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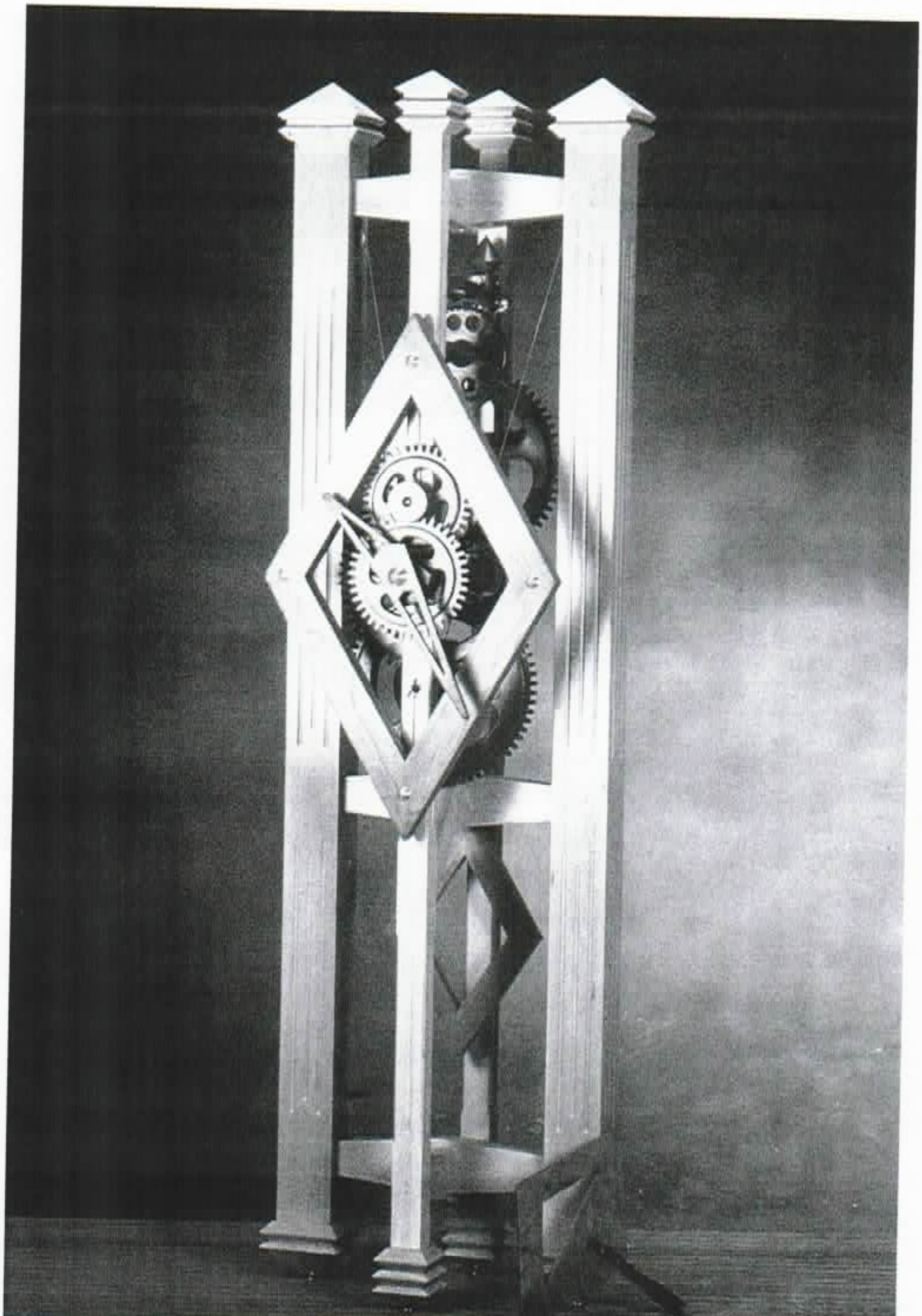
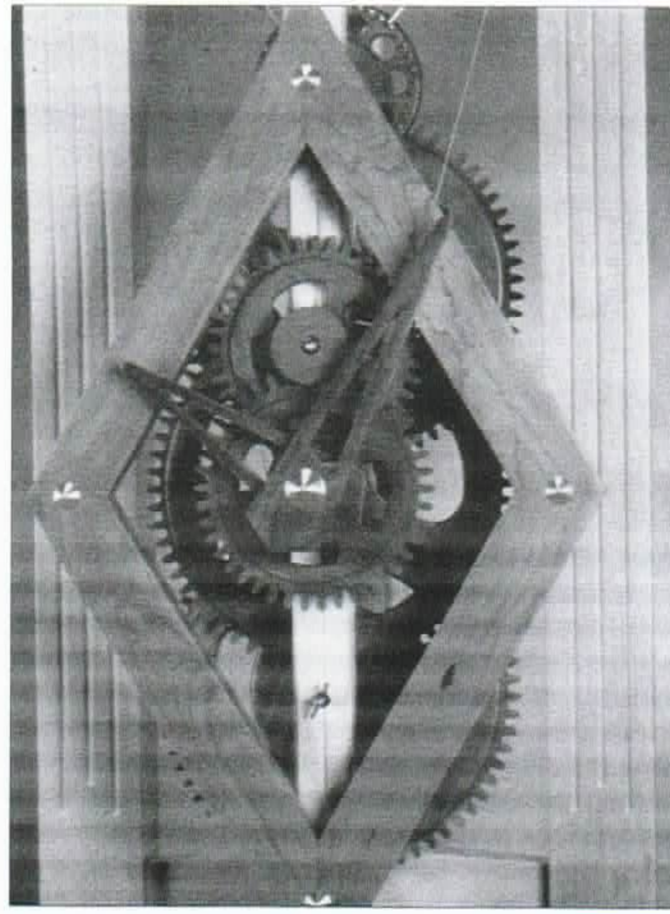


