APPENDIX SEVEN **A Royal 'Haagse klok'**

"Severyn Oosterwijck Haghe met privilege"

Reviewed by Keith Piggott

THE PENDULUM ~ ÆQUATIONS AND TIDES

[Reprinted from the author's *1994 Report and 1996 Thesis*]

BACKGROUND: Between 1989-1996 I studied the paradox of Fromanteel's ***ten missing masterpieces***, three of them having Royal associations. Oscar Wilde might say,*"to lose ONE Royal Fromanteel may be regarded as a misfortune, but to lose THREE Royal Fromanteels simply looks like carelessness*". John Aubrey's (1626-1697) '*Famous Lives'* (1683/4**)**, helped me to unlock that particular historic conundrum. In 1666, Fromanteel modified an "*old clock",* to show Nicolas Mercator's ***'Æquations'***; i.e. the time difference between local solar-time and mean clock-time. This was known to the ancients and was demonstrated in their ancient Analemma sundials; of course also known to all later astronomers, Tycho Brahe, Johannes Keppler, Johannes Hevellius, etc. Pendulum clocks gave ***Equations*** a new impetus, with Giles Martinot making the first pendulum observations in 1661, then Huygens publishing first manuscript Table, also in 1661. My examination, in March 1994, of a Fromanteel ***equation*** clock led to my hypothesis that Fromanteel had also contructed a ***tidal dial***- to Dr John Wallis' theory read to the Royal Society on 22nd August 1666. In their new modern scientific enquiries of the natural sciences, Galileo's pendulum and Huygens' pendulum clock had seemed a *pancea* for resolving their many questions; the uncertainties of Astronomy and Longitude; then turning their learned attentions to ***Solar Æquations and Tides***.

My examination in March 1994, of the only published Fromanteel *manual equation clock* at Belmont Park, was arranged by the Curator Jonathan Betts, by consent of the Trustees of 'Harris (Belmont) Charity', and hosted by Adminstrators Colonel and Mrs Grant - whose son was at my old school. My report (pp.16) and images (55) went to the Administrators and Curator for Trustees. Two years later, I incorporated that report into Part IIII of my thesis, *"EMERGING FROM THE SHADOWS, THE TRUE PATRIARCH OF ENGLISH CLOCK-MAKING, AHASUERUS FROMANTEEL THE ELDER (Norwich 1607-1693 London)"*. It was privately circulated; to the AHS, to referees, to the clock's Curator, also Ronald Lee and Peter Gwynn who had displayed the relic Sun-Clock at Bruton Place; and others including Dr.John Taylor. It is too long to repeat here (pp.164), only Part IIII is relevant to this Appendix 7, '*The Pendulum ~ Æquations and Tides'*. All the following **e**xtracts are from my Report and/or Thesis, incorporating my copyright images of the Fromanteel "*equation clock*", made by courtesy of the 'Harris (Belmont) Charity' - and is here republished. Jonathan Betts is still the Curator to this interesting collection formed by Lord Harris; he has asked me to point out that all opinions, [and commentaries], expressed herein are entirely my own, i.e. not opinions held by the Harris (Belmont) Charity and the professional Curator.

PREFACE: Before '*Longitude*' there was '*Latitude*'. [KP. for *'Longitude'* see *Appendices 4 and 5*]

By this I do not mean only the geographic latitude of observers' positions, but the ever changing astronomical latitudes of the sun's diurnal and annual course. The solar latitudes crucially determined all daily life, sunrise and sunset times, lengths of days and of nights, and of course the seasons of the year, also solar solstices and equinoxes. Sundials of many types measured the rudiments, ancient Analemmatic sundials (with elongated figure of eight scale) even displayed the inequality of solar time as against mean time -the 'Equations of Time'- being finally set to clockwork in the 17th Century. Dr Hans von Bertele claimed Joost Burgi achieved this in his '*book*' clock dated 1592; Alan Lloyd regarded it as being for *Lunar* equations. Certainly Fromanteel, by August 1666, had made a clock that was exhibited at the Royal Society by Nicolas Mercator from which the equations could be extrapolated; and Mercator sold another to France in 1669, before himself moving to France in 1682 at the invitation of Minister Colbert. The first clock to show solar equations *automatically* was invented and made in 1694/5 by Christopher Huygens (1627-1695), whose *equation-kidney* he relayed to Tompion and Quare via Constantijn, his brother in London, in William III's service who ordered them to construct several.

Nicolaus Copernicus challenged the geocentric solar system of Ptolomy, held to by the Church, and so proving the 3rd century BC hypothesis of Aristarchus of Samos who had first proposed a Heliocentric planetary system. Englishman Leonard Digges, with his son Thomas, championed Copernicus in '*A Perfit Description of the Celestiall Orbes*' (1576), that Galileo Galilei fatefully proved by Jupiter's moons, to the great displeasure of his friend Pope Gregory III of eponymous calendar fame. [Galileo thus *disproved* Geocentricity of the Universe]

To determine the several solar tables required observations of the sun's apparent positions. The sun's apparent latitudes, north and south of the equator in the course of the year, between the tropics of Capricorn and Cancer, called '***Declination****s*'. The sun's apparent daily compass points of rising and setting, called '***Amplitudes***'. Also the sun's changing height in the sky during each day at any given geographic latitude, called '***Azimuths***'. Horology's great challenge was to display all of these in one mechanical helio-astronomical clock.

Ante-dating all is the 'Antikythera Mechanism', representing complex hand-held instruments, encompassing ancient theories held by the ancients. Later, circa 50-BC, among the first astronomical 'clocks' was the Andronikos of Kyrrhos' "*Tower of the Winds*" at Athens [in the Roman Agora] which housed an elaborate '*Clepsydra'*, having a large rotating bronze planetarium within a zodiac.

As soon as mechanical clocks were invented their monotonous motions were encompassed to drive monastic alarms, also striking or chiming work, and were soon engaged to drive and display astronomical progress of the heavens, the moon, and the sun. In the 14th century, England's Richard of Wallingford (d.1336), Abbot of St. Albans, built his astronomical clock, with a tidal dial - [not repeated until Dr.Wallis's work in 1666]. By 1364, the Paduan Giovanni Dondi (1318-1389) had completed his great multifaceted planetary clock.

The first clock dedicated to show *solar* motions, an *Helio-astronomical* clock, recording the all sun's diurnal and annual motions, appears to have been the fabulous sun-clock described by John Evelyn on 1st November 1660, and also by William Leybourne in 1694 who had a hand in making it in 1649, with Fromanteel of London. This last date places it in the pre-pendulum era. That might explain why Oliver Cromwell championed Ahasuerus Fromanteel during 1655, and why King Charles II had it in his Closet of Rarities - after his restoration in 1660. Leybourne also describes this *Solar* clock's early use of a minute hand, with rare minute striking, grand-sonnerie strike, and changing musical barrels played three hourly. This complex *astronomical, solar-declination, and musical clock*, was commissioned by lawyer Mr Dudley Palmer of Grays Inn, maternal grandson of Thomas Digges. [gr.g.son of Leonard Digges; uncle Sir Dudley Digges was **Master of the Rolls**, his cousin Edward Digges, **Governor of Virginia,** became Palmer's Administrator in Intestacy, 26th Dec.1666]

Fig.1. Ahasuerus Fromanteel's *'Astronomical Zodiac Helio-Declining Musical Masterpiece'* of 1649.

Formerly this relic performed all Leybourne's motions, ie. matching descriptions of Dudley Palmer's clock, (see *'Pleasure with Profit'*, 1694); matching John Evelyn's descriptions, in the King's *Closet of Rarities,* and Dudley Palmer's home, (*Diary* 1st Nov.1660 and 9th Aug.1661). Fugitive evidence reveals three-hour detent for music-work [lost with former plinth], slots for quarter-striking, also vestigial remains of a *spring-remontoir* cited by Sir Robert Moray to Christopher Huygens in 1664, also a hitherto unknown *English pre-pendulum 'cross-beat' on radial saw-wheel'* (i.e. the great Joost Burgi's third form of cross-beat ~ my acronym BXR3). [KP. Its historic importance justifies my decision to preserve his only Solar-Clock *as found*, uncleaned with all witness marks, as a true '*Relic' of Fromanteel's pre-pendulum English horology*; see my card reconstructions of its *three* lost dials]

This author suggests that aspects of this solar clock by Ahasuerus Fromanteel (1607-1693), had been described incompletely by its contemporary sources, that has led to misunderstandings by modern horologists. This relic, found and recognised in 1989, is pivotal to the evolution of English horology. In fact, all of Ahasuerus Fromanteel's subsequent inventions can be traced back to its several cross-beat and remontoir innovations; pivoted-pendulum; bolt & shutter maintaining power; pendulum cross-beat; his or his acolytes' tic-tac also anchor escapements. It is pivotal to understanding Fromanteel's *oeuvre*! At any date before August 1666, by the simple addition of an ancient Analemma, Mercator's *Equations* with annual solar declinations might have been extrapolated. My title excludes any '*pre-pendulum'* clock, although it cannot actually be proven that the RS equation-clock indeed had a pendulum! Had Ahasuerus Fromanteel already converted it, probably to his first short pivoted-pendulum, before August 1666? [KP. My considered view, of the physical and historical evidence, is not then]. For the present, I leave that question unanswered. First, I look to another Fromanteel equation clock. [KP. hitherto Fromanteel's only published "*equation clock*" and previously his only known].

THESIS: "*EMERGING FROM THE SHADOWS, THE TRUE PATRIARCH OF ENGLISH CLOCK-MAKING, AHASUERUS FROMANTEEL THE ELDER (Norwich 1607-1693 London)*"

Introduction: In 1969, Ronald A. Lee and Peter Gwynn opened their milestone exhibition at Bruton Place, "*The First Twelve Years of the English Pendulum Clock, 1657-1669*"; an unique celebration of Ahasuerus Fromanteel's earliest pendulum Oeuvre. Michael Hurst's report appeared in Antiquarian Horology[i]. My interest in Fromanteel began then, furthered by erudite articles about Fromanteel's contributions to the craft of English clock making. [KP. rather surprisingly, Ahasuerus Fromanteel has no *biographer* nor any *catalogue raisssoné*]. I acknowledge my debt to all those authors, although some historical insights seemed to lack any *'hands-on'* scrutiny, especially of Fromanteel's presumed lost masterpieces. We forget that Fromanteel worked from the 1620s, as apart from lantern clocks -definitively marshalled by Sir George White[ii]- one rarely sees English house clocks of Charles I's or Cromwell's time. Fromanteel survived England's civil wars, its plagues, and London's great fire. His early clocks belong to a fertile period in horology, but arguably his most important masterpieces, last recorded in the 17th century, were all presumed lost.

The "Lost" Masterpieces: I could include Harvard's Fogg Museum Fromanteel Lunar clock[iii], lost to America, there wrongly said to have an original anchor (now corrected). But other important Fromanteels cited in correspondence, diaries, and histories, had all quite literally been lost;

