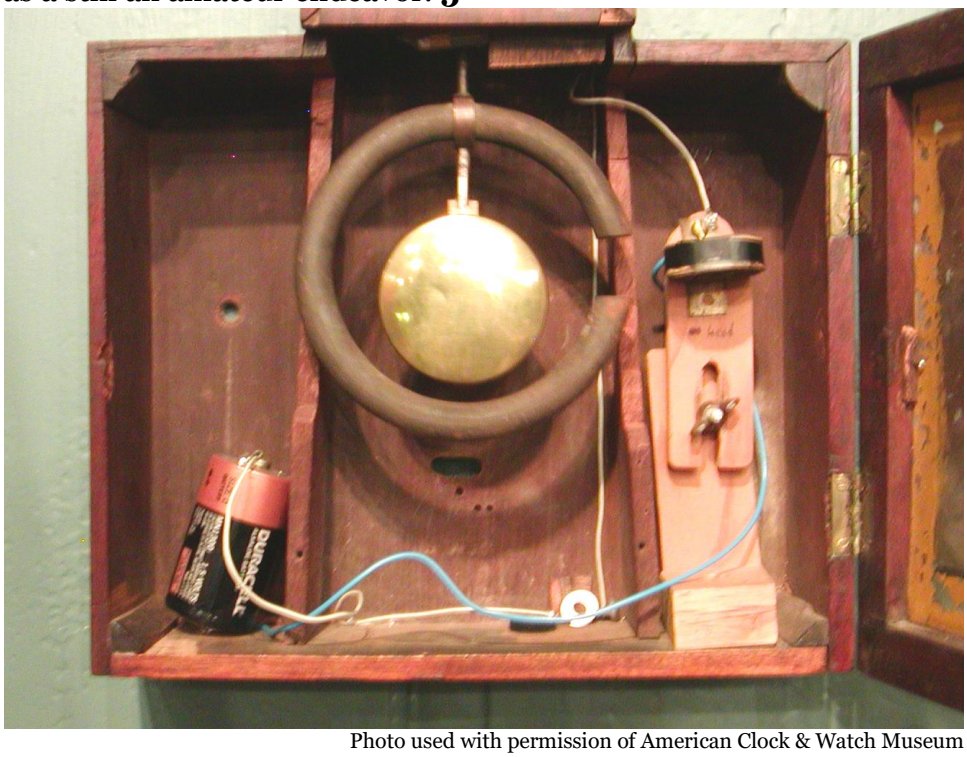


Photo used with permission of American Clock & Watch Museum

Photo 2A, Detail of Henry Warren's first electric (electrified) clock ca.1908.

Referring to the early patents (927,907, 1908, 1,089,886, 1909 and 1,144,973, 1910) it is clear that Warren was still working through various concepts for impulsing and making electrical contact during this time.

Photos 2B, C and D show early clocks that not survived to the author's knowledge.

Photo 2B, Prototype Clock 1

Photo 2C, Prototype Clock 2

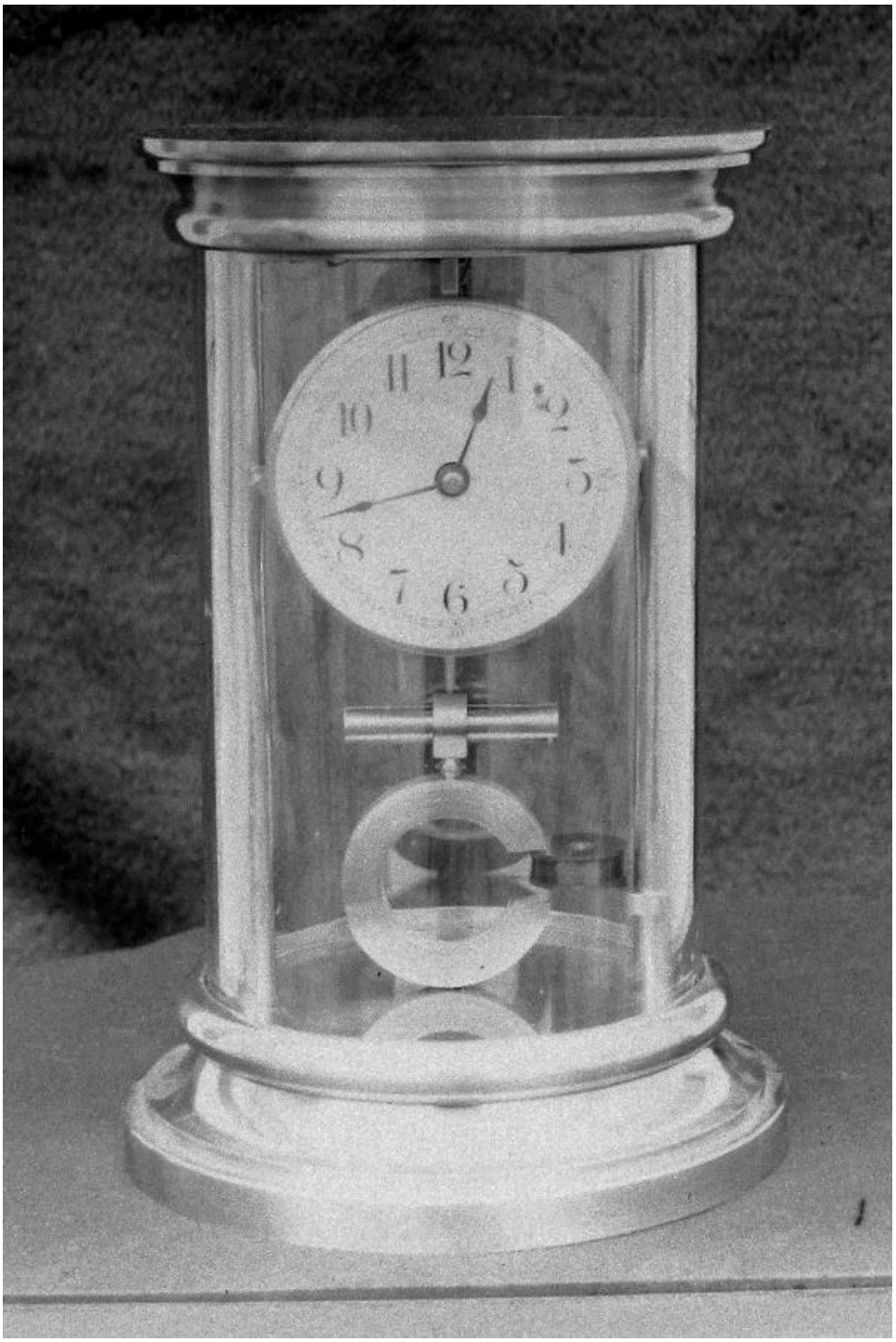


Photo 2D, Prototype Clock 3

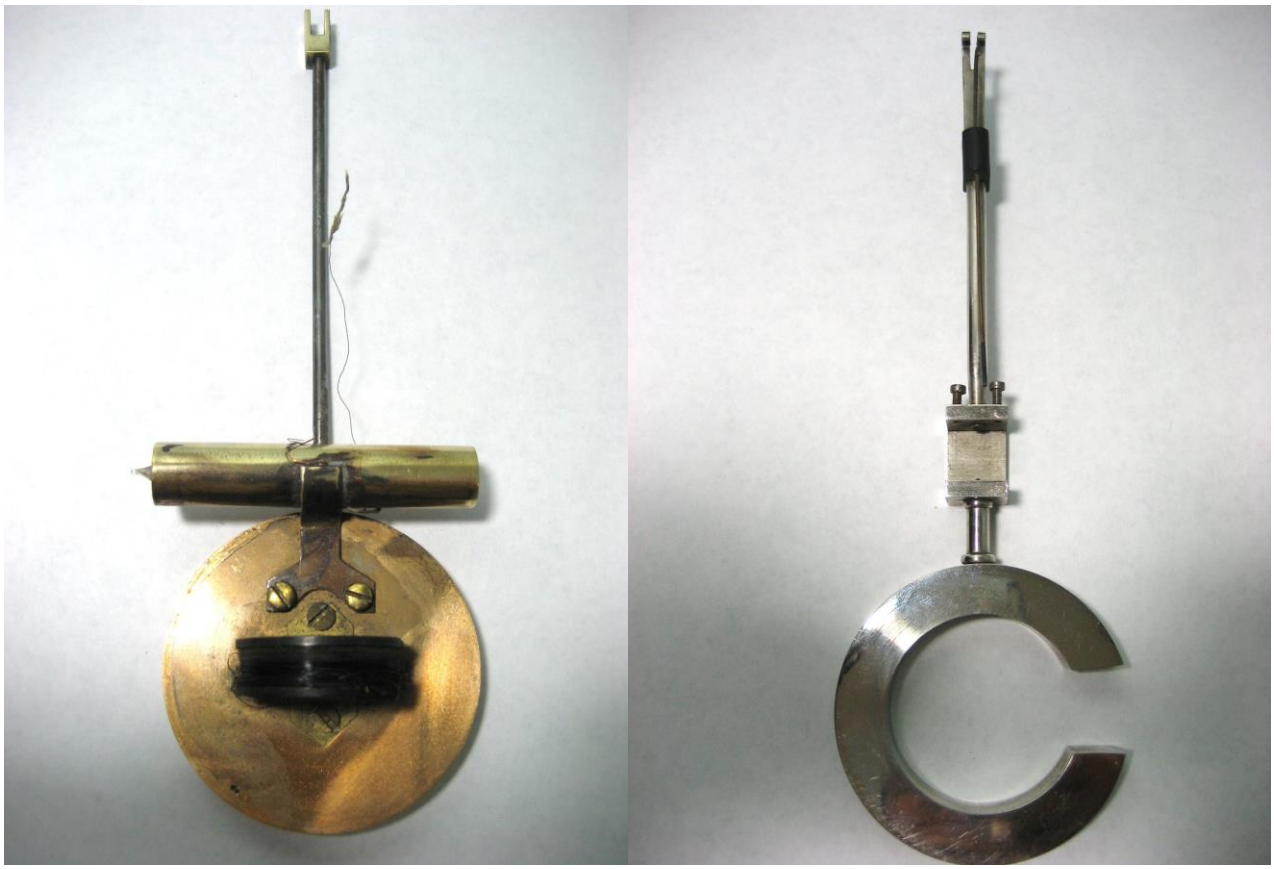
The collection of experimental pendulums shown in **Figures 3A and 3B** show a progression of ideas paralleling Warren's patent applications. Pendulums a and b show the "pulsator" rigidly fixed to the bob with first a wooden and then a metal (Invar?) rod without a means of leveling adjustment. In addition, the coil in a is fitted directly to the bob rather then the base as in the later designs. Refer to Sheet 3 of patent 1,089,886.

