Going through the motions

Some further considerations about the perpetuum mobile of Cornelis Drebbel, based on a manuscript discovered by Dr. Alexander Marr

by

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The Perpetuum Mobile is not the only invention of Cornelis Drebbel (1572-1633), nor perhaps even the most significant, but it is certainly the one for which he was best known by his contemporaries, and the one of which he remained most proud. It is also the instrument about which most has been written – both by his contemporaries and by modern scholars. What was Drebbel's famous instrument, how did it actually work, and why was it so important to the late Renaissance court? What can we add to the extensive accounts of Drebbel and his most famous work?

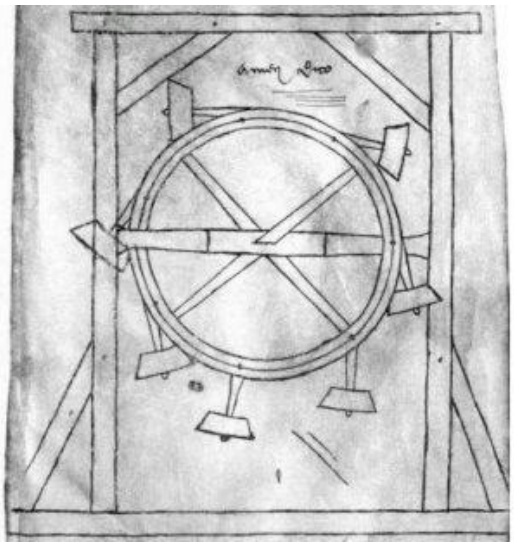


Figure 2. PPM by Villard de Honnecourt

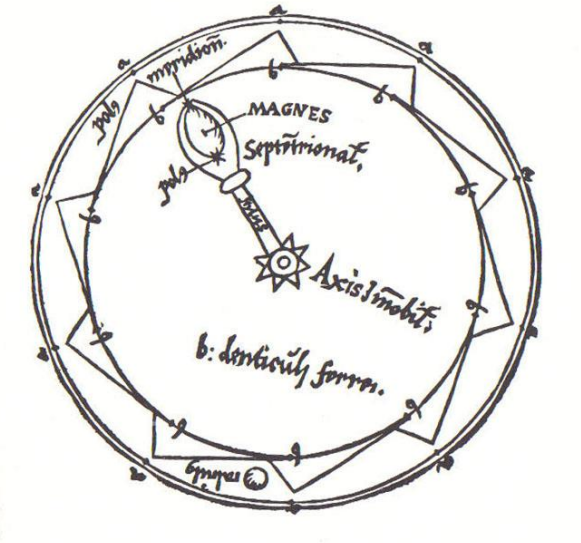


Figure 1. PPM by Pierre de Maricourt

The search for a device that would continue to move by means of its own power dates to Antiquity. Early attempts date as far back as the Archimedes screw, and Arabic sources tell of countless attempts to create perpetual motions using mills and water. The principles

commonly used to power perpetual motion machines were often discovered independently of one another, and dissemination fragmentary or discontinuous when it occurred at all. For example, in the 12th century the Indian astronomer and mathematician Bhaskara (1114-1185) described a Perpetuum Mobile made of a wheel with containers attached to its rim, partly filled with mercury. Only a few decades later, in 1235, Villard de Honnecourt described a similar overbalanced wheel with seven hammers attached to its rim. In 1269 Pierre de Maricourt described a hypothetical perpetual motion machine in his *Epistola De Magnete* which used the magnetic powers of the lodestone, a principle recycled by Johannes Taisnerius (Jean Taisner) in 1572, in a work much in vogue in the late 16th century.

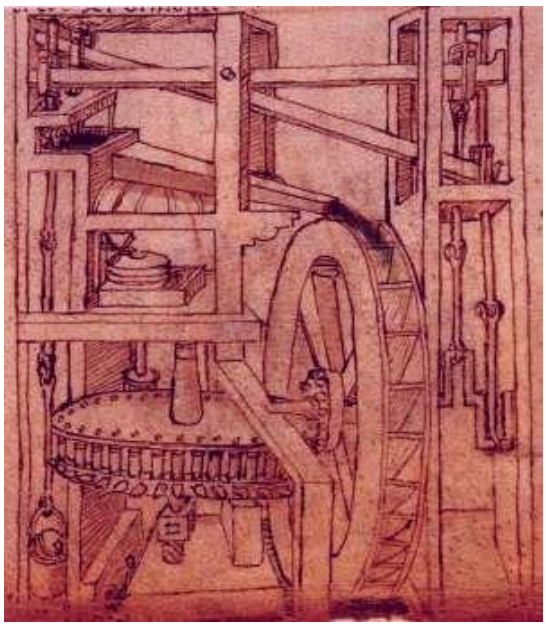
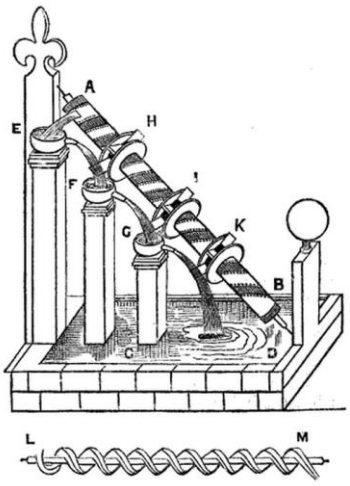


Figure 3. PPM by Francisco di Giorgio

By 1480, Francisco di Giorgio (1395-1482) had described several water mills based on the Archimedes Screw, called 'recirculation mills', in his *Trattato di architettura e machine*, and, around the same time, Leonardo da Vinci (1452-1519) made several sketches of perpetual motions similarly based on the Archimedes Screw and over-balanced wheels.



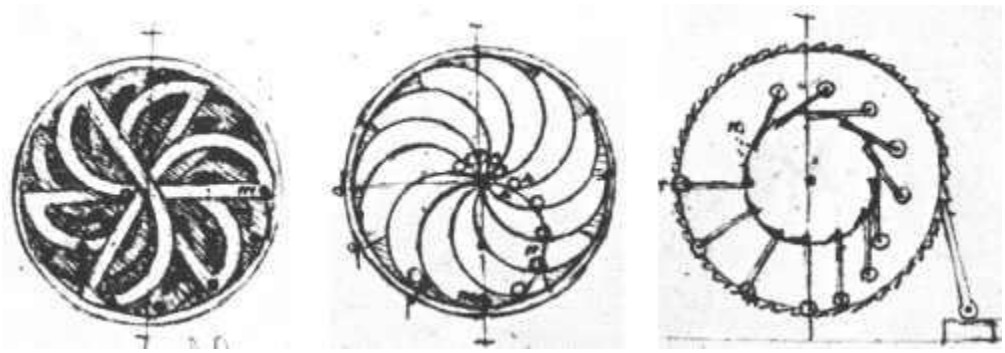


Figure 4. According Leonardo da Vinci

By 1586, in his *De Beghinselen des Waterwichts* the Dutch mathematician Simon Stevin (1548-1620) had already demonstrated the impossibility of perpetual motion based on a ramp and an endless chain, nevertheless, a mill wheel driving a bucket chain was proposed as a Perpetuum Mobile by Robert Fludd in 1618 in his *Tractatus Secundus De Naturae seu Technica macrocosmi historia*. In his 1607 book *Novo teatro di machine et edificii* Vittorio Zonca (1568-1602) depicted a Perpetuum Mobile based on the siphon principle, an idea he putatively borrowed from the influential Neapolitan natural philosopher Giovanni Battista della Porta (1535- 1615), who had in turn been influenced by the writings of Philo and Hero of Alexandria.

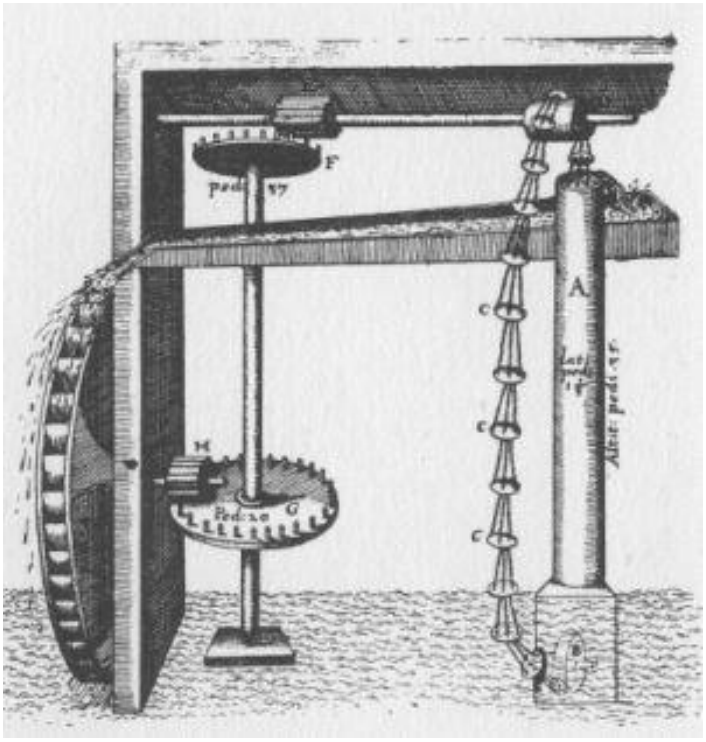


Figure 5. PPM by Fludd

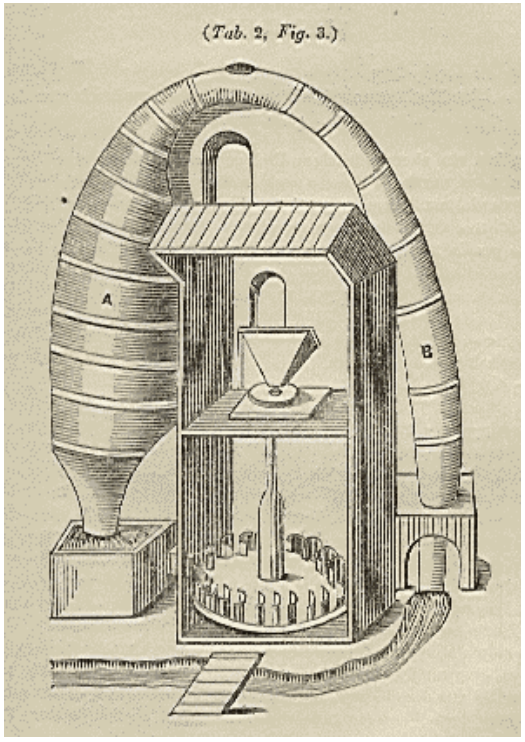


Figure 6. PPM according to Zonca

The Habsburg Emperor Rudolf II (1552-1612), whose court at Prague was the centre of Europe's intellectual universe from his election in 1576 until his death in 1612, was known to be fascinated by clockwork and instruments, and his court included several gifted instrument makers such as the mathematician Jost Burgi (1552-1632) who was the first to place a minute hand on a clock, and the court mechanician Erasmus Habermel (1536-1606), who made the

Figure 7. Clck made by Jost Burgi

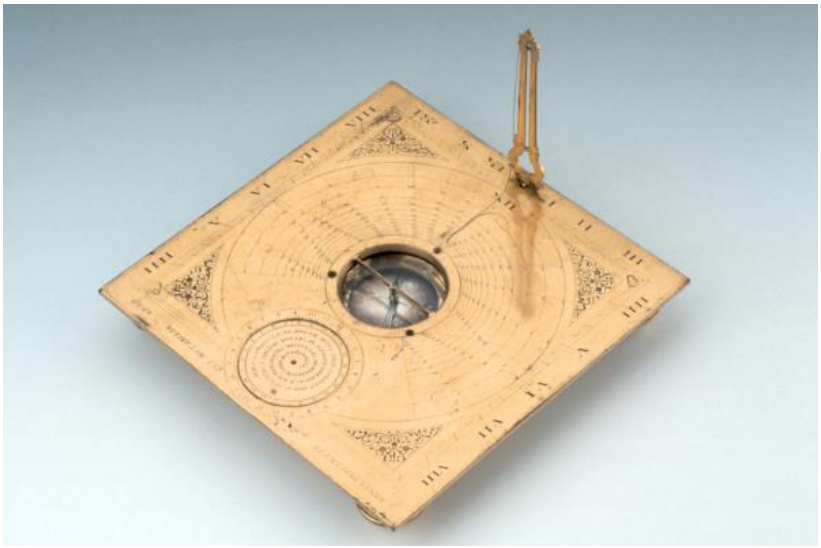


Figure 8. Compas from Erasmus Habernel

astronomical instruments used by Tycho Brahe and Kepler. Rudolf II is said to have made clockwork himself, and his natural son Julius Caesar (±1585-1609) was obsessed by them. Rudolf's interest in the Perpetuum Mobile is attested by his attempts to bring the fountain builder ('Wasserkunstler') Hans Oberer to Prague, after whom he enquired in 1592, to no avail. Nearly a decade later, in 1603, he requested Herzog Wilhelm of Bavaria, in whose service Oberer then was, to send one of Oberer's Perpetuum Mobile to Prague[1].

How do we know what we do about Drebbel's Perpetuum Mobile? The sources are not abundant, but suffice to show the importance of Drebbel's invention, which for a brief time was one of the wonders of Late Renaissance Europe. James I of England (1566-1625) was so impressed with it that he installed Drebbel in rooms at Eltham Palace around 1607, where foreign visitors admired the Perpetuum Mobile along with other Drebbel-constructed automata such as self-playing clavichords[2]. Ben Jonson (1572-1637) referred to 'the Eltham thing' in an epigram, and again in the *Epicoene* (first performed 1609),

> You do not know in what a misery I have been exercis'd this day, what a torrent of Evil! My very Houſe turns round with the Tumult! I dwell in a Wind-mill! The perpetual Motion is here, and not at *Eltham*.

and Henry Peacham (1576-1643) referred to the 'Heavenly Motion' at Eltham in 1611[3].