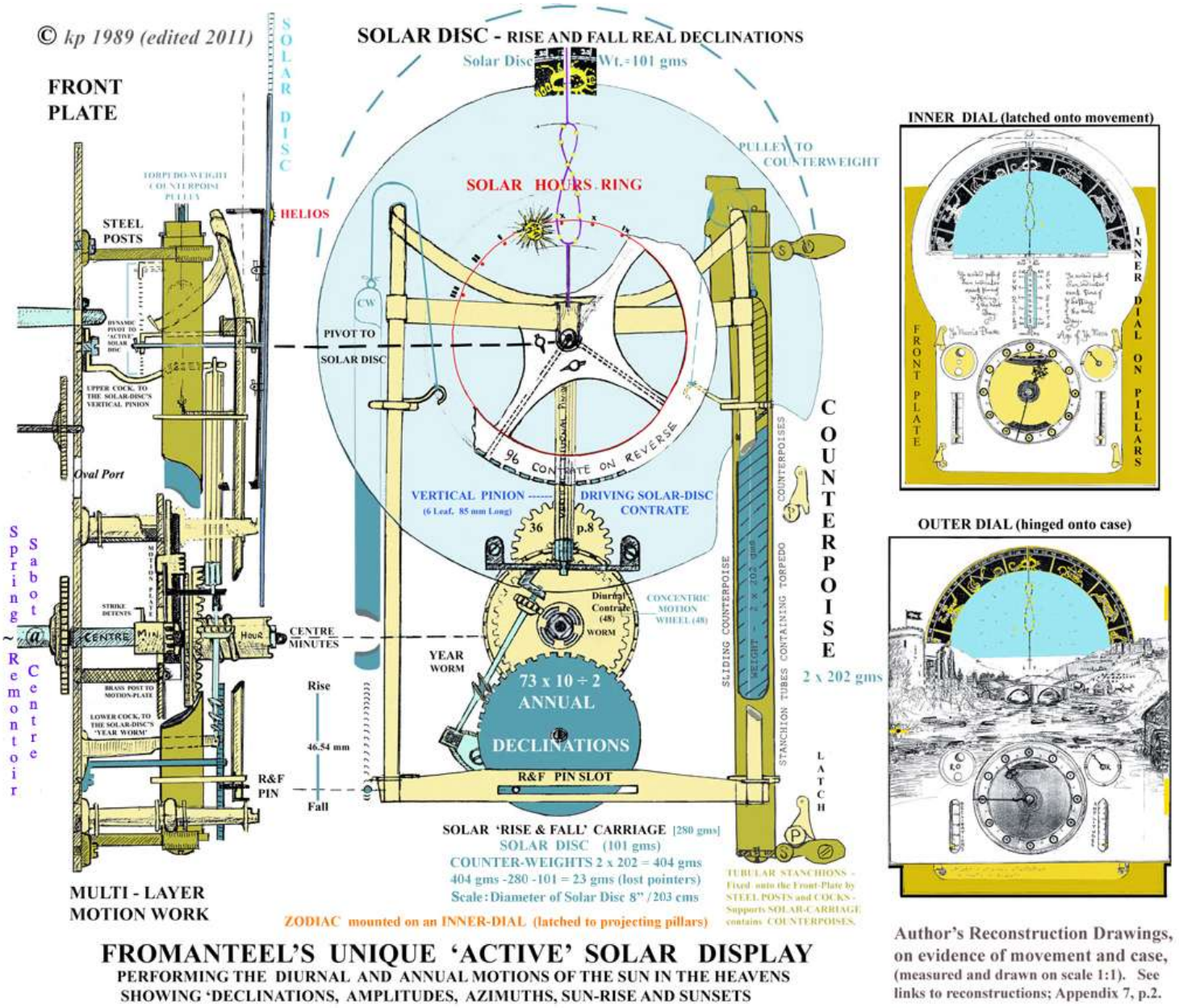
- 1650 silver automaton lady wine-server for Sir Robert Paston, (Leybourne, PWP, Mechanical XVI);
- his long-pendulum verge clocks to Huygens' design[iv]; (OC Feb/Mar 1664) [see box case]
- Seth Ward's gift to the Royal Society, commemorating Rooke[v] 1662, (Birch, Dereham 1694);
- his own "new form of long pendulum" - (cited to Sir Robert Moray by Hugens in February 1664);
- the King's old remontoir[vi], (correspondence of Moray and Huygens in August 1664);
- Mercator's equation clocks, at the Royal Society 1666, (Minutes, Aubrey 1683, Birch 1756);
- Colbert's equation clock of 1669 that Mercator took to France upon his recruitment;
- John's 1679 Austin Friars' clock[vii] lost to fire-bombs;
- Wren's weather clock[viii].
- his greatest masterpiece, the *Solar-Zodiac Clock*, cited by John Evelyn in the King's Closet of Rarities, (1 Nov.1660) one of his three clocks cited as having "Royal" associations.

In 1990 I mooted my discovery and new study of an unique Fromanteel ***sun-clock***, resulting also in my re-interpretation of horology's historic sources. Paradoxically, upon my discovery of this early relic *sun-clock*, my search widened when Sebastian Whiteston gave me Leybourne's description of Fromanteel's ***chef d'oeuvre*** of 1649, (from Leybourne's Pleasure with Profit[ix] of 1694); The noted mathematician claimed to have had a hand in its making. My new chronology corrects the misleading chronologies [of clocks] in *primary sources*;

1. Mr Dudley Palmer's pre-pendulum *solar-astronomical, musical, grand-sonnerie spring clock, showing and striking the minutes*, of 1649, (Wm. Leybourne, *'Pleasure with Profit'*, Mechanical, XXXVII, 1694)
2. The **King's** Closet of Rarities astronomical '*sun-zodiac'* clock, (Evelyn, Diary 1 Nov.1660).
3. Mr Palmer's rare *musical* clock, "*wound but once a Quarter"*, (Evelyn, Diary 9 Aug.1661).
4. The **King's** '*spring-remontoir'* clock, (correspondence Moray-Huygens Aug.1664).
5. Royal Society prototype **'*equation*'** clock, demonstrated in Aug-Sep.1666, was a *'rare clock and new motion*' to perform Mercator's equations, (RS minutes 1666, Evelyn 28 Aug.1666); [n. 'Rooke' (sic), Evelyn means Robert Hooke who succeeded Lawrence Rooke who had died in June 1661].
6. The **King's *equation*** clock, given to a Courtier then watchmaker Mr Knibb who understood it not, who sold it for £5-to Fromanteel who made it, who now asks £200- (John Aubrey, 1683).

I found historical sources relied on were often inconsistent, or ambiguous to horologists, like the cryptic nature of R.S.Minutes, or diaries of Robert Hooke and John Evelyn. Questions that aught to have been asked were not; at appropriate places I shall pose those questions! With the hindsight of my discovery, I began to question if ***six*** masterpieces had ever existed? Might they be just ***one*** clock, incorporating all their features? In his excellent Fromanteel genealogy Brian Loomes[x] touched on it, by inferring the Royal sun-zodiac and equation clocks were the same, modified by Fromanteel. It is a seductive line, but his conjecture needed resolving. {Loomes also argued that the Sun-Zodiac Clock had to be a *pendulum* clock] Historical clues were 17th Century sources, where physical evidence was presumed lost. With tangible new evidence and my reinterpretations, Loomes' conjecture is here reconsidered. Confluences suggested Royal connections, uncorroborated by any Royal inventory. But as Oscar Wilde would say, "to lose ONE Royal Fromanteel may be regarded as a misfortune, but to lose THREE Royal Fromanteels simply looks like carelessness". John Aubrey's (1626-1697) *'Famous Lives - Mercator',* helped me to unlock that particular historical conundrum. [KP. Several features in one, i.e. Fromanteel's 1649 *Chef d'Oeuvre,* made for better sense; Thesis, Parts I to VI, compared the historical and physical evidence of Sun-Clock; when that better sense was convincingly confirmed].

KP Ahasuerus Fromanteel's unique counterpoised year-carriage to the active 'Rise/Fall' Solar Disc performing the real *Declinations, Amplitudes, Azimuths, Sunrises and Sunsets.*



Nb. The provision of '***Analemma***' during 1666, would permit *extrapolations* of '*Solar Æquations*', so completing Dudley Palmer's 1649 Zodiac clock honouring his Digges ancestors' support of Copernican *Heliocentric* theory.

My re-interpretations of the historical sources, also many extant Fromanteel clocks, together with my ongoing investigations of the tangible evidence, led me to new insights into Fromanteel's working practices, ie. showing a wide knowledge of Continental developments being incorporated into his best clocks. Lessons must be drawn from his surviving clocks, and relics. I was invited to report on his unique musical weight movement, found on a Scottish white dial, clearly from Fromanteel's early Oeuvre circa 1660, having a 'staggered' triple-split front plate, interchanging music barrels, and detachable hammer unit arranged like similar spring clock's[xi]. I confirmed the workshop as Fromanteel's, [now 'restored'; with a reconstructed roller-cage, dial, chapter ring, hands, now also having forged '*signature*'].

Naturally one must examine horology's published icons, among these a Fromanteel *'equation clock*' prominent in "First 12 Years" and "Iden Collection". I counsel an open mind, even outstanding horologists can be too circumspect, or be misled; see H.Alan Lloyd[xii] "*Outstanding Clocks*" - this Fromanteel '*equation' clock with an 'original anchor'*. My examination of it in 1994 was a revelation (see Part IIII). I found its so called *'original anchor escapement'* movement had replaced two earlier long-pendulum escapements, one an unknown historic protoype; its early dial is associated; its 'equation' rings are added, but no *caveats* ever were published! However, taking this 'curate's egg' at face value, I realised its ['*contra-rotating equation hours'*] subsidiary is probably an unrecognised ***prototype tidal dial***, based on Dr Wallis's new tidal theories first read to the Royal Society during August 1666. [KP Wallis' research, read to the **R.S.** in Aug.1666, had to precede any Tidal Dial].

All the technical descriptions of this sun-clock, and other Fromanteels I have examined, are my own, and probably reveal my deliberate avoidance of bench practice. If I dwell too much on descriptions it is because I am cogniscent of the fact that my peers may seek other facets, or have better insights, that I have not explored; "*One man's maintaining-power is another's remontoir*", (Huygens v. Douw 1658). I expect to be challenged, and rightly so, but I also expect Fromanteel's sole surviving sun-clock to claim its rightful place in history, among its peers. Eventually, I hope to see it join a great public collection. I offer it first to members of the Antiquarian Horological Society, in two phases.

PHASE ONE: The historical context, and current state, of this extant sun-clock; **Parts I-VIII**; ie. RE-INTERPRETATION of historical sources, in the contexts of Fromanteel's hitherto "lost", Dudley Palmer sun-clock, remontoir clock, sun-zodiac clock, and equation clock; DESCRIPTION of a newly re-discovered multi-train sun-clock; IDENTIFYING Dudley Palmer's remarkable 1649 sun-musical clock; RE-APPRAISAL of a manual equation clock, its candidacy as first English pendulum cross-beat and Wallis' tidal dial; NEW EVIDENCE of Burgi's "cross-beat" and "remontoir" being used by Fromanteel (Douw); CROMWELLIAN and ROYAL associations with Fromanteel; considering ETHICAL restoration of an historic masterpiece; a NEW EVOLUTION of English horology; SUMMARY. In all the full extent of this paper; *APPEAL* to find other early Fromanteels, and/or his acolytes, [also 'pre-Greenwich' Tompions].

----------#----------

Part IIII. FROMANTEEL'S MERCATOR EQUATION CLOCKS, WALLIS' TIDAL DIAL

REAPPRAISAL of Belmont Park's little "*manual equations*" weight-clock signed "***A Fromanteel Londini fecit***" **(Fig.13)**; DISCOVERY of an English licensed "Huygens' long-pendulum"; also an unknown **long-pendulum cross-beat**; also an unrecognised **tidal dial**.

I investigated this, the then only published Fromanteel equation clock, for three reasons.

- **First,** to resolve its possible candidacy as a prototype equation clock Mercator demonstrated to the Royal Society at Gresham College on 29th August 1666. In the horological literature this clock is ruled out by being (ambiguously) said to have "Fromanteel's original anchor escapement", [ie. invented circa 1670][xiii]; an opinion I suspect serves horologists and historians poorly, as to me, stylistically, it always seemed to ante-date the earliest anchors by a full decade.
- **Second**, I realised that a new alternative candidate for the Royal Society equation clock had emerged, in the recently re-discovered sun-clock. Loomes mooted a possiblity that the "Royal" sun-clock might be a candidate, and Aubrey had revealed a new "Royal" association with the Mercator Fromanteel
- **Third**, to compare with Moray's description of an pendulum equation clock Mercator had offered to France's Prime Minister Colbert during 1668-9.

My interest centred on the Fromanteel equation clock Aubrey ascribed to a Royal provenance to. But, what aught to have been an routine inspection of Belmont Park equation clock challenged all previous conceptions of it. My discoveries opened up unexpected and unknown fields in Fromanteel's *Oeuvre*, and caused my immediate re-examination of the re-discovered and much earlier sun-clock's first (original) escapement at ***C0***. (see **Part V**).

Equation clocks were always rare. Depending upon one's viewpoint, the first was Jobst Burgi's lunar dial table clock dated 1591, or Mr Nicholas Mercator's Fromanteel of 1666. Dr Hans von Bertele and Klaus Maurice regard Burgi's as the first "equation" clock, but Lloyd dismisses it as having *only* 'lunar' equations. But Burgi was well aware of solar equations, his patrons were astronomers Brahe and Keppler. He put a compass and a sundial on one of his so called experimental clocks, No.1., to fix the local (true solar) time. Even given ancient analemma, in his 'pre-pendulum era', Burgi had no accurately derived tables to correct mean time from solar time or to predict the latter from mean time, and therefore no true "*solar equation*" clock.

Dr Reinier Plomp points to early use of a pendulum clock to measure inequality of sun's days, by Gilles Martinot in 1661. But Huygens was first to publish, in 1661, his manuscript of pendulum equations sent to Paris, then to Moray in London. Only then was this *sine qua non* for equation clocks satisfied. Huygens' printed tables for Gregorian calendar (1664) are now unfamiliar to our eyes; instead of four "zero" [datum] points he shows only one as he took his datum at the first maximum "sun-slow" variation in February. However equation clocks were now feasible and, in 1666, Mercator designed a prototype "solar" equation motion, fitted to an old clock. A moot point, did he use his own English equation tables, or Flamsteed's, or did he copy Huygens' style?

