TO THE HISTORY OF THE PRODUCTION OF GEODETIC INSTRUMENTS IN BOHEMIA

A PROPOS DE L'HISTOIRE DE LA PRODUCTION DES APPAREILS GÉODÉSIQUES EN BOHEME

ZUR GESCHICHTE DER HERSTELLUNG VON LANDVERMESSUNGSGERÄTEN IN BÖHMEN

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ABSTRACT

Out of the rich history of the production of geodetic, astronomic and mathematic instruments in Bohemia, this article is focusing on two periods. The first falls into the turn of the 16. and 17. century, into the time of the rule of Emperor Rudolph II. The second period is the time from the 19. century to half of the 20. century, i.e. the period of transition from the workshop to the industrial production. Special attention is given to the significance of the production of glass rings by the company of the Fric Brothers.

La contrubution s'occupe de deux périodes de l'histoire riche de la production des appareils géodésiques, astronomiques et mathématiques. La première période date du tournant des 16^{e} et 17^{e} siècles, de l'époque du règne de l'empereur Rodolphe II. La deuxième période est représentée par l'époque depuis le 19^{e} siècle jusqu'à la moitié du 20^{e} siècle, c-est-à-dire par la période du passage de la production de manufacture à la production industrielle. L'attention est prêtée à la priorité de la production des cercles en verre par la société des frères Fric.

Der Beitrag befaßt sich mit zwei Zeitperioden in der reichen Geschichte der Herstellung von geodätischen, astronomischen und mathematischen Instrumenten in Böhmen. Die erste Zeitperiode fällt auf die Jahrhundertwende des 16. und 17. Jahrhunderts, die Zeit der Herrschaft Rudolf II. Die zweite Zeitperiode ist die Zeit vom 19. Jahrhundert bis zur Mitte des 20. Jahrhunderts, d.h. die Zeit des Übergangs von der Werkstattarbeit zur industriellen Fertigung. Besondere Aufmerksamkeit wird der von der Firma Gebrüder Frič bevorzugten Herstellung von Glasringen gewidmet.

INTRODUCTION

Land surveying is one of the oldest mathematic-natural technical disciplines with close ties to the society. It developed already in antiquity, on the basis of the needs of intensive agriculture and land holding, military needs, civil engineering, architecture and urbanization. In its basic theoretic questions it was connected with astronomy and mathematics, but also with philosophy. In many, especially old civilizations, it also fulfilled cultic tasks. In the 18. - 19. centuries, higher geodesy branched out of astronomy as a representative of a newly developing science field (e.g. works for the examination of the shape and size of the Earth, triangulation and measuring by degrees), which belonged to the peaks of scientific efforts. In the applications of lower geodesy, the solutions often resulted from geometry, so that until the previous century it was called applied geometry.

The level of the profession always immediately reflected the economic, esthetic, educational and also political level of the civilization and the needs of state management. On these foundations also developed the geodetic instrumentation, with different instruments for the measuring of angles, possibly azimuths, lengths and elevations.

Small tools belong to the oldest artifacts, although many of them have a universal usage or are still today part of the instrumentation. The plumb line and surveying benches are recorded in the 2nd millennium b.c. in Egypt and the area of Tigris and Euphrates, since the 14th century b.c. the measuring line, bricklayer's level and the measuring ruler are known.

PRODUCTION IN BOHEMIA IN THE RUDOLPHINE AGE

The Czech lands have always been a traditional cross-roads of cultural influence and politic and economic interests. In the different periods of the development of the state we find therefore also a developed manufacturing of measuring instruments, according to its time. On the following pages we will focus on two significant periods, which have their beginnings in the 16., respectively 19. century (Hánek 1994).

In the 16. century a fish pond boom occurred in Bohemia. The theoretical basis became the writing „De piscinis" (About Ponds) of the Moravian humanist and later bishop of Olomouc Jan Dubravius (1486-1553). In this work, Dubravius introduces three leveling instruments - the famous reconstruction of the Roman (Etruscan) Chorobates, the water-level and his own adaptation of a gravity instrument with a visor, which was used for front-view leveling.

