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Hisashige Tanaka and His Myriad Year Clock

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Hisashige Tanaka was a man who bridged two worlds: the world of traditional craftsmen during the Edo period and the world of modern Western engineers during the Meiji period. Well-known by his popular name, Karakuri Giemon, Tanaka invented amusing automata, the most famous of which was "yumiiri dōji," or the bow-shooting boy, who shoots arrows and smiles when they hit their target. Another famous invention was the cup-carrying doll, who carries a cup on a tray, serves it to a guest and returns to its original position. Tanaka made not only entertaining toys such as these primitive robots, but also various ingenious machines, precisely like Renaissance engineers in Europe, including a fire extinguisher, a self-pumping oil lamp and an intricate calendrical clock. Toward the end of the Edo period, the Nabeshima clan's feudal lord recruited him to construct various Western machines, including a steam engine; and he was seriously engaged in importing Western technologies before and after the Meiji Restoration.[1]

This chapter will focus on and explain one of this craftsman's masterpieces, the machine called the Myriad Year Clock (万年時計or 万歳

1. Of the several biographies published on Hisashige Tanaka's life, the most authoritative is Tanaka Ōmi Ou Ken'eikai, ed., *Tanaka Ōmi Taijō* (Tokyo, 1931), which the editorship of Kenji Imatsu has recently republished together with the additional bibliography on the literature concerning Hisashige Tanaka compiled by Imatsu. Imatsu also has written a concise but good biography of Tanaka: Kenji Imatsu, *Karakuri Giemon: Toshiba Sōritsusha Tanaka Hisashige to sono Jidai* (*The Ingenious Giemon: The Life and Times of Hisashige Tanaka, the founder of Toshiba*) (Tokyo: Daiyamondo, 1992).

自鳴鐘).[2] He built it in 1851, after he already had established his career by making various inventions, and just before he left for Saga to help introduce Western industrial and military technologies. I will explain below this clock's basic structure and mechanism, and present some findings on his inventing process based on an analysis performed by disassembling its parts. After that, I would like to explain two other models Tanaka constructed before and after this machine; they are astronomical models based on Buddhist cosmology. Before doing so, however, I first will describe briefly Tanaka's life and works, and the social milieu of his activities as an inventor. I also would like to provide a brief explanation of the Japanese time system during the Edo period, and of wadokei, the Japanese clocks devised to indicate time according to this Edo time system.

1. Life and Works of Hisashige Tanaka

Hisashige Tanaka was born in 1799 in Kurume, a clan whose area formed a part of the present Fukuoka Prefecture, as the eldest son of a craftsman of tortoise shell work who made daily and ornamental tools such as combs. His infant name was Giemon, thus he often was called Karakuri Giemon—Ingenious Giemon. After he established his fame, he was offered the official name from the Ōmi Shrine and, accordingly, was called Ōmi Taijō. He therefore is also called Tanaka Ōmi or Ōmi Taijō, as well as "Tanaka Hisashige"; all these names are used in the titles of his biographies. Several biographies, both authentic and somewhat fictitious, have been written; and they all cite episodes in his childhood testifying to his inventiveness from his early days. He surprised his friends by making a locking pen case. He helped a neighbor inventor to devise and construct a machine to weave a special type of cloth in the area he lived—*Kurume gasuri*. When he toyed around with these ingenious devices, he concentrated on making them even if it required him to stay up all night for several days straight. When he was 17, his father died. As the eldest son, he

2. See ibid., pp. 56–68.

was expected to assume his late father's position and duties, but he conceded this position to his younger brother and continued to work on mechanical various devices.

