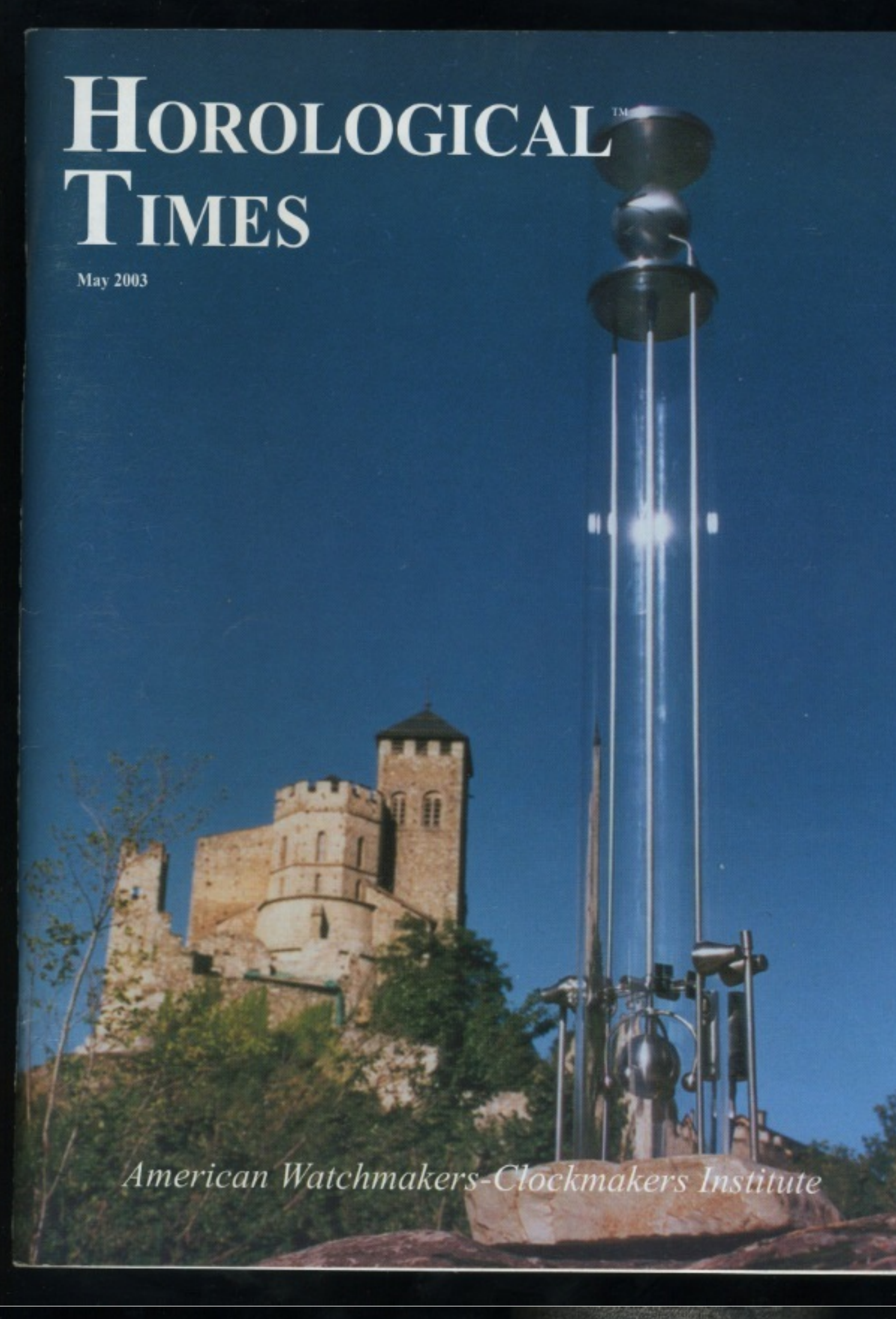
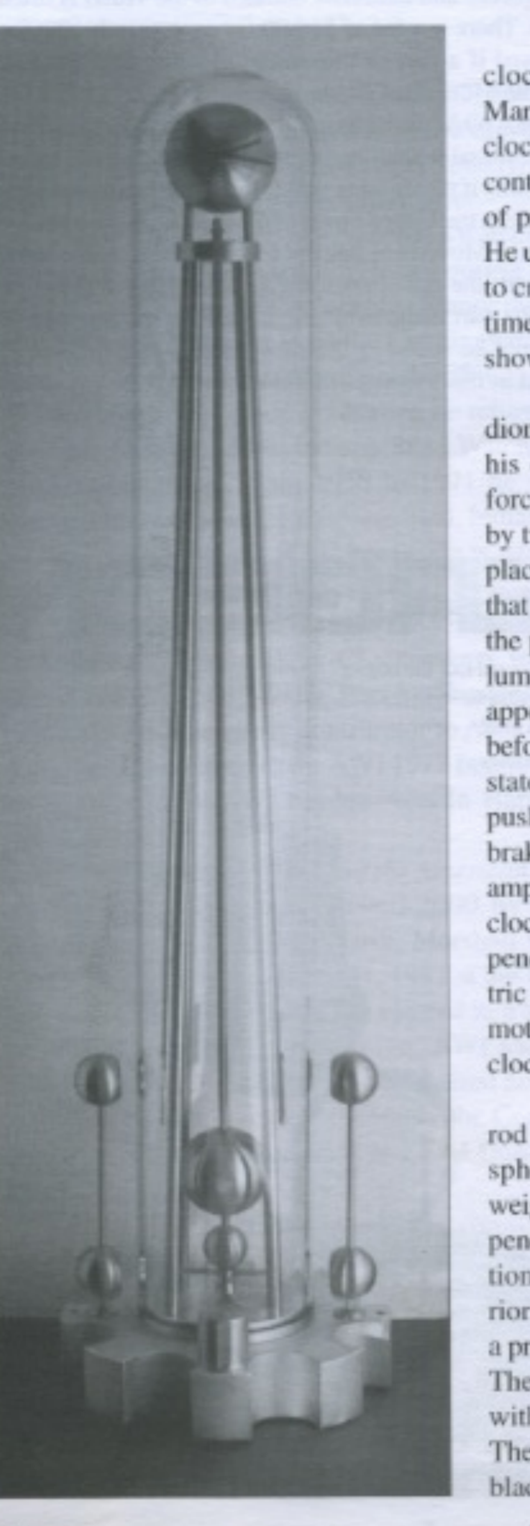