One of the peaks of the production of instruments on our territory can be dated into the period of the reign of the art-loving Renaissance ruler Rudolph II. (1552-1612). In the year 1583 he moved his seat to Prague, which became a significant European metropolis, attracting specialists of all fields. It is obvious, that the level of sciences and the need of their further development reflected also into the field of fine mechanics. At the imperial court worked the natural scientist and physician Tadeáš Hájek from Hájek, the author of the triangulation of the Prague area. By his merit the renowned astronomers Tycho Brahe and Johannes Kepler came to Prague. Both were also authors of scientific instruments. Kepler in the year 1611 described in the publication „Dioptrice" a new type of telescope, the so-called astronomic telescope. Because it creates the plain of the real picture, a reticule was later inserted and the telescope found broad usage in astronomy and geodesy. This was one of the first constructions of a telescope, which was discovered in the beginning of the century in Holland (Zinner 1967).

Besides these scientists, also some significant European mechanics were working in Prague, in the proximity of the ruler (Svejda 1997). Many of their works however were lost in the Thirty Year War.

The famous Jost Bürgi (lat. Iost Byrgi, 1552-1632), Swiss by origin, was the Emperor's watch-maker since 1604. Already since the year 1602 were his works protected by imperial privileges, a certain precursor of patent protection. With 1604 is dated an instrument for perspective drawing, which operated on the basis of a theodolite. In the year 1609 he fabricated for the Duke of Hessen a precise triangulation instrument, based on the similarity of triangles (von Mackensen 1979). The instrument is the pride of the collection of the Museum in Kassel, which in those days belonged to

the leading scientific centers. In the year 1610 Bürgi assembled logarithmic tables, which also Kepler was using. However, he was hesitating with their publication for ten years, and was thus surpassed by John Napier.

Another significant creator was Erasmus Habermel (+1606). He is the author of theodolites, the leveling instrument and of a triangulation and artillery measuring instrument, which are all in foreign collections. The decoration of the world renowned collection of gnomonic instruments of the National Technical Museum in Prague (NTM) is a functionally and by its artistic manufacturing, perfect equatorial sun dial with altimeter. In his shop also originated a collection of mathematical instruments (compasses, levels, angle measures), fabricated for the physician Franciscus Paduanius from Forli.

In the collections of the NTM is also a theodolite, which originates in the beginning of the 17. century. It was a universal instrument, besides for measuring of angles, it was also used for the measuring of time and for calculations. The scales of the sun dial and the mathematic functions are on a horizontal ring. The author is Heinrich Stolle, a collaborator with the mentioned J. Bürgi.

The mentioned instruments were exceptional by their design. Excellent results however also reached practical measuring, which documents the level of the usual measuring instruments. An example is the construction of the unique water tunnel, which was finished after an eleven year work effort in 1593. Today it is called Rudolph's Tunnel (Hanek 1994). The straight tunnel with a diameter of approx. (0.7-1.5) x (3-4) m traverses mostly natural rock. It is 1.1 km long with an elevation of the ends of only 1.12 m. The tunneling was done from both ends simultaneously, on the route were 4 vertical tunnels, coming from the surface. At the construction site gathered excellent experts of that age.

CZECH PRODUCTION IN THE AGES OF THE INDUSTRIAL REVOLUTION AND THE 20. CENTURY

The events of the Thirty Year War brought on our territory subsequently an economical collapse, an emigration of scores of educated people and an overall decline into provinciality, which also affected fine mechanics. In the following years, by small shops were mainly produced small measuring, mapping and drawing tools or single pieces, manufactured to order. Most of the instruments were imported. A revival arouse only in the 19. century, connected with the industrial revolution (Century of Steam) and with the national revival, which in the frame-work of the Habsburg monarchy corresponded to the growing economical influence and development of Bohemia. The first mechanical shop was founded 1808 by Josef Bozek (1782-1835), who was since 1805 watch-maker and mechanic at the Prague Polytechnic Institute. Successor in his function and in his shop became his son Frantisek Bozek (1809-1886) and he continued in the manufacturing of individual, often single scientific instruments, among them also surveying instruments. Above the average, in comparison with other European production, arouse works signed with the name Spitra. Three generations of the family (Frantisek, Vaclav Michal, Otakar) worked in Prague since 1820 until the end of the century. Since around 1840 another significant master, Mathias Richard Brandeis (-ys) (1818-1868), was producing measuring instruments. After his death, the shop was overtaken by the company Haase & Wilhelm (Prochazka 1975).