Tanaka's subsequent life as an inventor-craftsman can be conveniently divided according to his residential location. He started his career when he decided to become an inventor after his father's death. He stayed in Kurume and made various inventions. During this time, he made a grand tour making new devices, displaying entertaining toys, and learning new skills and knowledge. In 1834 he left his hometown and settled with his family in Osaka, and later in Fushimi. During this time, he opened his shop in the busy center of Kyoto, succeeded in making and selling his invented goods, and constructed the Myriad Year Clock. Immediately after its completion, the Saga clan's feudal lord invited him to visit in 1852. He then became an official engineer under Lord Nabeshima's patronage, and collaborated with other craftsmen and scholars to construct models of a steam ship and a steam locomotive, as well as artillery machines and weapons. After the Meiji Restoration, he went to Tokyo, established his own workshop, produced cutting-edge technological devices, and worked as an occasional engineering consultant for the government. A year after his death, his son-in-law opened a large factory, which became the origin of Toshiba, the present-day electronics company.

Tanaka's own biographical table notably recorded the festivals held at Gokoku Shrine five times from 1819 to 1830.[3] His frequent references to this shrine in his hometown meant that he performed shows there with the instruments he devised, and that he possibly earned money depending on how crowded these festivals were. This was probably his basic means of earning a living after he left home. He earned money by displaying his toys and machines, and entertaining the people who gathered at festivals. The shop he opened in Kyoto was prosperous. Tanaka made and sold many kinds of items—toys, tools and other useful goods. During his early period, Tanaka devised an air gun and a "mujintō," or "inextinguishable lamp," both of which contained a pump as one of their components and required a

3. *Tanaka Ōmi Taijō*, op.cit., p. 3.

technique for making an airtight structure. The air gun was popular among several engineers, and was known by rulers and scholars who were interested in Western military and production techniques, notably including the steam engine. The perpetual lamp was an oil lamp with a pump to push up rapeseed oil to be burned. Like Western oil lamps and unlike Japanese candles, it had a glass cover so that its fire and light would not fluctuate. The biographer Imatsu thinks that the fluctuation of light would have disturbed intellectual activities at night in Japan, and perceptively points out that the popularity of Tanaka's "inextinguishable lamp," which provided stable illumination brighter than previous oil or candle lights, reflected an increase in nighttime activities in Japan. Here Imatsu observes Tanaka's concern with rational and efficient use of time by Japanese people.[4] Tanaka's familiarity with pumping technology is important for his later involvement in understanding and constructing steam engines.

After 1847, Tanaka expanded his interests in astronomy and clock making. That year he started to learn the theory and practice of calendar making from the Tsuchimikado family, who were officially in charge of making calendars in Edo Japan. That same year, at a certain Buddhist monk's request, he initiated the design and construction of his own version of Shumisengi, which displayed a cosmological configuration to show celestial bodies' terrestrial structure and motion.

He then engaged in constructing the Myriad Year Clock, which, of course, he did not intend to move for 10,000 years. He expected it to remain in motion for several months, which was much longer than the duration of ordinary Japanese clocks at that time, a single day. This clock was a complex system that represented time and calendar through its six faces. It represented the Western time system, the Japanese time system, the days according to both solar and weekly calendars, the year counted by the Chinese system, and the day of the lunar calendar showing the moon's shape. Atop the clock sat an astronomical model with the sun and the moon rotating above and below a map of Japan. A set of two strong and heavy springs provided the clock's driving force, and the other set of two springs drove gears to

4. Imatsu, op.cit., pp. 45–47.

chime the bell. The timekeeping piece for the whole system was a French-made watch, which was connected to the other mechanical systems. But the system's most intricate part was the block, which designated the Japanese time system.[5]

