APPENDIX FIVE **A Royal 'Haagse Klok'**
"Severyn Oosterwijck Haghe met privilege"

ALEXANDER BRUCE'S ENGLISH AND DUTCH LONGITUDE SEA-CLOCKS REDISCOVERED

Reviewed by Keith Piggott

THE HISTORICAL BACKGROUND

Part II, '*Oosterwijck's Options'*, (**§** 6, pp.32-33), broached the first longitude sea trials of pendulum-controlled clocks by Alexander Bruce in 1662, then by Christiaan Huygens in 1664-5. ***Appendix Three*** suggests some lines for ***open research***, including these first Longitude clocks - depicted in Hollar's 1667 frontispiece to Thomas Spratt's '*History of the Royal Society'*. ***Appendix Four*** expounds on the *Longitude* applications of Simon Douw's 1658 patent spring-remontoir and oscillator; versus Huygens' (also Bruce's) pendulum constructions**.** As a consequence of ongoing research, positive feedback, and examinations, I find myself in the enviable position of having to expand on these references. This ***Appendix Five*** examines two of Bruce's *Longitude* relics; one known, but never reviewed, is signed *Seuerijn Oosterwijck Fecit Haghe,* (page 24); the other is unsigned, London made, and hitherto unknown, (page 8).

Through his statesman father **Constantijn Huygens (1596-1687)**, to whom Willem **Blaeu** had dedicated maps, young Christiaan **Huygens** (1629-1696) had a ringside seat to Frisius **Gemma's** (1508-1555) proposition in 1530, to determine Longitude by *accurate time-keepers* set to ports of origin; also to Galileo **Galilei's** (1564-1642) new *pendulum* and its application; when his father had sat on the Dutch Marine's board in 1635/6, to consider Galileo's offers of a '*manually impulsed pendulum with an integral counter'* he claimed would resolve '*Longitudes'* at sea. Early insights of that nature were formative to '*young Archimedes'* as his father fondly called him. Though Galileo's uncharacteristically unworkable idea was dismissed, its seed, evidently, was sown in a fertile young mind. Two decades later, that seed was to flourish.

View: Constantijn Huygens, and his Children, by Hanneman, circa 1640. Courtesy of *Maurithuis,* The Hague. Clockwise from top centre; Suzanna, Constantijn Junior, Lodewijk, Philips, Christiaan aged 10.

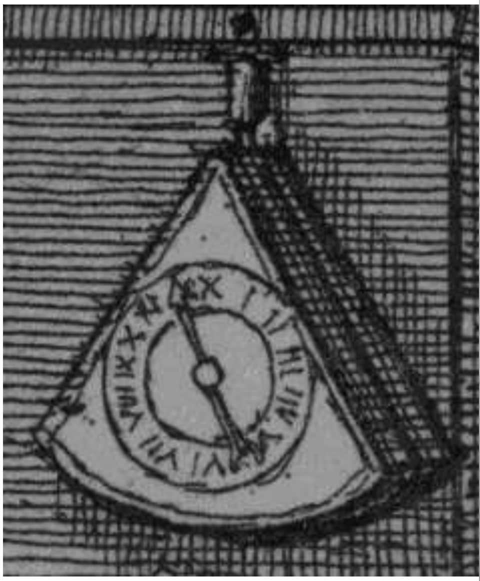
Holland was a major sea power, rewards for success in fixing Longitudes would be immense. I do not doubt that others had applied Gemma's method during the *pre-pendulum* era, but earlier '*sea-clocks'* had all failed. But come 1656, Huygens had in mind application of his new pendulum-clock to determining '*Longitudes*' at sea. Yet not till 1663 did he devote himself to designing and commissioning a *sea-clock*. Rather surprisingly, Huygens was not the first to use *his* new *crutched-pendulum* to that end; a Briton was to pre-empt him by more than two years.

In May 1660, a Scot from Culrose, **Alexander Bruce**, 2nd Earl Kincardine (c1629-1680), second son of Sir George Bruce, had returned to The Hague to escort **Charles Stuart** to England as **King Charles II.** Bruce was acquainted with the pendulum clock of Huygens; **Charles** had one that struck the ordinal hours, from **Severijn Oosterwijck** at The Hague - ***The Royal Haagseklok.*** Alexander Bruce, like Simon Douw, surely knew of Gemma's proposition. for a Longitude -Timekeeper.

Bruce had left Scotland in 1657, for political reasons, going first to Bremen, then Hamburg, lastly to The Hague. On 16th June 1659, he married Veronica the daughter of Cornelis van Aerssen (Lord of Sommels-dyck en Spyck) and Louise van Walts. Possessed of a great fortune, Bruce was knowledgeable in medicine, science, language, with a talent for mechanics. He served Charles II, and he was a founder member of the Royal Society, (link OC, Nr. 1073, n.3).

Bruce was astute and practical, he perceived the potential for a Longitude sea-clock based upon Huygens' claims for his new suspended-pendulum. We know little of Bruce's methodology, who he approached for advice or commissioned to construct his first clock. Yet, we know that **Robert Hooke** and **Christopher Wren** were in his circle, soon to found the Royal Society with **Sir Robert Moray** (*pro-tempore President*) and **Dudley Palmer** (*lawyer of Gray's Inn who drafted its Royal Charter)*, whilst **Ahasuerus Fromanteel** and **Edward East** were renowned pendulum-makers, associated with those and other eminent patrons.

View: **Frontispiece, Thomas Spratt's *'History of the Royal Society'* (1667)**; Engraved by Wenceslas Hollar, dd.1667. Designed and drawn by John Evelyn with Cardano-suspended sea-clock. **nb**.LX,IIV



Evelyn's drawing probably depicts one of Bruce's already retired *Sea-Clocks* with Cardano’s suspension, († p**.**3); but having a *single* hand? Its distribution of mass, in a '*triangular'* (sextant) brass case is suited to its marine purpose; but the single-hand is disconcerting to this identification. However, in reading Evelyn's diaries in another connection, I came to realise he was no horologist; (see dial, *IIV*, *LX*); so I plead Evelyn's *artist's licence,* and I do not doubt that Hollar engraved what he was given, exactly. Might Hooke, Wren, or the Fromanteels, have been involved in designing Bruce's original sea-clock? His *F-double crutch* retained Huygens' suspended pendulum - [but with or without prior consent?] In 1660/1 Bruce's obvious choice of maker for his first sea-clock, probably, was Ahasuerus Fromanteel. In April 1661, Huygens, soon to accept Membership of the Royal Society, visited London; at this visit Bruce showed Huygens his new sea-clock with his inverted **'F'** *double-crutch*; and John Evelyn took Huygens *"to Fomantils ye famous clock-maker to see some pendules"*, (Diary, May 3rd, 1661). In June 1661, Lawrence Rooke died, and Fromanteel made the Bishop of Exeter Dr. Seth Ward's commemorative gift of *"a large pendulum clock"*; **[**Dereham says, *"made in Huygens' way"*, (1694)**]**; which was still with the Royal Society at Crane Court in 1756, (see Thomas Birch, *'History of the Royal Society'*, 1756, p.98, *Minutes for 1661/2*).

Bruce intended his **'F'** crutch to counter *pendulum banking* in pitching-rolling ships, despite his clocks already having Cardano's suspension. Huygens recognised that Bruce had adopted his patent *suspended* pendulum, only changed his patent Crutch's single-loop by adding the second crank, (Lat. *Deorsum******), set across-wise, in the form of an '**F**' inverted**,** ('*Horologium Oscillatorium'*, p.17*).* Opposed cranks limit the plane of oscillation; but to no avail. Hooke had predicted inherent flaws in all sea-clock pendula; subject to ceaseless and incalculable accelerations, not being self-cancelling errors! In March 1663, even Moray had warned Huygens so. Hooke also knew that his *spring-pendulum-suspension* too could never compensate accelerations at sea. Nevertheless, Bruce, and Huygens, persisted with pendulum sea-clocks.

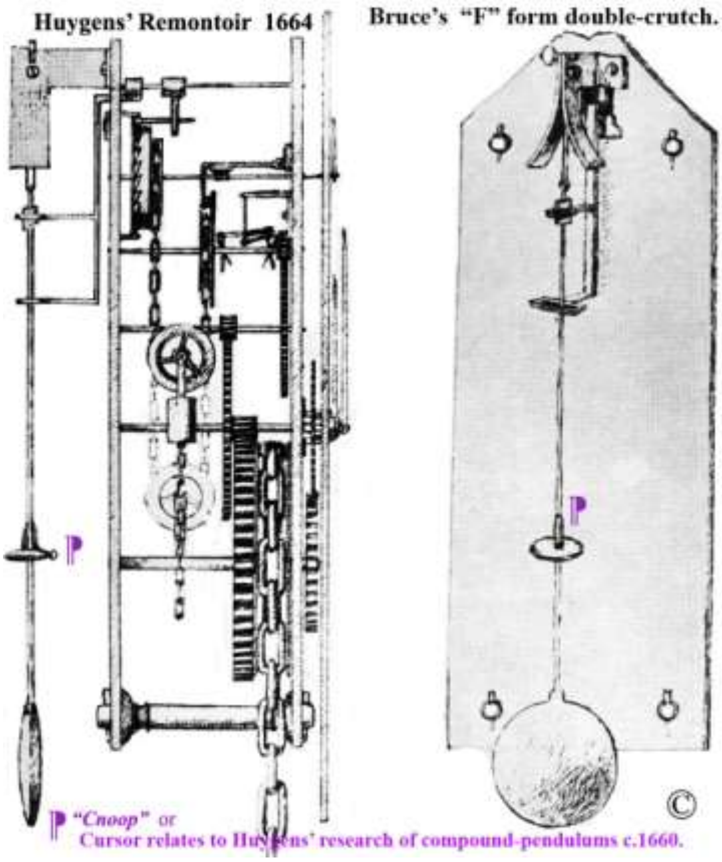
*****Volgraff' translates '*deorsum'* as '*manivelles'* (French, pl.), *'cranks'* (English, pl.). One translation gives *"doubling the weight",* (Prof. R.J *Blackwell, 'Christian Huygens The Pendulum Clock or Geometrical Demonstrations Concerning the Motion of Pendula as Applied to Clocks'*, p.28. Iowa State University Press,1986). I thought Blackwell's '*weight'* might mean Huygens' *remontoir-weight* was doubled, but that had made no sense in the context; Bruce's earlier sea-clocks were spring driven via fusees, without Huygens' weight-remontoir (1664); confirmed by my examinations of the relics.

†Girolamo Cardano (1501-1576), in 1557 described the angled '*ring-joint drive'* - now called '**Hooke's Joint**', ('*Mediolanensis philosophi et medici celeberrim'*, p.163). Cardano's '*ball & socket suspension'* provides for multi-plane freedom but without any coupling for drive function; anticipating '*pre-pendulum'* sea-clocks?

†Cardano's suspension; A steel ball is held, loosely, within a brass cylinder, being free to rotate in all planes, somewhat like a gimbal. Shown here applied to a '*Scheepsreisklok'* (NL. literally *ships' travelling-clock)* by Johannes van Ceulen of The Hague, circa 1680, (acknowledging copyright of H.M.Vehmeyer "*Antiek Uurwerken Een familieverzameling"*, p.374, invent. nr.94, Vehmeyer *1994*).

Probably, Bruce's 1661 *pendulum sea-clock* was tested in his several voyages between Holland and Scotland, between March and December 1662. And while residing in The Hague, until December 1662, he had Severijn Oosterwijck make him two '*copies'*, which he tested in a stormy return to Britain. One of the three, (Leopold says the '*old'* clock), was badly damaged; the *other* stopped. Had Bruce left one of Oosterwijck's two copies with Huygens? John Hilderson then made a further copy of Bruce's '*old'* clock. So, already, Bruce had commissioned ***four*** sea-clocks. And in 1664, Edward East John Fromanteel and another all made similar sea-clocks, (John Leopold, '*The Longitude Timekeepers of Christiaan Huygens*', pp.102-114; *The Quest for Longitude'*, editor William J.H. Andrews, Harvard, 1997). In his own historical terms, Christiaan Huygens 'had missed the boat'.

That must have rankled. Publicly he sows doubts, but privately he anticipates its success, ***"Monsieur Brus qui s'en est retourné en Ecosse, aura fait une experience sur mer dont j'attens le succes avec impatience parce qu'ell est de grand importance, dans cette affaire"*** (OC.vol 4, p.256). As to Bruce's '**F***'* crutch, he only refers to his co-inventor as *"a Scottish gentleman and a friend of ours"*, (*Horologium Oscillatorium*, p.16). He also states the first sea-trials, in a British ship, were in 1664(sic), when he, finally, had gotten actively involved. Huygens failure to publicly credit Bruce had caused their rift, but he had always regarded his pendulum and weight remontoir as needing no accredited co-inventors, (ditto **Thuret**); whereas Bruce thought his *'F-crutch'* a significant contribution. Had Huygens been thwarted, by Coster's purportedly cavalier use of his assigned Patent rights? [Some authorities assert Coster '*gave away'* Licence].



View: Huygens' Manuscript Book - drawings of weight-driven remontoir with Bruce's double-crank 'F' crutch, c.1664. (Courtesy Leiden University Library; acknowledging Kenneth Ullyett, *"In Quest of Clocks"* pl. LXVII, p.177).
[Note. Ullyett depicts several remarkable drawings from Galilei and Huygens, without fully developing their contexts]

Notably, Huygens first sketch of his own longitude-clock, having his new weight remontoir, already has Bruce's "F" double-crutch. Probably, it was roughed- out during August-September 1662, (University of Leijden Library: View: see J.D.Robertson, Op.Cit. Fig.23). By November 7th, 1662, Sir Robert Moray was already mentioning the exchanges between Huygens, himself and Bruce. (<OC_1076>). Despite parsimony in his public credit of co-inventors there is no doubt, from first concept, right to his patent (see p.3), Huygens always had committed himself to Bruce's new 'F-crutch'. **Note**. Fromanteel's pivoted pendulum did not need a crutch, itself being a *weighted-crank*; coincidence, or, if one rashly assumes Fromanteel's prior ignorance of Galileo's pendulum and *Discorsi*, his inspiration for alleged late conception?

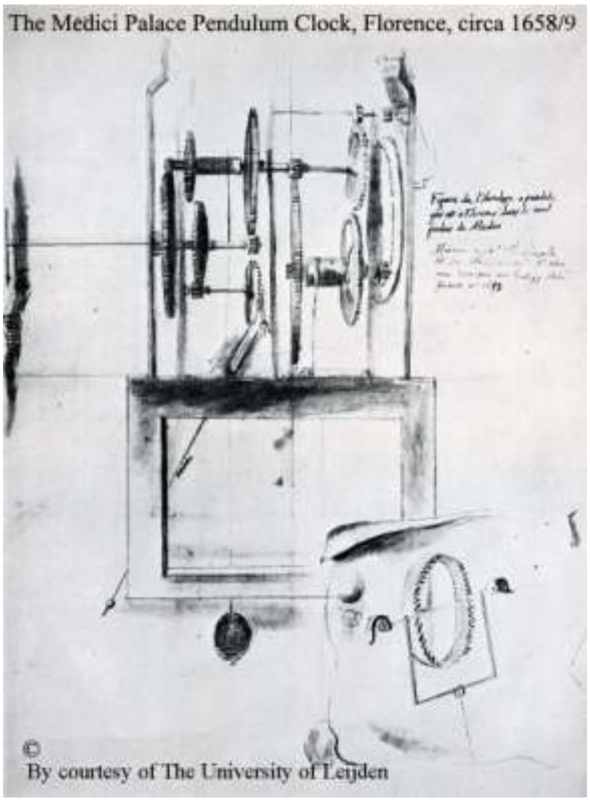
Huygens' fully developed patent drawings, circa 1664, clearly depict Bruce's double-fork crutch in the form of an '**F**' inverted. So Huygens' anonymous credit therefore gives insight into that egocentric character. Interestingly, Huygens' crested plates bear no resemblance to Bruce's larger triangular plates, but do resemble Fromanteel's elongated, crested, plates; perhaps noted when visiting Ahasuerus' London shop in the company of John Evelyn during May 1661.

It is outside the scope of this appendix to re-examine Huygens' flawed weight remontoir. However so far as is recorded, also supported by my own examinations of these two relics, Bruce's sea-clocks never were fitted retrospectively with Huygens' new weight-remontoir, after August 19th of 1664 when Severijn Oosterwijck brought it to passable fruition.

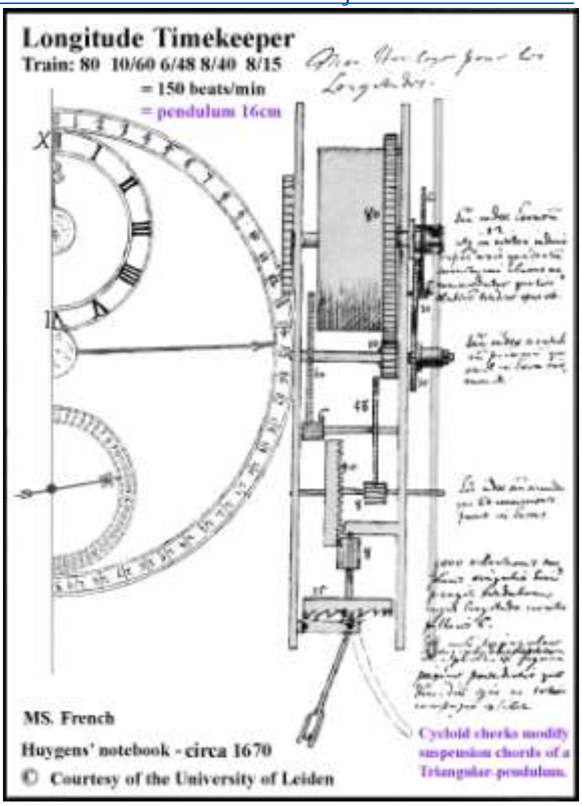
In February 1665, whilst ill in bed, Huygens observed the phenomenon he called *"pendulum sympathy"*, ie. anti-phase synchronocity of clocks mounted on the same beam. He hoped that this '*synchronicity'* might be advantageous at sea, to maintain his sea-clocks' mutual timekeeping. He reported this odd phenomenon to the Royal Society, where Alexander Bruce still supervised then ongoing longitude sea-trials, and on March 1st, 1665, Sir Robert Moray read Huygens' letter to Members. Members realised, conversely, that the phenomenon was a nail in the coffin for *pendulum* longitude sea-clocks. That soon proved to be the case, (see M.Bennett, M.F.Schatz, H.Rockwood, K.Wiesenfeld, '***Huygens's clocks***', §1, Introduction, p.563, Proc. Royal Society, <10.1098/rspa.2001.0888>). Huygens did not see it.

So the tenuous life-span of any *pendulum-controlled* 'Longitude' sea-clock is defined by Bruce's first demonstration of his "F double-crutch" to Huygens in May 1661, until the Royal Society's realisation in March 1665 that the pendulum was never going to resolve longitude at sea; just as the Royal Society's own Robert Hooke had always predicted.

Remarkably, English insights did not percolate into Huygens' mindset, fixed on his own pendulum. He persisted, fruitlessly, with various forms of pendula until 1675. His final, *pendulum*, longitude timekeeper had a spring going-barrel, still no fusee, driving a now *underslung escapement* in the manner of a pendulum conversion [by Treffler?] of the Medici Palace clock, a drawing of which Grand Duke Ferdinand had sent to Boulliau in Paris, who forwarded it to Huygens on 20th August 1659. In Huygens' final attempt at a pendulum solution to longitude, in 1672, he too employed an underslung escapement for a new *triangular-pendulum*. Images courtesy of Leiden University Libraries; http://www.bibliotheek.leidenuniv.nl/bijzondere-collecties/

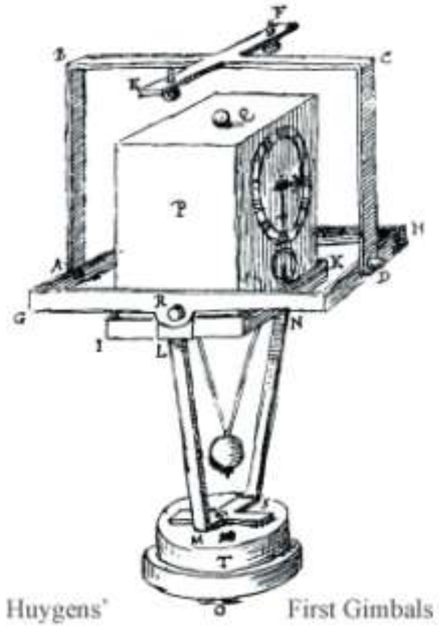


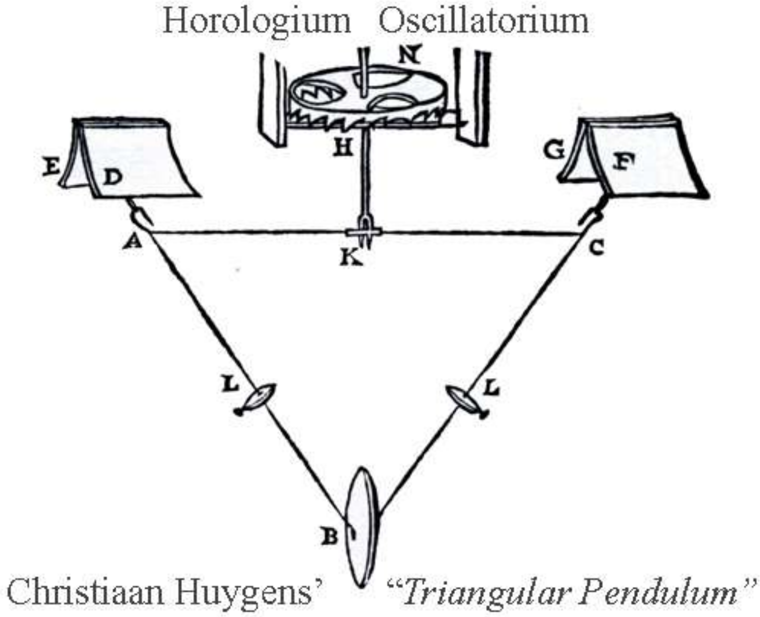
View The Medici Palace Clock, (modified to pendulum).



View Huygens' `New Underslung Pendulum

Unusually, in his new marine time-keeper with spring-drive, the champion of short trains (to avoid friction) first uses a *five-wheel* train. Typically, he announced it with great fanfare in *"Horologium Oscillatorium"*, (Part One, pp.19-20), explaining his triangular pendulum theory - and showing his sea-clock mounted in a heavy marine gimbal.