In 1666, the novelty of displaying the sun's equations could only be accomplished by one of four methods. The first, with sundial and regulator, is self-evident. Secondly, a datum set upon an analemma to show solar time and approximate equations. Third, a manual dial, set daily with reference to equation tables; this may be accomplished in several ways, eg. divided minute hands, adjustable minute ring. But the most complicated (and expensive) way needed a clock with a year calendar, to replace the zodiac with a calendar showing equations in tabular form. Zodiac clocks were then rare in England, but we do know Fromanteel had made one, at least, Mr Dudley Palmer's. Yet none of these had what we call "automatic correction" but were directly read or extrapolated. Yet even that was a novelty, until Huygens' new equation kidney (1695).

In 1669, Huygens had dismissed extra wheels to show the equations, he rejected all complexity detracting from this new isochronism. In 1674 Hooke instructed Tompion in "equating", it then meant regulation by the sun, [not as Symonds suggests; that Tompion had already made an equation clock]. Huygens' automatic correction by a kidney was passed to William III in 1695. Only then did our clockmakers use the equation kidney to "convert" mean time (Tompion), or to "beat" (Williamson for Quare) in solar time.

ENGLAND: **M**ercator's first demonstration of his equation clock to the Royal Society at Gresham College was four days before the Great Fire of London (2nd to 5th September 1666). **At Part I**, [of Thesis], I quoted the relevant minutes for August and September 1666. Sir Robert Moray proposed, Nicholas Mercator demonstrate his equation clock; the secretary was ordered to desire Mercator, "*if he made it not a secret*", to bring it to the next meeting; on 29th August, Mercator produced it. Evelyn was present, also Moray, and Palmer who died four months later. Evelyn gives us no description. Aubrey says Mercator's clock passed to the King's hands; thence to a courtier; to Knibb, who sold it to Fromanteel; who made it; who asked 200-Li. for it in 1683. (compare John's 1657 contract to make new pendulum clocks at 20 Guilders, to sell at 48 Guilders). Significantly, he priced it among the most valuable clocks of his day, equal to Evelyn's 1655 valuation of the late King's crystal ball clock (Pepys' bullet clock). Did he price only its new equations, or his *chef d'oeuvre's* secrets known only to himself? Did he then, make its *first* conversion to pivoted-pendulum? [KP. a second conversion raised the verge/crown for Hooke's 10" spring-pendulum]

We know surprisingly little about the equation clock Mercator showed to the Royal Society. We are not told whether it is a spring or a weight clock. RS minutes for 29th August 1666, (**Part 1**, n.47), show his "watch" (a going train, or timepiece) was approved but the Council wanted demonstrable proof "that his tables of equations are true ; and that the motion of the watch agrees therewith". It is a cryptic but probably significant observation.

Aubrey says it '*t'was a foot across'*, so complex it had even confounded Knibb. The British Museum's Horologist, John Leopold, holds that Mercator's RS equation clock was a pendulum clock with '*automatic correction'* for equations. I sought clarification of his evidence but remain unsatisfied.

I suggest Mercator's dial was manually set or tabular in form, but it is not inconceivable that he included an *Analemma*. RS minutes show that Mercator's prototype wanted in some respects; he was asked to prove "his equations" and that his "watch agreed therewith". Their requirement is instructive, as the Council would surely not challenge a manual dial that could not vary from daily tables, but they might well challenge analemmatic or tabular dials. As Flamsteed later recognised, any annual variation shows as errors in outdated tables or engraved dials. I favoured the manual dial set from annual tables as more of an astronomer's solution, but that gives no cause for the Council to challenge performance. RS Minutes show Mercator returned with his watch on 12th September, [KP. the week after the Great Fire!] and that his watch displayed the same equations as his tables that were indeed accurate. It infers he used a tabular equation dial. It was sufficient to gain Mercator's *FRS* membership on 14th November. We may reconsider Loomes' alternative, ie. the Royal sun-zodiac clock newly modified. [presuming it a pendulum, to maintain the clock Sun's course with the real Sun]

FRANCE: **F**rom 1666 to 1681, Huygens FRS, lived in Paris at Acadamie Royale des Sciences, under the patronage of Louis XIV, after being recruited by the Minister J.B.Colbert. Leopold has it that Mercator offered this same 1666 RS equation clock to Colbert in 1669. But Aubrey's history does not square with Moray's letter of 26th April 1669, to Huygens. Earlier, on 13th March 1669, Huygens advised Colbert not to load any clock with "extra wheels" to display equations. But I sense certain tensions, as Mercator had offered an equation clock to Colbert, Huygens had written to his friend Moray to ask for details. Moray's odd reply, "**your** pendulum in which each of its hands always shows the exact hour and minute without error according to table of equations", refers to directly read solar time. But is that "automatic correction"? Personally I do not think so. Yes, it had a pendulum, at that date nigh obligatory, but it does not rule out conversion of an old clock. But hands for equation hours, minutes, seconds, set *by reference to* tables (Belmont's clock) are not my *tabular* equations.

CONUNDRUMS: **W**as Belmont's the prototype equation clock Mercator demonstrated to the Royal Society, that Aubrey says the King received? I saw inconsistencies; Birch infers tabular equations, not equation hands; Aubrey's history, and Moray, infer the RS clock was not offered to France; though an offer to Colbert might be the spur Charles II had needed to acquire it, on Palmer's death [intestate], yet Jagger found no Fromanteel on Royal inventory; the King tired of the RS equation-clock, perhaps made obsolescent by 'equation hands' c.1669; Fromanteel had it back by 1683, Mercator [then living in Paris] died in 1687.

Was the new Royal, RS, equation clock the old Royal sun-clock (perhaps converted to pendulum) refitted with new tabular equations calendar? Did Mercator offer France his RS demonstrator in 1669, or Belmont pendulum type? If the same, and on the historical evidence alone I suggest it was not, was that sale consummated or pre-empted? What do French state archives reveal of Colbert's purchase? In absence, all the circumstances corroborate Aubrey's version.

THE TANGIBLE EVIDENCE: My initial inspection of the manual equation clock movement was without its case. The curator, Jonathan Betts, had already told me its case is not of the period and is probably by Van Winsum. But greater surprises were immediately evident.

First, any question of it being an "original anchor" was settled in seconds. There is clear evidence of two earlier escapements, and various conversions, so the timepiece itself is years older than the horological literature would now suggest. [Lloyd dated it 1670-1680, probably for having a purported "original anchor"]

Second, after closer scrutiny, I found that its movement and its dial are "associated". The dial feet had been replanted, to fit tall narrow plates. Ordinarily one would have set it aside but, in the interests of finding when association began and who carried it out, I continued. After all, Fromanteel could have modified an earlier clock, and to some extent I believe that to be partly the case. Because of the unexpected nature of what I found I believe it warrants a full description. It will help readers to evaluate my dating for themselves. The problem areas, chapter rings, dial feet, and regulator, all require very detailed metallurgical analysis by spectroscopy; what I now say is subject to that *caveat*.

Fig 2: The 'Manual Equation' Fromanteel, ©KP by courtesy of the '*Harris (Belmont) Charity*'

DESCRIPTION: This movement has "crested" tops to the tall slender plates. It was a short lived fashion, one Huygens perhaps noted at Fromanteel's shop in 1661. Thin plates are joined by six bugle shaped latches to the slender ringed pillars; their rivet heads very prominent, evidently before he used to file-off rivets. Original great wheel (96) has a truncated arbor inside ungrooved floating barrel, its winding square now drilled to hold a small hour hand. By its workmanship the centre wheel (8:60) appears to be Fromanteel's original. Whereas, both of the radial wheels above (third and escape) are later, ie. replacing the original contrate and crown wheel. [For Huygens' shaped plates see Manuscript Book "B", Aug-Sept.1662[xiv] also his Patent marine remontoir (1664)]

Extant maintaining power, to centre, has a robust forged coil spring, of earliest type. The wide bridge is fabricated, not cast, and also cut-away to avoid interference to the snaking shutter arm. To cock the train, the small hour hand must first be withdrawn from its square through the shutter to free cocking lever. It may be unique, surely an after thought or conversion; Lloyd regarded this dial as merely decorative, a "*contra-rotating equation hours dial*". Surely not Fromanteel's style. Of four hands one is original, the repaired minute hand, the other hands are all modern. The minute pipe's wheel has an added (later) counterpoise segment, neatly brazed, which suggests that some "**critical escapement**" was fitted retrospectively. [KP. i.e. after a first Crown-Verge, which I have identified as '*Long-Pendulum Cross-Beat*,' probably in 1663/4, *antedating Knibb's similar*].

DIMENSIONS: Key: "*" original, "x" modified or replaced, "?" uncertain
Dial - 21.0cm x 21.5cm (8.3"x 8.45") over-square - associated **[KP all dial feet relocated inwards]**
Plates - Height. 20.0cm (8.0") Width. 11.0cm (4.4") Depth. 5.8cm (2.0")

TRAIN	**Key**	**Pinion**	**Wheel**	**Diameters**
Floating Barrel	*			51mm (2.0") 16-19 turns, ungrooved but flanged.
Great wheel	*		96	88-92mm (3.65") click/spring
Centre wheel	*	8	60	55-59mm (2.33") centre B&S-MP!
3rd Arbor	?	7?	49x	45-49mm (2.00") once contrate!
Radial Escape	x	7	30	34-42mm (1.62") once crown!
Spring Pendulum	x			1-second * now a heavy brass strip crutch x.

GW turns = 96/8 = 12 hours. ; Duration 16 turns x 12 hours = 8 days. (maximum 19 turns)
Weight Drop (3.142 x 51mm) x (16/2) = 128cm (50.4").
[KP. Wheel Count 60/7 x 49/7 x 30x2 /60 = 60 beats/minute, for a 1-second pendulum of 99.4 cms;
Annex 1, p.22 gives alternate 3rd/4th wheels for 1.25 secs or 1.33 secs, Matrix Sheet 2 Weight, England].

DISCOVERY: A Prototype "Pendulum Cross-Beat" Escapement - (1663/4).

Around the raised back cock are two groups of filled holes. On the right side (from rear) is an open "clover leaf" on back plate only. But to the left (from rear), both plates have identical "clover leaves" of closely spaced pivots. [p.13, S30]. Paired clover leaves suggest three arbors were in close proximity, probably coupled by pinions (one linked to pendulum). This recalled to me Michael Hurst's drawing of Knibb's "pendulum cross-beat", having its pallet staffs coupled by a slotted link, not close-pinions as here. Had an earlier form of spring maintaining power been in this position? An external flat on top-right pillar boss hints at it, but a minor change to a cocking lever might also explain that. The crutch is of heavy brass strip, Dan Parkes associates that with Knibb's early pendulum cross-beats circa 1668/9. Knibb's twin verges held pallets spanning 5-teeth of radial escape wheel. Whereas, Fromanteel's had its triple arbors set very close, as if to span just 1-2 teeth. Two arbors were for pallet staffs coupled by pinions, with the third linked to a crank impelling a 1-second pendulum. I first called it a "radial *synchro-tic-tac* pendulum cross-beat", then "*Pseudo Tic-Tac*", (at **Part V**, I give it my code "PXR1"). Whereas, Knibb's wider span became my "*Pseudo-Anchor*", (my code "PXR2"). [KP. Acronyms are my descriptive codes for each of the earliest cross-beats and remontoirs listed in Tables of Thesis, **Part V**].

DISCOVERY: An Earlier "Crown-Escapement" c.1660/1:

The wide clover leaf high on the backplate [KP. on the IX side], suggests an early scrolling form of top potence. Also obvious, is the small bird-wing back cock, now the anchor staff's rear pivot. It is early of a 'crown-verge' type circa 1658-65. Clearly now raised and altered, extant pivot hole is heavily bushed, both the studs are original, but its central single retaining screw hole has been replaced by two new outer screw holes in the wings. Former fixing / positioning holes in the backplate are filled, (Fig.16). [see p.12, **G24** and p.13, **G29**].

Eventually I found the plugged hole for the bottom potence of the crown wheel's pinion. Original verge staff's front pivot was just below the extant anchor pivot, hence the lower back-cock position. Although interim cross-beat and extant anchor shared a radial escape wheel, and also a higher geometry than the crown wheel, the final escapement's anchor pivots required even more height than interim cross-beat to clear overhead anchor pallets.