2. Clocks and Seasonal Time System in Edo Japan

The time system used during the Edo period was the so-called seasonal time system.[6] In contrast to the clock time system, which divides each day into 24 hours of equal length, the seasonal time system divides daytime and nighttime separately into hours of equal length. Japanese seasonal time divided daytime and nighttime into six units of time, called "*koku* (刻)." Each *koku* was named after one of the 12 horary animals, from rat (子) to boar (亥). Each *koku* also was numbered in a rather unusual manner. Midnight, or the time of the rat, was numbered nine; the next *koku* was eight; the next was seven; the time of dawn was six; down to five, four and three, which was the last *koku* before noon. Noon was numbered nine, just like midnight; and the same numbering proceeded through the afternoon and evening. The crucial times in this seasonal time system were the times of boundary between daytime and nighttime. These boundary points in time, at dawn and dusk, were pragmatically defined as the times when three lines on a human hand became visible or invisible. Astronomers and calendrical experts precisely defined these chronometrical points as 36 minutes, or 1/40 of a day, before sunrise and after sunset. These experts used their own unit of time, which was also called a "*koku*," but which differed from the previously and ordinarily used *koku*. They divided 24 hours into 100 units; 36 minutes equaled 1/40 of a day, or 2.5 *koku*.

5. On the Myriad Year Clock, see Tei-ichi Asahina and Sachiko Oda, "'Myriad Year Clock' Made by G.H. Tanaka 100 Years Ago in Japan," *Kokuritsu Kagaku Hakubutsukan Kenkyū Hōkoku*, no. 35 (1954). The paper is a report of their investigation of the clock in 1969.
6. On the traditional timekeeping system in Japan, see Manpei Hashimoto, *Nihon no Jikoku Seido* (*Time System of Japan*) (Tokyo: Hanawa Shobō, 1994).

Japanese astronomers and calendrical experts further refined this definition at the end of the 18th century. At that time, they attempted to introduce Western astronomical theories to improve present calendars and, as a result, they proposed and adopted a new calendar called "Kansei reki (寛政暦)." This calendar defined the beginning and end of daytime, or "akemutsu (明六)" and "kuremutsu (暮六)," respectively, as the times when the sun was positioned 7 degrees, 21 minutes and 36 seconds below the horizon. Alterations of the definition arose because of astronomical considerations; the sun's angle and rate of descent differ from season to season. The astronomers deduced this fragmented number for the sun's position from the sun's position at equinoctical time and Kyoto's latitude. The new definition more precisely corresponded to the brightness of the twilight sky than the previous definition, but required calculations that were considerably complex for ordinary people.[7]

On a calendar, these defining points changed only 24 times each year, at the time of the turning of seasonal points called *sekki* (節気), or at the beginning and middle of each lunar month. The table attached in the Appendix shows the length of daytime counted by the astronomical unit, *koku*, according to three calendars: 1777, 1800 and 1844.[8]

How, then, can the clock be adjusted to this seasonal time system? Clockmakers devised several different types of clocks for this purpose during the Edo period.[9] The most notable methods were the "tempu" and "warikoma" methods. The first used two oscillating foliots, or horizontal bars, on the top of the clock, each of which moved and

7. On the definition of akemutsu and kuremutsu, see Takehiko Hshimoto, "Kanseireki to Wadokei: Yoake no Teigi o Megutte (Kansei Calendar and Japanese Clocks: Concerning the Definition of Twilight)," *Tenmon Geppo*, 98(2005): 373–379.

8. I have consulted the calendars of each year from those preserved at Seiko Tokei Shiryōkan (Seiko Institute of Horology) in Mukōjima, Tokyo.

9. On the history of Japanese traditional clocks, see Ryuji Yamaguchi, *Nihon no Tokei* (*Clocks in Japan*) (Tokyo: Nihon Hyoronsha, 1950), whose second version was published in 1942; Taizaburo Tsukada, *Wadokei* (*Japanese Clocks*) (Tokyo: Toho Shoin, 1960); Sachiko Oda, ed., *Seiko Tokei Shiryōkan Zō Wadokei Zuroku* (*A Pictorial Record of Japanese Clocks Preserved at the Seiko Institute of Horology*) (Tokyo: Seiko Institute of Horology, 1986), which visually and textually explains various different types of *wadokei*.

stopped alternately in the daytime and nighttime. The pallets were hung in a position on the foliot's teeth so that their oscillation period would be tuned to the varying hours of the seasonal time system, and this position changed bimonthly when *sekki* changed. The hands on the clock's face rotated at different speeds during the daytime and nighttime.