> And think them happy, when may be shew'd for a penny
> The Fleet-streete Mandrakes, the heavenly Motion of Eltham,
> Westminster monuments, and Guild hall huge Corinaeus,

As early as 1607, Rudolf II invited Drebbel to construct a Perpetuum Mobile, although he would not leave England for Prague until October 1610. Another foreign visitor who went to see it was Baron Schwarzstät, and his travel diary contains an account of the visit[4], The perpetuum mobile 'the like of which time past has not seen… is a globe made out of brass to the size of a human head, showing the course of the Sun, of the Moon, of the planets, the months and the days… The maker declares, it will resemble in enduring convolution the eternal heaven. Around the Globe there is a concave shell of glass which graphically shows the ebb and flow of the Ocean… Such a work, but greater in size, the same man is making for the Lord our Emperor.' Nearly two decades later, the French intellectual Nicholas Claude Fabri de Peiresc (1580-1637) asked Peter Paul Rubens (1577-1640) to procure him a Perpetuum Mobile from Antwerp in a letter written 1623, and the instrument was duly delivered in 1625[5]. John Winthrop Jr. (1606-1676) asked Drebbel's heir Jacob or Johann Sibertus Kuffler (1595-1677) for a Primum Mobile to be sent to the newly founded Massachusetts Bay Colony in 1636[6].

The fame of Drebbel and his Perpetuum Mobile spread rapidly, and the Perpetuum Mobile was still being cited as late as the 19th century, long after Drebbel himself had passed into obscurity. In the 20th century several biographies of Drebbel appeared, including Naber's breathless hagiography[7], Jaeger's critical and irascible study[8], Tierie's even-handed PhD thesis[9], and Harris's double biography of Drebbel and Humphrey Bradley[10]. Rosalie Colie devoted a whole chapter to Drebbel in her biography of Huyghens[11], and followed it with an important article on Drebbel and De Caus[12]. Recently Jennifer Drake-Brockman published a magisterial synthesis of all that is currently known about Drebbel's Perpetuum Mobile, including a newly discovered document placing the date of Drebbel's arrival in England no later than June 1604[13]. Due to the extent and quality of these works, particularly Drake-Brockman's, it is not necessary to repeat their extensive use of known sources, but instead to look in more detail at the questions that still surround Drebbel's Perpetuum Mobile and its construction.

What exactly is a Perpetuum Mobile, and how did Drebbel's differ from others? In his much-cited 1648 book *Mathematicall Magick*, the John Wilkins, Bishop of Chester (1614-1672) devotes chapter IX-XIV to the Perpetuum Mobile, in which he writes: 'The ways whereby this [perpetual motion] hath been attempted may be generally reduced to these three kinds:

1. By Chymical Extractions
2. By Magnetical Virtues
3. By the Natural Affection of Gravity

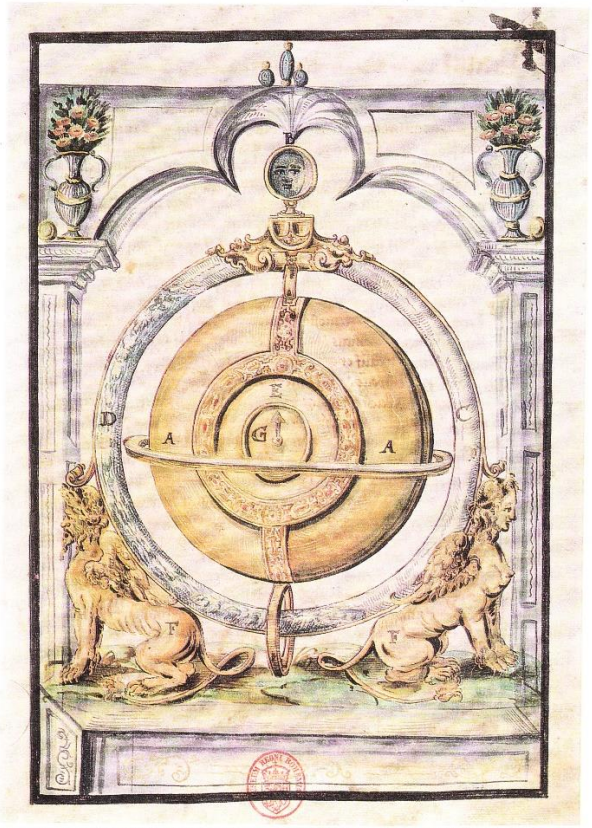
Magnetical devices included attempts by Athanasius Kircher and others, whilst perpetual motions based on gravity alone included the Archimedes Screw, wheels with metal balls such the Marquis of Somerset's and wheels with overbalanced moveable arms. Drebbel's Perpetuum Mobile was classified as a 'chymical' device, as Wilkins relied on Thomas Tymme's account, whereby the active principle was due to Drebbel '[…] extracted a fierie spirit, out of the mineral matter, ioyning the same with his proper Aire, which encluded in the Axeltree, being hollow, carrieth the wheeles, making a continuall rotation or reuolution, except issue or vent be giuen to the Axeltree, whereby that imprisoned spirit may get forth'. Wilkins quotes Tymme at length, but wryly acknowledges '[…] but methinks it sounds rather like a chymical dream, than a philosophical truth. It seems this imprisoned spirit is now set at liberty, or else is grown weary, for the instrument (as I have heard) hath stood still for many years.'

Given what we know from documentary sources, what more can be conjectured about what Drebbel's Perpetuum Mobile was and how it worked? By all accounts, Drebbel's instrument combined two features, first, a self-winding astronomical almanac showing the date and the phases of the moon, and second, a cylindrical ring in which water moved endlessly to and fro.

The gearing required to drive an almanac was well understood by Drebbel's time, and did not require the precise regulation that a clock would. At the turn of the 16th century, table clocks and automata the likes of which enthralled Rudolf II were mostly powered by springs, the minute hand was a recent novelty, and the pendulum clock would wait to be invented by

Christian Huyghens (1629-1695, the son of Drebbel's great admirer, Dutch poet and diplomat Constantijn Huyghens 1596-1687) in 1656, following Galileo's (1564-1642) discovery of the regular motion of the pendulum in the 1580s. Drebbel had clearly mastered the problems of gearing by the end of the century, and obtained a patent in 1598 for a 'watch or timepiece, which may be used for fifty, sixty, yea, one hundred years without being wound up or having anything done to it, as long as the wheels and other works are not worn out'[14]. The patent suggests that the Perpetuum Mobile's almanac hands and the turning of the moon that surmounted the instrument were driven not by a spring, however, but by the movement of the water up and down inside the body of the instrument. Precisely such a mechanism is described by Salomon De Caus in the first book of his 1615 *Les raisons des forces mouvantes* as Problème XII, where he shows a clock being driven by a counterweight raised by the expansion of water in a closed container.[15] Tellingly De Caus, who would have known and possibly worked with Drebbel in 1610 when they were both in the employ of Henry Prince of Wales[16] (and possibly earlier) remarks pointedly that this is not a perpetual motion[17], as only God could claim to be eternal. Nevertheless, the principle he demonstrates is clearly the same as that which drives Drebbel's Perpetuum Mobile[18], and indeed his use of the Aristotelian elements of fire, water and air has echoes of Drebbel's own language[19]. This same mechanism could be used to reset clockwork at noon, as Drebbel describes in a letter written to King James in 1613[20].

A self-winding astronomical almanac was surely a novelty, but it was the water moving in the glass ring that elicited the admiration of its onlookers. John Speed wrote 'my self stayed so longe that I sawe it ascend up the trunk a good height and left the lower compasse of the ring empty'. Hiesserle von Chodau's *Raiss Buch und Leben*[21] shows the fluid in the tube roiling violently, and the observers at James's court agreed that 'All these movements proceed of their own accord, and without one doing anything, which is to be seen as the most wonderful thing on earth.[22]' Clearly the water moved sensibly enough to warrant the description 'perpetual motion'. Although Drebbel himself explained the motion of the water as having the same nature as 'the floud, and the ebbe[23]' of the sea, the principles behind the motion of



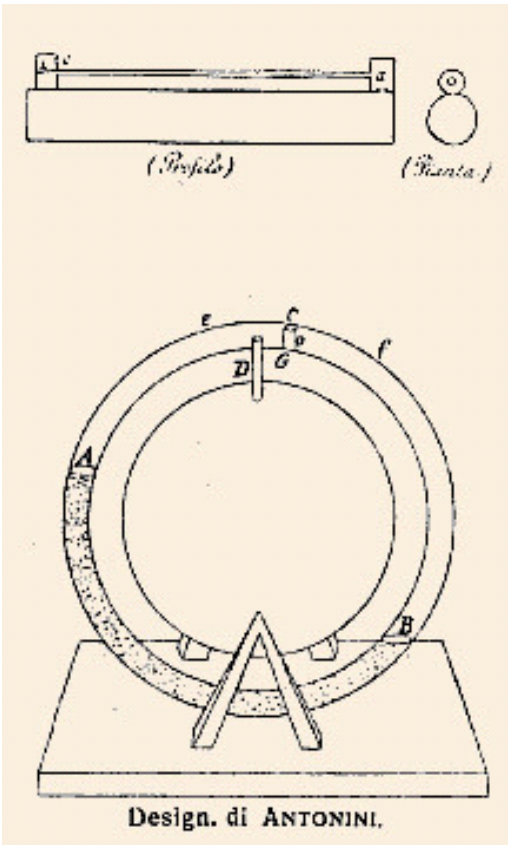


Figure 9. according to Hiesserle von Chodau *Figure 10. From a letter of Antonini to Galileo*

the water in the glass ring were beginning to be understood otherwise as early as 1612. As Daniello Antonini wrote to Galileo in February 1612 (while Drebbel was himself in prison for complicity in the Rucky plot[24]), 'the truth was that this motion came about through the alteration of the air, being caused by heat and cold.'[25]As Jennifer Drake- Brockman writes 'This was a quantum leap in thinking about Drebbel's machine; from uncritical wonder at the mere fact of observed movement, or speculation on magical or quasi-magical sympathies and correspondences, Antonini moved the debate into an area that is recognizably scientific in the modern sense […]'[26] And so it is, but there is still a small question left to answer – was Drebbel's instrument an air thermoscope, the water moving restlessly due to changes in temperature, or, as some have claimed, a baroscope, wherein the water level changed with atmospheric pressure. Or was it both?

The answer is not only interesting to historians of science, but bears directly on our interpretation of the known depictions of the Perpetuum Mobile. The possibilities are essentially threefold: the instrument could be a simple thermoscope[27], which would mean that the reservoir would have to be sealed (although the tube itself need not be; the instrument could be a differential thermoscope, with two sealed bulbs filled with liquid; or it could be a baroscope, in which the reservoir holding the liquid would be open to air pressure while the tube itself would have to be sealed at one end. So what was the Perpetuum Mobile? Clearly a liquid flowed sensibly back and forth at varying speeds in a reasonably sturdy cylindrical glass ring – visible in every known illustration of the instrument. This ring is sometimes supported from below by decorative figures, sometimes seemingly suspended from above by a strap or narrow tube joined to the rotating moon that surmounts all known drawings of the instrument. At first glance, the movement of the water would suggest a differential thermoscope, as Johann Sibertus Kuffler explained to Balthazar Monconys, as the temperature in two separate bulbs would rarely be exactly the same[28].

The physical evidence, which includes a full-sized drawing of the main flask of a Perpetuum Mobile in Peiresc's papers[29], suggests a simpler solution, at least for the earlier instruments. While in Brussels in 1612, Daniello Antononi wrote Galileo in two letters that he had heard of Drebbel's demonstration of the Perpetuum Mobile to James I and had reproduced the effect, first in a straight tube of some two feet [Florentine *braccia*] in length, then in a ring, both of which he illustrated[30]. In the version using a cylindrical ring, like Drebbel's, it is clear that the metal sphere Antonini used is connected to the ring by a narrow tube (*un canaletto*), and Antonini remarks that although Drebbel's device has a portion of the ring covered by a metal foil, this must conceal a small aperture whereby the air can enter. In the earlier of the two letters, that he had shown Archduke Albert the first device, and demonstrated how it could be used to power clockwork[31]. So although its behaviour could suggest a differential thermoscope, all the evidence seems to point to the Perpetuum Mobile being a simple thermoscope[32], which due to its design was also subject to the influence of barometric pressure[33], much as illustrated by De Caus in Problème XII of *Les raisons des forces mouvantes*.

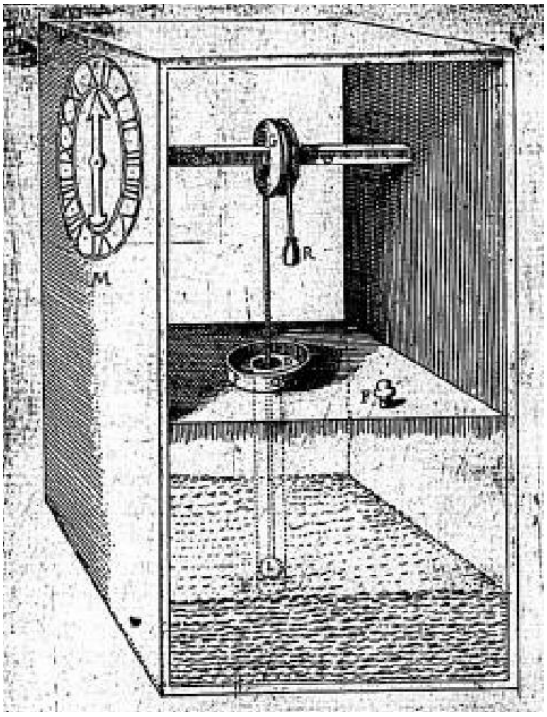


Figure 11. De Caus Les raisons des Forces Mouvantes

All the accounts we have of the Perpetuum Mobile attest to the fragility of its glasswork, which would suggest that a narrow glass tube joined the glass ring to a larger flask concealed by the gilded globe, consistent with its being a simple thermoscope[34]. Drebbel himself remarks on the glasswork in the *Wondervondt de eeuwige bewegingh* (1607) 'with a good understanding of the Nature of Water, willing itself of its own nature, to climb onwards through different flasks and pipes (bent in marvellous ways) […][35]'. The Perpetuum Mobile at Eltham was broken by Anne of Denmark (1574-1619 sometime in late 1610[36], if we are to believe what Drebbel writes to James I: 'then the Queen touched it [the Perpetuum Mobile] with her curious hand, with the result that all actions ceased.[37]' – a curious, but clearly clumsy royal hand. In 1623, Peiresc asked his friend Rubens to have a Perpetuum Mobile made for him in Antwerp, presumably after the meeting with the Kuffler brothers Aegidius (1596-1658) and Abraham (1598-1657) in Paris in September 1624 (a third brother, Jacob, had died in 1622 in Rome promoting Drebbel's double convex microscopes), which Rubens sent via his agent Valavez. He clearly voices his concerns about the fragility of the instrument '[…] please remove the cover and lift off the cloth enough to see the glass tube; if it is intact you

may be well assured about the rest. The danger is only for the tube; the flask is very solid and strong.'[38] Happily the instrument arrived intact in early 1625[39] In a letter to John Winthrop Jr.[40] from his agent Francis Kirby in 1636 we read '[I] haue not yet provided the things you wrote for, but I pray blame not Mr. Kepler [presumably Johann Sibertus Kuffler] nor my selfe; the cause being in the primum mobile [which was damaged in shipping]'[41]. Having failed once, Kirby would write the next year ''[I] haue delivered the inclosed to Mr. Keflar [Kuffler], and have received the glasses and the water from him and haue packed them carefully in a runled with 5 or 6 pecks of salt […][42]' Clearly Drebbel's Perpetuum Mobile did not take well to being banged about.