The inclusion of a new radial escape wheel, in the first instance for pendulum cross-beat, would have then obstructed old verge staff's alignment. In replacing verge's original pendulum suspension the new 'spring' pendulum's chops were riveted to a modified, dove-tailled, keeper plate for an overhead suspension with screw regulator. Due to shaped tops to his plates, Fromanteel set his new escapement to one side rather than above new radial escape wheel. The third arbor probably moved a rear link to a long pendulum suspended above the old verge cock, at its original position but with new spring chops. But before conversion to my "pseudo tic-tac" (spring pendulum cross-beat), there is good evidence that the original escapement was Huygens' crutched-verge over crown wheel to a suspended pendulum. Anchor conversion caused the verge cock to be raised for the new, higher, anchor pallet staff.

Contemporary Interest. An historical clue may even refer to this first conversion! From 1658 Huygens had used, and exported, proven 1-Seconds' pendulums with his escapement for observatory work. In 1661 he had "*a best London maker*" make long pendulum clocks to his design (see n.6); Moray had one! In March of 1664, Huygens alludes to Fromanteel's new way of long pendulum[xv], and to his (unknown) "sketch of an escape wheel turning horizontally". But the long pendulum was not a novelty, clearly Huygens must be referring to some new type of escapement. I interpret this as a wheel turning about an horizontal axis, ie. a radial escape wheel; Wallis had disposed of the alternative (teeth in a horizontal plane) in his 1659 correspondence[xvi], when Huygens claimed that form for himself. Might this new 1664 escapement be Belmont's Fromanteel pendulum cross-beat (PXR1)? If so, then it antedated Knibb's variant (PXR2) circa 1668-9. Presumably, a final conversion to the extant anchor escapement (PR2) was circa 1670/1 or even later.

In my chronology of conversions it may be significant that closed pivots, I associated with a first verge escapement, closely match colour of the plates, implying an homogeneity of materials and by implication their common origin. But a later overhead regulator bracket unrelated to its former life as a "verge" escapement is fabricated from distinctly non-homogenous components. That implies different and new sources of raw materials, i.e. even if made later in the original workshop.

The lower edges of both plates each have two opposed narrow slots, for locating holdfasts, (like his first musical weight clock).

I consider this to be one of Fromanteel's earlier weight pendulums, circa 1659-63, but solely on the basis of its boldly crested plates I date it conservatively to 1661-2 - when Huygens may have seen it in London.

Observatory Clocks With 1-Second' Pendulums - (1658-1664).

I do not mean to infer that before its first conversion to the long-pendulum cross-beat (PXR1) its original "crown escapement" had had a short pendulum. On the contrary, I believe it had always a long 1-second pendulum. It is a short train, weight driven, timepiece with early form of maintaining power; suggestive of a pure observation clock. As such, a 1-second pendulum clock was favoured by astronomers here and abroad. Dr.R.Plomp proved it, by his analysis of Coster and Pascal clocks exported by Huygens[xvii] in 1658-1661. Leopold too noted that Fromanteel made long-pendulums to Huygens' design in 1661-2. And Oosterwijk and Hilderson made them, for Brouncker and Bruce.

Technical evidence to support this proposition might yet be found in its original great and centre wheels (96 and 8:60). My calculations of former train, (above these wheels) found it impossible to arrange sufficiently high counts (8,400 or 9,000) for a short pendulum. I believe it corroborates my view that this movement began life with "Huygens'" crown escapement having a 1-second pendulum; fixing its date to 1661-2; also making it the only English Huygens' long-pendulum yet identified.

I cannot absolutely rule out alternate possibility that Huygens, in 1664, might have been remarking on Hooke's spring-pendulum-suspension, alone, rather than any escapement, whether crown/verge, or radial cross-beat. But I am confident Hook'e spring-suspension, developed in late 1661, probably was not fitted to this clocks original verge escapement. This putative Huygens' licensed long-pendulum raises a new, but also somewhat remote, possibility; might this movement or one just like it, have once been dialled with a ten-line inscription commemorating Lawrence Rooke at the Royal Society? Where is that inscribed clock? My discoveries and interpretations need validation, but this anchor is not this movement's original nor even its second escapement.

THE EQUATION DIAL:

The small dial is still a delight. The signature is genuine but partly obscured by an enlarged "equation minute" ring. Proportions and finish are good, matting uniform. Layout is like Huygens' longitude and triangular pendulum clocks, circa 1670. My examination quickly revealed that the object of my interest - its little equation dial - was '*doubly associated*', i.e., it did not originate on this movement; and it had began life as a conventional dial. It is an early dial, no doubt contemporary with the movement, but four open holes denote the inwards relocations of all dial feet - being originally made to fit wider plates than this timepiece. I saw no sign of filled holes for conventionally placed winding squares, a stock dial perhaps? Or a pull-wind movement? The dial also has four extra stud-holes, corresponding to an earlier, narrower, chapter ring. The present chapter ring has its own set of studs, probably the earlier chapter ring was narrower. Extra width of the present chapter-ring is due to additional, wider and now rotatable minute '*equation*' ring, thus forcing outwards the extant spandrels (cast by the *lost-wax* process) to new positions proven by filled inner screw and steady-pin holes.

The minute ring was stiff from disuse, but I set it up for different equations and found it simple to set and also to interpret. [KP. rotating Minutes subdivided into six, Minute Datum may be set within 10 seconds]. Each rotating ring can be set by pin-hole adjustment (in dots) to appropriate "equation", ie. second, minute, even hour (but read on). These allow equations to be set for each day of the year, for any year, from corrected astronomical tables. A lozenge[xviii] **[**Rhombus**]** replaces "XII" for "solar noon", ie. clock and sun concur in local time. Lozenges on smaller rings indicate Datum offsets. Mean time is read in the familiar way but some care is required. However, when reading the equations this small "hour" dial is superfluous. On a Fromanteel dial? This set off my temporal alarm bells! Investigators must often make such value judgements.

Published photographs do not reveal the unusual construction of this dial. [KP**.** refer pp.17-21] Subsidiary rings for seconds and hours do not fit onto the dial in any conventional way. Neither is proud of the zone, but is recessed flush with the dial. These small rings run freely, bevelled outer edges ride under a chamfer on the dial, and their chamfered inner edges retain the small matted discs also held into place by sprung cocks on reverse of dial. All the retaining cocks and zone discs are pierced, for hands. Even the winding square, *rotating anti-clockwise* with the barrel, has a subsidiary hour hand plugged through a hole in the shutter. The hour disc appears to be a typical weight pulley sliced in two, whereas the seconds disc may be from an old dial section - perhaps even from an original "verge" seconds' zone.

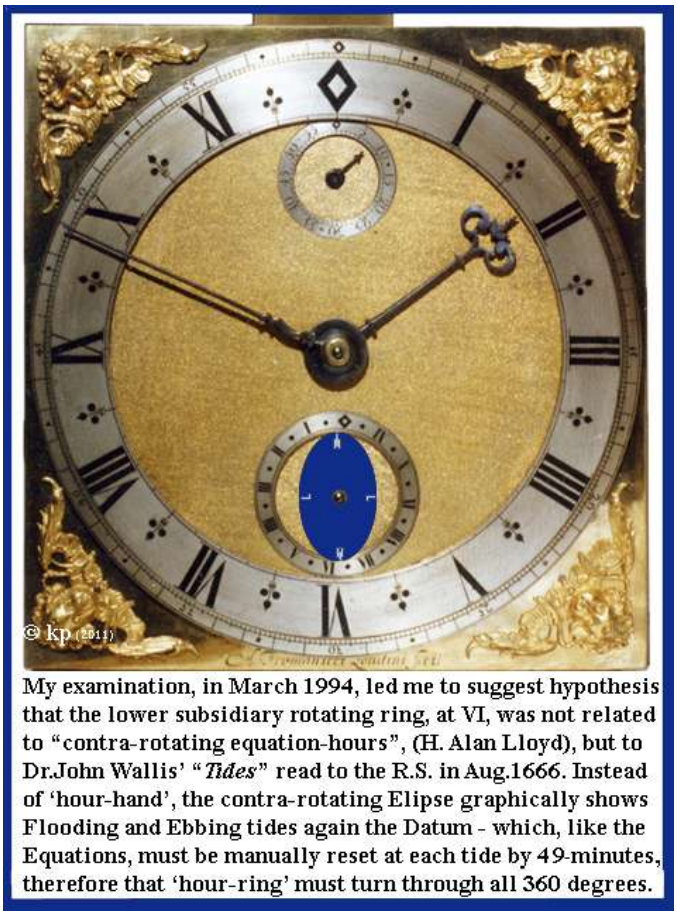
Under magnification the matting of zone and discs is uniform, so that cannot be original matting of an unmodified, "verge", dialplate. All four rings seem to be made from homogenous cast brass, finished by one engraver. They are superbly crafted, the turning of sliding faces is good. The rear of dial has a dark patination, expected of an early period, the chapter ring is patinated at eight points where it faced open dial holes. **[**KP. suggestive of an originally smaller chapter-ring, but being rotated 30 degrees]. All the rings seem of similar age, but that is hardly conclusive so I recommend spectrographic analysis of its parts to test homogeneity and confirm my provisional dating.

I found it odd that ALL three rings rotate a full 360 degrees. Equation tables give variations in the order of sixteen minutes, to nearest second. It follows that the "equation seconds" ring rotates a full 360 degrees, to set 0-60 seconds. Whereas, an "equation minute" ring need only to rotate through 96 degrees maximum, (16 minutes). But what seems totally redundant is a dial for "equation hours", given that time is read in usual way by familiar hands. An "equation hour" ring needs only to rotate through 7.5 degrees, at maximum variation. And why do "equation hours" turn anti-clockwise, ie. except that this was forced upon its maker by the barrel? Is it just over-engineered or has its purpose been misunderstood, even today? It also lacks Fromanteel's directness of purpose, or relevance to the function purportedly assigned to it, in direct contrast to his sun-clock with its scale model of sun's true declinations. I have to say it set me thinking, if Fromanteel's subsidiary dial, what might have been his intention? What other purpose had Fromanteel that demanded such an obtuse indicator?

AN EXPERIMENTAL "TIDAL DIAL" - WALLIS'S THEORY (1666).

I saw no need to display [Alan Lloyd's] contra-rotating *equation hours* at all. My suspicions arose that the "hour" part might not be for equations, but for some new motion developed between 1666 and 1669. I came back to this after reading minutes of the Royal Society for 22nd August 1666. Secretary Mr Oldenburg read Dr. Wallis' letter concerning his new "tidal theory". Following this new line I soon came across Alan Lloyd's article, "Tides and the Time", in an old Horological Journal. "*On 'Munday', August 6, 1666, Dr John Wallis had presented to the Royal Society an essay on his hypothesis about the flux and reflux of the sea."*– [in this context, Lloyd ignores his own examinations of the equation clock's subsidiary *'contra-rotating equation hour'* dial].

In fact Dr Wallis, a mathematician and a Huygens' correspondent, had alerted the Council to his tidal theories in May. Throughout 1666 meetings had discussed tides observed around many coasts[xix], and also Kent's extreme autumnal tides. Presumably Keppler's tidal theory was known to Wallis, who then also prompted Hooke to his remarkably quick under-standing of the solar-lunar gravitations; on which Newton (1642-1727) capitalised on unashamedly. Here I hesitate to tread further; but Lloyd noted Wallis' conviction that not only the moon but (its) equations affected tides. It recalls Burgi's lunar clock with "equations" of 1591, but that was much too early to incorporate Keppler's tides (1609).



My examination, in March 1994, led me to suggest hypothesis that the lower subsidiary rotating ring, at VI, was not related to "contra-rotating equation-hours", (H. Alan Lloyd), but to Dr.John Wallis' "*Tides*" read to the R.S. in Aug.1666. Instead of 'hour-hand', the contra-rotating Elipse graphically shows Flooding and Ebbing tides again the Datum - which, like the Equations, must be manually reset at each tide by 49-minutes, therefore that 'hour-ring' must turn through all 360 degrees.

However, I tentatively suggest Fromanteel's "solar" equation–clock had the subsidiary dial, showing *'reversed-hours'*, incorporated just for Dr Wallis' theory, a tidal dial. Tides would need a full range of "*hour*" settings, through a full 360 degrees. Anti-clockwise rotation would then work in a natural sense, rising tides advancing to a datum point. With this first "*universal tidal ring*" set to "III" (high tide at London Bridge at new moon), the hour hand or ellipse rotating anti-clockwise on the winding square would show the flux and reflux (ebb and flood) of tides dramatically over twelve-hours. Like solar equations this tidal dial would need to be reset manually, and after each tide,(a rule of thumb then commonly used would require a tidal ring to be reset 48-minutes per tide). [49?]