The second, or "warikoma," type had a face with movable plates, which were also repositioned by users or clock makers bimonthly so that they would indicate the seasonal time. Almost all these *warikoma*-type clocks were manually adjusted. An exception has been discovered recently in the storage area of the Takekawa family, located near Matsuzaka, south of Nagoya, which was in the former area of Kishū. The clock has a mechanism that could automatically adjust these movable plates to designate seasonal time. This mechanism has turned out to be fairly simple, using an eccentric circle and a comb-like sliding plate; but it has no similarity with any mechanism used in clocks or other machines.[10]

3. The Japanese Clock of the Myriad Year Clock

Another exception is Tanaka's Myriad Year Clock (Figure 2.1). It had a face of the *wadokei* or *warikoma* type which has an automatically movable mechanism. The mechanism differed significantly from the one discovered recently. Curators of the National Science Museum had investigated the mechanical details of this clock twice, in 1949 and 1969. In 2004, a new project was organized to disassemble and make a replica of this clock. The work of disassembling the machine and measuring its parts' sizes was done by scholars at the National Science Museum and former clock-making engineers of Seiko Company. These examinations have clarified its basic mechanism more precisely than the previous investigations. Like the

10. Katsuhiro Sasaki, Takehiko Hashimoto, Hideo Tsuchiya, Katsuyuki Kondo, and Kazuo Okada, "The Mechanism of Automatic Display for the Temporal Hour in the Japanese Clocks," *Bulletin of the National Science Museum*, ser. E, vol. 28 (2005): 31–47.

Figure 2.1 Hisashige Tanaka's Myriad Year Clock
(Photo by the author)

It has six faces on its side, including the Western clock and the Japanese *warikoma* type clock as seen on the photo, and a solar and lunar model on its top. The Japanese clock has a mechanism inside to move automatically *warikomas* on its face.

Takekawa family's clock, Tanaka's clock's own internal mechanism automatically slid its movable plates to their proper positions; but the mechanism is significantly more intricate than the Takekawa clock's. Making the plates move required the conversion of daily or hourly

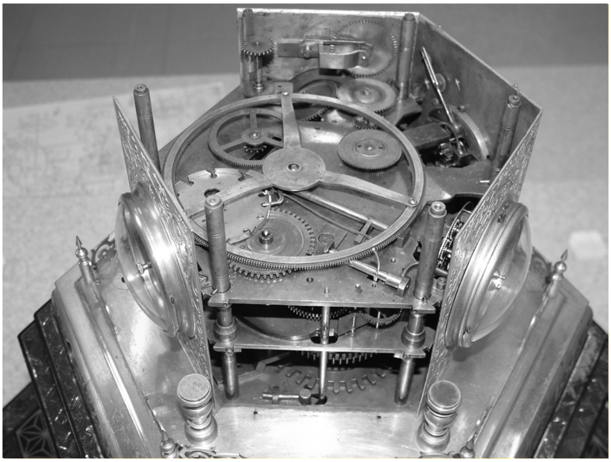

Figure 2.2 Complex mechanism inside the Myriad Year Clock (Photo by the author)

The conspicuous silver large wheel has 365 teeth to produce annual rotation. The three arms to support the wheel are slightly bent, apparently because its center had to be finely adjusted after it had been made. The lower right face displays the Japanese clock in front, and holds intricate encased mechanism behind.

rotational motion to annually oscillating motion. Tanaka used 10 tiny sun-and-planet wheels, an insect-shaped cog and special gears with teeth on only one of their sides. The last two elements converted rotational movement into oscillating, semicircular rotations; and the first ones converted these semicircular oscillations into linear oscillations.