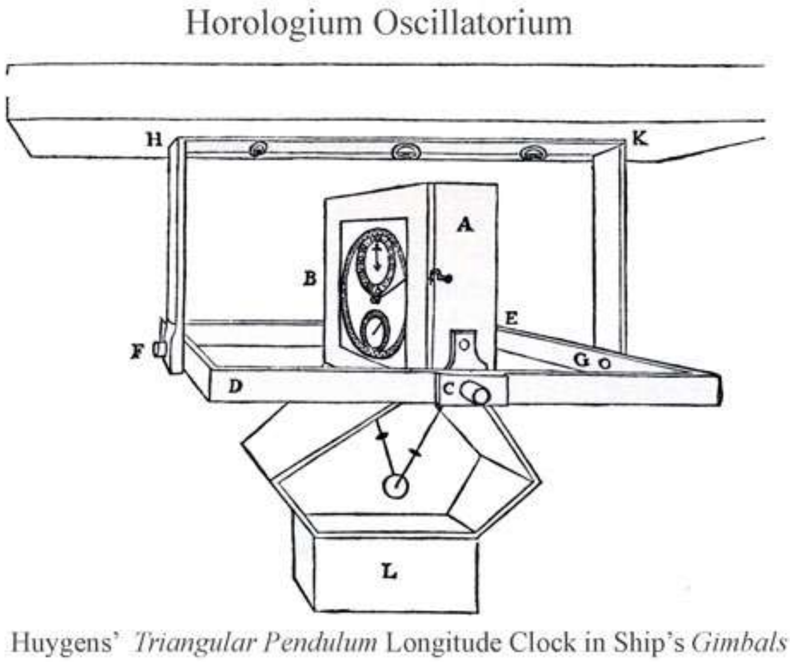


View: Huygens' Longitude timekeeper set in weighted *Gimbal* for stability at sea.

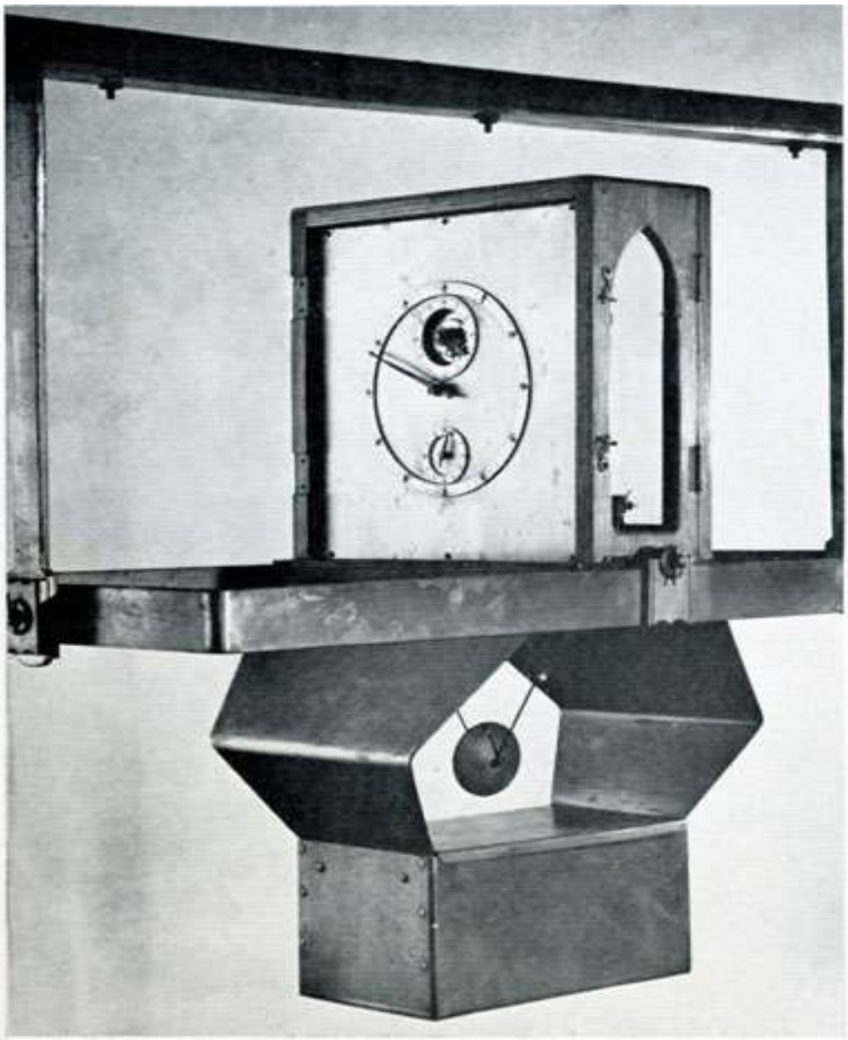
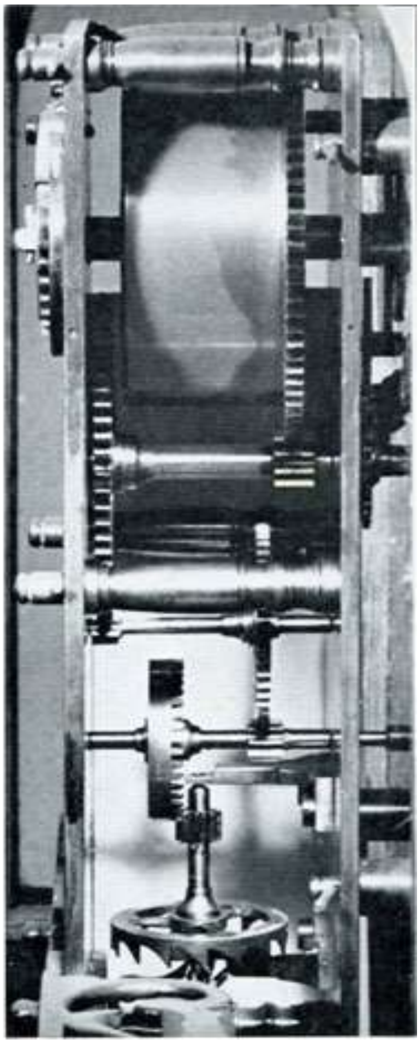
View: Huygens' underslung *Triangular Pendulum*, having two pairs of *Cycloid Cheeks* (NL. '*cycloidale lamellen*', or '*boogjes*').

Huygens' new underslung escapement's horizontal but now inverted escape wheel [N], drives the pallets of a pivoted verge [H], its central fork set into a swinging plate [K], midway along the triangular pendulum's base-line [AC]; itself attached to hooks [A,C] from the suspension chords oscillating between two pairs of cycloid cheeks* [E-D, G-F]; one pair on each suspension chord, supporting triangular pendulum [A-B-C]. ***** Huygens' geometrician's proof found Galileo's rolling body cycloid curve resolved the tautochrone problem; i.e. changing *pendulum-length* with amplitude, micro-adjusting the intessimal finite periods of swing; not *'raising pendulum-bob with amplitude'* as generally thought.

Adjustable cursors† [L], here named *Lunnettes* (Fr) in deference to his then French paymaster ***Louis XIV***, are set upon each isosceles chord [A-B, C-B] leading to a lenticular bob [B] at apex. †Huygens' '*Cnoops'* (Lat. *Lenticulae*) of 1660, *serve to* vary the *centre of oscillation* of the compound 6.3" pendulum - to correct beat 150 times per minute.



View: Huygens' drawing of his final arrangement with massive Gimbal its layout offered unrestrained freedom for his '*triangular pendulum'*. Huygens' longitude sea-clocks and gimbals became ever more massive. The Leiden Museum of the History of Science has, probably, the sole surviving example, (see next page).

View: **Huygens' 1673 Longitude Timekeeper with *Triangular Pendulum*.**
Train Count, **80 10/60 6/48 8/40 8/15** = 150 beats/min. Pendulum, 16cm (6.3").
Images courtesy of The Museum for the History of Science, Boerhaave, Leiden.

Huygens' inverted movement follows his drawing of a new Longitude clock with underslung escapement having his triangular pendulum; unrestrained by Bruce's **'F'** double-crutch nor even by clock-plates nor by case. His triangular pendulum longitude-clock is discussed by J.D.Robertson, ('*The Evolution of Clockwork'*, p.162. fig.27); also H.A.Lloyd, ('*The Collector's Dictionary of Clocks*', p.111. figs 287-288); K.Ullyett ('*In Quest of Clocks*', p.129, fig 24). Even his triangular pendulum too was fatally flawed for a maritime role. To an extant, Huygens much vaunted *ingenuity* and *practicality* must take a knock; in 1658 he had missed the longitude potential of Douw's patent spring-remontoir oscillator, (***Appendix Four***); then, for decades, he simply did not accept, nor even see, the inherent defects of pendula at sea, already long identified by Robert Hooke – even after he was cautioned by his new friend Sir Robert Moray.

In 1674, Huygens then set off in a new direction, no doubt being inspired by Sir Robert Moray's disclosure that Robert Hooke, in 1665 (sic, 1664) had lectured to the Royal Society on his new principle of a ***spring-balance controller**** for use both on the sea and land, (replacing the aberant pendulum).. *Dr.R.Plomp, *'A Longitude Timekeeper - Isaac Thuret with the Balance Spring invented by Christiaan Huygens'*, op.cit. ***Longitude*, §3.** [nb. Hooke's RS model made in 1666].

So, by January 20th 1675, we then see Huygens *'inventing'* his spring-balance, applied to a verge watch; unlike Hooke, Huygens used a long spiral-form. He assigned its manufacture to Parisian watchmaker Isaac Thuret, who had improved the little chain to his flawed weight remontoir - without receiving due credit In 1693 Huygens designed his '*Perfect Marine Balance'*, completed by Barent van der Cloese, (OC., vol.18, pp.562,569). Huygens applied it to his clock with a new ***equation-cam***† that he also disclosed to Tompion and Quare in 1694/5, via his brother, the Secretary to William III who immediately set both to make their Royal *equation* clocks. Williamson set the *cam* directly to Quare's pendulum.

†Here I follow H.Alan Lloyd, *'Some Notes on Very Early English Equation Clocks, and Joseph Williamson's claim to have made them all!'* (*Horological Journal*, BHI,1943). My "Lloyd stance", was repeated at the 1993 Joint RS-AHS meeting, again at Huygens' Legacy exhibition seeing the entry for Quare's equation-clock, led to a short correspondence with one of the Dutch authors - who still remains steadfast in attributing the equation-cam invention to England. Really, by now, 'antiquarian horologists' should have laid that canard to rest. [Note. Might differences in early Equation Tables be reflected in measurable differences between Kidney-Cam profiles; to relate Huygens' Tables to any maker's clock?]

THE ALEXANDER BRUCE '*LONGITUDE*' SEA-CLOCK RELICS, 1661- 1665

Returning to Alexander Bruce's pioneer ***pendulum sea-clocks***, I move to the rediscovered ***Longitude*** relics; I use '***relic***' in its antiquarian sense, without negative inference. Hollar's frontispiece to Spratt's history was drawn by John Evelyn. He shows a wedge-shaped timepiece with Cardan's suspension, back-wound, with but a ***single-hand*** - disconcerting to this identification; though elsewhere I came to realise that Evelyn was no horologist. The Severijn Oosterwijck relic is recorded; the London made relic is unrecorded. Each now has an associated dial and case, which I ignore. Neither do I delve into conduct of Bruce's sea-trials, nor into the Royal Society's part, both aspects well covered elsewhere, (see Mahoney, Op.Cit. §4; and Lisa Jardine,*"Scientists, Sea-Trials and International Espionage",* AH, 2009, Vol.29, nr.5, pp.663-683). Both relics have '*wedge' form* cited by Neilson, Leopold, and Anthony Weston - '*A Reassessment of the Clocks of John Hilderson'*, AH, 2000, Vol.24/4, p.431). Tony Weston reported, "*It still retains its four minute dial* engraved directly on the back plate"*. ***** In fact the relics' identical back-dials to contrate arbors are 'scribed ***'0-60'***. Both have under-dial motion work for ***hour*** and ***minute*** hands, but not for ***seconds'*** hands - hence their rare '0-60' back-dials?

The proposition that these relics are Bruce's sea-clocks, infers that each had once possessed Bruce's '***F'*** *double-crutch*, with Huygens' *suspended pendulum* and his *cycloid-cheeks*. So I give special attention to the extant *verges*, (one fixed to Fromanteel's simpler pivoted-pendulum; one fixed to Huygens' crutch for Hooke's spring-suspension); also to extant *back-cocks* for any evidence of alterations or substitutions in their conversions from Bruce's *F-crutch* with Huygens' *pendulum* to more basic pivoted and spring pendulums; both being acceptable for fusee or weight drives. The relics were spring-driven by fusee, dimensions are similar, pillars differ; from the Centre their *unequal* trains are identical. Weston's back-dial for *4-minutes*, caused pilot/solo-mariner Brian Walton to suggest its *sidereal* rating, (**Part II**, p.32). In fact, both back-dials record '0-60' *Units* [Seconds], the even units numbered. Meyrick Neilson's former clockmaker, David Todd now living in America, still retains his notes showing Oosterwijck's contrate turning in 4mins 15secs.(sic). Whereas 78/6 = 13 turns/hour, giving 276.92 seconds - exactly matching Bruce's English relic ***#1/4***. What significance has that imponderable period? Their *'0-60'* contrate-dials deny their extant trains. Weston's proposition, '*The fact that some of these clocks were weight driven*', must refer to Huygens' clocks; Huygens described Bruce's as having springs.

Pillar shapes may be Bruce's own preferences. The London-made movement has slender '*continental'* pillars - like Huygens' 1657 Patent drawing (***Part II***, p.30). No surprise in any Dutch movement, yet untypical of Fromanteel, but used by John Hilderson, (A Weston, Op.Cit. figs.28,34). Oosterwijck's relic has his slender *cannon* pillars. The English movement has been converted to weight-drive, now with an open holdfast on a post screwed to the back-plate; ie. not Oosterwijck's swivel-latch for the non-rigid suspended pendulum of his ***Royal Haagseklok***. Already we may infer that this holdfast probably was added at conversion from its first suspended to the simpler pivoted pendulum.

With their private owners' consents, I present Bruce's Longitude movements never previously reviewed. Each demands further investigation, without time constraints. Oosterwijck's movement has been cited previously but wrongly, and its English companion was previously unrecognised, its later dial having a spurious forged signature [the bane of research]. My descriptions and images of these two historic pendulum travelling clocks, *'Longitude'* or '*sea-clocks'*, are the first to be tendered under ***open research.*** It is my privilege to present these hitherto overlooked relics to all antiquarians**.**

Andries van Eertvelt, *'Fluyts in a Storm'*, monogram, c.1620, ink wash on paper, (196 x 298mm).
Preparatory sketch for "*The Battle of Lepanto*"(1623). Provenance, George Salting (1873), © Keith Piggott.

ALEXANDER BRUCE #1/4, A LONDON MADE *'SEA-CLOCK'*
#1 *AHASUERUS FROMANTEEL?* 1660/1, or #4 *JOHN HILDERSON* 1663/4

Private Collection: Descriptions and Images are published in this ***open-research*** by the Joint-Owners' kind consent. Keith Piggott is Copyright-Holder of all views, images, also post-production edited image originations.

As I viewed several undistinguished long-case clocks, my first sight and recognition of this relic came as a total surprise. The case and dial had excited no interest but, through a side glass, my attention was drawn to a *'wedge-shaped'* movement. The back-plate is unsigned, but it perfectly matched shape and proportions of Meyrick Neilson's movement signed '*Seueryn Oosterwijck Fecit Haghe'* (***Bruce Nr.2/3****, below*). I was allowed to have it dismantled on the bench for a closer examination, and consent given for my photographic record. I have yet to unlock all its secrets; was I looking at one of the first *pendulum travelling clocks*, intended to meet Gemma's proposition for safer navigation on the high seas? Here, by the owners' generous consent to publish, under this ***open research*** project, professional horologists are enabled to claim that singular honour.

First Description and Basic Dimensions:
The movement plates, isosceles triangles of equal bases 150mm. wide at clipped corners; having nominal 70 degrees base angles; their reduced heights now 160mm; their nominal 40 degrees apexes truncated to form differently shaped shoulders; the front-plate 43mm. across with a semi-circular '*up-stand'* for the verge pivot; the taller back-plate 35mm. across, now slotted for *knife-edge* verge pivot. Bruce **#1/4** is smaller but wider than Oosterwijck's **Bruce #2/3** (1662). **Exceptionally**, potences in both movements are set onto Front-plates.

The plates 38mm apart, supported by four continental Huygens' pillars riveted to the front-plate, pinned at back-plate; no evidence of latches. The pillar shape, unlike Fromanteel's, may be Bruce's choice. Weston shows this form relates to Edward East, *John Hilderson*, Edw.Hayle, Henry Jones, (Weston, op.cit., figs.28,34; "*Horological Masterworks*", op.cit, nrs.10,12,13; also "*Huygens' Legacy*", op.cit, p.71, nr.26).

View: The 'Wedge' Shaped, Verge-Pendulum Movement, 'III' and 'IX' Elevations.

View: The '*Wedge'* Shaped Movement with original Spring-Barrel replanted. The 65mm diameter Back-Dial, being inscribed **'0-60'** Seconds, centred on the Contrate arbor, (formerly **G3**, now **G4**). Cf. Oosterwijck's **Bruce #2/3**, (p.25).

The horizontal *verge-crown escapement* is mounted in unusual cocks; Front, a horizontal stirrup-shaped *upper-potence* to the escape wheel; Back, a full-span* trapezoid cock having a deep overhang to *knife-edge* suspension-plate, forming a long steel-keeper set in vertical dovetail. The verge fixed by an unusual '**I**' section tenon, pinned onto the now pivoted-pendulum, by the turned brass socket to a brass-Rod having brass-Bob. The front pivot a proud upstand. [*excludes higher position in formerly taller plates]

The '**I**' jointed verge, socketed and pinned to a *pivoted-pendulum* will form the basis of a more detailed assessment. At first sight it seems each could be original parts; ie. the long Verge slotting into Bruce's wide *'F' crutch*; with brass Pendulum-rod being pinned to Huygens' rare '*suspension-pulley'*.

View: Escapement, Top Potence, Back-Cock. Nb. Divided Screw-Hole Indicates Top-Edge Reduced?

The evidence of Huygens' *Cheeks* (by 1661, being cycloids) is now fugitive; the bold back-cock is not giving up the evidence that I had anticipated. Might it be a replacement having a knife-edge and steel-keeper, or, were the Cycloid Cheeks originally slotted into the extant cock by the dovetail now holding the steel-keeper?

View: Pivoted-Pendulum pinned to 'I' bar of long *Verge*.

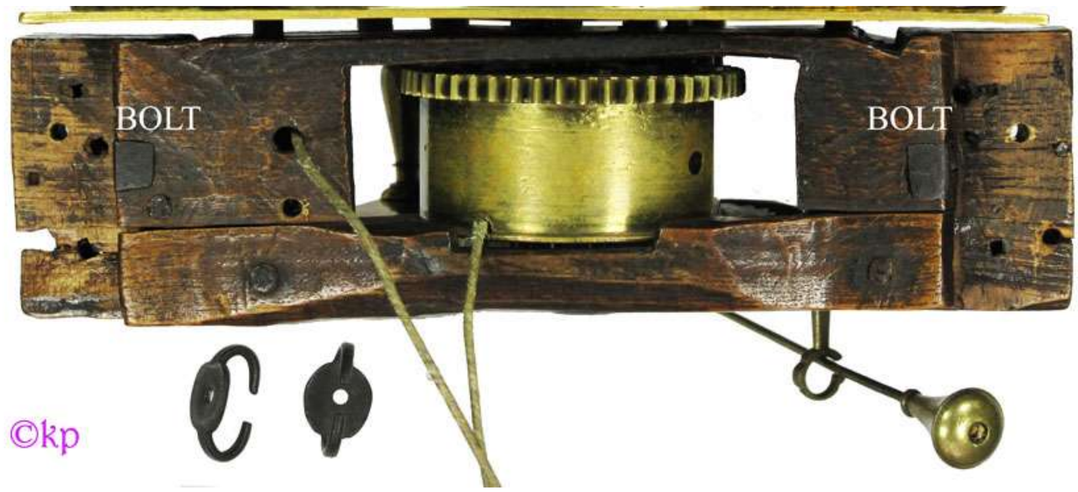
Views: Lower and Upper *Potences*, with Trapezoid *Back Cock*.

The probably original *lower-potence* is screwed onto the back-plate with a single foot cock; cf. Fromanteel cock. Its unusual extended *split-jaws,* holding the *adjustable brass screw* to vertical escape arbor (see p.22), having no evidence for the steel wedge; therefore suggestive of being a later design. Probably, its stirrup top-potence was added at the conversion from the Huygens-Bruce system to the robust, simpler, Fromanteel pendulum.

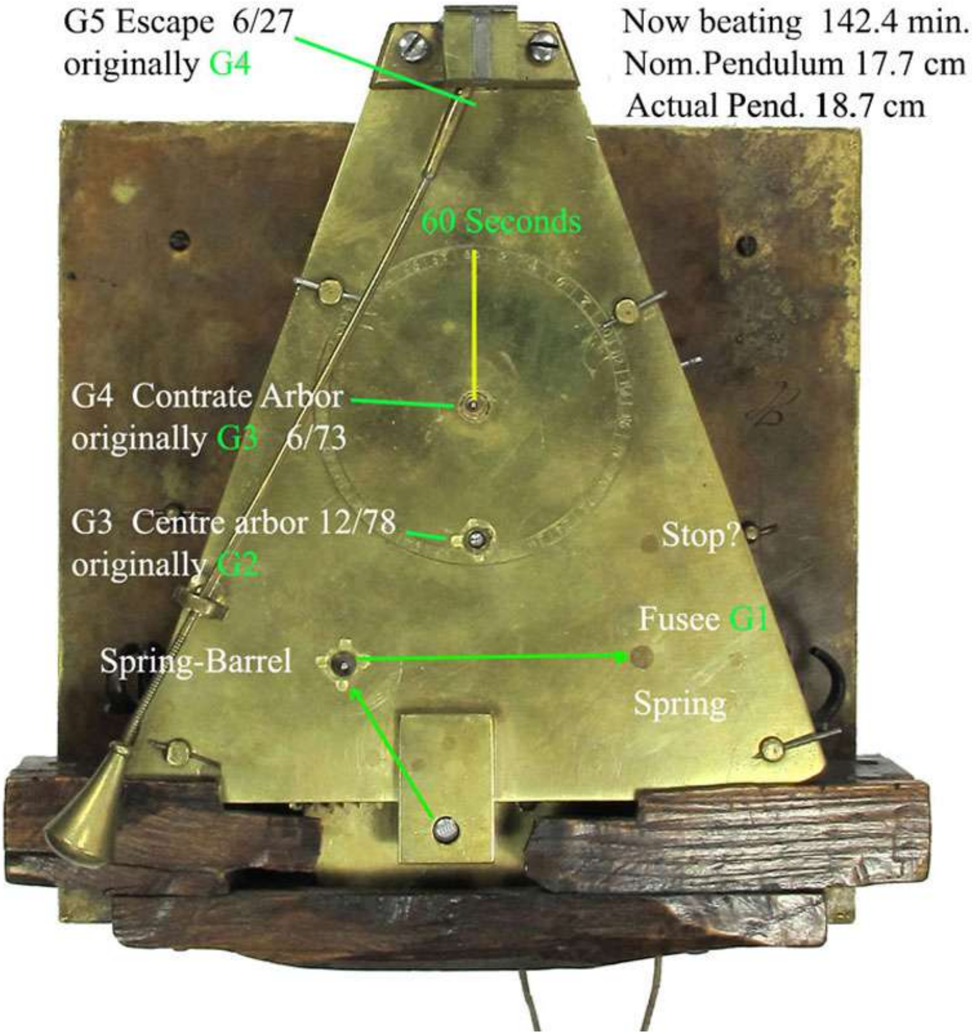
Stubby subsidiary brackets are riveted to the lower edge of movement, for the replanted brass barrel having a substantial added great-wheel. The ungrooved barrel reveals a steel attachment point of the former spring-hook. This accounts for the barrel arbor's shallow depth (just 28mm.), and large domed steel-collet to plant the narrow barrel within the plates to create overlap of the Fusee ground-wheel (***G1*** now **G2**). Therefore, this is the original spring-barrel, now adapted for a weight-line. The later great-wheel (**G1**) is fixed at the front of the barrel to engage a substantial later pinion to the replaced fusee arbor. The plain barrel's turned rear–cap still forms a proud rim, to secure the gut line, a feature seen in Ahasuerus Fromanteel's earlier movements.