How did Drebbel come to invent the Perpetuum Mobile? Drebbel had clearly explained the discovery, at least to family. Some thirty years later, the Kufflers described to Peiresc how 'at the age of eight he [Drebbel] first discovered perpetual motion, which he has since brought to perfection, and this was while he was playing, having made a little fountain out of a knuckle-bone and a straw, and that that was the foundation of his whole invention, which consists of nothing more than finding the means to raise water or any other substance that one might wish to use for these movements an inch or two, because having once made it rise it raises itself to greater effect by its fall. When it falls back again still greater force is created, and gives further movement to the instrument which he wishes to drive, for which no great force is necessary, as it is nothing more than a timekeeper.'[43] In fact, this description seems to correspond more closely to the fountain for which Drebbel obtained a patent in 1598[44] (along with the self-winding clock mechanism) which would 'raise water to a height of 30, 40, 50 feet or even higher' than the Perpetuum Mobile, although the patent indicates the extent to which Drebbel saw the two as related[45]. It is difficult to say how much of the originally disingenuous, and possibly fabricated account can be attributed to the Kufflers' second-hand information and how much to the secretive nature of the informant, their new Father-in-law[46].

Even if the Perpetuum Mobile was only a simple air thermoscope, Drebbel invested it with great mystery and great value, and saw it as a confirmation of the principles he elaborated in his *Ein Kurßer Tractat von der Natur Der Elementen*[47] first published in 1608[48]. Maybe there was more going on in the Perpetuum Mobile than meets the modern eye. Or perhaps we should take Drebbel at his word – or at least to try to understand what he thought he was

doing – when he speaks of the instrument's secret as 'the fiery spirit of the air'. As Jennifer Drake-Brockman astutely observes, Drebbel

stands on the threshold between two ways of looking at the natural world. As she writes 'On the one hand, were those philosophers, including Drebbel himself, who explained the machine in mystical or alchemical terms, and whose mind-set might be described as the Rosicrucian tendency[49]; their thinking was ultimately grounded in the Aristotelian universe, the building blocks of which were the four elements. On the other hand, were the exponents of the scientific tendency, whose efforts were directed towards an understanding of observed physical phenomena and to whom the Aristotelian worldview was increasingly an irrelevance; […]'[50]

Certainly Drebbel's own writings suggest that he understood the world (as did most of his contemporaries) in terms of the four Aristotelian elements, of which all 'seek their centre, except fire.' In the early 17th century, shortly before Europe descended into the chaotic and violent series of regional conflicts usually grouped under the rubric the 'Thirty Years War', it was not uncommon in certain circles to hold a number of loosely-associated beliefs; eirenic, millenarian, Hermetic, Neo-Platonic and often, but not exclusively, non-conformist. Drebbel in many ways is a child of his generation. Cornelis Jacobszoon Drebbel was born in 1572[51], in the West Friesian city of Alkmaar, a city that had recently come under the jurisdiction of the Protestant Prince of Orange. Born to a certainly Reformed, probably Anabaptist household, Drebbel was presumably exposed very early to a wide variety of heterodox influences. It appears that Drebbel attended the Latijnse school[52] in Alkmaar from 1578 (although he was later to profess to have no Latin – a disingenuous claim at best), along with the three sons of the engineer, Adriaan Anthoniszoon (1543-1620)[53]: Jacob[54] (?-1628), Dirk, and Adriaan[55] Metius (1571-1635). Another classmate was Gerrit Pieter Schagen[56] (1573-1616), poet and polymath, only one year his junior. After leaving the Latin school in Alkmaar he would have met the circle of thinkers around his teacher Goltzius, to whom he was apprenticed in 1590: Karel van Mander, Coornhert, Plantin, Ortelius, Van Barrenvelt (to name a few) – all of whom would have had an impact on his development. Later in his life, after his return from Prague he was often associated with the Rosicrucians[57], and his imagery sometimes recalls the language of the Rosicrucian treatises[58]. He is said to have been an Anabaptist[59] like his

parents, but his own religious beliefs are not clearly defined, even though his writings are deeply coloured by personal devotion. From the language used in his writings it could be argued that he was a Familist, in the sense the term was used in the early 17th century to describe anyone who was suspected of having vaguely antinomian, eirenic, and heterodox beliefs, and if he were, Drebbel's Familism would resonate well with his perfectionist alchemical beliefs[60]. In practice he was clearly a Nicodemist – equally at home in the Protestant court of James I, the militant Calvinist court of Henry Prince of Wales, or the putatively Catholic court of Rudolf II. Upon his return to London no later than 1619, given what we know of his personal beliefs, it is hard to imagine him being untouched by the strong antinomian undercurrents swirling about Puritan circles in London in the 1620s[61].

Looking at the large number of inventions that mark Drebbel's career, of which the Perpetuum Mobile is perhaps not even the most significant, it seems fair to pose the question where did he learn the skills needed to make his discoveries? What skills would Drebbel have needed to master, what 'situated knowledge' would he have to have had, and how would he have understood his own practice in a late Renaissance context? Surprisingly, most of Drebbel's inventions seem to rely on a quite limited range of practices and corresponding theories, and only certain of them bear directly on the Perpetuum Mobile[62]. It is not possible to go into these skills in detail in this article, but a brief overview will be outlined in below.

The first set of skills would be those of alchemy, the steps in the 'Great Work' of producing the Philosopher's Stone conventionally described as calcination, sublimation, solution, putrefaction, distillation, coagulation and tincture[63] (which shared much in common with what Drebbel would later call the 'Quintessence'). It is important to note that whilst suspect on theological grounds, alchemy had not yet earned the near-universal contempt which it garnered in the heyday of 19th century positivist science. As Lawrence Principe writes '[The pejorative view of] alchemy – which is not by and large supported by historical texts – was forged by historians laboring at a time when alchemy had been co-opted and thoroughly misrepresented by the occultist revival of the nineteenth and early twentieth centuries.'[64] Alchemy required not only a familiarity with stills and distillation, but in particular furnaces,

as many alchemical processes were believed to require keeping alembics at a low heat for long periods – often as long as a month.

Alchemy's ultimate purpose was to make sense of Nature – learning to read God's Book, in which He had written the secrets of His Creation. The search for practical results often intruded: the alkahest or universal solvent, the universal medicine or Elixir of Life, which would cure all diseases, and of course the Philosopher's Stone, capable of transmuting base metals into gold. The origins of alchemy can be argued to go back at least four millennia to ancient Mesopotamia, India, China and Egypt, and alchemical thinking shaped most early attempts to make sense of the complexity of natural world. Aristotle (384-322 BCE) drew on an alchemical as well as a philosophical tradition when he proposed that all worldly substances were composed of four elements: air, earth, fire and water. A fifth element, the aether or 'quintessence' (the fifth essence) was the substance of which the heavens were made. This elemental view was modified by Arab alchemists in the eighth century AD, in particular by Jabir ibn Hayyan, known in Europe as Geber, who proposed that all metals were formed of two elements, mercury and sulphur, mixed in various proportions. In the early 16th century, the Swiss army physician, Philippus Theophrastus Aureolus Bombastus von Hohenheim (1493-1541) known as Paracelsus, mounted a challenge to the Aristotelian and Galenic doctrines that were the philosophical and medical orthodoxy of the late Renaissance – he was often referred to as the 'medical Luther' although he himself rejected the identification. The only way to learn about nature, said Paracelsus, was to go out and observe it at first hand. Only the Bible was infallible, everything else was open to question. Paracelsus challenged Aristotle's theory of the four elements because fire was mentioned nowhere in Genesis. Borrowing from Geber's theory of metals, he postulated that there were three fundamental substances: sulphur, mercury and salt – although he defined these in a much more catholic sense than the modern usage.

It is often claimed that Drebbel learned his alchemical skills from Goltzius, who was reputed to be an alchemist, and is said to have lost an eye to an unsuccessful experiment in his later years. This seems unlikely, as the accounts we have of Goltzius's interest in alchemy all date from after 1605, after Drebbel had left for England[65]. Moreover, chemical skills are not a part of the practice of the late Renaissance engraver's studio[66], where most of the work was done

directly on the metal plate with a burin – a skill we know Drebbel mastered early[67]. More likely, perhaps, is that Drebbel first learned of distillation, fermentation, furnaces and pipes from Goltzius's brother – his brother-in-law after marrying Goltzius's younger sister Sophia Jansdochter – in 1595[68].– for whom he stood surety for a sum of 350 Florins on May 26th, 1603[69]. Drebbel's skill with ovens certainly dates from before his departure for England. In 1602 he received the second of his two patents from the States General, for 'a chimney with a strong draught'[70]. Later, in the 1620s, he became known for his incubators, which were able to hatch chicks without hens by using a self-regulating oven to heat the coops. A sketch in a manuscript dated 1666 shows an automatic furnace or athanor used as an incubator; this utilised a thermostat filled with alcohol joined to a U-tube containing mercury[71]. With the increase of heat, the alcohol expanded, forcing the mercury upward to raise a rod and by means of levers to close a damper. When the heat fell too low, the action was reversed by the contraction of the alcohol. This is the first recorded use of a mechanical feedback system, in which a mercury switch opened and closed a draught to maintain a constant temperature[72]. Nor was this merely an exercise in domestic husbandry: not only were well-regulated furnaces essential to many alchemical processes, one of the non-trivial puzzles that confronted natural philosophers at the turn of the 17th century was the phenomenon of apparent self-generation[73].

Early in his alchemical career Drebbel must have also begun to experiment with saltpetre, the so-called 'nitre' of Paracelsan alchemy, which he refers to explicitly in his 1608 book *Von der Natur der Elementen*[74]. This would suggest that he could have been familiar with at least some of the Paracelsan writers of the time such as Joseph Duchesne (1544-1609) whose works were also translated by Thomas Tymme[75], and possibly – although by no means certainly – Michael Sendivogius (1556-1636), whose most influential book was published in Prague in 1604 as *De lapide philosophorum* but was soon retitled *Novum lumen chymicum*, and whose writings had circulated in manuscript for some time before. Van Mander, whom Drebbel knew from Goltzius's studio (he had engraved designs after van Mander in the 1590s) had travelled widely before settling in Haarlem in 1583, first in Italy, then Austria, where he worked on the triumphal arch celebrating Rudolf II's accession in 1577, then to

Prague where Rudolf II surrounded himself with a court filled with artists, astrologers, alchemists, antiquarians and craftsmen.

Alongside his explanation of the workings of nature, much of which was based on traditional alchemical ideas, Sendivogius proposed something quite new[76]: 'Man was created of the Earth, and lives by vertue of the Aire; for there is in the Aire a secret fond of life.... whose invisible congealed spirit is better than the whole earth.' Sendivogius suggested that air is a mixture, not a single fundamental substance as proposed by Aristotle. By the mid-sixteenth century, the alchemists were convinced there was a 'universal spirit' – a vapour or soul – pervading all matter. It was in this spirit that the life-substance of all entities (including minerals) was believed to be located. Before Sendivogius nobody had identified this universal spirit with a real substance. Sendivogius saw the 'aerial food' pervading all life, by way of an innocent-looking, colourless, crystalline solid: saltpetre (nitre or potassium nitrate), a substance mainly derived in the 16th century from manure and fouled stalls. By observing the main source of saltpetre –farmyard soils – Sendivogius became convinced that the 'food of life' was condensed out of the air and grew into living saltpetre crystals. Saltpetre's life-giving power was visible in fertilizers and explosively demonstrated in gunpowder, of which it was the key ingredient. Saltpetre also seemed to have other miraculous properties: it was used in medicines and freezing mixtures and in the manufacture of nitric acid, *aqua regia*, which could dissolve gold. 'Aerial nitre' – what modern chemists would later call oxygen – seemed to be the key to nature; in its gaseous form, it made all animal life possible; condensed into solid form, as saltpetre (or nitre), it gave life to plants and minerals. It was, in Sendivogius's words: 'Our water that wets not our hands, without which no mortal can live, and without which nothing grows or is generated in the world'. To the great satisfaction of the Hermetic philosophers, Sendivogius's aerial nitre also seemed to be the solution to the fourth riddle of the Emerald Tablet – 'the wind carries it in its belly, its nurse is the earth'[77].