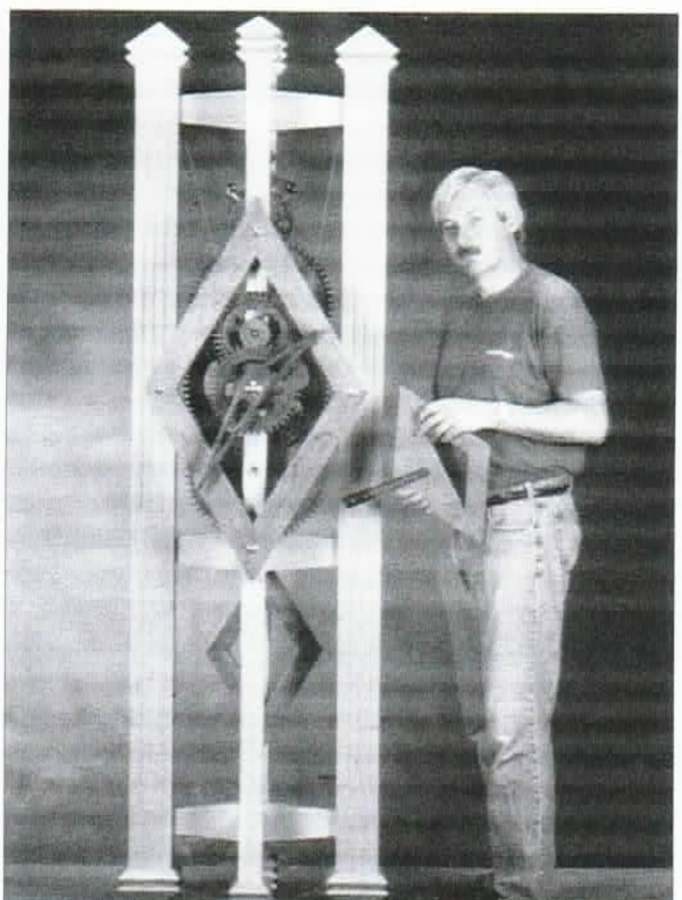
American Watchmakers-Clockmakers Institute