Close analysis achieved by disassembling the Myriad Year Clock's parts at the skilled hands of former Seiko engineers has disclosed the hidden characteristics of its mechanical construction: certain errors in gear ratio, redundant holes pierced in the *warikoma* clock's base plate, and traces of hand grinding the small teeth on a sub-millimeter scale. Although many of Tanaka's notebooks have been lost, one of his surviving sketchbooks shows three shaded figures, each precisely delineating the crucial comb-shaped component found in Takekawa's *warikoma* clock.[11] No other related components such as spokes or rails are drawn in the sketchbook. We conjecture that the remaining redundant holes and the shaded figures of crucial parts of the automatic warikoma clock suggest that Tanaka might have considered the use of a mechanism such as the one used in Takekawa's clock, with the comb-shaped plate; but eventually gave up on the idea to employ a far more complicated, but fragile, mechanism.

Observers of the disassembled components of the Myriad Year Clock would be amazed by the extraordinary complexity of the whole mechanism and the very finely manufactured gears (Figure 2.2). The components numbered just over 1,000, far superior to and far more complex than ordinary Japanese clocks. Tanaka's ability to design this whole complex system in a limited space, surpassed any other craftsmen in Japan. They would also be impressed with the precise processing of the fine gear teeth. All these gears, small and large, were constructed by hand. However, we are totally uncertain about the tools used by Japanese clockmakers, including Tanaka. Obviously, he must have used a file thin and fine enough to process a brass tooth a millimeter wide; and he must have noticed the great limitations of hand processing and the need for a machine tool for such precision manufacturing. Indeed, he introduced foreign-made machine tools for constructing mechanical parts such as screws.

How precisely did this clock designate time according to the seasonal time system used during the Edo period? As mentioned above, the beginning and the end of the daytime, *akemutsu* and *kuremutsu*, were defined as the times when the sun was 7 degrees and 22 minutes or so below the horizon; and this point in time corresponded, on the equinoxes, to 36 minutes (2.5 *koku*) before and after the sun passed the horizon. This length of time (1/40 of a day) corresponds to an angle of nine degrees (1/40 of 360 degrees). The inner mechanism of the Myriad Year Clock's *wadokei*, however, designates an angle slightly larger than this (10–11°, which corresponds to 3 *koku* instead of 2.5 *koku*) for the position of both the *akemutsu* and *kuremutsu*. Memos

11. *Tanaka Ōmi Taijō,* op. cit. contains the list of archival sources of Hisashige Tanaka, but many of them were destroyed by the Great Kanto Earthquake in 1923. The Edo Tokyo Museum presently preserves several remaining sources of Hisashige Tanaka.

from the previous disassembling investigation of the Myriad Year Clock also indicate that scholars were concerned with this specific value and recognized its discrepancy from the theoretical value.

This small discrepancy, however, had good reasons behind it. Tanaka stated in his advertisement for this clock that the daytime of summer solstice lasted for 66 *koku*, which was rounded up from the length designated by the calendar, a little more than 65 1/2 *koku*. The daytime on the winter solstice lasted for 46 *koku*, and therefore the value halfway between the two solstices is 56 *koku*. This value of 56 *koku* means that 3 *koku* are additional twilight during the morning and evening. Why does the mean value between the two solstices differ from the value according to the original definition of twilight's duration on the referential seasonal days of the year? This is because precise equinoxes are not exactly between the two solstices, but are a few days closer to summer solstices than to winter solstices in the northern hemisphere. In fact, equinoxes on Japanese calendars were not designated as true equinoxes until the calendric reformation of the Tempo years at the end of the Edo period. Tanaka's clock, therefore, quite accurately indicated Japanese time. In fact, it indicated seasonal time more accurately than calendars did, because its mechanical device changes the length of daytime continuously throughout the year; whereas calendars were officially designed to change it only bimonthly, at the time of each *sekki*.