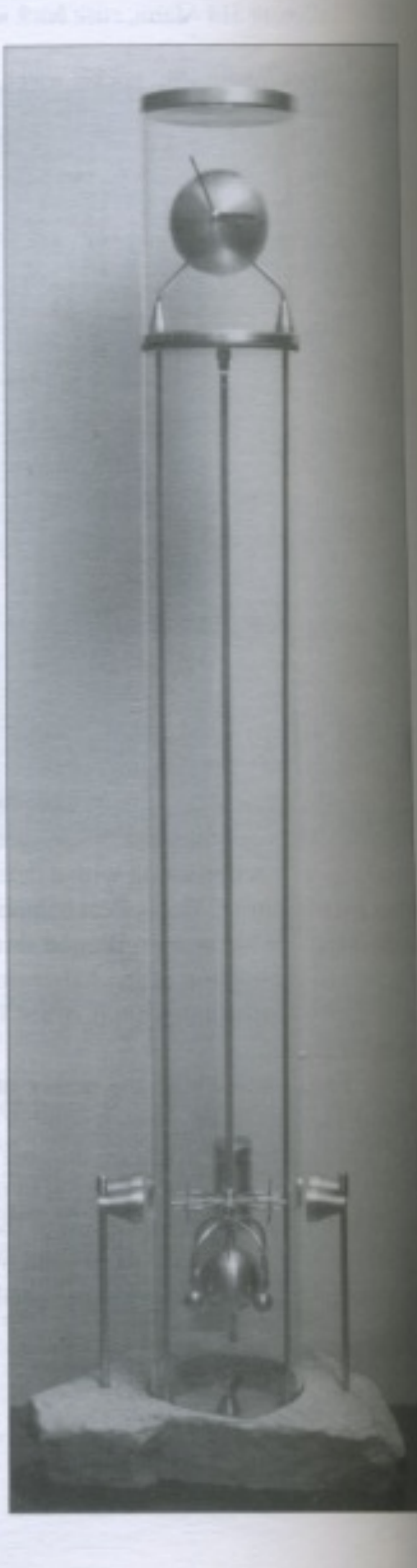