Filled holes in the lower plates show where a substantial arbor, fusee- stop and a stop-spring were all removed in conversion to weight drive, with a '*fifth'* wheel added to the barrel to extend duration; the original Fusee great-wheel, now, is the intermediate wheel with the fusee replaced by a substantial added pinion.

Long bolts with wrought iron thumbscrews secure the movement into the boat-shaped, compound seat-board; carved to accommodate the re-sited spring-barrel with new fifth-wheel, held by the extended bracket. This former spring-barrel now is modified into a weight-barrel; wound indirectly via the former fusee arbor; its gut-line now having a pulley.



View: Underside of Seat-board - Thumbscrews secure long Bolts.



View: The present 5-wheel Train, showing original 4-wheel plants.
Nb. The present wheel and pinion count gives an *unequal* train, unable to deliver Seconds at the Contrate arbor to the Back-Dial (see Matrix).

The ancient conversion from *spring-fusee* to *weight-drive is* indicated by obvious age of its modified seat-board for the added great-wheel. Conversion included the very substantial steel pinion on thicker arbor, added to its original fusee great-wheel with recessed click to internal-ratchet; its click-spring now replanted. The fusee has been turned-off, (removed), and replaced by a heavy straight-leaf pinion for new great-wheel.

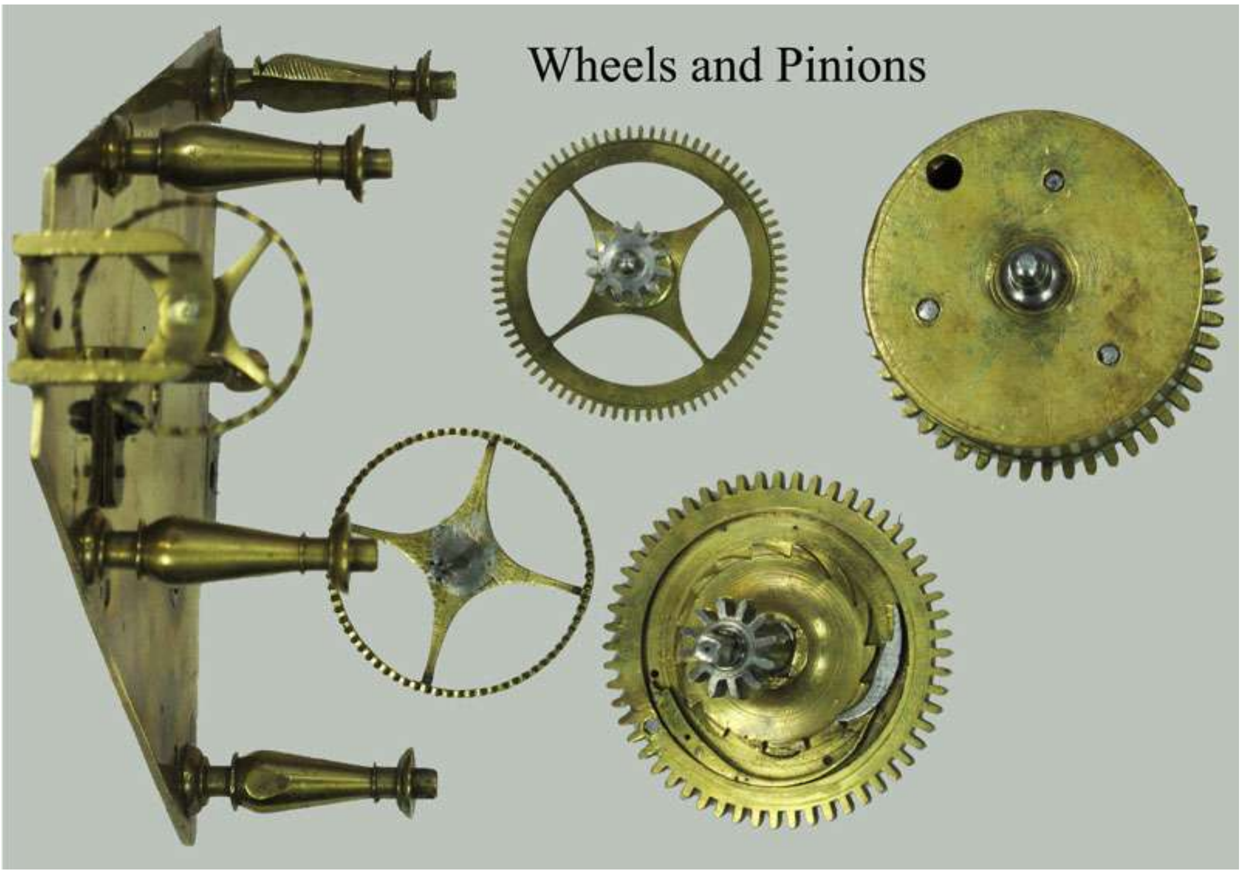
The later great-wheel, added to the spring barrel, is hand-cut. Its teeth have oddly rounded deeply scored roots; it would help ***open-research*** if this rounded root profile can, positively, be assigned to a particular maker. The tooth-form of the original fusee great-wheel, and internal ratchet, are very typical of Ahasuerus Fromanteel's pre-pendulums and early pendulums. Straight pinion-leafs and rounded roots are not.

View: Original Fusee Great-Wheel, New Wheel on Spring-Barrel

Evidently the extant line-barrel, having a rolled and seamed construction, has an internal hook; formerly it contained a main-spring. Its shallow form (28 mm), with steel spacing-collet, clears the original ***G1*** ground wheel that had once held the ***Fusee***, ratchet and click. Replanting the thicker and wider barrel on extended brackets, was forced by the triangular plates and the addition of a fifth wheel, the new Great-wheel, for the weight-drive conversion. Witness marks suggest a central pillar *may* have been removed at bottom-centre.

View: Original *seamed* Spring-Barrel, with added Great-Wheel.

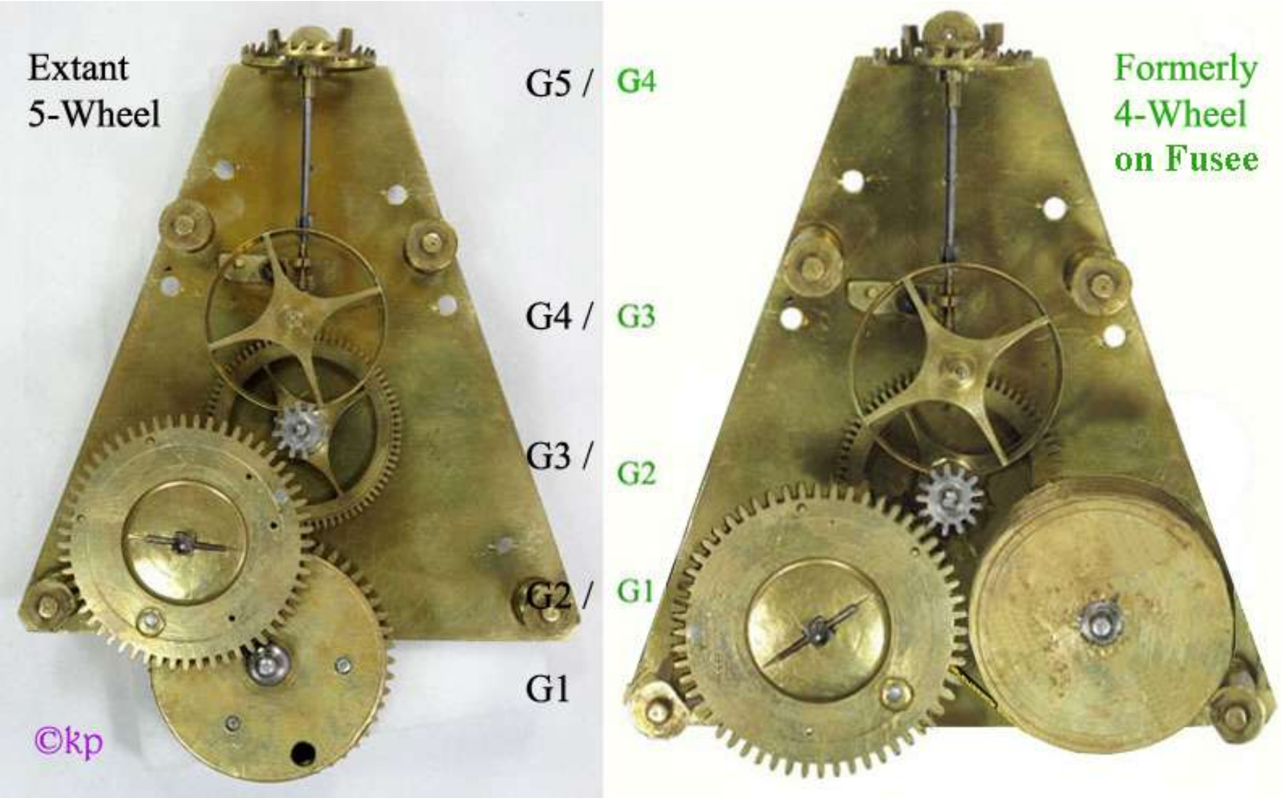
The Centre, Contrate and Escape have great age, but the square collets have a modern appearance, though they have precedents in the earliest pendulum *oeuvres* of Fromanteel (see AF collets) and Hilderson.



View: The Homogenous Appearance of the Train Wheels, Small-Pinions and Barrel.
English-standard wheels have **4-*'Crossings'*** [Dutch-standard wheels have **3-*'Spoken'*** (Eng. **Spokes**)]

The fact of this short-pendulum verge movement's ancient conversion, as a weight-clock, simultaneously gaining a longer duration, is telling evidence of this sea-clock's early retirement from its intended *longitude* application in a *marine* employment. Evidently, then, it was not thought worthwhile to convert this unequal train into a longer pendulum, nor later to the new anchor escapement. Yet this extant, unequal, Centre to Escape short-train, (exactly matching Bruce **#2/3**), infers changes have been made; also implied by evidence of the filled holes in the reduced upper plates.

View: Adapted 5-Wheel Train: **View: Original 4-Wheel Layout.**



Bruce Nr.1/4 **Unequal Train**
Extant 5-Wheel Train: 48 12/56 12/78 6/73 6/27 = **142.35 beats/min**
Extrapolated 4-Wheel Train: 56 12/78 6/73 6/27 = **142.35 beats/min**
Contrate turns **13** times per hour; period ***276.92*** secs, (4min 36.9sec).
Nominal pendulum length 17.66 cm. Actual length 18.7 cm.

Hypothetical ***Sidereal*** Train: 78 6/72 6/23 = **119.666 beats/min**
Nominal 25.024 cm. pendulum, [if compatible with Hollar type case?]
Hypothetical ≈***Mean***Train: 78 7/73 7/31 = **120.077 beats/min**
Nominal 24.825 cm. pendulum, [if compatible with Hollar type case?]

Incompatibility of extant or related alternate trains with a *60-Seconds* Dial.

BRUCE 1/4	*LONDON:* Ahasuerus Fromanteel 1661 or John Hilderson 1663							
Extant train	BRUCE 1/4	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	27	6	142.35	2.636111111	158.1666667		
Contrate wheel	G3	73	6	Pendulum cms	0.216666667	13	276.9230769	4min 36.92 sec
Centre wheel	G2	78	12	17.6645	0.016666667	1		
Fusee (former)	G1	56						
Sidereal train		Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	23	6	119.66667	2.601449348	156.0869609		
Contrate wheel	G3	72	6	Pendulum cms	0.216787446	13.00724674	276.7681	4min 36.768 sec
Centre wheel	G2	78		25.024	0.016675957	1.000557441		
Mean train (approx)		Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	31	7	120.077	1.936725806	116.2035484		
Contrate wheel	G3	73	7	Pendulum cms	0.185713433	11.14280601	323.078406	5min 23.08 sec
Centre wheel	G2	78		24.825	0.01666659	0.999995411		

Michiel van Hees provided the useful matrix formulae for calculating arbor-rotations, even that suggests no equal solutions for the Contrate to turn in ***60-Seconds***; (nor in ***4-Minutes***, as Oosterwijck's is said to do). Its contrate makes *13 turns*/hour; i.e. *4mins 36.92 secs*/turn, meeting no logical '*longitude'* standard. I found no evidence of motion-reduction-gear, like Trefler, to produce a useful number for a Contrate back-dial showing 0-60 units in single-unit intervals. [nb. at Concluding Observations (p.44) I propose a radical train solution]

Further examinations, and pondering, is needed to determine this longitude movement's original short-train, be that *Equal* or *Unequal, Mean* or *Sidereal* - as Brian Walton proposed. Open-research should enhance our chances of success**.** **[**Note. the relic Christiaan Reinaert movement with original escape-wheel in 5-wheel train, seems to have a similar arrangement - but sited on its intermediate arbor (*G2*), and without a seconds' dial. Berry van Lieshout observed this feature, but again no equal solution was found in that example].

Addition of the holdfast for the extant pivoted-pendulum suggests that the original suspended-pendulum also swung within a *40 degrees arc,* or thereabouts. That would account for Hollar's image (p.2), showing a small triangular case, probably all-brass, having Cardan's universal *ball and socket* hanger (p.3), one of which (*the old clock's*) is said to have failed in Bruce's stormy crossing to England in December 1662.

Under-Dial Motion Work.

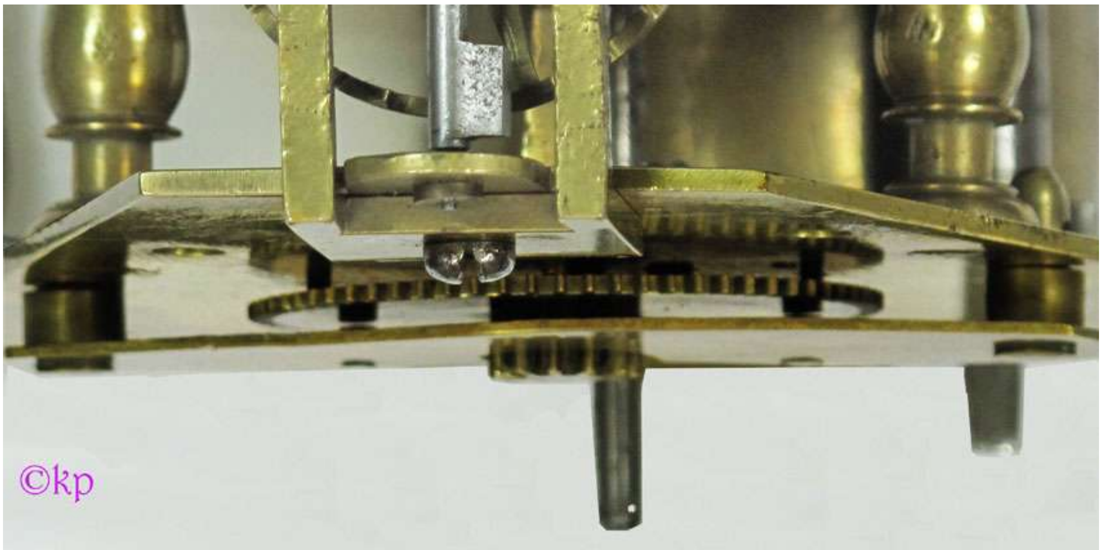
The front-plate is uncluttered but has remarkable features. At the apex is the rounded up-stand for the Verge's front pivot; looped around that is a stirrup-like top-Potence, held by steel studs and fixed by a single screw. Just below is a vacant pivot hole, to left of centre is a smaller filled hole. Flanking these are holes for the two upper dial-feet also two more at the lower plate. From the centre, a large plain Hour wheel (72 teeth), with an hexagonal cannon secured with a round key-plate. The small Minute wheel (35 teeth) having a stubby squared minute pipe, drives a larger Reverse-minute wheel (70 teeth) affixed onto a stubby arbor having a large brass pinion (12) driving the Hour wheel.

View: The Large Pedestal Bridge, Weight Barrel still wound at Fusee.
The front-plate offers no evidence of a Treffler reduction gear - to produce 60-Seconds' from present 276.92 sec. contrate rotation. [Whereas, Treffler's contrate arbor turning in 240 seconds, has a wheel of 60 geared down 60:15 to indicate Seconds on the dial-plate].

The large brass Bridge, of irregular trapezoid shape, is supported on round brass pedestals riveted into its outer ends, and pinned into the front-plate. The Reverse-Minute pinion *floats* in the Bridge 'cut-out', being held upright, *fore and aft,* by four brass studs on the front plate and three brass studs on reverse of the bridge, (the upper stud is missing). These seven studs affix the motion wheel position within a small tolerance; rubbing is evident on each face of that wheel, as seen in the succeeding view. The bridge has casting and tool marks commensurate with age and originality. As always is the case, only forensic spectroscopy can prove my impressions - gained from the materials used, tool marks, patina, also unique (?) construction.

View: Reverse Minute (Rev.) Ø 4.6 cm. Pedestal Bridge (Reverse)
Note *'fore-aft'* Positioning Studs on Front-plate (4) and Bridge (3).

Probably, it was thought the clock would suffer extreme agitation, on-board a pitching and rolling ship, and any derangement of motion work could stop the 'Longitude' clock, so this novel *'fore and aft'* pinning was intended to hold the wheel in a fixed plane. Why did this clockmaker not add a simple front pivot?



View: Reverse Minute Wheel *in situ*. nb. *fore-aft* positioning studs.
[It seems a most inefficient way of mounting, and very laboursome]

Construction of the Hour and Minute wheels, although conventional, relate closely to the work of Ahasuerus Fromanteel. Yet the attribution must wait until similar components by John Hilderson, another known maker for Bruce's 1663/4 English sea-clock, can be compared. John Hilderson is not such a prolific early maker that such judgements may be lightly made. His work exists only in a few collections, and has rarely been shown except in those public exhibitions recited by Weston. [Peter Gwynn had me free-up his Hilderson's striking, one of the very few occasions that I handled Hilderson's work - and insufficient to make a judgement here].

View: The Hour-Wheel (*72 teeth*), with Minute-Wheels of *35 teeth*.
Nb. Round Key-plate, Hexagonal Hour-Cannon, and Minute-Pipe, being typical of English constructions - as used by Ahasuerus Fromanteel.

Although I have ignored the presently associated dial-plate, and case, I remark that the blued-steel hands are well made, but the design of the hour hand in particular dates from a later period than the movement. Furthermore, I suspect that original sea-clock hands, always exposed to saline marine atmospheres, would have been of non-ferrous brass.

View: The Blued Steel Hands of a Later Period than the Movement.
This pattern is associated with the last two decades of the seventeenth century, and with some of the best London makers; but that is not to say any carried out this laborious conversion to weight drive.

Recording Components: Pendulum, Plates, Wheels.

In this first citation of Bruce's previously unrecognised, spring-driven fusee, sea-clock, it is too early to speculate on all possible solutions to the evident changes noted by several closed holes for pivots, cocks, also other witness marks. However, evidence for the conversion to weight-drive, also other alterations, have been recited above. In due course, a table of *component dimensions* shall be added, not possible within time constraints of my first inspection. Where I did record any dimensions these are included in respective images and/or captions.

The Long-Verge, the Pivoted-Pendulum, the Pendulum-Holdfast:

The image of the '**I**' bar attachment (see above, p.10) shows the extant method of fixing employed to fix the 18.7 cm pendulum rod to 6.6 cm long verge. It is possible that both the extant verge and pendulum may be the original parts, joined when converted from Huygens' suspended pendulum and Bruce's "F" double crutch attached to the verge by same '**I**' bar fixing. The long-verge itself is a clue to its English origin, with no evidence to suggest the short Dutch verge and block potence were ever fitted. However, further investigation is required.

View: Brass Pendulum (18.7 cm). Whereas the Dutch suspended pendulum, used by Salomon Coster, have steel-rods; set in brass crutches fixed to short steel-verges; in typical Dutch potence blocks. Whereas, this pendulum is entirely of brass, a marine concession, from its brass mortice fixing it to the long steel-verge, down to the brass bob with wooden plug holding it onto the threaded pendulum.

View: Open '*Holdfast*'

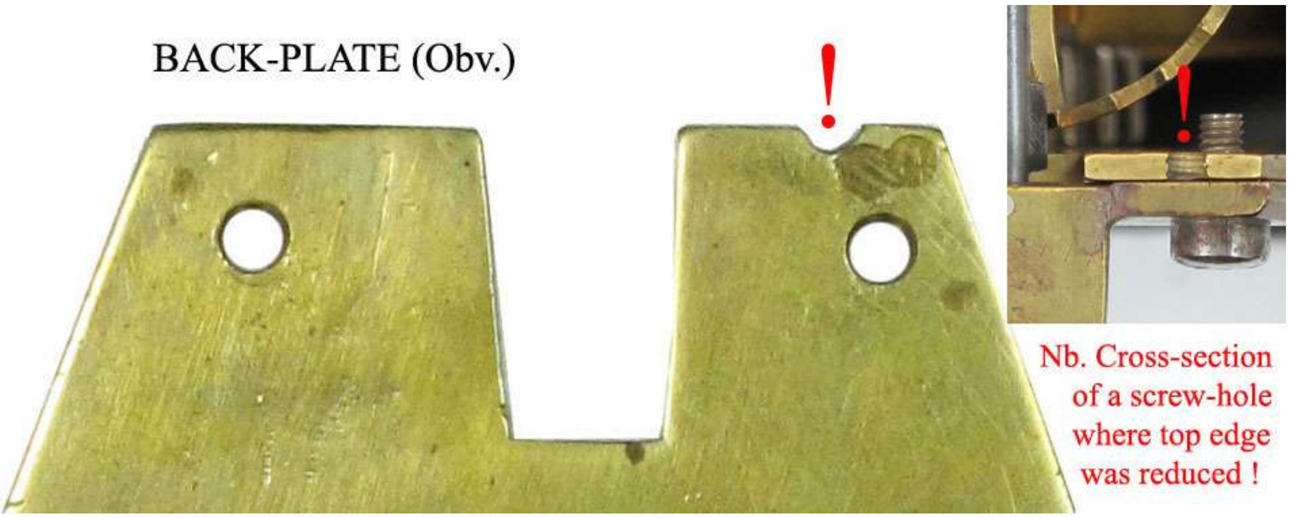
The Pendulum Holdfast appears to be made with particular care, also with some artistry, being apparently designed for a Pivoted Pendulum. Compare it with the tiny closing swivel-loop of **'*Royal Haagseklok*'.** The brass Bob, with wood friction plug, is turned. The brass pendulum rod is unusual, but it may confirm this, indeed, is an early pendulum; although that tradition did persist with certain English makers; Joseph Knibb, and John Ebsworth.

View: Back-Cock with a pivot *knife-edge*, '*dovetail*', steel *keeper*.

Nb. *Cycloid Cheek* and *Suspension* attachment points not observed.

View: Back-Cock Overhang. The deep, 22 mm, overhang from the back-plate is sufficient for Bruce's ***'F'*** *Double-Crank*, intended to limit Huygens' suspended pendulum to swing in a single plane at sea. Its unusual depth led me to think this may be the original back-cock - now modified with a '*knife-edge'* and a '*keeper'*.