What happened to the Myriad Year Clock after its completion? It was intricate and far more complicated than other Japanese clocks. He tried to sell it to a feudal lord or a wealthy merchant, but nobody dared to purchase it. It is said that a lord wanted to get it, but his men persuaded him not to because it appeared to be extraordinarily expensive. Tanaka intended to make and sell more than one Myriad Year Clock, but he could make only one. After the Saga clan recruited him, he geared his ingenuity toward industrial engineering to construct tools, instruments and machines for useful purposes, rather than entertaining aims. After the Meiji Restoration, he came to Tokyo to set up a new factory to construct and sell telegraphic devices and other modern machines.

4. Tanaka's Astronomical and Cosmological Models

Tanaka's Myriad Year Clock has a model above the clock system to represent solar and lunar motions. This astronomical model defined the beginning and end of daytime as the points in time when the sun was a specific angle below the horizon. The model consists of a rotating sun and moon, and a hemisphere that represented the earth, whose circular top face depicted a Japanese map. The sun and moon rotated to go below the earth, moving between this earth-representing hemisphere and the outer hemispherical bowl, which had a ring located 7 degrees and 22 minutes below the horizon represented by the inner hemisphere's plane. In his advertisement to this clock's potential users, Tanaka explicitly said that this ring represented the twilight boundary between daytime and nighttime (晨昏際), which meant that when the sun passed this point on the east side, daytime begins, and on the west side, daytime ends. The model clearly indicates that Tanaka learned the definition of twilight from the Kansei Calendar, and therefore probably also learned about the astronomical mechanism and structure behind the basic astronomical phenomena of daily solar and lunar motions.

Before he constructed the Myriad Year Clock, Tanaka was asked by a monk to make a clock-working Buddhist cosmological model, which was called "shumisengi (須弥山儀)."[12] The model represented a flat earth with a large central mountain and two astronomical bodies circling above the mountain. The mountain, shumisen, was supposed to be located at the center of the earth, and our world was located at the eastern quarter of this mountainous geographic square representing the earth. Outside the earth are seas with bits of small islands, and beyond the seas is a golden ring representing "konrinzai (金輪際)." The Buddhist monk Kanchū (環中), who was a disciple of the noted monk Entsū (円通), asked Tanaka to make this machine. Entsū had his own *Shumisengi* and walked around Japan teaching Buddhist cosmology and refuting the heliocentric cosmology recently introduced

12. See Kazuhiko Miyajima, "Shumisengi to Shaku Entsū no Uchūkan (The Cosmology of Shumisengi and Shaku Entsū"), *Wadokei,* nos. 7–9 (1988).

from the West. When Kanchū approached Tanaka and asked him to construct a pedagogical model to explain Buddhist cosmology, Tanaka apparently promptly accepted the monk's request. Tanaka indeed subsequently constructed several such models to represent Buddhist cosmology, some of which were replicas of the first model, and others were compact versions.

After the Meiji Restoration, another Buddhist asked Tanaka to construct a different version of a mechanical model that he intended to represent not only Buddhist cosmology, but also an epistemological theory to defend that cosmology. Unlike other cosmological models, it does not explain its cosmological structure to its viewers. It had a conspicuous helical spiral tapering down toward the main disk. On the main disk's plane are four spheres, each of which represents one of the four worlds corresponding to the four continents. The top of the spiral was a ring to guide the daily motions of the sun and the moon, and the ring was supported by a 40 cm high pole erected at the center of the disk.

The man who ordered this model was Kaisuke Sada, who wrote the booklet, "Description of the Model to Represent the Equivalency of the Visual and the Real (視実等象儀記)."[13]In it, he explained the model's structure and the philosophical reasons behind this unusual structure. He first stated that visual appearance did not represent nature's real structure. The daily rotation of the sun, moon and stars seemed to suggest their rotation around our world and our world's spherical structure. But another entirely different structure, which this model represents, would also reproduce the same astronomical appearance that our eyes see when we are standing on the earth. The sun and the moon were rotating high above the earthly ground, not around the earthly globe; and to our eyes, the rotation around the stellar ring above us should seem to appear as rotary motion around a smaller sphere on the continental ground. His explanation of this perceptual mechanism is, however, unintelligible to us. It is hard to understand what he argued about the visual equivalency of the stellar objects around the ring above and around the small sphere below, on the

13. Kaisuke Sada, *Shijitsu Tōshō Giki* (Tokyo, 1877).

ground.