It is often claimed that Drebbel realised of the importance of nitre from Sendivogius, although this is by no means certain[78]. Drebbel is known to have read and revered Basilius Valentinus, not unusually for alchemists of this period, particularly those

who followed Paracelsus. This due to the fact that, as Lawrence Principe writes, 'regardless of the fact that van Helmont (like most of the seventeenth century) mistakenly believed that Basilius Valentinus predated Paracelsus by a century and was plagiarized by him …'[79] Whatever his sources, Drebbel was already using the language of the aerial nitre – 'a fiery spirit of the air' – to explain the working of the Perpetuum Mobile in 1607, an instrument he certainly had constructed as early as 1604, making it unlikely that he had actually read Sendivogius's *Novem Lumen*, unless in manuscript. Nevertheless all of Drebbel's published work recalls Sendivogian language, and a central theme in Drebbel's second book, *Von der Nautur der Elementen* (1608) is the mixed nature of the elements – fire is mixed with air, air with water, water with earth. Whilst he does not refer to 'aerial nitre' explicitly, he clearly attributes a similar cause to lightning and thunder, which parallels in the heavens the effects of gunpowder on earth. Drebbel's familiarity with the properties of saltpetre/nitre would also accounts for his well-attested skill with fireworks – he may have helped stage the highly polemical anti-Habsburg *Barriers* on Twelfth Night, 1610 to celebrate the formal debut of Henry Prince of Wales[80], and with explosives – the last decade of his life was marked by his work on water petards to relive the siege of La Rochelle in 1627-28[81]. His ability to sensibly cool Westminster Abbey in 1620, to such a degree that James I and his courtiers were forced to withdraw, also probably relied on the use of nitre to supercool stored snow in metal trays[82].

In his *Von der Natur der Elementen* (1608)[83], Drebbel gives a clue to how he might have manufactured oxygen. In a passage on the origin of thunder, he writes: 'Thus is the body of the saltpetre broken up and decomposed by the power of the fire and so changed in the nature of the air'. This suggests he was aware that heating saltpetre causes it to give off a gas – and realised that this gas was the same substance that allows humans to breathe. This is the same principle he alludes to in his explanation of the Perpetuum Mobile, and notably, it is this passage that suggests that Drebbel used such a 'chymical liquor' – oxygen – to effect his submarine journey under the Thames before James I in 1621[84]. Given his persistent and skilled used of saltpetre and in particular the 'fiery spirit of the air' that could be extracted from it, it seems reasonable to assume that Drebbel's Perpetuum Mobile was filled, not with ordinary

air, but with oxygen-rich rarified air carefully collected by heating saltpetre? The fact that this would have not materially changed the way in which the Perpetuum Mobile functioned as an air thermoscope should not dissuade us from thinking that Drebbel fervently believed that his discovery was of great moment – and a great secret.

The second set of skills would have been those of hydraulics and pneumatics, which would equally fit into Drebbel's Aristotelian worldview understood as the interplay of the four elements. These skills would be closely allied with the mechanics of mills, pumps, piping and siphons. The late 16th century abounded with literature on mechanical devices such as pumps, mills and fountains, such as Ramelli's (1531- 1600) *Le Diverse et Artificiose Macchine*[85] Jacobo Strada's (1515-1588) *Kunstliche Abriss allerhand Wasser- Wind- Ross- und Handt Mühlen, etc.*[86] and Giovanni Battista Della Porta's *Magiae Naturalis libri viginti*[87]. Fuelled in part by the rediscovery of Hero of Alexandria's *Pneumatica*[88], first printed in Latin by Federico Commandino (1506-1575) in 1575[89], and followed by an illustrated Italian translation by Giovanni Battista Aleotti in 1589[90], courts thirsty for innovation vied with one another in creating spectacles, pageants and gardens filled with hydraulic and mechanical wonders, exemplified by the much-visited Medici villa at Pratolino[91] north of Florence, designed by Buontalenti (1536-1608) and featuring the myriad mechanical wonders[92] as well as the Fleming Giambologna's (1520-1608) remarkable statue of the Appenines lowering over a green pool.

As Alexander Marr writes, many contemporary historians mistakenly assume 'that the newly available printed source material of the Corpus Heronicum was widely distributed and thoroughly studied'[93]. In Drebbel's case, it is not clear where and when he would have come in contact with the sources that so clearly seem to underpin his practice, although there may have been manuscripts in circulation[94]. There is no evidence of Drebbel ever having visited Italy, but once again his association with Goltzius may provide the missing link. In 1590, shortly after Coornhert's death, the 32 year-old Goltzius travelled to Italy, leaving his stepson Jacob Matham in charge (Matham himself was to visit Italy some years later, leaving the workshop to Goltzius from 1593-97). Goltzius returned to Haarlem in 1591, marked by his first hand experience of both Classical and Renaissance culture, which included fastidious

studies of Roman ruins, statuary and paintings, as well as presumably the visits to the famous gardens of Pratolino and the Villa d'Este which were *de rigeur* for cultural tourists of the late 1500s. He was also marked by his encounters with a new network of artist and humanists, including Giambologna (sculptor of the great statue of the Appenines at Pratolino), Johannes Stradanus, Jacopo Palma il Giovane and Dirck de Vries, of all of whom he made portraits. Just as Coornhert had shared his contacts with Goltzius, it could be reasonably assumed that Goltzius share his contacts with his talented young assistant, and soon-to-be Brother-in-law, Cornelis Drebbel.

That Drebbel was known for his skill with fountains and waterworks before he arrived in England is not in doubt. In 1603 Drebbel was responsible for a fountain at the Noorderpoort in the important southern town of Middleburg[95], and he refers to his having 'made amusing little fountains, which in different ways, for some time spray their own water to a height of 20 or more feet'[96] in the letter to James I in his 1607 *Wondervondt de eeuwighe bewegingh*. It is interesting to speculate – and pure speculation it must remain in the absence of fresh documentation – about the possibility that Drebbel may have met Salomon De Caus prior to their being employed together at the court of Henry Prince of Wales in 1610 in London. De Caus had been Italy 1595-1598, and visited by his own account Pratolino. From 1601 (and probably earlier) until 1608 he was employed by the Archdukes Albrecht and Isabella in Brussels[97], not more than 70 miles from Middleburg, where Drebbel was working on his 'amusing' fountain. De Caus was appointed Chief Engineer in 1605, under the supervision of Wencel Cobergher, responsible for water-raising devices and other waterworks, as well as grottos and fountains. He is said to have left the employ of the Archdukes in a fit of spleen after the Duke of Condé left his ornate grotto 'rompu et gasté' in 1607[98], when Drebbel was already installed at Eltham Palace and a familiar of James I and Anne of Denmark.

If his preface to *La perspective avec la raison des ombres et mirroirs*[99] is to be believed, De Caus must have had good contacts at the English court, as he is already tutoring the young Prince Henry in drawing in 1608, to whom De Caus' first book is later dedicated. In 1609, he is employed by Anne of Denmark to create a Pratolinolike fountain and Mount Parnassus at Somerset House, whose decoration prefigures the *Tethys Festival*, on which Drebbel is said to

have worked[100]. We know that Anne too was no neutral observer, and had a keen interest in novelties – especially those that might bear on her much-enjoyed court entertainments – and certainly knew Drebbel. Not only was she said to have broken his Perpetuum Mobile at Eltham, by another account 'the Earl [Lord Percy, 9th Earl of Northumberland, imprisoned in the Tower along with Ralegh 1605-1621] got seaverall Learned persons to live and Converse with him' among them were 'Mr. Heriot [Thomas Harriot 1560-1621], who presented Queene Anne with a viol of water which ebbed and flowed at the same time as the Thames.[101]'. By whatever agency, by 1611 De Caus was appointed Architect to the court of Henry Prince of Wales[102], where Drebbel was also active, although he was forced to cede his place to the Florentine Constantine de Servi soon afterwards. Whether they had met before late 1610 (when Drebbel left for Prague) or not, the untimely death of Prince Henry in November 1612 shook the foundations of radical Protestant Europe, and the lives of both Drebbel and De Caus. Drebbel had to beg James I to have him released from Matthias's service in Prague (Rudolf II also died in 1612), and De Caus found service in Heidelberg at the court of Frederic V, the Elector Palatine and his young bride, Henry's sister Elizabeth.

A final set of skills would include those of lenses and lens-grinding, and a working understanding of optics, although important to understanding Drebbel's life's work, need not concern us here, as they do not bear directly on the fabrication of the Perpetuum Mobile (although they attest to Drebbel's glass-making abilities).

So when the 32 year-old Cornelis Drebbel, his wife and three children arrived in Ipswich in the summer of 1604, he was not a country bumpkin or an alchemical adventurer, but a skilled artisan, a trained experimental alchemist and a mature natural philosopher with an extensive network of contacts through Goltzius, Van Mander, Ortelius and Plantin that would help him open doors to the court of James I[103].

What do we know of what Drebbel's instrument looked like? First, rather simply what was its real shape? What significance does its ornamentation have, if any? Several illustrations of Drebbel's Perpetuum Mobile exist – ink drawings, watercolours and oil paintings – nevertheless there is no consensus on what the instrument really looked like. When a reproduction was needed for a recent exhibition in Dignes[104] (and then again for the new permanent installation of a Kunstkammer at the Walter's Art Gallery in Baltimore[105])

instrument maker Andrew Crisford constructed a nonfunctional Perpetuum Mobile according to information supplied by Anthony Turner and found in Jennifer Drake-Brockman's article. The result was a gilded globe, encircled by a fat cylinder partially filled with water, supported by a pair of harpies. But does this reproduction actually correspond to the known images and the existing accounts? There are relatively few known first hand depictions of Drebbel's Perpetuum Mobile, so it may be useful to look at both the written descriptions and the visual record of each in turn.

John Speed's letter of June 1604[106] is the earliest known depiction extant of Drebbel's Perpetuum Mobile. It is explicitly annotated, and drawn apparently to scale. It shows all the features which characterise later versions of the instrument: the gilded 'ball or globe', the glass ring in which a liquid is shown at two different heights, a circular dial in the centre of the globe, a 'small and thyne register of gold' spanning the globe horizontally, a gold fitting clasping the glass ring at the top and a ring through which the ring passes at the bottom, and a moon-phase globe on top. How the device is supported is not clear from Speed's drawing, although it features 'a boxe, pilllers and tope of Ibony very curyously wrought'. Unlike later depictions, it lacks the ornate harpies that support the glass ring, which seems to hug the circumference of the gilded globe. As Jennifer Drake-Brockman suggests, the sketch may merely be schematic, or a much simpler version that Drebbel brought to England with him prior to constructing the version he was to show to James I in 1607.

The elaborate colour illustration in Hiesserle von Chodau's *Raiss und Leben* (1607) is certainly more ornate than the simple version sketched by John Speed. Two mythological figures, one male, one female, now support a freestanding glass ring in which the water roils impressively. The figures sit on an elaborate base, flanked by pilasters which support a carved frame. The dial is clearly indicated, and a letter key explains the functions of the parts to the reader. It is not clear whether the moon-phase globe is connected to the glass ring by a small tube or a strap, but there is a clear physical link. Speed's 'fine and thyne gold register' is now a thicker circlet that encircles the gilded globe.

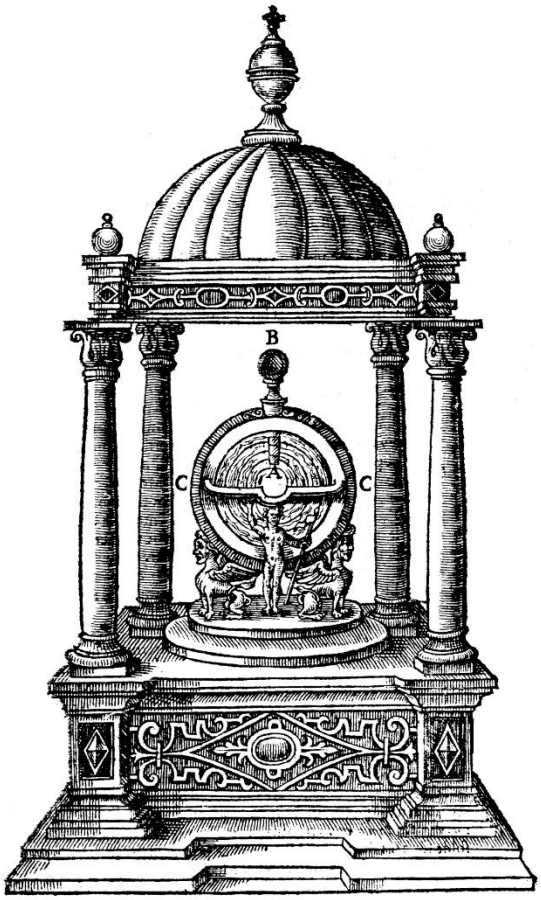


Figure 12. PPM volgens Thomas Tymme

Thomas Tymme's *Dialogue Philosophicall*[107] (1612) includes a detailed, albeit inaccurate, drawing of Drebbel's Perpetuum Mobile. It too stands on an elaborate box, under a cupola supported by four carved pillars. The instrument itself sits on a round based, the glass ring supported by two harpies of indeterminate sex. A naked Atlas seems to hold the 'register,' which bulged out conspicuously around the ballshaped dial in the centre. Curiously, the 'register' does not seem to encircle the globe as it does in other known illustrations, but shading suggests that it connects to a flat metal plate on either side, an impression reinforced by the shading behind the Atlas. Like Speed's sketch, the glass ring is shown clasped at the top directly underneath the moon-phase globe. Unlike von Chodau's illustration, the levels of the water are not shown, although oddly there are water-like wavy lines in concentric circles on the face of what should be the gilded globe. The overwhelming impression is whilst the description in Tymme's *Dialogue Philosophicall* may be largely accurate, the illustration is an 'artist's impression' of a description given by a third party who had seen the Perpetuum

Mobile, but that the artist himself had not. Nor, if he had been in Prague from late 1610, was Drebbel himself in a convenient position to correct any inaccuracies.

In the extensive account of his meeting with the brothers Abraham and Aegidius (Gilles) Kuffler in 1624[108], Nicholas Claude Fabri de Peiresc includes several small sketch illustrations. With one exception, none of them purport to show the Perpetuum Mobile. Peiresc clearly wants them to describe the instrument, and they try heroically: 'As he wanted to make a model of the perpetual motion to show to the King, he wanted to make a glass bottle of the size of the model it would be later, and about this shape (a small sketch is shown under this sentence, and a full size outline sketched on the last page of the account). It was two feet long in total, and four fingers wide; the neck was about four fingers long'[109].