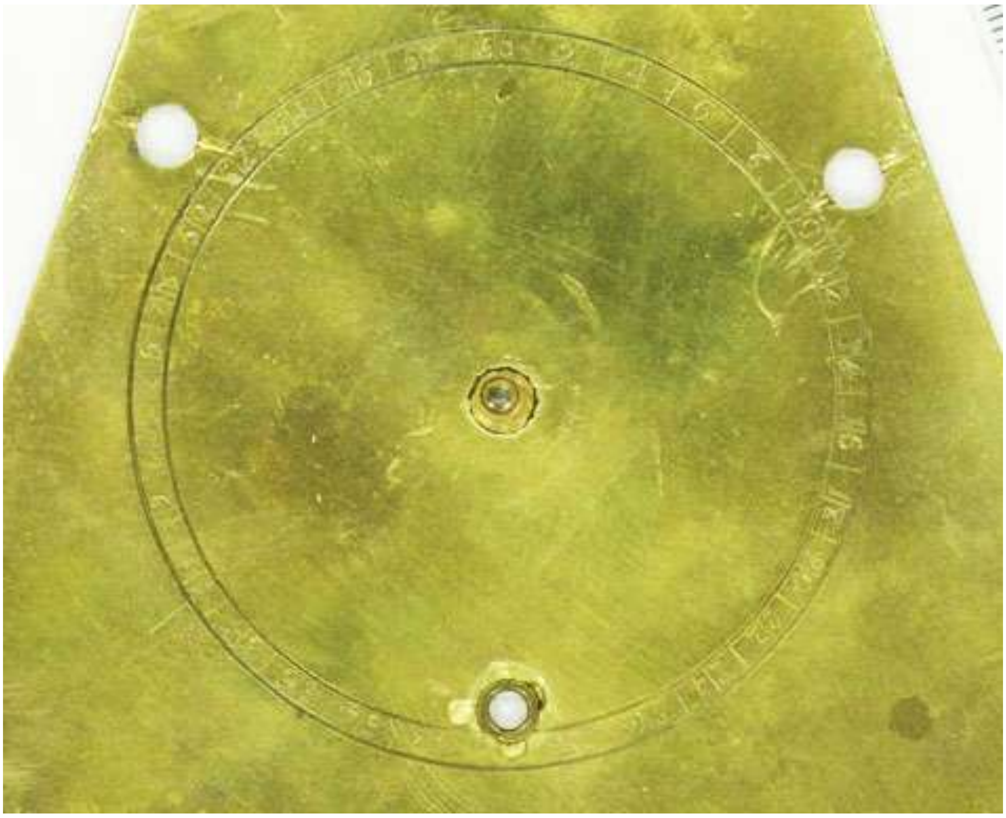
View: The 'tell-tale' divided screw-hole, signifying that the Back-plate has been reduced.



Caveat: Despite anticipation, I did not find any witness-mark evidence for Bruce's inverted '*double crank **F** crutch'*, Huygens' *'cycloid cheeks'*, nor '*silk suspension'* to independent pendulum. Possibly, this reduction of the upper plate/s has destroyed invaluable evidence, ie. compared with Oosterwijck's #2/3 unreduced plates, (see Overlays at p.41). Therefore, at present, the possible *originality* of the '**I**' bar fixing of the long verge onto a now pivoted-pendulum must remain speculative.

View: Back-Plate (Obverse), Height (reduced) is 161 mm. Note Contrate Seconds' Ring, and closed pivot-holes of Fusee/ Stop/Spring, also of Fromanteel Bolt and Shutter Maintaining Power (B&SMP) c.1660, for the ***fusee***-driven verge-escapement of short-duration.

View: Back-Dial, Diameter 65mm, Centred on Contrate Arbor, Marked '0-60', with *Seconds'* intervals, only the even numbers are inscribed. Evident here are bushings to Contrate, also altered Centre plant. Note pin-grooves to the pillars; there is no evidence of pillar-latches, that Fromanteel then used as standard.

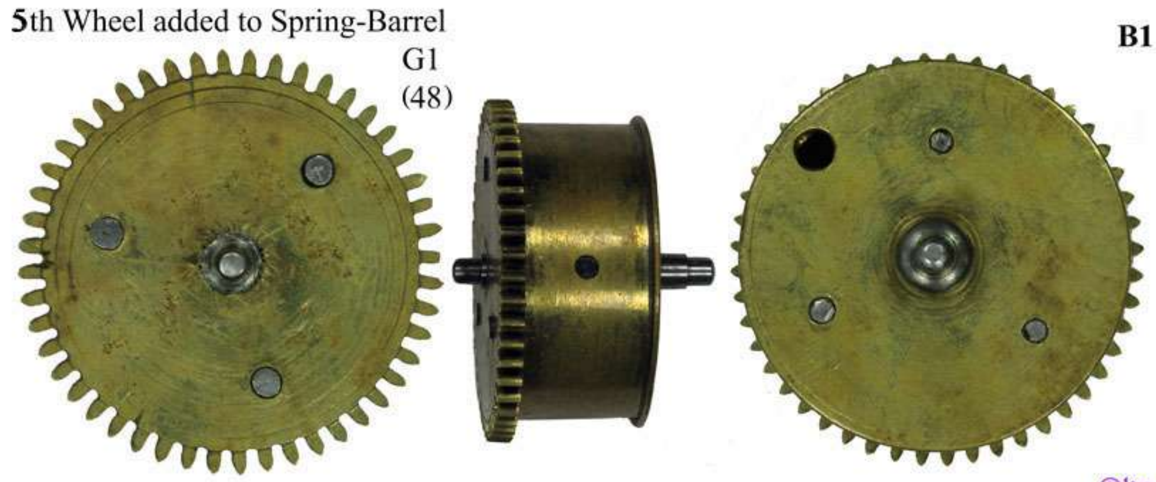


Nb. Oosterwijck's Contrate back-dial is identical and yet, obstinately, neither of these, so called, '*Longitude'* trains produces 60-Seconds' at their **0-60** back-dials. [See radical equal train, p.44, Concluding Observations, which produces 60 seconds Contrate rotation]

View: The Front-Plate (Obverse), Present height is 160 mm.
The prominent up-stand for a verge pivot may be the result of a reduced plate - (see back-plate, p.18). The added bracket is externally mounted, so as not to encroach on the distance between plates, for a now replanted (but original) spring-barrel in its new role as the weight line-barrel.

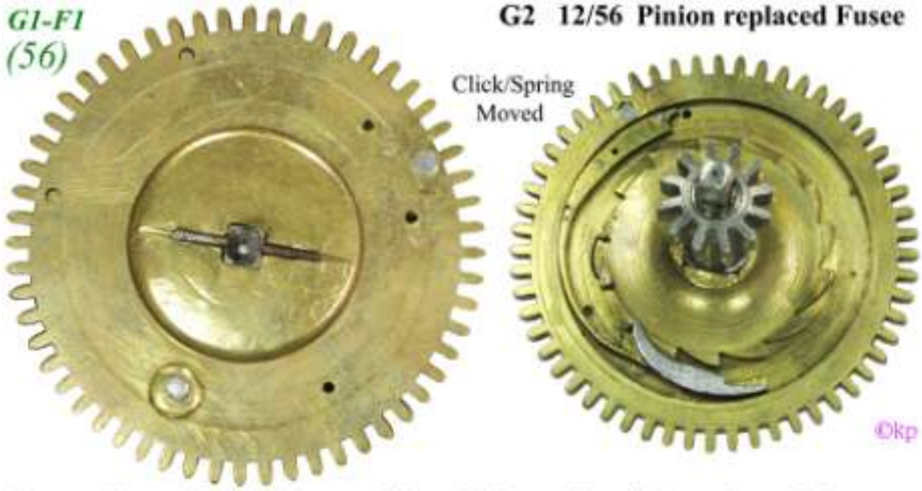
View: The Front-Plate (Reverse). nb. Evidence at bottom centre of attachment points to a brass case and possibly a fifth Pillar?

[Severijn Oosterwijck's companion relic does have a square 5th pillar, (pp.31,37)]



Diameter 6.2 cm. Depth of Teeth 4 mm   Depth of Spring-Barrel 2.8 cm.   Turned Barrel-Cap and Steel Collet

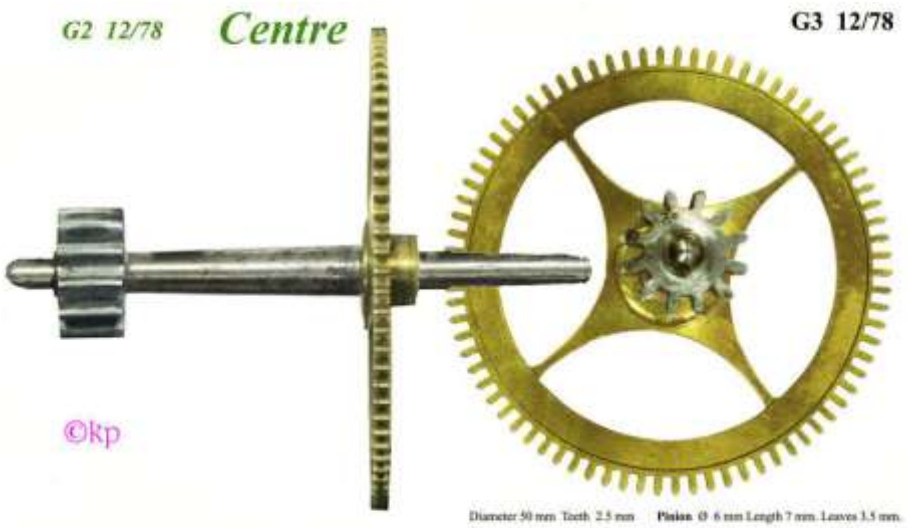
View: Former Spring-Barrel, now converted to Line-Barrel for Weight Drive , its Great-Wheel riveted across the Barrel Caps. Nb. Plain Barrel Cap forms a rim, like the earliest Fromanteel caps; but the rounded root form of the added 5th great-wheel is presently unattributable to any maker.



Diameter 62 mm. Teeth 3.5 mm.   **Pinion** Ø 17 mm. Length 7 mm. Leaves 3.5 mm.

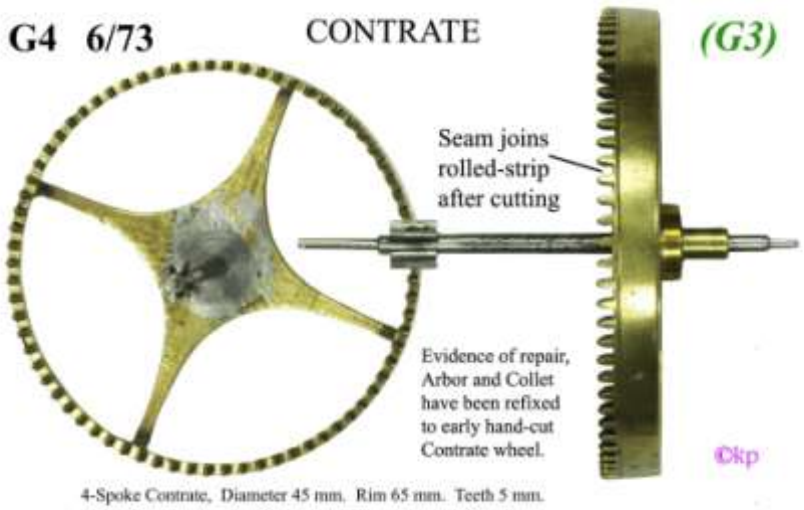
View: Original Fusee Wheel *G1 56*; now *Intermediate* - G2 12/56.

Nb. Straight-toothed pinion-leafs, of the weight conversion, are not '*Fromanteel*'.
Cf. Fromanteel 'floating-fusees' and uncrossed wheel pinned to arbor.

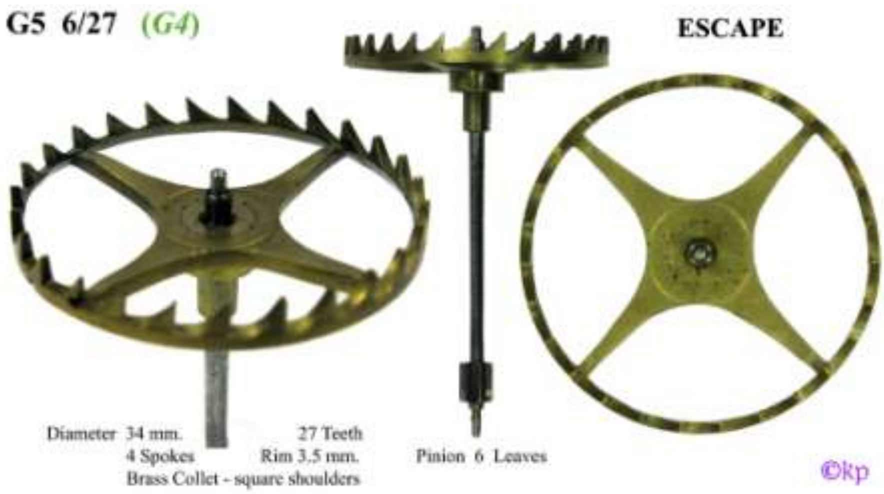


Diameter 50 mm Teeth 2.5 mm   **Pinion** Ø 6 mm Length 7 mm Leaves 3.5 mm

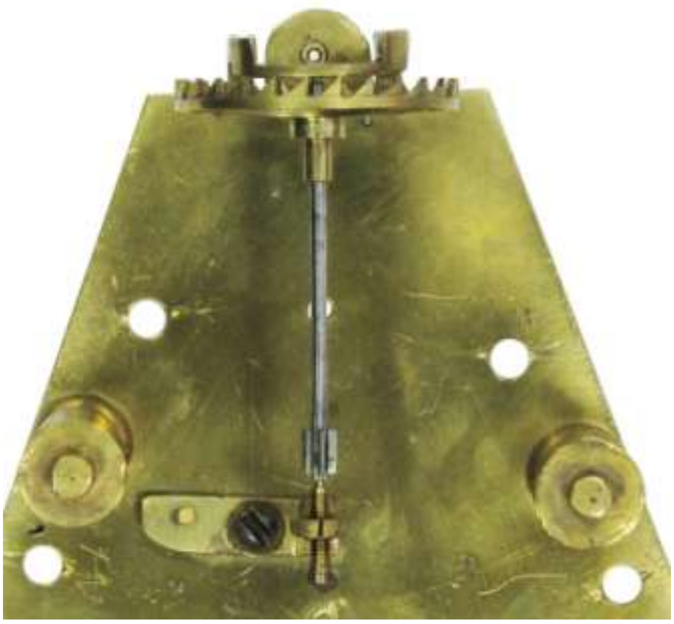
View: Original Centre Wheel and Pinion (*G2 12/78*), now G3.
Note the deep, square, spacer-collet, set tight against the front-plate.
English terminology *'Crossings'*, has its counterpart in Dutch '*Spoken*' (Spokes).



View: '4-Spoke' *Contrate Wheel* (G4 6/73) - Squared Collet.
The Contrate appears to be an early hand-cut wheel, but the arbor now is not extended and squared **-** for a Seconds' hand to the back-dial.

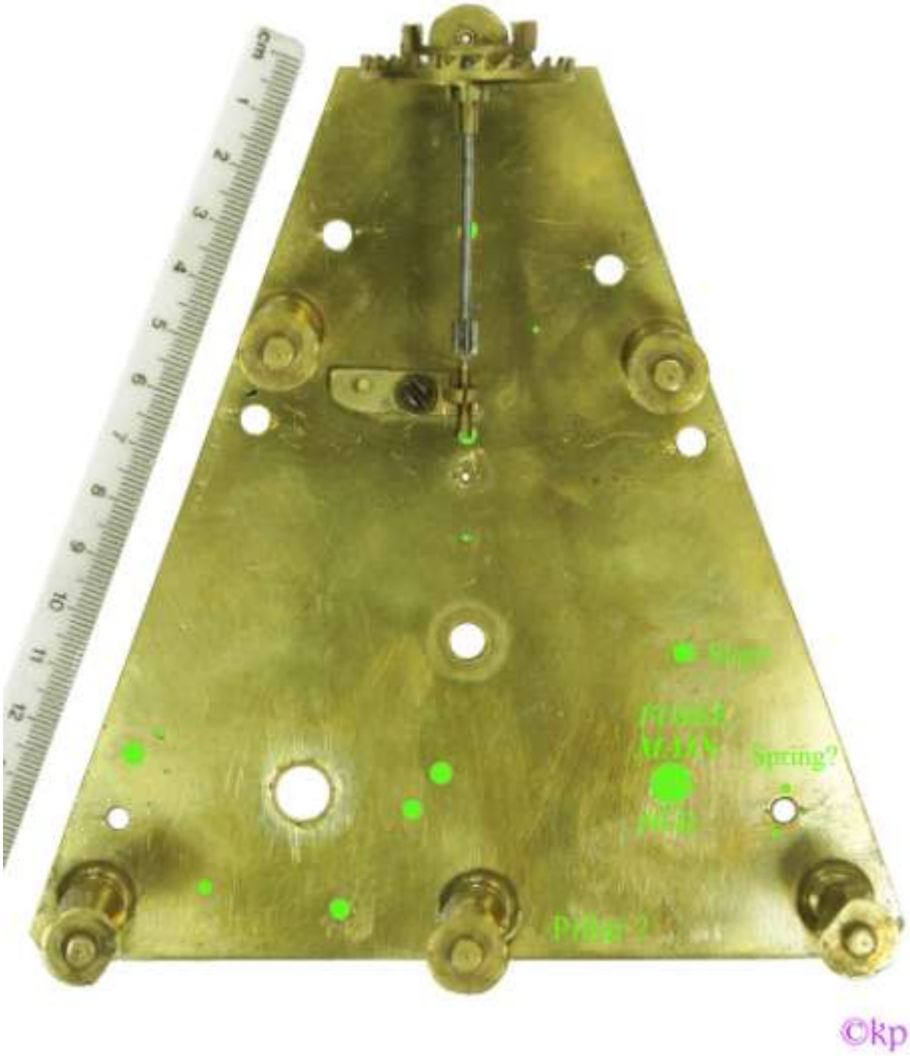


View: '4-Spoke' *Escape Wheel* (G5 6/27) - with a Squared Collet.
The Escape wheel appears to be homogenous with the Contrate wheel.



View: Arrangement of Potences and Escape Wheel G5 *(G4)*.
Lower potence appears original but adjustable brass screw is unusual.
No evidence for a wedge suggests this is a late design, i.e. not modified.

Front-Plate (Reverse), Height 160 mm: Resolving the Vacant and Filled Holes.



View: Witness Marks of Fusee Arbor (*G1-Fusee-Stop-Spring*) also Spring-Barrel (*ratchet, click, click-spring*); also, possibly, a centre pillar?

Post-1660, we expect Fromanteel's *Bolt & Shutter Maintaining Power* **(***B&SMP*) in English short-duration verge escapements with fusees. In the earliest period, *B&SMP* is less common in the East, Hilderson, and Jones traditions. A pointer to Fromanteel's authorship? But its baluster pillars suggest Hilderson, East, or Jones; yet bold wheel work suggests Ahasuerus Fromanteel. I leave that question open, but I admit leaning more toward John Hilderson, ie. towards this relic being **Bruce #4**.

Despite my original speculations, it is also open to conjecture whether, in fact, Bruce's '**F**' crutch with Huygens' pendulum suspended between cycloid cheeks constructions was fitted to the present back-cock. Yet its wedge movement is so close in concept to the acknowledged sea-clock by Severyn Oosterwijck recognised by Leopold and Weston as, purportedly, a 1662 Dutch copy of Bruce's English made sea-clock of 1661. Open research must address these caveats, also my observation that the '**I**' bar mortice fitting of the verge to the pendulum could also have served in Bruce's original 'F' crutch and pendulum constructions.

I am grateful to private owners, who would remain anonymous, for their consent to publish this rare English 'sea-clock' movement under my *'open-research'* project, *'A Royal Haagseklok',* hosted by the Dutch Horological Foundation. While I may not identify owners, nor intermediaries who introduced me and helped me investigate this early longitude movement, I already have thanked each personally to acknowledge their invaluable assistance also the excellent facilities provided for my inspections.

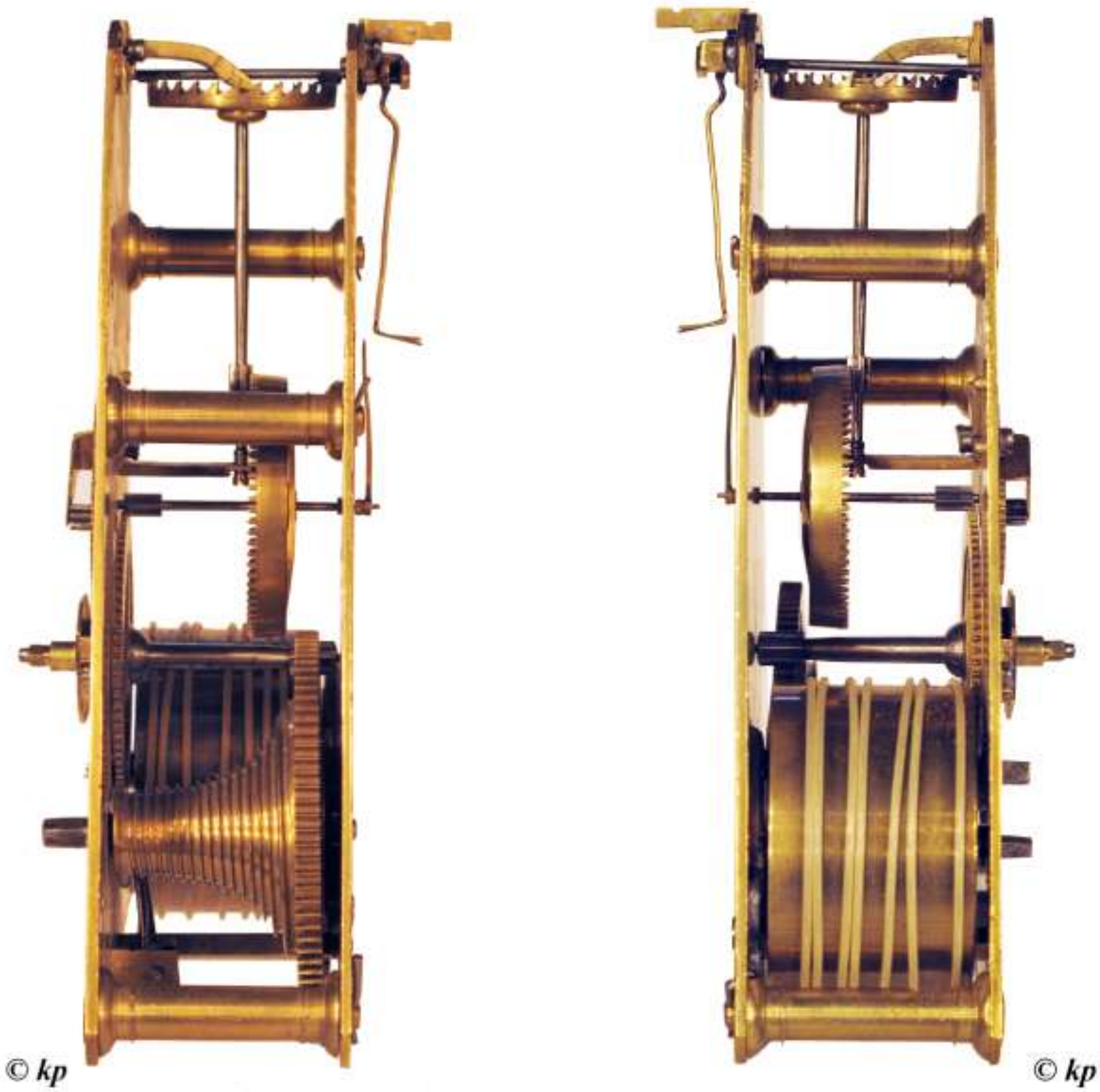
ALEXANDER BRUCE #2/3, A *DUTCH 'LONGITUDE' CLOCK*
Signed, '*SEUERYN OOSTERWIJCK FECIT HAGHE'*
Commissioned by Bruce, between March and December 1662.