Pillars

By Michael Kuyt



"Pillars" is a weight-driven wooden gear clock that stands 88 inches tall, weighs nearly 300 pounds and has gears (wheels) 15 inches in diameter. The pendulum is suspended on .010 inch diameter stainless steel wire and appears to float through the air as the clock runs. All wood components are solid cherry. The frame is stained white as opposed to being painted, allowing the beauty of the grain to show through. Accents are polished brass and gold leaf. The escapement is a modified Graham dead beat and the clock is driven by two 25-pound weights that run hidden inside the large pillars.

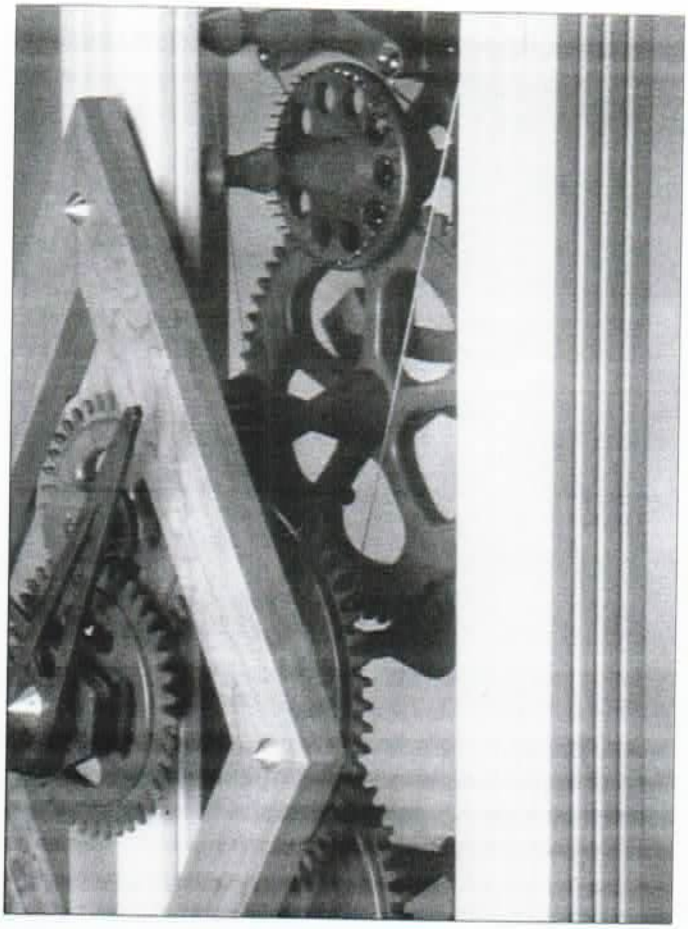


The architectural themes, geometric shapes, and white color of the frame contrast the darker wood tones of the working mechanical parts. The movement, therefore, stands out and becomes the focal point of the sculpture while the white frame integrates visually into the structure and decor of its surroundings. Typical functional and esthetic features no longer hold to conventional norms.

During the industrial revolution, mechanical devices were manufactured that allowed us more free time with which we could appreciate traditional art. Then, with the influence of modern artists such as Wendell Castle, functional furniture such as clocks, gained acceptance as a legitimate art form. Now we have the opportunity to go a step further in defining what constitutes art. We are starting to see more instances of the normally hidden mechanical parts of a device such as in a watch or clock become the main artistic and aesthetic theme of the piece.