Marcel Bétrisey's Radiometric Clocks

Bob Holmström

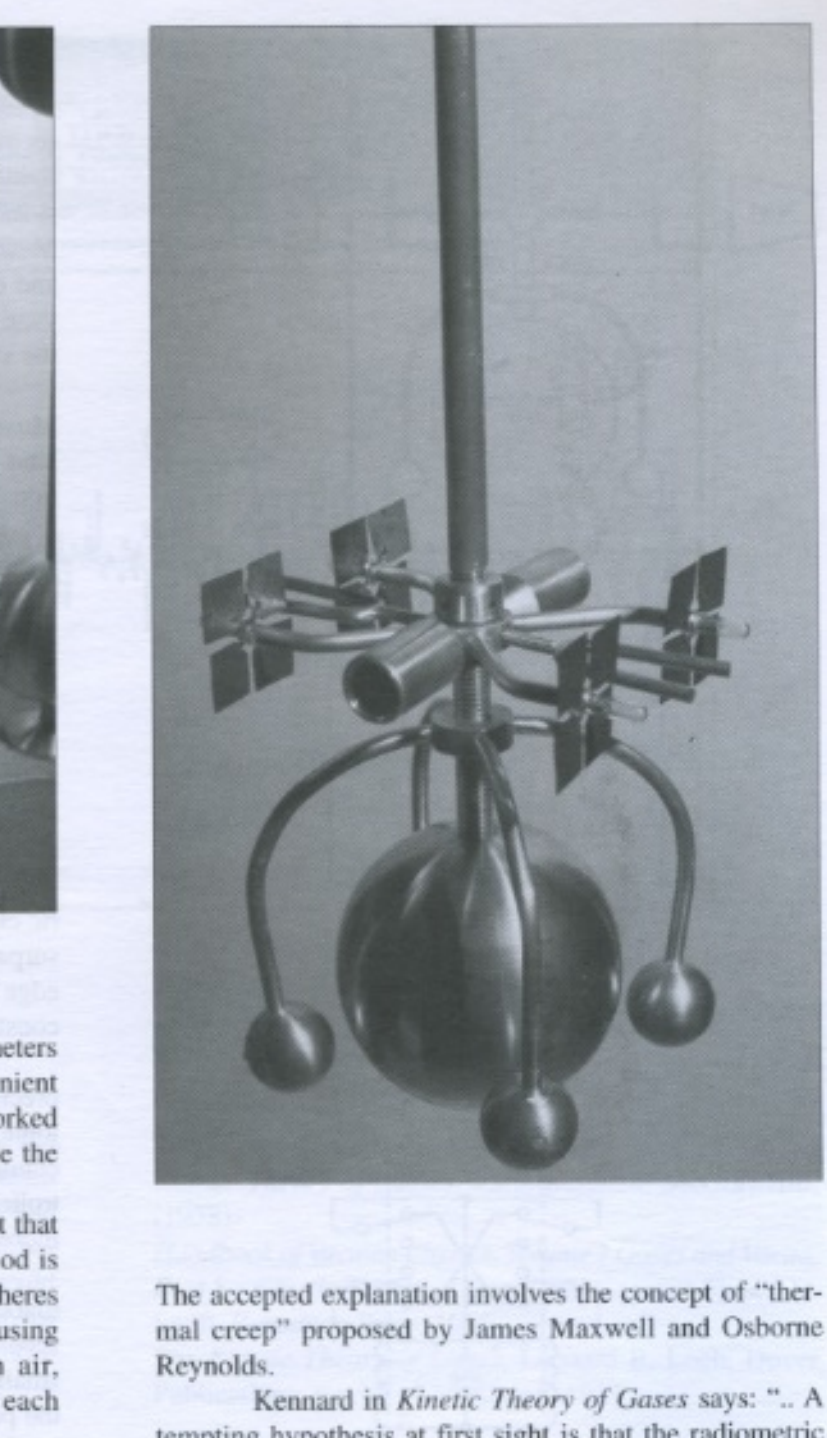




Marcel Bétrisey is a clockmaker in Sion, Switzerland. Marcel says that he may be a strange clockmaker because he prefers to use controlled "hazardous" effects instead of precise effects to drive his clocks. He uses puffs of air, moving balls, etc., to create his works of art that also tell time. His web site at *www.betrisey.ch* shows many examples of his work.

