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Flat Pattern Sheet Brass Development in Trombone Bell Making. The Graslitz Method

This paper takes a practical approach to developing 2D, flat, sheet brass bell patterns for brasswind instruments, as taught at the Imperial and Royal Musical Instrument-Making School in Graslitz. This study includes a geometric analysis of 23 functional flat sheet brass bell patterns and their corresponding mandrels from the collection at the Bundesfachschule für Musikinstrumentenbau Ludwigsburg. These results were compared with two 1920s drawings by Max Rölz, which provided essential insights into the method used. Our analysis demonstrates that the Graslitz Method offers a reliable framework for creating bell patterns. However, it still requires empirical work and trial-and-error adjustments. Despite its limitations, the Graslitz Method remains a valuable tool in contemporary brasswind instrument-making.

Introduction

The musical characteristics of a trombone bell are defined by its shape, surface conditions and vibrational behaviour. Consequently, the study of the parameters that have an impact on these aspects is an integral part of historically informed brasswind instrument-making. In addition to the chemical composition and metallurgical characteristics of the raw materials used, other parameters – such as wall thickness, the annealing temperature applied, the annealing time, rate of deformation and the metal spinning tools used – will influence the vibrational behaviour. From a practical point of view, the degree to which the brazed flat sheet metal pattern has to be deformed in order to bring it into a 3D shape on the mandrel is of particular relevance for the eventual vibrational behaviour of the bell. This in turn depends on how accurately the flat pattern is prepared. Since very few sources offer any insight into this procedure, unfolding a flat sheet brass pattern from a known mandrel shape presents a considerable obstacle to brasswind instrument makers. In his book *Metallblasinstrumentenbau* (1970),[1] the brasswind instrument maker Carl Nödl describes a methodological approach that was taught at the Imperial and Royal Musical Instrument-Making School in Graslitz (now Kraslice, Czech Republic).[2] This method is referred to in this paper as the 'Graslitz Method'. Unfortunately, Nödl's description is lacking in both adequate detail and practical examples, which leaves a gap between theory and praxis. In 2017, two drawings made in Graslitz by Max Rölz in the 1920s were discovered at the workshop of the brasswind instrument maker Walter Nirschl in Geretsried. These two drawings (Figs. 1 and 2) provide all the information needed to decrypt Nödl's description.

1 Nödl 1970, tables 99–99a. This book is based on Nödl's handwritten manuscript, edited by the South-Bavarian Guild of Brasswind Instrument Makers and published posthumously.
2 Dullat 1997, p. 146. See also Dullat 2010, pp. 349f.