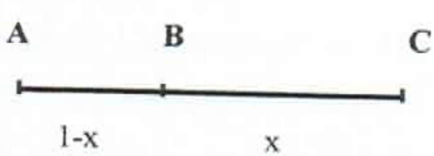
Golden Section

A number of the prominent visual features of "Pillars" are based on the proportion known as Golden Section. The width to length ratio of the dial, pendulum bob, and winding key for example are exactly golden section or 1 to .61804... . For centuries, even millennia, this proportion, sometimes called Golden Mean or the Divine Proportion,



has been considered by architects, artists, and composers to be the most pleasing to our senses. The Parthenon's front elevation, height to width is Golden Section. Leonardo da Vinci used it either by design or by default in his drawings. The lengths of related phrases or movements of music by Beethoven, Bella Bartok, and others have been shown to be exactly Golden Section. Furthermore, it occurs naturally in the world around us in truly stunning creations.

It can be defined mathematically several ways. Perhaps the most direct would be to consider a straight line AC with a point B in between. When AB/BC = BC/AC, you have Golden Section.



If you consider the length AC to equal one unit of measurement and x to be the length of BC, then;

$$\frac{1 - x}{x} = \frac{x}{1}$$

Deriving the numeric value for Golden Section using the quadratic equation is done as follows:

$$\frac{1\text{-}X}{X} = \frac{X}{1}$$

$$X^2 = 1\text{-}X$$

$$1X^2 + 1X\text{-}1 = 0 \qquad (ax^2 + bx + c = 0)$$

$$\frac{-1 \pm \sqrt{1 - (-4)}}{2} \qquad \left(\frac{-b \pm \sqrt{b^2 - 4ac}}{2a}\right)$$

$$\frac{-1}{2} \pm \frac{\sqrt{5}}{2}$$

$$-.5 \pm 1.11804$$

.61804 (X must be positive)

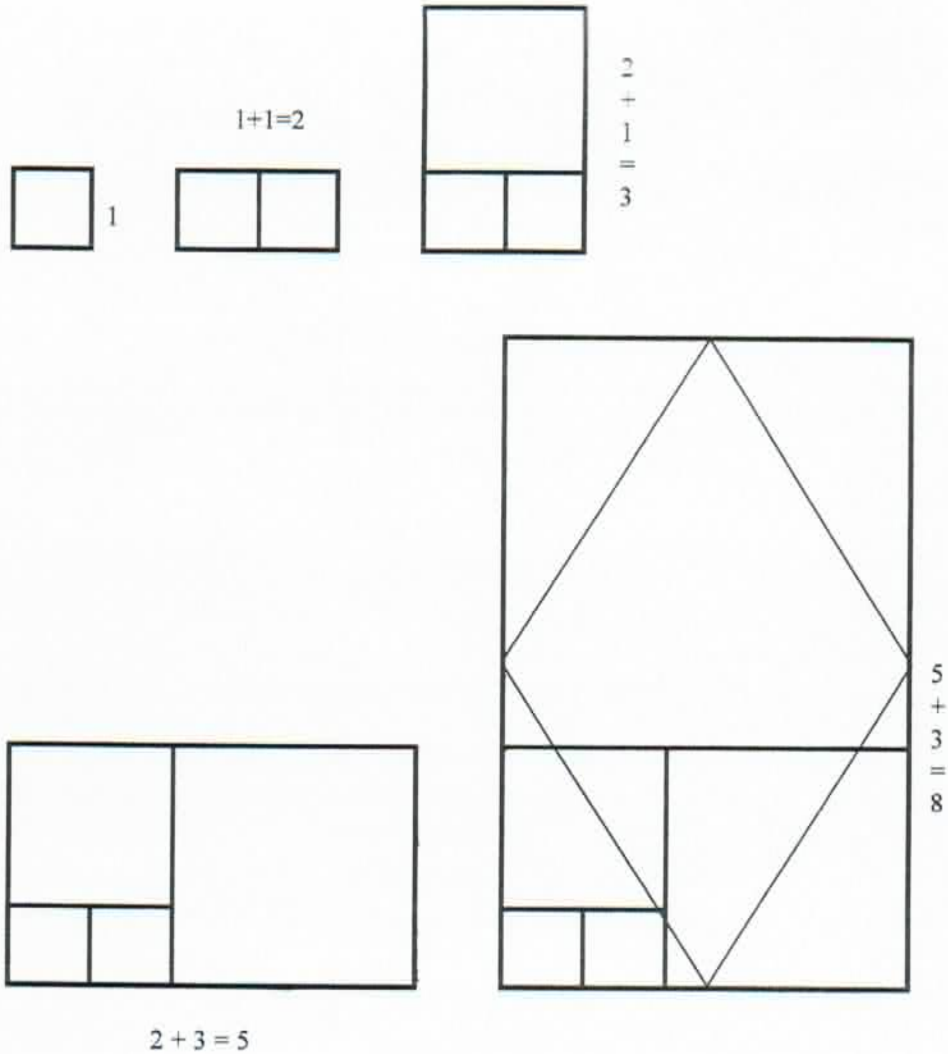
Golden Section is closely related to the following Fibonacci series of numbers based on integers. If you make a list of numbers starting with 0 and 1, and every new number is the sum of the previous two, it looks like this: 0, 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377, etc. The first few groups of two numbers in this list when divided by each other don't work so well, but very quickly you find that any two sequential numbers when divided into each other is very close to being Golden Section or .61804. As an example, 21 divided by 34 equals .61765 or 233 divided by 377 is .61803!'