The Chronolithe, with its radiometric pendulum is different from his other clocks in that the driving force is light. This force is provided by two pairs of 5 watt halogen lamps placed on either side of the pendulum that alternatively illuminate "flags" on the pendulum rod to push the pendulum. This "motor" is simple, and it appears that nobody has employed it before for driving a pendulum. Marcel states that the lamps act not only to push the pendulum, but also act as a brake thus controlling the pendulum amplitude to a very precise range. The clock is composed of a glass tube, the pendulum assembly, two photoelectric cells, two relays and the stepper motor from a quartz crystal controlled clock.

The pendulum has an Invar rod and the bob is a stainless steel sphere filled with lead. The total weight of the pendulum is 2.3 Kg. The pendulum is supported by a conventional suspension spring in the interior of a tube that is at a vacuum with a pressure of approximately 0.01 bar. The frequency of oscillation is 0.5 Hz with an amplitude of 5 millimeters. The flags are grey mica sheets. The black side is coated with lamp black



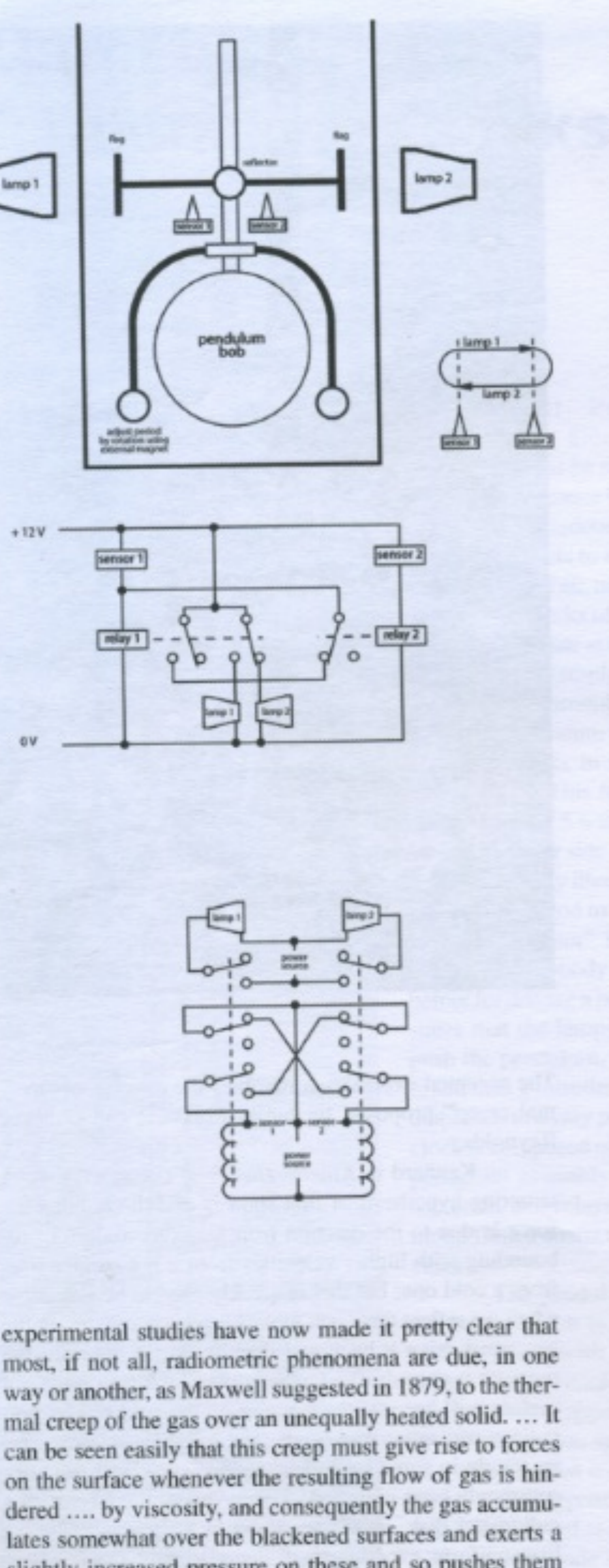
from candle smoke. Marcel used 4 Crookes radiometers with the vanes rotated because they were a convenient source and mounting for the mica material. The forked extension located between the flags is used to guide the pendulum assembly into the tube without damage.

