ABSTRACT

Title of Dissertation: AN ANALYSIS OF COMMERCIAL SINGLE REED MICROMETERS IN THE U.S. AND THE DEVELOPMENT OF A NEW MANUAL SINGLE REED MICROMETER

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Clarinetists are unendingly frustrated by a lack of consistency in mass produced reeds and the time and money spent searching for a performance-worthy reed. Most clarinetists buy commercial reeds from large companies. In a box of ten commercial reeds, it is fortunate to find even two that would be suitable for performance. A good reed is symmetrical from side to side and maintains a certain slope and proportion towards the center of the reed. When a reed is unbalanced, clarinetists can manually adjust the reed to make it symmetrical, which in turn produces a clear and beautiful tone. In order to identify what areas of the reed require adjustment, clarinetists need to measure the reed's thickness. These measurements are taken with a single reed micrometer, a precision gauge that measures small distances or thicknesses.

There are two single reed micrometers available in the United States: PerfectaReed and the Jeanne ReedGauge. However, these tools have numerous design flaws which make it impossible to achieve accurate and consistent results. When users cannot take accurate measurements of their reeds, they are prevented from being able to

make necessary adjustments to poorly performing reeds. Clearly, a new tool had to be invented to solve this market problem. I set out to invent an improved tool which would correct the flaws found in commercial single reed micrometers. After developing a series of prototypes, I invented the Manual Reed Mapper—known as Mr. Mapper—to serve this market need. Mr. Mapper was tested by ten individuals, and the data collected from these tests prove that Mr. Mapper has measurement consistency of 97%, making it the most accurate and reliable single reed micrometer available in the United States.

AN ANALYSIS OF COMMERCIAL SINGLE REED MICROMETERS IN THE U.S. AND THE DEVELOPMENT OF A NEW MANUAL SINGLE REED MICROMETER

by

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LIST OF ABBREVIATIONS

DRM	Digital Reed Mapper
Dr. Mapper	Digital Reed Mapper
MRM	Manual Reed Mapper
Mr. Mapper	Manual Reed Mapper
PAR1	PerfectaReed Version 1
PAR2	PerfectaReed Version 2

CHAPTER ONE: INTRODUCTION

Clarinetists use a thin piece of wooden cane to produce sound on the instrument. The cane reed is secured to a mouthpiece, and the reed vibrates according to how much air and lip pressure a player uses when blowing into the instrument. Most clarinetists buy commercial reeds from large companies, though some clarinetists make their own. A good reed is symmetrical from side to side and maintains a certain slope and proportion towards the center of the reed. When a reed is unbalanced, clarinetists execute manual adjustments to the reed to make it symmetrical and therefore produce a clear, in-tune, and even tone.

THE PROBLEM

Clarinetists are unendingly frustrated by a lack of consistency in mass produced reeds and the time and money spent searching for a performance-worthy reed. Within a box of ten commercial reeds (priced around $30), it is lucky to find two reeds that would be suitable in performance. Usually three to five reeds in a box are unplayable due to being too hard, too soft, too stuffy, or having a poor tone. Three to five reeds in a box might be adequate for practice or rehearsal purposes but not as performance reeds. A good reed plays in tune, has a pleasing tone, and responds easily. In order to maximize the return on investment of a box of reeds, clarinetists can manually adjust their reeds to address issues of response, intonation, and tone quality. In order to identify where to adjust a reed, clarinetists need to measure the reed's thickness. A micrometer, a precision gauge that measures small distances or thicknesses, is used to measure reeds.

I measured my own reeds with a micrometer in hopes of making them play better through adjustment. If there was a performance-ready reed in a box, I documented its dimensions so the contour could be replicated on other pieces of cane. I noticed from day-to-day I might capture different measurements of the same reed, a seemingly normal occurrence due to the reed's increase or decrease in internal humidity causing the reed to expand or contract. Measuring my own reeds showed that certain brands tended to be thicker on one side of the reed, which made me question if companies were sending customers consistent reeds. Were reeds cut consistently within a box, across boxes of the same brand, and across brands? Were companies delivering reliable and high-quality reeds as they promised? Theoretically, all reeds of the same strength were cut to identical dimensions because companies used state of the art digital measuring tools and laser cutting.

The original idea for this research was to provide an analysis of the consistency of clarinet reeds across brands at the consumer's hand. I thought if I could compare the consistency of reeds across a single brand, general inconsistencies could be identified. For example, was there statistically significant evidence that the left side of Vandoren V12 reeds tended to be thicker than the right side? If that were the case, then I could draw conclusions about which manufacturing process might be causing measurements to skew heavier on one side. I thought if I could compare reed consistency across multiple brands, the data would reveal which company had the most consistent reeds, and likely the most accurate and reliable manufacturing process. Therefore, clarinetists might choose that company over another and finally enjoy consistently cut, high quality reeds.

RESEARCH

It was difficult to choose a starting point from which to analyze the quality and consistency of a reed. An assessment of reed quality is subjective and based on a player's preference, equipment, environmental conditions, and the temperament of an uncontrollable and unpredictable organic material. What should be the starting point for analysis? Should analysis go all the way back to the beginning of a reed's life when and where was harvested? Should analysis start where the reed reached the manufacturing facility? Should the distribution process be considered? Because everything up to the moment a player opens a package of reeds is out of the consumers' control, I chose not to analyze any activities which occurred before the player opened the box.

Now a consumer has opened a box of reeds. There is nothing they can do about the quality of cane they received. Among the many variables which affect cane quality are density, flexibility, warpage (if the reed was packaged warped), cane color, harvest date, aging period, manufacturing date, and internal humidity. There are of course instruments capable of measuring these characteristics, but the average consumer does not own such specialized tools, and they are unlikely to be willing to pay more than $500 for tools that could improve reed performance. With all of these uncontrollable and subjective variables at play, I chose to analyze reed thickness. Reed thickness is the only objective quality because it can be measured with a reed micrometer.

TESTING

I decided to conduct test measurements on various brands and cuts of reeds. To minimize the effects of humidity, age, and deterioration of the cane's physicality, a

measurement methodology was established to ensure that measurements were taken at the same moment in a reed's life (straight out of the box), with the same tool (PerfectaReed), with the same person conducting each measurement (myself), and the same order of measurement taken every time (starting from the tip of the reed).

In December 2018, I began measurements on brand new D'Addario Reserve Classic 4+ B♭ clarinet reeds using the PerfectaReed single reed micrometer. At some point, I became curious about how I might determine my own ability to measure consistently. Was I measuring every reed the same way every time? Were my results truly comparable? To test this, I measured the same reed three times in a row, at which point it was discovered that there was variation in the recorded dimensions. The error was not drastic in the uppermost portion of the reed (no more than one-thousandth of an inch), but as the reed's slope increased the error was exacerbated to a difference of two- to three-thousandths of an inch. When measuring such a small subject, every thousandth of an inch is important, and every adjustment can completely alter the feel and response of a reed. Thinking this error could possibly be due to the reed absorbing or losing moisture rapidly after it was removed from the box, the same measurement procedure was repeated on plastic Légère reeds, reeds which do not change over time in response to environmental conditions. Again, I found discrepancies between measurements of the same plastic reed despite my best efforts to measure precisely.

Frustrated by an inability to repeat results, I partnered with Robert DiLutis to have a second person conduct these measurements. After I measured a reed and documented the dimensions, DiLutis would measure the same reed and record the results. These measurements were compared, and the inconsistencies between two individuals were

even greater than those found in repeat measurements by one person. We theorized the discrepancy could be due to differing measuring procedures, so in an effort to standardize the physical measurement gestures, we discussed exactly how to guide the reed with the hands and where to place the tip to unify how each of us executed measurements. Even still, the differences between sets of readings sometimes reached four-thousandths of an inch. This discovery generated a new set of questions. Why was it impossible for an individual to achieve the same results measuring the exact same reed multiple times? Why was it not possible for two individuals to achieve the same results after standardizing the measurement process? The conclusion was there were key design flaws in the micrometer which made it impossible to replicate measurements.

A NEW RESEARCH DIRECTION

Up to this point, the only micrometer used for test measurements was the PerfectaReed. After its inaccuracies were discovered, I sought out other micrometers because if another tool were deemed reliable for measurements, the research project could continue as planned. Two tools emerged: a 1969 version of the PerfectaReed (hereafter referred to as PerfectaReed Version 1, for the sake of differentiating the two versions discussed in this document), long since retired, and the Jeanne ReedGauge. I conducted similar measurement tests on both tools. While these tools demonstrated superior consistency compared to PerfectaReed Version 2 (used in the first series of test measurements), they too were incapable of producing identical measurements. They shared some design flaws with PerfectaReed Version 1 and had idiosyncratic flaws unique to their designs. Left with no reliable tool with which to conduct my research, a

new project emerged. I chose to invent a new single reed micrometer which corrected flaws found in commercial single reed micrometers.

There are no documents that examine the tools with which woodwind players measure their reeds. There are numerous articles, dissertations, and other documents devoted to adjacent topics: cane's scientific properties and structure, reed storage and maintenance, reed adjustment suggestions from individuals based on anecdotal experience, cane harvesting, and reed production. However, no one has analyzed the accuracy and reliability of commercial single reed micrometers. Indeed, no one knew the accuracy of commercial micrometers should be questioned, as it was just assumed the inventors, engineers, and manufacturers perfected the apparatus. It was in my quest adjusting reeds to perform at a higher level that I began doubting the accuracy of the tools I used to execute measurements.

The rest of this chapter provides a brief overview of clarinet reeds and reed manufacturing to contextualize the following discourse on reed micrometers. Chapter Two provides analysis of the positive and negative features of three commercial reed tools: PerfectaReed Version 1 (1969, only available through second-hand sellers), PerfectaReed Version 2, and the Jeanne ReedGauge. Chapter Three provides the framework of the improved reed tool, while Chapter Four describes the invention process of the Manual Reed Mapper. In Chapter Five, the inception of a digital micrometer is discussed. Chapter Six outlines the methodology used to test the reliability of the Manual Reed Mapper and provides results of test measurements. Appendix A provides supplementary information about reed manufacturing, how to care for and adjust reeds, and factors affecting reed playability other than thickness. Appendix B includes product

descriptions and usage instructions of single reed micrometers as stated by their inventor or production company. Appendix C contains test measurement data collected using prototypes in the development of the Manual Reed Mapper and the final marketable product, Mr. Mapper.

SCOPE

The purpose of this document is to provide an analysis of the flaws found in commercial single reed micrometers in the United States, outline characteristics of an improved reed tool, and take the reader through the invention process and final product construction of the new micrometer, the Manual Reed Mapper. This dissertation is written with the assumption that clarinetists purchase reeds from commercial reed companies and cannot control for all the variables that affect a reed's playability before it arrives at a consumer's door. Three micrometers were analyzed, as these are the only tools available in the U.S., and of those three, only two are still being produced. Supplementary information adjacent to reed micrometers has been confined to the appendices.

Discussion of Scope

While clarinetists and saxophonists may be familiar with the terms used in this text, a glossary of terms is available at the end to clarify jargon used in the discipline. The following points apply to the scope of the body of this document.

- Statements regarding cane reeds refer specifically to single reeds, such as those used for clarinets and saxophones, as opposed to double reeds (two pieces of cane tied together used by instruments such as oboes and bassoons).

- Outside of Chapter One, “micrometer” always refers to a micrometer adapted to measure single reeds, as opposed to a double reed micrometer or micrometers unrelated to music.
- Reed micrometers use both the metric and Imperial systems and will be specified as such on a per tool basis. Reed micrometers measure in hundredths of millimeters and/or thousandths of inches.
- In this context, the definition of “consistency” is having the same thickness across reeds of the same brand’s reed cut.
- Generally, statements referring to clarinetists may also apply to saxophonists, as they are single reed instrumentalists as well.
- Reeds are graded by “strength,” a measure of how resistant a reed feels at the player’s lips. Clarinetists use the words “strength,” “thickness,” and “hardness” interchangeably, though in this document “thickness” always refers to the literal quantifiable thickness of a reed. The strength is positively correlated with the thickness of a reed. Companies use strength values in the range of 2 to 5, with 2 being the least resistant and 5 being the most resistant. The average clarinetist might play a 3 or 3.5 strength reed. Thicker reeds (higher strength) feel resistant, and thinner reeds feel open and free (lower strength). Sometimes a thin reed may feel as resistant as a reed one degree thicker due to the quality of the cane, so the feeling of resistance is not an accurate measurement.

AN OVERVIEW OF REEDS

Cane reeds are used to produce sound on clarinets and saxophones. The major reed companies are Vandoren Paris and D’Addario (D’Addario acquired Rico in 2004), both with production based in southern France.[1] Reeds are made from *Arundo donax*, a plant similar in appearance to bamboo cane, though not as hard. Within a year, *Arundo donax* grows to full size, and it takes two years to dry after it is harvested.[2]

In the reed manufacturing process, the cane is cut into tubes at each node, then split into four long pieces, cut to reed blanks (the first rough cut of a reed), and given its

[1] Christian Wissmuller, “D’Addario’s Robert Polan on the Rico Acquisition,” last modified January 23, 2014, accessed December 5, 2019, https://mmrmagazine.com/issue/upfront-q-a/d-addario-s-robert-polan-on-the-rico-acquisition/.

[2] Eberhard Frost, “Reeds,” The Clarinets, accessed October 20, 2019, http://www.the-clarinets.net/english/clarinet-reed.html.

final series of cuts to create the finished reed. Commercial reeds are packaged in individual plastic sleeves and sold in sealed boxes of ten reeds. Boxes are shipped to distributors and individual players around the world. For readers seeking further detail on cane harvesting and manufacturing, see Appendix A.

Performers produce sounds by fashioning a reed to a mouthpiece, which is attached to a musical instrument, and blowing air through the instrument, vibrating the reed to produce tones. The anatomy of a reed is labeled in figure 1.1 and will be the guide for this document's description of reed parts. Figure 1.2 demonstrates how a B♭ clarinet reed is secured to a mouthpiece.

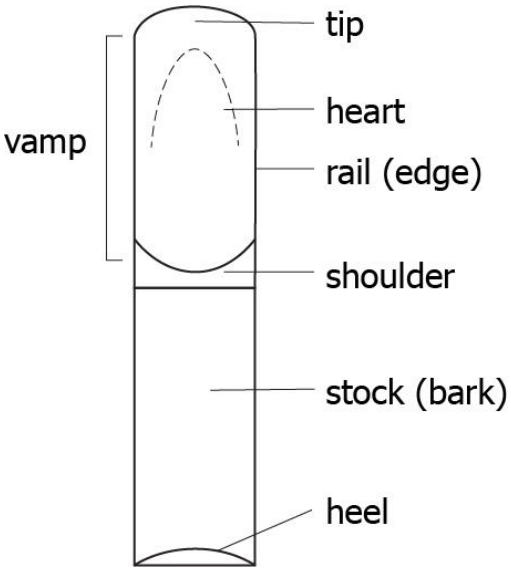


Figure 1.1: Anatomy of a reed.
Source: Peter Spitzer, "Adjusting Saxophone and Clarinet Reeds," Hope Street Music Studios, accessed February 11, 2019, http://www.hopestreetmusicstudios.com/articles/adjusting-saxophone-and-clarinet-reeds.

Figure 1.2: B♭ clarinet reed fashioned to mouthpiece.
Photograph by Natalie Groom.

REED MICROMETERS

Reeds are measured with a tool known as a micrometer. Micrometers are precision gauges used to measure small distances or thicknesses. These instruments have readout divisions in hundredths of millimeters or thousandths of inches. Because reeds are so small and the slightest variation can determine whether a reed is "good" or "bad," accuracy is imperative. A standard micrometer has a rated accuracy of ±0.0001 inch.[3]

A basic micrometer includes a dial indicator which displays numeric measurements, a dial tip which contacts the surface being measured for thickness, and a base against which the dial tip rests when not in use. This base is the "zero" point, or the benchmark position against which everything will be measured for distance or thickness. Micrometers can be adapted to measure reeds, either single reeds or double reeds. Figure 1.3 shows the front of a standard single reed micrometer, the PerfectaReed Version 2, and figure 1.4 shows a side view of PerfectaReed Version 2 complete with the company's nomenclature. While this nomenclature is not universal to single reed micrometers, it provides a glimpse into the various possible components of a single reed adapted micrometer.

[3] "General Micrometer Information," Starrett, last modified July 16, 2011, accessed December 6, 2019, https://web.archive.org/web/20110716132738/http://www.starrett.com/download/222_p1_5.pdf.

Figure 1.3: PerfectaReed Version 2 clarinet and saxophone reed micrometer.
Source: "Reed Wizard PerfectaReed," The Reed Wizard, accessed October 22, 2019, https://www.amazon.com/Reed-Wizard-Perfectareed-PerfectaReed/dp/B000XZXD7O.

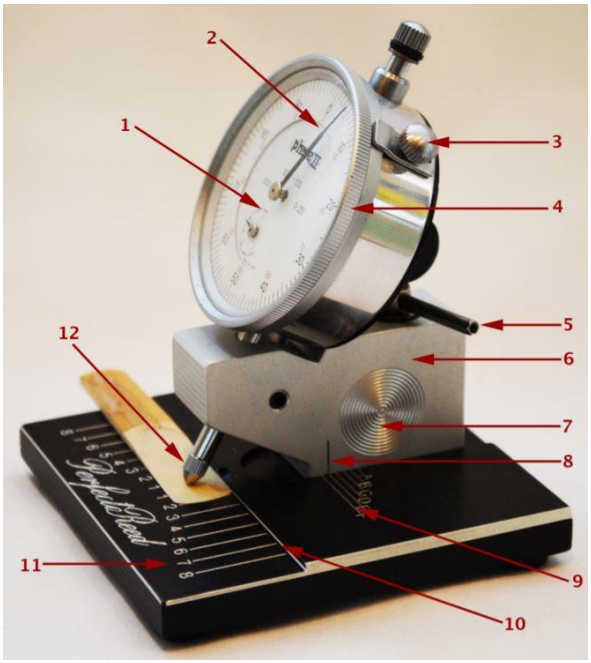


Figure 1.4: Nomenclature of PerfectaReed Version 2.

1.	Dial indicator	7.	Grab circle
2.	Pointer	8.	Black line
3.	Dial screw	9.	Upper base letters
4.	Dial frame	10.	Ridge
5.	Lock pin handle	11.	Lower base numbers
6.	Carriage	12.	Sensor

Source: Ben Armato, "PerfectaReed," The Reed Wizard, accessed April 4, 2019, http://www.reedwizard.com/PerfectaReed Insert.pdf.

To measure single reeds, which have only one curved side, the reed is placed on the numbered base underneath the dial tip. The distance between the base and dial tip against the reed's surface is the thickness of the reed at that point. The reed may be slid along the base to capture dimensions at other points of the reed. There are only two single reed micrometers currently available in the U.S.: PerfectaReed Version 2 and Jeanne ReedGauge. The PerfectaReed has gone through two iterations. The earliest version, referred to as PerfectaReed Version 1 in this document, has been retired and is only available from second-hand sellers such as those found on Ebay.

A second type of micrometer is adapted for double reeds. Because they have curved surfaces on both sides of the reed (literally double a single reed), a double reed micrometer suspends the reed in air, as the reed cannot rest flat on a base, and measures both sides by the user flipping the reed over (figure 1.5).

Figure 1.5: Oboe reed micrometer.
Source: "RDG USA Dial Indicator," RDG Woodwinds, Inc., accessed October 22, 2019, https://rdgwoodwinds.com/products/rdg-usa-dial-indicator?variant=30284602500.

Double reed micrometers are widespread, and many brands and styles are available. If someone were to search for a reed micrometer online, most results would be for double reeds, as this is the standard. Double reed micrometers are highly marketable because professional oboists and bassoonists make their reeds by hand. Everything is hand cut, hand sculpted, and hand adjusted. It is frowned upon for double reed players to purchase commercial reeds, as the quality is generally poor, reeds must be customized to an individual's instrument and preferences, and it is economically unfeasible to only purchase finished double reeds. One finished double reed may cost $20–30, but if a

player crafts a reed by hand, the cost per reed is reduced to $0.25–0.30. By contrast, an entire box of ten commercial B♭ clarinet reeds costs approximately $30.

The economics of double reeds versus single reeds is likely what has driven the widespread availability of double reed micrometers but not single reed micrometers. Double reed players are dependent on micrometers and demand multiple options to accommodate an industry of handcrafted reeds. Single reed players are conditioned to purchasing comparatively cheap mass-produced reeds and enjoy the luxury of throwing a reed away if it does not play as desired. As a result, clarinetists and saxophonists are not as likely to spend time adjusting reeds if they have the disposable income to buy another box and hope for one to three "good" reeds. Thus, companies have not produced single reed micrometers of various brands and styles. The market demand has been small, reserved primarily to the few clarinetists who make and adjust their own reeds. However, as single reed players become increasingly frustrated by the lack of consistency and reliability within a box of commercial reeds, players are seeking options to increase their return on investment. Assume optimistically that a performer deems 50% of their reeds to be concert worthy. Considering the average professional musician burns through one to two boxes of reeds per month, at $30 per box, the amount of money lost on bad reeds in a year is easily in the hundreds of dollars.

The purpose of a micrometer is to allow players to measure a reed's thickness and identify spots that are not symmetrical. Reeds should be symmetrical from left and right of center. Figure 1.6 maps the contour of a sample B♭ clarinet reed. In the columns immediately to the left and right of the center line, the numbers should match if the reed is symmetrical. Similarly, the columns at the reed's rails should match. A reed is sloped

from the tip (thinnest) to the end of the vamp (thickest) and from the rails (thinnest) toward the center (thickest).

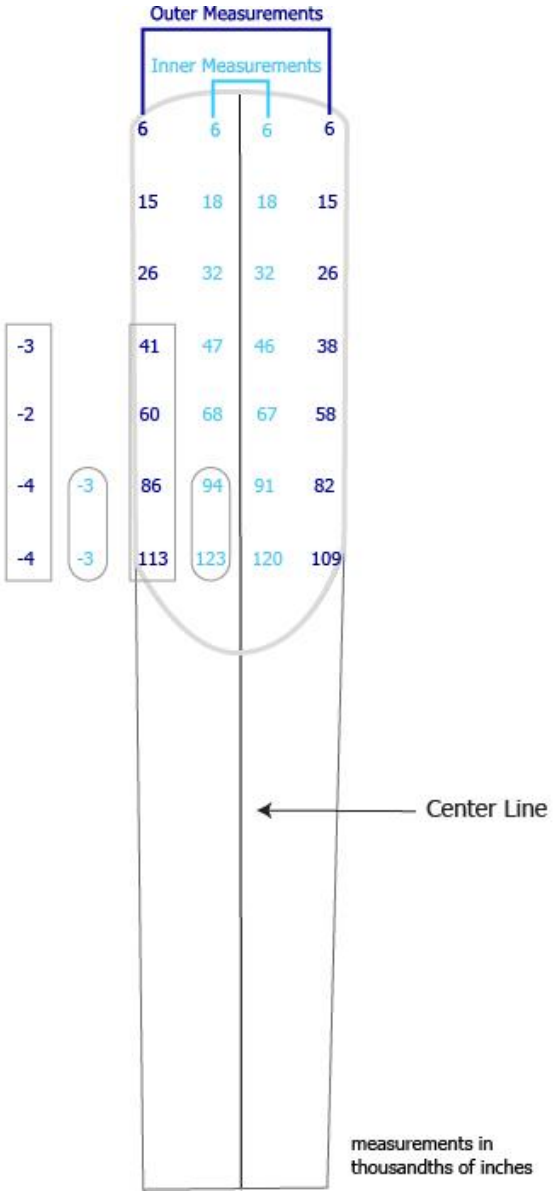


Figure 1.6: Demonstration of lack of symmetry of B♭ clarinet reed.
The numbers indicate the thickness of the reed at a given point in thousandths of inches. Reed should be symmetrical from left and right of the line of symmetry. The outlined numbers identify points which are not symmetrical to their counterparts, and the numbers to the left of the reed indicate how many thousandths of inches of cane should be removed from each point. The rectangular outline to the left of the reed corresponds to the numbers on the reed that are also outlined in a rectangle.
Image by Aishwarya Shettigar.

In figure 1.6, the outlined numbers on the reed denote areas which are not symmetrical to their counterparts on the right side. Presented in thousandths of inches, the left side of this reed is thicker by two- to four-thousandths of an inch in six locations. Once the problem spot is identified, players sand or scrape to make one side even to the other; the outlined numbers to the left of the reed show how many thousandths of an inch should be removed from the six points to make the left side as thin as the right side. Over time and with enough data, a player can identify personal preferences for thicknesses across a reed and adjust accordingly.

CHAPTER TWO: COMMERCIAL REED TOOLS

Commercial reed micrometers include PerfectaReed Version 1 (hereafter referred to as PAR1), PerfectaReed Version 2 (hereafter referred to as PAR2), and the Jeanne ReedGauge. For the sake of this document, the only tools used in test measurements were these three U.S.-based tools, though there are other micrometers available in other parts of the world, such as Reeds 'n Stuff's digital measuring device produced in Germany. Aside from the summary of micrometer flaws and following analysis of each micrometer provided in this chapter, each companies' product description and instructions for their micrometers can be found in Appendix B.

There are several design flaws with commercial micrometers. This section itemizes these faults, including the problematic starting position of the reed tip or heel, reed shifts during measurements, analog dial challenges, cosine error, issues with an angled dial tip, and the possibility of losing parts of a tool.

Tools that start measurements from the reed's rail (see figure 1.1 for reed anatomy) cause multiple problems. The dial tip runs parallel to the ridge against which the reed rests (such as the ridge seen in PAR2, figure 1.4). However, reed rails are not parallel to each other. Reeds taper slightly from the tip (widest) to the heel (narrowest). Figure 2.1 shows the variation in taper across four cuts of the same reed brand (Vandoren). Observe how wide the tip is versus the heel.

Figure 2.1: Vandoren Reeds.
Taper from tip to heel in Vandoren reeds.
Source: "Reeds Technical Elements: The Different Cuts of Clarinet Reeds," Vandoren Paris, accessed February 18, 2019, https://vandoren.fr/en/reeds-technical-elements/.

Suppose a user wishes to measure the center of a reed. If a micrometer aligns the rail of the reed against a ridge, the dial tip will contact everything but the reed's center line because the reed's center is not parallel to the ridge; it is at an angle proportional to the tip width minus the heel width. Figure 2.2 shows the true center of a reed versus what the micrometer captures. The same logic applies to all positions on a reed, but it is easiest to demonstrate using the center line.