Pendulums c and d show the “C” shaped magnet of the design used in production models but both show prototype mounting schemes for the pulsator. The first, a rigid mounting and the second an adjustable mount with screws operating above a fulcrum point to adjust the pulsator level.

Pendulum e/f is a prototype of the “living hinge” used in the production clocks. Note the glass pulsator strapped to the top of the hinge.

a

c



b **d**

Photos 3A
Author's Collection

e

f

Photos 3b
Author's Collection

Lift and Drop" model Clocks.

While Warren Patent #927,907 shows a conventional index wheel and pawl, no clock with this arrangement is known to exist. **Refer to Figure 3.** What appear to be the oldest surviving Warren Battery clocks (with the exception of the Electrified Banjo Clock mentioned earlier) judging by the patent numbers and other features are of the "Lift and Drop" mechanical variety. This name results from the action of the count wheel, which is lifted and then dropped by the pendulum through a mechanical toggle linkage once every time the pendulum passes through the center position advancing one tooth of the count wheel in the process.

Only two of these style clocks were available for study during preparation of this article, and one of those only through photographs. **1** Both are without serial numbers so these clocks could have been the result of prototype efforts and/or offered as early production models. Their Lift and Drop mechanism was not the subject of a patent, so it is difficult to imagine that Warren spent much time producing it or in the end valued the design highly. These models are also missing some of the later "Production" features found on the magnetically coupled models such as; base mounted rate adjustment and movement cover.

The first "Lift and Drop" clock is called Clock #1 because it contains the fewest production features and therefore might reasonably be expected to be the earliest. **Refer to Photo 4.** There are a few clues to dating this example. The first is a plaque affixed to the back plate. **Refer to Photo 5**. It shows two patent dates, July 13th '09 and Mar. 10th '14. It's easy to assume that it was built sometime after the last patent date and probably before the final mystery patent was granted on Jun. 27th '15 (which is marked on the movement covers of the magnetically coupled production examples observed in the study). The battery that was found in this clock furnishes additional information as to the production date. There is every reason to believe it is original to the clock and as such a unique survival; it is dated Oct 18th 1914. This is most likely an installation date. Both methods confirm that production was in 1914. Additionally, the presents of the original battery suggests that the clock may not have been satisfactory in some way and was just put on a shelf.

Most authors writing about the operation of the Warren Magnetic Clock caution that the clocks must be level to operate. It is also this writer's experience that these clocks are indeed "fussy" about leveling. So it would be a surprise that a production model was ever produced without leveling feet! It is doubtful that such a clock would ever "be a hit" with the public and leveling feet must have been added very shortly thereafter.

The general condition of the clock would also indicate a short service life. The Magnetic coupling patent was applied for on Nov. 30th '14, so by this time Warren's thinking had evolved along different lines and it's hard to believe

that these “Lift and Drop” models were built much after this time. This example could well be a “Red Barn” clock.

Photo from Author’s collection

Photo 4, Clock #1, an early “Lift and Drop” model. A Red Barn Clock?

Photo from Author’s collection

Photo 5, Patent dates on clock #1.

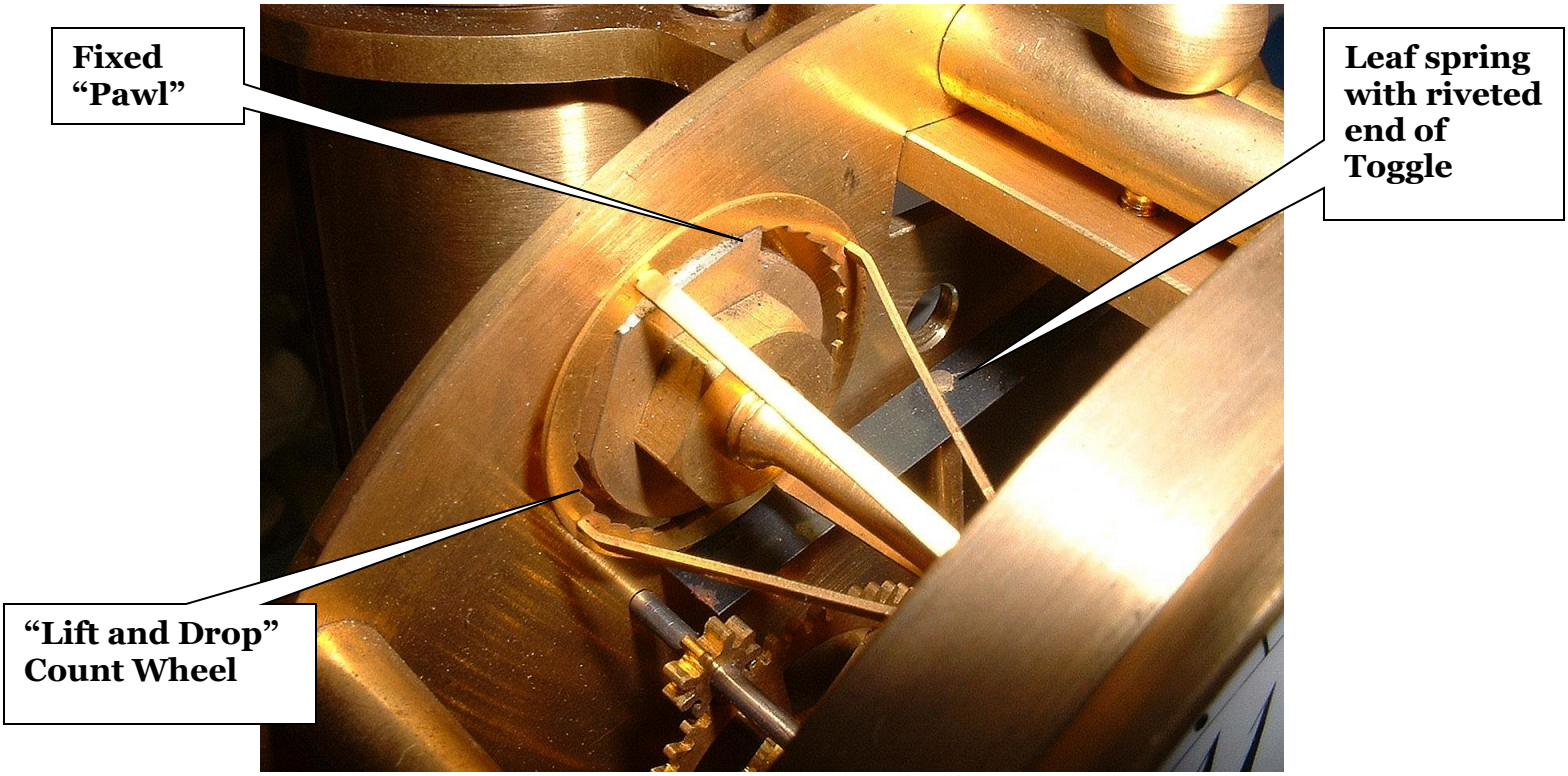


Photo from Author's collection

Photo 6, Lift and Drop mechanism in Clock #1.

The "Lift and Drop" mechanism on clock #1 is actuated by a jointed toggle, the point of which rests inside of a "cup" mounted on the upper pendulum rod. **Refer to Photo 7.** A bit like a Hipp toggle, it is pivoted on a shorter radius then that on which the pendulum swings thus it is lifted at the center of each swing. Lifting the toggle in turn lifts a leaf spring thus lifting the edge of the internally toothed count wheel. When the leaf spring is released it causes the count wheel to drop onto a fixed pawl, advancing one tooth. **Referring to Photo 6** the count wheel and below it the leaf spring can be seen. At the opposite end of the arbor carrying the internally toothed wheel there is a pinion that drives the time train (hidden by the front plate in this photo).

Recently while searching the NAWCC message board the description and a photo of another Warren clock very similar to this one surfaced. It has the same coupling "toggle", and is missing the regulation in the base, movement cover, serial number and leveling feet. In addition, a lone pendulum for one of these clocks recently was for sale on EBay.

Photo from Author's collection

Photo 7, Lift and drop style pendulum from clock #1 along with original single 1 1/2Volt battery installed October 18th 1914

Photo used with the permission of John Anderson

Photo 8, "Lift and Drop" Clock #2 showing crutch actuation

Clock #2, **Refer to Photo 8**, is similar to clock #1 in that between the plates it has the "Lift and Drop" mechanism. The difference is in the coupling to the pendulum, which is by means of a one-legged crutch, which actuates the leaf spring and internally toothed count wheel. This clock has most of the "production" features (including leveling feet and rate adjustment in the base) with the exception of obvious patent dates. It is not known if this clock is serialized.

“Production” Magnetically coupled models:

This is the model usually referenced in articles and seen at sales. The general characteristics that these clocks share are; they are serialized, have leveling feet, rate adjustment in the base and a movement cover which is stamped with patent information for three dates; July 13th ’09, Mar 10th ’14 and Jun 29th ’15.

Author’s collection

Photo 9, Henry Warren production Mystery clock S/N “4051” (there is doubt about the authenticity of this serial number since it is written in pencil and not in the usual places) with a magnetically coupled pendulum driving synchronous, oil-filled “motor” with sealed drive gears.

The serial numbers assigned to these clocks (or rather to the components) were originally marked in several places on the clock sub-assemblies. The ink used is rather fragile and it may be rare these days to have all the serial numbers survive. S/N 1086 is particularly well preserved to illustrate the marking scheme. **Refer to Figures 10-12.**

Photo used with permission of Rick Thomes

Photo 10, Showing clock serial number marked on back of pendulum.