The merit of my new interpretation is, Fromanteel's small hour dial is no longer '*superfluous*', or merely '*decorative'*. It now has a rational purpose, requiring full 360 degrees of rotation, and resolves one of many questions I had with this fascinating, but seemingly flawed, Fromanteel *equation* dialplate.

Is this tiny '*equation-hour subsidiary'* in fact the earliest 'Tidal Dial' *extant*? (Leyland's description of Richard of Wallingford's tidal dial is still the earliest known). Lloyd shows Ferguson's tidal dial (1756) with also manually set dial reading *counter-clockwise* like Fromanteel's. Coincidence? No! Its tidal role had determined its dial.

THE MERCATOR CONNECTION?

Can it [the subject equation clock] be connected to Mercator? That is very much a value judgement, based on when one believes escapement changed from "verge" and when "associated" dial was engineered. Aubrey's history of Mercator's RS equation clock is against this manual equation timepiece on grounds of size, (its dial is not "a foot diameter"), nor is it so complex as to defeat Knibb, [who apparently had the equation clock], also availability, and now the anachronism of **Tides**. This clock Whereas, Moray's 1669 letter mentions a similar type of dial. From Birch I infer an entirely different dial is described, so we may expect to find different displays in those (extant) clocks.

In context of Royal Society minutes, and Aubrey's description, I now believe Fromanteel modified an older clock with year calendar work, and changed or re-engraved its zodiac calendar to display new equations directly in a non-correcting tabular form. It was already complex, large, and not understood by the watchmaker Knibb. It was possibly already converted to pendulum, but this complicated multi-function clock might, with good reason, have been highly valued by Fromanteel in 1683, ie. 200-Li. Was it once Dudley Palmer's clock? If it were Palmer's, commemorating his ancestor Thomas Digges and heliocentric solar system, displaying the sun's real declinations and azimuths, it is not inconceivable that he might wish to enlarge its solar indications, to make it more complete by adding Mercator's new quantified solar equations for mean and true time.

However, in the context of Colbert, the Belmont Park equation clock really comes into its own. It was always a pendulum clock, its hands do read the exact hour and minute (and second) when set to daily equation tables. It is a precision timepiece, with English spring maintaining power, ie. a simple observation clock beating and indicating seconds. Presumably Colbert would expect no more, and no less. First conversion to "pendulum cross-beat" (PXR1) was probably picked up by Huygens and reported to Moray in same year 1663/4. It was adapted to show equations, an act of faith is required to make those contemporary, but if its small hour dial is for Wallis's tidal theory it cannot be the R.S. equation clock of August 1666, but it still might be the clock offered to Colbert in 1669. Clover leaves of pivot holes were filled during last conversion, after 1671, ie. when Clement had added his finishing touches to the true "anchor". The new anchor escape wheel, also indicating seconds, occupied the same pivots as the former radial cross-beat escape wheel, but new overhead pallets caused the old verge back cock to be raised.

Tabular equation dials are a compromise. Annual almanacs would appeal more to astronomers, setting dials from daily equation tables, to nearest second. But if not Mercator's design, and clock, then whose? Where are his papers? They would be better evidence, like Huygens' archives. **T**his dial [KP. the subject Fromanteel] is surely an astronomer's solution, [it may have been a pointer to Huygens in laying out his longitude clock's dial, c.1670], but did it go to France in 1669? [KP, or February 1682, when Mercator took his family to Paris?]

The presence of my putative tidal dial is an anachronism on a clock demonstrated in August 1666, ie. when Wallis' paper on tides was first read. By 1669 that might be an unique selling point. By then Wallis' tidal theory could have been given practical form, by this new and *universal* tidal dial. I should like to know where Walter Iden found this rare movement, England or France? I doubt the manual equation clock could ever be so misunderstood, as Aubrey infers of Mr Knibb; whereas the sun-clock still conceals most of its secrets. Belmont Park's manual equation clock does seem to relate to Moray's description of Colbert's clock in 1669 - perhaps the first universal tidal dial, but it cannot be the first equation clock shown to the Royal Society on 29th August 1666. So there is still a vacant candidacy for that, and another candidate is now in the wings; the extant Fromanteel *sun-clock*.

There remains my "caveat", an implicit question of fakery. It must now be addressed and resolved, otherwise students will be left with misleading impressions given by the horological literature. While standing by my given descriptions and "first pendulum-cross-beat" hypothesis, on principle of "ab uno disce omnes" I suggest a full spectroscopic analysis of all parts before finally accepting what may ultimately be a sophisticated fake, we have enough of these and they are being added to every year [with huge commercial implications] ~ faster than any dilatory unmasking.

New Directions: As one door closes another opens. Belmont Park's equation clock was not what I sought, ie. not Fromanteel's 1666 equation clock at the Royal Society. But this apparently unknown application, and probably earliest English pendulum cross-beat (PXR1), virtually a "pseudo-tic-tac", much closer than Knibb's "pseudo-anchor" pendulum cross-beat (PXR2), set me thinking of Fromanteel's modus operandi. How did he first come to his pendulum escapement, and when? Even the nomenclature, "cross-beat", turns one's mind to Jobst Burgi (1552-1632), and to early research carried out by Dr Hans von Bertele (and Dr Wolfram Block) upon the discovery of his Radeloff clock.

Like Von Bertele's recognition of his Radeloff's empty pivot holes; I came back from Belmont Park, on 25-3-94, and I immediately looked at the sun-clock's "central" escapement and asymmetric pivot holes in its back cock, aligned with an oval hole in frontplate - for twin pivots, a tangent to any radial escape wheel on contrate arbor (see Figs.7-8). It brought Leybourne's description and dating to mind, and it finally shed its pendulum disguise. I recognised it as a rare, uniquely English, pre-pendulum cross-beat, "*eureka*"! I knew little about Burgi, but I knew his escapement had still found favour with Radeloff and Mayr into the 1660s. Therefore it had had something to commend it and deserved attention. I read Lloyd "Outstanding Clocks", his source was Dr von Bertele. Eliot Isaacs (BHI) located Dr von Bertele's "*Precision Timekeeping in the Pre-Huygens Era*" and "*Early Clocks in Denmark*", (HJ, 1953-54), also Dr.Block's restoration[xx]. These were invaluable, I could not have arrived at my systematic classification of Burgi's, Fromanteel's, or Douw's, escapements and remontoirs at Part V. without them. [KP. with Alan Lloyd's articles for the BHI (1943), '*Early English Equation Clocks'* also *'Tides and the Time',* all are important papers in antiquarian horological research, still instructive].

The import of my discoveries was immediately apparent to me, but at first I could not make sense of Burgi's variations and many derivatives, especially their unfamiliar contexts in Fromanteel's *Oeuvre* with import on English horology's evolution. If I "over-egg the pudding" at Part V, it is because, in dealing with new English paradigms, I felt it inappropriate to ignore their context in the history of time keeping. Chauvinism obscures the obvious, English horology was never devoid of European influences. Perhaps its former greatness was due to Fromanteel's willingness to draw upon inspiration from abroad, equally valid today. Burgi was long dead, so from whom did Fromanteel learn of Burgi's cross-beats and his associated torque mechanisms we call remontoirs? It is not enough to suppose he knew Hagar's? Arnstadt cross-beat, circa 1630, now in the British Museum. At Part V, I attempt to resolve this, but I had found an unexpected and unique English context in Mr Dudley Palmer's clock which if proven alters all perceptions of the history and evolution of English horology. Being also the *famous old clock* that Mr Dudley Palmer let be used to add Mr Mercator's ***'Æquations'***.

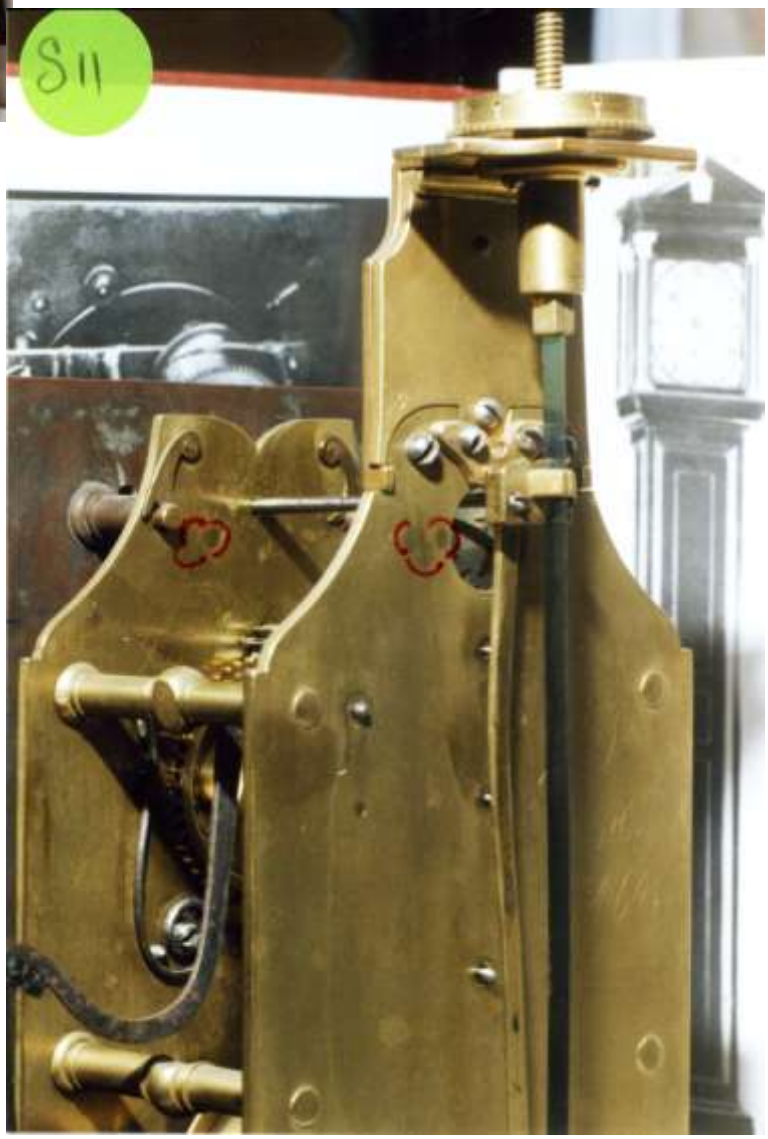
---------- END OF THESIS PART IIII ----------

SELECTED IMAGES (1994 Report), here republished by consent of the *'Harris (Belmont) Charity'*.
Keith Piggott is copyright owner of all images. **Films**: Konica Super SG200/36 (**S #**), Kodak Gold 200/36 (**G #**).
NB. All commentaries are my own, not opinions held by the Harris (Belmont) Charity and professional Curator.

The Dial: My first sight, being the standard published view, and the reason for my disquiet at its purporting to have an *'original anchor escapement'* (only invented a full decade later than its early stylistic appearance).

G16 The signature of *Ahasuerus Fromanteel Londin fecit:* this fine signature is now partialiy obscured by the wider *equation-minutes* ring.

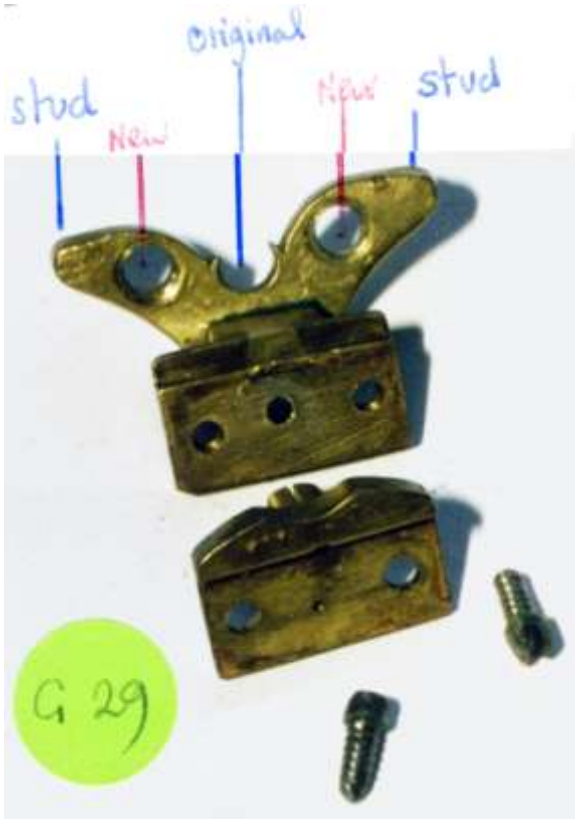
Scribed line marks the edge of the associated dial's original Chapter-Ring, now having a wider chapter-ring; i.e. not the original ~ or greatly modified original!