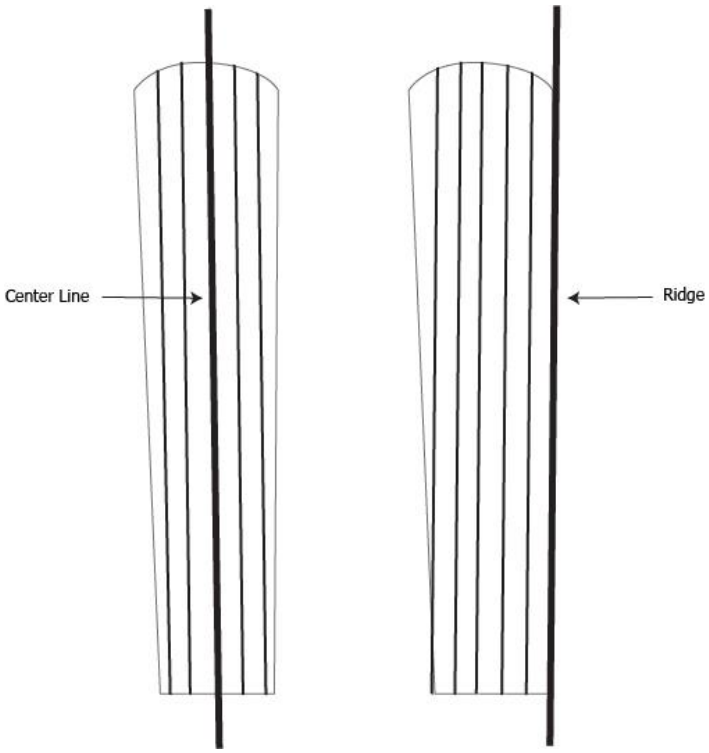


Figure 2.2: Skewed measurements when the reed is aligned to a ridge.
On the left, the lines of measurement are derived from center; therefore, each line is parallel to the center line. On the right, the lines of measurement are derived from the rail against the ridge; each line is parallel to the rail.
Image by Aishwarya Shettigar.

Reeds with minimal taper from tip to heel will have measurements closest to true center because the outer rail is nearly parallel to the ridge. The more tapered a reed is, the more the measurements will be skewed; measurements toward the tip are slightly right of center, and measurements towards the heel drift left of center. Users can still measure reeds and compare across one brand's cut because the amount of error will be uniform when isolated to one reed type. However, suppose a user wants to compare measurements of a Vandoren Traditional and a Robert DiLutis Reed. Because the taper of a Robert DiLutis Reed is more pronounced than a Vandoren Traditional, the degree that the tip drifts from the desired line of measurement will be different between reeds, and the measurements will not be comparable because they fall on different points of each reed.

Another similarly related problem emerges with micrometers aligning reeds to a ridge. Assume for a moment that reeds are not tapered, so a micrometer of this style is capable of capturing a measurement line perfectly centered on the reed. What if the tool does not have a position matching the reed's center when the reed is pressed against the ridge? Indeed, this is the problem with both PAR1 and PAR2. Suppose Position E of PAR2 (figure 1.4) was built specifically to be the true center position of a Vandoren Traditional reed beginning 6.5 mm from the ridge. If another style of reed is measured, the true center might be somewhere between Positions D and E, perhaps 6 mm from the ridge. If so, the dial tip's starting point will be further left of center than the other. Thus, it is impossible to find the true center of a reed or to use the micrometer to accurately compare reeds across cuts or brands. Again, the micrometer can be used to compare reeds of the exact same cut but not across cuts or brands. It is not reasonable to assume a user will stick with the same reed brand and cut their entire life, so it is not practical to own a tool incapable of providing accurate comparisons across brands and cuts.

What about a micrometer that starts measurements from the reed's heel? The Jeanne ReedGauge (figure 2.3) takes this approach. The dial tip is aligned with Position 0 (seen on the outer edge of figure 2.3), and the reed is placed on a sliding table with the heel aligned to a ridge.

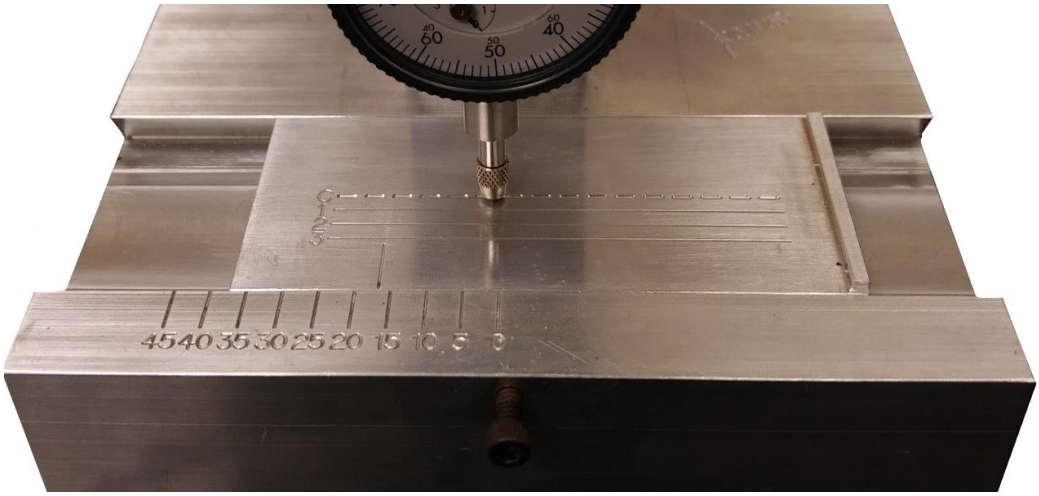


Figure 2.3: Jeanne ReedGauge sliding table.
The reed heel is placed against the raised bar on the right side of the reed table. The upper leftmost part of the reed is aligned to lines 1, 2, 3, or C.
Photograph by Natalie Groom.

This design eliminates the problem of the dial tip drifting from a reed's center but introduces a new issue. Suppose Position 0 of the Jeanne ReedGauge was built specifically to begin measurements 2 mm from the tip of a Vandoren Traditional reed, and a Vandoren Traditional reed is 67 mm long from tip to heel. If another style of reed is measured that happens to be 69 mm long, Position 0 will begin 4 mm from the tip of the reed, a difference of 2 mm from the Vandoren Traditional which will then trickle down a difference of 2 mm in all following measurements beyond Position 0. Thus, it is not possible to compare measurements of different styles of reeds when the starting position is variable due to a reed's length.

No commercial tools hold the reed in place to prevent it from drifting while taking measurements. With PAR1 and PAR2, the user slides the reed with their hand. With Jeanne ReedGauge, the user moves the reed table. The reed can drift from the guide line due to friction between the dial tip and cane as the reed table slides. It is also difficult to ensure the reed remains in the same position at all times, as it is impossible for the human

eye and hand to execute consistent placement and motion across hundreds of reed measurements.

Every commercial micrometer in the U.S. has an analog clockface dial. Analog dials introduce room for human error, tie a user to measuring in either inches or millimeters (not both), and they are inefficient. The clockface can be difficult to read properly due to how small the lines and numbers are, and it requires recalibration over time as environmental conditions change. Recalibration is particularly tedious with PAR2 because the dial must be recalibrated every time the carriage is moved from Position A through E (figure 1.4).

An accurate measurement comes from a dial tip measuring perpendicular to a flat surface. Because the surface of a reed is curved, there is cosine error present when measuring reeds with a micrometer. Cosine error occurs when measuring a surface at an angle, whether the dial indicator is at an angle or the measurement subject is at an angle. The wider the angle, the greater the error. Figure 2.4 demonstrates this mathematical principle along an angled surface.

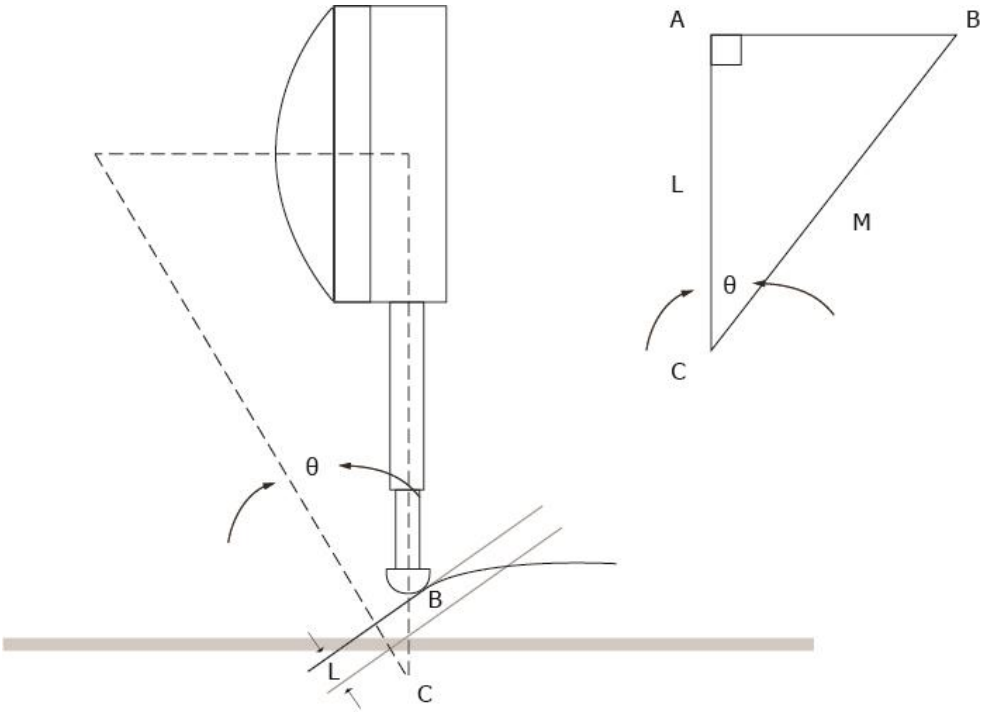


Figure 2.4: Cosine error example.
The curved figure under the dial tip represents the surface of a reed.
L = Length to be measured
M = Actual measurement
$\text{Error} = M - L = M - M\cos\theta = M\,(1 - \cos\theta)$
Source: Adapted by Aishwarya Shettigar from Santosh B., "MQC On Mechanical Engineering," LearnPick, 2015, accessed October 22, 2019, https://www.learnpick.in/prime/documents/ppts/details/4353/mqc-on-mechanical-engineering.

Observe how the dial tip is not flush with the surface being measured. The right edge of the tip contacts the surface which provides a false reading that is thicker than the point truly at the center of the dial tip along the dotted line. Essentially, the tip does not make contact perpendicular to the reed; the tip is measuring along an angled surface. This effect is exacerbated the thicker the reed gets, as the curvature steepens and the angle is more pronounced.

There is no way to eliminate cosine error when measuring reeds in the context of the micrometers discussed in this document. The standard dial tip of most micrometers is quite wide considering the surface area it is meant to measure. However, cosine error can be reduced if a thinner dial tip is used. Figure 2.5 provides a highly magnified view of the ball tip end of a dial indicator making contact with an angled surface, which represents the reed. The amount of cosine error is shown by the arrow bracket. Now suppose the tip is reduced in size. Figure 2.6 demonstrates this thought experiment and shows that a smaller tip leads to a smaller angle between the tip and the surface, resulting in reduced cosine error.

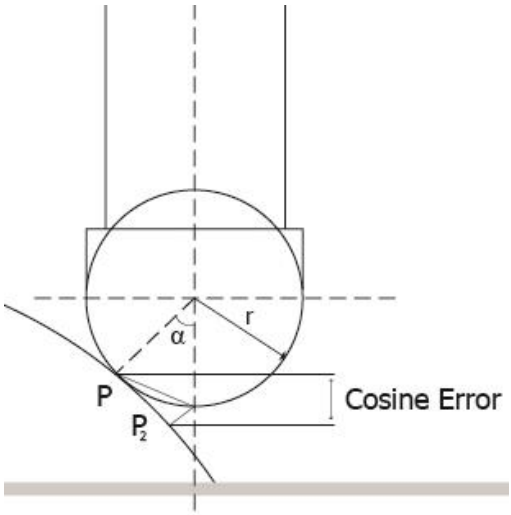


Figure 2.5: Cosine error example with thick dial tip.
P is the Point of Contact.
P_2 is the Theoretical Point.
r is the radius.
a is the angle.
The cosine error is the difference between P and P_2.
Source: Adapted by Aishwarya Shettigar from Zhaolin Han and Maoxing Yuan, "Research on the Vector Measure Method of Coordinate Measuring Machine," *Key Engineering Materials* 561 (July 15, 2013): 574, https://doi.org/doi:10.4028/www.scientific.net/KEM.561.572.

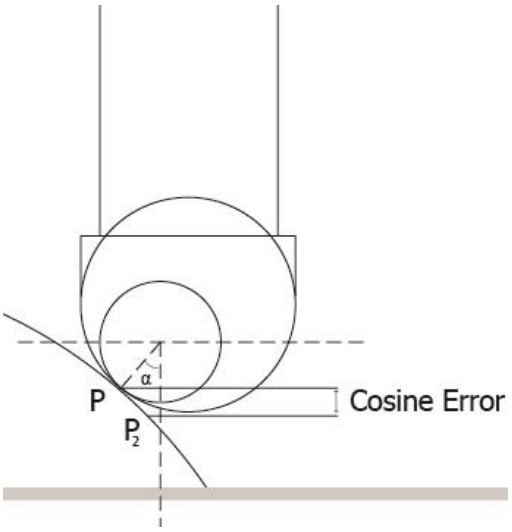


Figure 2.6: Cosine error reduced with thinner dial tip.
P is the Point of Contact.
P_2 is the Theoretical Point.
a is the angle.
The cosine error is the difference between P and P_2. The error is reduced when the diameter of the dial tip is reduced.
Source: Adapted by Aishwarya Shettigar from Zhaolin Han and Maoxing Yuan, "Research on the Vector Measure Method of Coordinate Measuring Machine," *Key Engineering Materials* 561 (July 15, 2013): 574, https://doi.org/doi:10.4028/www.scientific.net/KEM.561.572.

Tools with an angled dial tip, such as PAR2, introduce yet another problem. An angled dial tip will produce inconsistent measurements because the dial tip minutely pushes the reed away from the ridge. This effect becomes more pronounced as the reed gets thicker and the slope is steeper; the dial tip drifts towards the outer rails of the reed. Perhaps having an angled dial tip reduces cosine error because the dial tip makes contact with the reed at a point closer to the center of the dial tip. However, the angled dial tip is not helpful if it pushes the reed away from the ridge, even if it did minimize cosine error, and once the tip passes the center of the reed (a position which changes on a per reed basis), the cosine error is at its worst when the backside of the dial tip is against the reed's surface. Figure 2.7 demonstrates that there is no true point of reference without cosine error when the dial tip is at an angle.

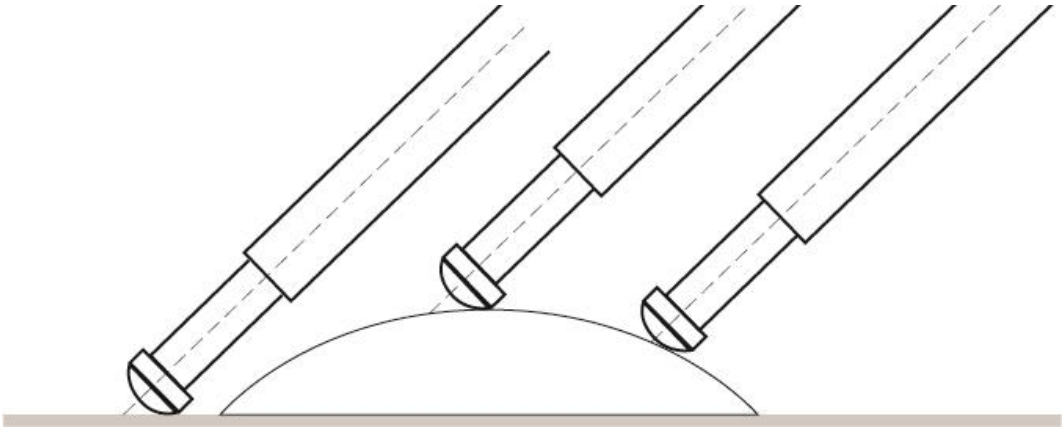


Figure 2.7: Angled dial tip.
Image by Aishwarya Shettigar.

There is no point at which the user can be confident that no cosine error is present. There may be one point at which the angle of the dial tip and curvature of the reed match precisely, and at that point there is no cosine error, but that point will not be detectible by the user and will change reed-to-reed because the curvature of each reed is different. By contrast, making the dial tip perpendicular to the surface being measured assures at least

one position (center) at which no cosine error is present (figure 2.8) because the dial tip is perpendicular to the reed's surface.

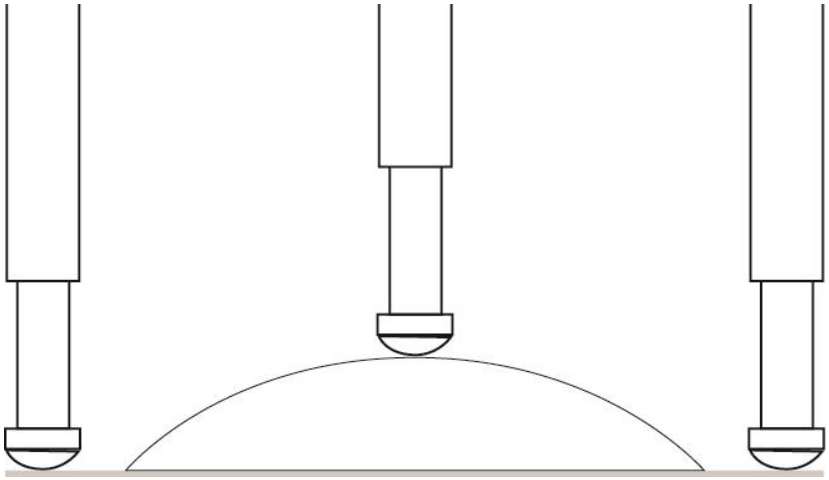


Figure 2.8: Perpendicular dial tip.
Image by Aishwarya Shettigar.

It is important to consider cosine error when engineering tools in order to draft appropriate designs and understand the mathematics behind the tool's function. However, for the purpose of a user measuring clarinet reeds, this knowledge is unnecessary; for the small amount of cosine error present, as long as a user measures reeds with the same tool, the amount of error is uniform across all measurements so it is still possible to compare reeds across brands and cuts.

Both PAR1 and Jeanne ReedGauge have external parts that can be lost or damaged. PAR1 requires a black plastic bar as the ridge barrier. It is easy to lose. On the specific PAR1 device I tested, the back track was cut too large for the bar causing it to wobble in its position, thus creating inconsistent readings (though not greater than one-thousandth of an inch difference). The craftsmanship is not consistent between tools, and an error such as this distorts measurements. The Jeanne ReedGauge table can be removed and lost. Users must purchase additional tables to measure reeds of different lengths.

Each tool is ambiguous as to where to line up the reed. On PAR2, it is up to the user to pick where to place the tip of the reed on the base of the micrometer. Should it be at the inner edge, outer edge, or center of the guide line? PAR1 is easier to use because the guide lines are thin and leave less room for interpretation. The Jeanne ReedGauge locks the sliding table in place with a pin, but the vertical guidelines (C, 1, 2, and 3 in figure 2.3) are difficult to align with the reed edge due to their thickness.

Finally, it has been mentioned in passing in the preceding discussion, but it should be stated plainly that current models leave too much room for human error. They all extensively depend on user hand movements and visual judgement. The micrometers are dependent on the user to physically control reed placement, properly calibrate the dial clockface, and move the dial indicator or accessory parts. They are dependent on the user's visual ability to interpret the dial face measurements and choose how to place a reed against guide lines. It is impossible for a user to operate so many moving parts with the same level of attention, accuracy, and consistency every time over the years and across hundreds of reed measurements.

Having just summarized the key design flaws in commercial micrometers, the following section discusses in detail the positive and negative features of each individual tool, including aesthetic choices, not just those which impair accuracy and reliability. Supplementary information related to each tool may be found in Appendix B. The discussion begins with PerfectaReed Version 1, the earliest commercially produced single reed micrometer.

PERFECTAREED VERSION 1

Ben Armato's PerfectaReed Version 1 was invented in 1969. Though it has long since been retired and replaced with a revised tool (PAR2), many professionals still own PAR1, and it is still available through second-hand sellers. Pictured in figure 2.9, this version is owned by Robert DiLutis, and he lent it to me to conduct tests for this project. PAR1 has a Mitutoyo dial indicator that measures in thousandths of inches. Measurements are derived from a black plastic reference bar which can be adjusted in two grooved tracks on the front and back side of the device. The side rail of the reed is pressed against the black bar. Rotating the black bar allows the user to capture measurements in increments of 1 or 2 mm from the reed rails in the outer groove and increments of 3 or 4 mm in the inner groove.

Figure 2.9: PerfectaReed Version 1.
Source: "REED WIZARD REED Wizard LN - $249.98 | PicClick," Google Images, accessed November 9, 2019, https://images.app.goo.gl/5qgHcEyr2q5kqc887).

There are eight scribed lines on either side of the dial tip spaced 3/16 of an inch apart, allowing the user to flip the reed to measure the thickness and symmetry of both sides. At line 1 closest to the tip, measurements begin approximately 2.5 mm from the tip of a reed. For a B♭ clarinet reed, only seven positions are needed along the reed table. The reed table between the grooves is 16 mm wide. The dial tip strikes approximately 12 mm from the back of the reed table and 4 mm from the front. PAR1 measures soprano saxophone, E♭ clarinet, B♭ clarinet, and alto saxophone reeds. Bass clarinet and tenor saxophone reeds can be measured the full length of the vamp if a user goes beyond Position 8 to the end of the reed table, placing the reed tip where Position 9 would be if it were numbered. Baritone saxophone reeds are too large for this table, though measurements can continue if the user pushes the reed tip beyond the edge of the reed table.

Assuming a player measures a B♭ clarinet reed in all available positions, PAR1 collects 56 data points (four increments on two sides of the reed across seven vertical positions). On the particular PAR1 tool used to conduct tests, the black bar is too thin for the back track causing the bar to wobble in its position. As a result, measurements taken with the bar in the inner groove are inconsistent between measurements of the same reed. See Appendix B, tables 7.1 and 7.2 for a data output of a 4.25 Légère reed test measurement on PAR1 which demonstrates this inconsistency. These are the positive and negative features of PAR1.

Positive Features

- Dial tip perpendicular to reed
- Most reliable measurements between PAR1, PAR2, and Jeanne ReedGauge

Negative Features

- Only measures two sides clearly, no universal center line
- Measurements are derived from distance from reed's rail, not

- Easy to use
- No recalibration required between measurements (dial indicator is stationary)
- Small and portable
- Capable of measuring various reed sizes
- Guide lines are thin, leaving little question about where to line up the tip of the reed

center which distorts readings because reeds taper towards the heel
- Reeds must be flipped to measure symmetry from the same table position
- Clockface dial is difficult to read for exact measurement
- Clockface dial requires recalibration over time as environmental conditions change
- Measurements only available in thousandths of inches (digital dial preferred to capture in inches or millimeters)
- Black bar can easily be lost, the only tool to provide an external measurement barrier
- On the device pictured, the back track is loose which causes the black bar to wobble, thus creating inconsistent readings
- Using Armato's measurement template, the user collects 56 data points on B♭ reed

PERFECTAREED VERSION 2

Revised approximately 30 years after its invention, the second version of PerfectaReed (PAR2, figure 2.10) eliminates the need for guide bars and places the dial tip indicator at an angle to the reed. There is no documentation available to explain the selected revisions, but it is assumed the changes are the result of user feedback and new ideas generated by inventor Ben Armato.

Figure 2.10: PerfectaReed Version 2.
Source: "Reed Wizard PerfectaReed," The Reed Wizard, accessed October 22, 2019, https://www.amazon.com/Reed-Wizard-Perfectareed-PerfectaReed/dp/B000XZXD7O.

PAR2's Mitutoyo dial indicator measures in thousandths of inches. Measurements are derived from a ridge on the tool behind the dial tip; the reed's rail presses against the ridge. There are eight scribed lines on either side of the dial tip, allowing the user to flip the reed to measure the symmetry and thickness of both sides. At Position 1, measurements begin approximately 2.5 mm from the tip of a reed and move increments of a quarter of an inch. Positions A through F move in increments of an eighth of an inch. For a B♭ clarinet reed, only seven vertical positions are needed along letters A through E, with position E giving the closest center reading. Like PAR1, PAR2 measures all reed sizes, even if the tip of a large reed must go beyond the end of the tool's base.

PAR2 is more convenient to use than PAR1 because the black guide bars are eliminated. As described in the opening section of this chapter, the angled dial tip makes PAR2 less accurate than the founding version because it pushes the reed away from the

ridge. This effect is exacerbated as the reed gets thicker. Additionally, the carriage (refer to figure 1.4 for nomenclature) must be moved manually to Positions A through E, a process which requires dial recalibration at each position and leaves room for human error matching the carriage lines to the upper base letters. These design flaws create measurement inconsistencies even when the same reed is measured by the same individual using a standardized measurement methodology. Table 7.5 of Appendix B contains a data output demonstrating this inconsistency.

Using Armato's prescribed measuring method, the user collects 70 data points on a single B♭ clarinet reed (Appendix B, figure 7.7 is a copy of the company's suggested measurement template), a number which is entirely too many data points in my view. The following list states the positive and negative features of PAR2.

Positive Features

- Easy to use
- Small and portable
- Capable of measuring various reed sizes
- Measures five horizontal positions with carriage movement
- Dial face angled up for easier reading

Negative Features

- Dial tip is at angle to the reed which pushes the reed away, skewing measurements
- Recalibration required for every horizontal measurement in positions A through F
- Measurements are derived from reed's rail, not center which distorted readings because reeds taper towards the heel
- Reed must be flipped to measure symmetry from the same table position
- Guide lines are thick, leaving ambiguity about where to line up the tip of the reed (left edge of line, center of line, or right edge of line)
- Clockface dial is difficult to read for exact measurement
- Clockface dial requires recalibration over time as environmental conditions change

- Measurements only available in thousandths of inches (digital dial preferred to capture in inches or millimeters)
- Using Armato's measurement template, the user collects 70 data points on B♭ reed

JEANNE REEDGAUGE

Sold by Jeanne Inc., the Jeanne ReedGauge Mitutoyo dial indicator measures in hundredths millimeters. Measurements are derived from the heel of the reed which rests against a ridge on the sliding reed table. The Jeanne ReedGauge is pictured below in figure 2.11.