Photo used with permission of Rick Thomes

Photo 11, showing serial number marked on movement mounting block. Some clocks have the markings on top of the mounting post as well.

Photo used with permission of Rick Thomes

Photo 12, Showing serial number marked inside base.

Lacking markings in these locations, another magnetic clock showed serial number 4051 marked on the motor and written on the bottom of the column in what appeared to be pencil. There is some doubt that this serial number is original given that the next highest serial number encountered was in the 1,000s. The takeaway from this is to be careful when handling and cleaning these clocks as valuable information could be erased!

Private label Clocks

One private label clock has surfaced during the preparation of this article labeled "Frank A. Andrews Inc.". **Refer to Figure 13.** The Boston directory for 1905 lists "Andrews, Frank A. jeweler 10 School h(ouse St.) at Brookline (St.)". **10** While the 1925 directory lists "Andrews, Frank A. pres and treas Frank A Andrews Inc 276 Wash(ington St.) at Nahant (St.)". **11**

Photo 13, Frank A. Andrews labeled Warren

Photo 14, Note Unusual Wooden Base

Referring to Photo 14, it would appear that an ordinary magnetic model has been mounted to a later turned wooden base. The shape of the base is almost identical to the metal bases used on production clocks. Like the "Lift and Drop" models this clock lacks leveling feet, however, unlike these models there is no provision for rate adjustment in the base and in fact no way to regulate this clock at all! All this leaves the author skeptical as to the originality of this clock.

"Motor" styles

"The Warren Battery (Mystery) Clock is a unique clock in that there is no mechanical connection between the pendulum and the movement. A pair of small horseshoe magnets carried in a horizontal plane on the pendulum rod propel a worm gear in almost continuous motion which in turn drives the clock." **12**

In this section, reference is made to "Motors" in the Warren Battery clocks. Functionally they resemble the "B" rotors used in the later synchronous clocks made by Telechron in that they are sealed units permanently lubricated and separate by a metal case from the rotating magnetic fields that actuate them. From the point of view of power transmission, they serve the same function.

Warren's patent for the Magnetic Clock referred to the magnetic flag concept as a "magnetic coupler" but it could be just as well described as an armature in a clock motor.

Patent **1,160,346 (Figures 6 and 7),** shows a cylinder shaped polarizing magnet, this style magnet is seen in **Photo 13** There are three styles of Motor in the clocks examined during the preparation of this article. All are based on the same non-magnetic (Zinc?) casting with minor variations in the magnets/placement, oil filling and the mounting methods.

1. S/N 926 Features a Style I motor mounted from the backside of the Dial Plate. The Polarizing magnet is exposed on one end. The other end is used as the upper pivot of the worm gear. This style most closely resembles the patent drawing. Oil is added through the cork-plugged hole in the upper left motor casing. **Refer to Photo 15.**
2. S/N 1086 Features a Style II motor, again mounted from backside of Dial plate. In this case the polarizing magnets are completely contained within the motor case. Refer to **Refer to Photo 16**.
3. S/N 4051, Features style III motor, in this case the motor casing is screwed in from the front side of the dial plate. Refer to **Photo 17**.

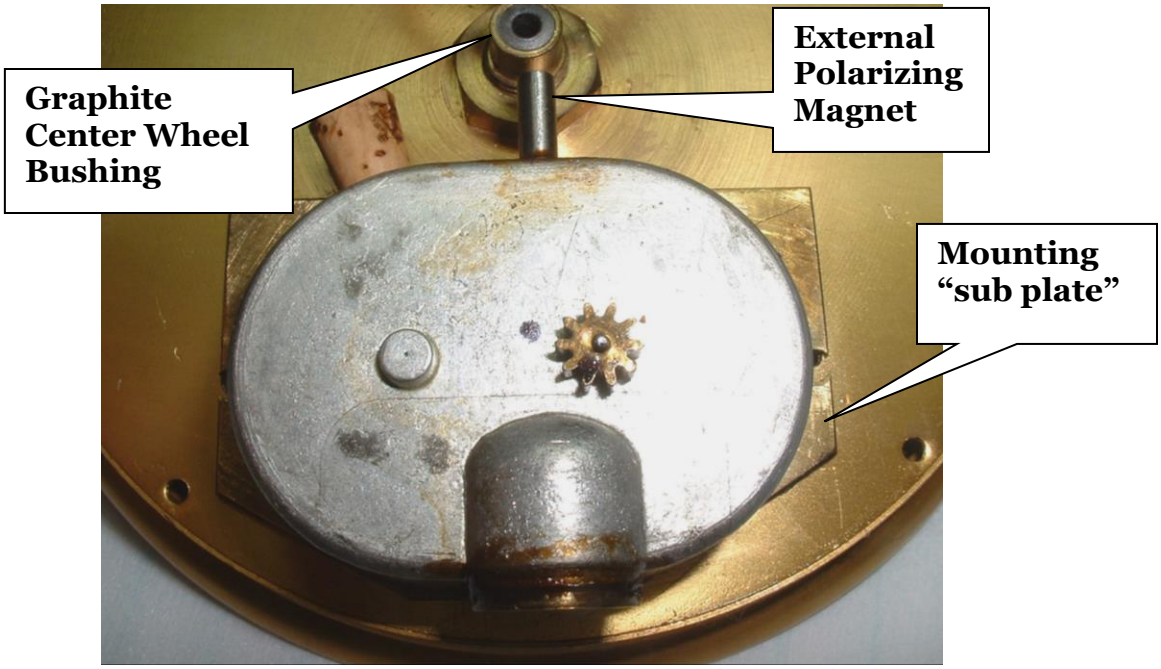


Photo from Author's collection

Photo 15, Serial Number 926 with Style I Motor.

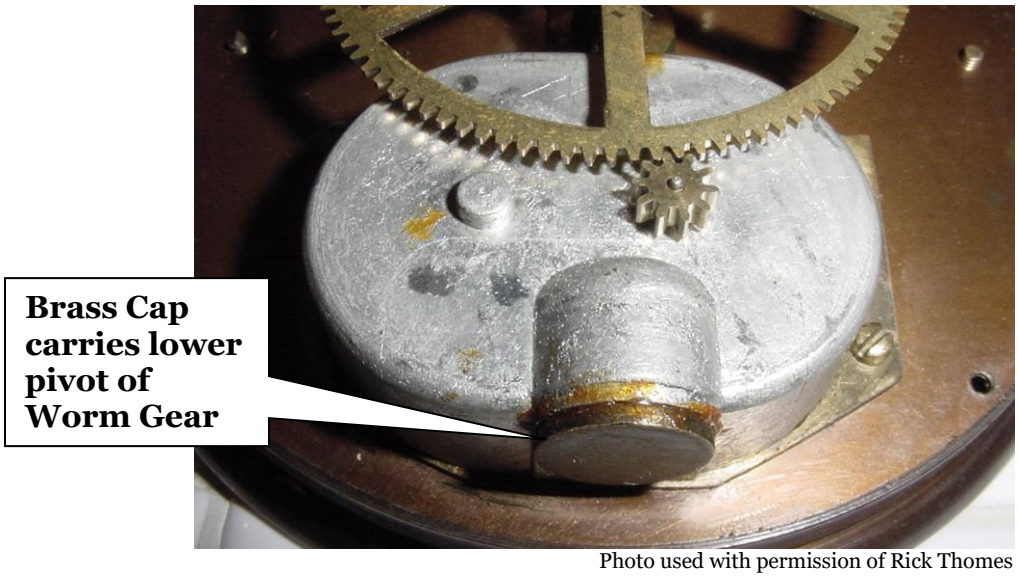


Photo used with permission of Rick Thomes

Photo 16, Serial Number 1086 with Style II Motor containing internal polarizing magnet.

Photo from Author's collection

Photo 17, Serial Number "4051" with Style III motor

4. All motor cases are sealed to the mounting plates/dial plate, brass cap and polarizing magnet with shellac.

Patents

The following are Henry Warren's Clock Patents pertaining to the Magnetic Clocks arranged by date of application.