Private Collection: Description and Images by the Owner's consent to publish in this *open research* project. Keith Piggott is the Copyright Holder of all Views, Images, and Originations**.** Copyrights reserved.

Severijn Oosterwijck's *wedge* movement (**Bruce #2/3)** was advertised in 1977 by Meyrick Neilson of Tetbury, later cited by John Leopold and Anthony Weston as an early *Longitude sea-clock*. Yet it has never been reviewed, nor even properly examined. This relic is the second of its type, Bruce's triangular so called *sea-clocks* I had an opportunity to examine. It was this private owner's verbal description that allowed me, in the first instance, to recognise the English relic, **Bruce #1/4.** These companion relics, being the first known *pendulum travelling clocks* intended to meet Gemma's proposition for safe navigation on the high seas.

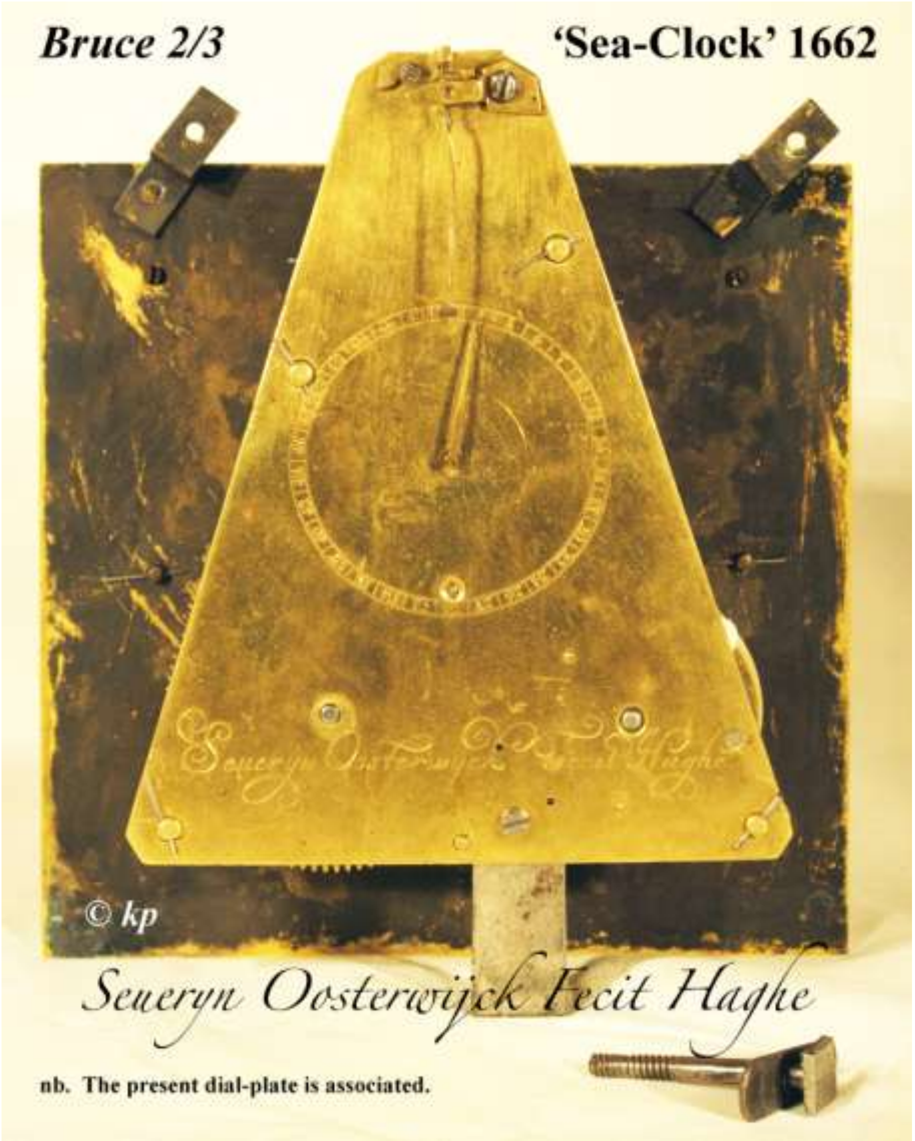
First Description and Basic Dimensions:

Oosterwijck's '*wedge*' movement, (below), has his slender '*cannon'* pillars, (my Pattern PP6); like his earlier clock (Plomp *D9*) at *BoomTime Foundation*, and '*Lieberge'* alarum, also *Huygens'* 1664 Remontoir. As noted in ***Appendix Three***, (p.3), to my knowledge, this is the earliest extant Hague clock to be fitted with a Fusee. Also visible is a rare '***dished'*** Contrate, as Oosterwijck had used in earlier ***'RH'*** **(*Part I*, p.9)**, but not in ***'D9*'**.

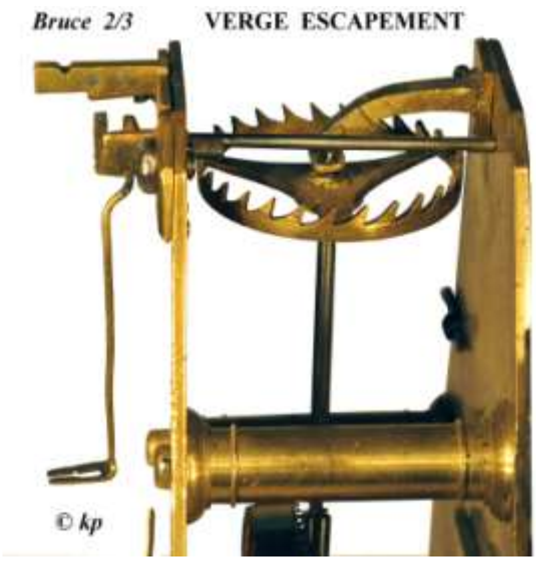


Views: The 'III' and 'IX' sides of Oosterwijck's 'Triangular' (Wedge) Timepiece Movement.

Oosterwijck's plates, also isosceles triangles, also 38mm apart, have bases of 142mm across clipped corners; the base angles of 72 degrees, to nominal 36 degree apexes being truncated to form rounded-shoulders 32mm across. Their respective heights being, 168mm (front-plate), and 166mm (back-plate), are thus marginally taller but narrower than its companion English wedge movement, Bruce **#1/4**, (see above).



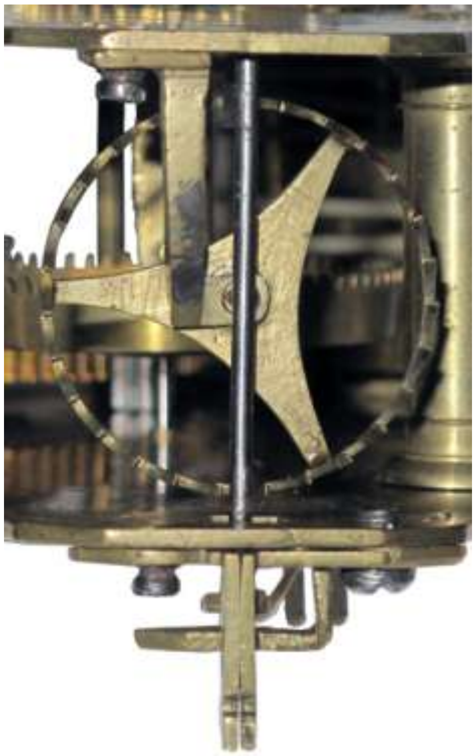
View: Oosterwijck's *Wedge* Movement.
Note the contrate Back-Dial, 65mm diameter, and scribed **'0-60'** Seconds, being identical to Bruce *#1/4***.**



View: Severijn Oosterwijck's Horizontal Verge Escapement. The original *'verge and crown'* escapement, having a *long-verge* across plates with a *strap-potence* in the English tradition, being like Oosterwijck's ***Royal Haagseklok,*** (see **Part I,** p.10,Fig.15b). **Exceptionally**, the top-potence is mounted on front-plate. These features are very rare in a Hague-clock. Both the back-cock and pendulum cock are originals: the latter shows alterations for Hooke's pendulum *spring-suspension*, from its former Huygens' *silk-suspension*, having *Cycloid cheeks*; (new when Bruce incorporated them into his 1661 design, nigh *obligatory* when Bruce had this movement made in 1662).

[nb. Dutch terminology is *'3-Spokes'*. English *'crossings'* requires four spokes for a 'Cross' to materialise].

Oosterwijck's pendulum-cock, with leaf-shape foot, shows convincing evidence of having had Huygens-Coster '*pendulum-suspension'*, with '*cheeks*' to counter *'Circular Error'*. After 1660, cheeks were Cycloid in form. The cock's present use as *Pendulum Chops*, without Bruce's deep 'F' double-crutch, may have resulted in this original cock being shortened to just 15.5 mm. Whereas, Bruce #1/4 has a pendulum-cock with a much broader and much deeper 22 mm overhang, (see page 18).



View: Fromanteel-type Long-Verge with a frontal Strap Potence, Joined-Cocks for Cycloid-Cheeks and Pendulum Suspension. The added pendulum-notch exhibits no signs of interrupted screw threads, (unlike Bruce *#1/4*, p.18). The cock's upper surface is not reduced; the *notch* was added to locate a later English pendulum with Hooke's spring suspension, (i.e. now converted from Huygens' original chord suspension - with Bruce's 'F' crutch).

Whereas the lower surfaces must have been reduced, by original *Cycloid Cheeks* being cut away. Formerly the separate cheeks on cocks were joined by one screw, that secured the silk-suspension. As a rule, during this early period, each cheek was a part of, or was held by, a separate cock; Oosterwijck did not 'clamp' cheeks between chops. (See earlier Oosterwijck cheeks at, ***'RH', Part I*, p.13, *Fig.36***, also **MemoOosterwijck *D9*,** also ***'Lieberge'*).**

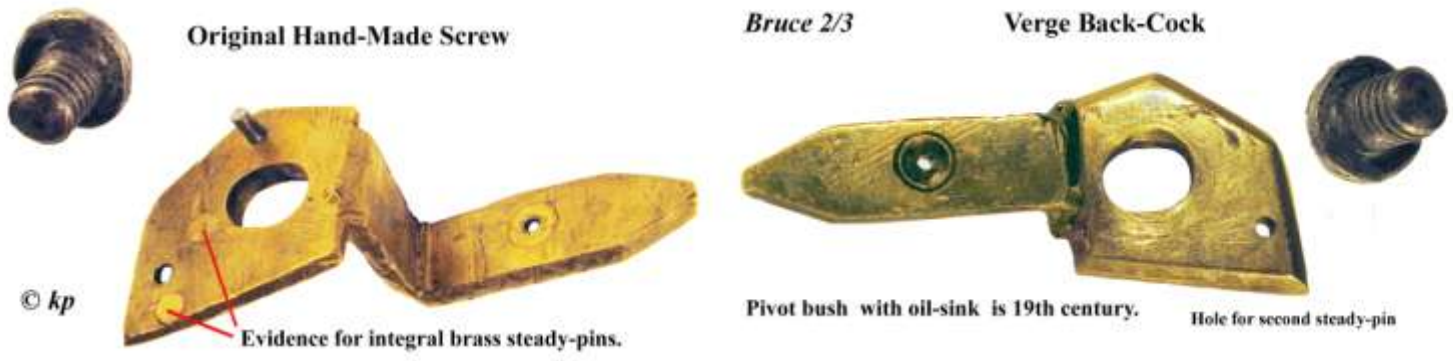
Visible here (Right) is the English style Strap-Potence, like its lower potence, both uniquely mounted on the Front-Plate. Did the Bruce **#1** also have that previously unknown construction, and did Fromanteel ever use that construction in his English oeuvre**?** It may be evidence towards identifying the maker of Bruce's **#1.**

View: Original Suspension-Cocks, having the former Cycloid Cheeks cut-away.

The original pendulum-cock is formed in two parts, but having only one cock affixed to the back-plate by a single screw, the other cock having integral steady-pin, formerly joined by a transverse screw; now having three steel rivets, for conversion into *'Chops'* to Mr.Hooke's *'Pendulum Spring-Suspension'*. Huygens' '*Cycloid' Cheeks* having a silken *Pendulum Suspension* were once an integral part of this Pendulum Cock. The relic now has modified Huygens' *Crutch,* although it now lacks Bruce's *double-crank 'F' crutch*, which all Bruce's sea-clocks are thought to have possessed.

Nb. Circa 1660/1, Ahasuerus Fromanteel had first used Robert Hooke's *compromise spring-suspension, to pendulum**, yet retaining Huygens' pivotal crutch, as an alternative to Huygens' suspended-pendulum. Hooke's spring allowed a more robust, yet still reasonably accurate, pendulum timekeeper for spring or weight clocks; see ***Appendix Seven***, his Equation-Tidal clock. [* Robert Hooke's pendulum-suspension system was still used in spring-clocks throughout the 18th and 19th centuries, and even is still being manufactured today for cheaper spring-clocks]

View: Original Verge Back-Cock. nb. The verge pivot-hole is bushed.



One of the later steel steady-pins is now lost. Formerly, the cock had possessed two integral brass steady-pins, both now neatly filed off, (see images above); the back-plate still having the confirming and still open holes. These signs are important evidence, proving the originality of this vital part. Were the integral brass steady-pins damaged by an accident; like the damaged escape and potence I already have cited?

Instead of a typical Dutch potence and verge block, this has the English *strap-form;* exceptional for a Hague clock, but also seen in Oosterwijck's earlier ***'Royal Haagseklok' (RH)***. The integral brass steady-pins also mimic his ***'RH'.*** Elsewhere, I infer a probably earlier connection between Fromanteel's London workshop and Oosterwijck, possibly before John Fromanteel's curious Contract with Salomon Coster on 3rd September 1657, (see ***Part I***, p.12). [Nb. Dutch feature in English clocks are more common than English in the Dutch].

View: Original Top Potence of English Strap-Form.

Note the evidence of an ancient repair to the cranked strap, a complex brazed tenon-joint also the still distorted screw hole at the cock's foot. I have no doubt this is evidence of damage sustained in use, not of alterations in fabricating. Oosterwijck would not have let a distorted, torn, cock leave his hands; and he did not need this complex tenon fixing (or repair). Furthermore, his earlier ***Royal Haagseklok*** also has wrought *strap-potence*, and its cranked end is homogenous, without any joints. The pivot bush with oil-sink is later.

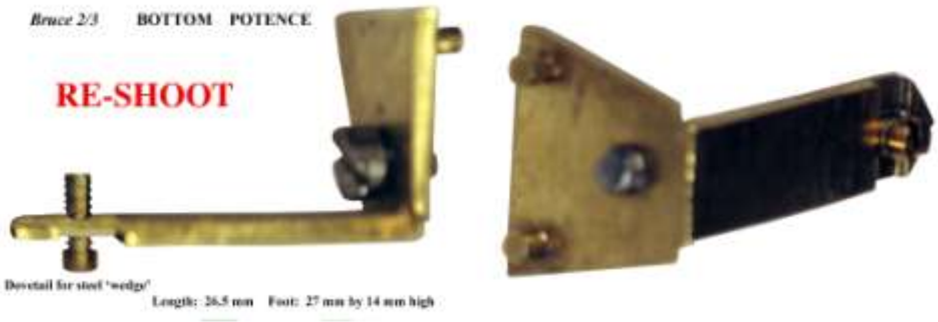
The historical records say that on Bruce's return voyage from Holland, in December 1662, one of the sea-clocks' Cardano suspensions failed, it clock fell and was badly damaged. Records say *'the old clock'*, i.e. the London prototype. Records say the other clock -which would be one of Oosterwijck's 2 copies- stopped. However, the evidence here of extant damage and old repairs is undeniable. I also noted evidence of repairs to the escape wheel collet, (see p.38), and the loss of two integral steady-pins to the back-cock (see above).

However the damage was caused, it seems very likely that Bruce #2/3 sustained the damage during one of its voyages. This evidence of multiple repairs is quite unambiguous. Could that identify which of Oosterwijck's sea-clocks this is, and how, where, and on which voyage the damage was sustained.

[A new search of Bruce's and Oldenburg's papers is being undertaken by Rebecca Pohancenik, already she unearthed Hartlieb's correspondence citing Douw's invention - (see ***Appendix Four, Annex 1***, p12). Rebecca is sponsored by Dr. John C. Taylor OBE, whose company Fromanteel Ltd, promotes extraordinary exhibitions, publishing superbly illustrated catalogues; '*Horological Masterworks'* (Oxford 2003*), 'Huygens' Legacy'* (Apeldoorn 2004), *'Time and Place'* (Oxford 2007), see p.8. I await *A Definitive English Collection*].

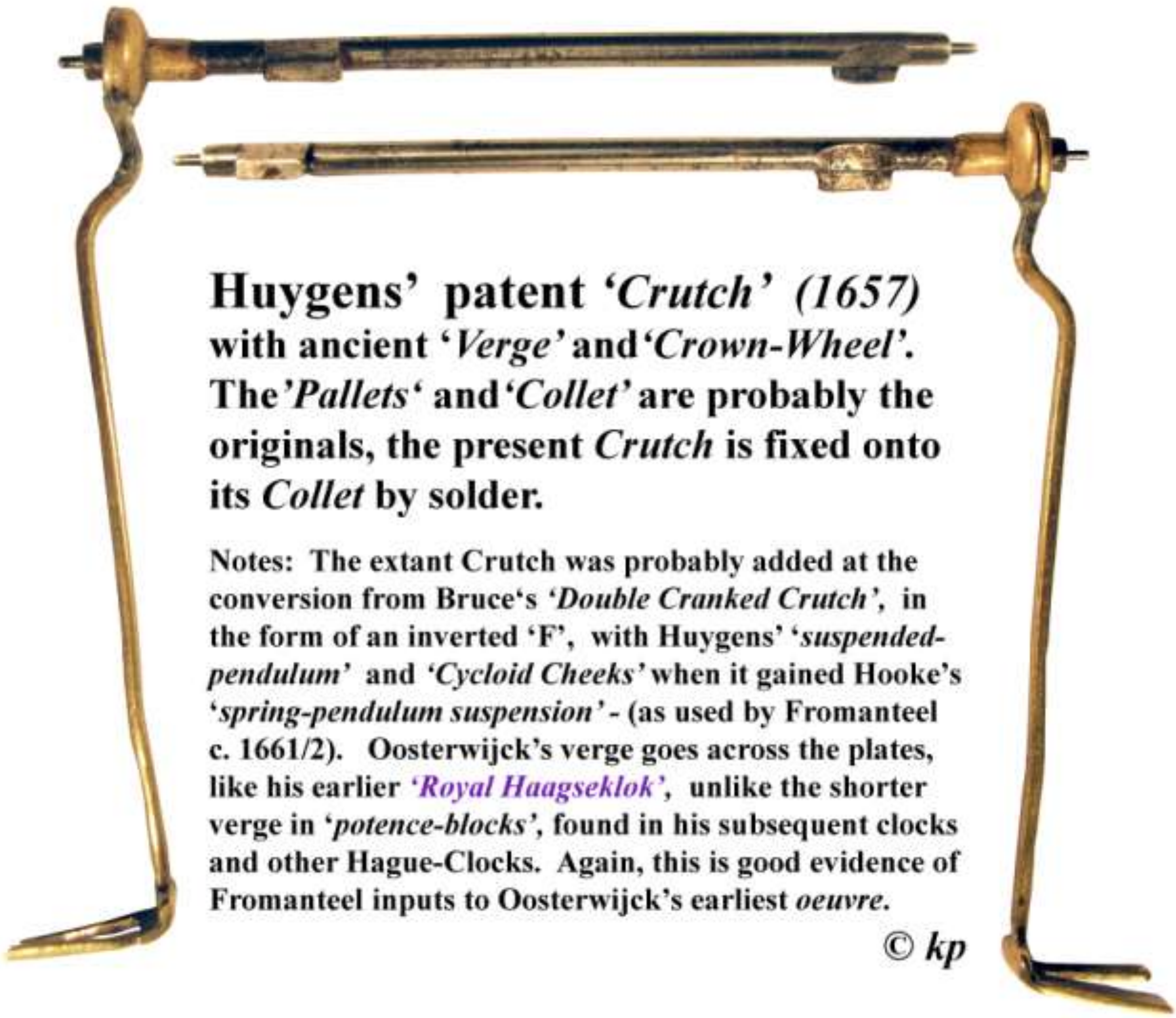
View: Original Bottom Potence:

The brass lower potence reverts to normal Dutch form, i.e. lower potence **exceptionally** having the cock screwed to the front-plate; and departing from Oosterwijck's own earlier ***RH,*** having English form, of a posts riveted to the back-plate, (usual site).



The cupped screw brass supporting the escape arbor is a modification, to adjust escapement depths. It is evidence for a longer escape-pivot, or different arbor, even train. The dovetail for steel wedge is a feature of Coster, Fromanteel, and Oosterwijck ***'RH'***. [***Bruce #1/4*** has similar potence screw, but no evidence for a dovetail for a steel wedge, so it may be original; being based on this, perhaps earlier, modification, see p.22]

View: The Original Long-Verge with Huygens' Crutch (Now Adapted).