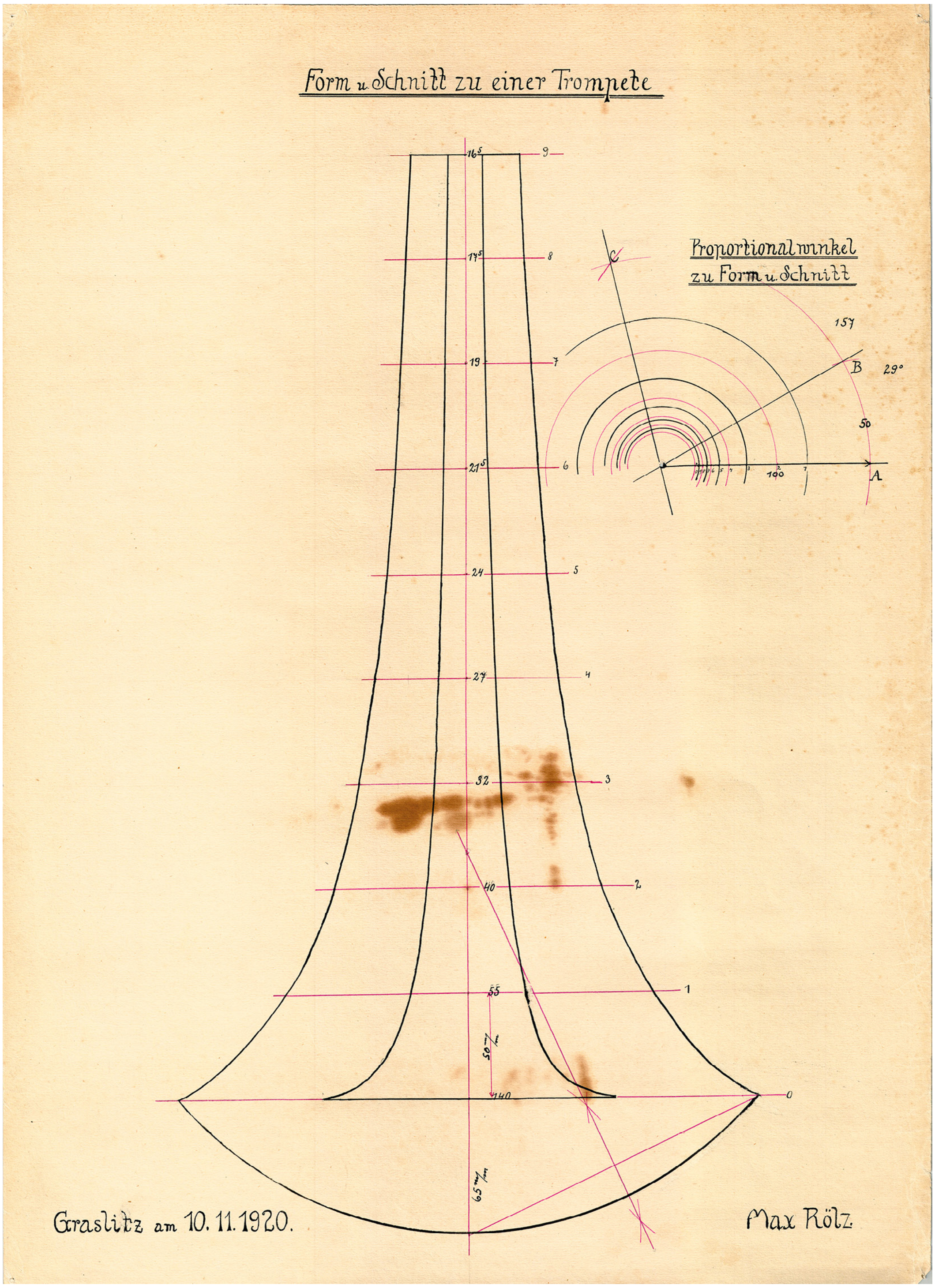

Fig. 1 Drawing of a trumpet bell pattern by Max Rölz (Graslitz, 10 November 1920).