In 1890 were in Prague, which was the center of production, 24 shops of this specialization, at the end of the century already forty. Many Czech experts designed individual instruments - often for companies in Vienna. To name at least a few: the hypsometer by the significant professor at the Prague Technicum Karel Frantisek Edvard Knight Koristka (1825-1906), the instrument for graphic leveling by Prof. Frantisek Müller (1835-1900), the co-author of the first modern Czech manual for geodesy, or the logarithmic tachymeter by the renowned forester and railroad geodesist Dipl.-Ing. Antonin Tichy (1843-1923).

The enterprise J. and J. Fric

In 1883 came a turning point in the hitherto production of geodetic instruments, when Josef (1861-1945) and Jan (1863-1897) Fric founded in Prague the „Shop for Precise Mechanics". Their first product was a polarizer and analyzer of own constructions for Prof. K. Preis. The area of interest and creative invention of both brothers was very broad. Besides the designing and the production of manufacturing instruments for the equipment of their own shops, the bareoscope for the indication of the density of sugar juices must be mentioned as an example. With a big success ended their participation at the General Land Exposition in Prague in the year 1891. After the year 1906 the company J. and J. Fric manufactured a polarimeter for the indication of sugar content, which was accepted as the official standard in the USA.

Immediately after the founding of the enterprise, a collection of geodetic, namely leveling instruments was created, which earned at the District Exposition in Pribram the Silver State Medal. Then followed constructions of manufacturing machines for the dividing of rings for measuring instruments, for the polishing of lenses and mirrors and a number of other constructions (Hanek – Svejda 1993). The family led enterprise of the Fric Brothers produced during its existence a whole line of geodetic instruments, including the prestigious triangulation theodolite 6R (screw micrometers and reading by estimation of 2'') and special instruments for the measuring of the deformation of dams and for the construction of tunnels. The enterprise went under after its nationalization, at the beginning of the fifties years, where in the context of the national enterprise Meopta it was changed to another production.

In the years 1884/5 a small series of the mine theodolites DUPLEX was produced, where for the first time in the world a divided horizontal ring of glass was utilized (Hanek 1985). The theodolite was to be universally usable, not only for angle measurements (astronomical connection on the surface, polygonization and steep measurements in the underground), but also for leveling. The Fric Brothers posed themselves for the construction of this instrument 17 conditions, of which today some are commonplace: a folding easel, possibility of standing on consoles or a spread beam, fixed or flexible fastening, possibility of nadir or zenith centering, insertion telescope with visor illumination, covering of the rings and of other parts and the possibility of complete rectification of all mechanical axis relations. Further they required a repetition arrangement of the axes with fine scales on both axes and the decreasing of the size to half of the then usual sizes (Fric J. & J 1886). (For comparison: the Duplex had a height, including the setting level, of 28 cm and a width of 21 cm. The until recently produced theodolite Zeiss Jena Theo 010B has a height with truss of 34 cm and a width of 19.5 cm). For easy targeting in vertical plains, two telescopes of variable length were chosen (thus the name of the instrument). The axis of the telescope for steep measurements went through the turning axis of the top and insertion telescope and it was in the objective part rectangularly bent.

The horizontal divided ring with the diameter of 130 mm was made from 8 mm thick mirror glass. On the upper edge it was divided with a diamond chisel by 1°, the numbering was engraved with a pantograph of Milanese type with 25x reduction; both instruments were especially construed for this purpose. The engraving was filled in with graphite powder. The ring was illuminated by a window at the bottom of the ring cover. The readings were done through two opposite microscopes with 24x enlargement with the optical axis bent by a prism for greater comfort of the surveyor. The length of the actual picture of one particle is approx. 4 mm, which allowed the reading through a two row screen of a microscope with 60 particles, of which each tenth was numbered. Angle minutes were therefore read directly, by estimate 30'' (Hanek 1985).

