# Paper Communicated.

## The Ellipsograph of Hazama Gorobei Shigetomi.

By Baron Dairoku Kikuchi, *Rigakuhakushi*

(Read Nov. 12, 1912)

Hazama Gorobei Shigetomi[1] (間五郎兵衛重富, 1756–1816) was a pawnbroker of Osaka, having succeeded to his father's trade. He was from his boyhood remarkable for his inclination to astronomical studies; he became a pupil of Asada Gôryû (麻田剛立, 1734–1799), who had been a physician to the Daimyô of Kitsuki, but being fond of astronomy had left the service to devote himself to his favorite study, and had settled in Osaka. In 1795, the almanac having gone wrong in the incapable hands of those in charge, Asada was summoned to Yedo by the Shôgunate to take charge of its revision. Asada excused himself on the ground of old age but sent his two pupils, Takahashi Sakuzaemon Yoshitoki (高橋作左衛門至時, 1764–1804) and Hazama in his place. The revision of the almanac was accomplished under their direction, and Hazama returned to Osaka, while Takahashi was placed permanently on the staff of the Observatory. Being a man of some means, Hazama always had artisans working under him, and constructed various instruments. Among these were a thermometer and a barometer, with which he began to make meteorological observations, which were kept up till about 1865. The instruments used by Inô (伊能勘解由忠敬) in his survey of Japan were also made under his direction. There is in the Library of the Academy a manuscript[2] entitled *Daen Kigen* (楕圓起元), giving a description by his son Jûshin (重新) of an ellipsograph devised by him. My assistant, Mr. Mikami Yoshio, has translated it into

1) The names of men are all given in the usual Japanese way, i.e., with *the family name first*.

2) Copied under the direction of my assistant, Mr. Endô Toshisada, from one in possession of Mr. Kubota Seitarô.

English; and an account of it is, I think, not without interest.

The manuscript begins with a preface, which I give in full.

"In the first years of the Kwansei era (1789-1800), my late father constructed an ellipsograph (楕圓規) for the first time. Although such an instrument was but a trifle among various instruments of observation constructed by him, yet we are told that he had some trouble in devising it. He used to say that the instrument being made of wood, different parts were defective and their motion inaccurate, neither was it so simple and convenient as could be desired but it was sufficient to show how an ellipse could be described by a complete revolution of a circle. Unfortunately the instrument was lost together with others in a fire in the spring of the third year of Kyôwa (1803). Having some recollection of its construction, I desired to reconstruct it after the old model and made inquiries of my father. This was in the spring of the first year of Bunkwa (1804), when he was on the eve of his departure for Yedo, [whither he had been summoned for the second time by the Shôgunate on the death of Master Takahashi], myself being nineteen at the time. "Accuracy and simplicity," my father told me, "are not likely to be attained, unless it is made of brass. I shall therefore have it made for you in Yedo by Yasaburô." He also explained to me some points in the theory of the ellipse, which enabled me afterwards to understand the principle of the instrument; this was in my twenty-first year. My father served in the Observatory for six years, during which under the pressure of many important matters he had no time to spare for such a trifle as this. After his return home, he one day spoke to me about the matter, saying, "you ought to design and construct a simpler instrument yourself; I also will think about it." I thought to myself, the instrument had once been made, and it would certainly be simpler and more accurate, as my father says, if it were made of brass. I expected to design a new instrument and have it made by Tôsaburô; but time has slipped by, and more than ten years have now elapsed since my

father's death, without the instrument being made; the fact that when I wanted to describe an ellipse, the method of three pins with a string passing round them was sufficient, naturally made the matter less pressing. Recently I had occasion to bring out a box from a go-down and in it I happened to see a small paper parcel. On picking it up and removing the cover to examine it, what was my surprise and joy to find that it was nothing else than the ellipsograph supposed to have been destroyed in the fire! For twenty-six years from the first year of Bunkwa (1801) [the year of the fire][1] to the present eleventh year of Bunsei (1828), it has been lying in the go-down lost from sight, and now it has been brought to light. It was not destroyed by the fire at all; it had simply been missing on account of my culpable negligence in never once thinking of looking for it in the go-down, assuming it to have been burned. Being a small object, it had been hid among other things, which caused it to be missed so long. But now I am only too happy to have recovered the very instrument constructed and used by my father, after forty years that have elapsed since the first years of Kwansei. The instrument may be a trifle, yet who could have designed it without being deeply versed in the theory of the ellipse and giving a great deal of thought to it? It is said, and it is very natural, that at the time of its invention, Dr. Baiken (another cognomen of Takahashi), old Master Gôryu (Asada) and Ban Shinzô admired it exceedingly. Twenty-six years have passed as a single moment, but my father's words and doings during his lifetime are vivid in my eyes and ears. With my hands on the recovered instrument, I am lost in the recollection of those days: tears fall in a thousand drops, which when I wipe them away, are succeeded by myriads more. I have at last made diagrams descriptive of the old instrument, and

1) So runs the manuscript: this would make it only twenty-five years to 1828, counting in the Japanese way. In the earlier part of the preface, the fire is said to have taken place in the third year of Kyôwa (1803), which would be twenty-six years to the eleventh year of Bunsei according to the Japanese way of counting.

recorded the principle on which it is based, and now reverently place them before the portrait of my father along with this account.