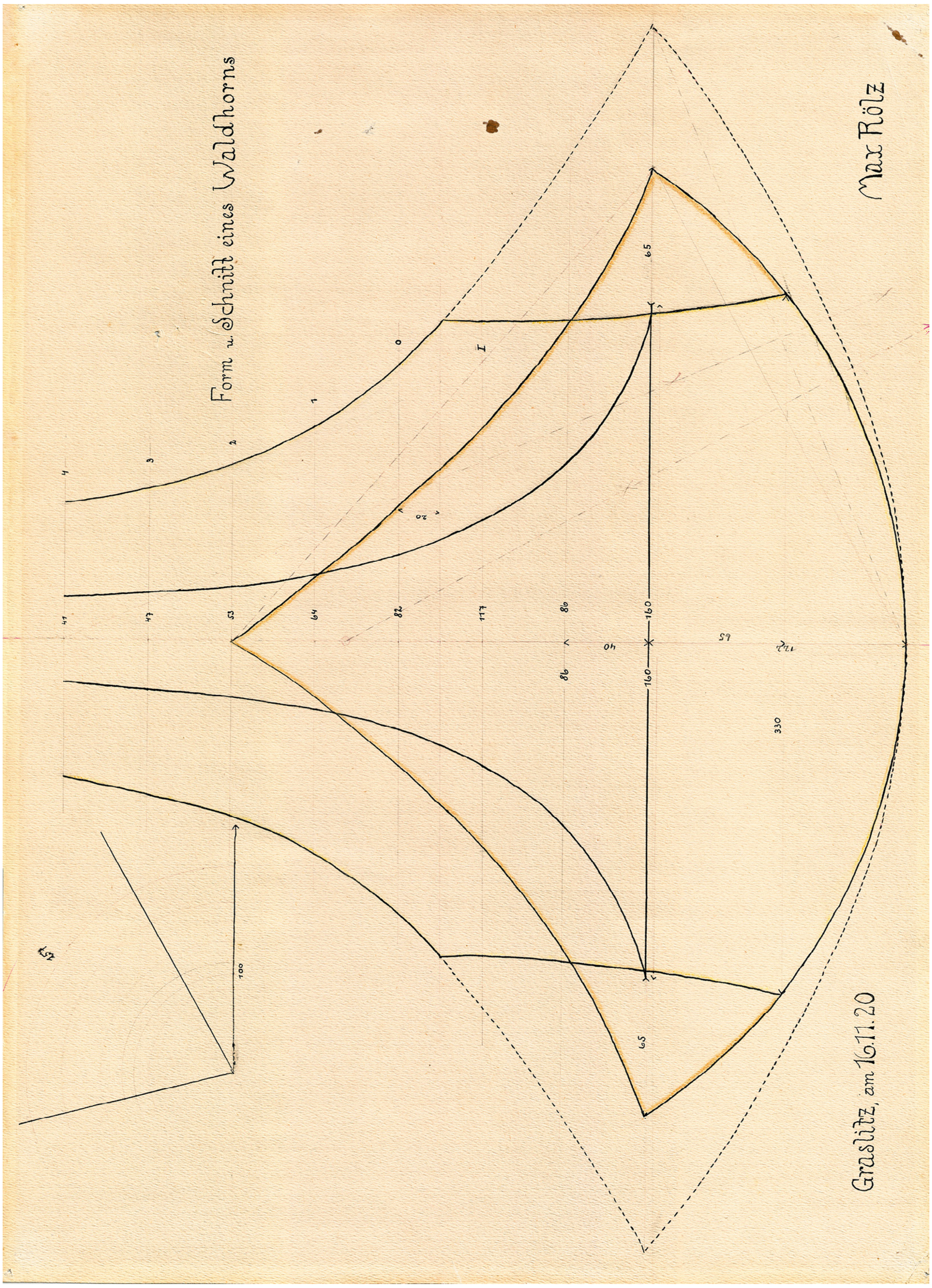

Fig. 2 Drawing of a horn bell pattern by Max Rölz (Graslitz, 16 November 1920).

The main purpose of this article is to provide both a deeper theoretical and practical understanding of the principles of the Graslitz Method as they were taught at the Musical Instrument-Making School and used in the workshops of the town and region. To this end, a geometrical analysis of twenty-three functional flat sheet brass bell patterns was conducted. These, and the associated mandrels, belong to the collection of the Bundesfachschule für Musikinstrumentenbau Ludwigsburg. The results of this analysis were checked against Rölz's drawings. Furthermore, in order to investigate the significance of the Method for the praxis of brasswind instrument-making today, it was applied in the development of a flat sheet brass pattern for a given trombone bell mandrel.

The rest of this article will discuss the following topics: (1) the geometrical analysis of a functional flat bell pattern; (2) the working principles of the proportional compass as used in the Graslitz Method; and (3) a step-by-step application of the Graslitz Method using a practical example. We shall conclude with a summary, highlighting the advantages and limitations of the Graslitz Method for brasswind instrument-making today.

Geometrical analysis of a functional flat bell pattern

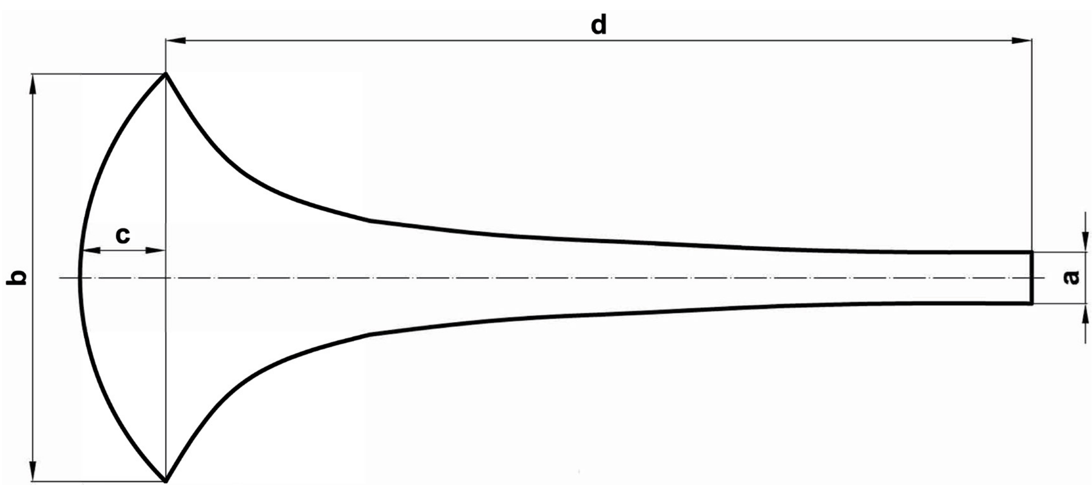

Fig. 3 Core dimensions of a flat bell pattern.