Figure 2.11: Jeanne ReedGauge.
Photograph by Patrick Lill, adapted by Natalie Groom.

The reed table has four engraved lines. The dashed C line serves to visually center the reed; it is not used as a point of alignment. When the left edge of the reed tip is aligned with Line 1, the left side of the reed is measured. Line 2 measures center approximately, and Line 3 measures the right side of the reed. Lines 1, 2, and 3 are marked in 3 mm increments, while Positions 0 through 45 are in 5 mm increments. It is unclear why the inventor included three positions at 35, 40, and 45 mm because the longest B♭ clarinet reed vamp is 30 mm in length. The inventor specifically designed this reed table to only measure B♭ clarinet reeds, so the additional 10 mm are not necessary. Perhaps the inventor thought it might be useful to measure reed thickness at the bark (beyond 30 mm from the tip of the reed) to compare bark thickness across reeds, though from an adjustment standpoint, scraping the bark does not change a reed's sound. Assuming a

user measures three points horizontally across the reed and seven positions vertically, the Jeanne ReedGauge collects 21 data points on a B♭ clarinet reed.

At Position 0, the reed table starts measurements approximately 2 mm from the tip of a B♭ clarinet reed. As mentioned at the beginning of this chapter, measuring a reed based on the distance from its heel makes it impossible to compare reeds of different sizes. Because reeds are different lengths from tip to heel, Position 0 can be a slightly different distance from the tip of the reed from brand-to-brand. The pictured device only measures B♭ clarinet reeds, as the guide lines and length of the reed table are customized to B♭ clarinet reeds. The company requires users to purchase other size reed tables separately for an additional $27.50 (as of April 2020), and Jeanne, Inc. only offers additional sliding tables for alto saxophone/alto clarinet and tenor saxophone/bass clarinet.[4] It impossible to measure smaller reeds (soprano saxophone, E♭ clarinet) or larger reeds (baritone saxophone) because there are no reed tables available to accommodate those size reeds. With PAR1 and PAR2, the user can potentially measure reeds of all sizes if the reed is pushes off the edge of the tool. This is not the case with Jeanne ReedGauge. As pictured in figure 2.12, even if a user wanted to utilize the tool to measure reeds of various sizes, being bound to Position 0 as the locked starting point prevents users from doing so.

[4] "Jeanne ReedGauge, Metric Dial (Millimeters)," Jeanne, Inc., accessed April 24, 2019, https://www.jeanne-inc.com/mm5/merchant.mvc?Session_ID=18bb15b6e48aa6f1ca6e73e9a37b4876&Screen=PROD&Store_Code=JI&Product_Code=JT400M&Category_Code=JT-CRG.

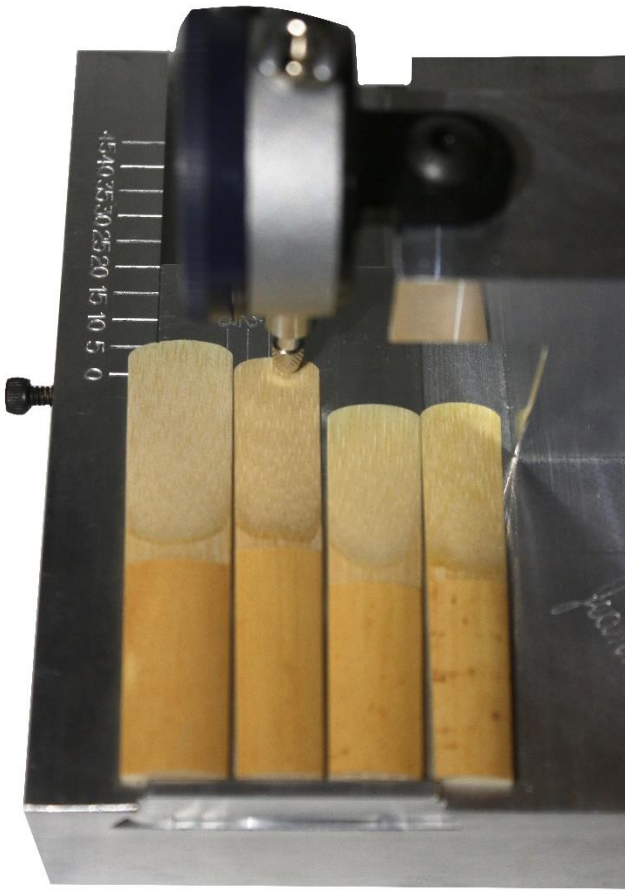


Figure 2.12: Jeanne ReedGauge with four different reeds.
At Position 0, this is the point of contact between the dial tip and a reed. Reeds from left to right: alto saxophone, B♭ clarinet, soprano saxophone, and E♭ clarinet.
Photograph by Patrick Lill.

At Position 0 (labels on left edge of figure 2.12), the dial tip touches 5 mm from the tip of an alto saxophone reed. The tip reading is the most important to understand a reed's response and clarity, so it is necessary to begin measurements approximately 2 mm from the tip. It is possible to remove the locking pin and slide the reed table back far enough to be 2 mm from the alto saxophone reed's tip, but there are no guide lines to the right of Position 0. If Jeanne, Inc. had merely scribed lines in both directions from Position 0, it would be possible to measure longer reeds with the same reed table. I suspect the reason they did not do this was to force users to buy additional reed tables. At the other end of

the reed length spectrum, soprano saxophone and E♭ clarinet reeds cannot be measured unless moved to a starting position of 10, a position which places the dial tip approximately 4 mm in from the reed tip. People can still use the tool to measure any point of a reed, but users will not be able to line up with the guide lines.

It is possible to remove the reed table and flip it to the opposite side of the micrometer, but in doing so it becomes impossible to line up the reed table's guide line with Positions 0–45, as the scribed line only exists on one side of the sliding table. If Jeanne, Inc. had scribed the line on both sides of the sliding table, it could be effectively reversed to capture measurements on the flipped side. The inclusion of this line would have been a very small cosmetic cost that could have added a lot more flexibility and practicality to this tool without taking away from sales of additional reed tables.

It is unclear why Jeanne, Inc. chose a base so thick and heavy. Perhaps the inventor thought this would make the base secure and weighty enough to not be easily knocked over. Whatever the reasoning, weighing in at 54.6 ounces (by contrast, PAR1 weighs 9.7 ounces, and PAR2 weighs 14.2 ounces), this seemingly cosmetic choice is a burden without obvious benefit. Jeanne ReedGauge is unwieldy, particularly when traveling and transporting by air. The tool's added girth does not facilitate measuring large reeds, a benefit which would perhaps be reason enough to incorporate added weight. Another potential problem of which users should be aware is how to calibrate the Jeanne ReedGauge dial. It should be calibrated with the dial tip on the flat part of the reed table to the left of Line C (figure 2.13) because a calibration made while the dial tip is touching Line C's grooves will produce a reading error of two-hundredths of a millimeter (figure 2.14).

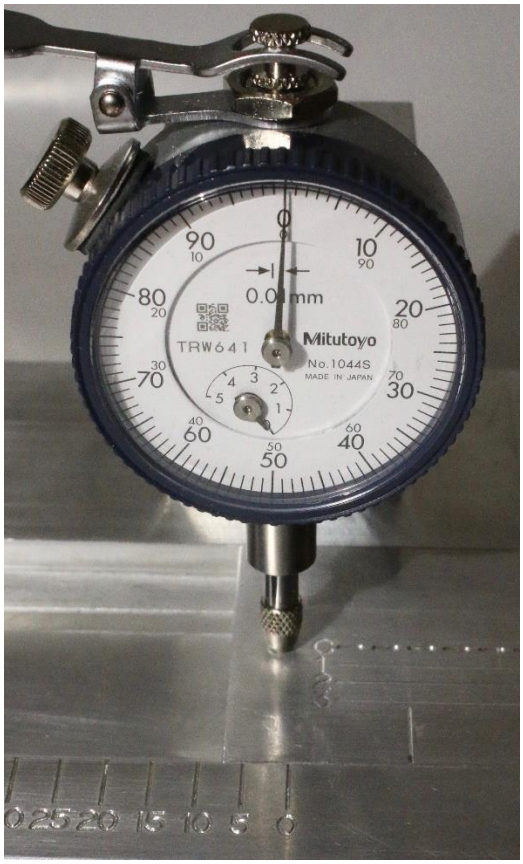


Figure 2.13: Jeanne ReedGauge calibrated.
The dial is calibrated to zero at the flat part of the sliding reed table.
Photograph by Patrick Lill.

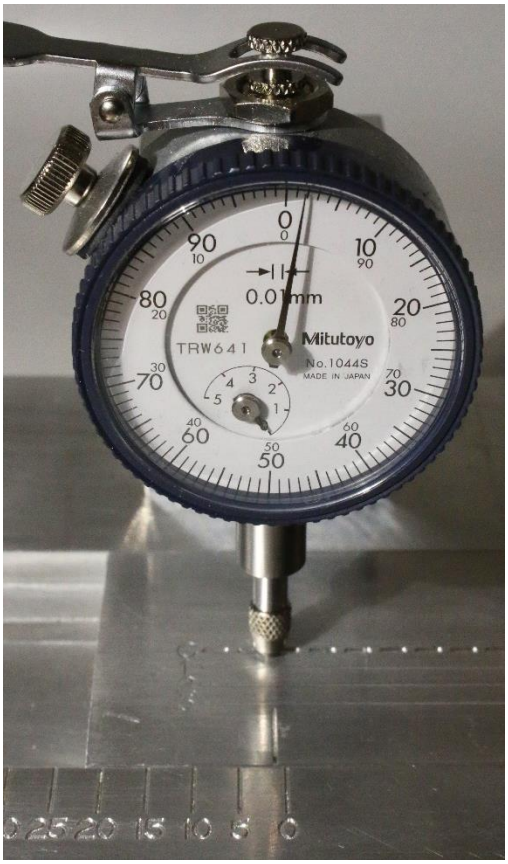


Figure 2.14: Jeanne ReedGauge recalibrated.
Two-hundredths of a millimeter error occurs if calibrated where dial tip contacts Line C grooves.
Photograph by Patrick Lill.

The following list states the positive and negative features of the Jeanne ReedGauge.

Positive Features

- Dial tip is perpendicular to reed
- Easy to use
- Sliding table is convenient for vertical measurements and smooth sliding
- Pin locks table in place if desired
- Guide line and table line are easy to align
- No recalibration required (dial tip indicator is stationary)
- Reeds can be flipped to measure on left or right side

Negative Features

- Nothing holds reed in place to prevent drifting while measuring
- Does not measure horizontal positions easily because it is up to the user to visually inspect and align the reed to the sliding table's guide lines
- Measurements are derived from the heel of the reed rather than the tip, making it impossible to benchmark tip readings from reed to reed

- Clockface dial is difficult to read for exact measurement
- Clockface dial requires recalibration over time as environmental conditions changed
- Recalibration must be derived from flat areas on the sliding table, not on the guideline depressions
- Measurements only available in hundredths of millimeters (digital dial preferred to capture in inches or millimeters)
- Base unnecessarily large and very heavy making it not easily portable
- To measure reeds of various sizes, the user has to purchase another size table

REEDS ‘N STUFF DIGITAL MEASURING DEVICE

It is worth mentioning here that there is another micrometer available in Germany from Reeds ‘n Stuff which shares features with U.S. micrometers and is the only other single reed micrometer that can be found online (pictured in figure 2.15). It eliminates several problems found in PAR1, PAR2, and the Jeanne ReedGauge. I have not used this tool, as U.S. distributors do not carry it and the procurement costs are prohibitive. However, based on visual observation and correspondence with the manufacturer, I can discuss its abilities.

Figure 2.15: Reeds ‘n Stuff’s digital single reed micrometer.
Source: “Reeds 'n Stuff: Digitaler Messplatz,” Reeds 'N Stuff, accessed October 23, 2019, https://www.reedsnstuff.com/Klarinette/Messen-Pruefen-Testen/Digitaler-Messplatz.html.

Reeds ‘n Stuff’s Digital Measuring Device uses a digital dial indicator that reads in hundredths of millimeters or thousandths of inches. The dial is stationary which means it does not require recalibration between positions. Measurements appear to be derived from the center of a reed, a feature which allows users to compare reeds of different sizes and cuts. There are three moveable plates to the upper, left, and right side of the reed against which the reed’s tip and sides rest (like the PAR1 and PAR2 ridge). It uses a locking pin mechanism to secure each plate in place. The user lifts the black ball handle, slides a plate, then drops the pin to secure the plate. The left and right side plates are adjustable in increments of 1 mm. The plate at the tip of the reed is adjustable in increments of 2 mm. There is nothing holding the reed in place, and it appears that the lower half of the reed hangs off the tool. Based on the available image and product description, these are likely the positive and negative features of this micrometer.

Positive Features

- Dial tip is perpendicular to reed
- No recalibration required (dial tip indicator is stationary)
- Small and portable
- Capable of measuring large reeds
- Guide lines are thin
- Pull-pins ensure exact measurement position every time
- Measurements start at the tip and center of reed
- Measurements are adjustable in increments of 1 mm from left to right, and in increments of 2 mm from tip to heel

Negative Features

- Reed is not secured to prevent movement
- Pull-pin action is tedious and time consuming
- Difficult to measure large reeds due to pin locations, reed table width, and reed table length

CHAPTER THREE: INVENTING A NEW TOOL

Chapter Two laid the framework for potential improvements for a new single reed micrometer based on flaws found in commercial micrometers, and this chapter details what improvements were determined to be necessary to warrant the invention of a new tool. While the original research intent was to measure reeds of four different brands to test their consistency, this idea had to be put aside when I discovered that commercial reed micrometers did not yield consistent or reliable results. A new micrometer needed to be invented to one day be able to carry out the original research intent. I first compiled a list of requirements.

The improved micrometer must derive measurements from the center and tip of the reed. The center of the reed is the only position that does not have a counterpart to check for symmetry which is why it should be the starting point. As demonstrated previously on the left in figure 2.2, deriving measurements from the center of the reed means each line of measurement will be parallel to the center of the reed. This allows a user to compare measurements across various reed cuts, sizes, and brands. By contrast, when the reed rail is aligned to a ridge, the lines of measurement run parallel to the ridge and capture angled lines of measurement across the reed's surface (figure 2.2, right). Lines of measurement to the left and right of center will always be parallel to the center line rather than tilting in at an angle proportional to the difference between the tip and heel widths. However, this is acceptable because as long as the line of measurement is parallel from the reed's center, symmetrical measurements can always be compared.

The dial tip should be perpendicular to the reed because an angled tip pushes the reed away. An additional benefit of a perpendicular dial tip is that the downward force

pushes the reed down and flush with the measurement table, a desirable feature when measuring cane reeds that have warped over time. The dial tip diametershould be as small as possible to reduce cosine error, but not so small or pointed that it catches on the reed or creates indentations. The dial indicator should remain stationary to circumvent recalibrating every time it moves, and it should read out to no more than four decimal places, as any more than this is unnecessarily granular. It is important that the micrometer parts are attached to each other, as loose parts or extra accessories can be lost. The dial indicator should be digital rather than an analog clockface. The most obvious advantage to a digital indicator is the ability to toggle between inches and millimeters, making it user friendly for the rest of the world operating in the metric system. Digital dials calibrate to zero at the press of a button rather than relying on a user to properly recalibrate a dial face. Additionally, the digital indicator displays a numeric measurement rather than the user counting the number of rotations across the dial clockface and possibly misreading the display.

The reed must be clamped in place to keep it from naturally drifting, and having a clamp reduces human error by ensuring the reed stays aligned to center at all times. Thinking of the instrument's aesthetics, it should be as small, lightweight, and as compact as possible while maintaining an ability to measure reeds of all sizes. Each position should be clearly labeled with a mechanism to lock positions, and there should be no ambiguity of where to line up parts of a reed. These design choices reduce opportunities for human error, as the dial calibrates at the touch of a button and presents clearly printed readings; the user will not move the reed while it is clamped in place; and individual reed positions lock in place so there is no question of where to take a measurement.

CHOOSING SPECIFICATIONS

After brainstorming these design features, I decided what incremental measurements the micrometer would capture. Using a standard B♭ clarinet reed as a baseline—because it is the most widely used reed of the clarinet family—it was determined that the ideal number of points to measure would be 35, five positions from left to right across the reed, and seven positions from tip to the end of the vamp. These data points provided enough detail to map the contour of a reed, and not so many that the level of specificity would be unhelpful. As diagrammed in figure 3.1, horizontal increments were spaced 2.5 mm from the reed's center; vertical measurements began 2 mm from the tip of the reed and moved in increments of 5 mm thereafter.

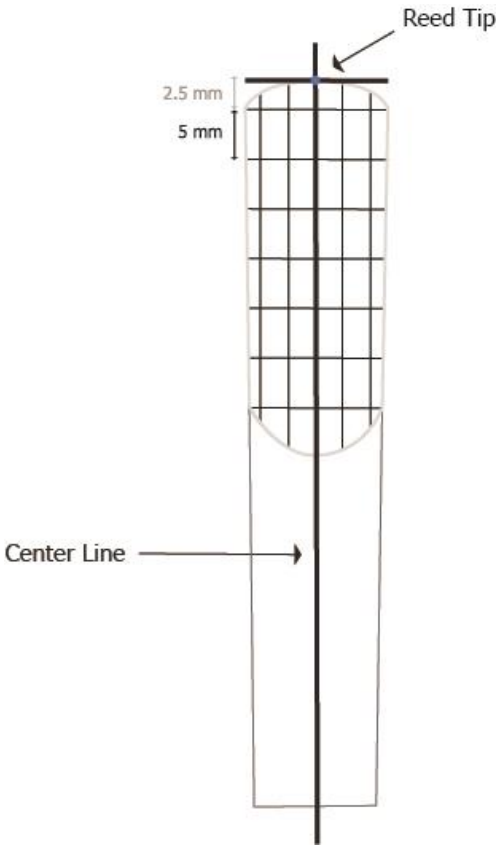
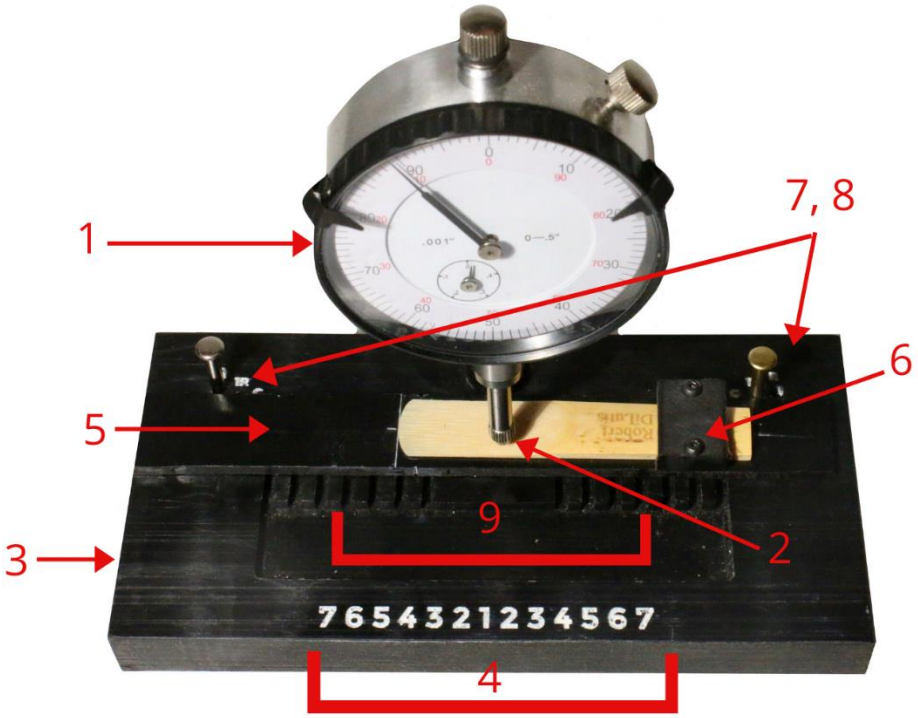


Figure 3.1: Ideal data points collected on a B♭ clarinet reed.
Vertical measurements start from a ridge which meets the tip of the reed. Vertical measurements begin 2.5 mm from the tip of the reed and move in 5 mm increments thereafter. Measurements from left and right of center are in 2.5 mm increments.
Image by Aishwarya Shettigar.

With these design choices and measurement specifications, the first prototype was produced in collaboration with Robert DiLutis, professor of clarinet at the University of Maryland, College Park.

PROTOTYPE 1



1. Dial indicator
2. Tip
3. Base
4. Base numbers
5. Reed table
6. Clamp
7. Pins
8. Pin holes
9. Grooves

Figure 3.2: Prototype 1.
Photograph by Patrick Lill, adapted by Natalie Groom.

Prototype 1 was constructed from 3D printed black plastic. The base was 5 ½ inches across the front, 2 ¾ inches across the side, and 5 inches tall. The reed was centered on a white line on the reed table and held in place towards the heel by a box-like clamp. At the front of the base were Positions 1 through 7 extending both directions as a palindrome from Position 1 so that the reed table could be flipped to measure from the opposite side. Pins at the back left and right side of the tool put the reed table at five positions from left to right across the reed (seen in the upper view of Prototype 1 in figure 3.3). To take vertical measurements, the reed table slid out and into the next comb-like groove; the underside of the reed table had a notch which threaded in each groove of the base. Prototype 1 collected 35 data points on B♭ clarinet reeds and 30 data points on E♭ clarinet reeds.

Figure 3.3: Prototype 1 upper view.
View of five pin positions and comb grooves.
Photograph by Patrick Lill, adapted by Natalie Groom.

Two flaws emerged. First, because of how narrow the reed clamp was, only E♭ and B♭ clarinet reeds could be measured. Second, Positions 1, 6, and 7 were unstable because the reed table was not long enough to reach the pins. One end of the reed table would rest against a pin, but the other end was too short which caused the table to rest at an angle. No method was in place to keep the reed table perfectly straight. The first prototype was successful in its attempt to physicalize the design features which previously only existed conceptually. Prototype 1 was built at low cost to test ideas with minimal financial commitment. After its creation, I took note of the positive and negative features of the device to draft an improved version.

Positive Features

- Dial tip was perpendicular to reed
- No recalibration required (dial tip indicator was stationary)
- Small and portable

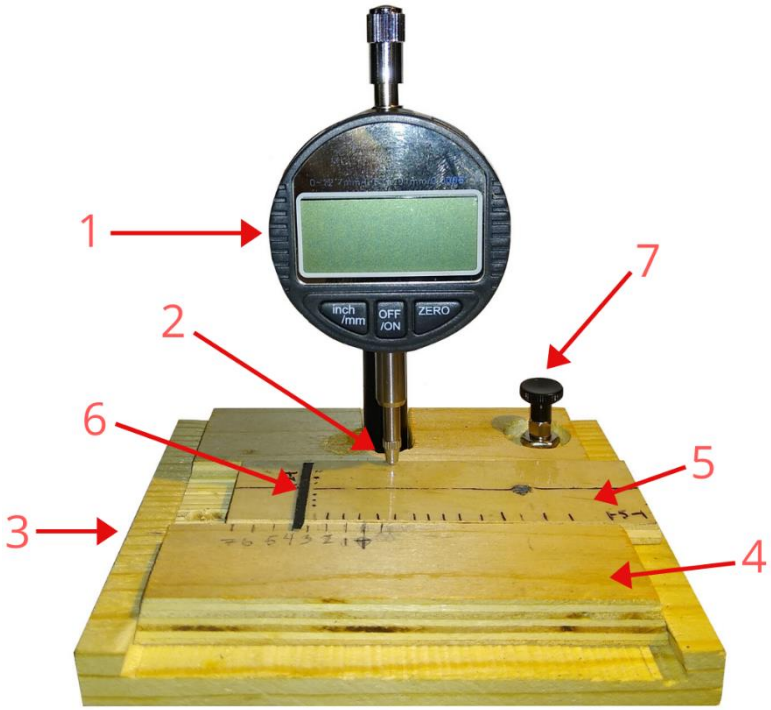
Negative Features

- Cumbersome to use because of the comb-like movement and pins

- Comb movement locked the reed in place
- Clamp prevented reed from drifting

- Only measured E♭ and B♭ clarinet reeds due to the size of the reed clamp
- Positions 1, 6, and 7 were unstable because the reed table was not long enough to reach the pin, causing it to rest at an angle
- Clockface dial (digital preferred)

PROTOTYPE 2



1. Dial indicator
2. Tip
3. Base
4. Horizontal plane
5. Vertical plane (reed table)
6. Ridge
7. Pin

Figure 3.4: Prototype 2.
Photograph by Robert DiLutis, adapted by Natalie Groom.

Prototype 2 was constructed from wood in three layers. The base was 5 ⅛ inches across the front and 4 ¼ inches across the side. The layer on top of the base was a moving plane which captured horizontal measurements across the reed; it moved from the front of the base towards the dial indicator and was locked in place with the black pull pin at the back right corner, known as an indexing plunger system (figure 3.5).

Figure 3.5: Indexing plunger system.
Source: "M-IPN-5-M10X1-F," Ruland Manufacturing Co., Inc., accessed November 23, 2019, https://www.ruland.com/m-ipn-5-m10x1-f.html.

The user lifted the black pin, slid the horizontal plane, then dropped the pin to secure the plane's placement. On top of the horizontal plane was a second moving plane on which the reed sat. This reed table captured vertical measurements across the reed; it slid from the left side of the base to the right side. In this prototype, the reed tip rested against a black rubber ridge and was centered on a cosmetic line drawn on the reed table. The reed was not clamped in place. The second prototype had more positive features than negative features.