More importantly, as we will see later, the Kufflers tried to describe a device that echoes the description Drebbel gives in his letter to James I of 1610: 'the painted model that he made to show the King was nothing but a clock mounted on a large base that also supported a small figure on each side: on the one side a satyr who held a horn from which spouted a small fountain, that spilled into a large shell that was at his feet, and the other was a young child, who sees from his feet a fountain spurting upwards and falling back into a similar shell before flowing back into the base. These two fountains. The two fountains should be of quicksilver, and the streams no larger than an iron needle. I haven't any idea whether this is to take advantage of the wind or the air to make the first rise, and by this means to give impetus to the movement. Kuffler also told me that the aforementioned Drebbel had made one of these perpetual motions for the Prince of Wales.'[110] It is interesting that the Kufflers refer to 'the painted model' Drebbel made for the King – was the 1610 letter perhaps accompanied by a coloured sketch? In any case, the sketch underneath this description is merely a literal illustration of the account – a rather staid looking clock, flanked by a satyr spouting liquid from a horn and a child beside a shell fountain. It would be difficult to maintain that this is a visual record of any instrument Drebbel himself built at any stage in his career.

It is clear from Peiresc's account that the Kufflers didn't really have much detailed knowledge of Drebbel's inventions – after all, they had only known him two or three years, and Drebbel was renowned for his reticence. It is highly unlikely that they had ever seen one of his Perpetual Motions, let alone understood how they worked. At several points Peiresc

records the Kufflers saying tentatively ‘there are two wheels that give it the motion, one with 32 teeth and the other I don’t remember’ and ‘there was also another little thing that I don’t remember, and a little wheel that turned the clockwork’[111]. When it comes to the Kufflers, their reports must be taken with a large grain of salt: first, they were clearly an opportunistic family (their subsequent behaviour amply demonstrates their commercial interests in exploiting Drebbel’s ingenuity), second, none of them – with perhaps the exception of the youngest, Johann Sibertus, who was a Padova-trained doctor who only arrived in London in 1627 – were experienced alchemists, mechanics, or natural philosophers, and third, they could only rely on Drebbel’s own accounts for their information about events that had often taken place decades beforehand.

The evidence of Elias Ashmole’s (1617-1692) drawing[112] – presumably made several years after Drebbel’s death – points to it being a copy of the illustration in Tymme’s *Dialogue Philosophicall*. Not only is the drawing found next to a ‘demonstracon Theologicall Philosophicall and Mathematicall’ attributed to Thos. Tymme, it is clearly has all the features of Tymme’s 1612 published drawing, as well as showing (which Tymme’s illustration does not) the differing water levels in the glass ring. There are several anomalies, however, such as the connection of the ring and the moon-phase globe omitted in Tymme, a forward facing lion instead of a harpie, and ornaments supporting the moon-phase globe that are more reminiscent of von Chodau’s illustration than Tymme’s, but these may merely indicate fanciful copying, rather than pointing to an unknown original or illustration[113].

There are also a number of unambiguous depictions of Drebbel’s Perpetuum Mobile by the Antwerp artists Frans Francken II (1581 - 1639), Willem Van Haeght (1593- 1637), Henri Staben (1578-1658), Corneille de Baellieur (1607-1671) and Adriaan van Stalbemt (1580-1662) painted in the 1620s and 30s[114]. There seem to be two distinct versions of the Perpetuum Mobile in evidence: one with harpies supporting the glass ring and a cross surmounting the small moon-phase globe, and one without the harpies and with no apparent on the small globe. Although the Cabinet painting genre was extremely popular at the time, the Perpetuum Mobile is not featured indiscriminately as a studio prop[115] as some have suggested. The Perpetuum Mobile oddly only occurs in paintings that have to do with either Albrecht and/or Isabella or Rubens – such as Rubens’s studio interior by de Baellieur, the

visit of Albrecht & Isabella to Rubens's Cabinet by Frans Franken II or their 1615 visit to Cornelis van Geest[116] by van Haeght. It seems that Albrecht and Isabella's version had both harpies and a cross, whereas Rubens's has neither, and that some of the paintings were painted using earlier paintings as reference rather than from an actual model.

Figure 13. Jan Brueghel de Oude en Hieronymus Francken, (of Frans Francken d.J./Adriaen Stalbemt?) The Archdukes Albert and Isabella visiting a collector's cabinet 1621-23

Nevertheless, it seems more than coincidence that Drebbel's Perpetuum Mobile features in paintings related to Albrecht and Isabella or Rubens. Albrecht is known to have had an interest in the Perpetuum Mobile as early as 1612, for he was presented with Antonini's experimental model of the Perpetuum shown to James I, news of which had certainly reached the court, either by visitors to Brussels or from Albrecht's brother Rudolf II, who had summoned Drebbel to Prague to build him one. It is known that Albrecht petitioned soon after Rudolf's death in early January 1612 to receive his share of the famed Kunstkammer, but there is no evidence that the Perpetuum Mobile was ever part of his inheritance.[117] It is also said that Drebbel made the Archduke a Perpetuum Mobile in 1615, for which he received

a microscope in return[118], while possible, seems unlikely, given that Drebbel himself is credited with the invention of the double convex microscope as early as 1609[119]. It is interesting to note that the Perpetuum Mobile features in a painting attributed to van Haeght of Archduchess Isabella alone in her studio in 1627, in mourning after the death of Albrecht. Clearly the Perpetuum was associated with the Archducal couple. Rubens of course must have been associated with the Perpetuum Mobile, as it was to Rubens that Peiresc turned when he wanted a copy in 1624 – even though he had met the Kufflers and probably Drebbel himself[120].

If we are to believe the evidence of all these illustrations, what can we say about the form of Drebbel's Perpetuum Mobile? First of all, it seems difficult to escape the conclusion that – at least in most cases – the instrument was not spherical. With almost no exception, and then only when the depiction appears to have been copied from another source, the images show a donut-shaped lozenge, surrounded by a wooden rim which bulges when it goes around the central dial. It is true that its shape is commonly reported as a 'globe' or a 'runde Kugel', but even now it is difficult to find a word that precisely and unambiguously describes the shape we see in depictions of the Perpetuum Mobile. Then, as now, the word 'globe' would have had to do. The fact that the Perpetuum Mobile's odd shape was not merely an artefact of inexperienced painters (which might have been the case in earlier illustrations by von Chodau and Tymme) is obvious from the Antwerp paintings, in which armillary spheres are rendered correctly in perspective, while the Perpetuum Mobile is shown with its odd – and presumably correctly depicted – torus-like shape. The Perpetuum Mobile is what it is shown to be, a donut-shaped gilded lozenge with a dial on its face, supported by decorative figures (usually harpies) and surmounted by a moon-phase ball. This observation has no real importance when it comes to understanding how the Perpetuum Mobile worked, but may perhaps inform future reproductions if and when they are required.

In 2004, Alexander Marr, made a startling discovery in the library of Queen's College, Oxford, whilst he was a Fellow of the College. He had been looking for something entirely different – an early edition of Vitruvius's 'Elements of Architecture' when his eye was caught by a thin, worn volume beside the Vitruvius, bound in old vellum, untitled. Instinctively taking it off the shelf he opened it to find pages of drawings, pasted down engravings and

annotations from early 17th century England – and a heretofore unknown watercolour illustration of Drebbel's Perpetuum Mobile.

Figure 14. copy from Queen's College library, Alexander Marr 2004

Here was the first new visual evidence of Drebbel's work since Jaeger's biography was published in 1922. Since the discovery was made, both the discoverer, Alexander Marr, and the author have worked on identifying the individual images in the folio and the artist responsible for them. The results of this research will be presented in detail in a future article on the court of Henry Prince of Wales by Alexander Marr. For the purposes of this paper it is sufficient to briefly describe the content and context of the MS in order to establish the significance of the illustration of Drebbel's Perpetuum Mobile.

The vellum-bound large folio contains 48 pages, on which some pages have pasted down engraving, others pasted down drawings, and still others are drawn upon directly in pencil, charcoal, ink and watercolour. The illustration of Drebbel's device is by far the most elaborate. The illustrations in the book seem to be by several hands, or possibly the same hand at different times, reflecting the acquisition of new drawing skills over time (still another group of pasted down illustrations clearly belongs to a much later date). The illustrations seem to suggest a fascination and a familiarity with the court of Henry Prince of Wales, and include copied portraits of Sir Walter Ralegh (1552-1618), one of the young Prince's heroes, Sir Henry Lee (1533-1611), who had out of retirement shortly before his death in 1611 to advise Henry Prince of Wales at his newly formed court at Richmond and presented the young Prince with a set of armour[121], and Henry Prince of Wales himself. Some of the illustrations are carefully copied, some, in a state of partial completion, directly from pasted down engravings. Others were clearly copied from known originals the artist had clearly seen, while still others are freehand sketches of naturalia and sailing ships.

When were these drawings made? Are they contemporary with Henry's court, or the work of a later antiquarian? Some of the drawings can be dated quite precisely. The portrait of Henry Prince of Wales is by William Hole, published by Michael Drayton (1563-1631) in 1613, and the rampant lion is surely the one recommended for copying by young artists in Henry Peacham's *The Art of Drawing with the Pen*, first published in 1606 and reprinted in 1612[122]. There are also two small oval portraits, drawn and coloured, partially completed, with the inscription 'Sanderson fecit 1609' (a second oval portrait, probably of Philip II, is signed 'G.S.').

The watercolour sketch of the Perpetuum Mobile is remarkable, and has most of the features we have already seen in other illustrations (although notably it is not in an elaborate frame). The glass ring is supported, unusually, by satyrs, one clearly blowing a horn, the other seeming to carry a heavy load. The water is clearly shown at different levels in the ring, and the ring is separated from the globe and connected by a gold filet to the moon-phase globe as in the von Chodau illustration of 1607. The dial in the centre of the gilded globe is clearly drawn, with the months of the year shown. A list on the left notes the function of the instrument in English in a careful hand. The 'register', this time in wood or a dark metal,

clearly suggests (as do most of the other illustrations of the instrument) that the ‘globe’ is in fact donut-shaped.

So whose book was this? The evidence of the signatures, and the an inscription under a carefully drawn coat of arms ‘LH: I know not what charges this Gules c[]he Ra[]h /BELOW: Daughter of Snedale [?] of Exeter shee was there w [?] Sr Walter Ralegh married [?] w Saunderson’ suggests that the owner of the book, and its artist was in all probability William Sanderson (1586-1676), a merchant’s son who had been associated with the courts of James I, Henry Prince of Wales and Charles I. Sanderson was said to have been ‘brought up at court’, whilst his father was active in promoting the idea of a Royal Exchange. The great-nephew of Sir Walter Ralegh[123], he later

served as secretary to Henry Rich, earl of Holland[124], when the latter was appointed chancellor of Cambridge University in 1628. Sanderson’s reputation was primarily as an historian and apologist for the reigns of James I and Charles I. He is known for his *Aulicus coquinariae* (1650), his *Compleat History of the Lives and Reigns of Mary Queen of Scotland, and of her Son James* (1656) based at least in part on his personal knowledge of court and *Compleat History of the Life and Raigne of King Charles from his Cradle to his Grave* (1658), A confirmed Royalist, he was knighted by Charles II[125].

Oddly perhaps for an historian, Sanderson's final work, published in June 1658, was *Graphice: the Use of the Pen and Pensil* on the history of various forms of painting. In it he recommends that the student of drawing ‘Get a booke in folio of a double quire of fine paper (as also some sheets of Blew papers and other colours) to avoid leaves soon lost, that by overlooking your first draughts thereon, you may with incouragement delight in your proficiency. […] Begin your exercise by a copy or print.’ It seems incontrovertible that the folio in which the annotated watercolour illustration of Drebbel’s Perpetuum Mobile was Sanderson’s own[126], likely drawn by him from life, sometime in the years 1608-1615.

If Sanderson were to have been a young man at the court of Henry Prince of Wales, perhaps his fascination with the art of drawing is not so odd as it might at first appear. As Roy Strong notes in his 1986 history of the short-lived court of Henry Prince of Wales ‘the sudden emergence and appreciation of drawings can be linked to the Prince’s circle. In 1612 Henry Peacham, a hanger-on of the St. James’s court and a populariser of its ideals, published his

Graphice, and updated version of his *The Art of Drawing with the Pen* (1606), which is the earliest publication to make any plea at all that gentlemen should learn to draw.'[127] It should therefore come as no surprise that one of the hand-drawn sketches in Sanderson's folio is a rampant lion, drawn exactly as Peacham instructs in his 1612 Graphice.

So which Perpetuum Mobile is it? With great reluctance we have to turn to the unreliable brothers Kuffler for evidence. In September 1624 they related to Peiresc a rather confused account of everything they knew of their father-in-laws life and work, which Peiresc dutifully noted down, attempting occasionally to illustrate the Kufflers' words with small hesitant sketches. As noted above, the Kufflers maintained that 'Drebbel had made one of these perpetual motions for the Prince of Wales.'[128] This is alluded to in the account of Heisserle von Chodau as well '[the instrument] could be put to any purpose and he [Drebbel] would make it into a wonderful instrument for the young prince[129]'. The Prince we know was interested in such things. 'In the last two subjects [Mathematics and Cosmography], Henry was instructed by Edward Wright, who was his tutor. Apparently "with the help of some German workmen" he "caused to be made for that hopeful Prince, a large sphere with curious movements, which by the help of Spring-work, not only represented the Motion of the whole Celestial Sphere, but shewed likewise the Particular Systems of the Sun and Moon, and their Circular Motions, together with their places, and possibilities of eclipsing each other"'[130]. Moreover, note the description of the Perpetuum Mobile by the Kufflers: 'on the one side a satyr who held a horn from which spouted a small fountain'[131]. In all the extent illustrations, satyrs are notable by their absence. Speed shows unadorned columns, von Chodau harpies[132], Tymme harpies, the Antwerp paintings harpies, and Ashmole a harpy and what appears to be a small grinning lion – everything but satyrs. The evidence of the Sanderson MS is that Drebbel did indeed make a Perpetuum Mobile for the Prince of Wales, who surely would have been interested, and that the glass ring of this instrument was supported by 'a satyr blowing a horn'.

So how many Perpetual Motions did Drebbel actually make, and for whom? By Peiresc's account, the Kufflers said that Drebbel had made 17 or 18 instruments that showed the motion of the tides by September 1624, not including the one made for Rudolf II[133]. I list below the instruments for which we have some evidence, albeit not always conclusive:

- Cornelis Drebbel Ipswich 1604
- James I Eltham Palace 1607
- Henry Prince of Wales [?] c. 1610
- Rudolph II [?] Prague 1611
- John Dee London c.1608
- Albert & Isabella Brussels c. 1615
- Rubens Antwerp c. 1615
- [Peiresc Carpentras 1625]
- [John Winthrop Jr. Boston 1636]

Clearly there are some instruments to be accounted for if the Kuffler brothers are even more or less correct in their estimate.