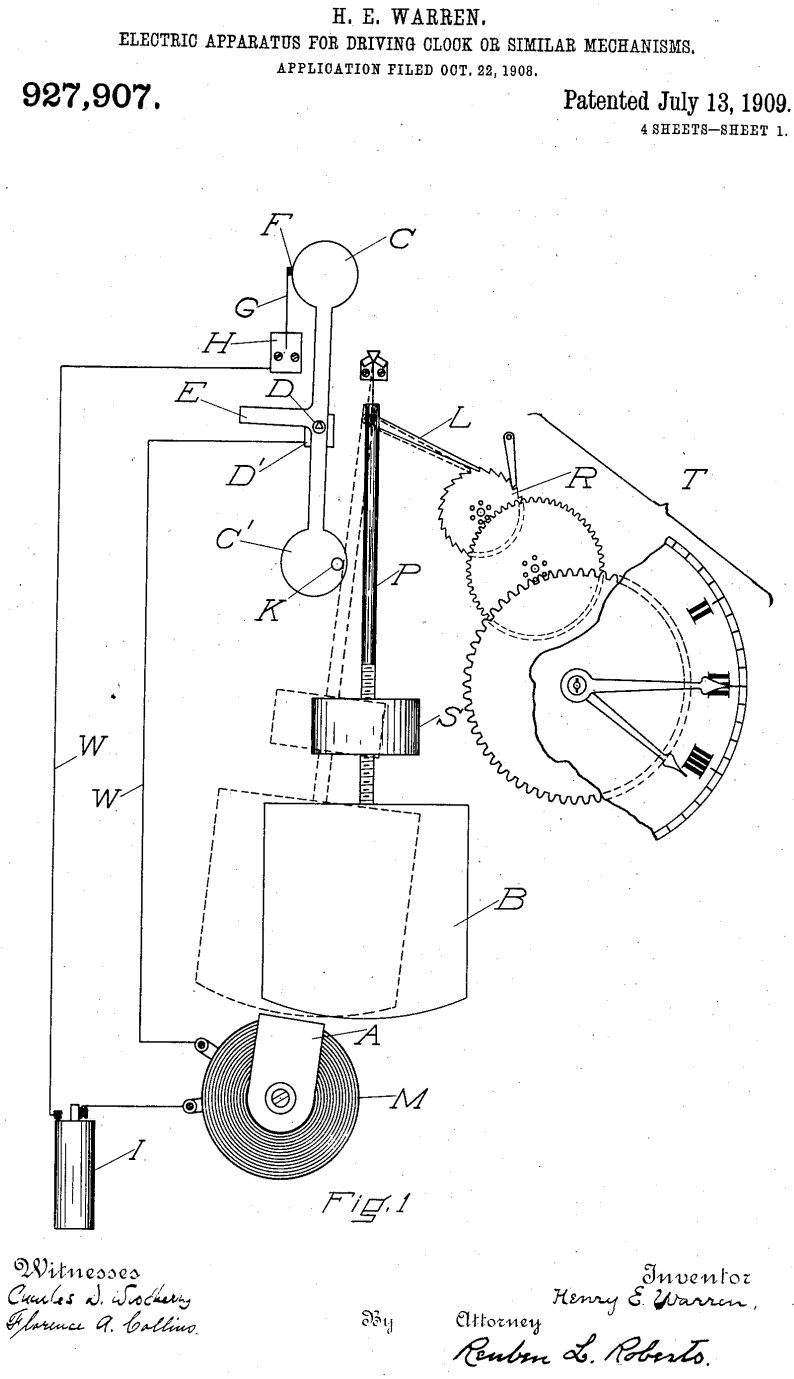


Figure 3, Patent #927,907, Application October 22, 1908. Henry Warren's first patent for an Electrically Impulsed clock.

In this patent an oscillating switch mechanism is applied to impulsing the pendulum. The oscillating switch mechanism was later replaced by a mercury switch, which was employed on all prototype and production Warren clocks to the author's knowledge. It is clear from the description accompanying this patent that the design of the oscillating switch was intended to stabilize the pendulum amplitude. This would be desirable for two reasons; first it limits circular error and secondly permits variations of the battery voltage to occur without an undue affect on the timekeeping. This was also the object of the Mercury Switch used in the later clocks with the added advantage of ensuring a reliable contact through the exclusion of air, dirt and etc. Few of these concepts found their way into either the prototype or production Magnetic Clocks.

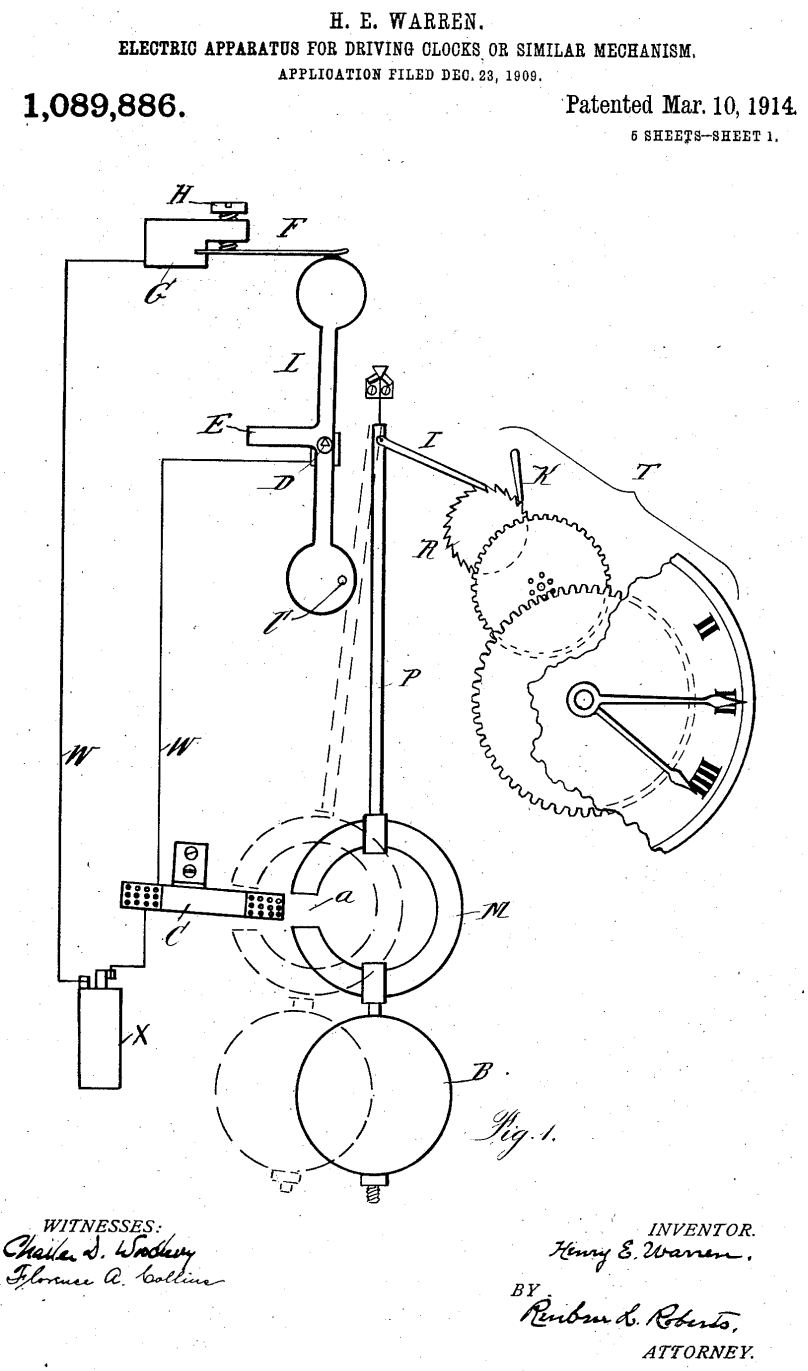


Figure 4, Patent 1,089,886, Application date December 23,1909. The origin of the "C" shaped magnet and coil impulsing. Still retains the earlier oscillating switch mechanism.

Note that the clock in **Figure 4** retains a bob and rating nut not used in the prototype or production Magnetic Clocks but seen in his Banjo Clock modification.

H. E. WARREN.

ELECTRIC APPARATUS FOR DRIVING CLOCKS OR SIMILAR MECHANISM.

APPLICATION FILED DEC. 23, 1909.

1,089,886. Patented Mar. 10, 1914.

5 SHEETS—SHEET 3.

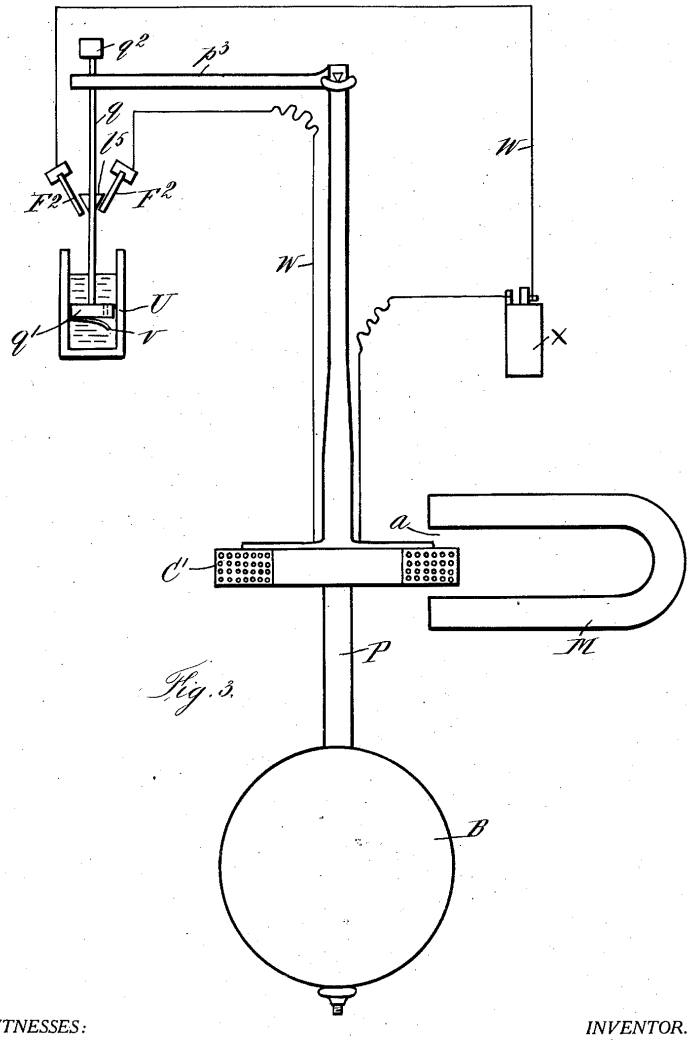


Fig. 3.

WITNESSES:

Charles J. Woodbury

Florence A. Collins

INVENTOR.

Henry E. Warren.

BY

Reuben L. Roberts.

ATTORNEY.

Figure 4A, Patent 1,089,886,. Moving Coil and Fixed Magnet concept as shown in the prototype pendulums. .

ELECTRIC APPARATUS FOR DRIVING CLOCKS OR SIMILAR MECHANISM.

APPLICATION FILED JULY 27, 1910.

1,144,973. Patented June 29, 1915.