Positive Features

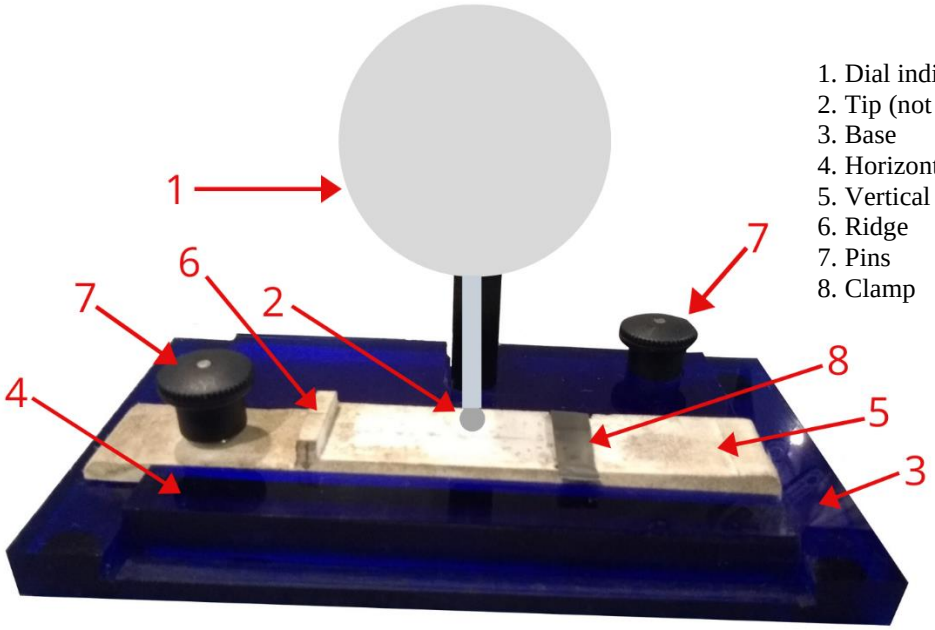
- Dial tip was perpendicular to reed
- No recalibration required (dial tip indicator was stationary)
- Dial tip indicator was digital
- Small and portable
- Two planes of movement allowed users to easily capture any dimension any direction
- Pins locked the lower table in place
- Measured single reeds of all sizes

Negative Features

- Easier to use than Prototype 1
- Reed was not secured down so it drifted during measurements
- Base or reed table needed to be longer so reed heels did not hang off the end of the tool
- Lacked number or letter guides to show what position was being measured

The most significant improvement that needed to be made in the following prototype was ensuring the reed was secured in place. As the designs became increasingly sophisticated, the next prototype was constructed from sturdier material.

PROTOTYPE 3



1. Dial indicator (not pictured)
2. Tip (not pictured)
3. Base
4. Horizontal plane
5. Vertical plane (reed table)
6. Ridge
7. Pins
8. Clamp

Figure 3.6: Prototype 3 (missing dial indicator and tip).
Photograph by Wesley Rice, adapted by Natalie Groom.

Prototype 3 was constructed from blue and silver plastic. The layer on top of the base was a blue moving plane which captured horizontal measurements across the reed; it moved from the front of the base towards the dial indicator and was locked in place with the black pin at the back right corner. On top of the horizontal plane was a silver moving plane which captured vertical measurements across the reed; it moved from the left side of the base to the right side and locked in place with a black pin. The reed tip rested against a ridge built into the reed table, and the reed was clamped in place with a metal spring bar. The function of Prototype 3 was significantly improved but still had some negative qualities.

Positive Features

- Dial tip was perpendicular to reed
- No recalibration required (dial tip indicator was stationary)

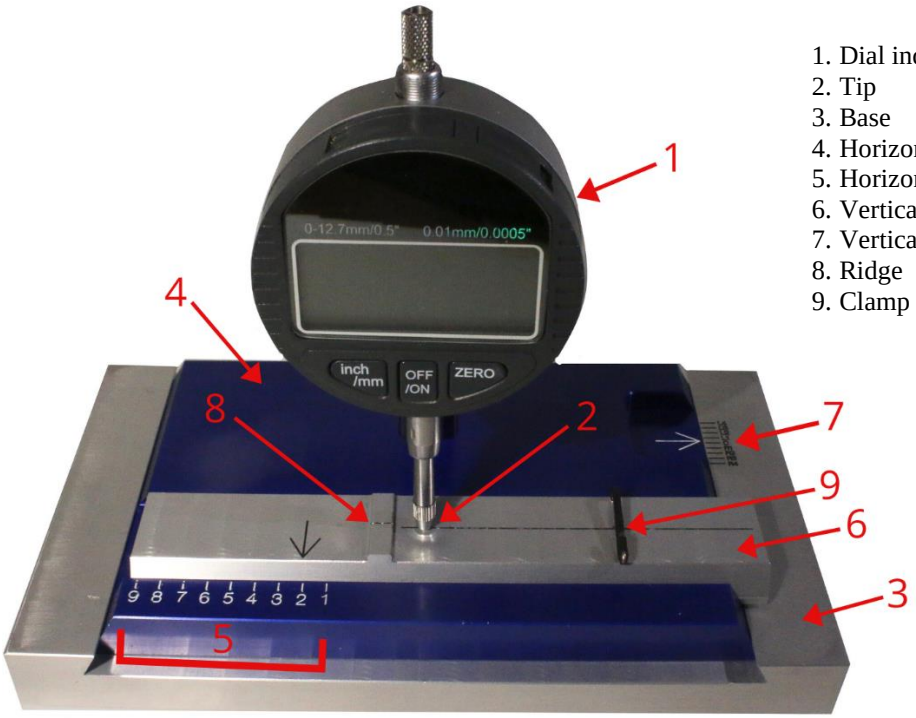
Negative Features

- Pin action was slow and cumbersome

- Dial tip indicator was digital (not pictured above)
- Small and portable
- Two planes of movement allowed users to easily capture any dimension any direction
- Pins locked the tables in place
- Measured single reeds of all sizes
- Reed clamped in place
- Lacked number or letter guides to show what position was being measured
- Clamp was effective but had sharp edges

Having solidified the core components necessary for a working and potentially marketable tool, design specifications were sent to a machinist to produce the next prototype.

PROTOTYPE 4



1. Dial indicator
2. Tip
3. Base
4. Horizontal plane
5. Horizontal plane numbers
6. Vertical plane (reed table)
7. Vertical plane numbers
8. Ridge
9. Clamp

Figure 3.7: Prototype 4.
Photograph by Patrick Lill, adapted by Natalie Groom.

Prototype 4 was constructed from blue and silver metal. The base was 6 ⅞ by 3 ⅞ inches and 5 ½ inches tall. The blue layer on top of the base was a moving plane which captured horizontal measurements across the reed; it slid from the front of the base towards the dial indicator using a ball plunger system (figure 3.8) which slid into grooved indentations at each position (figure 3.9 and 3.10).

Figure 3.8: Ball plunger system.
Source: "Teco .250 Steel Press Fit Ball Plunger," KBC Tools & Machinery, accessed November 23, 2019, https://www.kbctools.com/itemdetail/1-903-53702.

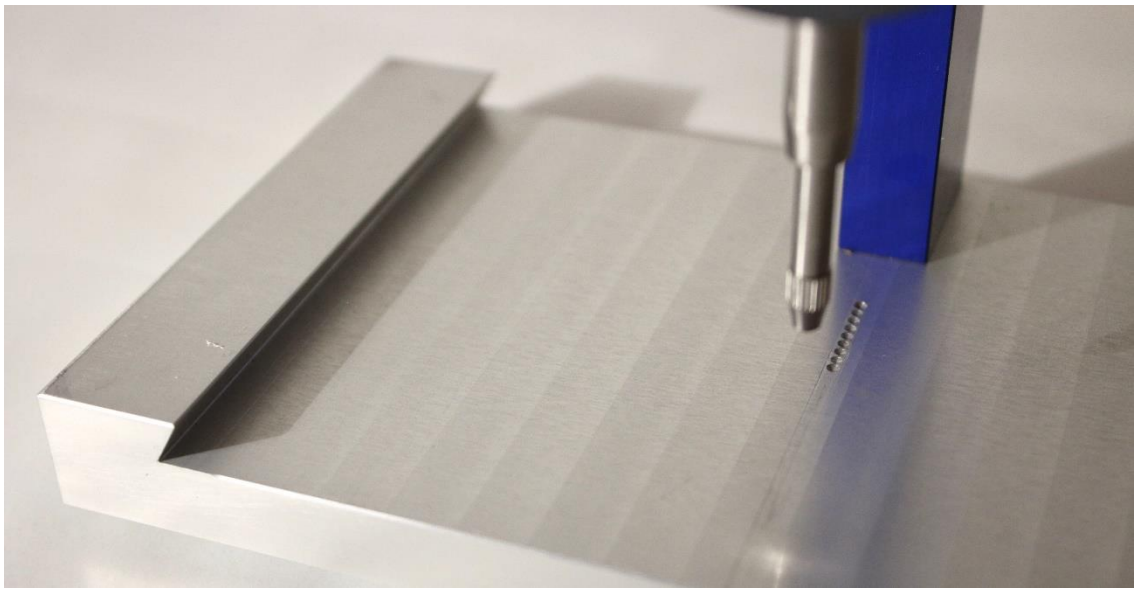


Figure 3.9: Ball plunger grooves on base.
Photograph by Patrick Lill.

Figure 3.10: Ball plunger grooves on horizontal plane.
Photograph by Patrick Lill.

On top of the horizontal plane was a silver reed table which captured vertical measurements across the reed; it moved from the left side of the base to the right side and slid into position using the same ball plunger system as the horizontal plane. The reed tip rested against a ridge built into the reed table, and the reed was clamped in place with a metal bar. The base of Prototype 4 had nine grooves (figure 3.9, Positions L4, L3, L2, L1, C, R1, R2, R3, R4), and the top of the horizontal plane (figure 3.10) had nine grooves (Positions 1–9). By pushing a plane, the roller balls slid into the next groove. Figure 3.11 provides a view of the roller balls affixed to the bottom of the silver reed table and blue horizontal plane.

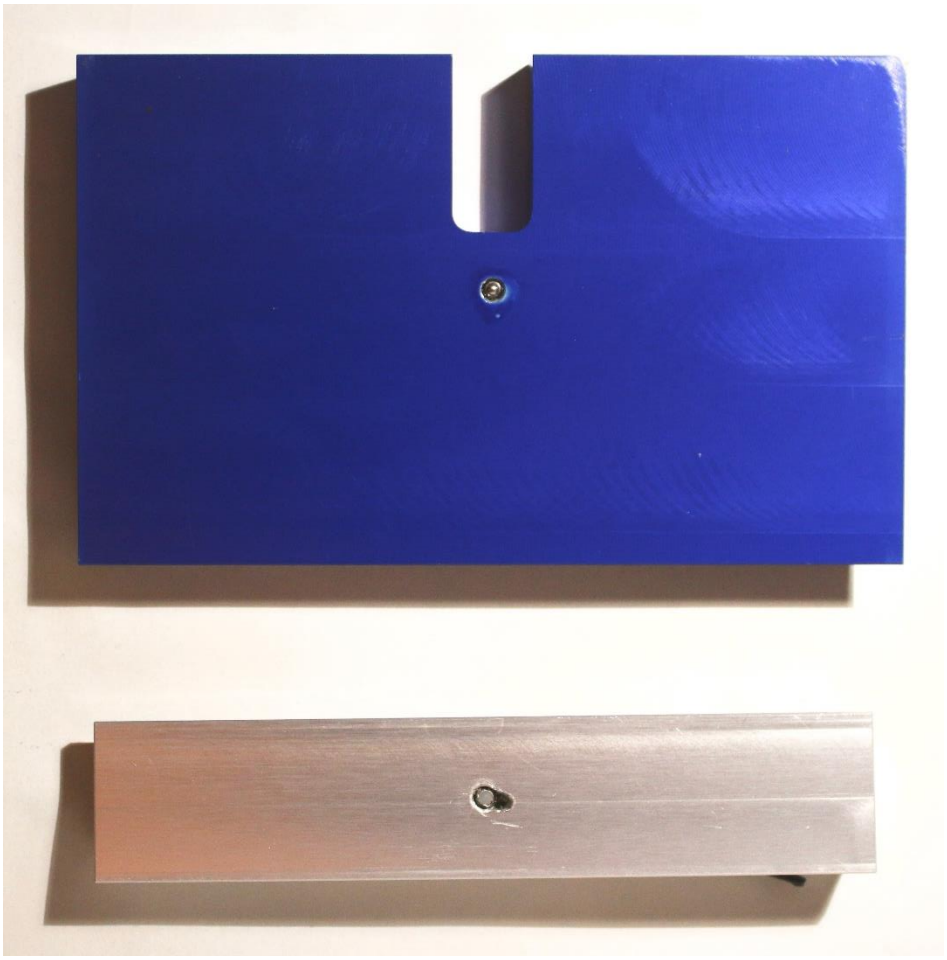


Figure 3.11: Roller ball positions on two planes.
Photograph by Patrick Lill.

While the machinist was asked to repeat the indexing plunger design seen in Prototypes 2 and 3, they thought a ball plunger system would be superior and produced this instead. Conceptually and aesthetically, the idea was attractive because a sliding motion was more convenient than raising and lowering a locking pin at every position. It meant fewer moving parts and reduced the chances of breaking or losing a pin. However, in practicality this was a poor choice. The roller ball method introduced wobble in each position, thus producing inconsistent results. If the user tapped the reed table to the left or right, measurements could be altered up to two-thousandths of an inch while sitting in the same position. For example, in Position C2 measuring a Légère 4.25 reed, the ball

plunger movement caused a difference of one-thousandth of an inch; at Position C7, the difference increased to two-thousandths of an inch. Across all available positions on the fourth prototype, 13 positions could be altered one-thousandth of an inch or more as denoted by the shaded cells in table 3.1. Differences greater than one-thousandth of an inch needed to be eliminated for the micrometer to be deemed reliable. This wiggle room made it impossible to achieve consistent results measuring the same plastic reed multiple times.

Table 3.1: Sixth reading using Prototype 4's roller ball system.

	LEGERE 4.25 READING 6				
	L2	L1	C	R1	R2
1	7	7.5-8	8-8.5	7.5-8	7-7.5
2	16.5-17	18.5-19	19-20	18-19	16-16.5
3	28.5-29	32-32.5	33-34	31.5-32	27.5-28
4	41.5-42	46.5-47	48-48.5	46-46.5	40-40.5
5	56-56.5	62.5-63	64.5-65	61-62	54-54.5
6	73-74	81.5-82.5	84-85	80-80.5	70-71
7	96.5-97.5	107.5-109	110-112	105-107	92.5-93.5

In thousandths of inches, the shaded cells denote wobble of one-thousandth of an inch or more in a given position.
Table produced by Natalie Groom.

The wiggle room was exacerbated at each subsequent measurement as the ball plunger became increasingly loose. See Appendix C, table 7.6 for a data output detailing the inconsistencies found between six readings of the same reed as the tightness of the ball plunger deteriorated.

The machinist was asked to construct measurement increments in the following manner: vertical measurements beginning 2 mm from the ridge and in 5 mm increments thereafter, and horizontal measurements derived from a center line with four positions to the left and right of center in increments of 2.5 mm. However, after conducting a series of readings it was discovered that the dial tip was not actually touching the center line

(figure 3.12), forcing me to unscrew the dial indicator and manually align it to center. Additionally, Prototype 4 had been manufactured to read in increments of 2 mm from left to right instead of 2.5 mm as requested (figure 3.13).

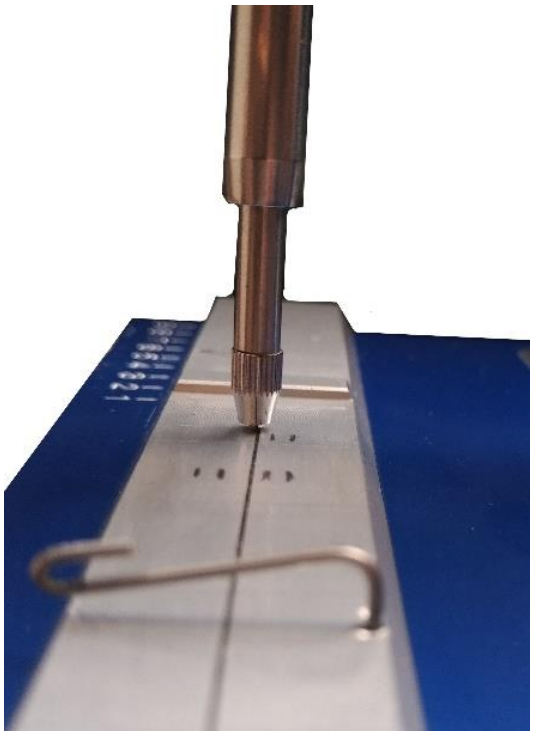


Figure 3.12: Prototype 4 dial tip.
The tip of Prototype 4 was left of the center line. This was manually adjusted so that the dial tip made contact with the center line.
Photograph by Natalie Groom.

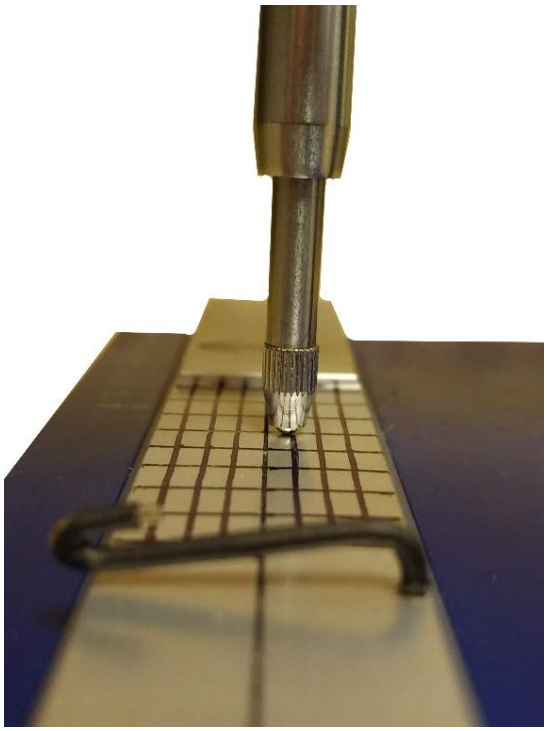


Figure 3.13: Prototype 4 dial tip.
Horizontal measurements had been built in increments of 2 mm instead of the desired 2.5 mm. Here, the lines are scribed at 2.5 mm increments, and the dial tip falls just short of meeting the line.
Photograph by Natalie Groom.

Aside from these design flaws which were the result of inattention at the hands of the machinist, I compiled a list of positive and negative features of Prototype 4.

Positive Features

- Dial tip was perpendicular to reed
- No recalibration required (stationary dial indicator)
- Digital dial indicator
- Two planes of movement allowed users to easily capture any dimension any direction
- Measured single reeds of all sizes

Negative Features

- Ball plunger system left too much wiggle room in a given position
- Base was thick and heavy
- Clamp was difficult to use and too small for large reeds
- Horizontal measurements should have been in increments of 2.5 mm, but they were manufactured to 2 mm

- Cosmetic center line made it easier to center reed
- Reed secured with a clamp to reduce reed movement
- Ball plunger system was smooth and easy to use

Having come close to a marketable invention, Prototype 4 became the model for the Manual Reed Mapper.

CHAPTER FOUR: THE MANUAL REED MAPPER

The Manual Reed Mapper (hereafter referred to as “Mr. Mapper”) is the new commercial micrometer that evolved from the development of the four prototypes described in Chapter Three.

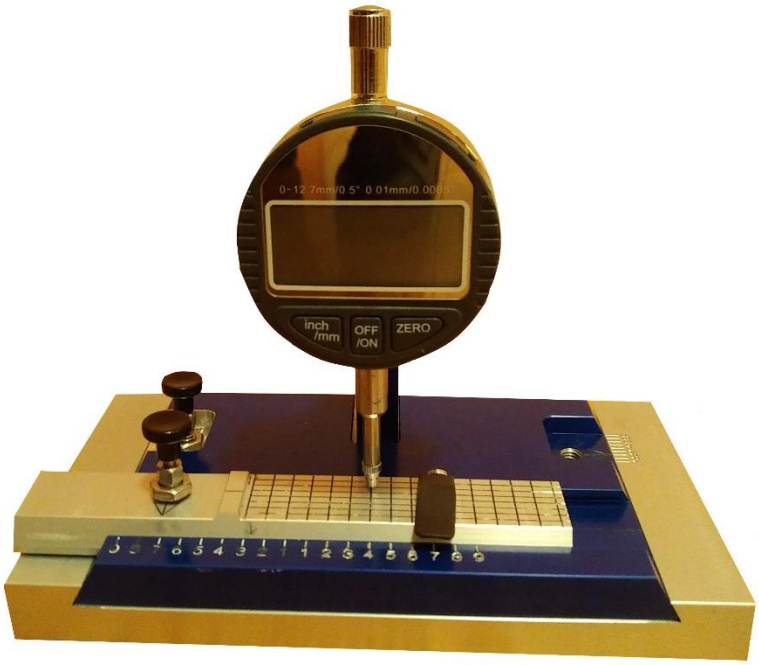


Figure 4.1: The Manual Reed Mapper.
Photograph by Natalie Groom.

Unlike other commercial single reed micrometers, Mr. Mapper captures measurements for reeds of any size, from E♭ clarinet to baritone saxophone. The length and width of the measuring planes has been determined by using a baritone saxophone reed as the largest model, thus requiring a minimum of nine positions to measure across the reed and nine positions from the tip to the vamp. Figure 4.2 compares clarinet and saxophone reeds drawn to actual size to show the variety of measurements which can be taken.

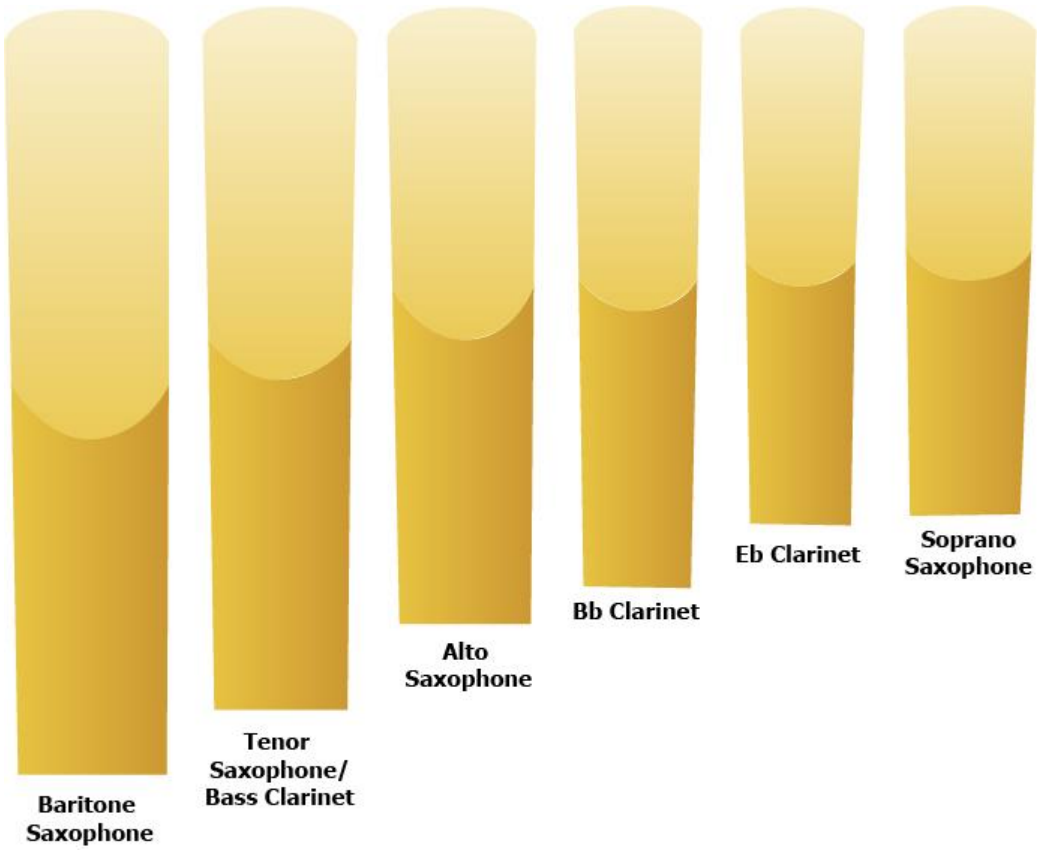


Figure 4.2: Actual size of six reed types.
From largest to smallest, the actual size of baritone saxophone, tenor saxophone/bass clarinet, alto saxophone, B♭ clarinet, E♭ clarinet, and soprano saxophone reeds.
Image by Aishwarya Shettigar.

Mr. Mapper measures in increments of 2.5 mm from left and right of center and in increments of 5 mm from the reed's tip. I decided 35 data points is ideal for a standard B♭ clarinet reed. More data points than this is unnecessarily granular, and less than this provides an incomplete picture of the reed's contour. Mr. Mapper collects 35 data points on a B♭ clarinet reed, while PAR1 captures 56, PAR2 captures 70, and Jeanne ReedGauge captures 21. Table 4.1 compares the available datapoints from commercial tools and Mr. Mapper. The plus sign means measurements may continue off the reed table even if there are no guide lines.

Table 4.1: Data points collected by single reed micrometers.

	Mr. Mapper	PAR1	PAR2	Jeanne
E♭ clarinet, soprano saxophone	30	48	60	unavailable
B♭ clarinet	35	56	70	21
Alto saxophone	49	56	96	unavailable
Bass clarinet, tenor saxophone	63	72	96	unavailable
Baritone saxophone	81+	72+	96+	unavailable

Table produced by Natalie Groom.

PAR1 and PAR2 provide an excessive number of data points, while the Jeanne ReedGauge captures fewer than desired on a B♭ clarinet reed. The Jeanne ReedGauge cannot measure other reed sizes unless a separate reed table is purchased. Figure 4.3 shows a granular view of the data points mapped across reeds of all sizes with Mr. Mapper.