The pendulum is started by use of a magnet that is moved close to glass. The adjustment of the period is done from the outside by turning the 4 planetary spheres as a group around the sphere of the pendulum bob using the same magnet. This avoids having to let in air, dissemble the clock and re-evacuate the air for each adjustment.

The illustration on page 13 shows the performance measured using a MicroSet for a period of 2 ½ days. Measurements were made every 10 seconds. Marcel thinks that the short term instability shown is due to inaccuracies in the infrared sensor/receiver and cat's-eye reflector used to control the lamps.

The basic principle of Chronolithe's operation was demonstrated by Sir William Crookes 120 years ago. Crookes found that the force was proportional to the intensity of the illumination. The force also increases with gas pressure to a maximum and then falls rapidly. The pressure at which the peak occurs decreases as the flag dimensions increase. The mechanism by which it operates is very complex and is frequently stated incorrectly. The accepted explanation involves the concept of "thermal creep" proposed by James Maxwell and Osborne Reynolds.

Kennard in *Kinetic Theory of Gases* says: ".. A tempting hypothesis at first sight is that the radiometric force is due to the reaction from gaseous molecules rebounding with higher velocities from a hot surface than from a cold one; but this is quickly seen to be untenable when we reflect that such molecules, upon reentering the gas, must drive it back and thereby thin it out until the pressure is reestablished, whereupon the force on the hot surface will become the same as on the cold one and no radiometric action can occur. The cause must, therefore, be sought in some secondary action. The effect has very commonly been regarded as occurring at the edge of the radiometer disk, where condition in the gas must be far from uniform; experiments designed to show that it is simply proportional to the length of the perimeter failed, however, to yield this result. Recent theoretical and



experimental studies have now made it pretty clear that most, if not all, radiometric phenomena are due, in one way or another, as Maxwell suggested in 1879, to the thermal creep of the gas over an unequally heated solid. … It can be seen easily that this creep must give rise to forces on the surface whenever the resulting flow of gas is hindered …. by viscosity, and consequently the gas accumulates somewhat over the blackened surfaces and exerts a slightly increased pressure on these and so pushes them back, …."

The action of the Chronolithe pendulum is also effected by the alternative heating and cooling of the flags as evidenced by the following statement from a reference on the Web: "Why a radiometer runs backwards after the light is turned off - Heat escapes quickly from the black sides of the vanes. Thus, the black molecules cool off first. Meanwhile, the white molecules take longer to lose heat and cool down. The result is that gasses from the white vane push off with more force (Newton's third law) and the vanes spin in the opposite direction."

Chronolithe is now on loan to the International Museum of Horology in La Chaux de Fonds, Switzerland. Chronolithe won the first prize in July 2002 International Kinetic Art Competition.

Marcel ends the description of Chronolithe on his web site with the statement: *"I've learned a lot with this clock. The most difficult thing was always to keep the look I wanted. It would have been much easier to build something bigger, with a bigger glass pipe, without the stone base, without all those vacuum tight problems... The next clock will be different: I want to make the most precise clock I can with the same radiometric principle, and this time I won't care about aesthethics. At least it's what I'm thinking now...*

Marcel has now constructed his second radiometric clock. It is called Conti and Marcel says that it should surpass Chronolithe since it has inherited all the knowledge that Chronolithe slowly instilled into him during its construction.