2 SHEETS—SHEET 1.

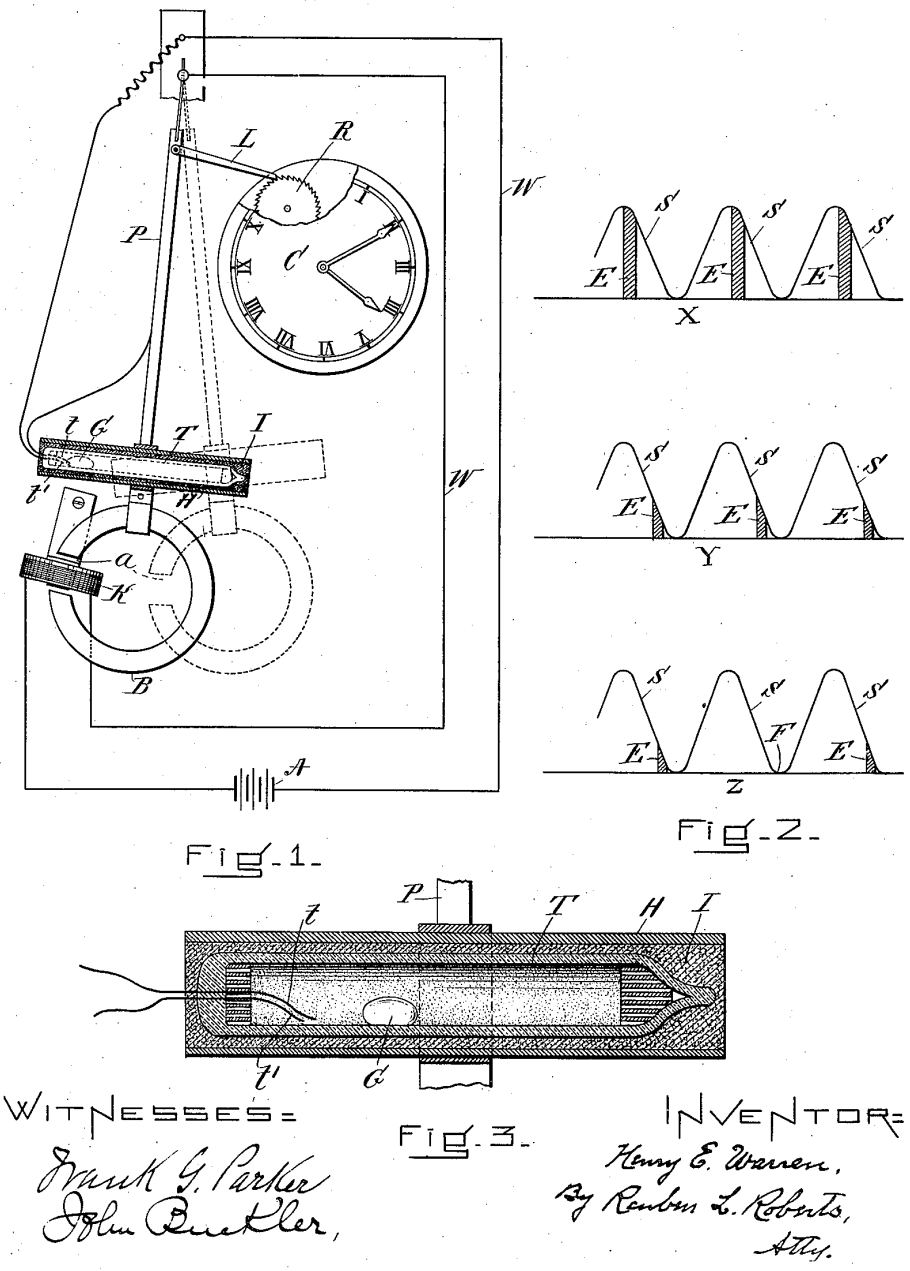


Figure 5, Patent 1,144,973, Application date July 27, 1910. Mercury switch applied.

All prototype and production clocks feature mercury switching, Refer to **Figure 5**. The claims in the patent description for the mercury switch are substantially the same as for the earlier oscillating contact, that it will stabilize the amplitude and provide for reliable electrical contact. Note that index wheel is still driven by a conventional pawl; the "Lift and Drop" mechanism of the prototype clocks is not in evidence however the bob and rating nut are dispensed with. Wave drawing on right side (patent figure 2) illustrates Warren's claim that

the Mercury switching system used controls the pendulums arc by varying the impulse time.

CLOCK MECHANISM.

APPLICATION FILED NOV. 30, 1914.

1,160,346.

Patented Nov. 16, 1915.

3 SHEETS—SHEET 1.

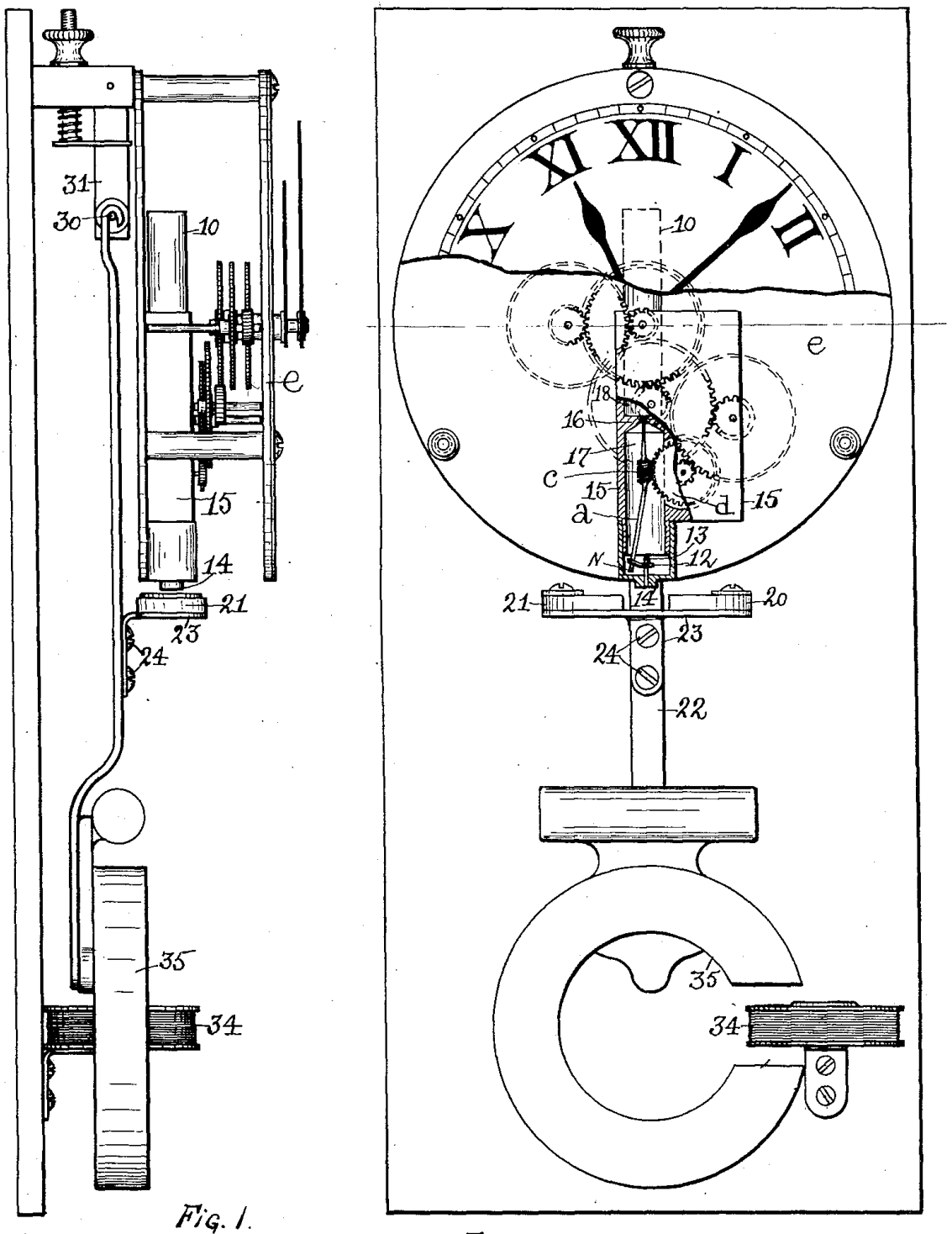


Figure 6, Detail of Patent #1,160,346, Application date November 30, 1914.

Figure 6 shows the "Mystery" clock patent in it's final form, with synchronous "Motor", the rotating magnetic field is supplied by two horseshoe magnets #20 and #21. The "Lift and Drop" concept by this time has been discarded in favor of magnetic coupling. Note the shape of the motor, a vertical cylinder with a prominent polarizing magnet on the top.

This clock patent utilized the magnetically coupled rotating field (synchronous) for the drive mechanism, which is the precursor of the A.C. Synchronous motor of 1916. Note straight polarizing magnet #10 in **Figure** 7, additionally the clock shown in the patent has a back plate and no cover is shown over movement. Regulation is by means of a slotted piece moved up or down the suspension spring (this feature is seen in many spring driven mantle clocks) like the "Lift and Drop" models. Also like the "Lift and Drop" models the pulsator is squared off. Unlike any surviving models however, there is no leveling adjustment for the pulsator.