Figure 3 shows the four core dimensions of a flat bell pattern: the minimal pattern width (a), the maximal pattern width (b), the arch rise (c) and the length of the pattern without the arch rise (d). In order to gain insight into how the shape of the bell correlates with a flat sheet pattern, the geometry of the aforementioned 23 functional bell patterns and associated bell mandrels of different kinds of brasswind instruments were analysed. This analysis demonstrated that the maximum pattern width exhibits a proportional relationship to the circumference of the largest bell diameter. Furthermore, the arch rise of the pattern is similarly proportional to the maximum pattern width. It was noted that the total length of the pattern, excluding the arch rise, did not correspond to the surface line of the bell. Our most important insight was perhaps that the width of the pattern appeared to be smaller in the significantly flaring part of the bell than the associated circumference of the bell diameter.

A statistical analysis of the geometrical data showed that the proportional relationship between the maximum pattern width and the circumference of the largest diameter reaches a value of between 58% and 68%. Figure 4 shows that 50% of the measured data exhibits val-

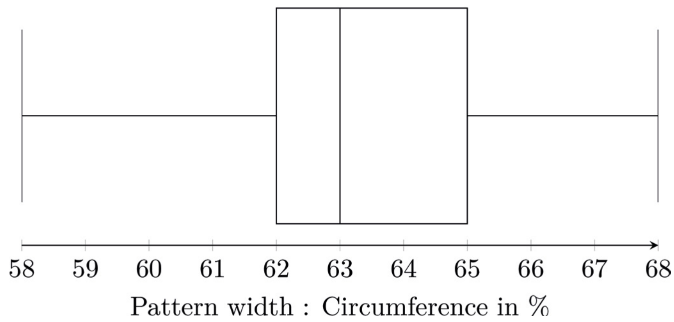

Fig. 4 Ratio of pattern width to circumference of the largest bell diameter.

ues between 62% and 65%, with a median of 63%. However, flügelhorns and trumpets feature somewhat higher values when compared to the bell patterns for horns.

The proportion between the arch rise and the maximum pattern width shows values measured between 19% and 29%, with a median of 22%. 50% of the values fall between 20% and 25%. Bell patterns for horns and trombones feature rather higher values than those for trumpets.

Fig. 5 Ratio of arch rise to pattern width.

The proportional compass

A proportional compass is a geometrical calculation aid that was known to craftsmen as early as the sixteenth century.[3] In graphic design, a proportional compass is applied to scale drawings.[4] It can be used in musical instrument making, for example, to design a violin-scroll or to lay out the labium of an organ pipe. The working principle of the proportional compass is based on the first theorem of intersecting lines. It is used in the bell-patterning process to determine half of the circumference of the bell mandrel at a specific point. Using the law of cosines, the aperture angle of an isosceles triangle with a leg-length equal to the diameter and a base of half the circumference can be calculated as 103.51°.

Assuming that one wants to determine half of the circumference of a circle with a diameter of 60 (or 100) mm, one could draw, in such an isosceles triangle with an angle of 103.51°, a circle with its centre at the intersection point of the two legs, with a radius that equals 60 (or 100) mm (see Fig. 6). This circle will intersect both legs of the isosceles triangle. If one connects these points, the length of this line will be exactly half of the circumference (thus 94.24 or 157.07 mm respectively for a diameter of 60 or 100 mm). This length can be easily transferred to a flat brass sheet using a pair of compasses. Today, the use of the proportional compass can be