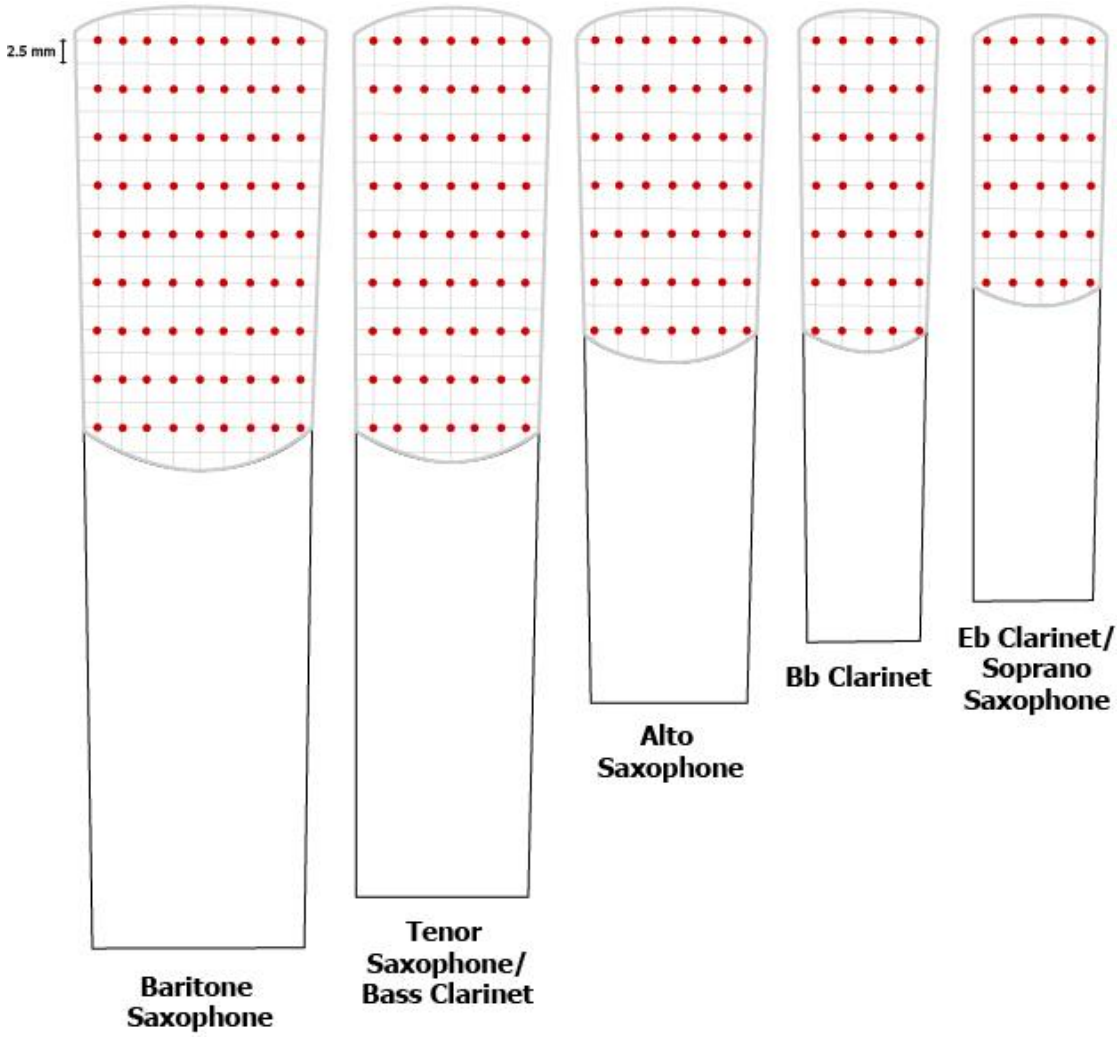


Figure 4.3: Magnified view of reed data points.
This is a magnified view of the data points Mr. Mapper captures across reed types.
Image by Aishwarya Shettigar.

Mr. Mapper was developed from refinements to Prototype 4. The base is 7 by 3⅞ inches and 5 ¾ inches tall, and it weighs 41.5 ounces. The tool is constructed in three layers from silver and blue metal. The most significant alteration between Prototype 4 and Mr. Mapper is the switch from a ball plunger system (figure 3.8), in which the planes slid along ball plungers, to an indexing plunger system, in which the planes lock into place using drop pins (figure 3.5). Additionally, the reed clamp has been revised and cosmetic grid lines added to the reed table to make it easier to center the reed.

When contemplating a product name, Manual Reed Mapper has been selected because users operate the micrometer manually as they move the planes around, and the micrometer "maps" out the contour of a reed. This can be shortened to Mr. Mapper, as the "m" and "r" are an abbreviation of "manual reed." Similarly, Dr. Mapper (discussed in Chapter 5) stands for Digital Reed Mapper with the additional fun implication that the tool graduated to a higher level that is completely computerized and automatic.

FINANCIAL CONSIDERATIONS

Playing clarinet assumes a financial burden of frequent reed purchases. For a professional, it is typical to go through one to two boxes of reeds per month. Some performers buy even more because they discard reeds that are not playable straight out of the box. While I am speaking anecdotally, it seems most players would say they are pleased with one to three reeds per box and that the rest are not performance worthy, though they might be suitable for rehearsals or practice time. Table 4.2 provides some insight into the minimum financial commitment single reed players face every year.

Table 4.2: Yearly expenses of reeds.

Boxes per month	Price per box	Cost per reed	% performance worthy reeds	Cost per year	Wasted dollars per year
1	$30	$3	30%	$360	$252
2	$30	$3	30%	$720	$504
1	$30	$3	60%	$360	$144
2	$30	$3	60%	$720	$288

In a year, the average clarinetist wastes $252–504 if only 30% of reeds are useable. When the percentage of performance worthy reeds increases to 60%, clarinetists recoup $108–216.
Table produced by Natalie Groom.

Assume optimistically that a performer deems 30% of their reeds to be concert worthy. Considering the average professional musician burns through one to two boxes of reeds per month, the amount of money wasted in a year on poor reeds is a minimum of $252.

If Mr. Mapper can increase the percentage of playable reeds to a conservative 60%, the annual loss a box-per-month player experiences decreases by $108 (row 3 of table 4.2). Assume Mr. Mapper is priced at $350. Because of the financial benefit the tool provides, it pays itself off in 3.2 years for consumers who use a box per month and 1.6 years for consumers who use two or more boxes per month. For a lifetime of reed use, the investment is completely worthwhile and can also help players reduce the number of boxes they require per year because they are able to use more reeds per box. These figures do not even take into account the fact that Mr. Mapper measures reeds of all sizes without having to purchase additional parts, unlike its competitors. Consider the many performers who use auxiliary instruments such as E♭ clarinet, bass clarinet, and multiple saxophones. For clarinetists, it is expected a player will double or even triple on E♭ or bass clarinet, and saxophonists frequently play other size saxophones within the typical four-instrument family; jazz woodwind players perform on saxophones *and* clarinets. Those players are purchasing a box of reeds per month per instrument, so Mr. Mapper pays itself off in the first year of use. Mr. Mapper has been compared to its competitors and proven to be accurate and reliable. See Chapter Six for the full account of measurement methodology and testing results. With PAR2 retailing at $319 from The Reed Wizard (April 2020) and Jeanne ReedGauge from Jeanne, Inc. retailing at $325 (April 2020), consumers will likely be willing to pay approximately $350–400 for Mr. Mapper because of its tested and proven measurement accuracy, ability to measure reeds of all sizes, and ease of use.

THE COMMERCIALIZATION OF MR. MAPPER

Mr. Mapper is available for purchase at www.thereedmachine.com and www.reedmapper.com. The following material is the product description and instruction manual designed for commercial advertising and sale.

Mr. Mapper Product Description

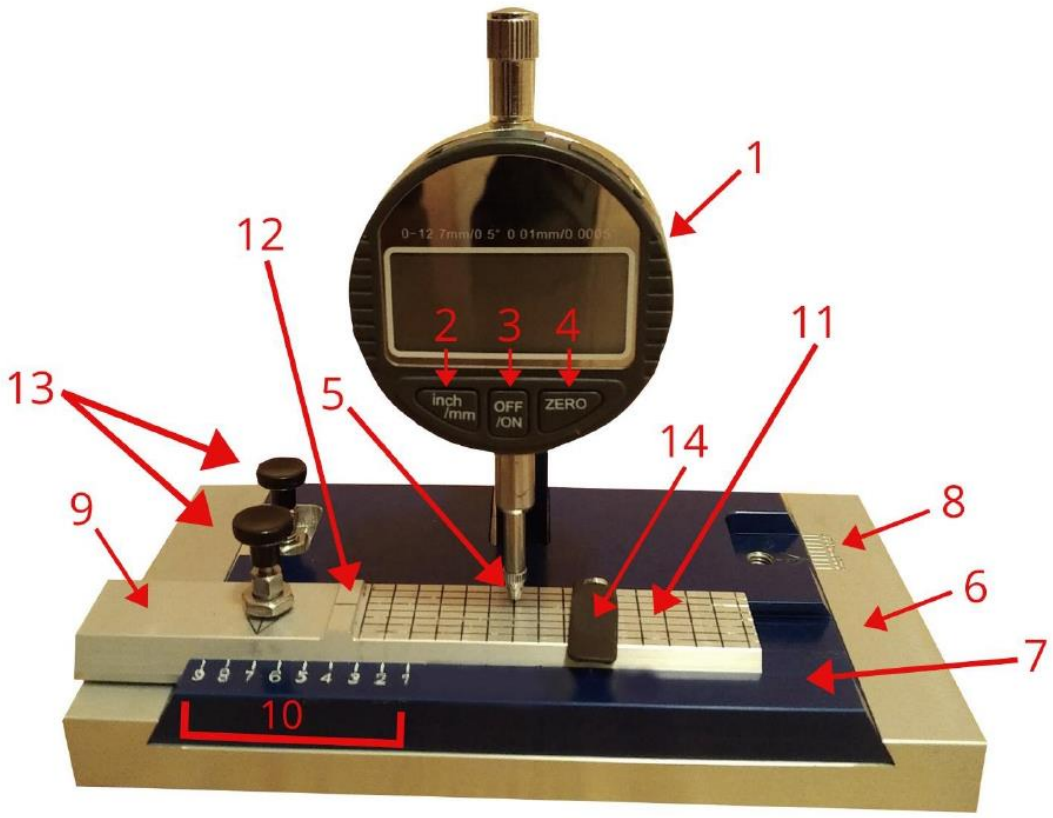
Dimensions	7 x 3 ⅞ x 5 ¾ inches
Weight	2.9 pounds
Dial indicator brand	Etopoo
Dial indicator measurement increments	0.000 inches or 0.00 millimeters
Vertical plane increments	5 mm
Horizontal plane increments	2.5 mm

The Manual Reed Mapper, or Mr. Mapper, is a micrometer designed to measure the thickness of single reeds (clarinet and saxophone) of any size. This user-friendly precision tool helps you improve reeds by identifying areas which need adjustment. Mr. Mapper uses a digital dial indicator, two planes of motion, and a set of pins to allow different areas of the reed to be measured and compared.

The ideal reed should be symmetrical from the center, but commercial reeds often fail the player in this regard. Use Mr. Mapper to identify points lacking symmetry, and adjust the reed's symmetry for a purer tone, snappier response, and improved intonation. Mr. Mapper can be used to reproduce reeds to identical dimensions of your favorite reed. Empower yourself to get more life out of a box of reeds by making more of them playable.

Instructions

Mr. Mapper is shipped in a storage container lined with foam to protect the tool and provide a measure of shock absorption. Familiarize yourself with the anatomy of Mr. Mapper before using.



1. Dial indicator
    - The dial indicator displays measurements.
2. Imperial/metric increments
    - The inch/mm button allows you to toggle between measuring in thousandths of inches or hundredths of milimeters.
3. Power button
    - The power button turns the dial indicator on and off.
4. Calibration button
    - The calibration button is used to establish the zero point as starting position.
5. Dial tip
    - The dial tip makes contact with the reed.
6. Base
    - The base is a sturdy metal block designed to balance and support measuring activities.
7. Horizontal plane
    - The horizontal plane measures nine positions from left to right across the reed: L3, L2, L1, C, R1, R2, R3.
8. Scribed letters
    - The scribed letters correspond to which position of the reed is being measured. C is center, L1 is the first position to the left of center, L2 is the second position to the right of center, and so on. The letter R corresponds with positions to the right of center.

9. Vertical plane (reed table)
    - The vertical plane measures nine positions from the tip of the reed to the end of the vamp.
10. Scribed numbers
    - The scribed numbers correspond to which position of the reed is being measured. Position 1 begins 2 mm from the tip of the reed, and Position 2 is 5 mm from Position 1.
11. Grid lines
    - The grid lines are used to correctly center the reed.
12. Ridge
    - The tip of the reed rests against the ridge.
13. Indexing pins
    - Raise and lower the indexing pins to unlock the horizontal plane or reed table and slide them to a new position.
14. Clamp
    - The clamp secures the reed in place by hugging it over the bark.

Using the Dial

Turn on the digital dial by pressing the "Off/On" button. The dial will automatically calibrate to zero based on where the tip is located when the dial is powered on. To properly calibrate the dial, be sure the tip is making contact with a perfectly flat spot on the reed table and then press "Zero." This dial gives the user an option to take measurements in thousandths of inches or hundredths of millimeters. To toggle between the two measurement systems, press "inch/mm."

Using the Tool

Before taking measurements, make sure that the dial has been calibrated. To use the tool, lift the dial tip from the reed table. Place a reed on the silver reed table, lining up the center of the reed with the marked center line and securing it in place with the clamp. Place the reed tip so that it is lightly touching the tip guard, being careful not to bend the tip by pushing too hard. Lower the dial tip gently to make contact with the reed.

To measure from the reed's tip to the end of the vamp, lift the reed table pin and slide the silver reed table back and forth. Drop the pin to lock it in place; the scribed arrow should line up with the guide lines at the scribed numbers. There are nine available positions. Position 1 begins 2 mm from the tip, and every position thereafter is in increments of 5 mm.

To measure horizontally across the reed from rail to rail, lift the horizontal plane's pin and slide it back and forth. Drop the pin to lock it in place; the scribed arrow should line up with the guide lines at the scribed letters. There are nine available positions. In the middle, position C provides measurements at the center of the reed. Positions L1–L4 measure to the left of center in 2.5 mm increments, and positions R1–R4 measure to the right of center in 2.5 mm increments. The tip can be left lowered during the entire measurement.

Data Collection

For the speedy and efficient readings, start at the reed tip and measure the length of the vamp before moving to the next left or right position to measure again from the tip to the vamp. With this procedure, one can measure a reed in as little time as 90 seconds.

When measuring a reed, it is good practice to record each measurement as it is taken so that problem spots are easier to identify. Use a table similar to this to record each measurement.

	L4	L3	L2	L1	C	R1	R2	R3	R4
1									
2									
3									
4									
5									
6									
7									
8									
9									

Sample data entry table.

Using the following table as an example, identify symmetrical counterparts which have differences of one-thousandth of an inch or more.

	L2	L1	C	R1	R2
1	6	6	6	6	6
2	15	18	20	18	15
3	26	32	34	32	26
4	41 (+3)	47	52	46	38
5	60 (+2)	68	74	67	58
6	86 (+4)	94 (+3)	100	91	82
7	113 (+4)	123 (+3)	128	120	109

Example data entry table with measurements of a B♭ clarinet reed.

The shaded cells denote the points that are thicker than the opposite side. The parenthetical numbers indicate how many thousandths of inches of cane should be removed. Remove cane using a reed knife, reed rush, or 600 grit sandpaper to make the counterpart symmetrical.

Care and Maintenance

When storing Mr. Mapper, insert a piece of foam between the dial tip and the reed table to prevent dents and damage. Return Mr. Mapper to the foam-lined storage case between uses. Do not drop the tool. Always carry Mr. Mapper from the base, not the dial or dial arm.

Suggested Supplementary Tools

4 x 6 inch reed glass
1 x 3 inch reed glass
Reed knife, reed rush, or 600 grit sandpaper (3M WetOrDry)
Reed clipper

Adjustment Considerations

When removing cane from a reed, do so slowly and patiently, removing a little bit at a time. It is preferable to measure a reed before it has been wetted, as moisture causes the reed to expand. Some reeds absorb more than others, and the rate of absorption is different reed-to-reed, making it difficult to compare measurements across wet reeds.

Wet the reed and sandpaper (if using) before scraping. Play test frequently after removing cane to reassess the mouth-feel. A reed that feels too soft can be clipped with a reed clipper. This puts the heart closer to the tip, thus increasing resistance.

No two reeds will measure and feel the exact same; organic materials vary in their cell structures. However, reeds of the same brand and same cut will fall within a predictable range. After measuring several reeds, a pattern should emerge of the average dimensions.

Reed Considerations

Aside from adjusting reeds, be sure to take care of reeds to extend their lives and help them play better. Have an established breaking-in process, and rotate reeds regularly. Store reeds in a humidity controlled case to prevent warpage. Soak reeds in water before playing rather than wetting in the mouth to quicken moisture absorption and limit saliva's impact on the reed. Avoid playing reeds while drinking coffee, after eating, or anything else that might latch on to the reed. Discard reeds that were used during illness, as the bacteria can still thrive in the cane.

Other than cane quality, a warped, worn, or chipped mouthpiece can make reeds sound poor. Make sure the clarinet is in good playing order, sealing properly, and has easy response.

CHAPTER FIVE: THE DIGITAL REED MAPPER

A few months into the development of the Manual Reed Mapper, I approached the Mechanical Engineering Department at the University of Maryland, College Park as a resource for design and construction ideas. What was originally intended to be a collaboration to refine the manual reed tool turned into the invention of a digital micrometer. The Digital Reed Mapper (hereafter referred to as "Dr. Mapper") was constructed with the help of Majid Aroom, Machine Shop and Product Innovation & Realization Laboratory Suite Lab Manager.

The first meeting with Aroom occurred April 8, 2019. The discussion included background information on the work done to date, a demonstration of commercial reed tools, an overview of Prototype 3 (the most recent at the time), and specifications required for the next tool iteration. Within the month, Aroom created their own prototype, and we met to discuss it a few weeks later. Aroom's machine was digitally operated and fully automatic. At the touch of a button, it mapped out the entire reed at five points from rail to rail and seven points from the tip to the end of the vamp in the span of 70 seconds. The measurements were sent to a computer program which generated a three-dimensional visualization of the reed's surface. The reed was held in place by a flexible metal bar, and the center of the reed plate was aligned to the center of every reed to be able to compare across sizes. Figure 5.1 is a picture of this first rough draft of a digital prototype.

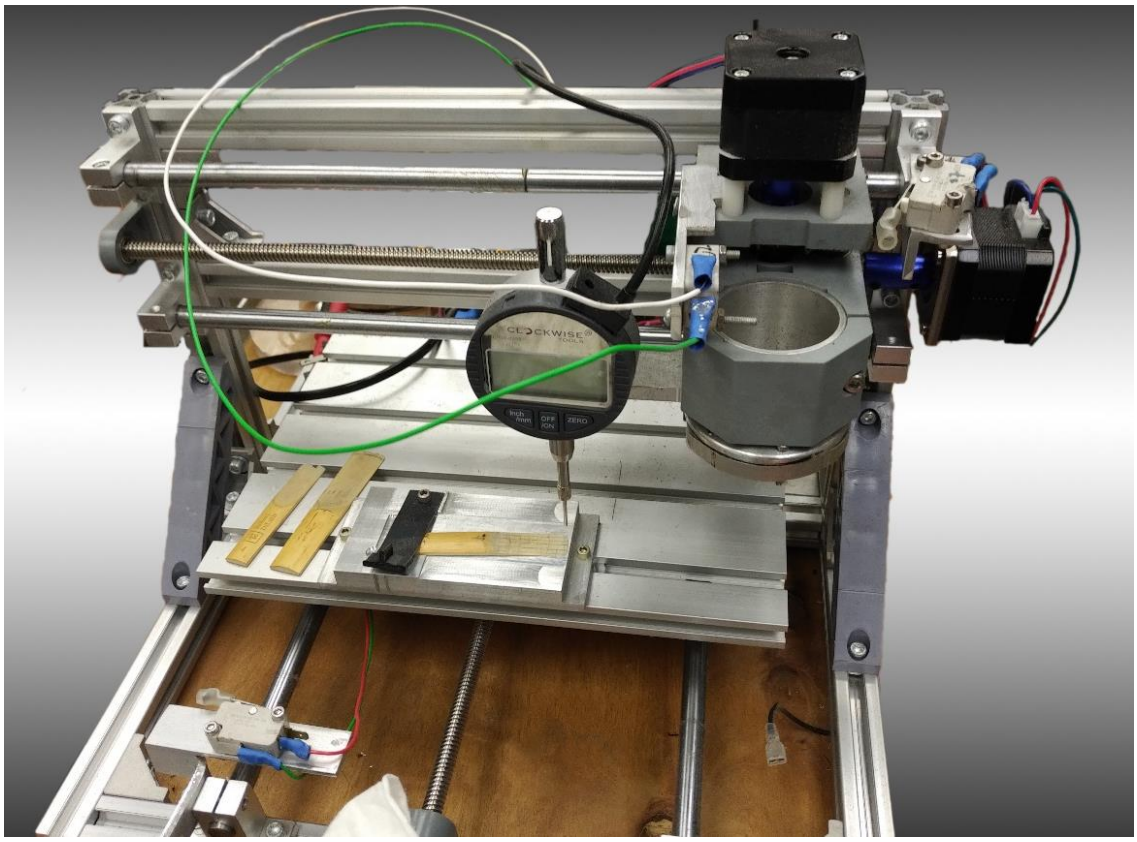


Figure 5.1: Prototype 1 of the Digital Reed Mapper.
Photograph by Natalie Groom, adapted by Pat Doyen.

This prototype was very large because the intent was to make a functioning tool which could then be scaled down; building at a large scale was the most cost-effective option while in the development stage. Two motors powered the dial indicator's movement across the reed. In the first reed table iteration (not pictured above), the reed table was an orange 3D printed plate with three sets of notches (figure 5.2, left) so that the reed tip was centered between the notches. The dial indicator was calibrated to find center on that table. No mechanism secured the reed in place.

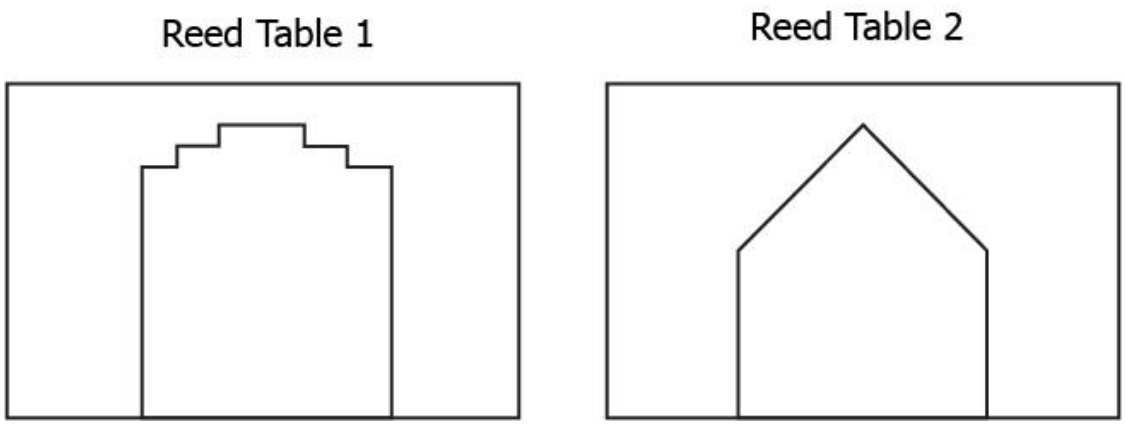


Figure 5.2: Dr. Mapper reed table shapes.
The top of each reed table is pictured. In the first iteration (left), the reed table was shaped in notches. In the second iteration (right), the reed table was shaped as a triangle.
Image by Aishwarya Shettigar.

The problem with this design was that a B♭ clarinet reed would rest closer to the plate's first notch opening, while a bass clarinet reed would rest further back at the third notch. With nothing holding the reed in place, there was no way to center reeds of various sizes, as the width of some tips would be too narrow or too wide to be secured by the notches. As learned in the Manual Reed Mapper's prototyping process, measurements needed to be derived from the same starting point from the tip of the reed in order to successfully compare reeds of all sizes and brands. Thus, a flat table was recommended in which the heel of the reed was clamped down and the tip met a ridge, similar to the design of Mr. Mapper. The second reed table produced by Aroom did not meet this requirement, as they instead created a table with a triangular notch (figure 5.2, right). One advantage of this approach was that any reed would naturally center within the bounds of the symmetrical triangular shape, but the problem still remained of not being able to derive measurements from the same starting point at the tip of all reeds. Aroom's third reed table (as seen in figure 5.1) eliminated the notch design and had the reed fastened to a flat table.

Though an increasingly complicated and expensive endeavor, the Digital Reed Mapper was an alluring idea. A particularly attractive feature of this design was its automated data output to a computer program. DiLutis, Aroom, and I discussed how to optimize this computerized capacity. A data export required a power source by way of an outlet or batteries. Regarding power options, the questions were posited: Can the product also be used completely offline if a user does not have a power source? What kind of batteries might be used? Is it an option to have a rechargeable battery? If it must be powered by an outlet, can the tool be easily converted for international audiences?

Regarding the data export function of the tool, the questions were posited: How will a user save files? How will the data be stored? How will the user export data? What program or operating system is required? Could a program automatically identify points on the mapped out reed which were not symmetrical? The team also discussed the possibility of controlling the tool with a cellphone application. If so, who would design the application? Could the computer output and application be synced? Could it be used offline? What would it cost to build an application with the minimum functionality required?

After this second meeting, I compiled a list of changes and considerations for the next set of revisions. The measurements needed to be captured as fast as possible without sacrificing accuracy, and the base needed to be as small as possible to remain reasonably portable. The reed table notches were to be removed entirely and the reed table elongated so that the ends of large reeds did not hang off the table. It was deemed beneficial to engrave a cosmetic center line in the middle of the reed plate to make it easier to center

reeds. I sent these suggestions, a list of program measurement patterns, and a list of programmable reed dimensions (E♭ clarinet through baritone saxophone) to Aroom.

In the next meeting in September 2019, Majid Aroom asked Kevin Aroom to join us. No changes had been made to the digital micrometer since the previous meeting over four months prior. The first half of the meeting was spent orienting Kevin Aroom to the progress that had been made to date and explaining what changes needed to be made for the next iteration. It was emphasized that measurements should be derived from a center line with vertical measurements starting 2 mm from the tip. Kevin Aroom suggested using a laser to measure reeds because of the speed capabilities, cost-effectiveness, and the option to have no physical contact with the reed. These lasers were cheaper than the dial indicator, but it was determined this was not a viable option because of an inability to put pressure on reeds which were warped. The advantage to a dial indicator was that the dial tip pushed the reed down to be flush with the reed table, a feature particularly important when measuring used reeds which were more likely to have warpage. The team discussed the possibility of patenting the design, and Kevin Aroom offered to send a budget proposal for the purpose of applying for grants.