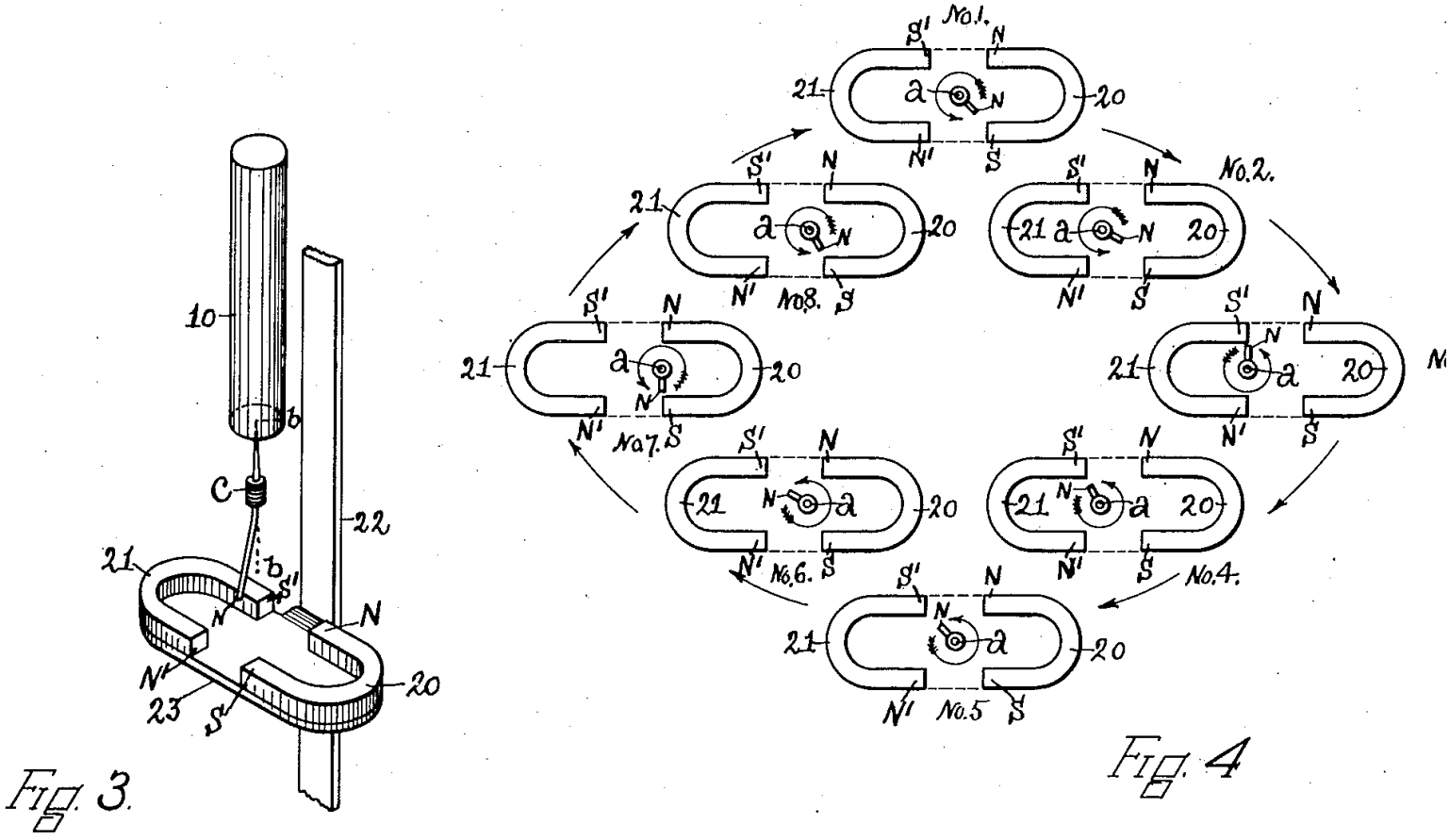


Fig. 3.

Fig. 4

Figure 7, Patent 1,160,346, Detail of synchronous "Motor" armature (Original Fig. 3 in Patent) and rotation within the magnetic field formed by the horseshoe magnets moving on the pendulum.
(Patent #1,283,430, Application date November 2, 1915 granted for the broader claim of "Apparatus for converting reciprocating motion into continuous rotary motion". Note the same drawing accompanies the patent as in #1,160,346.)

Development of an A.C. synchronous motor is nearly achieved in this clock drive. The totally incased drive armature is magnetically rotated in sync with the periodic influence (rotating field) of the two permanent magnets fixed on the

pendulum. This system needs only to replace the pendulum by a rotating 60 Hz field to result in a mains powered synchronous clock motor. Refer to **Figures 6 & 7**.

Synchronous Motor Development

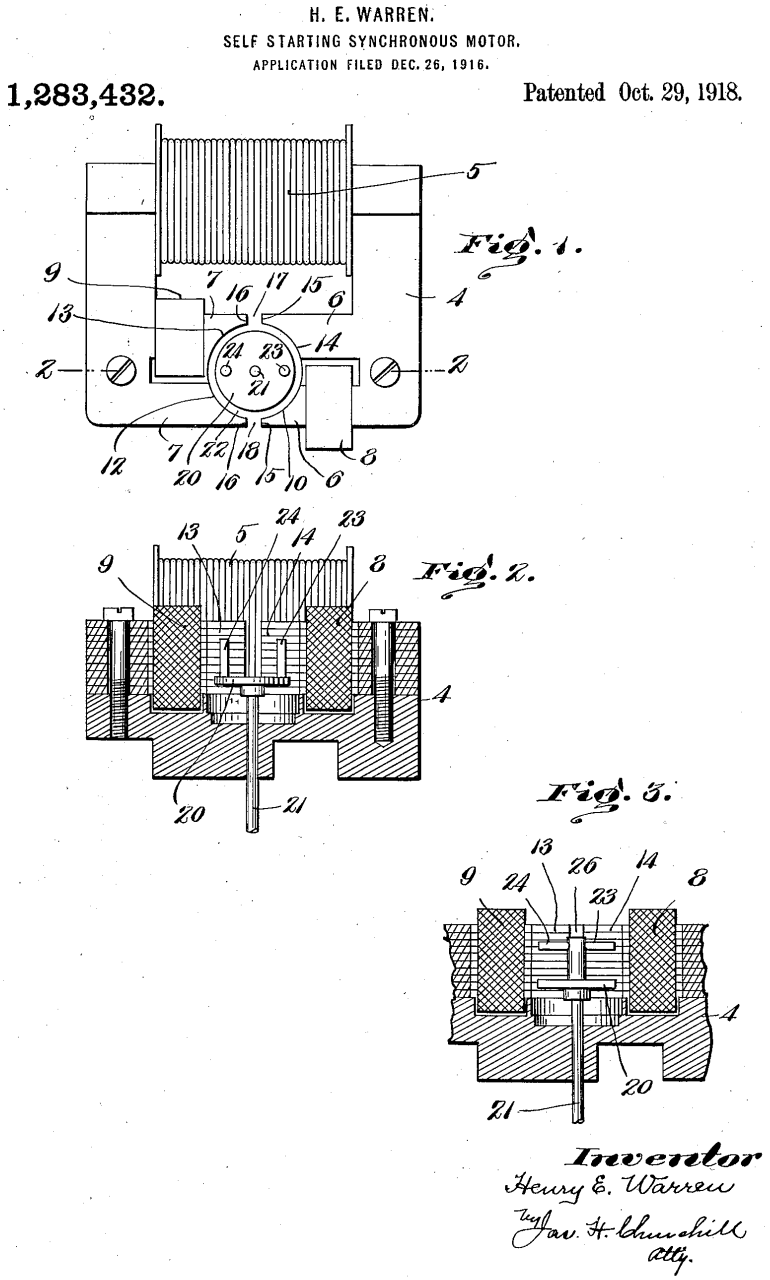

H. E. WARREN.
SELF STARTING SYNCHRONOUS MOTOR.
APPLICATION FILED DEC. 26, 1916.
1,283,432. Patented Oct. 29, 1918.
Fig. 1.
Fig. 2.
Fig. 3.
Inventor
Henry E. Warren
by Jas. H. Churchill
Atty.

Figure 8, Patent #1,283,432, Application date December 26, 1916. Patent for Self-Starting Synchronous Motor, showing shadings 8 & 9 upper figure. These provide the rotation of the magnetic field, taking the place of the horseshoe magnets used in the "Mystery" clocks.

"In 1916 the inadequacy of the battery clocks which I had been able to design and build impressed me so forcibly that I began exploring other possibilities in the art of telling time."... "In order to use the alternating current for accurate time-telling purpose I was compelled to devise a small reliable alternating current motor in which the rotor would follow the alternations of the current with extreme accuracy. There could be no slip between the rotor and the rotating field, otherwise my clocks would be unreliable. A motor having these characteristics was long ago designated as "synchronous" from two Greek words meaning, "equal time". **5**

By the early summer 1916, Henry Warren had developed a new mains powered synchronous motor suitable for powering small clocks. *"By utilizing...a rotor of hardened steel which could be permanently magnetized and then made to revolve synchronously in a rotating field there was created a device admirably suited to drive even small clocks."* **5**

The above description of his synchronous motor is strikingly similar to the following paragraph, an excerpt from Patent 1,283,430 Filed November 30th 1914 granted October 29th 1918. (This claim was originally part of the "Mystery" clock patent application, but perhaps by being of wider scope it required greater diligence, and was split off and issued it's own number).

"*The means for magnetically coupling the reciprocating member* (Pendulum magnet tray – Author's note) *preferably consists of a polarized rotatable member having one pole capable of revolving about that of said member, and permanent magnets co-operating with said polarized member and one of which is movable with the reciprocating member so as* ***to produce a magnetic field, in which considered with relation to the axis of the rotating member there is a virtual polar rotation".*** (The bolding is the author's emphasis).

What was required for a successful A.C. synchronous motor was to cause the magnetic field to rotate as it had done in the "Mystery" clock "motor". This was achieved through the use of pole shadings that caused the magnetic field development to lag in two poles relative to the other two and hence to effectively rotate. **Refer to Figure 8.**

The above demonstrates the a progression of ideas, used in the Warren Magnetic clocks, that led up to the Synchronous motor of 1916. The A.C. Synchronous motor is functionally the Magnetic Clock Motor with an A.C. rotating field rather then an oscillating magnet tray. Hence these early battery clocks should be viewed as direct precursors of the A.C. Motor models and not as the evolutionary "dead ends".

Warren Magnetic Clock - Repair, Restoration or Conservation?

"...at least do no harm"

Hippocrates, *Epidemics, Bk. I, Sect. V.*

Before attempting the actual "repair" of these clocks it is well to understand the definitions of the three methods of approaching this work as defined by the BHI. **13**

Repair. *"The mending, that is, the putting into functional order of a clock or watch."* This leaves the door open to any operation that puts the clock into working order.

Restoration. *"The reinstatement of a clock or watch to its conjectured former state and function."* A more limiting operation then "Repair" only original materials and/or parts made to original specifications would be acceptable. No modification to the original existing mechanism would be allowed.

Conservation. *"The stabilization of a clock or watch so that it is preserved in its existing state."* No repair work attempted, just preservation. Most collectors will not be satisfied operating within these strict limitations.

Since these clocks are very scarce plus it is doubtful that anyone would be depending on them for day to day accurate timekeeping, Repair at any cost, as a utilitarian need, should be ruled out.

Before beginning work of any kind, a sound operating principle to adopt is to ***assume that the clock functioned correctly as built*** and that either damage, wear or faulty repairs are the reason that it currently is not operational. This will help guide the efforts and avoid misdirected "reengineering" of the original mechanism! Modifications to existing components should not be necessary, as there should be very little wear with this design.

The patents and advertisements for the Warren clock stress a modular construction that allows removal of the pendulum or movement by "unskilled hands". While that may be the case, repairs to those "modules" may prove more challenging requiring non-standard horological diagnostic and repair skills!