The ancient users of Golden Section may have derived these numbers through a simple geometric process. If you begin with a square and define the length of the sides as 1 unit and then lengthen it by a distance equal to its height, you have a rectangle with dimensions 1 by 2. If you take the longer side of the rectangle and add that dimension to its height, you now have a rectangle 2 by 3. Take the longer side of that and add it to the width and you have 3 by 5. Add its 5 dimension to the 3 and you have 5 by 8. If you continue this a number of times, you will get very close to the Golden Section proportion.

The shape of the dial for "Pillars" is shown inside the resulting Golden Section rectangle. (See illustration on page 12.)

Windmills

My interest in large wooden gear devices began as a boy when my dad told me stories of the windmills in his native Holland. He told of wooden gears up to 8 feet in diameter and 300 years old that were still turning and doing the work they were originally designed to do. The gears were sometimes set on fire and then put out to create



carbon that would serve as a natural lubricant. When the wind was brisk, some of these mills could generate upwards of 300 horsepower! The large turning blades of the propeller were a force to be reckoned with and it was advisable to stand well clear. In our world of fast changing technology, where your computer is obsolete a year after you buy it, I find it fascinating that these wooden works devices have endured so long and are still hard at work today.

As a young man I decided to study clocks and took the clockmaking course offered by The American Watchmakers Institute in Cincinnati. With the help of excellent instructors I learned a great deal about horology, clock theory, and design. I now own and operate a small clock repair shop in Rochester, New York. I have had the privilege of restoring two tower clocks, a large Seth Thomas built in 1905 which is located in the Sibley Building on Main Street in Rochester and an "A" frame by Reeves and Company built in 1849 for the City Hall of Canandaigua, New York. The large massive gears and skeleton format of tower clocks is consistent with my particular interests in clockmaking and it was a real privilege to work with and learn from those historic pieces.

The Gears (Wheels)

The gear teeth on "Pillars" are true epicycloids. A custom-written computer program allows me to plot out 10 times actual size the profile of teeth based on various criteria such as gear ratios and pitch circles, etc. With the help of an optical comparitor, cutting knives are precision ground to the correct scale.