The team reconvened at the end of October 2019. No new adjustments had been made to the original machine, and there was no new prototype. Instead, Kevin Aroom introduced a new design concept in which an array of pins would cover the entire width of any size reed (figure 5.3). The array needed to be positioned such that each pin point was 2.5 mm apart. The array needed to be 11 pins wide so that at least two were always touching the reed plate on the left and right side of a reed to establish point zero.

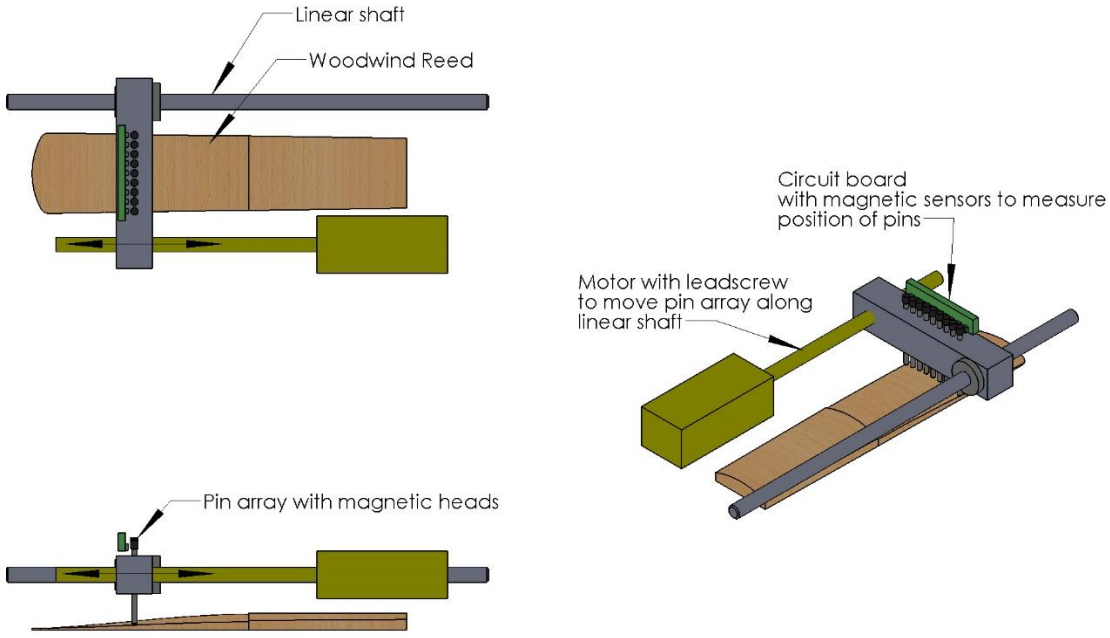


Figure 5.3: Pin array proposal.
This was designed by Kevin Aroom for the next prototype of an automated Digital Reed Mapper.
Source: Kevin Aroom, e-mail message to the author, September 29, 2019.

At this juncture, prototyping of the Digital Reed Mapper stalled because collaboration with the Arooms could only continue with a grant award or budget plan of approximately $10,000. No grant was awarded. Thus, the Digital Reed Mapper remained incomplete, and no patent application was filed.

CHAPTER SIX: TESTING THE ACCURACY AND RELIABILITY OF THE MANUAL REED MAPPER

Because it was not possible to complete the Digital Reed Mapper, the Manual Reed Mapper became my default device for measuring reeds. After its development, it needed to be tested for its accuracy, reliability, and ease of use. In order to have confidence that Mr. Mapper stood apart from its counterparts, I conducted a series of measurement tests similar to those which were used in the infancy of the project. The tests sought to answer to the following questions.

- If a user measures the same reed multiple times consecutively, will they achieve the same results?
- If two different users measure the same reed, will they achieve the same results?
- Is there increased consistency in results after users acclimate to the tool?
- Does the starting position and order of measurement affect the accuracy of measurements?
- Are there any features of Mr. Mapper that make it difficult or confusing to use?
- With minimal instruction provided, is Mr. Mapper intuitive to use?
- Are there any features that could be improved in future versions?

ESTABLISHING A REED MEASUREMENT METHODOLOGY

Aside from myself and Robert DiLutis, ten individuals were selected to perform test measurements. Of the ten participants, only four were clarinetists. Others were wind players, string players, and vocalists. This selection was intentional. I felt it was important to have non single reed players test the tool because they would have little to no background knowledge of single reed micrometers or reeds. Their input was unbiased and valuable in evaluating the tool's intuitive (or lack of intuitive) features.

The test reed was a 4.25 plastic Légère reed to ensure it did not change over time due to environmental conditions. Prior to each test, I demonstrated the tool setup, measurement action, and calibration for each participant. Participants were given brief verbal instructions (none written) on how to fasten the reed to the table, how to center the reed, and how to maneuver the moving planes. I purposefully kept the instructions brief in order to ascertain how little instruction could be provided and a user still intuit the function of the tool. I was curious to see what questions might arise during the measurement attempts; few did, which suggests Mr. Mapper was intuitive to use.

Each participant placed the Légère reed on the tool themselves, measured the same reed three times, and recorded measurement data by hand on a document provided by me (figure 7.9, Appendix C). For measurement values that included a number in the hundred-thousandths of an inch decimal place, participants were instructed to include decimal places rather than rounding up or down. The first measurement attempt served as the learning curve attempt, while the following two attempts were the authentic attempts. Between each attempt, I inspected the reed to ensure it was still symmetrically aligned on the reed table. 35 data points were collected on every B♭ clarinet reed—five positions across the reed from rail to rail, and seven positions from the tip to the end of the vamp. The measurement order was the same every time. Attempts 1 and 2 read R2:1–7, R1:1–7, C:1–7, L1:1–7, L2:1–7. Attempt 3 read L2:1–7, L1:1–7, C:1–7, R1:1–7, R2:1–7; the reasoning behind this was to measure the reed from opposing directions to see if the starting position or order of movement altered results. The data did not indicate a difference in results based on the measurement order. Figure 6.1 illustrates how the labels on Mr. Mapper corresponded to specific positions on a B♭ clarinet reed.

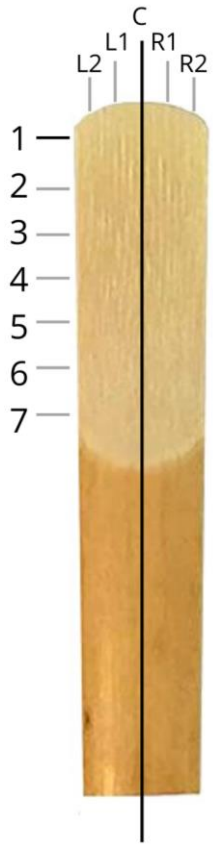


Figure 6.1: Mr. Mapper measurement positions demonstrated on a B♭ clarinet reed.
On the vertical plane, there are seven positions starting from the tip of the reed. On the horizontal plane, there are five positions. C is the center line. L1 represents the first position to the Left of Center, L2 represents the second position to the Left of Center, and so on and so forth.
Image by Natalie Groom.

Though only two positions to the left and right of center are pictured in figure 6.1, Mr. Mapper extends to four positions beyond center, L4 and R4, to accommodate the widest reeds. The vertical plane extends to Position 9.

TEST RESULTS

I was interested in observing how quickly participants adapted to the learning curve of using Mr. Mapper. The clearest evidence of participant adaptation was the

improvement in reed measurement timings across measurement attempts, as seen in figure 6.2.

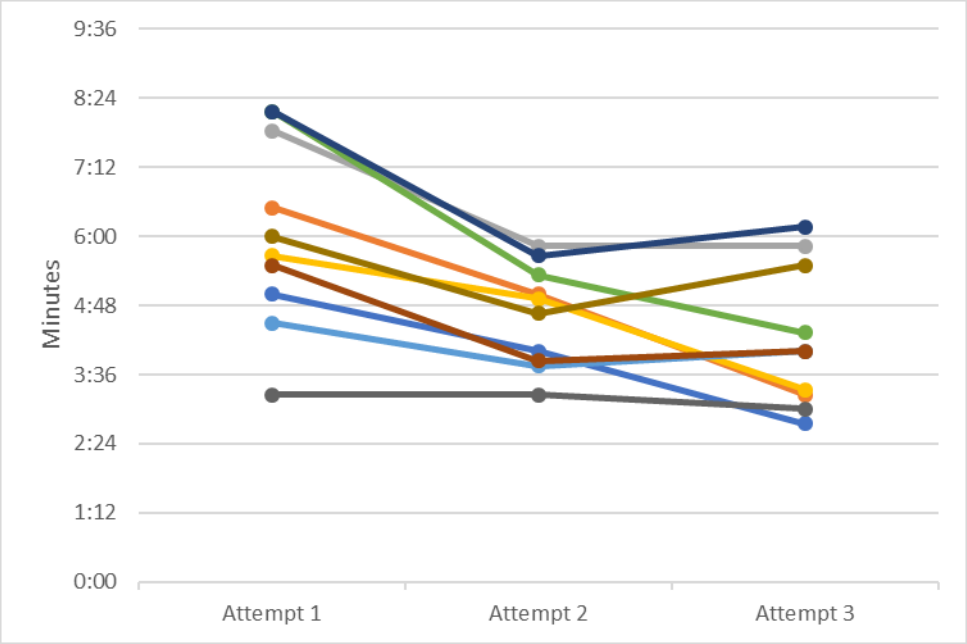


Figure 6.2: Timings across measurement attempts.
Image by Natalie Groom.

Every participant (each represented by a different color line) improved their performance time between Attempt 1 and Attempt 2. This demonstrates that even with minimal instruction, after using Mr. Mapper once, users experience significant gains in reading times and intuitive usage. For myself, someone who has used the tool to conduct hundreds of measurements, I average a measurement time of two minutes.

Measurements from the participants were compared to evaluate consistency across different users. Here, I will analyze the data and describe the findings. See Appendix C, table 7.7 for the full data output from every participant. The most important testing aspect of Mr. Mapper was its consistency across measurement attempts by various participants. I am pleased to report that when comparing the average thickness at a given point on the reed, the amount of difference was one-thousandth of an inch or less, as seen

in table 6.1, with the exception of position R1:6 which had a difference of 1.15 thousandths of an inch between Attempt 1 and Attempt 3 but was within one-thousandth of an inch between Attempt 2 and Attempt 3.

Table 6.1: Test readings, group average.

LEGERE TEST READING #1: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.55	7.55	7.9	7.6	6.8
2	15.3	18.65	19.85	17.6	14.7
3	26.05	31.85	33.7	30.6	24.1
4	37.6	45.95	48.55	44.6	35.55
5	50.4	61.05	64.3	59.15	47.5
6	65.45	79.65	83.8	76.6	61.6
7	85.35	104.75	110.3	101.35	77.9

LEGERE TEST READING #2: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.6	7.9	8.15	7.6	6.65
2	15.75	18.8	19.85	18.05	14.9
3	26.05	32.05	33.6	31.1	24.75
4	37.5	46.2	48.6	44.75	35.95
5	50.45	61.55	64.7	59.3	48.1
6	65.5	80	84.2	77.1	62.05
7	85.6	105.35	110.45	101.5	77.7

LEGERE TEST READING #3: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.7	7.8	8.05	7.9	6.55
2	15.25	18.75	19.8	18.1	14.8
3	25.6	31.85	33.75	30.95	24.8
4	37.7	45.85	48.75	44.9	35.7
5	50.05	61.1	64.55	60.1	47.9
6	65.25	79.55	84.15	77.75	62.2
7	85.05	105	111	102.15	78.55

These tables represent the average of ten participants' results across three measurement attempts. The yellow cells show that position R1:6 had a difference of more than one-thousandth of an inch between Attempt 1 and Attempt 3. The group average demonstrates that Mr. Mapper is 97% consistent. Table produced by Natalie Groom.

While this table may appear unremarkable, it demonstrates how consistent and reliable Mr. Mapper is across measurement attempts at the individual level and across users. For

example, compare position L2:1 across attempts with an average of 6.55, 6.6, and 6.7, respectively; behind these numbers are 30 recorded measurements which still averaged to be within one-thousandth of an inch of each other.

Similarly, the standard deviation of the group also demonstrates Mr. Mapper's consistency across users and measurement attempts.

Table 6.2: Test readings, group standard deviation.

LEGERE TEST READING #1-3: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.25	0.37	0.35	0.36	0.38
2	0.67	0.50	0.50	0.76	0.45
3	0.70	0.57	0.61	0.72	0.85
4	0.87	0.67	0.60	0.81	0.87
5	0.82	0.61	0.43	1.07	1.07
6	1.05	0.84	0.55	1.30	1.24
7	1.52	1.02	1.10	1.40	2.21

LEGERE TEST READING #2-3: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.29	0.37	0.35	0.38	0.35
2	0.74	0.57	0.54	0.77	0.43
3	0.71	0.63	0.69	0.70	0.70
4	0.93	0.64	0.57	0.77	0.73
5	0.84	0.63	0.32	0.92	0.97
6	1.10	0.91	0.44	0.96	1.15
7	1.28	0.99	1.01	1.03	2.21

The upper table represents the standard deviation of ten participants' results across three measurement attempts. The lower table represents the standard deviation of the group after discarding Attempt 1 data. The yellow cells denote positions which have a difference of more than one-thousandth of an inch from the mean after being rounded up (values of 1.25 or greater are rounded up to 1.5 on the micrometer readout). When considering the group standard deviation, Mr. Mapper is 94% consistent.
Table produced by Natalie Groom.

The standard deviation identifies the amount of deviation, in thousandths of inches, from the mean (the averages seen in table 6.1). Again, it is evident that Mr. Mapper is reliable to one-thousandth of an inch in every position except L2:7 and R2:7.

It is not possible to compare reliability across tools measuring the same reed because each tool captures a different quantity and location of data points, but it is

possible to compare internal reliability on a per-tool basis. Table 6.3 demonstrates discrepancies between test measurements of a Légère reed using PAR2.

Table 6.3: PAR2 test measurements.

PERFECTAREED VERSION 2						PERFECTAREED VERSION 2				
Test Measurement 1						Test Measurement 2				
in thousandths of inches										
order of measurement: tip to heel										
Legere 4.25										
red denotes mismatch between Test Measurement 1 and 2										
RIGHT						RIGHT				
	A	B	C	D	E	A	B	C	D	E
1	10	10	10	11.5	11.5	9	10	10	11	11
2	17	20	22	23	23	17	20	21	23	23
3	26	31	35	37	38	26	31	35	38	38
4	36.5	42	48	52	53	36	42.5	48	52	53.5
5	47	55	63	68	70	47	55.5	63	68	70
6	59	72	80	88	92	60	71	81	88	90
7	72	90.5	104	113	119	72.5	90	103	113.5	118.5
LEFT						LEFT				
	A	B	C	D	E	A	B	C	D	E
1	8	10	10	11	11	8.5	10	10	11	11
2	16	19.5	21.5	22.5	24	16.5	19.5	22	23.5	23.5
3	25	31	35	38	38	26	31	34	37	38
4	35	42.5	48	53	54	35.5	43	48	52	53
5	45.5	55.5	63	69	72	47	56	64	68	70.5
6	58.5	71	80.5	88	92	59	71	81	88	91.5
7	71	91	103	114	120	73	91	103.5	115	119

The data demonstrates a lack of internal consistency when measuring the same reed multiple times using PAR2. When measuring with the reed on the left side of the dial, there are 13 positions which differ by one-thousandth of an inch or more. When the reed is on the left side of the dial, 7 positions differ. Table produced by Natalie Groom.

PAR2's internal reliability is very low with a total of 20 positions differing by one-thousandth of an inch or more, or 71% reliability, when comparing measurement attempts. By contrast, Mr. Mapper has only two positions that could be improved, proving a reliability of 94–97 %.

Other metrics I examined included the mode and range of results at a given position, for which the data may be found in tables 7.9 and 7.10 in Appendix C. Using Participant 1 as an example in table 6.4, the range of difference between Attempts 2 and 3 was less than the difference between all three attempts.

Table 6.4: Test measurement ranges of Participant 1.

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0.5	0
2	0	1	0.5	0.5	0.5
3	0.5	1	1	1.5	1
4	0.5	1	2	2	1.5
5	1	1	1.5	2	2.5
6	1	0.5	1.5	3	2.5
7	2.5	0	2.5	4	4

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0.5	0
2	0	1	0	0	0.5
3	0.5	0.5	0.5	0	0
4	0	1	0.5	0	0.5
5	0	1	0.5	0	1
6	0.5	0.5	0.5	0.5	1
7	0.5	0	0.5	1	2.5

The upper table shows the widest range of difference at each reed position across all three measurement attempts. The lower table shows the range of difference at each reed position between Attempt 2 and Attempt 3. Green cells denote reduced range when Attempt 1 data is discarded.
Table produced by Natalie Groom.

The numbers within the cells represent the range of results between measurement attempts. Comparing three attempts, the widest range of difference was four-thousandths of an inch (Position R1:7 and R2:7); comparing Attempts 2 and 3, the widest range of difference was 2.5 thousandths of an inch (Position R2:7). The green cells denote positions which saw improvement in range differences when Attempt 1 was discarded from analysis. Once the participant acclimated to the tool, their results were consistent

within one-thousandth of an inch, with the exception of position R2:7. Additionally, their measurement accuracy improved over time. See table 7.11 in Appendix C for each participant's range across all three attempts and a reduced comparison which only includes Attempts 2 and 3. The data did not reveal any patterns or items of note when the group range was documented (table 7.10, Appendix C).

Unsurprisingly, across participants and measurement attempts, the positions with the most variation were at the end of the reed's vamp; this is because these points are at the turnaround position on the reed where the vamp starts to meet the bark. The slope is unstable here. The dial tip may slide around. Positions L2:6, L2:7, L1:7, C:7, R1:7, R2:7, and R2:6 are the most affected by this. However, when making reed adjustments, these positions are also the least important because changes at these points do little to alter a reed's sound. While the goal is always to have Mr. Mapper perform as accurately as possible at all positions, it is understandable if those seven positions have greater ranges of difference across measurement attempts. The group average and standard deviation proves that even those unstable positions can be reliable within a thousandth of an inch with the exception of L2:7 and R2:7. Though this data collection only represents B♭ clarinet reeds, the outermost and lowest positions on any reed will produce the most inconsistent results because of being at the cusp of cut reed and the reed bark. PerfectaReed and the Jeanne ReedGauge share this struggle, but those tools are also inconsistent across the entire reed surface.

This test study was limited in its number of participants, but considering that over half of participants had little to no knowledge of clarinet reeds and micrometers, it is a testament to Mr. Mapper's reliability that the results were this consistent. I originally

intended to exclude data from Attempt 1 from my analysis because it was the learning curve attempt for participants to acclimate to the tool. However, I did not because I was surprised to find that even when including Attempt 1, Mr. Mapper was reliable to one-thousandth of an inch. There are future research opportunities to expand the participant pool for more comprehensive data collection. In the following section I summarize the verbal feedback provided by participants after completing all measurement attempts.

PARTICIPANT FEEDBACK

Participants felt positively about the measurement experience. Numerous users commented on Mr. Mapper's simplicity and ease of use in addition to the aesthetic design being "fun" and "cool." Everyone appreciated the clicking sound of the pin locking in place each time. This sound was louder along the silver vertical plane, and participants expressed they wished the click were louder along the horizontal plane as well. The sound made them feel confident the indexing pin was locked in place. Everyone appreciated the grid lines on the reed table, as this made it easier to center the reed. Clarinetists remarked that Mr. Mapper was easier to use and appeared to be more consistent than other tools they had used in the past.

Placing the reed on the table and properly centering it was cited as the most "stressful" or "difficult" part of the whole process, as it required great attention and care. It was difficult to center the tip and heel of the reed simultaneously, and centering one end at a time sometimes caused the opposite end to drift from center. The plastic reed appeared to drift more easily than a cane reed because of its slick surface. Participants expressed anxiety that inconsistencies might have been due to their own error, an

insecurity more pronounced in the non-reed players. This could indeed be true, but my thinking was that the average user of Mr. Mapper would likely be less attentive even than these selected participants, colleagues who I knew strived to be conscientious and detailed in their measurements because of their relationship to me and their desire to produce accurate results. Therefore, I was not overly concerned with documenting things that could be interpreted as human error when I wanted to examine Mr. Mapper's reliability to the average user with average error.

While many of the participants' suggestions cannot translate to product alterations, I noted that a Frequently Asked Questions document would be beneficial to include in product packaging when Mr. Mapper is available for commercial use. The FAQ will also be on the product website. This will explain why the design features are the way they are. For example, if someone were to ask, "Why can't the reed be locked in place with a square clamp?," I will be able to explain that a square clamp for the heel of the reed would not allow users to measure reeds of all sizes, as the clamp would be the incorrect size for anything other than B♭ clarinet reeds.

CONCLUSION

It was a challenge designing measurement and testing methodologies that would be telling indicators of accuracy and reliability across commercial micrometers and Mr. Mapper, but I am confident the use of plastic reeds and an organized and thorough testing process yielded trustworthy results. This dissertation has provided context of the commercial reed industry so that a discussion of single reed micrometers could be accessible. Having outlined the many faults found in the handful of micrometers

available in the U.S., it is clear a new tool was needed to fill a gap in the market. After going through many iterations, the precision gauge Mr. Mapper was invented to address this market need. Mr. Mapper has been subjected to numerous tests to evaluate its reliability and consistency across users, and the data prove that Mr. Mapper is the superior single reed micrometer at 94–97% measurement consistency. Looking to the future, now that Mr. Mapper has been invented, it is possible to carry out the original research idea of analyzing the consistency of reeds across multiple brands.

APPENDIX A: CONCERNING REEDS

REED PRODUCTION

There are no industry-wide standards on how to manage cane growth or quality. Given how sophisticated agricultural methods for other plants have become, it is a shame that none of these innovations have been applied to the reed cane *Arundo donax*.[5] While commercial reed companies have individualized production processes in reed making, a generalized approach can be summarized here.

Clarinet reed cane comes from the *Arundo donax*, a plant which thrives in sunny, moist climates as found in the Var region of southern France.[6] It is a warm-temperate or subtropical species similar in appearance to bamboo, though not as hard. It is native to countries surrounding the Mediterranean Sea, but commercial reed companies attempt to grow around the world, such as D'Addario's plantations in Argentina and California. Good quality cane has been produced in North Africa, Kenya, South America, Mexico, Cuba, Texas, and Virginia as well, proving that *Arundo donax* can thrive in a variety of soils. This giant reed plant grows taller and thicker than most grasses, often achieving a height of seven to eight meters, as seen in figure 7.1. It grows remarkably fast in favorable conditions, sometimes 0.3 to 0.7 meters per week.[7] In its first year of growth, the hollow cane is red; in the second year it turns green and grows leaves which encircle

[5] Ben Armato, *Perfect a Reed...and Beyond: Reed Adjusting Method* (Ardsley, NY: PerfectaReed, 1996), 2–3.

[6] Lawrence J. Intravaia and Robert S. Resnick, "A Research Study of a Technique for Adjusting Clarinet Reeds," *Journal of Research in Music Education* 16, no. 1 (Spring 1968): 45.

[7] Robert E. Perdue, "Arundo Donax-Source of Musical Reeds and Industrial Cellulose," *Economic Botany* 12, no. 4 (October 1958): 369.

the cane. These leaves trap moisture and contribute to the cane's marbled appearance after it has been harvested; this does not affect the quality of the cane.

Figure 7.1: *Arundo donax*.
Source: Stephanie Duer, "Arundo Donax," Garden Wise Salt Lake City (Garden Soft), accessed November 29, 2019, http://www.slcgardenwise.com/eplant.php?plantnum=24787&return=l4.

After two years or three years, the cane is cut during the winter and left to dry in the sun for several months, at which point it is moved to warehouses where it dries for a year or more. The exact harvest and drying time is a secret kept by individual farmers, as they want to guard their production processes. Sun exposure and the drying process removes the remaining green color so the aged cane appears yellow. Curiously, cane is not harmed by rain. After the cane has cured, it is cut into tubes along the internodes of the stalk. The shortened tubes of cane, known as culms, are then sorted by diameter

which correspond to what size reed will be made from each culm.[8] The culms are split into quarters, then given a preliminary cut to start a reed blank. Reed blanks are cut again to define the reed's vamp and make the final determination in what strength (hardness, or thickness) the reed will be. Commercial reeds are sold by boxes of the same "strength," a term used to define how resistant a reed will feel to a player. Strength has to do with how dense or hard a reed is and its thickness. Strengths typically range from 2 to 5 with 2 being the least resistant and 5 being the most resistant. The average clarinetist might play a 3 or 3.5 strength reed.

Examining the reed production of one specific company, Rico (later acquired by D'Addario) described its production process in 2009 in the "How It's Made - Rico Reeds" video.[9] Rico harvests cane on the Mediterranean coast. After it is harvested in the winter, the cane poles are dried for several months. In the summer, the poles are dried in direct sunlight for 12–18 days, then rotated to the other side to dry for another 6–12 days. The poles are then stored in a warehouse before moving to the sawing department where they are sliced into tubes to remove the nodes.

The tubed cane is graded according to its diameter and wall thickness and then split into four pieces. The split pieces are planed flat and tapered at the sides to create a reed blank. Optical lasers cut the reed blanks to specific dimensions to produce reeds of all sizes. The blanks are inspected by a color video inspection system to sort out cane with color or quality flaws. Polishing discs flatten and smooth the backside of the reed

[8] Karen F. Schmidt, "Good Vibrations," *Science News* 140, no. 24 (December 14, 1991): 393.

[9] D'Addario Woodwinds, "How It's Made - Rico Reeds," video last modified February 11, 2009, accessed February 18, 2019, https://www.youtube.com/watch?v=MwOUEsdpuI0.

before it moves on to the final step of cutting the reed vamp. Natural diamond cutters slice the reed vamp with extreme precision.

After the vamp has been cut, the reed's hardness is tested. Based on this, it is sorted into categories with like strengths. The finished reeds are laser engraved with the company logo, inserted into individual plastic sleeves, and packaged in boxes of ten reeds for final distribution.