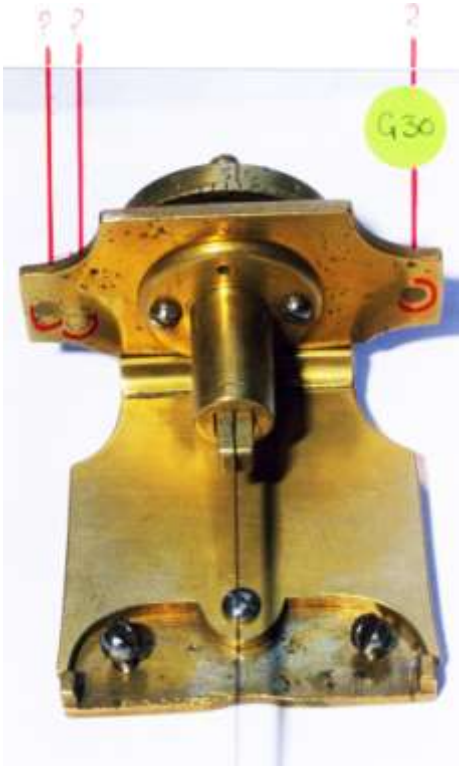
S11 The Movement: My first view, turned about. The 'clover-leafs' on both plates (highlights in red) and the modified early bird-wing back-cock (for a verge-crown escapement), immediately brought the realisation that the present anchor escapement was neither '*original*' nor even only escapement in the evidently much longer life of this verge and later cross-beat pendulum relic.

G24 Proof of the raised back-cock, therefore of 'original anchor escapement' being a conversion from earlier crown-verge escapement, (at least).

[KP. 'Alert' markings, only on photographs.
Blue markings denote 'original' or 'content']

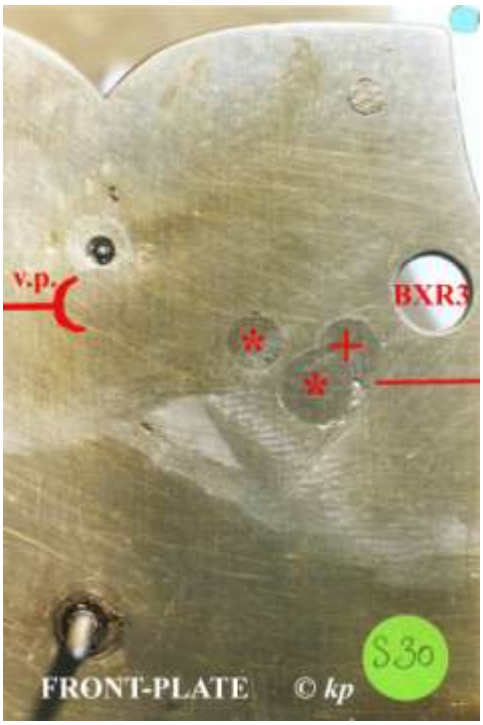


Original early 'bird-wing' verge back-cock.
G29 Extended with a later plate on the dovetail, supporting a plate for *pendulum-chops fitting*. Cock is altered. from a central single screw to a double-screw fixing for a heavier pendulum. The original verge-cock raised for new anchor**.**



G30 Overhead-Regulator (Post-Anchor) now having Hooke's spring-suspension. Nb. Three now *unrelated* filled holes, showing the *'bolt-on'* stirrup-bracket.

G37 Filled Holes, (slots/steady/screw-holes added)
3 Top: Verge centre screw, outer 2 integral-studs
3 Left: Verge top potence screw, 2 integral-studs.
3 Right: Cross-beat pivots, ditto on Front-plate.
Pivot for radial wheel (BXR3 then Anchor)
2 Bottom: Verge potence - screw and steady.



G30 FRONT-PLATE: unusual *'fish-tail'* top.
V.P. - Former "verge-pivot" hole
BXR3 - Triple-pivots matching the back-plate's cloverleaf to *'Pendulum 'cross-beat'* having Burgi's *coupled-verge pinions* to a side mounted *staff,* linked to the crutch.
The new radial escape wheel, displacing the old crown-wheel, would raise its pallets so forced XB to be mounted at the side.

Evidently, this is **not** an *'original anchor'*! Ronald Lee and Peter Gwynn agreed, their entry was written by owner and "*First 12 Years"* printed before the clock arrived.

THE *'PIVOTAL EVIDENCE'* OF THE CLOVERLEAF GROUP OF FILLED HOLES.

Seeing the plate-evidence of groups of filled-holes in matching '*cloverleafs'*, led to my study of pre-pendulum and pendulum *cross-beat* escapements in English contexts. Before my evidence, in a Thesis on Fromanteel's Solar-Musical Clock of 1649 for Mr Dudley Palmer, the former was unknown to English horology. However, the latter *pendulum-cross-beat* form was recorded by Ronald Lee and Michael Hurst, in a clock by Joseph Jnibb, said to ante-date the first Anchor escapement. My own study arrived at an hypothesis, which is better explained by images rather than words; therefore, here I insert an observed pendulum cross-beat (courtesy of Laurence Harvey), and my *digital reconstruction* to match the cloverleafs in Fromanteel's equation clock.

Pendulum Cross-Beat Pallets - Variations

Fromanteel's famous solar clock, made in 1649 for Mr Dudley Palmer, with Burgi's third *'Cross-Beat'* with a radial *'saw'* wheel (BXR3): > probably inspiring Fromanteel's *new way of long-pendulum* (1663/4).

Fromanteel's '*new way of long-pendulum*' cited by Huygens (Feb.1664) added a third arbor - being linked to his new pendulum also to one cross-beat pallet staff - either by a short link or a large pinion. The twin-pallets coupled by pinions, acting in unison on the '*saw-wheel*'. While this first *'pendulum cross-beat'* has not yet been observed, see vestigial evidence in Fromanteel's equation clockplates, a *cloverleaf* of filled pivot holes alongside a '*saw-wheel*' replacing original Crown.

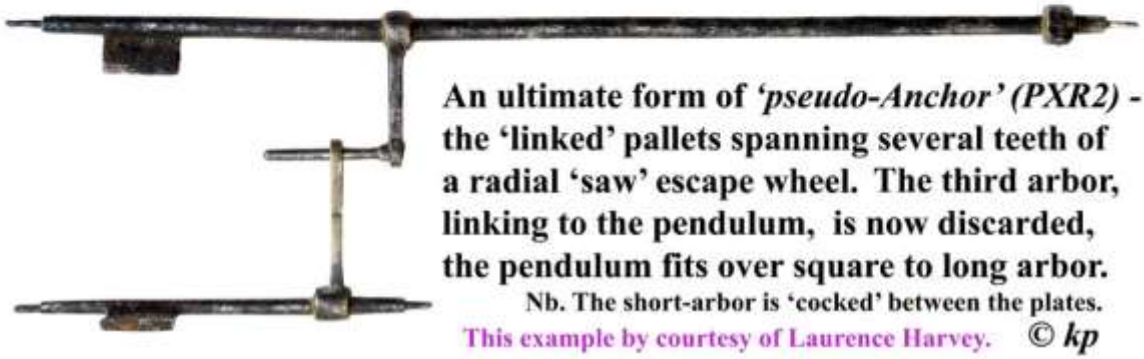
(Reconstruction)

Nb. close-set Pallets of my '*pseudo tic-tac*' (PXR1)

SQUARE to an external Crank

CRANK from offset XB 'cloverleaf' to central long-pendulum

Second form of Pendulum Cross-Beat widens the pallets to a '*pseudo-Anchor*' (PXR2) escapement, still on Burgi's '*saw-wheel*', probably '*invented*' by Joseph Knibb before the true '*Anchor*', (Ref. Ronald A Lee, '*The Knibb Family - Clockmakers*', p.143, Plate 159, drawing by Michael Hurst).



An ultimate form of *'pseudo-Anchor' (PXR2)* - the 'linked' pallets spanning several teeth of a radial 'saw' escape wheel. The third arbor, linking to the pendulum, is now discarded, the pendulum fits over square to long arbor.

Nb. The short-arbor is 'cocked' between the plates.

This example by courtesy of Laurence Harvey. **© *kp***

HYPOTHETICAL EVOLUTION, VIA '*CROSS-BEATS'*, TO '*TIC-TAC* ' AND '*ANCHOR*'. The final forms of *'Tic-Tac'* and '*Anchor*' were realised by joining the pallets as a single unit.

NEW *'SPRING'* MAINTAINING POWER.

Ahasuerus Fromanteel's original form of his '*Bolt & Shutter Maintaining Power*' (*B&SMP*).

G33 G34 Between the plates, this *B&SMP* is mostly original. At page 7, I suggest an external flats to two pillars suggests that the cocking lever has been revised; I suggest, probably,when the bolt-arbor arbor was extended for the present shutter.

S35 Report and Thesis regards this as earliest form of Fromanteel's B&SMP invention. The early bolt-spring is of coiled steel wire, i.e. ante-dating his blade springs; Its bolt engages with the original Centre-wheel; it could never engage with the Contrate-wheel of original verge and crown construction, (having Huygens' long-pendulum).

My hypothesis, for the evolution of English B&SMP, is that Fromanteel arrived at his own *spring-maintaining-power* to avoid his old verge-escapements *backing-up* when winding. Probably, his intellectual-leap was directly from his *spring-remontoir* in Dudley Palmer's famous Solar-Musical Clock of 1649. Essentially, B&SMP is only a *short-duration spring-remontoir,* being *manually cocked* before each rewinding.

The shutter part of Fromanteel's early B&SMP is less convincing, even assuming that a shutter was fitted in first instance. Here, a shutter may have been an afterthought, superfluous except as a reminder to 'cock' BMP, hardly necessary when the winding-square is 'occupied' - either by extant hour-hand, or by my preferred **'*Tidal Elipse*'.**

S32 Shutter Closed and Locked by the Hour-Hand

S29 Hand removed, Shutter now unlocked.

S33 Shutter "cocked", note hole in square.
Thesis replaces hand with a "Tidal Elipse".
Nb. unusual bridge, set on pier blocks, and
cut-away to clear this curious Shutter-Arm.

S34 Shutter arm bent under seconds arbor.
Nb. 'Seconds' and Shutter Arm probably,
not part of Fromanteel's original concept,
having a 'verge crown-wheel' escapement.

NB. Barrel turns *anti-clockwise* in 12-hours; ideal for my *Tidal Elipse* p.19. (now with *equation-hand*).

G28 Note the refinement of a '*counter-poise'* added to the minute wheel to compensate for the minute hand's unbalancing weight. While not an original fitting, it might not be an anachronism - Fromanteel was known to continually refine his components, thus to achieve ever higher standards of accuracy. [Examine all Fromanteels]

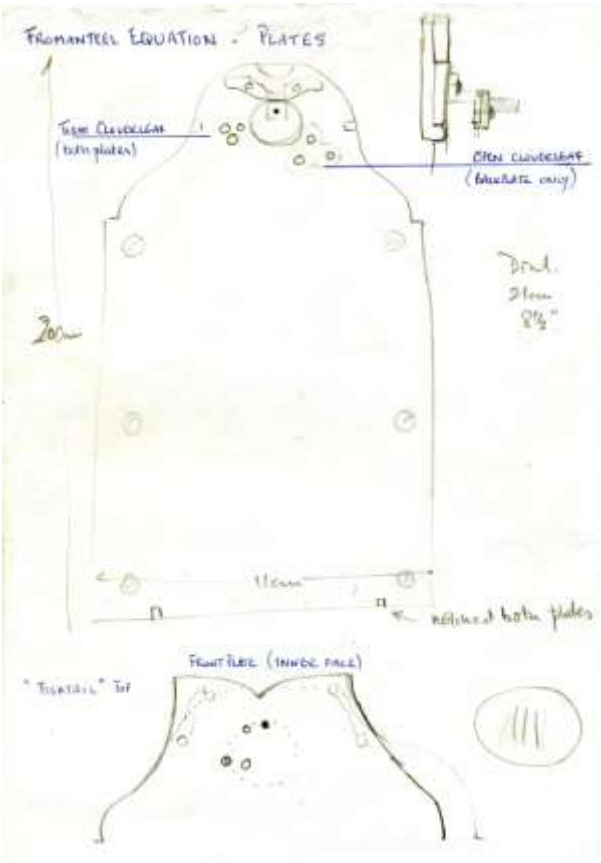
G28. The*'Bugle'* shaped latches are typical of the early Fromanteel workshops.

G28. Shutter, closed over the Winding-Square, to reveal the hole now used to 'peg' the Hour-Hand.

G36 The typical early Fromanteel '*Floating-Barrel'* having an integral Ratchet-wheel, a rare ungrooved barrel, with a flange to retain the gut-line, all early features. Note cruciform spring under the Minute-wheel. The minute counterpoise is '*applied*'.