There is an excellent article published in the Journal of the Electrical Horological Society November 15, 1976 by H.R. Cramer **12**. In it Mr. Cramer presents a good overview of repairs and troubleshooting tips. Since this article is copyright, summarised below is a the significant information.

> When troubleshooting these clocks, start with the pendulum since this is key to the clock running. Initially check the mercury switch. Stand the pendulum vertically and check the resistance between the pendulum rod and the rod behind it. The mercury switch is closed only when the pendulum is vertical and moving the upper end of the pendulum left or right should break continuity. This tests both the mercury switch and the insulation between the pendulum rod and the conducting rod behind it. If the switch appears defective, check the insulation first. If the mercury switch appears defective, care is required in disassembly. One of the leads to the mercury switch is soldered to the inside of the end caps and attempting to twist the cap off will risk permanently damaging the switch.

If these elements appear to be functioning correctly, check the rod attached to the back of the pendulum where a springy flat piece at the top should conduct current from the suspension spring. The brass clip around the lower part of the suspension spring and the pin through it on which the pendulum hangs are insulated from the suspension spring itself. Check that this insulation is effective. The suspension spring extends below the brass insulated part so that the spring on the rod behind the pendulum touches only the suspension spring, not the brass. The suspension spring itself is connected to the case of the clock and the brass insulated element at the lower end has a coiled spring connecting it to the battery terminal.
Test the resistance of the coil, which should be 60 to 65 ohms. If there is not continuity checked the connections to the coil unless there is damage to the surface of the coil, since these usually fail first.

The battery is held in the tubular movement support and only certain brands of D sized cells will fit. Should the battery leak or swell it will not be possible to remove it and so it is recommended to run these cells on a C sized cell, making a cardboard tube insert to hold the smaller cell. Only a single 1.5V cell is required.

After these elements have been checked, hang the pendulum, making sure that the hook and hanger pin are polished for good electrical contact and that the small rod at the back contacts only the suspension spring. The pendulum requires a push to get it started and should build up amplitude until the open end of the C-shaped bulb swings past the centre of the coil. If the pendulum over swings so that it knocks into the coil, adjust the screw on the back of the pendulum. This adjustment alters the angle between the mercury switch and the pendulum rod. It is difficult to set this as there is only a narrow range of correct setting. In order for the clock to run the maximum amplitude is required and adjusting the screw between 1/8 and 1/4 turn is usually sufficient adjustment. If there is insufficient amplitude, try 3 V to get the clock running, clean all the contact points again and adjust, before returning to run the clock permanently on 1.5 V.

Once the pendulum is swinging correctly, mount the movement. The movement is turned by the magnets in the shallow box just below and behind the front edge of the movement case. The force transmitted is very small and there must be almost no friction. The magnet case must be as close as possible to the movement without fouling on the casing as the pendulum swings. It's possible that the horseshoe magnets could have been turned round. Check the polarity with the diagram in this paper and if necessary after dealing with the movement and gearbox, consider re-magnetising.

A non-running movement may need cleaning. To see whether the movement needs cleaning, remove the gear casing and its worm gear, fibre wheel and brass gear. The lower end of the worm gear is

magnetised and turning the gearbox over in the hand should be sufficient to allow this to turn freely under its own weight. If not, the pivots in the gearbox will need cleaning. There are different designs and in some the upper pivot can be screwed out of the gear case but in others you need to remove the brass at the bottom of the gear case. In both types the pivots are delicate and the worm is easily broken. On reassembly the lower pivot must be carefully aligned because otherwise its jewelled pivot will bind the worm gear.

The clock is regulated by the adjustment screw in the top of the base. This works by moving a small steel strip in relation to the pendulum bob.

Since there are few clocks in circulation, repairs on these clocks are not too frequent. Therefore it is important that the information on repair work be shared so a common body of knowledge is evolved. The clocks that have been through the author's hands all showed some form of damage and/or were misassembled. One should expect that there might be one of all of these issues to deal with:

1. Drive coil continuity. The design of the Warren does not offer any significant protection to the wire windings on the drive coil. It is possible to break wires while removing the pendulum and in some cases just moving the clock, when sharp edges of the "C" shaped bob or beat pointer come into contact with the coil.
2. Tray Magnets. These have in some cases either been reversed or lost. The gilt brass cover is a press fit on the tray carried by the pendulum. If this tray comes open the magnets are free to fall out.
3. Motor. If the motor casing remains sealed there is a good chance that it remains operational. However, if there is evidence that it has been tampered with then it will be worth taking a closer look during a diagnostic phase.

Adjustments. There are many misalignments that can affect an otherwise operational clock and cause the repairman to look for problems where there are none. If after going through the check procedures the clock does not function or only functions intermittently look at the relationship of tray magnets to the cap of the motor and assure yourself the absolute best alignment has been attained.

1. Coil

The most common damage is to the coil. The windings are composed of fine "horsehair" wire unprotected by a wrapping or cover. It is easy to strike a sharp edge of the "C" shaped bob against the coil when hanging or removing the pendulum. Repairs to the coil can be made without too much trouble and can be almost invisible, once the break(s) is (are) found. Start with a visual inspection with a magnifying glass of the outside windings facing the pendulum bob and look for sharp creases in the outer windings. Employ a needle to inspect the integrity of the wire at these points. Once the break is found, use an X-acto knife or razor blade to scrape off the varnish insulation from both sides of the wire for a short distance. Hopefully there is only one break. Use an ohmmeter to determine if there is continuity from both sides of the break back to the two rods running up the backside of the column. If there is more than one break the windings will have to be carefully unwrapped in order to find the pieces to be removed. Again most of the problems will be near the outside of the coil. Take your time and don't unwrap too much of the coil at one time. Once the disconnected pieces are removed the remaining ends can be tinned, twisted and

soldered together so that the joint is almost invisible. To protect the solder joint, used a little brown or black candle wax over the joint. Set a piece over the joint and use the heat from the soldering iron to cause it to flow.

2. Tray Magnets

As Mr. Cramer discussed above, get the pendulum oscillating without the movement mounted first. With the movement mounted and after following his instructions it still will not run, then a motor service may be indicated. But before the motor is condemned first check the magnets in the pendulum tray. For this operation a toy compass of small diameter, say 3/8-1/2" is handy. With the pendulum oscillating (and the movement removed), hold the compass in the position normally occupied by the brass cap on the motor. The compass needle should begin to rotate in step with the oscillations of the pendulum. If not, suspect that either the magnets have been replaced in the wrong polarity or they are demagnetized. The tray cover can be carefully pried off of the tray and the horseshoe magnets removed. **Refer to photo 18.** Re-magnetizing will not be treated in this article but can be accomplished readily. For practical information refer to Peter Smith's website http://www.horologix.com/ which shows methods for re-magnetizing Bulle magnets as well as measuring their strength.

Photo 18, Magnet tray with Horseshoe Magnets.

3. Motor

If the oscillating magnets in the tray caused the compass needle to rotate there is a good chance that the problem lies in the motor with the worm gear and the magnetized arm attached to it's lower end. Remove the four screws that attach the movement cover. Remove the minute hand nut and the minute hand. This will allow the minute wheel to be removed giving access to the motor. Remove the 2 screws from the motor mounting plate. (If your clock does not have a mounting plate then remove the dial and then the four screws securing the motor housing). Remove the four mounting screws from the mounting plate that attach it to the motor housing. Remove the mounting plate; it may be attached to the housing with Shellac that shows up as a brown material. If so, then soak it in denatured alcohol over night and try again. *Caution, when the plate is removed oil may drain out of the motor case.* Once the plate is removed the motor should

look very similar to the one shown in **Photo 19.** At this point it should be easy to verify the freedom of the worm gear. If doesn't, as Mr. Cramer says, *"turn freely as the case is turned in the hand"* then the unit needs service.