The description of the construction was also publicized in 1886 by the prestigious magazine „Zeitschrift für Instrumentenkunde" (Fric J. & J. 1886), in the same year it was introduced at the Conference of Engineers in Budapest. Divided rings of glass swiftly became the standard in geodesy only at fourth try in the theodolite Zeiss Th I, which began to be manufactured in 1922. The design of the concept and the production of the rings and the reading is the work of the renowned constructeur H. Wild.

At the exposition in Brussels, in the year 1888, another remarkable novelty was introduced, a hanging mining measuring compass of Kassel type with a vernier needle. The cross vibrations of the knife needle were so well absorbed by a friction mica disk, that there were verniers on both ends. The division was done into the traditional 24 hours, the smallest particle of the ring had the value of 2^m, the particle of the vernier 10^s, i.e. 2'30'' in the sexagesimal division of the ring in 360° (Hanek - Svejda 1993).

On the basis of the brilliant idea of Prof. F. Nusl, the construction of an astronomic-geodetic circumzenithal for the definition of geographic coordinates by method of same heights was designed. The advantage, compared to astrolabes, was among others, a vertical division of the picture and the placement of a mercury horizon in the center of the instrument. In the year 1932 the impersonal micrometer according to the design of Prof. E. Buchar was introduced. In the 70ies years the construction was further improved by the Research Institute for Geodesy, Topography and Cartography (VUGTK, now located in Zdiby), which is producing the instrument under the name 1000/100.

The enterprises Srb & Stys and Meopta

In the year 1919, the optic-mechanical company Srb & Stys was founded in Prague, which was quickly developing, mainly thanks to military orders. The success of the company lay especially in the modern system of factory production and also in the fact, that the enterprise gained a number of excellent mechanics, which were raised by the enterprise of the Fric Brothers. Already since the year 1923, a complete line of geodetic instruments and tools was being produced. Also were produced instruments for special purposes, e.g. for the measuring of the water level. Among the most successful constructions was the triangulation theodolite (screw microscopes, reading precision by estimation of 1"), the school theodolite Th S, the theodolite TN 25 and the technical leveling instrument NN 25.

After the year 1945, on the foundation of the geodetic department of the company Srb & Stys, the state enterprise Meopta Praha - Kosire was created, which adopted the manufacturing program. In the enterprise worked a number of designers (A. Holy, Höger, A. Dvorak), which in time caught up

the set-back, caused by the war, and reached a solid European level. In the catalogue from the year 1961 was offered a modernized version of the theodolite TH 30x (metal rings and reading by verniers of 30'') and the type $T1^{c}$ from the year 1955 (glass rings and reading by simple optical micrometer with estimation of 20^{cc} (2 mgon), for the army it was equipped with a periscope). From our own experience we can confirm, that these instruments were almost indestructible. In the catalogue were further a balloon (meteorological) theodolite, a topographic set, the construction leveling instrument NK 30x with a glass minute ring, the older small (so-called pocket) instrument KNK 8, 8x and the novelty MN 10x.

In the same year, the professional public was introduced to the development of a complete line of geodetic instruments, excellent in their functions and their designs. Among the theodolites, these were MT 0 for rough tasks (enlargement 15x, reading of 5^{c}), MT 10 (28x, 1^{c}), which in the version with an automatic index for the vertical ring had the name MT 11 and the prepared MT 20 (28x, 10^{cc}) and the seconds MT 30 (34x, 1^{cc}). The line was completed by school and compass theodolites and of course a complete line of accessories. None of these instruments came into practical usage, because already in the year 1963, the production was suddenly canceled by directive and delimited in the context of the then Council of Mutual Economical Help; the enterprise with a new program was incorporated into the ZPA. A little better - at least from the view of the history of land surveying - was the situation for leveling instruments, where was developed the type MN 20 with a micrometer, designed for precise leveling and the construction type MN 10, which went into production. The last produced model was the elegant MNK 20 for technical leveling with an automatic adjustment of the measuring line by help of a compensator.

CONCLUSION

This paper was focusing only on the production of the most typical geodetic instruments. Purposely were excluded the photogrammetric and map-reproduction instrumentation, which was produced in the 20. century by Prague enterprises like Koula, Haager or the Brno Zbrojovka. Not mentioned were the constructions of Czech nationals, which were produced during the monarchy outside of the territory of Bohemia or instruments and specialized set-ups esp. for astronomic-geodetic purposes.

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