G35 Truncated main arbor to *Floating-Barrel*, note long click with a leaf-foot to click-spring. The Great and Centre wheels are original, having hand-cut teeth and crossings, with traces of gilding apparent. The Centre pinion is fixed on the wheel, both positioned at the back-plate, (cf. Coster timepieces, Plomp ***D1 to D5***).

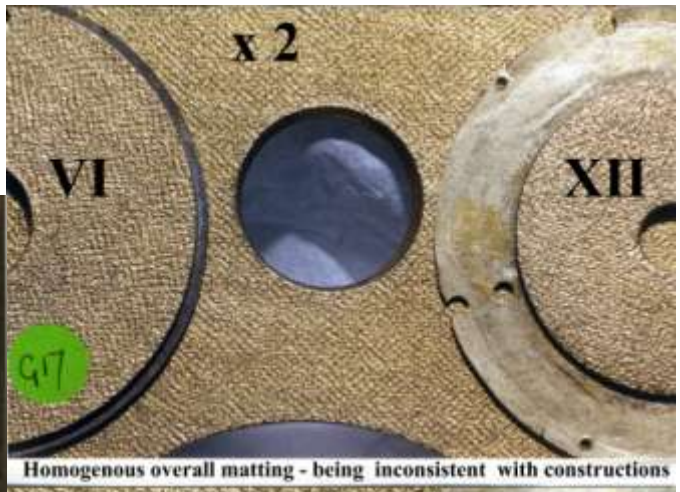
Nb. Wheel-count for Main and Centre indicates the original and intermediate escapements were also to long-pendulums, at least 1-second, 1,25-secs, 1.33-secs. (p.22, also Matrix Sheet 2, Weight Clocks, England).
Later Third Wheel and Anchor-Escape Omitted.



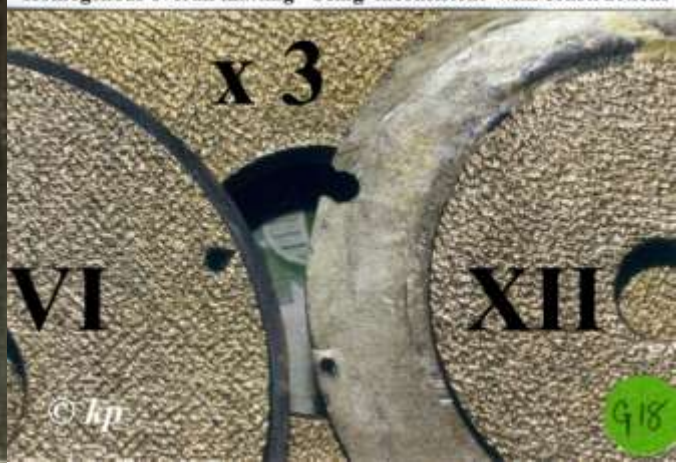
Sketch (25th March 1994): showing my evidence for a former top-potence and an early *bird-wing* verge back-cock formerly at a lower height; also showing the tight *'clover-leaf'* of triple-pivots on the front and back-plates, being evidence of some intermediate form of escapement - prior to the extant later Anchor.
Note. I consider its clover-leaf of pivots as proof of having a long-pendulum cross-beat, [developed by Fromanteel from his famous 1649 Solar-Clock that had Burgi's third cross-beat, ~ given BXR3, but with a long-pendulum ~ given PXR1]. In *first conversion,* from Huygen's long-pendulum crown escapement to the pendulum cross-beat on radial saw-wheel, its pendulum could have beat Seconds, 1.25-secs, or even 1.33-secs (see Annex 1, p.22). Then, the original dial-plate may have had a Seconds' ring added. The present dial is not the movement's original, but has been thus '*associated*' by an unknown hand which, possibly, might even be Ahasuerus Fromanteel, John Fromanteel, etc..

Note. This 'double-arched' back-plate resembles an early 'Edward Stanton' grand-sonnerie spring clock.
The 'fish-tail' flourish to front-plate is unusual.

G17-18 Details of Static Zones to Subsidiary Rings



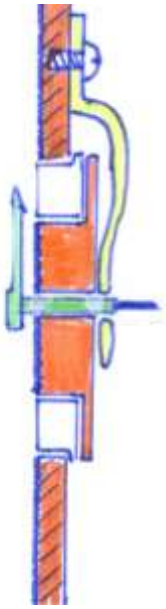
Homogenous overall matting - being inconsistent with constructions



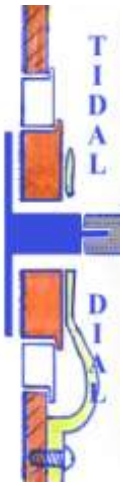
DIAL-PLATE (see composite at p.7, also pp.19-20).
Constructions of Subsidiary Dials' Rotating Rings.

Evident here, [more evident in composite at p.7; also see p.20], are inwards-relocated Dial-Feet to fit the narrow plates of the presently 'associated' movement; also the curious relocations of this Chapter-Ring's original studs ~ or evidence of a different Chapter-Ring.

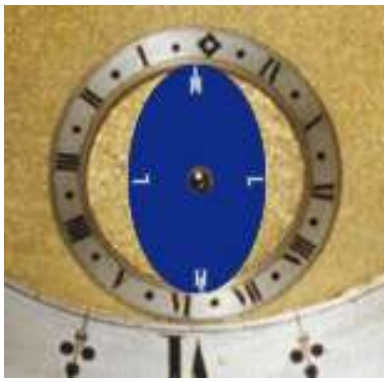
At following page are my sketches of constructions of manually rotated subsidiary dials at VI and XII, (p.17). At XII, *'equation seconds'*. At VI, my *'tidal-dial'* resolves Alan Lloyd's incongruity of *'equation hours'*, i.e. contra-rotating, the Datum ring made to turn 360 degrees, but needing only *7.5 deg*. maxima. for 16 minutes.

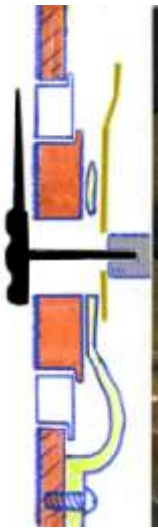


G14 360º Rotatable *'Seconds-Ring'*: flange behind dial, held by its Zone-Disc, supported by a Bracket**.**



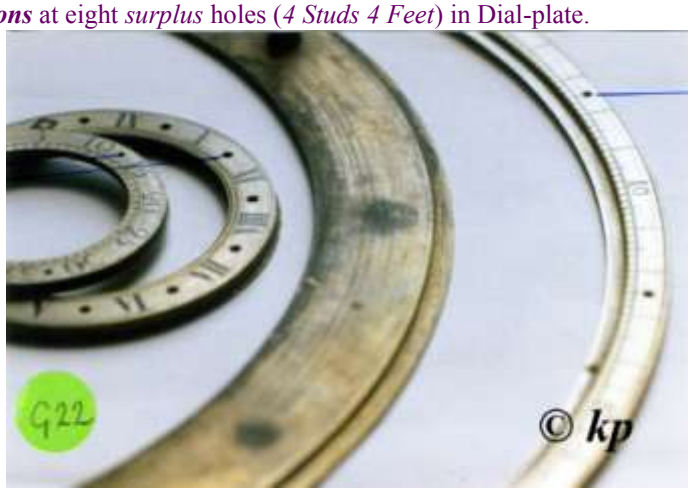
Elipse to my *'Tidal Dial'* goes *counter-clockwise*; showing the *'High Tide Ebbing'*. Simple!





G13 360º Rotatable *Hours-Ring'* to contra-rotating winding-arbor: Similar construction, my 'Tidal-Elipse' goes through disc, bracket, and shutter into socketed end of the winding-square. Shutter reminds one to cock maintaining-power, but here is superfluous as re-winding is only possible with any fitting being first removed.

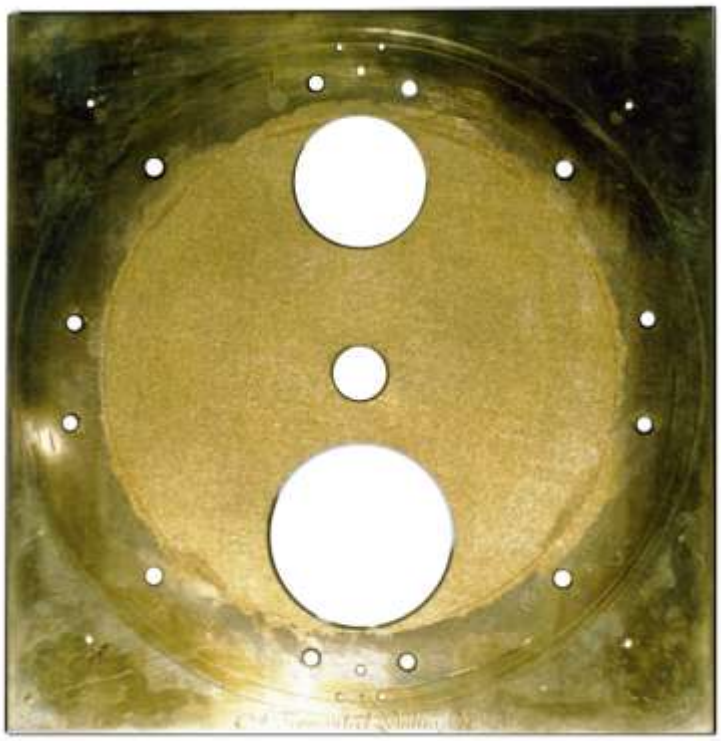
G21/G22 FIXED CHAPTER-RING: NB. Age ***oxidations*** at eight *surplus* holes (*4 Studs 4 Feet*) in Dial-plate.



360º, *MANUALLY ROTATABLE, RINGS*: Small tolerances of flanges/bevels are necessary, to secure each ring between dial and subsidiary-zone (see sketches), yet permit its manual rotation for Equations and Tides.
360º *EQUATION MINUTES:* subdivided to 10-seconds, 5th minutes numbered, note *Pinhole* adjustments.
360º *EQUATION SECONDS:* divided into 60-seconds, 5th seconds numbered, note *Pinhole* adjustments.
360º ***TIDAL HOURS:*** 12 Roman Hours in Reverse Order, subdivided into Quarters, note *Pinhole* adjustments.
NB. **Oxidation**, through eight *surplus* open-holes in dial-plate, suggests a considerable age to this conversion.

G20 Superb 'Small-Cherub' Spandrels
(Fromanteel's fix: screw and steady-pin)

G05 DIAL-PLATE (reverse), fittings removed.



< G06 DIAL-PLATE (obverse)
Re-gilding is limited to the central matted zone. The appearance of the reverse is evidence of being hammered flat after "bowing" when the zone was re-matted; with the subsidiary discs. Fromanteel often saved on gilding beneath dial fittings, but always gilded ALL *visible* surface.

G04 DIAL-PLATE (reverse) Witness Marks:
Nb. [] Relocated Dial-Feet [see Spandrels]
Nb. () Relocated Chapter-Ring Studs
Nb.)) Spandrels ditto. Such relocations need no explanations; except "When?" and "By Whom?"

G19 (reverse) Lost-wax cast Spandrels, note ID punched pellets - in the manner of Fromanteel.

<G15 3rd *Lost-Wax* Spandrel (reverse). Nb. triple punched ID us repeated on the dial plate. he scribed outline, at the original inner spandrel position, is witnessed by a relocation of its screw and steady-pin to accomodate wider *Equation* Minute-Ring. The evidence of ID punches, and purposeful relocations, adds to the *bona fides* of superb Fromanteel Spandrels.

S36 Bolt of B&SMP: shown here engaged to drive the Centre-Wheel.

Note the late form of Anchor, also the unusual Escape-tooth form [XB?]; also note the fine stepped-dome Collet

Fromanteel's *first conversion*, from old *Crown and Verge*, to Burgi's *Radial 'Saw' Wheel,* for Pendulum-Cross-Beat′ allowed Seconds' to be shown, i.e. before the movement's *ultimate conversion* into exant *Anchor* escapement. Extant overhead *rating-nut Regulator* is considerably later.