3 See Galilei 1606.
4 See Meyer 1890, p. 18.

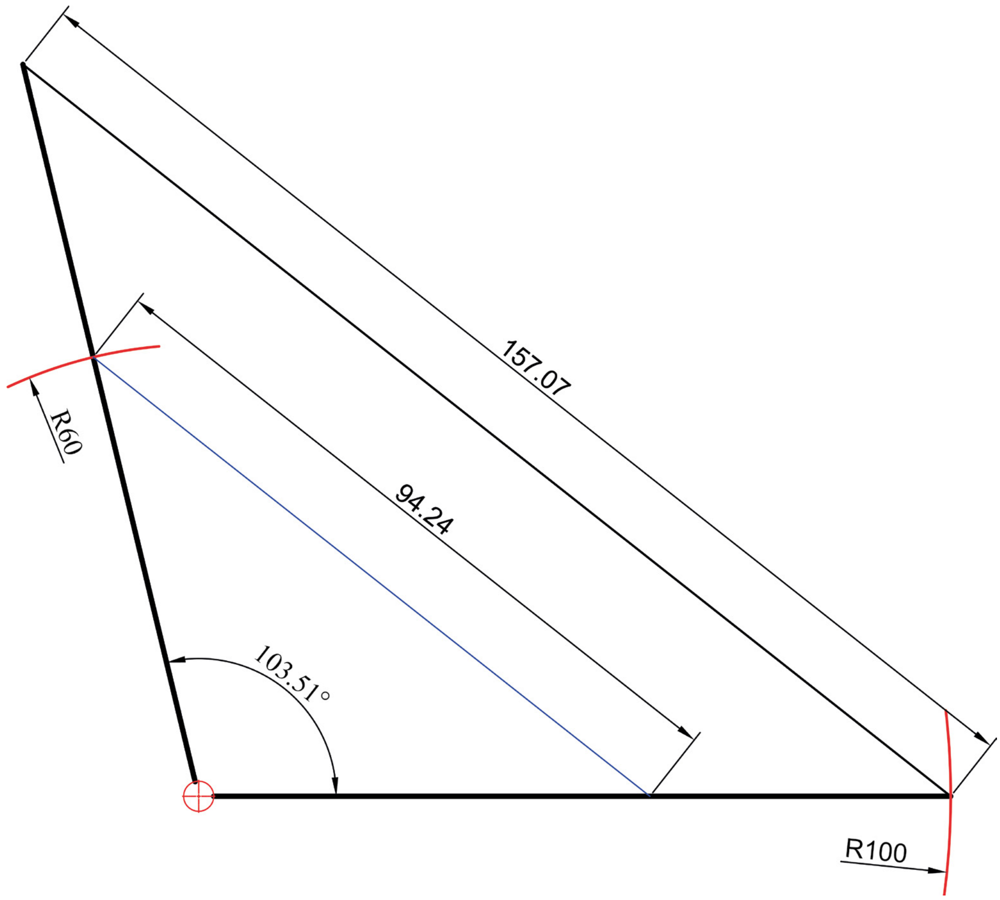

Fig. 6 Principles of the proportional compass as applied in the Graslitz Method.

replaced by a spreadsheet. From a practical point of view, the advantage of the proportional compass method is that it is easy to handle, fast and reliable. Furthermore, it requires only compass, ruler and pencil.

Trombone bell patterning using the Graslitz Method

In order to verify the Method in praxis, it was employed for the flat patterning of a trombone bell, using a spreadsheet, software designed for numerical computations and a 2D-CAD program. The spreadsheet was used to process the data measured and to calculate the circumference and arch rise. Computational software was used for the cubic spline interpolation, while the 2D-CAD program was used to draw the bell pattern. The drawing was then printed at a scale of 1:1 and used as a template to cut the pattern out of the sheet brass.

The initial starting point of the Graslitz Method is the measured bore profile, given as a list of x and y coordinates. Here the x-value represents the distance from the zero-point in mm, while the y-value represents the diameter in mm at point x. It is important to smooth the measured data, in order to filter out potential measurement errors.