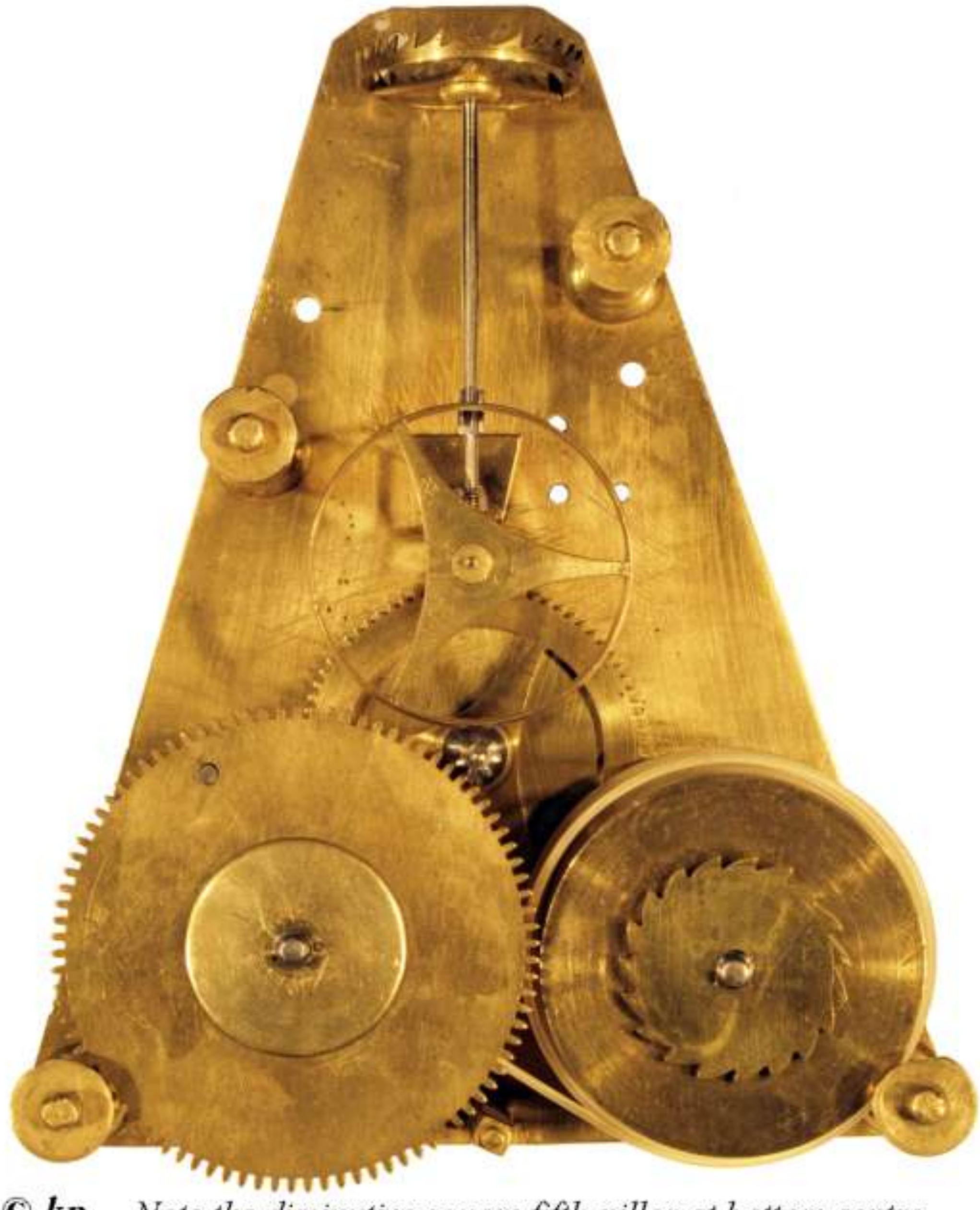
Hooke's pendulum spring-suspension, (invent 1660), retains Huygens' *patent crutched verge,* (invent 1656)- now modified to a simple fork from Bruce's **'F'** *double-crutch,* (invent 1661). The extant crutch is brazed to a hemi-spherical brass collet, attached to probably original verge. Nb. It is worth repeating, Huygens never invented *escapements*, he kept the ancient *verge and crown**. Huygens only *invented* new ways of utilising the controlling oscillator, at that date invariably pendulum. *In Dutch terminology, *'kroon-rad'* (crown-wheel) refers to the Contrate; Escape is *'gangrad'* (going-wheel), also '*spillerad*', or '*schaeckelrad*' (Ancient).

Having established this movement's *bona fides,* as having had Huygens' pendulum and cheeks when made, (not an English pivoted-pendulum), I readdress features of Severijn Oosterwijck's companion to Bruce #1/4.

View: Original Wedge Front-plate; the 4-Wheel layout - the Fusee and Barrel replaced.

Bruce 2/3 ***Severyn Oosterwijck 'sea-clock' circa 1662***

Front-Plate (reverse) **4-Wheel Train exposed**



© ***kp*** *Note the diminutive square fifth-pillar at bottom centre.*

The resemblance to Bruce #1/4 (p.13) is not a coincidence. However, one lower cannon pillar has a typical flat for the spring-barrel, yet is more deeply rebated at the front-plate, as if for a reversed fusee great-wheel which I suggest could not possibly be accommodated in this wheel-train. Further examination is required.

***Caveat*:** my suspicion of a centre pillar in Bruce #1/4 perhaps is borne out here by this *square* 5th pillar. but this is very differently riveted to the four main cannon pillars; and therefore, possibly, it may only have been added with the subsequently 'improved' larger barrel for a stronger main-spring to new fusee? [see page 37]

The replaced Fusee/Wheel (88 teeth) and replaced wider spring barrel, give a longer duration than in first instance. But from Centre-Wheel up, the homogenous vertical *short-train* is identical to Bruce #1/4, namely;

Extant Short-Train: Centre 6/78, Contrate 6/73, Escape 6/27 = 142.35 beats/minute.

This Contrate, like Bruce #1/4 (p.13), turns 13 times/hour, (i.e. 4 minutes and 36.92 seconds; being 276.92 secs/turn), This imponderable number is *unequal*, having no relationship to its Contrate Back-Dial of '0-60' units - again exactly identical to Bruce #1/4. Tony Weston states the Back-Dial indicates 4-minutes, it does not, but even that would need Treffler 15:60 reduction gear to produce 60 seconds; I found no evidence for. Presently, neither of these extant trains, nor even related hypothetical *Mean* or *Sidereal* alternatives, could produce Seconds' for navigation, i.e. determining Longitude - let alone if the pendulum could ever perform at sea as both Bruce and Huygens evidently anticipated; which no pendulum ever could!

Incompatibility of the extant, extrapolated, or related hypothetical trains with a *60-Seconds'* Back-Dial

BRUCE 2/3	*HAGUE*: Severyn Oosterwijck 1662					Matrix formulae courtesy of Michiel van Hees		BACK-DIAL
Extant train	BRUCE 2/3	Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	27	6	142.35	2.636111111	158.1666667		4min.00 sec
Contrate wheel	G3	73	6	Pendulum cms	0.216666667	13	276.9230769	4min 36.92 sec
Centre wheel	G2	78	6	17.3	0.016666667	1		4min 15 sec
Fusee	G1	88						
Sidereal train		Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	23	6	119.66667	2.601449348	156.0869609		
Contrate wheel	G3	72	6	Pendulum cms	0.216787446	13.00724674	276.7681	4min 36.768 sec
Centre wheel	G2	78		25.024	0.016675957	1.000557441		
Mean train (approx)		Nr. Teeth	Pinion nr.	Beats per Minute	Turns per min	Turns per hour	Rotation Secs.	Rotation Mins.
Escape wheel	G4	31	7	120.077	1.936725806	116.2035484		
Contrate wheel	G3	73	7	Pendulum cms	0.185713433	11.14280601	323.078406	5min 23.08 sec
Centre wheel	G2	78		24.825	0.01666659	0.999995411		

Neither Bruce #2/3 nor Bruce #1/4 meet any *'longitude'* expectations. Intermediate gears from the Contrate would facilitate the provision of meaningful numbers to the Contrate arbor dial; like Treffler's Medici timepiece showing Seconds, by 15:60 reduction gearing by a wheel of 60 on Contrate arbor turning in 240 seconds, (see ***MemoTreffler***, p.5). But, I found no evidence for such gearing in Oosterwijck's movement, nor in its London companion Bruce #1/4. Nor did Michiel van Hees' useful matrix produce an equal solution. Further, we do not know the sizes of Bruce's compact triangular (sextant) case, depicted by Hollar, so that a *longer* pendulum (ca. 10"/25 cm), to obtain my hypothetical *equal* or *sidereal* ratings, might even not have been compatible with the original cases.

Note. I have put all these imponderables to several professional horologists; no solution was offered. However, Sebastian Whitestone suggests the back-dials did not assist navigation directly, but two similar clocks might test each other's performance for the accuracy of their Cycloid Cheeks, i.e. *low* versus *high* spring states to test, *empirically* each clock's '*Circular Error*' at *minimum* and *maximum* amplitudes. As a hypothesis, it is most astute; but to practical mariners, it would sound like the later astronomer Maskelyne's impractical lunar sightings - which both exasperated also encouraged John Harrison in all his endeavours.

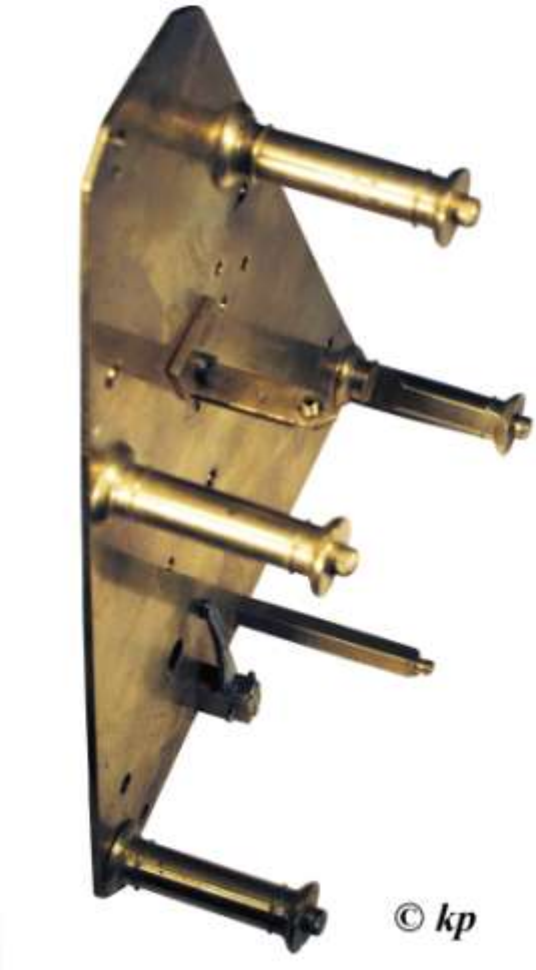
I therefore leave this curious back-dial for other participants in *open research* to resolve; believing that it is the advantage of "*open research"* that many authorities are enabled to bring their special expertise to bear on any horological problem immediately *as it is identified* - without waiting decades for publication in learned journals or reference books, or, indeed in many other noteable instances, '*never'* **!**

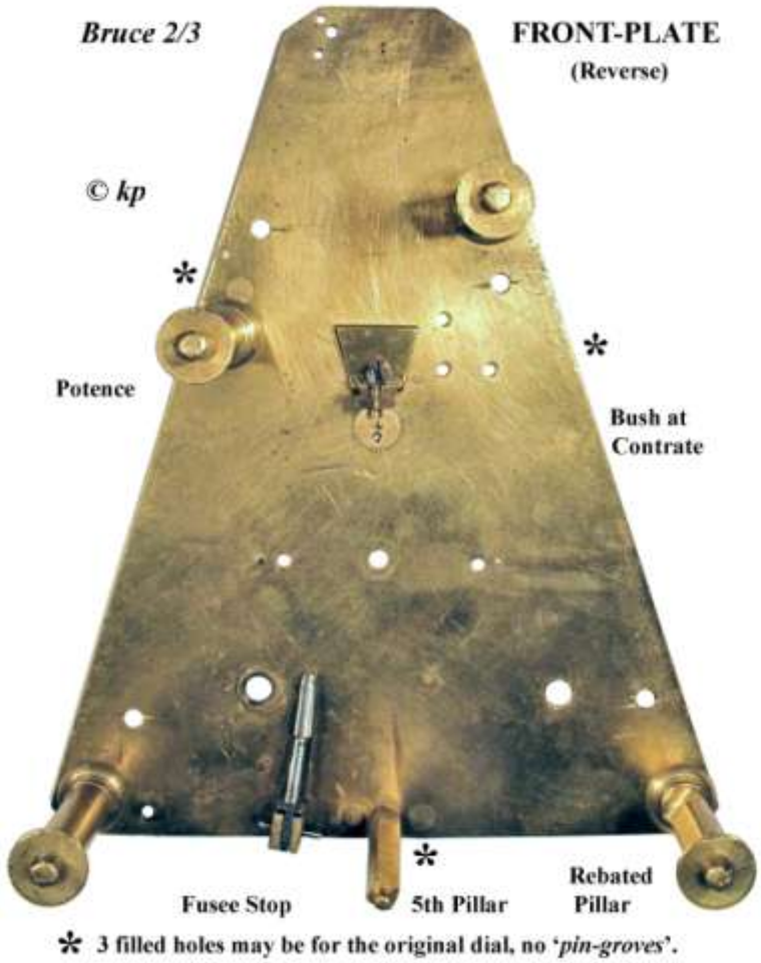
[Addendum. At Concluding Observations, (p.44), I propose a radical train solution]

Oosterwijck's movement is well made - only to be expected from the man who had made King' Charles II's striking-clock, given to banker and friend Sir John Shaw in 1660, **(**see ***'A Royal Haagseklok', Part I***). Later, in 1663, he was chosen by Huygens, to make his Longitude sea-clocks with pendulum; and on 19th August 1664 he finished Huygens' *'weight remontoir'*, fitted into Huygens' own sea-clocks, only to compound the inherent design flaws present in both his remontoir and his pendulum weight clock. Severijn Oosterwijck's craftsmanship is always outstanding, whereas his illustrious Patrons', so called, *Longitude* designs are not.

Nevertheless, in a marine context, this is a well-balanced movement of reasonably compact size. The four dial-feet holes, having pin-grooves, might not be original - asterisks mark three neatly filled holes for the original dial-plate; lacking grooves, perhaps with latches. Pivot bushes are present at the Fusee, Centre, and Contrate (being particularly big, to include the motion-wheel). Near the square 5th pillar, is a replanted fusee-stop (damage?) and a dial-foot. The stop has a grooved base - however I am not aware of its purpose.

Views: Oblique and Reverse of *Wedge* Front Plate (c.f. pp.12, 20).





View: Robert Hooke's pendulum spring-suspension, Invented circa 1660/1.

Probably, Ahasuerus Fromanteel was the first clockmaker to use Hooke's new pendulum spring-suspension. The wedge-plates of Bruce #2/3 are not reduced, so their evidence of original height of Oosterwijck's verge-escapement, and the former arrangement of Huygens' suspended-pendulum and cycloid cheeks, may all be taken as confirming the historical record. Post-conversion, in any terms, original evidence is a lucky survival.

FRONT-PLATE

(Obverse)

Bruce 2/3

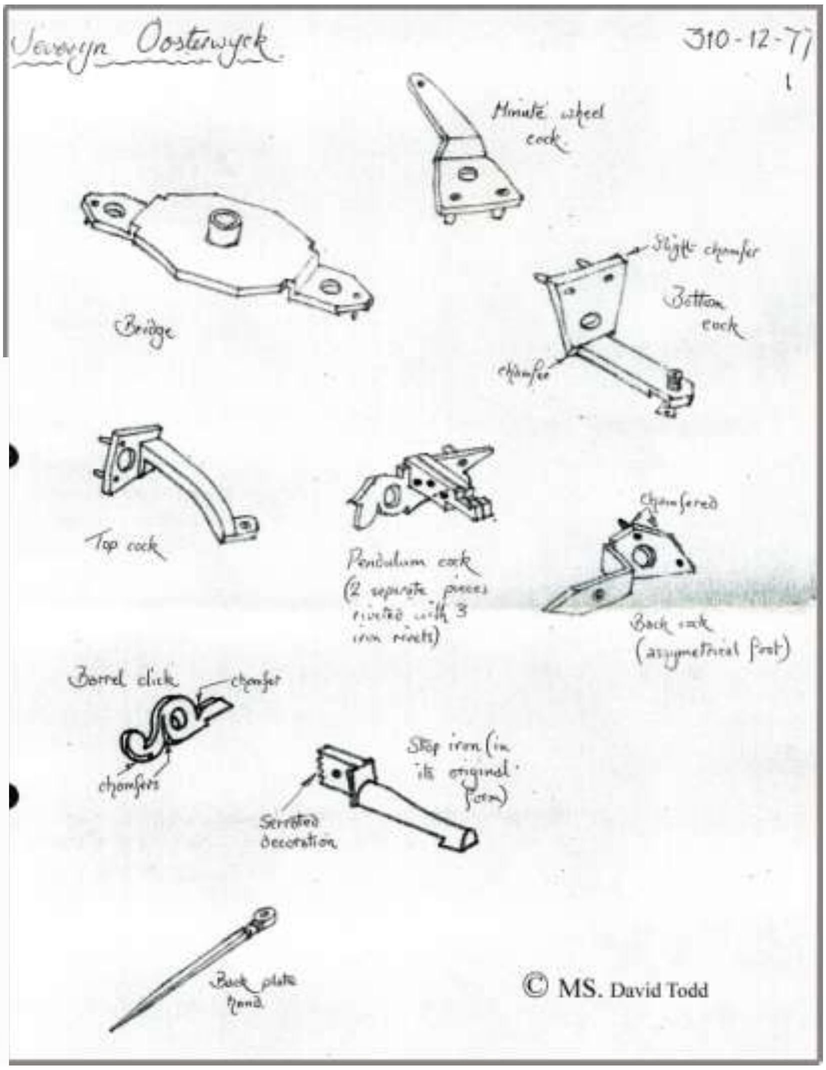
* **Neatly filled holes are possibly for original dial, but no '*pin-grooves*' on reverse. Octagonal bridge shape is reminiscent of Coster timepieces. Steady-pins in plate like his '*RH*' (and Fromanteel). Motion Cock is like Oosterwijck D9 Back-Cock. The extraordinary cleaved pillar-rivets, either are brutal repairs, or intended to be "*shock-proof*" in anticipation of violence in the marine environment. © *kp***

Bruce 2/3 **Motion Bridge**

Bruce 2/3 MOTION COCK

Original Bridge and Minute Cock (all Brass).
Their forms relate closely to Salomon Coster's time-piece *bridges,* and to Severijn Oosterwijck's typical *cocks*, (see ***D9*** and ***Lieberge***). The Bridge *steady-pins* are set into the front-plate like his ***RH*** (bring Ahasuerus Fromanteel's early practice).

Meyrick Neilson's Advertisement (1977). "Rare portable spring time-piece by Severyn Oosterwyck, The Hague. The movement has a verge escapement and the plates are wedge shaped. 13in. high, c.1675".



David Todd's sketch of small parts, (1977). The forms of several components are not typical of the Hague 'school'. Todd shows two steady-pins were set into the *bridge*. Now, only a single, steel, steady-pin is recessed flush into the front-plate. Oosterwijck's ***'RH'*** also follows this *'Fromanteel'* steady-pin practice, which may give a bearing on the original clock-maker for ***Bruce #1***, whom Oosterwijck was commissioned to copy. ***Open Research*** is here justified by ***antiquarian horology*** gaining decades-old unpublished studies from America. [The owner's own research suggests the purpose made Olivewood case, with only the front door glazed, is of late seventeenth century construction].

Motion-Work: Minute-Wheel **30**, Reverse-Minute **30/6**, Hour-Wheel **72**, **nb.** plugged Cannon.

Bruce 2/3 BACK-PLATE (Obverse)

Height 168 mm

BACK-DIAL '0-60'
Diameter 65 mm

Width 142 mm > 32 mm

© *kp*

View: The Back-plate is fully signed: ***'Seueryn Oosterwijck Fecit Haghe'***
Nb. *Severijn* is spelled phonetically like ***'RH'***; 'O' interrupts the bush, i.e. '*refreshed*'. In the Hague canon, this is an early signed back-plate, ditto '*Fecit*', (cf. Fromanteel). Note bracket steady-holes.

View: Oosterwijck's *Contrate* back dial identical to Bruce #1/4 except for having a *brass* pointer, that may be an original hand, (ie. having a *non-ferrous* marine specification I anticipated, (p.16).

A closer examination reveals the remarkable, also curious, similarity both in style and execution of the numerals, apparently by the hand of one engraver, (see back-dial overlays, p.42).

However, we are no further to resolving the mystery of 276.92 second Contrate rotations, on dials scribed for 0-60 seconds? **That hiatus is devoid of all logic.**

BACK-PLATE

(Reverse)

BRUCE 2/3

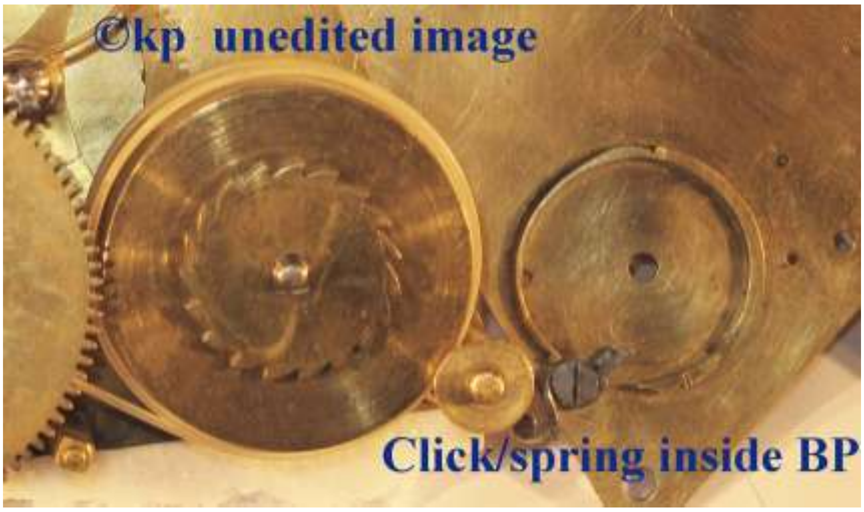
© *kp*

The '*detached*' *Click-Work* inside the back-plate is most unusual, the *Ratchet Wheel* must be inserted before threading the squared Barrel arbor into the plate. [Avoids covering the signature]

View: De-mounted Back-Plate, showing '*detached*' Click-Work, i.e. free of its Barrel-Ratchet set on the Squared Arbor.

see [Supplementary Views](), (p.2. *'CURIOSA' - Detached Click-Work.*

The author would appreciate notice of similar 'detached' click-work.

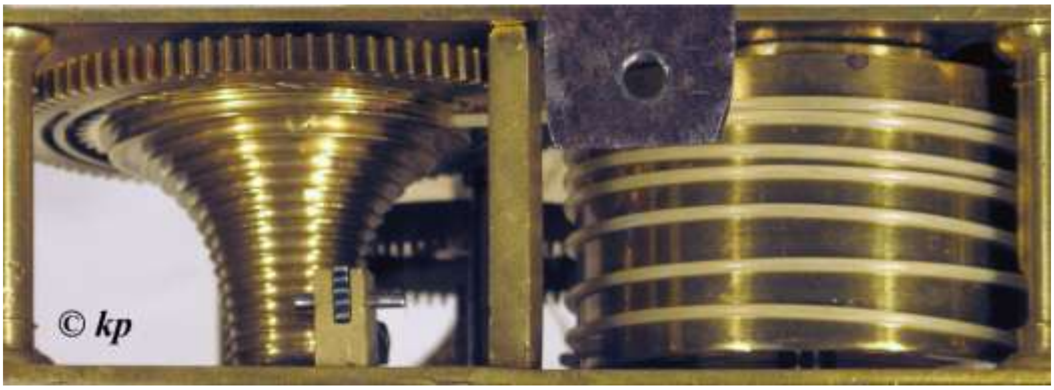


Views: Motive Power, Spring-Barrel and Fusee (modified)
Dutch/Hague-clocks, typically, are powered by Going or Split-Barrels.

Clockmaker Laurence Harvey has examined Oosterwijck's movement. He has determined that a new larger Fusee-Wheel and 15-Turn Fusee, also a deeper Spring-Barrel (for greater power), and thinned Centre wheel, are later additions to extend original short duration significantly. I am grateful to Laurence for his informative and most instructive notes, (p.37).

Laurence Harvey: "Excerpts from my brief notes made on SO".