Setting aside this basic problem, readers might wonder how the argument about these two systems' visual equivalency leads to an argument for the plausibility of one over the other. Sada cited here the recent news about the exploration to the north pole to refute the cosmological model and assume the earth as a spherical globe. It took explorers starting from a high latitude much longer than they expected to get to the north pole. Sada calculated from the time they took to arrive at their destination that the distance from this geographical point to the north pole was much longer than indicated by the simple assumption that the earth was a sphere, and used this calculation as evidence to assume that the earth was, in fact, a vast plane. He subsequently cited, rather anachronistically, ancient Chinese cosmology, "Gaitianshuo(蓋天説)," which presupposed the flatness of the earth and the celestial hemisphere over it.

We do not know how Tanaka considered this Buddhist cosmology and Sada's epistemological reasoning. He was a close friend of a Dutch-educated Japanese scholar, Genkyō Hirose, and knew Western science and technology well. It is therefore safe to assume that he accepted Western cosmology, based on which Westerners developed all the science and technologies that enabled them to make their world-wide commercial and military activities. Philosophical arguments that criticize the epistemological basis of the scientific theories developed in Sada's treatise might have not been a concern for Tanaka the technologist, whose interest more and more focused on modern Western technology such as steam engines, weapons and telegraphy.

Appendix

The table of the length of daylight in 24 seasonal periods according to the three calendars published in 1777, 1800 and 1844.

明け六つ ～暮れ六つの時間	1777 年 （文政 2 年）	1800 年 （寛政 12 年）	1844 年 （天保 15 年）
1 月		48.75	48.75
1 月中	49.5	50.75	50.5
2 月	52.5	53	52.75
2 月中	55	55.25	55
3 月	57.5	57.75	57.5
3 月中	60.5	60	59.75
4 月	62.5	62.25	62
4 月中	63.5	64	64
5 月	64.5	65.25	65.25
5 月中	65	65.75	65.75
6 月	64.5	65.25	65.25
6 月中	63.5	64	64
7 月	62.5	62.25	62
7 月中	60.5	60	59.75
8 月	57.5	57.75	57.5
8 月中	55	55.25	55
9 月	52.5	53	52.75
9 月中	49.5	50.75	50.5
10 月	47.5	48.75	48.75
10 月中	46.5	47.25	47
11 月	45.5	46	46
11 月中	45	45.75	45.75
12 月	45.5	46	46
12 月中	46.5	47.25	47

The unit of the numbers in the table is the astronomical *koku*, 1/100 of a day. On calendars, the length of daylight between akemutsu and kuremutsu is rounded: The fraction of half was designated by *amari* (余) on calendars, and is conveniently expressed as 0.25 in the table above. On the oldest calendar, mid-February (2月中) represented the spring equinox, and the three calendars designated the length of daytime as 55, 55.25 and 55 *koku*, respectively. These numbers' difference from the number 50, half length of the day, signified twice the twilight's duration, 2 × 2.5, in the morning and evening. The calendar from 1800, which was the Kansei Calendar, adopted the equal division method (平気法), dividing a year into 24 equal lengths. This method, however, set the day of the two equinoxes somewhat nearer to the summer solstice than to the true equinox because of the sun's elliptical orbit, which caused the additional fraction of 0.25. The following 1844 calendar, which was the Tempo Calendar, changed again to a round number, because it adopted the fixed division method (定気法), which divided the year according to the sun's position in relation to the zodiac.