READ ME? Datums for the Hours Minutes, Seconds, are set "*15 minutess"* in advance of Mean. **Solar time** showing as *02.04.59* **Mean time** as *01:49:59.* Here, one discovers the difficulty in *reading* this dial: *Split-minute hands* were more effective, and much cheaper! But this is, apparently, a first-step in the application of the pendulum-clock to providing "*Equation of Time'.* Despite my questions, the evident associations and the several conversions could well show Fromanteel's hand; and even be the *Equation Clock* that Nicholas Mercator sold to France in 1669, or took in 1682. As first *caveat* infers, only *spectroscopic analysis* can provide answers.
[Note. To fully incorporate this equation movement into the *bona fide* corpus of Fromanteel's *Oeuvre,* the Harris (Belmont) Charity will, eventually, have to submit the parts to such analysis as will determine, at least, the unique signatures and proportions of metals used; to be compared with original early dial and movement plates]

ANNEX 1 - WHEEL TRAIN CALCULATIONS BASED ON ORIGINAL GROUND/CENTRE

A Fromanteel Londini fecit: Weight Timepiece: modified to Equation and Tidal Dial - Harris (Belmont) Charity, Belmont Park, Kent						
VERGE & CROWN !-sec	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	HYPOTHETICAL
Escape wheel	21	6	60	1.428571429	85.71428571	circa 1660/1
Contrate wheel	60	7	Pendulum cms	0.142857143	8.571428571	
Centre wheel	60	8	99.4	0.016666667	1	Option 1
VERGE & CROWN 1.25-s	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	HYPOTHETICAL
Escape wheel	21	7	48	1.142857143	68.57142857	circa 1660/1
Contrate wheel	56	7	Pendulum cms	0.142857143	8.571428571	
Centre wheel	60	8	155	0.016666667	1	Option 2
VERGE & CROWN 1.33-s	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	HYPOTHETICAL
Escape wheel	15	6	45	1.5	90	circa 1660/1
Contrate wheel	54	6	Pendulum cms	0.166666667	10	
Centre wheel	60	8	177	0.016666667	1	Option 3
PENDULUM XB 1-sec	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	HYPOTHETICAL
Escape wheel	30	7	60	1	60	circa 1663/4
Contrate wheel	49	7	Pendulum cms	0.142857143	8.571428571	Huygens Feb.64
Centre wheel	60	8	99.4	0.016666667	1	Cloverleafs
ANCHOR 1-second	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	EXTANT
Escape wheel	30	7	60	1	60	post 1670
Contrate wheel	49	7	Pendulum cms	0.142857143	8.571428571	
Centre wheel	60	8	99.4	0.016666667	1	

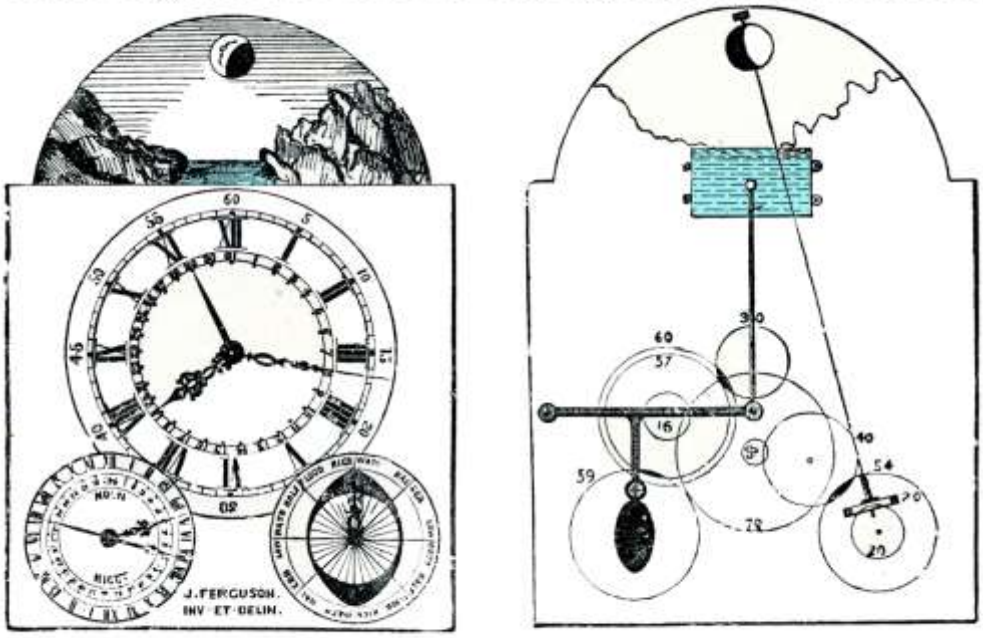
Matrix Showing Extant and Hypothetical, 1-second, 1.25-second, 1.33-second Trains: Original Verge-Crown 1660/1, A First Pendulum Cross-Beat 1663/4, Extant Anchor. Nb. ALL Trains are grounded on the original Centre (8/60) and Great (96) Wheels.

Astronomers and Horologists are familiar with free pendulums of almost any length, used according to the requirements of observations, occultations, eclipses, etc. Robert Hooke tested free pendulums from *fourteen feet* to *two-hundred feet* (in St.Paul's with Moray, 1664). In clockwork, Horologists are familiar with long-pendulums beating the *Seconds'*, (60 beats/minute with pendulum of 99.4 cms); also *One and a Quarter* Seconds, (48 beats/minute with pendulum of 155 cms); even Tompion's and Van Ceulen's extreme pendulums beating *Two-Seconds*, (30 beats/minute with pendulum of 398 cms). However, most Horologists will not have encountered an early clock-pendulum beating *One and a Third Seconds* (1.33 seconds) beating 45 beats/minute with a pendulum of 177 cms; [Jura-Comptoise clocks excepted].

Yet they do exist, and probably did exist in larger numbers when the mantras then dictated *the longer the pendulum, the greater the accuracy*; **Circular Error** becomes less significant. But unknown coefficients of expansion, and air friction, were to upset those mantras. Jürgen Ermert brought attention to a German longcase weight clock having a pendulum beating *One and Third* Seconds on Anchor; it is early 18th century, unsigned, entirely original; its train is 80:8/60:8/63:7/20=2700 beats/hour. (Ermert, J. *'Deutsche 1⅓-Sec-Pendel Bodenstanduhr van 1713'*, Klassik Uhren, 5/2007). I see no reason why our greatest early pendulum clockmaker should not have produced such a pendulum, even with a verge and crown escapement. Huygens had shown that it was possible. The original Great and Centre wheels in this earlier than hitherto realised movement would accomodate that experimental super-pendulum, (fifteen years before Tompion's *2-Seconds'* pendulum at Greenwich). In fact, I found it impossible to arrange any sufficiently high counts (8,400 to 9,000) for a typical short-pendulum; now heed those perfect numbers, **1:10:90!** Might Ahasuerus Fromanteel have found them useful in an experimental observatory timepiece; the original purpose of this associated movement? To answer that question, is to enter the fascinating realm of horological archeology normally reserved for "*dead clocks*", i.e. incomplete relics.

ANNEX 2 - JAMES FERGUSON'S TIDAL DIAL 1756. (see reference at page 10).

James Ferguson's TIDAL DIAL having Elipse and Water Levels



Acknowledging F.J.BRITTEN, *"Watch and Clockmakers' Handbook - Dictionary and Guide"*, (p.439, Figs.449-450)

James Ferguson (1710-1776), "An eminent astronomer and mechanician. Pub. 'Tables and Tracts.... London 1771. ' Select Mechanical Exercises...' dealing with clocks, and 'An introduction to Electricity., London 1775, containing the first English reference to electric clocks. Made orreries and a 3-wheel and other special clocks. Compass dial M.M.A." (G.H.Baillie, *'Watchmakers and Clockmakers of the World'*, p.107. N.A.G. Press Ltd, London 1966).

Ferguson's reputation for mechanics is sufficient to believe that he may, independently, have arrived at his pictorial ***Tidal Elipse*** dial with water levels circa 1756. However, it is possible that Fromanteel too had arrived at his Tidal Elipse some ninety years earlier. Quite possibly, Ferguson might have seen or at least known of Fromanteel's Equation and Tidal clock with its first natural representation of the Flooding and Ebbing of the Tides. In the case of the Harris (Belmont) Charity's Fromanteel Equation Clock, and for those to whom a Fromanteel-Wallis' Tidal Dial is not a well founded hypothesis, I leave this solution by a later clockmaker.

▲ (Back to Top) HF ▲ (Back to RH)

END NOTES: [KP. I recommend all these informative sources].

---

i Michael Hurst, "The First Twelve Years of the English Pendulum Clock", AH, June 1969 [**KP**. reprinted by the AHS as a pamphlet].

ii Sir George White, "English Lantern Clocks", ACC, 1989, Chapt.III, Figs. III/22, III/64, III/68. [**KP.** a definitive work, but gems still appear]

iii R.A.Lee & R.T.Gwynn, "The First Twelve Years of the English Pendulum Clock, or The Fromanteel Family and their Contemporaries 1658-1670", 1969, plates 92-97. [**KP.** inspired new generations of *Fromanteelians*]

iv J.H.Leopold, "Christiaan Huygens, The Royal Society And Horology", Antiqurian Horology. Vol.XXI No.1, Autumn 1993, p.38, n6.

v Thomas Birch, "History of the Royal Society of London", 1756, Vol.1, p.98; [Index by G.E.Scala, The Royal Society, 1974]. Also see Rev. Wm. Dereham, "The Artificial Clockmaker" 1696, pp.95-96; (E.L.Edwardes, "Story of the Pendulum Clock", p.58. Dereham). Dr Ward's clock was at Gresham in 1696 and RS in 1756. Inscribed with dedication to Lawrence Rooke (1622-62), first RS curator, and Hooke's predecessor. Dereham says it is "made exactly to Mr Zulichem's directions", (silk suspended "crown" pendulum). Birch infers a 1-second pendulum - perhaps with a long-case?

vi Remontoirs were probably invented by Burgi to facilitate his "cross-beats", equalising driving torque at escapement, they allowed a "rate" to be set to predict error for first time. When set lower in the going train they can significantly extend duration - (see spring clocks signed Johan Zuyller Ulm).

vii Anon, "Watch and Clock Maker", NAG, 15 Dec.1930, pp.388-9.

viii Birch, Op.Cit. Vol.I, pp. 68, 341, 344.

ix William Leybourne, Philomathes; "Pleasure With Profit, Consisting of RECREATIONS of Divers Kinds", London 1694, Mechanical, XXXVII, p.31. Also see Mechanical XVI, p.27). See facsimiles Part I**,** Figs.2 and 3.

x Brian Loomes, "Country Clocks and their London Origins", Bracken 1976, Chapt.2, 'The Fromanteels', p.53. [Excellent genealogy+biographies].

xi Lee & Gwynn, Op.Cit. Exhibit 6, 30-hour musical spring clock, Plates 21-24. Also P.G.Dawson, C.B.Drover, & D.W.Parkes, "Early English Clocks", ACC 1982, Chapt.XI, pp.501-512, Figs. 744-758. [caveat, STOLEN in burglary 24-4-95, if seen notify AHS]. [KP. Peter recovered his clock].

xii H. Alan Lloyd, "Some Outstanding Clocks Over 700 Years 1250-1950"; ACC 1981, p.80., Plate 87(b), n.87. By same author, "Some Notes on Very Early English Equation Clocks", HJ, December 1943, Figs.5-6, pp.318-9 (describing the same Belmont Fromanteel equation clock).

xiii ie. despite Dawson's optimistic pre-1667, (1987) Op.Cit. p.37.

xiv Robertson (1975), Op.Cit. p.145-8, Fig.22, Facsimile. Also, Kenneth Ullyett, "In Quest of Clocks", 1968, p.177, Plate LXVII.

xv Leopold, John (1993), Op.Cit. p.39. n.14, citing "Oeuvres Complete de Chr.Huygens", Vol.V, no.1218. (Huygens to Alexander Bruce).

xvi Edwardes & Dobson, "The Fromanteels and the Pendulum Clock", AH, Sept. 1983, pp.250-1.

xvii Dr R. Plomp, "The Dutch Origin of the French Pendulum Clock", AH, December 1972, p.36, clock X3, and Huygens' own, and C3?

xviii In 1679, John set a lozenge in the minute ring of his Austin Friars month clock with ting-tang quarters, also in second and minute rings of his similar clock, see Lee & Gwynn (1969), Op. Cit. Exhibit 29. Were these purely decorative, or also functional as 'Datum' points?

xix Birch, Op.Cit. Vol.II. pp.89,93,98,119,122,127,129,133-135.

xx Dr Hans von Bertele (BHI), "Precision Timekeeping in the pre-Huygens Era", HJ Dec.1953, pp.794-816. From the same author, "Early Clocks in Denmark", HJ Dec.1954, HJ Jan.1955, HJ Mar.1955, HJ Apr.1955, HJ Jun.1955. Also see Dr Wolfram Block, "The Radellof Cross Beat Clock of 1660", AH, Sep.1972, pp.700-703. Lloyd (1981), Op.Cit.pp.61-69, 97-98.