The moisture content of the wood used is carefully monitored. The ideal and most stable moisture content for furniture to be used in most of the United States is approximately 8%. In Florida and some South East States the ideal number is around 11% and for the Arizona-New Mexico region, it is about 6% . The moisture content of wood can be determined by taking a small sample and quickly and accurately weighing it before any moisture exchange takes place. Then it should be placed in an oven at between 214 and 221 degrees. Within 48 hours, most species will be completely dry. Remove the piece and quickly weigh it before it absorbs any moisture from the surrounding air. The moisture content is then calculated as follows:

$$\frac{\text{starting weight - dry weight}}{\text{dry weight}} \times 100 = \% \text{ of moisture content}$$

I am now using quartersawn cherry for the gears because it expands and contracts across its grain half as much as plain sawn with moisture changes. The coefficients for dimensional change in black cherry per 1% moisture change within the 6% to 14 % range are as follows:

For tangential or across the width of plain-sawn boards it is .00248".

For radial or across the width of quartersawn boards it is .00126".[2]

The gears are made up of many wedge-shaped pieces of wood arranged in a circle. Each tooth has equal strength since the wood grain runs radially out from the center all the way around. Two wooden flanges sandwich the core tooth layer for added strength and stability.

In addition to aliphatic glue (yellow wood glue), epoxy is used on some of the many pieces that make up the wheels. Aliphatic glue dries by giving off water which is absorbed by the wood causing a small amount of swelling and movement in the structure. Epoxy dries without any moisture exchange. It is a self-contained chemical process, the only significant by-product being heat. All wheels are carefully balanced after finishing.

Ball Bearings

A combination of ball bearings, brass bushings, and Teflon-impregnated cintered bronze bushings are used depending on the application. I am very grateful to Ron Pierik, a mechanical engineer, for his input and recommendations relating to bearing selection. The arbors that run in the bearings are steel and are machined on a Sherline lathe.

Ball bearings are not often found in clocks. Laurie Penman, well-known author and expert in the field of clock design, indicated that ball bearings may not be well suited for clock mechanisms. There are so many contact points where the numerous balls touch the races, and at very slow speeds and low torque, bushings are probably a better choice. In the vast majority of applications, I believe that he is correct. However, I have difficulty resolving that widely held view with data that resulted from some simple experiments done in my shop with very large and heavy wheels.

I devised a method of imparting an impulse of measured and repeatable force to one of the large wheels from one of my clocks. When running on shielded ball bearings with a lightweight lubricant, the wheels would consistently rotate 5 to 6 times as far as with bushings. The ratio between distance of rotation on ball bearings versus bushings seemed to be constant even when the experiment was conducted using a range of amounts of impulse imparted and at relatively slow speeds. My experiments were limited in scope. Further research needs to be done to determine at what point in clock design ball bearings would be preferential to bushings.

Features

The wood turnings are done on a full-size machinists lathe by John Crombe, a mold maker and good friend of mine. The profiles of the turnings consist of straight lines and sharp angles and the compound slide of the machinists lathe provides the accuracy required for the turnings to properly complement the angular aesthetic design considerations of the rest of the clock.

The clock runs for three days on a winding and is wound by a large cherry key. A red wooden flag pops out of the lower part of the right pillar when the weights are nearing the bottom of their travel as a reminder to the owner that the clock should be wound. A green flag near the top of the same pillar indicates that the clock is fully wound and prevents overwinding.

A knurled brass disc is turned for precision beat adjustments. Regulation is done from the top of the pendulum assembly by turning tuning pegs normally found in a viola. The pegs draw up the wires that the pendulum bob is suspended from to make the clock run faster or can be turned to let wire out to make it run slower.

The escapement is a Graham dead beat with the only exception being the shape of the escape wheel "teeth." They are half-round pins instead of points of teeth on a wheel. The round shape of the pins contribute somewhat to the impulse along with the impulse surface of the pallets and in this way combines a little bit of a "Brocot" type action into the escapement. The pallets are individually adjustable and the verge runs on an adjustable bushing for depthing.

REFERENCES

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2. Forest Products Laboratory, *Wood Engineering Handbook*, Prentice-Hall, Englewood Cliffs, New Jersey, 1990, pps. 14-2, 14-7, 14-14.