Moreover, it is not at all clear whether Drebbel ever actually completed a Perpetuum Mobile for Rudolf II, despite his boasts. Drebbel only arrived in Prague in October 1610 with his family. In May 1611 Rudolf was deposed by his brother Matthias (1557-1619), after months of mounting tension. Drebbel, supposedly living in the Prague residence of Matthias's protector Khlesl, Bishop of Wiener Neustadt (1552-1630), can hardly have been ideally disposed to building delicate instruments, especially if his glass globe was to have been accompanied by 'a fountain that could rise 1000 feet (sic) if he wanted, for which there would be a very high structure, on the top of which would be placed his perpetual motion, which would also serve as a clock. In the centre of the machine he would make an artificial sun, which would burn day and night[134], thereby three great and rare inventions[135]. Given the rarity and notoriety of such an instrument, it seems fair to assume that it would appear in the many inventories of Rudolf's Kunstkammer made after his death as the heirs squabbled over their inheritance. Nonetheless, despite the abundance of carefully documented clockworks, astronomical instruments, automata and mechanical devices recorded in the inventories[136], there is no trace of Drebbel's Perpetuum Mobile. Given Drebbel's reputation for being a

‘windmaker’ or braggart, it is quite possible that his plans to build a Perpetuum Mobile for Rudolf II just did not materialise.

On the other hand, John Dee, the illustrious Renaissance magus who died in poverty at Mortlake in 1608, may well have had one of Drebbel’s devices. In their comprehensive inventory of John Dee’s library[137], Watson and Roberts relate that Dee’s heir Pontois apparently had ‘a clock with mocons’ described by Hawes as ‘a Clock, dyall and perpetuall mocon all in one fframe’ which he apparently inherited from Dee and was catalogued after his death in 1624[138]. Not only would have Drebbel’s work as an alchemist interested Dee, who returned to London from Manchester in 1605, but Dee’s assistant (and also assistant to the ‘Wizard earl’ of Northumberland) Roger Cock was apparently Drebbel’s assistant in Prague – the two petitioned for passports to return to England in 1612[139].

So where does this leave us? What have we been able to add to the already extensive and some might argue exhaustive studies of Jaeger, Tierie, Harris and Drake- Brockman? What new evidence has been uncovered that allows us to understand Drebbel, his work and his times more fully?

First, the Sanderson MS has brought a new illustration of Drebbel’s Perpetuum Mobile to light, and with it, a new insight into the exceptional nature of life at the court of Henry Prince of Wales. Despite his reputed taciturn nature, the Prince was not short of ambition. As Frances S. Bullough writes, ‘In 1607 Henry’s household had grown so large that it had become unable to support itself. In November 1607, Sir Thomas Chaloner wrote to the Chancellor of the Exchequer to tell him of the inconvenience of the size of the household for its means of support, and remarked that it was intended for a “courtly college, or a collegiate court”[140]. The idea of creating a militant Protestant, Puritan intellectual counterpoint to the debauched court of his father James I was a pet project of the young Henry Prince of Wales, and the idea lived on after his untimely death in 1612. ‘Buckingham brought forward a scheme in the House of Lords on March 5th 1621, apparently that of the Academ Roial, which Portal describes as ‘a plan of the late Prince Henry for a place of education for the young nobility’[141]. By all accounts it was a very large court for so young a prince, and ‘Henry’s household at St. James’s in 1610 included ‘few lesse than Five-hundred, many of them young Gentlemen, borne to great Fortunes; in the prime of their years’[142]. The Prince’s household included, among many others:

Sir Thomas Chaloner (1561-1615), Adam Newton (d. 1629), Sir John Harrington (1592-1614), Sir Charles Cornwallis (d. 1629), Lord Lumley (d. 1609), Edward Wright (1561-, David Murray (1567-1640), Joshua Sylvester (1536-1618), George Chapman (1560-1634), Inigo Jones (1573-1652), Solomon de Caus (1573-1626), and Cornelis Drebbel.[143]. Surely this was a fertile environment, with myriad possibilities for encounters, exchanges and the cross-fertilisation of ideas. The number of opportunities for contact might even suggest that Drebbel and De Caus worked more closely together than heretofore suspected.

Second, it suggests that we must that we build a far more comprehensive picture of the networks active in the early 17th century than has been done to date, and place Drebbel in the context of these networks. The networks in which Drebbel played a part – sometime smaller, sometime larger – include Goltzius (1558-1617) and his circle (which may include the Hiël sect of the Family of Love), publishers such as Plantin (1520-1589) and Basson (1555-1613)[144]; the Janssen brothers (Zaccharias Janssen 1558-1631) and the lens-making circle in Middleburg, the university of Franeker and the Dutch Jesuits, and the English Family of Love, still active in the Jacobean court[145].

Drebbel's dependence on court patronage makes an understanding of his networks all the more important. Drebbel was employed at the court of James I, raised as a Calvinist, the court of James's eldest son Henry, Prince of Wales, a militant protestant who, until his untimely death in 1612, was seen as the successor to the converted Huguenot Henry IV's anti-Habsburg policies, and by Rudolph II, a pantheistic lapsed Catholic Emperor, then again by the courts of James I and his son Charles I. As a courtier, Drebbel would have to work in different confessional settings, some of the markedly less tolerant than others. Was Drebbel a Nicodemist, merely feigning a particular confession in order to pursue his studies of nature unencumbered? Nor do the networks to which he belonged include only the courts of James I and Henry Prince of Wales, but also Anne of Denmark and the circles around influential Lucy Harrington (1581-1627) and the Killigrews.

The continental courts of Rudolph II and Albrecht & Isabella were connected through diplomats and artists such as Constantin Huyghens (1596-1687), Balthazar Gerbier (1592-1663) and Peter Paul Rubens (1577-1640) to Drebbel and his patrons Duke of Buckingham (1592-1628) and Charles I, whilst Frederic V and Elisabeth remained an important part of English court life, keeping in contact from their court in Den Haag after their disastrous

sojourn in Prague resulted in the destruction and annexation of Heidelberg and the Palatinate. The Ruldophine diaspora had a major influence on England in the 1620s and afterwards, with Michael Maier (1568-1622), Mayerne (1573-1655), Jan Amos Comenius (1592-1670), and Samuel Hartlib (1600-1662)[146] being only a few of the players that shape the intellectual climate prior to Cromwell. European alchemical circles included Drebbel's known friends Joachim Morsius[147], Peter Lauremberg (1575-1639), Moriaen (1593-1644)[148] and Johannes Hunyades (1576-1646), and the English alchemical circles around John Dee (1527-1608), the Earl of Northumberland (1564-1632) and Robert Fludd (1574-1637) were also clearly important.

The continental Republic of Letters, including Drebbel's Dutch contemporaries such as Beeckmann and Huyghens as well as De Thou, Peiresc[149], Cesi, Galileo, Kepler and Burggraf and their English counterparts such as Camden (1551-1623), Peacham (1546-1634) and especially Francis Bacon (1561-1626) situated Drebbel in an exceptionally active universe of discourse. Finally, but no less importantly for Drebbel, English antinomian circles – the so-called 'the Puritan underground' – which included John Everard (1575-1650), Edward Howe, John Dury (1596-1680), the Kufflers and the members of the several 'Strangers' Churches in London. Drebbel's confession is not a trivial issue when it comes to understanding, for instance, the influence of Puritanism on Drebbel during his last years in London from 1619 until his death in 1633, where the circles he is known to have moved in had a distinctly antinomian, perfectionist – even heretical tinge. All must be understood better in order to fully understand the intellectual ferment of Drebbel's world – a world standing at the threshold of palpably felt but yet undefined changes.

Finally, in a broader sense, it may also help us understand better the intellectual climate at the turn of the 17th century. Whilst it is true, as Jennifer Drake-Brockman argues, that Drebbel's Perpetuum Mobile can be seen as the fruitless dead-end of 'the Rosicrician tendency', with Drebbel as a frustrated inventor of the old magical school toiling fruitlessly in the fields where the new experimental science would soon flourish. On the other hand, Drebbel's Perpetuum Mobile may also be seen as one facet of a fertile mind actively trying to make sense out of the natural world, whilst struggling to incorporate new Paracelsan chymical categories into the older structures and strictures of alchemical thinking. Seen against the

background of the political, religious, economic, and social tensions that erupted into the Thirty Years War in Europe, the rise of Puritanism in England and ultimately the English Civil War, the Perpetuum Mobile can be seen as a symbol of the old world of courtly patronage in which Drebbel had made his reputation giving way to the brave new world of the Kufflers, a world opportunism, religious intolerance and political intransigence was stampeding headlong into the unknown.

[1] Lhotsky, A.Die Geschichte der Sammlungen, in Festschrift des Kunsthistorischen Museums, Ferdinand Berger, Vienna: 1941-45 Second part, first half p. 275

[2] The journal of Hans Jacob Wurmsser von Vendeheym, quoted from W.B. Rye, England as seen by foreigners, London: 1865, p. 61

[3] Peacham, H. in Sights and Exhibitions in England, prefixed to Coryates Crudities, London: 1611

[4] Akrigg G.P.V. England in 1609 Huntingdon Library Quarterly 14, 1950 no.1 pp. 92/3 in Bullough, F. S. Science and Supernaturalism in the Jacobean Age, unpublished Ph.D thesis presented to Aberdeen University, 1967

[5] Rubens Letters (n. 31), no. 58, pp. 97-98

[6] The Winthrop Papers, Massachusetts Historical Society, Volume 3, 1631-1637. ed. Bailey Forbes, A. 1943 Francis Kirby to John Winthrop Jr. London, 7th May, 1636 p. 259

[7] Naber H.A. De Ster van 1572 Wereldbibliothek ed. L. Simons No.54 Amsterdam: 1907

[8] Jaeger, F.M. Cornelis Drebbel en zijne Tijdgenooten, Groningen: 1922

[9] Tierie, Dr. G. Cornelis Drebbel (1572-1633) H.J. Paris, Amsterdam: 1932

[10] Harris, L.E. The Two Netherlanders, Brill, Leiden: 1961

[11] Colie, R. Some thankfulnesse to Constantine, Nijhof, Den Haag: 1956 pp.92-127

[12] Colie, R. Cornelis Drebbel and Salomon De Caus: Two Jacobean Models for Salomon's House, Huntingdon Library Quarterly 18 (1954-55), 245-69

[13] Drake-Brockman, J. The Perpetuum Mobile of Cornelis Drebbel, published in Learning, Language and Invention: Essays presented to Francis Maddison ed. W.D. Hackmann and A.J. Turner; Variorum, Aldershot: 1994

[14] cited in Jaeger op. cit. Appendix XI p. 119

[15] The principle had been alluded to in Della Porta's Natural Magick (Book XIX). It could also be found in Hero's Pneumatics, and seen illustrated in Aleotti's 1589 Italian translation

[16] See Strong, R. Henry, Prince of Wales and England's Lost Renaissance, Thames & Hudson, London: 1986

[17] Salomon's *Les raisons* was later revisited by his younger brother Isaac, who published an edited version entitled *Nouvelle invention de lever l'eau plus hault que sa source avec quelques machines mouvantes par le moyen de l'eau et un discours de la conduite d'icele* (London, 1644) in which he was less reticent about making claims for a perpetual motion in Problem IX. An English edition was subsequently printed in 1659 by Joseph Moxon, friend of Robert Hooke and printer for the Royal Society. The English edition is entitled: *New and rare*

inventions of water-works shewing the easiest waies to raise water higher then the spring : by which invention the perpetual motion is proposed : many hard labours performed : and varieties of notions and sounds produced : a work both usefull profitable and delightfull for all sorts of people.

[18] C.S, Maks, De Caus's biographer, calls it a 'thermomètre inachevé' Mak C.S. *Salomon De Caus*, Jouve, Paris: 1935 p.63

[19] For instance compare Drebbel's explanation in his *Wondervondt van des eeuwighe bewegingh* (1607) 'at last I accomplished that which till then had involved me in error: that which is the cause of the primum mobile, by which the sky, stars, the planets, water and earth are moved, and by which means the earth is borne up in the midst of the air, the water encompasses the mass of the earth in a circle, and all things seek their centre, except fire.' with 'I will leave aside the words perpetual or without end, and show here the fabrication of a machine that works from its own power, provided that it is maintained by the four elements of which it is composed. I demonstrated in my Fifth Theorem how water could be raised higher than its level by the aid of fire. I also demonstrated in the first definition how all heat could be called elementary fire, thus this natural disposition of heat and the lack of heat to raise water.'

[20] 'In the first place I have a means whereby all forms of clockwork are given a perpetual motion, so that this is self-regulating and automatic, or to explain more clearly – if the hour hand is about two or three hours late in the morning or the evening – when the sun shines it will go back to the true hour of the day and even to the minute, of which invention Emperor Rudolf has seen an example' cited in Jaeger, copied from the Journal of J.S. Beeckman, Fol. 294v-295v March 15th, 1631

[21] Hiesserle von Chodau, H. *Raiss Buch und Leben* Prague National Museum MS vi A 12 ff. 48v-50r

[22] ibid.