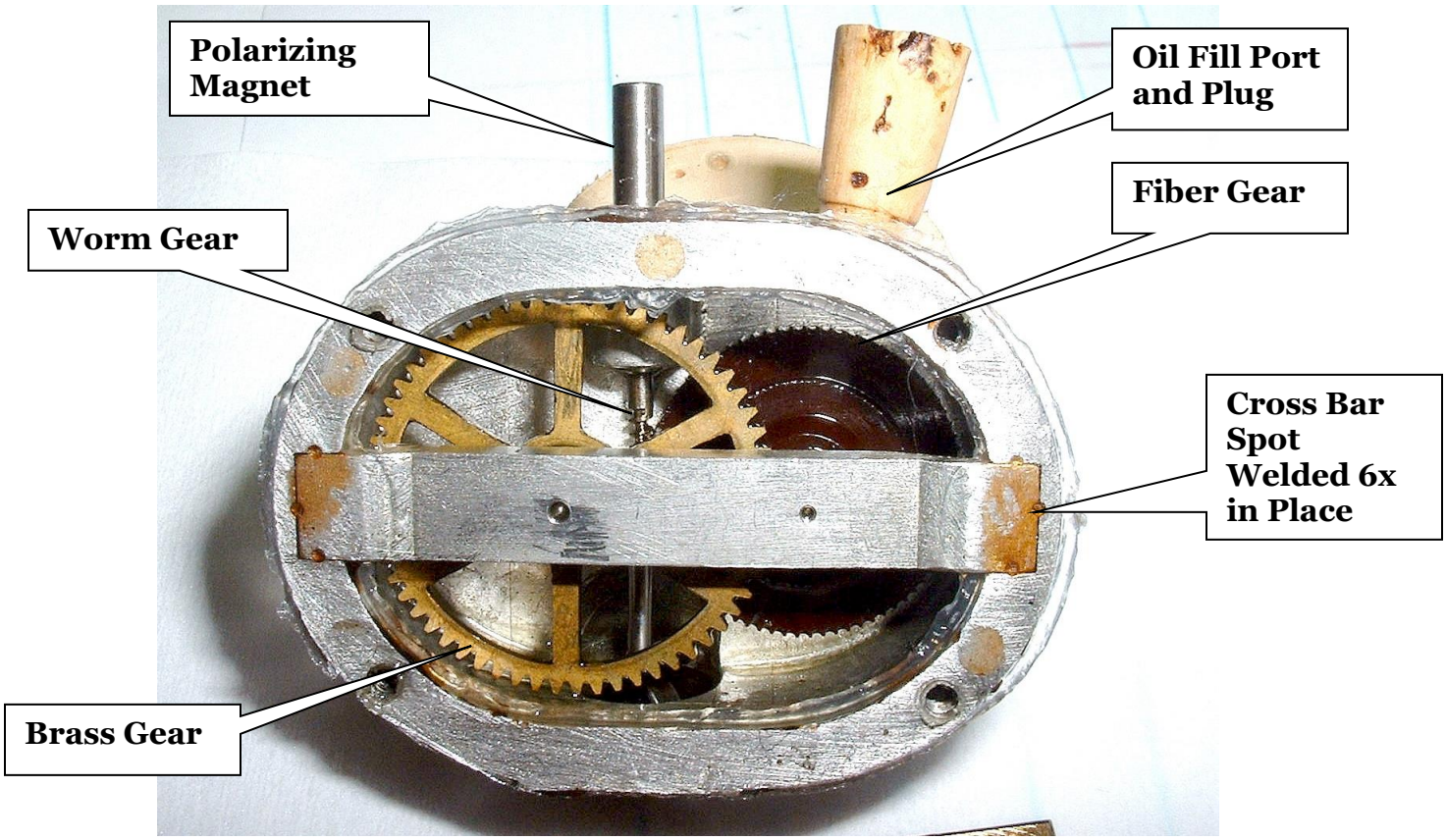


Photo 19, Motor housing with Mounting Plate Removed.

Removing the Worm Gear. To remove the Worm Gear, begin by soaking the motor in alcohol overnight. The best alcohol for the job is Shellac thinner, which is free of water that could cause rusting. Do not use stronger solvents as the fiber gear could be affected.

While the overnight soaking process is going on, prepare the new shellac "glue" for reassembly. Place ~1 teaspoon of shellac crystals in the bottom of a jar with a lid and add enough alcohol to just cover the crystals. Cap and allow to stand overnight. The next day the crystals should have dissolved and formed a sticky, thick liquid. This is the shellac cement that will be used in replacing the Brass Cap, Polarizing Magnet and sealing the Motor Case to the Mounting Plate.

After soaking overnight, use a "Q" tip and a sharpened piece of pegwood to remove the majority of shellac from the outside of the case and especially the area surrounding the Polarizing Magnet (if your motor has an external one) and the Brass Cap. Before beginning the Cap removal, place two "witness" marks one on the Cap and one on the Motor Housing to enable the Cap to be replaced in the original orientation. Keeping the Brass Cap area wetted with alcohol, try to find a gap in which to introduce the edge of a double-edge razor blade. Once the edge of the blade is introduced, rotate the motor housing while holding the blade in the gap firmly. Watch out for cuts! Keep the area wetted with alcohol and soon an even gap should appear. Switch to a single edge razor blade and then to a case opener or pocketknife. Take your time! Once a pocketknife blade can be pressed into the gap a ***slight*** prying action can be attempted, something like opening a paint can. Take care not to pry too much on one side or the Cap will become jammed or the Worm Gear pivot broken.

Once the Cap is removed, ***carefully*** shake out the Worm Gear. Examine the pivots under a magnifier for damage or adhered metal shavings. **Refer to Photo 20.** Next, preferably while holding the external Polarizing Magnet with a collet in a lathe, begin to try and loosen it. Gently twist the Motor Housing back and forth until the shellac gives way and the magnet is free. Note, some of these external magnets may be threaded into the housing. Examine the inside end where the pivot of the Worm Gear runs. Look for obvious signs of wear, elliptical holes such as in a clock plate. Also, because they are magnetized, both the Worm Gear and the Polarizing Magnet will attract and hold any steel shavings. Use Rodico or a similar product to remove them.

Inspect but do not remove the Brass and Fiber Gears. The Cross Bar in this model is spot-welded into the case and if the gears turn freely there is no need to remove them.

Cleaning. Using an Ultrasonic Water-Based Clock Cleaning solution, clean the motor components. After the cleaning bath and holding them in a strainer, rinse in hot water, blow off excess water using a hand blower or a can of dust-off. Rinse in denatured or 90% Isopropyl alcohol and again blow off the access liquid. Transfer parts into a warm oven to finish. Inspect to ensure that all remaining shellac and other foreign materials have been removed. Be sure to inspect the Worm and Polarizing Magnet for steel particles adhering to them!

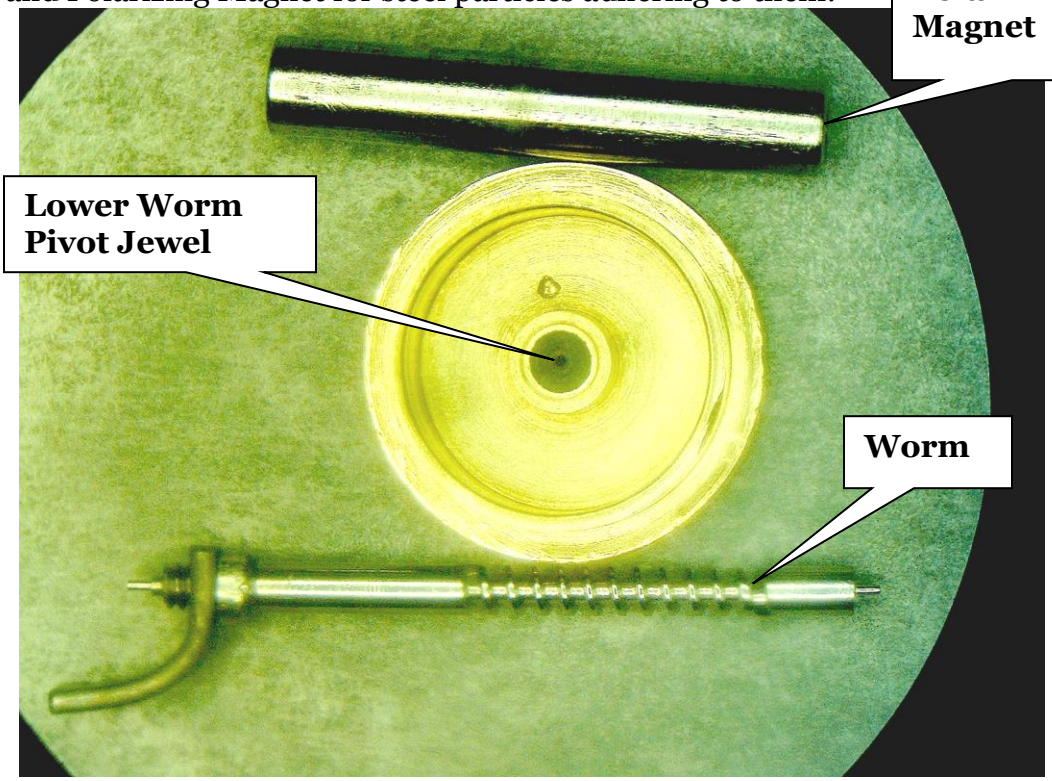


Photo 20, Worm, Lower bearing and Polarizing Magnet.

Reassembly. Ensure the Motor case is clean and dry before beginning. Place the Worm Gear into the housing (be sure it's in the right way before continuing). Start the cap into the Motor body, taking care to align the "witness" marks and at the same time pressing the Cap in evenly. Do not allow the Cap to wedge against the Worm Gear pivot! Once it is in ~ ½ way, apply a thin but even layer of shellac glue around the body of the Brass cap and press it firmly home. Some shellac should ooze out, wipe off the excess. Start the Polarizing Magnet into the case making sure that the pivots of the Worm Gear enter into the

bearings in both the Cap and the Polarizing magnet. When both pivots are in the bearings, paint a small amount of Shellac around the magnet and case and work it in to the gap by rotating the magnet. Check to make sure that the Worm has just a little end shake. Try rotating the Worm Gear by passing the magnet tray back and forth under the motor, and then put the motor housing aside to harden.

When the shellac has hardened the motor case can be joined to the mounting plate. Paint shellac on to the edge of the motor plate that comes in contact with the adaptor plate. Be careful not to let too much shellac enter the mounting screw holes. Bring the adaptor plate into position with the motor housing and start the four screws into the motor casing. Tighten so that the casing and the adaptor plate come together evenly. Wipe off the excess shellac, and allow to harden several days at least. When the shellac is hard to the touch, continue with the assembly.

After several days the shellac should be dry and the motor case can be partially filled with mineral oil. The Keystone article refers to the motor casing having "*a cup or depression filled with a fine quality of light mineral oil"* **8.** With this specification in mind, Crystal Plus 70FG was chosen. It is a lightweight (about the same as 10 weight motor oil) food-grade mineral oil available from STE Oil **14**. Using an eyedropper or syringe, insert ~1 ml (about 1/5 teaspoon) of oil into the motor casing. Wipe any excess off of the outside of the casing and insert the plug. It appears that in the case of this unit at least that a cork like the one shown in **Photo 19** was originally used. Apply shellac to the cork to motor casing interface. Again, allow the shellac some time to dry before installing in clock. No other oil should be used on the Warren clock. Most of the arbors run in graphite bearings and as such are self-lubricating.

Batteries

These clocks were designed to run on a custom single-cell battery of 1 ½ Volts. **Refer to Photo 7.** A "C" cell should be used with an adaptor (the center tube from a roll of fax paper will sometimes work). The spring required can be had from a toilet paper roll holder stretched to give a positive contact force. Care should be taken not to use too stiff a spring or the contact arm on the column will be bent.

There are many variations in the Warren clock construction, it is however hoped that the above information and instructions will furnish the basics with which to not only place them in a rightfully prominent position in the development of the synchronous motor powered clocks but also to appreciate them for their own unique technical charms.

Conclusions and Request for Further data.

One of the most attractive aspects of collecting and researching timepieces is opportunity to continue to learn. The Warren clocks are a prime example of an unfolding history. If you have information to share on these fascinating objects please contact the author @ richfhatch@hotmail.com

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