The principal challenge in designing a flat pattern for a trombone bell is that the bell is composed of a developable part and a non-developable part. A developable surface is one that can be flattened into a plane without stretching or compressing. Cylindrical and conical surfaces are developable because their outline curves are straight-lined from all viewing angles.[5] The

5 Köhlert/Strohmaier 2002.

quasi-conical stem of the bell is developable, and as such, the circumference can be supposed as the pattern width. Seaming the pattern together, both sides overlap, which makes the pattern a few millimetres smaller. However, this is equalised since the forging of the brazing seam makes it wider again. The flare of the bell is non-developable because it exhibits a double curvature. It is curved along the longitudinal axis and also towards the bell end. The point at which the shape of the bore profile is not developable can be found by trial and error. In the non-developable part of the bell, the pattern width should be somewhat smaller than the circumference. Nödl indicates that half of the maximum pattern width is double the value of half of the bell; in other words, the pattern width equates to about 64% of the circumference of the maximum bell diameter. This value could also be observed during the analysis of the functional flat pattern.

In the next step, the profile should be divided into a variable number of equal sections. Nödl notes that "the division of the pattern into n-number of equal sections depends on the shape of the bell".[6] By means of trial and error, usable results were achieved for a trombone bell pattern by a division into eight equal sections (see Table 1). Dividing the pattern into fewer sections will result in a narrower bell flare. Nödl provides two examples of a pattern divided into ten equal sections and one into seven equal sections. As can be seen in Figure 1, Rölz divides his trumpet bell pattern into nine equal sections. Furthermore, as can be seen in Figure 2, he divides his horn bell pattern into seven equal sections. For our example, however, the x and y coordinates were sought for eight equal sections. The total length of the bell is 566 mm, and the maximum bell diameter is 235 mm before flanging. Subsequently, one section equals $\frac{566}{8} = 70.75$ mm. The x-y coordinates at each part can be found by using a cubic spline interpolation, setting the interpolation interval at 70.75 mm. This list will provide ten coordinates. The circumference of the first nine diameters equals the pattern width. Half of the maximum pattern width is found by calculating $\frac{\pi \times \varnothing}{2} \times 236.13$ mm = 98.39 mm. Nödl indicates in his drawings an arch rise of 5/24 or rounded 21% as a value for the ratio of the pattern width.[7] Consequently, in our case having a pattern width of 236.13 mm results in an arch rise of $\frac{5}{24} \times 236.13$ mm = 98.39 mm. Using this data, shown in Table 1, the pattern can be drawn by means of connecting a spline through all y-points. In Table 1, "x" represents the distance from the zero-point and "y" the associated diameter of the bell at this specific point. The "width" indicated in Table 1 is thus half of the maximal pattern width calculated at this point.

point	x	y	width
1	0.00	16.55	25.98
2	70.75	18.21	28.59
3	141.50	21.39	33.58
4	212.25	24.98	39.22
5	283.00	29.23	45.89
6	353.75	34.49	54.15
7	424.50	43.97	69.03
8	495.25	67.16	105.44
9	566.00	235.00	236.13
		arch =	98.39

Table 1 Cornerstone data of the exemplary trombone bell patterning using the Graslitz Method.

6 "Die Einteilung der Zuschnitte hängt von der Form des Instrumentes ab" (Nödl 1970, table 99).
7 Ibid., table 99a.

The result was a functional pattern that fit well on the stem of the bell mandrel. It was possible to spin it on the mandrel without an excessive amount of annealing. This first pattern provided a good basis, though in order to turn it into a very good pattern a certain amount of empirical research still had to be done. During this process, it could be observed that the thickness of the raw materials has a considerable effect on how well a pattern fits, as does the distance a bell maker can reach with his metal spinning tools into the flare of the bell. Subsequently, since each workshop has its own specific tools and practices for the use of raw materials, a good functional flat pattern does not automatically work well for another workshop. This depends on the settings of the workshop and on the bellmaker themself. As Tuells and Painter point out in their book on metal spinning: "The distance that metal can be drawn without annealing, can only be learned by experience."[8]

Conclusions

The Graslitz Method is a tried and tested method to develop 2D flat sheet brass bell patterns. It is based on the assumption that a bell profile is to be divided into a variable number of sections whereby all except for the largest can be flat patterned just by calculating the circumference of the associated diameter. The pattern width of the point of the largest bell diameter will be somewhat smaller than the circumference, with a mean value of 63%. The arch rise is proportionally related to the pattern width. A good trombone bell pattern was found by dividing the model into eight parts. This Method provides the maker with a good framework, but further empirical work is needed to derive a very good flat-sheet pattern. As such, it is a method that still requires some trial and error. Furthermore, how well a pattern fits involves several other parameters, including technical skill and a good deal of experience.

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8 Tuells/Painter 1912, p. 17.