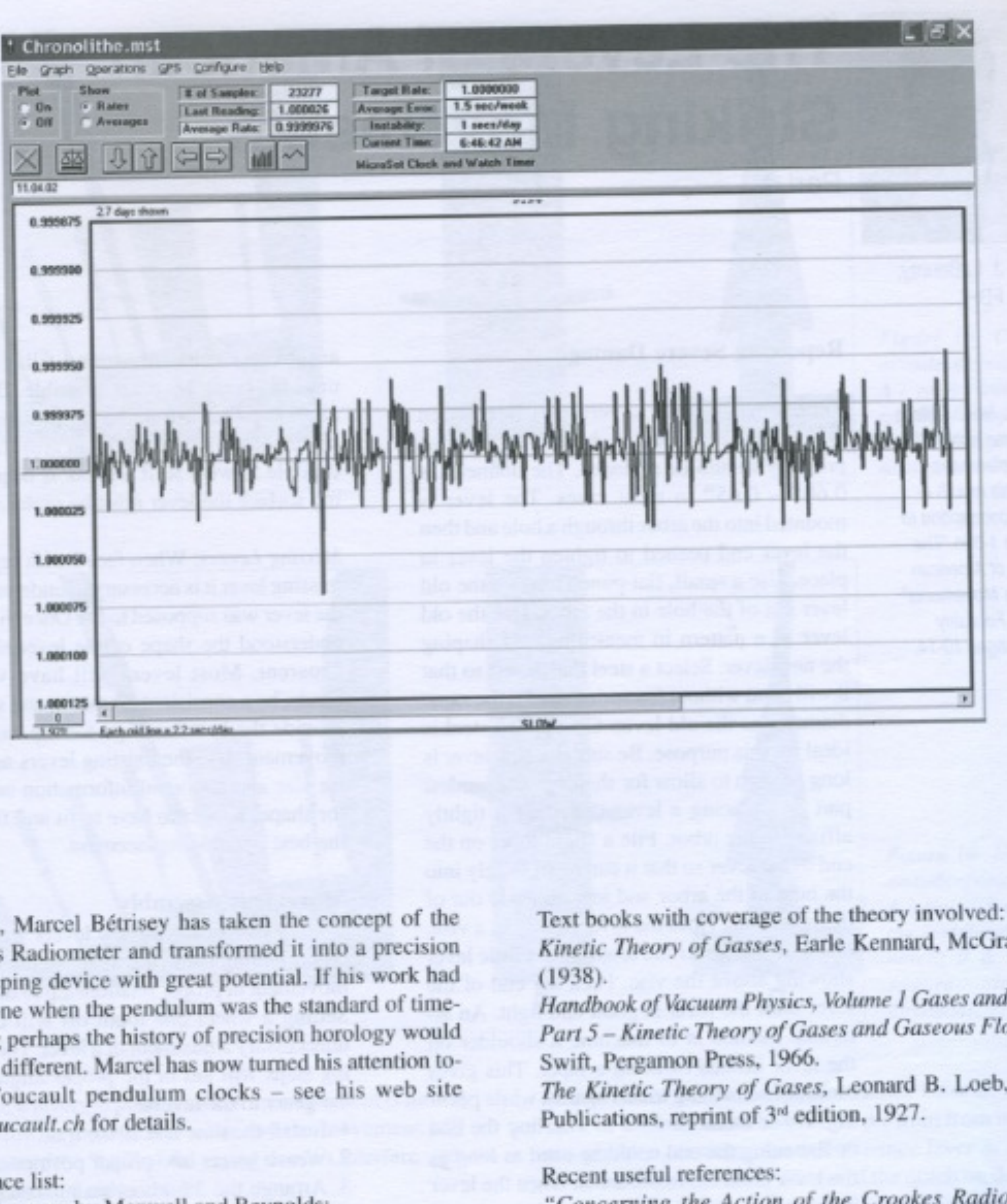
Conti is designed to be superior in sealing and precision. It is superior in sealing because it has only one joint at the bottom of the tall glass dome and no internal clamping rods. It is superior in precision because it is controlled by laser and not by infra-red sensors. It is also much more practical to work on and to adjust.

The driving force of the pendulum is the same as that of Chronolithe. The hands for the hours, minutes and seconds are moved by a stepping motor connected to two small solar panels that are illuminated at the same time the pendulum is impulsed.

The glass dome enclosing Conti is 1300 mm high, 200 mm wide and has a thickness of 20 mm. The pendulum rod is Invar. The pendulum is a sphere of stainless steel filled with molten lead and weighs approximately 4 kg. The base is a massive piece of bronze.

Two laser beams "look" at the pendulum rod. When it passes between them, the lamps in one side are turned on (depending on the sense of the swing). The lower lamp moves the pendulum, the higher lamp powers a solar panel which moves the magnet of the stepper motor for the seconds hand. The main difference from Chronolithe is that the lamps are only on during the period when the pendulum rod blocks the laser beams.

Without the benefit of horological or scientific



training, Marcel Bétrisey has taken the concept of the Crookes Radiometer and transformed it into a precision timekeeping device with great potential. If his work had been done when the pendulum was the standard of timekeeping perhaps the history of precision horology would be very different. Marcel has now turned his attention toward Foucault pendulum clocks – see his web site *www.foucault.ch* for details.

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Recent useful references:
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