On the memorial day of my father's death, the twenty-fourth day of the third month of the eleventh year of Bunsei, being the year of *tsuchi-no-e no ne* in the sexagesimal cycle.

Reverently recorded by
Jûshin."

In a second note, the author tells us that Takahashi also made an ellipsograph, which he one day saw on his father's table in Yedo. Although unfortunately he had not time to observe its details carefully, he saw that it was almost the same as his father's, except that it had wheels moved by a rack, and not by the string wound round them, and that the lengths of major and minor axes could be varied at will. His father told him that this ellipsograph by Dr. Baiken was very ingenious and that it would be well to construct a new one with some improvements on this one. Some twenty years after, being in Yedo, the author made inquiries of Takahashi Sakuzaemon, junior, and was told that it had been destroyed in a fire some years ago.

Then follow the diagrams of the instrument and its parts, with explanatory notes, and he proceeds to the explanation of the principle, on which the instrument is based, which he calls the *Daen Kigen* or "the Origin of the Ellipse." I shall reverse the order and begin with the latter.

The general principle of the instrument is of course due to Shigetomi, but the actual form of the explanation is, I believe, Jûshin's and is somewhat tedious and not strictly logical, and not worth reproducing in full.

The ellipse was regarded by the old Japanese mathematicians as a section of a cylinder by a plane. By means of a folded-paper-model of a right circular cylinder and planes, Jûshin proceeds to show that if in the plane of the section a radius vector be drawn through the centre (intersection of the plane with the axis of the cylinder) to intersect the circles drawn in the plane with

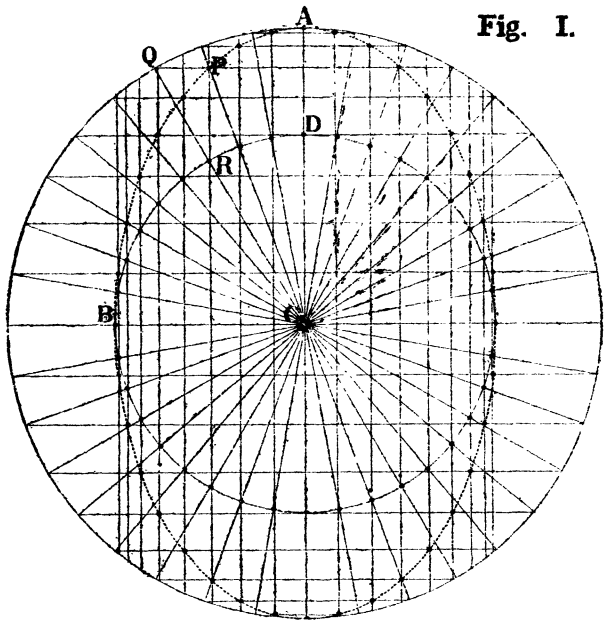
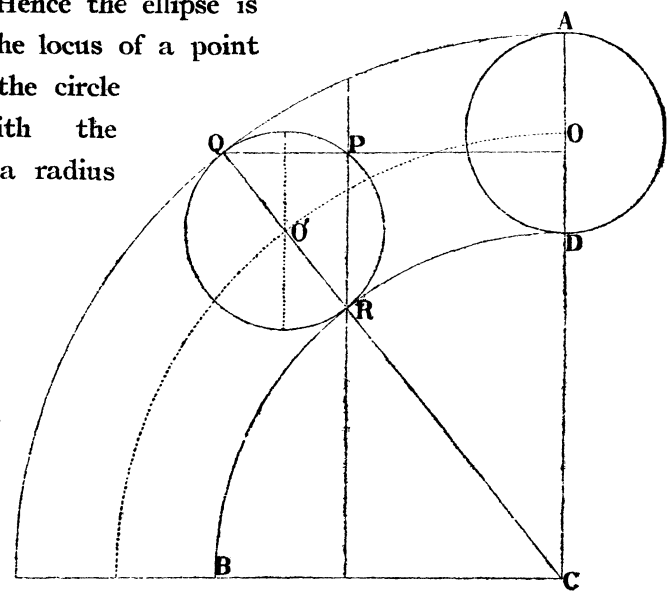