Barrel - The wall is made from extruded brass tube rather similar to that used in cheap 'dial' clocks. The end caps may well be original as they show the pink 'veining' of the clock castings. The top cap has an extended bush to accommodate the short barrel arbor which is of great age and of wrought steel. It may well be original (as is set up click-work) and could give a true indication of original barrel/fusee heights.



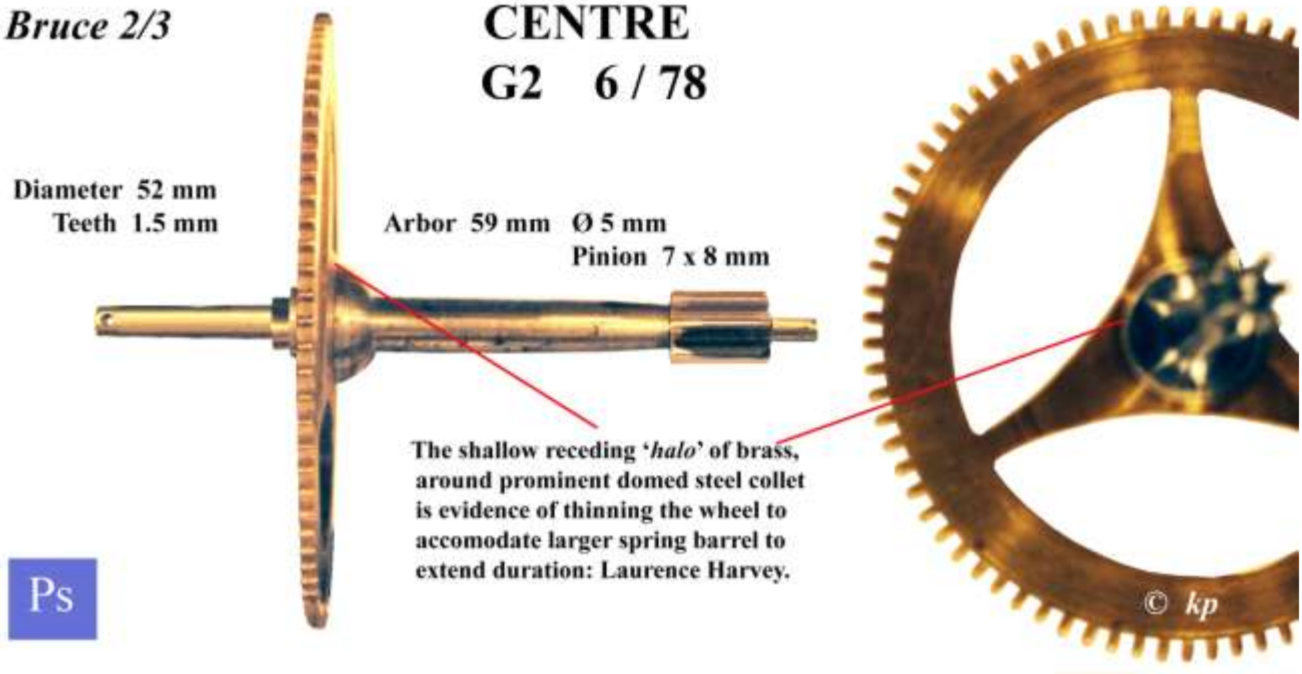
Fusee - Wheel is completely new. The dished brass keep could well be original. The fusee is late Victorian and again of cheap dial clock genus and has a modern click wheel screwed onto the back. The arbor is not part of the modern fusee. It is of wrought manufacture and has been soldered into the cone. Possibly original though doubtful.

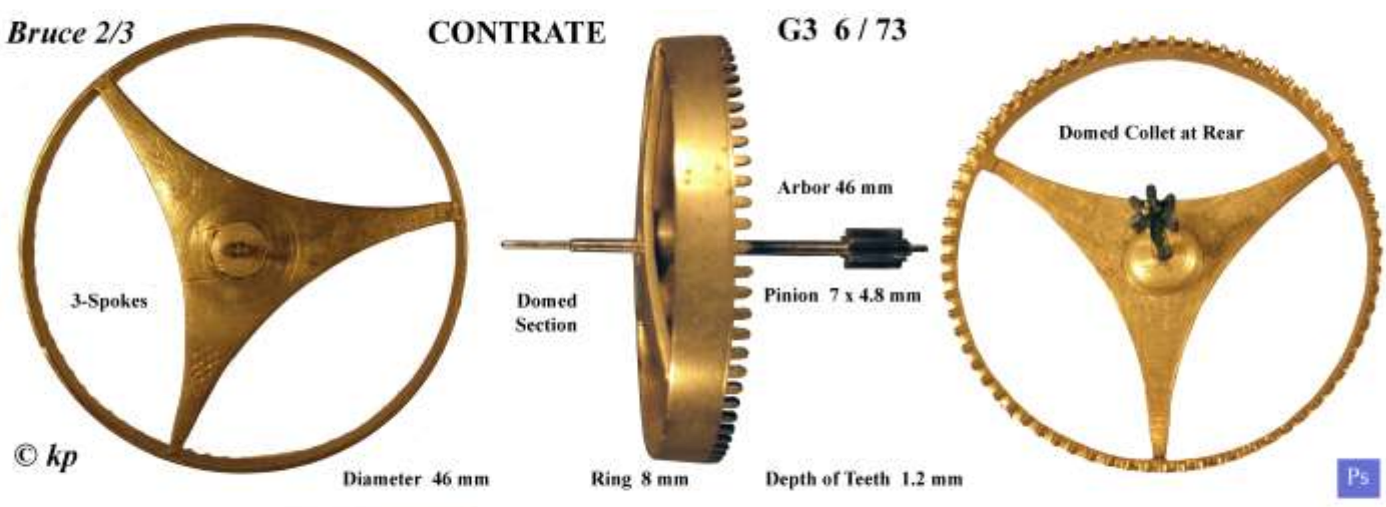
The small square pillar has been twisted to avoid the new larger fusee wheel and not cut away (thank goodness). The original centre wheel has been much reduced in thickness to clear the new fusee and barrel arrangement. [see next page, p.38]

I think that the original fusee bearing/s have been drawn down the plate/s to depth the new larger great wheel with the centre pinion.

Laurence evidently is content with the originality of upper train-wheels, though he found the Centre wheel has been reduced in thickness (see p.38). His attention to every detail emphasises the need, both for amateurs and collectors alike, to heed proper specialist advice in the acquisition of historic clocks, even ancient relics.

All wheels are up to the high standard of Oosterwijck's ***Royal Haagseklok.*** Examination reveals the hand-cut pinions and wheels, even the clear punch-marking setting out the crossings, ('spokes'). All wheel collets are proudly domed, (compare square collets of Bruce #1/4). The escape-collet appears to have been disturbed, with heat used in its re-fixing, possibly damaged in same presumed incident as its top potence, (see p.27).



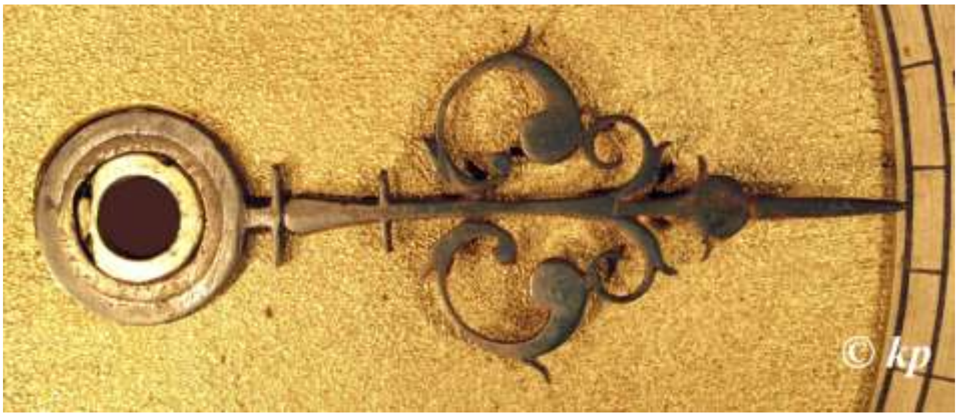


Three 'spokes' (crossings) are the Dutch standard. Whereas, Oosterwijck's *'Royal Haagseklok'* uses Fromanteel's English standard of 4-crossings; also having this most unusual '*dished'* Contrate.

It is instructive to compare the train of Bruce #2/3 with Bruce #1/4, (see pp.21-22).

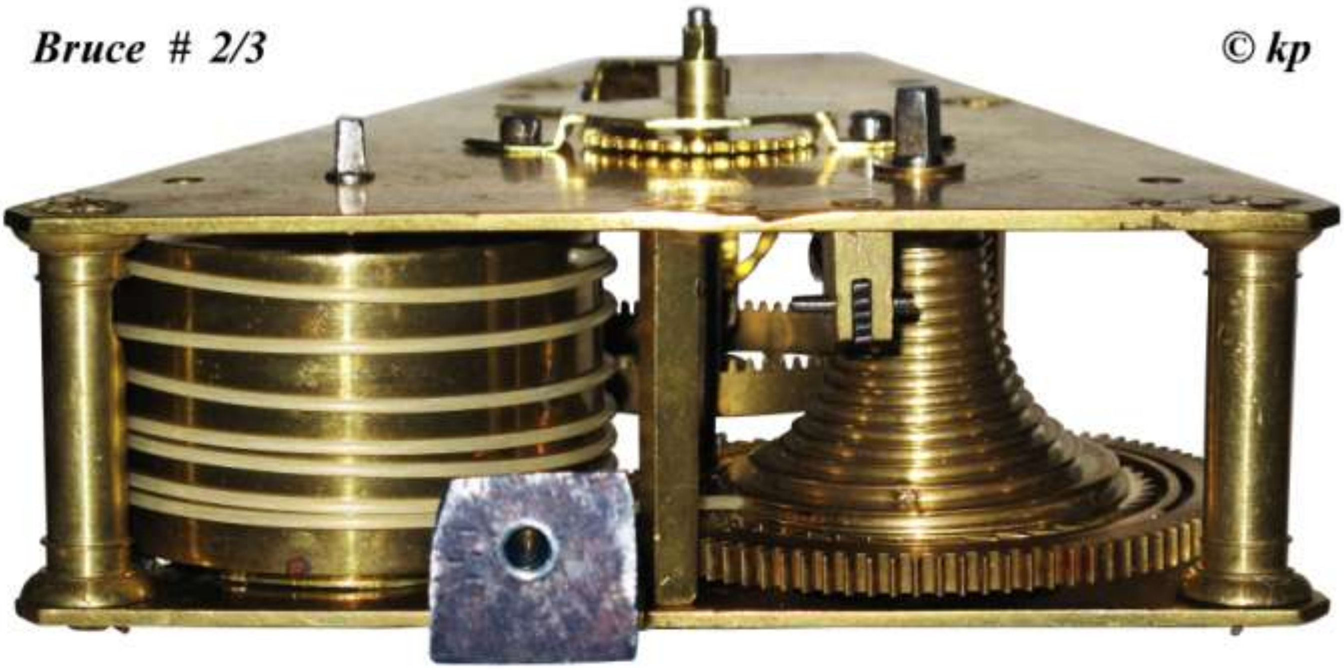
Ps Image partially rescued by PhotoShop: Re-shoot these components

View: The Hour-Cannon, being plugged into the Hour Motion-wheel, (see p.33).
Visible here is the single lateral pin-hole through the canon, to secure a later *'non-marine'* hand. Whereas, Oosterwijck's earlier ***Royal Haagseklok,*** uses *two* opposed transverse pins to secure that hand, (view).



CONCURRENCE OF THE SEA-CLOCK TRAINS: -
The original vertically planted Centre, Contrate and Escape is typical of Dutch layouts, yet also seen in Bruce #1/4. Oddly, each relic has a later, brass, escape-depthing screw in its lower potence, where a steel wedge should support the Escape arbor. Identical short trains produce Contrates turning 13-times per hour, (276.92 seconds per revolution), giving imponderable counts on Back-Dials of **0-60** units (Seconds')**.**

EVIDENCE OF SECURING TO ORIGINAL 'WEDGE' (SEXTANT) CASE.
The original dial-plate would be attached to triangular brass case by some means. The iron bracket, mounted at lower centre of back-plate, would fix the movement into case; but this of uncertain age might be too long.



View: Underside of Movement, showing the bracket now securing the Back-plate to the present case. Nb. deeply grooved Fusee-Stop - what purpose do these deep grooves serve?

I am grateful to the private owner, who would remain anonymous, for his consent to publish this movement under my *'open-research'* project, *'A Royal Haagseklok'*, hosted by the Dutch *Horological Foundation*. He enabled my ongoing investigation into first pendulum *sea-clock Longitude* movements. If, as I have reasoned, Bruce #1/4 above is confirmed as John Hilderson's #4, then his Bruce #2/3 relic may be the earliest known of Alexander Bruce's *'longitude sea-clock'* now extant.

COMPARING ALEXANDER BRUCE'S ENGLISH AND DUTCH MADE FIRST *'LONGITUDE SEA-CLOCKS'* - (1661 to 1664).

SUMMARY: Hollar's Frontispiece of Evelyn's drawing, probably of Bruce's retired 'sea-clock', shares a remarkable similarity to the relics. It fixes a common origin, date, and context, that matches the historical records across two clock-making cultures. Notwithstanding my proper *caveats*, I submit my summary and reserved conclusions, hoping other examples shall be found. Unfortunately, no headway was made tinker-ing with *unequal* trains, lacking a Treffler reduction gear to change imponderable Contrate rotations (276.92 seconds) into useful Seconds on identical **0-60** back-dials. Sebastian Whitestone's view is that those defects disqualify them as 'Longitude marine chronometers'. We now regard them rather as pendulum travelling clocks, [like Van Ceulen's *scheepsreisklok* with spiral-balance], puffed by their Scottish inventor as functional *sea-clocks* - able to determine the Longitudes. Huygens, too, was never averse to puffing his own 'Longitude Clocks' in his private correspondence, publications, and several patent applications.

PILLARS: Both relics have their pillars riveted into the front-plate, like *Coster* pendulums. The plates of each separated at 38mm, the early standard. An unexpected difference in a so called Dutch *'copy'* of Bruce's original English sea-clock; Bruce **#1/4** has 'baluster' pillars; whereas Oosterwijck's, Bruce **#2/3**, has slender 8mm 'cannon' pillars (Pattern PP6) like his earlier striking clock, (Plomp, ***'Chronology'*** ***D9*** c.1660). Huygens' Remontoir patent (1664) depicts even more slender cannons, by then perhaps an Oosterwijck hallmark. Cannon pillar may have been derived from lantern clock pillars, yet are untypical of early English pendulum clocks; and neither the pillars of Bruce #1/4, nor of Bruce #2/3**,** are like any by Ahasuerus Fromanteel; which I admit was a surprise to me. Was Bruce already bored by square pillars? He accepted Oosterwijck's own 'cannon' pattern (PP6), but had he imposed on his English clockmaker to use Huygens' pillars, perhaps plagiarised (copied) from '*Horologium'* (1658)?

I surmised Bruce #1/4 might have lost a fifth pillar at bottom centre; but does O**o**sterwijck's square fifth pillar in Bruce #2/3 support that? Perhaps its 5th pillar was only added for the later stronger new mainspring?

TRAINS: Despite having different Fusees and Centre-pinions, from Centre-wheels up, the short train of Bruce #2/3 exactly matches my extrapolated train of Bruce #1/4. I assert, that that is not a coincidence!

Bruce Nr. 1/4 An English model, 1661 or 1664: Unequal Train!

Extant 5-Wheel Train: 48 12/56 12/78 6/73 6/27 = **142.35 beats/min**
Extrapolated 4-Wheel Train: **56 12/78 6/73 6/27** = **142.35 beats/min**
Contrate turns **13** times per hour; period ***276.92*** secs (**4min 36.92sec**)
Nominal Pendulum Length 17.66 cm. Actual Length 18.7 cm.

Bruce Nr. 2/3 Oosterwijck's Dutch *copy*, 1662: Unequal Train!

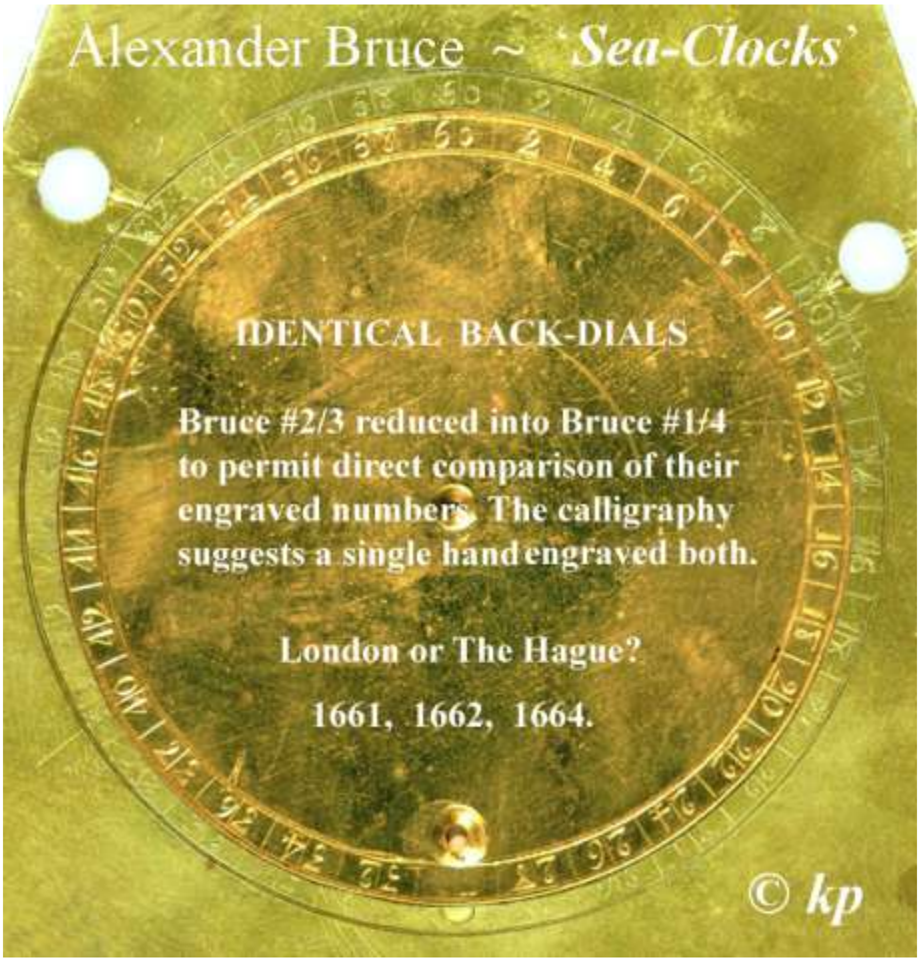
Extant 4-Wheel Train: 88 6/78 6/73 6/27 = **142.35 beats/min.**
Contrate turns **13** times per hour; period ***276.92*** secs (**4min 36.92sec**)
Nominal Pendulum Length 17.66 cm. Actual Length 18.7 cm.

Both relics now have unequal trains; Escapes of 27 teeth on 6-leaf pinions, Contrates 6/73, Centres of 78. Both Bruce #1/4 and Bruce #2/3 Contrates turn 13 times an hour, *276.92* secs/turn; having identical back-dials of 0-60 Units (Seconds), in 1-unit intervals, but only even units are numbered.

Nb. If as has been suggested these are 'afterthoughts' in design, after trials, there should be evidence of rear extensions to contrate arbors, or disturbed collets, where Contrates were modified to display seconds on the back-plates. There should be some forensic tests done to test any evidence remaining. However unlikely, in my view the back-dials are not distant copies, I suggest their engraving suggests a common hand; (see p.41).

BACK-DIALS: Contrate arbors of Bruce #2/3 and Bruce #1/4 share identical back-dials, each 65mm diameter, inscribed with '**0-60'** units presumed Seconds', only even units numbered. Tony Weston cited Oosterwijck's Contrate period as **4**-minute*s*; David Todd recognised its 0-60 back-dial, but he suggests it gives **4.15** seconds per unit. In fact, neither is correct, the Contrate period is **276.92** Seconds, (4mins. 36.92secs). For what purpose, such eccentric periods are inappropriate to **0-60** back-dials. So are the unequal trains. Therefore, the back-dials are unsuited for Longitud*e* calculations**.** One suggestion for their use is comparing rates to re-set 'like' clocks? Solo-mariner Brian Walton proposed a sidereal solution to a 4-minute dial. His new challenge is to find any Mariners' significance in 276.92 seconds' periods. Failing that, one must infer that Bruce #1/4 and Bruce #2/3 have been altered, yet provided with identical short-trains, (Nb. see my proposed radical train at p.44).

ENGRAVING OF NUMERALS: The engraver of the back-dials left evidence of his personal hand.



View: Comparative evidence of the calligraphy used in dial engravings.
Examination is persuasive that a single hand having engraved both dials.

Conversely, the fact of their matching forms and trains from different clock-making traditions is not a coincidence but is good circumstantial evidence that, by their very existence, they prove the historical record of Alexander Bruce's first longitude experiments. Admittedly, both relics now lack Bruce's Double Crank "F" Crutch, also Huygens' Cycloid Cheeks, and suspended Pendulum. Now, each has an English pendulum; Bruce #1/4 has Fromanteel's first 'pivoted pendulum'; Oosterwijck's has Hooke's next 'pendulum-spring-suspension'. Both relics have re-bushed pivot-holes, suggesting much use, although probably not in their intended marine roles, but perhaps in their later domestic roles. Evidence of bushings in upper trains is not of significance. Laurence Harvey is of the same mind, though he showed Oosterwijck's Bruce #2/3 now has a replaced (new) fusee, new main wheel, also a wider spring barrel; and its centre wheel reduced in thickness to accommodate the wider barrel, (p.37). However, any changes to the relics' lower trains are immaterial to the identical short-train counts - wherein lies the problem of incompatibility with common back-dials, and presumed Navigation or Longitude roles assumed by attributing these early pendulum relics to Bruce.