In 2016, D'Addario published an updated video about its new production processes after acquiring Rico in 2004.[10] The modifications were a response to customer complaints about a lack of consistent quality across boxes reeds, and users expressed frustration at only being able to find one or two good reeds per box. Most of D'Addario's reeds are grown in Hyères, France because of its ideal growing climate. It is sandy, moist, and rarely sees frost. From first planting, it takes five to seven years to see a crop yield of high enough quality to use for single reed production.

After being harvested by hand and separated into one-year and two-year old cane bins, the poles are shucked of its leaves. The cane poles are graded by hand and stored in bundles. At the appropriate time, poles are cut into tubes at the cane's nodes. The tubes are sliced into multiple pieces longways and transformed into reeds via a digital vamping system at the D'Addario factory in California. Digital vamping systems make it easy to adjust the reed cut style and overall dimensions. Electronic sorting quickly sifts out reeds that do not fit the specifications. Reed quality is play tested by individual players.

[10] D'Addario Woodwinds, "D'Addario Woodwinds: Craftsmanship for the 21st Century," video last modified September 23, 2016, accessed February 24, 2019, https://www.youtube.com/watch?v=6UIa5HF806c.

CANE QUALITY

Much like the quality of a wine, the quality of the organic material *Arundo donax* is subject to environmental factors such as climate, temperature, humidity, soil content, sunlight, and more. Companies that produce reeds are at the mercy of these variables. However, it is also the harvester's responsibility to gather cane when it has aged an appropriate amount of time. Cane should be aged a minimum of 6–12 months, and a longer period is considered desirable, but oftentimes market demand encourages manufacturers to harvest too early and use poor quality cane.[11] There is no point in the consumer storing reeds to age it themselves because the aging process is determined when the growers chose to harvest. If the cane was immature at the time of harvest, additional storage will not help.[12]

As reeds deteriorate due to use, so does their sound quality. Oftentimes reeds become warped, a result of reeds living in a cycle of water absorption and drying. Like any wooden compound, the cane changes over time. To test if a reed has warped, set it on a flat surface, preferably a piece of glass; alternating the index finger and middle finger on the left and right rails of the reed, tap the sides of the reed along the vamp. If the reed teeters, the reed is warped. Similarly, inspect the tip by holding the reed parallel to the eyes with the tip facing the observer. If there are waves in the tip's contour, the reed is warped. Polish the backside of the reed by rubbing it along the glass to attempt to remove the warpage. One way to test the fit between the reed and mouthpiece is to remove the mouthpiece from the clarinet, place the mouthpiece tenon opening against a hand to seal

[11] Perdue, "Arundo Donax-Source of Musical Reeds and Industrial Cellulose," 383.

[12] Armato, *Perfect a Reed...and Beyond: Reed Adjusting Method*, 15.

the end, and inhale to vacuum seal the reed closed against the mouthpiece. If the suction does not hold for five or more seconds, this is evidence of warpage, though it is not clear if it is the result of the reed or mouthpiece being warped.

REED MYTHS

There are many myths about cane that have been perpetuated over the years. Some people claim the only good quality cane comes from France, or that cane with flecks of color in the bark (mottle) has certain sound characteristics. These myths likely come from professors and professional musicians who experience anecdotally a pattern of good versus bad reeds which they attribute to some unscientific factor. Regarding the myth that all good cane comes from France—a fable happily eternalized by companies based in France—it is entirely false that good quality cane cannot be produced outside of southern France. Botanists have proven on multiple occasions that equally sound cane has been produced along the Mediterranean Sea and in Mexico, South America, northern Africa, California, and Texas.[13]

Many myths circulate about how the color of cane corresponds to its sound. There is almost no way to determine the quality of cane by examining its color features. Teachers of the past encouraged students to discard reeds that did not have a golden yellow color. While properly aged cane generally does have a golden yellow color, cane that does not fit this criteria may also have a lovely sound. The bark may be dark brown, mottled, or yellow and still perform satisfactorily. Mottled stains on the bark are caused by rotting leaves that dried on the cane during the curing period. Botanists claim that the

[13] Perdue, "Arundo Donax-Source of Musical Reeds and Industrial Cellulose," 380.

most important factors in cane quality are a healthy plant structure and an even distribution of thin, straight xylems—the inner vascular tissues in a plant—extending to the tip of the reed.[14]

Another myth is the belief that reeds from "back in the day" were of superior quality and thus did not require special storage considerations or additional adjustments. It is entirely possible that the commercialized cane industry has progressed towards putting out less and less quality product, but there have been no studies to validate this claim. Indeed, it would be difficult to execute because reed quality is subjective and if one were to compare brand new reeds boxed fifty years ago to reeds produced this year, it would not be a fair comparison because the fifty-year-old reeds have been aging five decades. The only way to quantify reed quality over the years would be to assess it in the year it is produced, and then compare the results after thirty years of yearly readings. It seems the "grass is greener on the other side" thinking continues to have traction in the single reed world.

Theoretically, reeds should feel more consistent to present day consumers because reeds are manufactured with state-of-the-art laser technology and sorted into increasingly specific strength categories. It used to be that brands only carried strengths in 0.5 increments (2, 2.5, 3, 3.5, et cetera), but now brands carry reeds in 0.25 increments (2.75 or denoted as 2.5+, as an example). Suppose a player purchased a box of 3 strength reeds from a brand that boxed in 0.5 increments. The reeds in this box could range anywhere from 2.7, 2.8…to 3.2 or 3.3; the range between the softest and hardest reed in a box could

[14] Armato, *Perfect a Reed...and Beyond: Reed Adjusting Method*, 14.

be ±0.3 increments. Contrast that with modern production increments of 0.25 strengths. That same box of 3 strength reeds might only vary by ±0.15 increments.

Some players believe if a reed requires any adjustment, it must just be a bad reed. This is false, as there is a lot of variation in *Arundo donax* that can be adjusted quite simply to produce a pleasing reed. To begin with, commercially produced reeds often require light buffing over the reed's surface to remove splinters and textures that may be uncomfortable at the player's lips. Other than this cosmetic adjustment, because reed xylems do not grow perfectly straight or evenly across the surface of a reed, certain spots might have denser cane than others. If the xylems on the left side of a reed are denser than the right side, a slight removal of material from the left side may make the reed feel and play balanced even if the left side ends up being thinner than the right. Similarly, the heart of a reed should have a parabolic shape of normal distribution from the center of the reed. No reed has a perfectly symmetrical heart, and visual observation can indicate if the heart of the reed is skewed. Nearly every clarinetist has been told at some point to never adjust the heart of a reed, and that is a good general principle so the heart's proportions are not disturbed; but, when the heart's parabola is askew, an adjustment can make it perform better. If a reed feels too hard overall, taking sandpaper over the width of the reed where the lip makes contact can make it feel more responsive. Generally, if a reed feels hard, it is because the heart is too thick.

Another myth is that saliva drives reed deterioration. While it cannot be argued that saliva must be dirtier than water, there are no studies which track the rate of deterioration a reed faces when wetted by saliva versus water. Bacteria and enzymes in saliva do break down the reed's xylems, but it is unclear to what degree and how much

quicker than water. This is difficult to test because every player's saliva will have different enzyme prevalence, and so some players may experience swifter cellular break down in their reeds than other players.

FACTORS AFFECTING REED PLAYABILITY

Aside from the quality of cane, there are variables that affect reed playability. A player may have idiosyncrasies which influence the resonance, intonation, or sound quality of a reed. For example, an embouchure that is too tight or pinched will produce a thin sound and sharp intonation even on the best reed, while an embouchure that is too loose will produce a spread sound and flat intonation. The angle of the mouthpiece can affect a reed's sound, as a closer angle generally puts more lip on the reed, thus dampening vibrations. Too wide an angle can produce a wild sound, as there is too little lip making contact with the reed to control vibrations. The mouthpiece itself may be warped with warpage manifesting on the rails and facing (see figure 7.2).

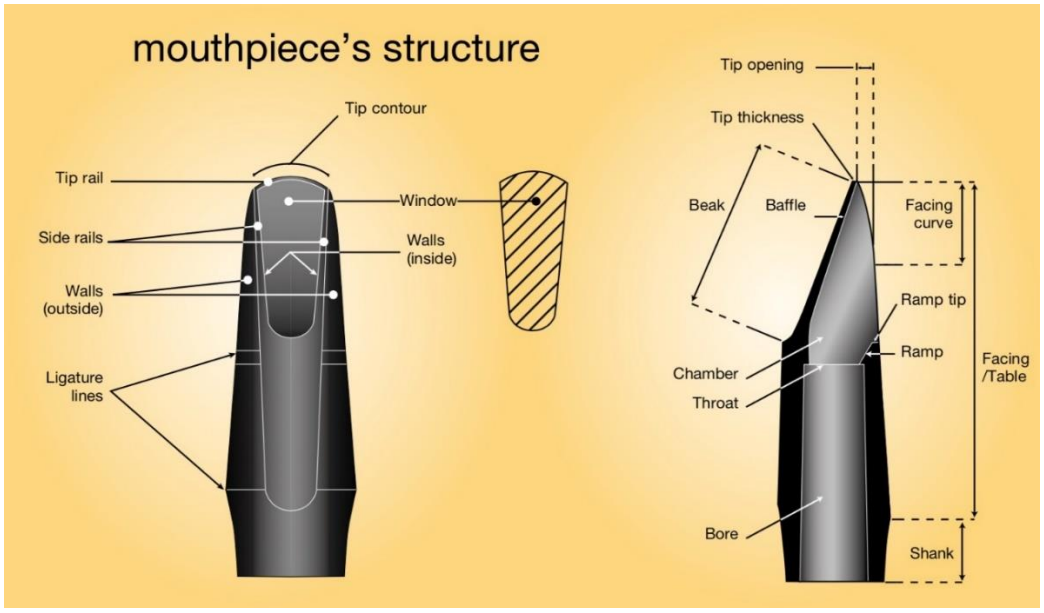


Figure 7.2: Anatomy of a mouthpiece.
Source: "Mouthpieces Technical Elements," Vandoren Paris, accessed November 29, 2019, https://vandoren.fr/en/mouthpieces-technical-elements/.

If any part of the facing is warped or uneven, the reed will not sit flush against the mouthpiece and will therefore not play with a balanced sound. If a player finds that reeds that are harder on the right side seem to perform better, this could be because the mouthpiece is misshapen in such a way that it requires an unbalanced reed to produce its best tone.

The facing of a mouthpiece determines what strength reed should be used. In general, close facings require hard reeds and open facings require soft reeds. If a player has mismatched the strength of their reeds and the length of their facing, they may never be happy with the sound it produces even while using a perfectly adequate reed. In "Perfect a Reed…and Beyond," Ben Armato suggests the following checklist when selecting a mouthpiece:

- Does the mouthpiece facing respond quickly to adjustments?
- Does it produce a good legato?
- Can staccato and articulation be executed with ease?
- Does it have a wide range of dynamics?
- Is the sound and color even in all registers?
- Does it feel comfortable to play?
- How are the blending qualities?
- Does the mouthpiece allow the embouchure to make pitch adjustments?[15]

The ligature may make a reed feel dull, stuffy, bright, thin, or any other number of characteristics. The ligature's function is to fashion the reed flat onto the mouthpiece with as little obstruction to reed vibration as possible. Ligatures that contact the reed in many places may dampen vibrations. On the mouthpiece itself, manufacturers often scribe lines on the sides to designate the optimal ligature placement. However, depending on the length of the reed vamp, a ligature may need to be placed higher or lower to maximize

[15] Armato, *Perfect a Reed...and Beyond: Reed Adjusting Method*, 8.

the reed's vibratory potential. Furthermore, the clarinet itself, including the barrel and bell, can alter how reeds respond. Understandably, the complex interaction between a reed, mouthpiece, ligature, clarinet, and individual is enough to frustrate anyone seeking the ideal setup for beautiful tone production and response.

VARIABLES AFFECTING REED PERFORMANCE

Assuming a reed is of superior quality and perfectly balanced, the position of the reed on the mouthpiece will alter its sound. Strive to center reeds on the mouthpiece first, then tilt it off to the side if it is necessary to accommodate an unbalanced reed. A reed that is lower than the outer edge of the mouthpiece's tip rail will feel softer, and a reed that is higher than the tip rail will feel more resistant. Strive to align the reed tip with the tip rail such that when a player pushes down lightly on the reed tip, it is flush with the outer edge of the tip rail.

Reeds perform better if they are "broken in" slowly. A reed that is played heavily straight out of the box will lose life quickly, as the xylems are exposed to undue stress too soon. Instead, establish a breaking in process in which moisture and stress are introduced in small, methodical increments within a rotation (see "Prolonging the Life of a Reed" below). Intertwined with the break in process is attention to humidity control and environmental factors. Reeds subject to fluctuating humidity, air flow, water retention, and playing environments will continue to feel unsettled and unpredictable. Stabilize the reed's performance by adjusting to the local conditions. For example, if performing in a desert climate, keep reeds humidified at lower than ideal conditions (30–50%) so the

difference between the internal case environment and external environment is not as drastic.

ADJUSTING REEDS

When adjusting reeds, use 600 grit WetOrDry 3M sandpaper. This is easier to control and manage than alternatives such as reed rush or a reed knife. Fold the sandpaper into 1 x 1 inch squares; the added thickness gives the user more control while sanding. Wet the reed and wet the sandpaper before applying changes. Set the reed on a flat glass surface and sand the desired locations.

A player can test a reed's balance without even measuring it. Play test the reed on an open G. Then rotate the mouthpiece to the left so that sound is being produced by the right side of the reed. Rotate again with lip pressure on the right side of the reed so that sound is being produced by the left side of the reed. These three positions should feel and sound similar. If they do not, that means the sides are unbalanced. Identify which side sounds too dull compared to the others, and sand that side to make both rails equally light. Identify which side sounds stuffy compared to the others, and sand lightly approximately 2 mm from the reed tip along the stuffy rail.

Visual inspection can be highly informative. Hold the reed up to a light source and notice the contour of the xylems, particularly how they are congregated at the heart of the reed. An ideal reed will have a parabolic distribution of xylems at the heart, though many reeds skew to one side. If xylems are concentrated on one side of the reed, it can be beneficial to angle the reed off the mouthpiece slightly towards the softer side to make it feel symmetrical, or to sand the side with dense xylems. Another telling visual cue is

when certain xylems extend all the way to the tip, are thicker than those around it, or are broken in the middle. These irregularities may be what produces undesirable sounds.

For a data-driven analysis of a reed, turn to a reed micrometer such as Mr. Mapper to obtain accurate measurements of reed thickness. Measure the center of the reed and two positions to the left and right of center. Record the measurements and identify positions that are not symmetrical. Using a soft lead pencil, mark a dot on the reed of the section that needs to be sanded. Use 600 grit sandpaper to reduce thickness on the desired location. When making adjustments, be sure to "feather" in any scraping to avoid leaving divots in the reed's surface. The contour should remain smooth and proportional. Make small adjustments and play test between each scraping, as cane cannot be added back on. Measure the target positions after scraping to judge how much progress has been made and where to continue scraping. Do a few adjustments at a time, then revisit the reed the next day because it will change as it dries and rehydrates.

PROLONGING THE LIFE OF A REED

Reeds that have been broken in will last longer and behave more consistently. Purchase commercial reeds or make reeds from scratch. Remove the reeds from the box and individual sleeves. Buff all sides of the reed with 1000 grit sandpaper: vamp, back, sides, and heel. This removes splinters and irregularities at the edges. Wet one reed at a time, soaking in water for one minute. Play the reed for five minutes, then set it aside to dry on a piece of glass or in a reed case before moving on to the next reed. Always store reeds in a humidity-controlled case to prevent warpage. Rotate reeds to keep each one at a consistent humidity and optimize their longevity. On the second rotation, soak each

reed for one minute and play for 5–10 minutes. On the third rotation, soak each reed for 30 seconds and play 10–20 minutes. On the fourth rotation, soak each reed for 15 seconds and play 20–30 minutes. Ideally, always rotate reeds in 30-minute increments or less.

Use water to wet reeds rather than the mouth, as water penetrates the reed quicker and is cleaner than saliva. Cane is cellulose and porous in nature. Like a sponge, it is not readily useable before it has been soaked. To keep a reed hydrated, it should be played regularly within a rotation and stored in a container which retains an optimal moisture level of 60–75% humidity.[16] Discard reeds that were played during illness, as the bacteria may still thrive in the cane, thus prolonging illness and accelerating the reed's rate of deterioration.

[16] Frost, "Reeds."

APPENDIX B: COMMERCIAL SINGLE REED MICROMETERS

To conduct this research, multiple commercial reed micrometers were tested to compare instrument consistency. The results were used to catalog features which would make Mr. Mapper and Dr. Mapper the most accurate and competitive tools on the market. There are two commonly used clarinet micrometers available in the U.S.A.: Ben Armato's PerfectaReed and the Jeanne ReedGauge. Outside of the U.S.A., the most similar product is Reeds 'n Stuff's Digital Measuring Device. The following information is supplementary to the body of the document. To be fairest to each manufacturer and paint them in the most favorable light, I have included their own product descriptions and manuals so that the reader sees the source information and not just my own summary.

PERFECTAREED VERSION 1

The PerfectaReed was invented by clarinetist Ben Armato in 1969. Armato published a companion book in 1980 called "Perfect A Reed," a scientific method for adjusting single reeds. In 1995, Armato revised and republished the book as "Perfect A Reed… and Beyond." Since its inception, multiple PerfectaReeds have been released with minor revisions. The two versions included in this document represent the widest differences between versions. Compact and lightweight, PerfectaReed Version 1 measures 3 ½ x 2 ¾ x 3 ¼ inches and weighs approximately two pounds. Measurements are derived from a black reference bar which can be adjusted in two grooved tracks on PAR1. Rotating the black bar allows the user to capture measurements in increments of 1 or 2 mm from the reed rails in Groove I and increments of 3 or 4 mm in Groove II. The

company provided the tool's nomenclature in its original packaging instructions (figure 7.3).

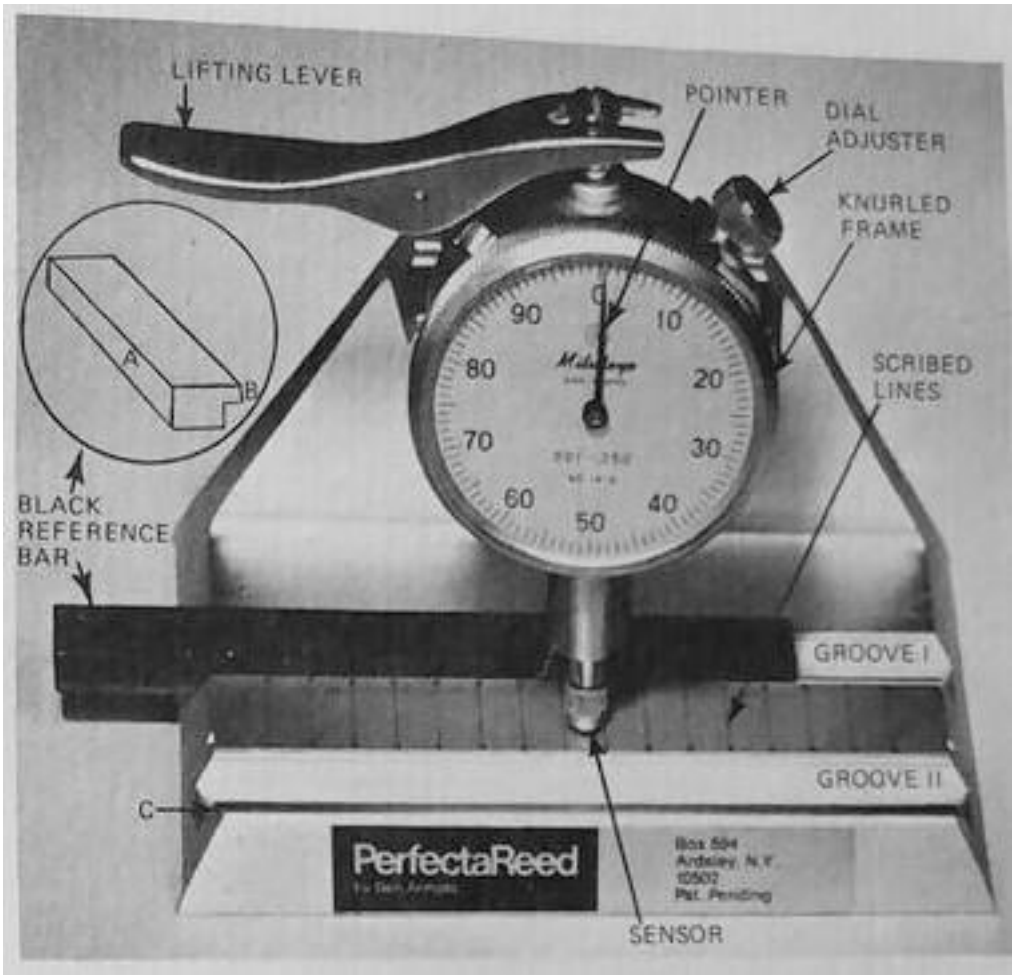


Figure 7.3: PerfectaReed Version 1 nomenclature.
Source: Ben Armato, "PerfectaReed," The Reed Wizard.
This image is excerpted from the product paperwork included in the packaging when the product was purchased.

On the particular tool used to conduct tests, the black bar is too thin for the back track causing the bar to wobble in its position. As a result, measurements taken with the bar in Groove I are inconsistent between measurements of the same reed. The following tables show one set of measurements with the bar in Groove II (table 7.1), and the second shows measurements with the bar in Groove I (table 7.2).

Table 7.1: PAR1 measurements in Groove II.

PERFECTAREED VERSION 1				
bar towards outside of device (Groove II)				
in thousandths of inches				
Legere 4.25				
	Lip out, reed left	Lip in, reed left	Lip out, reed right	Lip in, reed right
1	15	16	16	15.5
2	25	28	28	25
3	36	40.5	40	36
4	48	53	53	47
5	60	67	67	60
6	75	84	83	75
7	95	106	106	95
	denotes differences of one one-thousandth of an inch or more			

These are test measurements of Légère 4.25 in Groove II of PAR1 demonstrating the tool's consistency. Groove II has 93% accuracy.
Table produced by Natalie Groom.

Measurements taken with the reference bar in Groove II demonstrate that PAR1 measures accurately, as the symmetry of the plastic reed is consistent side-to-side with only four positions having a difference of one-thousandth of an inch.

Table 7.2: PAR1 measurements in Groove I.

PERFECTAREED VERSION 1				
bar towards inside of device (Groove I)				
in thousandths of inches				
Legere 4.25				
	Lip out, reed left	Lip in, reed left	Lip out, reed right	Lip in, reed right
1	12	15	15	12
2	21	24	25	22
3	30	35	35	30
4	39	46	46	40
5	49	58	58	49
6	60	72	71	61
7	75	90	89	74
	denotes differences of one one-thousandth of an inch or more			
*these errors are a result of the black bar not fitting tightly in Groove I, causing the bar to wobble.				

These are test measurements of Légère 4.25 in Groove I of PAR1 demonstrating inconsistencies as the result of a loose reference bar. Groove I has 50% accuracy.
Table produced by Natalie Groom.

By contrast, measurements from Groove I are highly inconsistent, with 14 positions having a difference of one-thousandth of an inch. These errors are the result of Groove I being too loose for the reference bar, causing the bar to wobble in its track.

The following is a product description and instruction pamphlet provided by the company in the original packaging of PAR1. From its invention year of 1969, this tool and document is no longer available for purchase or viewing through The Reed Wizard. RJ Music Group holds the patent and manufactures PerfectaReed. The company discontinued production of PAR1 years ago. However, many individuals still own this early version, and it can be found through second-hand online vendors such as Ebay.

WILLIAM R. HULL
10-31-69

PerfectaReed
by Ben Armato

REED
ADJUSTING
INSTRUMENT

©Ben Armato – 1969

PerfectaReed

REED
ADJUSTING
INSTRUMENT

PERFECTA-REED enables both the skilled and unskilled musician quickly to adjust reeds to vibrate and play freely.

PERFECTA-REED, for the first time, eliminates human "feel".

PERFECTA-REED is a precision instrument that accurately measures the thickness of all single reeds to determine any unbalance. When the higher side of the reed is scraped down to correspond in thickness with the lower side, the reed becomes balanced and playable.

PERFECTA-REED uses a precision dial indicator, a movable black reference bar, and a base with numbered scribed lines to allow different areas of the reed to be measured and compared.

PERFECTA-REED enables the user to reproduce reeds to identical dimensions.

Be sure to thoroughly read the following simple procedures to produce not only better sounding reeds but also increase their service life.

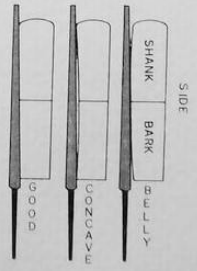
PREPARATIONS

Before one uses PREFECTA-REED, there are certain preparatory steps that are important in making good sounding reeds.

1. Use cane reeds that are golden-colored with a fine, even, close grain and specks of brown in the bark. The grain and fibers should be straight and parallel.

2. Check butt end of reed making sure that its sides are even. Eliminate reeds with uneven butts and thin butts since they produce a false and uneven sound.

3. Place reed side perpendicular to wood file (bastard file) and view against the light to see that reed touches file evenly to check for a concave or a belly, which usually produce a false, uneven sound. If reed doesn't touch file evenly, stroke back and forth lightly until reed side makes even contact to file. Repeat for opposite side.



4. Round corners of reed with emery board to prevent chipping.

5. Having taken these steps to obtain several trial reeds, try producing a sound on the clarinet or saxophone using the selected reeds while still dry. Choose

those reeds that respond to save time and energy. Save others for experimentation to achieve different sounds.

6. Using a sharp knife, cut away bark from the shank of these reeds to measure 31 or 32 millimeters from tip of reed. This should correspond with the measured window opening of your mouthpiece. Reeds being less than 32 millimeters will be sharp and more than 32 millimeters will tend to be flat. Most reeds as supplied by manufacturers are made to measure 13 millimeters across tip of reed and 10 millimeters at bottom shank of reed. This tapered shape keeps the sound from spreading, supports the pitch, and keeps the reed from sounding light and thin.