[23] Tymme, Th. *A Dialogue Philosophicall Wherein Natures secret closet is opened and the cause of all motion in Nature shewed out of matter and forme, tending to mount mans minde from Nature to Supernaturall and Celestiall promotion: and how all things exist in the number of three Together with the wittie inuention of an Artificiall perpetuall motion, presented to the Kings most excellent Maiestie.* T.S for Clement Knight, London: 1612 p.60

[24] See Svatek, J. Bilder as Böhmen, |Braumüler, Vienna: 1879 p.251 and also Gindeley, A. Rudolf II

[25] Letters dated February 4th and 12th 1612/13 cited in Jaeger op. cit. (n8). Appendix X, pp. 115-118

[26] Drake-Brockman op. cit. p.137

[27] not a thermometer, as the ring is not calibrated, unless the dial itself was meant to indicate the temperature – a feature not referred to in any contemporary account

[28] Samuel Reyner, basing his account on Monconys report of a conversation with the irrepressible propagandist Johann Sibertus Küffler, Drebbel's son-in-law, referred to 'the instrument for examining the ebb and flow of the sea, which Drebbel invented. It consists of two bulbs, connected by a little semi-circular siphon, into which some liquid is introduced, and sometimes approaches one bulb, sometimes the other' from Samuelis Reyneri Dissertatio de aere, Kiel: 1670 fol. D1r cited in Knowles Middleton W.E. Johns Hopkins, Baltimore: 1966 p. 25

[29] Peiresc N.C.F MS 1776 fol. 413v Bibliothèque Inguibertine, Carpentras

[30] Cited by Jaeger op. cit Appendix IX p. 115-118 from the Opere di G. Galilei, Ediz. Nat. (1901) XI p. 269 and 275, Letters dated February 4th, 1612 and February 11th, 1612

[31] How this would be done is not clear from Antonini's second model, as the metal sphere he used was empty, whereas Drebbel's globe presumably concealed a winding mechanism based on the rise and fall of water in a tube similar to De Caus' illustration of Problème XII, however it seems clear that Antonini understood the principle, as he states he demonstrated it to Albert VI

[32] A striking illustration of a calibrated weatherglass with a circular glass ring (which the Perpetuum Mobile in fact was) can be found in John Bate's The Mysteries of Nature and Art, 2nd Edition, London: 1635 p. 36, followed by a range of different air thermometers, including a sealed differential thermometer on pg. 40

[33] see Knowles Middleton op. cit. 'When the variability of the pressure of the air became known in 1644, a capital defect of the air thermometer at once showed itself; namely, that it responds to changes of pressure as well as of temperature.'

[34] The Kufflers also related to Peiresc, although probably erroneously, that 'Quand l'Empereur Rodolfe fut mort et l'archiduc Mathias esleu en sa place, il y eust force filosophes et mathematiciens qui voulurent voir l'invention de ce globe de Derbbel, et persuadèrent l'Empereur de leur permettre de le rompre, l'asseurant qu'ils en fairoient après facilement. Ayant eu ceste permission et s'estant assemblez à cest effect, pas un d'eux n'osa entreprendre de rompre ceste piece qu'ils jugeoient miraculeuse. Neantmoins ayant bien envie d'en voir l'invention, ils firent casser le verre par un fol de l'Empereur; mais en le cassant il rompit force petitz tuyaux de verre qui estoient dedans se globe, de sorte qu'ils n'y apprirent rien, et ne le peurent plus rabiller. L'Empereur envoya prier le Roy d'Angleterre de le luy renvoyer pour rabiller se globe, et envoya un carrosse pour le prendre, mais **Drebbel** n'y voulut jamais aller' Peiresc Carpentras MS op. cit. fol. 410

[35] From the 1688 Dutch edition, Amsterdam p.96

[36] Drebbel himself showed the Eltham motion to Lewis Frederick of Würtemburg in May 1610 see W.B. Rye, England as seen by foreigners, London: 1865

[37] From a letter preserved among the Balfour MSS printed in Abbotsford Club *Miscellany*, vol. 1, 1837 pp.111-113, cited in Drake-Brockman op. cit. p. 131

[38] Letter from ns to Valavez, Antwerp, December 26th, 1624 in The Letters of Peter Paul Rubens, transl. and ed. Saunders Magurn, R. Harvard, Cambridge: 1955 Letter nr. 59 Rubens also mentions that he has sent a special fluid for the instrument 'There is also a little glass half-filled with green water, and with the same water I have filled the tube as much as is necessary for its operation.'

[39] ibid. Letter nr. 60 January 10, 1625

[40] John Winthrop Jr. played an important role in the Massachusetts Bay Colony, and presided over the antinomian controversy. He was also persuaded by the virtues of alchemy, supported plans to make Massachusetts an 'alchemical colony' and kept up a correspondence with young alchemists such as George Starkey. He was instrumental in establishing mines, smelters and alchemical laboratories in the new colony (see Woodward, W. W. Prospero's America : John Winthrop, Jr., alchemy, and the creation of New England culture 1606-1676 unpublished PhD thesis University of Connecticut). He is also known to have had an extensive alchemical library, and owned a copy of Valentinus Basilius: 'this was once the booke of that famous philosopher and naturalist Cornel: Drebbell, wh. he Usually carried wt. him in his pockett and after his death was given me by his sonne in law Mr. Abram Keffler' cited in R S Wilkinson, 'The Alchemical Library of John Winthrop', Ambix, XIII (1965), pp. 139-86

[41] The Winthrop Papers, Massachusetts Historical Society, Volume 3, 1631-1637. ed. Bailey Forbes, A. 1943. 7th May, 1636 p. 259

[42] ibid. 10th April, 1637 p. 385 [43] Peiresc N.C.F MS 1776 fol. 407-413v Bibliothèque Inguibertine, Carpentras

[44] The patent also recalls the wording of Isaac De Caus' *Nouvelle invention de lever l'eau plus hault que sa source avec quelques machines mouvantes par le moyen de l'eau et un discours de la conduite d'icele* (London, 1644), which was taken almost directly from his brother Salomon's *Les raisons des forces mouvantes* (1615)

[45] cited in Jaeger op. cit. Appendix XI p. 119

[46] The ulterior motives of the Kufflers should always be born in mind when evaluating the reliability of their accounts of Drebbel's work

[47] Drebbel, Cornelis, Ein Kurßer Tractat von der Natur Der Elementen und wie Sie den Windt, Regen, Bliß und Donner verurſachen und wwer zu Nußen durch Cornelium Drebbel in Niederlandiſch geshrieben uund allen der Naturliebhaberen zu Nuß ins Hochteutſch getreulich uber geſeßt Gedruckt zu ſenden in Hollandt Beij Henrichen von Haeften im Jahr Chriſt 1608

[48] Several of Drebbel's biographers refer to a 1604 Dutch edition, but after looking at the records of the Leipzig and Frankfurt Book Fairs for the first decade of the 17th century, it appears as though the assertion of a 1604 edition is due to the erroneous deduction from the title page 'ins Hochteutſch getreulich uber geſeßt' that there was an earlier Dutch edition. No trace of this edition has been found, and the title likelyy refers to an earlier Dutch manuscript. This is of considerable importance, however, as it means that Drebbel's Natur Der Elementen

appeared after the 1607 *Wondervondt* in which he announced the Perpetuum Mobile, and after he had arrived in England in 1604.

[49] The Augsburg physician, Karl Widemann suggests in his Sylva Scientarium that Drebbel is behind the pseudonym Julianis de Campis under whose name a defence of the Rosicrucians was written in 1615 see Janssen, F. Dutch Translations of the Corpus Hermeticum in Theatrum Orbis Librorum and Cimelia Rhodostaurotica, Bibliotheca Philosphica Hermetica, Amsterdam: 1995 p. 97, 113 and

[50] Drake-Brockman op. cit. p. 138

[51] Noted in Rademaker's Alckmaar Kronyck, 1645

[52] It was often reported that Drebbel had little Latin, that he learned Latin late in his career, or that he had no Latin at all (Hartlib/Epheremides 1039/4 30/04/1635A). While the latter contention could be contested on the grounds of Latin letters to James I in Drebbel's hand, it seems that in all cases he enjoyed at least a basic grounding in Renaissance Europe's lingua franca

[53] Adriaan Anthonisz. was to become Mayor of Alkmaar in 1582

[54] Jacob Metius is credited with the co-discovery of the telescope; one of the first to bring together a concave and a convex lens in a tube. He applied for a patent in 1608, but could not establish priority over H. Lippershey, who applied a few months before. He made several different inventions, but was extremely secretive about them, and burned all of his instruments before he died in 1628.

[55] Adriaan Metius worked under Tycho at Hveen briefly in 1594, thereafter traveled to Rostock and Jena, where he gave lectures in 1595. He returned home and assisted his father in military engineering.1598, appointed professor extraordinarius at Franeker (1600-1635), professor ordinarius of mathematics, navigation, surveying, military engineering, and astronomy. He was allowed to teach in the vernacular. De Waard (Dictionary of National Biography 1922) says that he was a practicing alchemist and spent time pursuing the philosophers' stone.

[56] Drebbel's first published work 'Wondervondt van de Eeuwighe Bewegingh' (1607 Alkmaar) was issued by Gerrit Pieters Schagen, a bookbinder from Alkmaar, who taught himself some ten languages, occupied himself amongst others with astronomy and alchemy, and allegedly sympathised with the Rosicrucians. The larger part of the work consists of a Dutch translation of the *Corpus Hermeticum*, made on the basis of the Italian translation by Tommaso Benci (1548, reprinted 1549).

[57] Maier, M. Silentium post clamores, Frankfurt: 1624 ch. Viii, p.168 cited in Drake-Brockman op. cit. p. 142 n. 41

[58] Drake-Brockmam op. cit. p.143

[59] Tierie, op. cit. p. 18

[60] 'For Familists and Behemists, so influential on Ranters and Quakers, alchemy was an outward sign of internal regeneration. John Webster, Erbery's heir, had been a pupil of the Transylvanian chemist Hans Hunneades [the same Hunyades, who signed Morsius's Liber Amicorum along with Drebbel in 1619], who worked at Gresham College. Webster also pressed the study of alchemy and natural magic on the universities, and was attacked as a proponent of the 'Familisticall-Levelling-Magicall temper'. (T. Hall Vindiciae Literarum, 1655, p. 199) One alchemist, of whom Newton thought very highly [Eiraneus Philaletha Cosmopolita] hoped that 'within a few years' thanks to alchemy 'money will be like dross', and so 'that prop of the antichistian Beast will be dashed to pieces … These will accompany our so long expected and so suddenly approaching redemption', when 'the new Jerusalem shall abound with gold in the streets.' From Hill, C. The World Turned Upside Down, first published 1972, Penguin books reprint, 1991 p.290

[61] For a discussion of Jacobean antinomianism see Como, D. Blown by the Spirit, Stanford: 2004

[62] Even the discovery of tin mordants for fixing cochineal dye, which may have been a chance discovery, stems from Drebbel's obsession with nitre, as it was putatively discovered while using aqua regia – nitric acid. Ironically it is perhaps his most important, as officers' uniforms of the British Army were coloured with the 'Bow Dye' (named after Drebbel's dyeworks at Stratford-Bow) until 1952 – without Drebbel there would have been no 'Redcoats' see Findlay, V. Color p. 156

[63] the many examples of alchemical literature circulated in the early 17th century include Khunrath, H. Amphitheatrum sapientiae aeternae, Hanua: 17609 (although the Imperial privilege was granted in 1598, suggesting that a manuscript was complete at that time), Michelspacher, S. Cabala, Spiegel der Kunst und Natur: in Alchymia Augsburg: 1616, see also Maier, M. Atalanta Fugiens, Theodor de Bry, Oppenheim: 1618 or Lambsprick. Lucas Jennis, Frankfurt: 1625 (the unillustrated German original appeared in 1599)

[64] From The Aspiring Adept: Robert Boyle and his alchemical quest, Lawrence M. Principe, Princeton, 2nd edition (paperback) p.19, see also Principe and Newman, Some Problems with the Historiography of Alchemy, in Secrets of Nature: Astrology and Alchemy in Early Modern Europe, ed. Grafton and Newman, MIT Press, Cambridge: 2001 pp. 385-431

[65] See the exhibition catalogue for Hendrick Goltzius, Waanders, Amsterdam: 2003 p.20 n.59

[66] see Landau, D. and Parshall, P. The Renaissance Print Yale, New Haven: 1994 and Dackermann, S. Painted Prints, Baltimore Art Museum, Baltimore: 2003

[67] Several engravings by Drebbel are known, as well as an aerial view of Alkmaar in 1597

[68] Drebbel's first child died soon after he was born in 1596, but the remaining three, Anna (1597), Catherina (1599) and Jacob (1601), all survived to adulthood

[69] Tierie op. cit. p. 4

[70] Jaeger op. cit. Appendix XI p. 120

[71] University of Cambridge MS No. 2206 L.1.8

[72] Tierie op. cit. p. 44

[73] For an extensive treatment of the issue, see Newman, W. Promethean Ambitions, Chicago: 2004

[74] op. cit.