Consummate horologist Berry van Lieshout is loath to accept these trains, seeing they have no counterparts in their 60-seconds back-dials. He is unable to provide a better explanation solely on a basis of images alone. [Berry's opinion finally made me 'grasp the nettle'; start over with wholly new trains. At my Concluding Observations, (p.44), I propose a radical train solution to provide an equal 60 seconds' back-dial at Contrate**]**

Note *variation* in Plates and Bridges yet *identical* Contrate Back-Dials

OVERLAYS: **Bruce # 2/3** ***(Oosterwijck) 100% Opacity*** **Bruce # 1/4** ***(London) 46% and 80%Opacities***
DATUM POINTS: ***FRONT-PLATE - Centre Arbor*** ***BACK-PLATE - Contrate Arbor / DIAL***

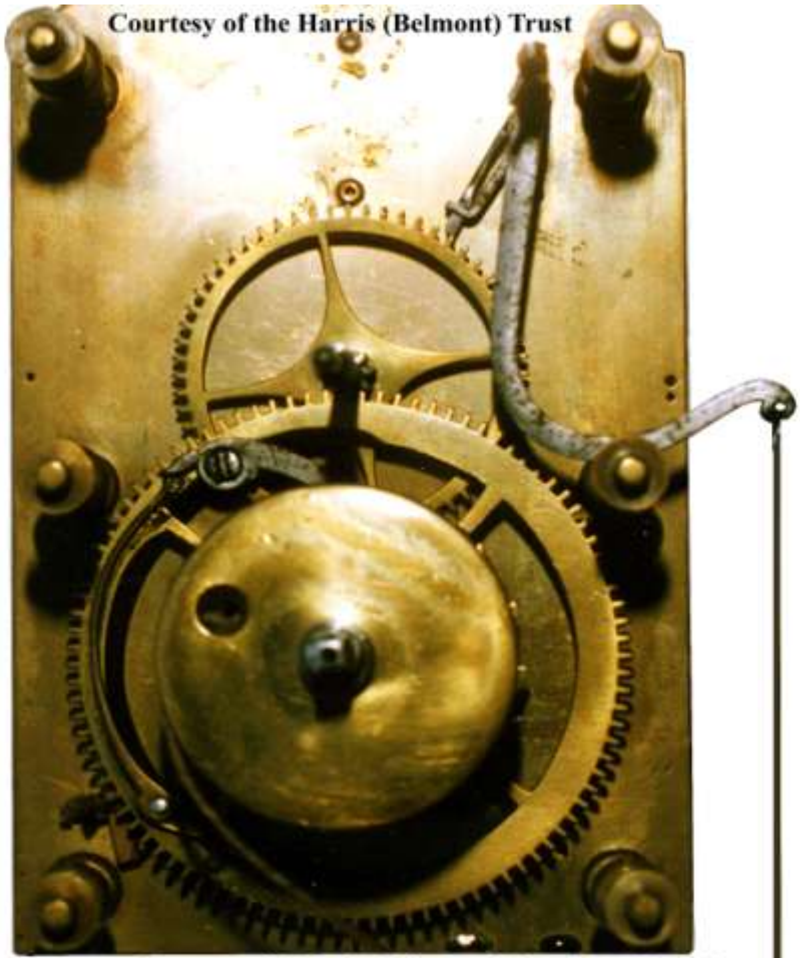
PINIONS AND CROSSINGS ('SPOKES'): English design is also confirmed by the absence of the Dutch **5-leaf** pinion; all being of **6-leafs**, the English standard. However Oosterwijck's Centre Pinion, also **6-leaf**, is quite exceptional; possibly even unique. Oosterwijck's wheels have **3**-spokes, the Dutch standard; whereas the English clock train uses standard **4**-crossings **-** as Oosterwijck notably had also used in his earlier ***'RH'***.

MOTION-WORK: An obvious difference between these movements is the unusual motion-work of the English relic. Oosterwijck's typical Anglo-Dutch motion-work of Bruce #2/3 has a neat bridge and cock, having **30:30/6:72** wheel-count to Minute and Hour wheels. Whereas, Bruce #1/4 motion-work floats higher on the plate, (above Left), within an oversized bridge; its much larger reverse minute wheel lacks any cock, held and aligned in a cage of studs; with an extraordinary count; **35:70/12:72.** The doubled pinion corrects its curiously unequal minute and reverse-minute. This construction, as much as its other features, like pillar shape, persuades me that Bruce #1/4 is not by Ahasuerus Fromanteel's hand, yet might possibly be John Hilderson's, but at present I have to admit insufficient knowledge of Hilderson's work to make a judgement.

Hour-wheel cannons are also different. Bruce #1/4 has a demountable canon, held to its wheel by a slotted round brass key-plate, typical of Fromanteel and his London acolytes. Whereas, Oosterwijck's canon is plugged direct into its Hour-wheel, therefore a permanent fixture, but simpler and cheaper to make. Compare his ***'Royal Haagseklok'.*** **Oosterwijck's potences set on the front-plate are a unique exception to the rule.**

REDUCED PLATES (BRUCE #1/4): Horologically, the difference between these two is the English relic has reduced upper plates, with extraordinary top potence, also verge slot in back-plate, (see pp. 9-10, also pp.18-19). I suggest its front mounted stirrup-potence looks like 18th Century work; but the verge, pendulum-rod, contrate and escape wheels, their positions, the dovetail steel keeper, all appear to be 17th century, and materially of the early pendulum era. And if Bruce #1/4 was converted later in the 17th or early 18th centuries, I suggest Hooke's spring suspension would have been preferred, rather than this Fromanteel pivoted-pendulum, apparently made from original parts of Bruce-Huygens' systems, yet nevertheless giving me more confidence in its modification's earlier dating.

FROMANTEEL'S BOLT & SHUTTER MAINTAINING POWER (*B&SMP*):



Ahasuerus Fromanteel's '*Bolt & Shutter Maintaining Power*' (B&SMP), the cocked Bolt, (its spring on front-plate), shown engaging and driving the Centre-wheel . © *kp*

After 1660, in early English verge-movements, one expects Fromanteel's *B&SMP*. For navigation its need is even greater, as mariners should not suffer Flamsteed's frustration at Tompion's timepiece, "*backing up several seconds at each winding"* - because its did not have a maintaining-power***.** That defect also applies to Dutch copies of an English fusee sea-clock. Navigation would disappear out of the stern, whenever a Longitude sea-clock backed-up. Going-barrels eliminate that problem, but exacerbate Circular Error. Bruce #1/4 appears to have filled holes where *B&SMP* should be expected, (see p.23), Oddly, the Dutch relic offers no evidence *of B&SMP*. Why had Oosterwijck's none? Is it a 'sea-clock'? For what purpose, perhaps for astronomical sightings of short durations. That would seem to debar its use in fixing a ship's Longitudes. Contemporary reports, lauding their success at sea, now appear improbably 'rose-tinted' - as Huygens knew.

*Fromanteel's *spring-remontoir* of 1649, Huygens' *endless-rope pulley* of 1657, Douw's *spring-remontoir* of 1658, Fromanteel's *bolt & shutter maintaining-power* (*B&SMP*) of 1660, Huygens' *weight-remontoir* (1664), all countered *'backing-up'* during winding. Nb. Joost Burgi's original remontoirs did so between 1582-1610.

CONCLUDING OBSERVATIONS: Apropos both minor and major differences, I suggest the differences are the circumstantial evidence that it was not this English movement (Bruce #1/4) that Alexander Bruce took to The Hague in 1662, to commission copies by Severijn Oosterwijck as Bruce #2/3**.** Therefore, this London relic is not **Bruce #1** of 1661, but with a degree of confidence is cited as **Bruce #4** of 1663/4.

Leopold and Weston named John Hilderson, Edward East†, John Fromanteel, as English makers involved in constructing Bruce's later 'sea clocks'. † East's clock, *"hauing 2 springs to turne one pinion* [i.e.true tandem-barrels] *but with no cheeks"* [i.e. either Fromanteel's pivoted-pendulum, or Huygens' ***OP***-gear]. Any persons familiar with Hilderson's work may provide their own insights via our open research project.

Robert Hooke had long predicted the folly of pendulums on the sea's incalculable accelerations; Huygens' observation in 1665 of 'pendulum sympathy' as a way to synchronise ship-borne clocks, actually proved the opposite to learned members of the Royal Society, but did reveal a pendulum to be a far more sensitive instrument than hitherto realised. Hooke's experiments with springs applied to balances, was relayed to Huygens in 1665, he altered Hooke's spring to spiral form to proclaim '*invention*' (1673), only perfected in 1693 as his most successful Marine Longitude enterprise, his *'perfect marine balance'*.

For too long, all spotlights and credits centred only on Huygens' part in the search for a marine 'Longitude' timekeeper. Huygens pride in his real achievement, adapting clockwork to the pendulum, became such an obsession that he had missed other more promising signposts; Douw's spring-remontoir to pivoting-oscillator (***Appendix Four***); and he ignored Hooke's disdain of pendulums at sea - confirmed in his Dover coach-ride and 1662/3 sea-trials; setting three clocks at angles to each other. Here, Alexander Bruce finally receives the credit due to him, which Christiaan Huygens had been loath to give publically; both in Patent applications for his weight-remontoir with Bruce's crutch (1664), and in his great 1673 *Opu*s, Horologium Oscillatorium.

My title signposts Alexander Bruce's Longitude sea-clocks that Hooke always knew could not work, because of their reliance on pendulum, [Chapt. ***'Pendulum Clocks at Sea'***, pp.5-6] The very existence of two such movements, across two clock-making cultures, is suggestive of mutual originality, and affirms the historic record of Bruce's experimental sea-clocks. Yet, given their back-dials scribed 0-60, any *Longitude* function of the extant trains is irreducible to logic! Here, I suggest the extant identical trains are not so designed.

A serious obstacle to 'Navigation' is these contrate back-dials, inscribed for 60 seconds, yet with contrates revolving in 276.92 seconds. Berry van Lieshout agrees, originally the Contrates should turn in 60 seconds; so demanding different trains. Here, the nettle now must be grasped! Are the relics' apparently early trains, one seemingly original, in fact replacement trains; by one workshop, when maritime trials had ended? Here I opt for a shorter pendulum, 11cms* beating 180 times/minute, having Escape 7/15, Contrate 5/42, Centre 75. *i.e. rejecting extant pendulums, also my thesis at p.9. [Huygens gives Bruce's pendulum as '*half a foot in length*' (15cms/153beats); his own Triangular-pendulum (16cms/150beats) possessed a 60-seconds Contrate]

The Triangular '*Sea-Clocks*': #1 Ahasuerus Fromanteel? 1661. #2/3 Severijn Oosterwijck 1662. #4 John Hilderson 1663.

A radical 'Longitude' train respecting their Contrate '0-60' back-dials

Wheels (short-train)		Teeth	Pinion	Beats/Minute	Turns/Min	Turns/Hour	Rotation in Secs.	Rotation in Mins.
Escape wheel	G4	15	7	180	6	360	10	6
Contrate wheel	G3	42	5	**Back-Dial**	1	60	60	1
Centre wheel	G2	75	x	**Pendulum**	0.066667	4	Motion-work 4:1	60
Combined Great/Centre		300	x	10.795 cms	0.016667	1	Standard motion-work	60

© kp

The Contrate turns in 60-secs; the Centre turns four-times/hour and may be geared-down (4:1) to improve readability. [A Great/Centre wheel of 300 teeth would turn in one hour; there is no evidence for that].

However, **Dr Robert Hooke's** report on Alexander Bruce's sea-trials in 1662, (Annex 1) cites pendulums vibrating 'half-seconds', (thus 10inches or 25cms long). Accepting that as fact, it seems that Bruce probably adopted Huygens' wheel train described in 'Horologium' (1658), but here with a conventional verge, not the "OP-gear" for long-pendulum. Whereas Huygens' train planted coaxial Seconds within Hours at dial-plate, the sea-clock's Contrate arbor would be independent, exiting at the back-plate to indicate Seconds on 0-60 back-dials. Huygens' Horologium train is recorded at 'openresearch' Matrix, (page 2, weight clocks), but here may be applied to Bruce's fusee driven spring-clocks.

Huygens' equal train showing Seconds at the Contrate's back-dial, having a half-second pendulum.

The Triangular '*Sea-Clocks*': #1 Ahasuerus Fromanteel? 1661. #2/3 Severijn Oosterwijck 1662. #4 John Hilderson 1663. *A radical 'Longitude' train respecting their Contrate '0-60' back-dials*								
Wheels (short-train)		Teeth	Pinion	Beats/Minute	Turns/Min	Turns/Hour	Rotation in Secs.	Rotation in Mins.
Escape wheel	G4	15	7	180	6	360	10	6
Contrate wheel	G3	42	5	Back-Dial	1	60	60	1
Centre wheel	G2	75	x	Pendulum	0.066667	4	Motion-work 4:1	60
Combined Great/Centre		300	x	10.795 cms	0.016667	1	Standard motion-work	60

© kp

An insurmountable obstacle remains; ***'Navigators' Clocks'*** must run continuously, or '***Longitude***' flies out of the stern-window. Both these relics had short durations, purportedly used in voyages of longer durations. But without a going-barrel, rewinding any verge-pendulum's fusee brings its own problem, the escapement 'backing-up' so that all continuity of time keeping is lost. Mariners should never have to contend with John Flamsteed's complaint; timepieces intended for navigation must have maintaining power, or a remontoir, to ensure a continuous duration; uninterrupted for entire voyages; without exceptions!

Any backing-up or any interrupted operation, meant that navigation or determining Longitude, from the local time at a port of origin, would be impossible. Bruce's English relic has filled holes to suggest former presence of *B&SMP*. Its absence in Oosterwijck's movement rings bells, unfortunately not 'ships' bells'! What am I missing? What other purposes remain for the Dutch 'sea-clock' without maintaining power?

Was Oosterwijck's movement only for short-duration use, say *24-hour* sightings, of stars - at sea? Why then the back-dial turning in c.277 seconds? Despite semblances of logic, I am not enthusiastic about hypotheses that the identical dials were to cross-test performance of cycloid-cheeks, or were merely engravers' trials. Mariners had no use for the first proposition; and the existence of these Anglo-Dutch triangular-twins would be inexplicable without the historic Bruce connection! Furthermore, the back-dials themselves seem to be engraved by a single hand. Neither did Bruce, initially, anticipate using two sea-clocks to enable esoteric cycloid corrections at sea, or to be run in tandem for continuity whenever one clock backed-up or stopped. However, in January 1663, Huygens and Moray had each advised Bruce to run 'two well-adjusted clocks'.

By late 1662, Huygens saw the need for a remontoir; (Simon Douw recalled, and vindicated**).** Probably, Bruce did not; or at least he did not instruct Oosterwijck to add Fromanteel's spring-maintaining-power, *B&SMP to **#2/3***, [see ***Appendix Seven,*** p.13]. Had **#1** Fromanteel's spring-remontoir, or his *B&SMP**?*** Did Bruce instruct a London maker of **#4** to add *B&SMP*? By 1663, best London makers would add Fromanteel type *B&SMP* as a matter of course - or so surviving early English pendulum movements would persuade us.

Consequently, and having regard to the intractable problem of identical back-dials, and having identical but unequal trains, my reserved conclusions must challenge the general assumption made at my title. *Vis à vis* back-dials, I must conclude by questioning the originality of both the extant trains - each irreducible to logic.

In Concluding Observations I propose a radical 'equal' train, to resolve the clear evidential requirement for a 60-seconds contrate period; by using a suspended version of Fromanteel's original 11 cms pivoted-pendulum of 180 beats/minute; (like *Mell's* automaton-musical chamber clock). Whereas, in Ahasuerus Fromanteel's Equation and Tidal Clock, (see *Appendix Seven*), I could not discover any ***shorter*** pendulum than one-second beating, *at least*, to fit its apparently original Great and Centre wheels retained throughout its evident several *long-pendulum* escapements; i.e. Verge (1660/1), Cross-Beat (1663/4), lastly Anchor (1670/1). Whereas, in Alexander Bruce's longitude movements, unless anticipating Huygens' 1673 train (see p.6), I cannot propose any ***longer*** pendulum that meets identical '0-60' back-dials' implied 60 seconds' Contrate rotations; therefore my radical short-train; Escape 7/15, Contrate 5/42, Centre 75, beating 180/minute, with 60 seconds' Contrate.

Yet again, even in this respect, needing a shorter pendulum to work, Fromanteel's name comes to the fore, as the probable maker, and perhaps designer, of the original triangular sea-clock, Alexander Bruce's **#1**, who included Bruce's 'F-crutch' that Christiaan Huygens first saw in London, in 1661. Did Huygens meet Bruce at the new Royal Society, or was that the unstated real purpose of John Evelyn leading Monsieur Zulichem, '*by Fromantil's y^{e} famous clock-maker to see some pendules*'? (John Evelyn, Diary, May 2nd1661).

My mother used to say *'slower cooking gives the better flavours'*, so is it with such limited opportunities to examine historic artefacts. Admittedly, my own investigation is yet incomplete; it lacks full technical studies of both trains, and lacks spectroscopic analyses. Even several of my original digital images must be re-shot.

Nevertheless, I bring these triangular sea-clock 'Longitude' relics before their first public scrutiny, whether amateur enthusiasts or professional horologists, to encourage all who support ***open research*** to pick up the reins, to resolve these sea-clocks, being properly attributed to their acknowledged *inventor*, the 2nd Earl Kincardine Alexander Bruce between 1660/1 and 1665.

Footnote A. (27 September, 2012)**:** Robert Hooke's posthumously published works include "*The Lord Kingkardine's Observations of the pendulum Clocks at Sea, in 1662*" in which Hooke also had participated in the sea trials. Refer to ANNEX 1 below. In this context, recently, an invitation to examine Bruce's papers still in private hands may soon widen our scanty knowledge to permit the further development of historical and technical backgrounds to this earliest quest for longitude by *pendulum*. (see **First Fruits**, also **Annex 1**).

Footnote B. (31 March, 2013)**:** It is encouraging to inform RH followers that academia, at least the museum world, has accepted Alexander Bruce's 'sea-clock' by Severijn Oosterwijck (Bruce **#2/3**) into its august fold of experimental Longitude time-keeping. Oosterwijck's 'triangular movement' is presently being exhibited at the **Royal Society**, its private owner feels ultimately it should rightly return there permanently, which generous intended bequest I happily endorse.

From the Royal Society, Bruce's earliest known extant 'sea-clock' movement shall join a travelling exhibition that will celebrate the tri-centenary of the British Longitude Act of 1714. The **'*Longitude*'** exhibition will tell the story of the search for successful methods of fixing a ship's position at sea. So that followers might mark their diaries to obtain a first glimpse of this rediscovered relic, here are the present prestigious bookings;

Beginning at **Royal Museums Greenwich**, London,	11 July 2014 to 4 January 2015.
Folger Shakespeare Library, Washington DC. USA.	April-September 2015
Adler Planetarium, Chicago, USA.	November 2015-March 2016
Palace Museum, Beijing, China.	July-September 2016
Australian National Maritime Museum, Sydney,	November 2016-March 2017.

If other place or dates be added I shall update this list. Rather a fitting irony, that 352 years after Alexander Bruce Lord Kincardine's first sea-trials, his Severijn Oosterwijck relic finally will circumnavigate the Globe.

Believe it or not, the relic's owner needed encouragement before confirming acceptance; an opportunity most owner's would give their eye-teeth for - and pay handsomely! When that was put to him, the absence for a mere four years of a treasured historic possession was seen in its proper context. It might well be the only chance that antiquarian horologists and maritime historians ever will have to see Bruce's first modern attempt to resolve Frisius Gemma's 'longitude time-keeper' method with a pendulum-clock; albeit destined to fail, as the Royal Society's Robert Hooke was first to realise a decade before Huygens' own epiphany. (see **Annex 1**)

Nevertheless Bruce's British 'sea-clocks' (albeit this particular example by Oosterwijck made under licence) began the search for a successful 'longitude timekeeper' - that was to defeat even great Christiaan Huygens, but which our humble, indefatigable, dedicated, and intuitive, John Harrison made into his own memorial.

First Fruits add important new insights into Bruce's entrepreneurial enterprises. Apparently, when he was to return from Holland, he shipped *thirty 'unfinished' pendulum movements* directly to his home, Culrose on the Forth in Scotland; but storms drove that ship into Ipswich, where Customs seized all the movements and when dues were not paid apparently the movements were destroyed. That ship's name or a date may enable research into Customs' archives. Thirty movements would represent their unnamed Dutch workshop's entire output for two years. Perhaps from several workshops, but why '*unfinished*' movements? If Bruce wanted Fromanteel to finish, he should have shipped them to London. Whom, in Scotland, had Bruce intended to finish? Humphrey Mills of Edinburgh? Had Bruce thought to capitalise on a Scottish *pendulum* revolution?

Keith Piggott 6th April 2013

▲ (Back to Top) ▲ (Back to RH)

Appendix Five, Annex 1: (27/09/2012).

ALEXANDER BRUCE'S ENGLISH AND DUTCH LONGITUDE SEA-CLOCKS REDISCOVERED

ROBERT HOOKE, ON ALEXANDER BRUCE'S FIRST *'LONGITUDE SEA-CLOCKS'* (1662).
(Published posthumously in 1724)

Dr. HOOK's *Experiment*
PENDULUM CLOCKS *at Sea.*

The Lord Kingkardine's *Obſervations of the Pendulum Clocks at Sea, in* 1662.

THE Lord *Kingkardine* did reſolve to make ſome Trial what might be done, by carrying a *Pendulum* Clock to Sea; for which End, he contrived to make the Watch Part to be moved by a Spring inſtead of a Weight; and then making the Caſe of the Clock very heavy with Lead, he ſuſpended it, underneath the Deck of the Ship, by a Ball and Socket of Braſs, making the *Pendulum* but ſhort; namely, to vibrate half Seconds, and that he might be the better inabled to judge of the Effect of it, he cauſed two of the ſame Kind of *Pendulum* Clocks to be made, and ſuſpended them both pretty near the middle of the Veſſel, underneath the Deck; thus done, having firſt adjuſted them to go equal to one another, and pretty near to the true Time; he cauſed them firſt to move parallel to one another, that is, in the Plane of the Length of the Ship, and afterwards he turned one to move in a Plane at Right Angles with the former; and in both theſe Caſes it was found by Trials made at Sea, at which I (*i.e.* Dr. *Hook*) was preſent, that they would vary from one another, though not very much, ſometimes one gaining and ſometimes the other, and both of them from the true Time, but yet not ſo much but that we judged they might be of very good Uſe at Sea, if ſome farther Contrivances about them were thought upon, and put in Practice. This firſt Trial was made in the Year 1662; whereupon, theſe being found to be able to continue their Motion without ſtopping, ſeveral other Clocks of this Nature were made and ſent to Sea, by ſuch as ſhould make farther Experiment of their Uſe. And we have an Account which was given from Sir R. *Holmes*, who tried them in ſailing from St. *Thomas* Weſt-ward about 800 Leagues, and then tacking about ſteer'd about 300 Leagues N. N. E. towards the Coaſt of *Africa*, and by obſerving theſe Clocks only, he was able to judge much better than the Maſters of the other Veſſels that were in Company, who differed from his Account, ſome 80, ſome 100 Leagues, ſome more Leagues; and whereas ſeveral of them thought themſelves near to *Barbadoes*, he judged by his Clocks that he was not far from *Fuego*, one of the Iſlands of *Cape Verde*, and the next Day by Noon reached that Iſland. But yet this was not ſo exact as was expected; however, it performed ſomewhat towards this Effect of finding Longitudes ſomewhat more than ordinary, and enough at leaſt to give inquiſitive Men Occaſion to ſpeculate, and make farther Trial. And though there hath been no very conſiderable Improvement of that Inſtrument, or Experiment ſince that Time by any, and tho' I fear it may at beſt be inſufficient to perform what is neceſſary to this Matter, yet I queſtion not but that there may be ſome other Way that may perform it to a much greater Degree of Perfection, as I ſhall hereafter endeavour to prove.

Comment: Hooke's was present at early sea trials, also recorded is his disappointment with the pendulum clock he tested during a coach ride to Dover. This description, involving the use of three similar sea-clocks must infer that this particular sea-trial took place during December 1662, upon Bruce leaving Holland with the original London made sea-clock (**BRUCE #1)** also with Severijn Oosterwijck's two copies (**BRUCE #2** and **BRUCE #3)**. It is recorded that the 'old clock' was damaged by falling from its Cardan suspension.

Here, Hooke's vivid descriptions of the clocks' precise placements within the ship, and varied alignments of the three clocks, both in respect to the ship's axis and to each other, tells us of the methodical empiric scientific nature of the first major sea trial of pendulum controlled sea-clocks. It adds to a new appreciation of Bruce's 'longitude' endeavours long before Huygens' marine project had even got underway, although Bruce had consulted Huygens as early as April 1661 in London. **KP** *27/09/2012.*