**Fig. I.**

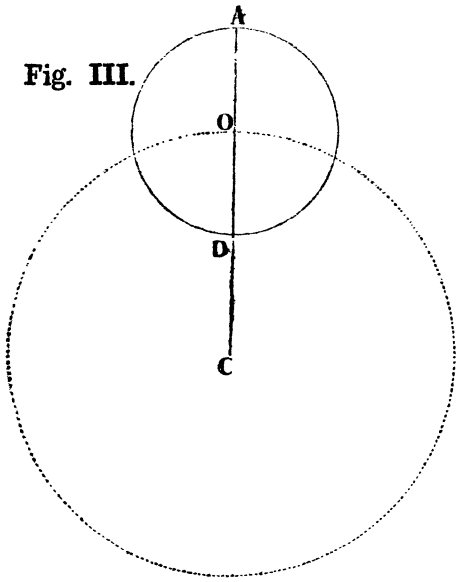
the same centre and the radii equal to the major and minor semi-axes respectively, and if straight lines be drawn through the points of intersection parallel to the minor and major axes respectively they will intersect on the ellipse. Now let a circle be described (Fig. II.) on AD as diameter and let it be moved till its centre O is on the radius vector CRQ; then the vertex P of the right angled triangle PQR, whose side RP is parallel to CA, is a point on the ellipse, and the angle QO′P is equal to twice the angle ACQ. Hence the ellipse is obtained as the locus of a point P, taken on the circle described with the centre O′ on a radius vector CRQ, touching the fixed circles, so as to make an angle QO′P = twice the angle ACQ.

**Fig. II.**



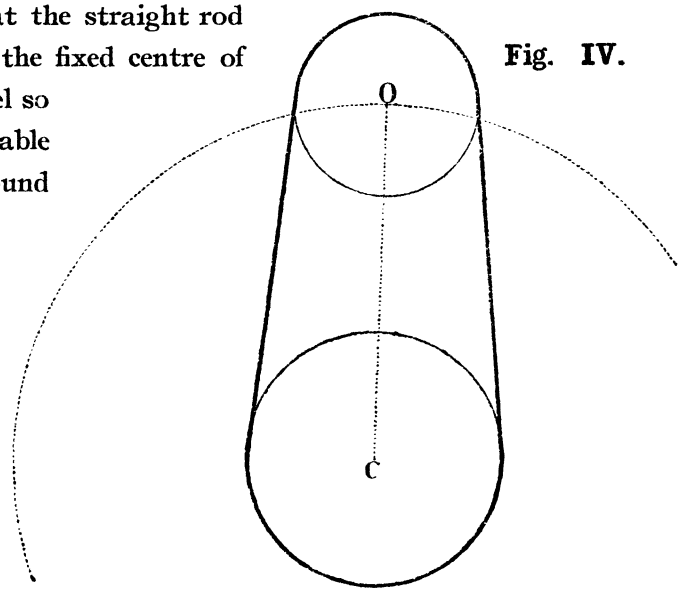

In order, then, to describe an el-

Fig. III.




lipse, it is only necessary to devise a mechanism, by which a wheel, whose centre O is on the circumference of another wheel turning round a fixed centre C, can be made to turn in a sense contrary to that of the fixed wheel through double the angle through which the latter turns. Then any point on the circumference of the second wheel will describe an ellipse, such that half the sum of its major and minor semi-axes is equal to the radius CO of the fixed wheel and their difference to the diameter AD of the movable wheel. Suppose that we had three toothed wheels with their centres on a straight rod, the radius of the first wheel being double that of either of the other two, and that the straight rod is pivoted on the fixed centre of the first wheel so as to be capable of turning round it; it is evident that such an arrangement would satisfy the required condition, but the lengths of the axes

Fig. IV.



would be fixed and could not be adjusted at will.

Let us therefore take two wheels, C, O, (fig. IV), the radius of the wheel C being double that of the wheel O. The centres of the two wheels are rigidly connected and a string passes over the peripheries. The centre of the wheel C is fixed; if now the line of the centres be made to turn round C, the two wheels will turn in contrary senses, the wheel O turning twice as fast as the wheel C. Hence a point rigidly connected with the wheel C will describe an ellipse. By varying the distance CO, the sum of the axes can be changed at will; and the distance of the moving point from O which can be adjusted at will by a simple contrivance is the difference of the semi-axes. We can thus describe an ellipse with any axes. The instrument actually constructed by Hazama is shown by fig. V, which is copied (as also other figures in this paper) from the manuscript in the Library of the Academy.

**Fig. V. Ellipsograph of Hazama Gorobei.**
(actual size)