[75] The practise of chymicall, and hermeticall physicke, for the preseruation of health. Written in Latin by Iosephus Quersitanus, Doctor of Phisicke. And translated into English, by Thomas Timme, minister London: printed by Thomas Creede, 1605

[76] This account of Sendivogius's theories is largely based on Szydlo Z. and Brzezinski, R. A New Light on Alchemy, History Today, Vol. 47, 1 January 1997 pp. 17-23

[77] Drebbel was also presumably exposed early to Hermetic texts, and the 2nd known Dutch translation of the Pimander (and the first to be printed) is appended to his *Wonder-vondt van de eeuwighe bewegingh* (1607). Remarkably, Drebbel's text only takes up 10 of 71 pages of the entire work, the rest being given over to a dedicatory poem by Pieter Schagen and the translation (presumably by Schagen himself) of the Pimander

[78] Note for example that Drebbel's works are often bound with Basilius Valentinus (see the Wellcome Institute), or with Sendivogius, see Drebbel's Von der Natur der Elementen in Herzog August Bibliothek in Wölfenbüttel A:145.1 (2) is bound with Sendivogius Novum Lumen Chymicum (Boetzerum Coloniae 1614) which is identical with the British Library copy except for a handwritten note: Prima editionis, videlicet Pragensis, huius libri titulus sive inscriptio sic habet; DE LAPIDE PHILOSOPHORUM Tractatus Duodecim & Natura fonte & manuali Ex periatia deprompti. Autor sum qui DIVI LESCHI GENUS AMO / ANNO MDCIV

[79] From The Aspiring Adept: Robert Boyle and his alchemical quest, op.cit. p.41

[80] See Drake-Brockman op. cit. p. 130 n8

[81] See Tierie op. cit. Chapter VII pp. 72-75

[82] The use of nitre to cool snow was not unheard of by 1620. Della Porta wrote of it in 1591 (op. cit.), Francis Bacon describes the effect in his Novum Organum, and and Thmas Chaloner devoted a whole book to the subject see Schactmann, T. Absolute Zero and the Conquest of Cold, Houghton Mifflin, London: 1999

[83] op. cit. Chapter 7

[84] see Tierie op. cit Chapter 6 and Jaeger op. cit

[85] Paris:1588

[86] Published by his grandson Ottavio at Paul Iacques, Francfort sur le Main: 1617 [87] Revised and updated version published by Wechel; Frankfurt: 1591

[88] Boas, Marie Hero's Pneumatica: A Study of Its Transmission and Influence *Isis*, Vol. 40, No. 1 (Feb., 1949) pp. 38-48

[89] Heronis Alexandrini Spiritalium Liber, ex Græco in Latin ed F. Commandino, Urbino: 1575

[90] Gli artifitiosi et curiosi moti spiritali di Herrone transl. G.B. Aleotti Ferrara: 1589

[91] for instance see Fynes Moryson , An Itenerary written by Fynes Moryson, Gent. First in the Latine Tongue, and then translated by him into English. (Containing his ten yeeres travell through the twelve dominions of Germany, Bohmerland, Sweitzerland, Netherland, Denmarke, Poland, Italy, Turky, France, England, Scotland, and Ireland.). J. Beale: London: 1617

[92] For contemporary descriptions of the wonders of Pratolino, see Vieri, Francesco de', called Il Verino Secondo. Discorsi di F. de' V. delle maravigliose opere di Pratolino e d'Amore Firenze: 1586, a leter description can be found in Sgrilli, Bernardo Sansone, Descrizione della regia villa, fontane e fabbriche di Pratolino Firenze: 1742. These description strongly suggest that Hero's works were known to Buontalente, either from Commadino's Latin edition (1575) or from manuscripts circulating earleir

[93] Marr, Alexander, Understanding Automata in the Late Renaissance, Journal de la Renaissance, Vol. II 2004 p. 211

[94] see Marr op. cit. p.214 about Biringuccio's and other MS of the Corpus Heronicum

[95] Gemeente Archief Middleburg, VIII, F, p. 119 cited in Tierire, op. cit. p.92

[96] Wondervondt o[. cit. p. 96 Drebbel uses a phrase which recalls the wording of his 1598 patent for a device which would 'raise water to a height of 30, 40, 50 feet or even higher'

[97] See Saintenoy,Paul, Les arts et les artistes à la cour de Bruxelles, Brussels:1932,33,35

[98] see Strong, R. The Renaissance Garden in England, Thames & Hudson, London: 1979 especially Chapter IV

[99] De Caus, S. La perspective avec la raison des ombres et mirroirs, Jan Norton, London: 1612

[100] Strong op. cit. pp. 141-158 and 216-217

[101] Shirley J.W. The Scientific Experiments of Sir Walter Raleigh, the Wizard Earl, and the Three 'Magi' in the Tower. Ambix 4, 1949 nos 1&2, pp. 52-66

[102] See Strong, R. Henry Prince of Wales, Thames & Hudson, London: 1986 especially pp. 86-138

[103] Van Mander was in London for James's coronation in 1604, where he painted the 'Chess Portrait' reputed to be of Ben Jonson and Shakespeare, and could even have provided an introduction for Drebbel at court. Van Mander was the guest of Sir Edward Coke, an antiroyalist who championed the 'rule of law.' Coke repeatedly challenged King James and the his belief in the 'divine right of kings.' It seems reasonable to assume that van

Mander shared Coke's views, and moved in similar anti- Royalist circles. which were held by contemporaries such as Christopher Marlowe who pledged 'to wrong the wronger...until the state government changed from kings to counsels.'

[104] For the exhibition Pierre Gassendi: explorateur des sciences, Musée de Digne, 19 May – 18 October 1992

[105] The new installation was curated by Dr. Joaneath Spicer, and opened October 15th 2005 with a reproduction of the Perpetuum Mobile based on the painting of a gallery interior with Archduke Albert and Archduchess Isabella by Frans Francken the Younger and Jan Breughel Iat the Walters Art Gallery [106] see Drake-Brockman op. cit.

[107] op. cit.

[108] Peiresc N.C.F MS 1776 fol. 407-413v Bibliothèque Inguibertine, Carpentras 'Relation de ceque iay apris de la vie et inventions de Cornelius Derbel de la Ville d'Alcmar en Hollande par Abraham son gendre et Gilles Kuffler son frere à paris au commencement de Sept. 1624

[109] Op. cit fol. 407v 'Lorsqu'il voulut entreprendre de faire icy un modelle de ce mouvement perpetuel pour le faire voir au Roy, il voulut faire faire une bouteille de verre de la grandeur et du modelle, qui sera cy après et de ceste forme. Elle a deux pieds de long en tout, et quatre doitz de large; le colet a quatre doigtz de long' The full-size sketch appears on fol. 413

[110] ibid. fol. 408r Le modelle en peinture qu'il fit faire pour monstrer au Roy n'estoit qu'une monstre d'horloge portée sur une grande basse, qui supportoit aussy une petite figure de chasque costé; de l'un un satire qui tenoit un cor duquel sortoit une petite fontaine, qui venoit à retumber dans une grande coquille qui estoit à ses pieds, et l'aultre un jeune enfant, qui voyoit sortir à ses pieds une fontaine qui rejaillissoit en hault et venoit retomber dans une pareille coquille et rentroit dans la base 2). Ses deux fontaines debvoient estre de vif argent, et ne pousser pas pourtant plus gros que le fer d'une eguillette. Je ne sçay si ce n'est point pour prandre du vent ou de l'air pour faire ceste eslevation premiere, et par ce moyen donner force au mouvement: Kuffler me dict que ledit sieur Derbbel avoit faict un de ses mouvements sans fin pour le Prince de Galles

[111] ibid. fol. 407r

[112] Bodleian Library, Oxford MS Rawl D 864

[113] See discussion in Drake-Brockman, op. cit. p. 133 [114] Drake-Brockman maintains that the evidence of the Antwerp paintings shows the Perpetuum Mobile's need to be placed in the sunshine to be made to work. This does not follow strictly from its function as a simple thermoscope (and even less if it was a differential thermoscope), which would work as long as there were temperature and barometric changes regardless of their cause, but would only be of relevance if the Perpetuum Mobile in question used the mechanism proposed by Drebbel to James I whereby if the noon sun were to fall on it, the device would reset itself.

[115] For instance it is not shown in any Cabinet paintings by Jean 'Velvet' Brueghel, Frans Francken I, Frans Francken III, Jan van Kessel, Jean Breughel II, Jean Jordaens, III, or David Teniers the Younger.

[116] Van Haecht's painting celebrates the visit of Albrecht and Isabella to Cornelis van Geest's Cabinet on August 23rd, 1615, although it was painted much later, in 1628, so it cannot be used to convincingly date the Perpetuum Mobile's arrival in Antwerp.

[117] De Maeyer M. Albrecht en Isabella en de Schilderkunst, Brussels: 1955 pp.316-18 Item 104 Inventory of the artwork from Rudolf II's inheritance, September 6th, 1615

[118] see The mechanical construction of the microscope from a historical stand-point, with special reference to certain instruments now in the Science Museum, South Kensington Alan Pollard 1922 *Trans. Opt. Soc.* 23 334-349

[119] Drebbel enquired of his friend Ysbrandt van Rietwijk about the new telescope in 1608 (see Jaeger Appendix VI p. 110) and was presumably aware of the Middleberg lens grinders Zacharias Janssen and his Alkmaar schoolmate Jacob Metius. The development of the double convex microscope can thus be dated to sometime after 1608/9 (most probably after his sojourn in Prague 1610-13). Jacob Kuffler was selling the microscopes in Rome when he died of the Plague in 1622, already demonstrated it to Peiresc in Paris May 22nd same year. When Galileo presented Federico Cesi (1585-1630) with a microscope in 1624, Cesi immediately ordered a better one from the Kufflers see Freedberg, D. The Eye of the Lynx Chicago: 2002 p. 152

[120] In his letter to Peiresc August 9th, 1629, some four years before Drebbel's death, in addition to the oft-quoted passage about his appearance and the futility of the Perpetuum Mobile, he says he will 'visit him at home, and talk with him intimately if possible.' The familiar tone strongly suggests that Rubens had met Drebbel on previous occasions, probably in Antwerp, which appears highly likely, given the association of the Perpetuum Mobile with Rubens's studio. Rubens Letters op.cit. Nr. 196 p. 323

[121] see Strong, R. Henry Prince of Wales op. cit.

[122] Peacham, H. The Art of Drawing with the Pen, London: 1606 p. 38

[123] His mother Margaret, was daughter of Hugh Snedale of Cornwall, who had married a sister of Sir Walter Ralegh. DNB op. cit.

[124] Henry Rich, the Earl of Holland, was also the patron of John Everarde, a well-known antinomian preacher accused of Familism, and translator of the *Theologica Germanica* and the *Corpus Hermeticum*. The correspondence with John Winthrop Jr. suggests links between Drebbel and Everarde

[125] Details from Woolf, D.R. in the Dictionary of National Biography

[126] The identification is confirmed by Sanderson's signature, which appears in the folio, and in his own copy of the Aulicus Coquinariae BL 292.a.35.

[127] see Strong, R. Henry Prince of Wales op. cit. p. 120

[128] ibid. fol. 408r Le modelle en peinture qu'il fit faire pour monstrer au Roy n'estoit qu'une monstre d'horloge portée sur une grande basse, qui supportoit aussy une petite figure de chasque costé; de l'un un satire qui tenoit un cor duquel sortoit une petite fontaine, qui venoit à retumber dans une grande coquille qui estoit à ses pieds, et l'aultre un jeune enfant, qui voyoit sortir à ses pieds une fontaine qui rejaillissoit en hault et venoit retomber dans une pareille coquille et rentroit dans la base 2). Ses deux fontaines debvoient estre de vif argent, et ne pousser pas pourtant plus gros que le fer d'une eguillette. Je ne sçay si ce n'est point pour prandre du vent ou de l'air pour faire ceste eslevation premiere, et par ce moyen donner force au mouvement: Kuffler me dict que ledit sieur Derbbel avoit faict un de ses mouvements sans fin pour le Prince de Galles

[129] von Chodau Raiss und Leben op. cit. transl. in Drake-Brockman op. cit. p. 129

[130] Sherburne, Sir Edward, The Sphere of M. Manilius made an English poem London 1675 Appendix p.86

[131] ibid. fol. 408r Le modelle en peinture qu'il fit faire pour monstrer au Roy n'estoit qu'une monstre d'horloge portée sur une grande basse, qui supportoit aussy une petite figure de chasque costé; de l'un un satire qui tenoit un cor duquel sortoit une petite fontaine, qui venoit à retumber dans une grande coquille qui estoit à ses pieds, et l'aultre un jeune enfant, qui voyoit sortir à ses pieds une fontaine qui rejaillissoit en hault et venoit retomber dans une pareille coquille et rentroit dans la base 2). Ses deux fontaines debvoient estre de vif argent, et ne pousser pas pourtant plus gros que le fer d'une eguillette. Je ne sçay si ce n'est point pour prandre du vent ou de l'air pour faire ceste eslevation premiere, et par ce moyen donner force au mouvement: Kuffler me dict que ledit sieur Derbbel avoit faict un de ses mouvements sans fin pour le Prince de Galles

[132] I refer to these half-human, half lion figures as harpies, although in fact they might be better – and more appropriately – be described as Sphynxes, a clear allusion to the riddle of the perpetuum mobile

[133] Peiresc op. cit fol. 411v Kuffler me dict qu'oultre ce globe, qu'il avoit faict pour l'Empereur, il avoit inventé 17 ou 18 sortes d'instrumens, qui monstroient le flux et le reflux de la mer.

[134] Drake-Brockman suggests this recalls the everburning lamp of the Rosicrucian fama, found in the tomb of Christian Rosenkreutz, op. cit. p. PAGE

[135] Peiresc op. cit fol. 409v ‘Estant avec l'Empereur, il luy fit ce globe de verre, et entreprint de luy faire en une place une fontaine qu'il fairoit monter mil pieds (*sic!*) s'il vouloit 9), dont le structure seroit fort haulte, et mettroit au dessus son mouvement perpetuel, qui fairoit aller un horloge. Et au milieu de la machine il faisoit un soleil artificiel 1), qui auroit tousjours esclairé jour et nuit, qui estoient trois grandes et bien rares inventions.’

[136] This includes Fröschl’s 1607-11 Inventory, the 1615 Inventory, the 1621 Inventory, Leopold Wilhelm’s 1647 Inventory, and Kaiserin Anna’s 1660 Inventory. In particular, one would expect that Fröschl – who was imprisoned along with Drebbel for complicity in the Rucky plot immediately following Rudolf’s death in January 1612 – would have recorded the Perpetuum Mobile had it been made

[137] Roberts, J. and Watson, A. John Dee’s Library Catalogue, London Bibliographical Society, London: 1990

[138] ibid. p.60-62 n.53-57

[139] Jaeger op. cit. Appendix XII b.

[140] Bullough, F. S. Science and Supernaturalism in the Jacobean Age, unpublished Ph.D thesis presented to Aberdeen University, 1967 citing Birch p.80, Wilson pg. 50, Hill pg. 214

[141] ibid. citing Portal, E.M. The Academ Roial of King James I, Proceedings of the British Academy 1915/16, p. 192

[142] ibid. citing Cornwallis p. 321

[143] see Birch, T. The Life of Henry Prince of Wales, Dublin 1760 cf Henry's wages book 1610 p. 319 and the Calendar of State Papers (Dom) 1603-10, London 1857 and British Library Harleian MS 7007

[144] see Van Dorsten Thomas Basson: English Printer at Leiden, Thomas Browne Institute, Leiden: 1961

[145] see Marsh, C. The Family of Love in English Society 1550-1630, Cambridge: 1994

[146] see Dickson, D.R. The Tessera of Antilia, Brill, Leiden:1998

[147] see Schneider, S. Morsius und sein Kreis, Otto Quitzow, Lübeck: 1929

[148] see Young, J.T. Faith, Medical Alchemy and Natural Philosophy

[149] see Miller, P. Peiresc's Europe, Yale, New Haven: 2000