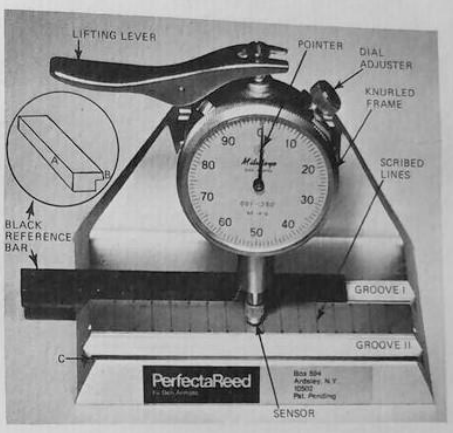
7. Reeds often do not have flat bottoms and should be sanded until flat and even using 600 3M WETORDRY TRI-M-ITE paper. About 20 strokes is usually sufficient. Next, this process is repeated on a non-abrasive surface capable of polishing and sealing the pores of the cane. A satisfactory surface is paper or newsprint. Both operations should be carried out preferably on plate glass or other flat surface.

8. Reeds should now be placed in about two inches of lukewarm water and allowed to soak for about one minute. This is preferable to mouth wetting for the reeds' first exposure to moisture. Saliva contains some acids which accelerate deterioration of the fibers. Remove the soaked reeds, place on a flat surface, and rub lightly with finger until reed is almost dry. **Now, reed is ready to be measured and scraped using PERFECTA-REED.**

PerfectaReed

OPERATING INSTRUCTIONS

The operation of PERFECTA-REED is very simple and quick. Examine PERFECTA-REED to familiarize yourself with its operating functions.



A. Your dial indicator is of high quality and reliability and is sensitive to atmospheric conditions. Loosen dial adjuster and rotate the knurled frame until the "0" on the dial face lines up with the pointer. Tighten dial adjuster to lock the frame. Each line on the dial face represents one thousandth of an inch.

The scribed lines are numbered 1 to 8 on either side of the sensor and both sets of numbers are spaced equal distances from the sensor. For instance, the left scribed line is the same distance as the right scribed line from the sensor. This pattern applies to the other numbers. The black reference bar is a guide for obtaining horizontal readings at one, two, three and four millimeters, if desired, in from each side of the reed.

Record the measurements of your present reed or any old reed that you favored and use it as a model for dimensioning new reeds. PERFECTA-REED makes it possible to duplicate its measurements.

B. Place black bar with "A" side facing sensor in groove I. Take one of the reeds you have prepared and place reed on the base with its bottom side down and its side against the "A" side of the black bar making sure it bears **against** the side "A". Lift sensor by pushing down on lifting lever. Push reed tip under sensor to line 1 and release lever. Take dial reading and record number on paper. Slide reed to line 2, take reading and record measurement. Continue this procedure for each of lines 3 to 8. Lift sensor and remove reed from base. Reverse reed 180° and place back on base making sure you use lifting lever (to avoid damaging reed tip) before pushing reed to the opposite line 1. Now measure and record the reed thickness along the opposite side following the previous procedure. When these steps have been completed, remove the reed from the base. Compare the recorded numbers and scrape down the higher side the necessary amount to match the lower side. If necessary, repeat measurements and scraping until reed thickness is uniform to within approximately one-thousandth of an inch or until desired sound is obtained. (The reed is now even, one millimeter in from each side and at eight reference points on each side.)

C. Reverse black bar and reinsert in groove I so that side "B" faces sensor and repeat the entire procedure of measuring, recording and scraping until the reed is even at three millimeters in from side of reed. Repeat the same procedure with the black bar in groove II. With side "A", readings are obtained at two millimeters in from the edge, and with side "B" readings

are obtained at four millimeters in from the edge.

D. For Saxophone and Bass Clarinet reeds the same procedure is followed with the exception that to obtain the one-millimeter reading the reference bar is not used; place reed against Rail "C".

E. After reed adjusting steps are completed, thoroughly wet reed and rub lightly dry with your finger on a level surface. Place reed on your mouthpiece and enjoy the flexibility, resistance and sound of playing a PERFECTA-REED adjusted reed.

CHANGING QUALITY OF SOUND

More depth of sound and clarity can be achieved by carefully scraping the right tip of reed about 1/16 of an inch back from tip of reed.

If high notes don't sound free and vibrant, scrape left tip about 1/8 of an inch from tip of reed.

If the sound is thin and light, clip reed.

If the reed sounds heavy, scrape reed 1/2 inch back from center (heart) of reed towards tip, or save for use during winter months. The bottoms of thick reeds can also be sanded on 3M 600 paper until desired strength and quality is produced.

Experiment with your reeds by making them heavier on one side or the other to give you the sound you desire. Many artists prefer reeds heavier on one side because of idiosyncrasies of their embouchure or mouthpiece.

TIPS ON CARE OF REEDS

Reeds should be thoroughly wiped after use. This reduces accumulation of saliva and acids which would destroy the fibers of reed.

Allow more time for wetting older reeds. Older reeds take longer for saliva to penetrate due to the curing, sealing, and dirt, clogging the pores.

Wait at least a day before making final adjustments to reeds. New reeds often change due to the density and swelling of the cane. This change sometimes may be as much as three thousandths of an inch.

Use of a plastic bag for storing your mouthpiece with the reed on is highly recommended. The plastic bag slows the process of the reed drying out too quickly, which can cause warpage.

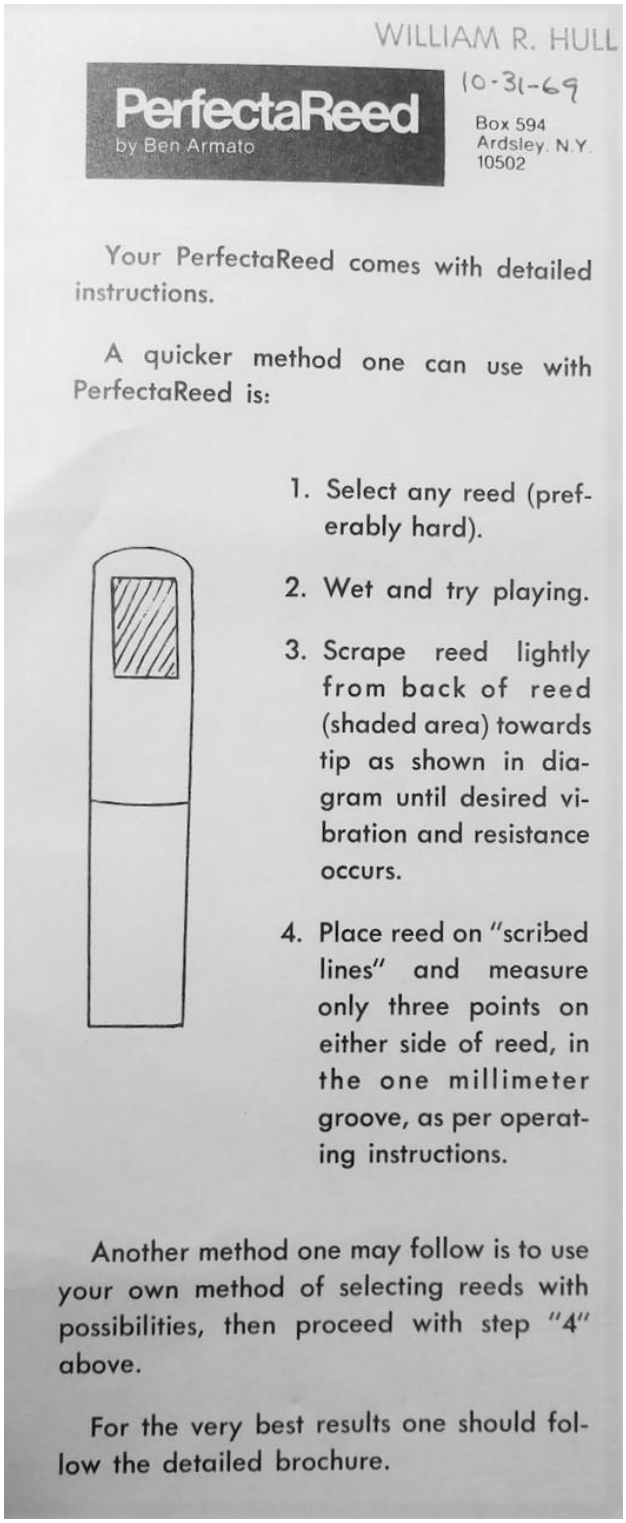
Reed cane improves with age. Periodically buy reeds and store for use years from now. Be sure to record date of purchase.

As your reed gets older, occasionally scrape back of reed with a celluloid or plastic card to remove saliva and dirt that has accumulated there. Do this while reed is wet. Keeping the back of the reed clean not only helps in sustaining its life but also keeps the reed vibrant.

Recommended Equipment—
glass plaque
bastard file
No. 2 file — needle and pillor
dutch rush
3M 600 Wetordry Tri-M-ite sandpaper
emery board
millimeter ruler
reed knife — or any scraping device
reed clipper

PerfectaReed
by Ben Armato

Box 594
Ardsley, N.Y.
10502
Pat. Pending



WILLIAM R. HULL

PerfectaReed
by Ben Armato

10-31-69

Box 594
Ardsley, N.Y.
10502

Your PerfectaReed comes with detailed instructions.

A quicker method one can use with PerfectaReed is:

1. Select any reed (preferably hard).
2. Wet and try playing.
3. Scrape reed lightly from back of reed (shaded area) towards tip as shown in diagram until desired vibration and resistance occurs.
4. Place reed on "scribed lines" and measure only three points on either side of reed, in the one millimeter groove, as per operating instructions.

Another method one may follow is to use your own method of selecting reeds with possibilities, then proceed with step "4" above.

For the very best results one should follow the detailed brochure.

Figure 7.4: Instruction manual included in the packaging of PerfectaReed Version 1.
Source: Ben Armato, "PerfectaReed," The Reed Wizard.
This brochure was included in the product packaging.

PERFECTAREED VERSION 2

Small and easily portable, the PerfectaReed Version 2 measures 3 ½ x 3 ½ x 4 ¼ inches and weighs approximately two pounds. Between Version 1 and 2, there must have been another iteration because an intermediary model was discovered through the Ebay marketplace, pictured below in figure 7.5. However, it is not available for sale by The Reed Wizard, and most images of the transitionary models have been scrubbed from the internet. No product details are available.

Figure 7.5: PerfectaReed, a model between Version 1 and Version 2.
Source: "Reed Wizard PerfectaReed Reed Adjusting Device - New Old Stock," Ebay, last modified October 25, 2019, accessed November 2, 2019, https://www.ebay.com/itm/REED-WIZARD-PERFECTAREED-REED-ADJUSTING-DEVICE-NEW-OLD-STOCK/174024336003?hash=item2884a8a283:g:jlwAAOSw7PNddWsE.

The most current version of PAR2 is sold by RJ Music Group, The Reed Wizard, and other retailers.

PAR2 has been tested for its reliability and repeatability by measuring the same Légère 4.25 reed twice. At each numbered position, the reed tip is aligned to the furthest outer edge of the guide line so that the reed tip completely overlaps the guide line. Positions A through E are used to measure horizontally across the reed, and every vertical measurement is taken from the reed tip to the end of the vamp. In the first reading, no effort is made to press the reed down or in towards the ridge to prevent it from drifting, and the following results are recorded.

Table 7.3: First test reading of Légère 4.25 using PAR2.

PERFECTAREED VERSION 2					
Test Measurement 1					
in thousandths of inches					
order of measurement: tip to heel					
Legere 4.25					
red denotes mismatch between the left side and right side of Test Measurement 1					
RIGHT					
	A	B	C	D	E
1	10	10	10	11.5	11.5
2	17	20	22	23	23
3	26	31	35	37	38
4	36.5	42	48	52	53
5	47	55	63	68	70
6	59	72	80	88	92
7	72	90.5	104	113	119
LEFT					
	A	B	C	D	E
1	8	10	10	11	11
2	16	19.5	21.5	22.5	24
3	25	31	35	38	38
4	35	42.5	48	53	54
5	45.5	55.5	63	69	72
6	58.5	71	80.5	88	92
7	71	91	103	114	120

This demonstrates an inability to achieve identical results on opposite sides of the reed.
Table produced by Natalie Groom.

Red cells denote positions which differ in one-thousandth of an inch or more between the left and right side. It is evident that Position A along the reed's rail is most problematic. So close to the edge of the reed, the dial tip slides around and sometimes off the reed's surface. Légère reeds have a slick surface which contributes to the dial tip sliding, but the problem persists with cane reeds as well. The second-most problematic areas are Positions D and E. This makes sense because these two positions are closest to the center of a B♭ clarinet reed. Here, the way the angled dial tip approaches the reed's surface is most unstable because the reed's slope is steepest. Refer to figure 2.4 for a description of how steeper angles increase cosine error. Measurements appear to stabilize in Positions B and C. Far enough from the reed for the dial tip not to slip and still before the crest of the reed, these positions produce the most consistent measurements.

To combat the issue of the angled dial tip pushing the reed away, in the second measurement of the same reed it is measured with the user actively pushing the reed down and towards the ridge. The following results demonstrate increased consistency.

Table 7.4: Second test reading of Légère 4.25 using PAR2.

PERFECTAREED VERSION 2					
Test Measurement 2					
in thousandths of inches					
order of measurement: tip to heel					
Legere 4.25					
red denotes mismatch between the left side and right side of Test Measurement 2					
RIGHT					
	A	B	C	D	E
1	9	10	10	11	11
2	17	20	21	23	23
3	26	31	35	38	38
4	36	42.5	48	52	53.5
5	47	55.5	63	68	70
6	60	71	81	88	90
7	72.5	90	103	113.5	118.5
LEFT					
	A	B	C	D	E
1	8.5	10	10	11	11
2	16.5	19.5	22	23.5	23.5
3	26	31	34	37	38
4	35.5	43	48	52	53
5	47	56	64	68	70.5
6	59	71	81	88	91.5
7	73	91	103.5	115	119

This demonstrates increased consistency if the user pushes the reed down and in toward the ridge. Table produced by Natalie Groom.

Contrast this with column A of Test Measurement 1 (table 7.3). This handling adjustment greatly increases reliability. Curiously, Position C is less consistent. B7 and D7 remain variable, though this is unsurprising, as these positions are at the transition point between the end of the vamp and the bark.

Using the same tables shown above, the following images demonstrate inconsistencies between Test Measurement 1 and Test Measurement 2. The point of this side-by-side comparison is to highlight the fact that it is difficult to achieve consistent results even when the same user is measuring the same reed consecutively with an identical measuring methodology.

Table 7.5: Comparison between two measurements of the same Légère 4.25 reed.

PERFECTAREED VERSION 2						PERFECTAREED VERSION 2					
Test Measurement 1						Test Measurement 2					
in thousandths of inches											
order of measurement: tip to heel											
Legere 4.25											
red denotes mismatch between Test Measurement 1 and 2											
RIGHT						RIGHT					
	A	B	C	D	E		A	B	C	D	E
1	10	10	10	11.5	11.5		9	10	10	11	11
2	17	20	22	23	23		17	20	21	23	23
3	26	31	35	37	38		26	31	35	38	38
4	36.5	42	48	52	53		36	42.5	48	52	53.5
5	47	55	63	68	70		47	55.5	63	68	70
6	59	72	80	88	92		60	71	81	88	90
7	72	90.5	104	113	119		72.5	90	103	113.5	118.5
LEFT						LEFT					
	A	B	C	D	E		A	B	C	D	E
1	8	10	10	11	11		8.5	10	10	11	11
2	16	19.5	21.5	22.5	24		16.5	19.5	22	23.5	23.5
3	25	31	35	38	38		26	31	34	37	38
4	35	42.5	48	53	54		35.5	43	48	52	53
5	45.5	55.5	63	69	72		47	56	64	68	70.5
6	58.5	71	80.5	88	92		59	71	81	88	91.5
7	71	91	103	114	120		73	91	103.5	115	119

Table produced by Natalie Groom.

The right side measures more similarly than the left, though it is not clear why. Perhaps it is because I, the user, am right handed. Some of these inconsistencies could be due to my

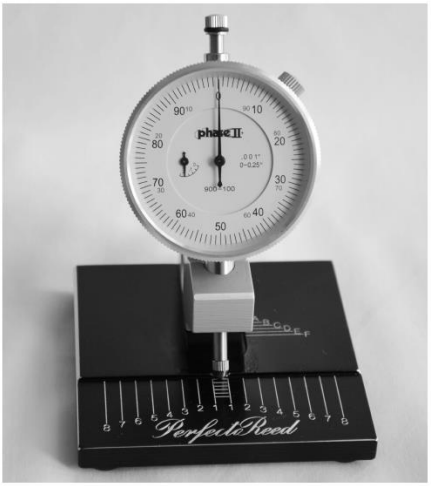
own human error. However, this strengthens the case that a reed micrometer should eliminate opportunities for these errors.

The following images are provided by The Reed Wizard on its website and mailed product instructions, and the product description is quoted directly from The Reed Wizard's website.

PerfectaReed

Takes the guess work out of reed adjusting!

The PerfectaReed is a user friendly precision instrument designed to measure all single reeds. This ingenious device accurately identifies imbalances in commercially made reeds, enabling the user to manually adjust reeds to individual specifications or to precisely copy a model reed.



GENERAL INSTRUCTIONS

Examine the PerfectaReed to familiarize yourself with the instrument.

Dial indicators are sensitive to atmospheric conditions that can cause the pointer to move from either side of zero. To adjust the pointer, loosen the dial screw and rotate the frame until the "zero" on the dial face lines up with the pointer, then tighten the dial screw. Each line on the dial face represents one thousandth of an inch.

Numbers 1-8 on the lower base are evenly spaced on either side of the sensor, to measure along the length of the reed. Letters A-F on the upper base are evenly spaced to measure across the width of the reed.

PerfectaReed

Precision Reed Measuring Instrument

reedwizard.com
rjmusicgroup.com
ph: 410.798.8251

MEASURING PROCEDURES

The PerfectaReed is shipped with the pin in locked mode and aligned with the black line in the "A" position. This secures the carriage from moving during shipping. The "A" position measures the reed's rails. Place the reed on the lower base parallel to the base ridge. Using the ridge as a guide, slide the reed's tip under the sensor to #1 line. Record the dial reading on paper and continue this procedure for #2 – #5.

Compare readings on opposite sides of the reed to determine which side has more mass. Remove material from thick side to match with thin side.

Remove the reed from the base. Turn the lock pin handle 180° counterclockwise. This unlocks the carriage. Remember, only move the carriage in the unlocked position! Using the grip circles, move the carriage to "B" line. Match "B" line to black line on carriage. Move the lock pin handle 180° clockwise to lock the carriage position. Check that the black line is always perfectly aligned to the letter line.

Continue moving the carriage throughout positions C, D, E and F using the procedure of measuring and recording numbers.

TIPS FOR BEST RESULTS

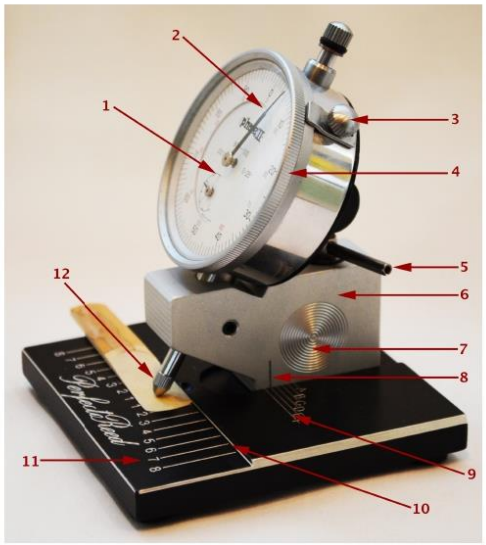
Reeds may be measured wet or dry. A wet reed will tend to hold to the base better than a dry reed.

Use a favorite reed as a model for the basis for your measuring.

Test play the reed after each cycle of measuring and scraping.

Clarinet reed measurements will use only #1–5, saxophone reeds will require #6–8 also.

Visit reedwizard.com/perfectareed.html to find a worksheet to document your measurements.



NOMENCLATURE

1. Dial indicator
2. Pointer
3. Dial screw
4. Dial frame
5. Lock pin handle
6. Carriage
7. Grab circle
8. Black line
9. Upper base letters
10. Ridge
11. Lower base numbers
12. Sensor

Caution: Never move carriage in locked position.

Figure 7.6: PerfectaReed Version 2 Instruction Manual.
Source: "PerfectaReed," The Reed Wizard, accessed November 12, 2019, http://www.reedwizard.com/PerfectaReed%20Insert.pdf

PerfectaReed Version 2 Product Description

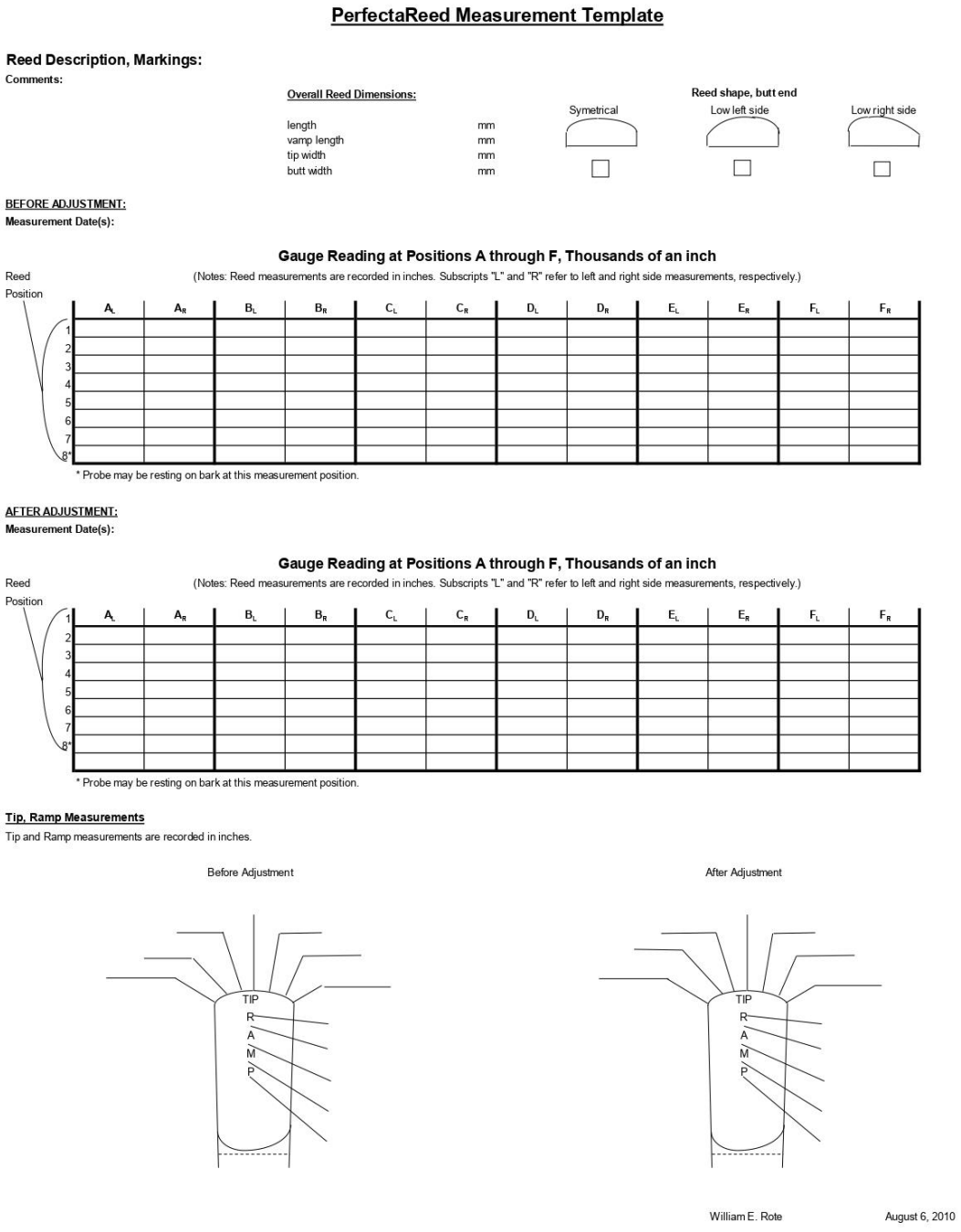
The PerfectaReed is a precision instrument designed to measure the entire reed surface to locate any imbalances. This ingenious device can quickly and easily pinpoint the exact area that needs to be corrected to allow the reed to perform at its maximum.

PerfectaReed takes the guesswork out of reed adjustments. This unique tool enables both skilled and unskilled players to adjust reeds to respond, vibrate, and play freely. Eliminating unreliable "human feel" the user can reproduce reeds having the proper parabolic design or redesign any reed to new specifications.

By following the detailed instructions, a series of measurements is taken to locate imbalances on the reed's surface. Using the PerfectaReed, the user knows exactly where and how much mass to remove from the reeds surface to match and balance the transverse side.

Your PerfectaReed has some new distinguishing features. The name plate is engraved and the ruler has additional markings. These notations make it possible to measure the entire tip area, plus the center dimensions of the reed which provides information for selecting reeds having the proper parabolic design which are compatible to one's mouthpiece.[17]

[17] Ben Armato, “PerfectaReed: All You Need for the Perfect Reed,” The Reed Wizard, accessed April 4, 2019, http://www.reedwizard.com/PerfectAReed.html.



PerfectaReed Measurement Template

Reed Description, Markings:

Comments:

Overall Reed Dimensions:

length	mm	
vamp length	mm	
tip width	mm	
butt width	mm	

Reed shape, butt end

Symetrical ☐ Low left side ☐ Low right side ☐

BEFORE ADJUSTMENT:

Measurement Date(s):

Gauge Reading at Positions A through F, Thousands of an inch

(Notes: Reed measurements are recorded in inches. Subscripts "L" and "R" refer to left and right side measurements, respectively.)

Reed Position	A_L	A_R	B_L	B_R	C_L	C_R	D_L	D_R	E_L	E_R	F_L	F_R
1												
2												
3												
4												
5												
6												
7												
8*												

* Probe may be resting on bark at this measurement position.

AFTER ADJUSTMENT:

Measurement Date(s):

Gauge Reading at Positions A through F, Thousands of an inch

(Notes: Reed measurements are recorded in inches. Subscripts "L" and "R" refer to left and right side measurements, respectively.)

Reed Position	A_L	A_R	B_L	B_R	C_L	C_R	D_L	D_R	E_L	E_R	F_L	F_R
1												
2												
3												
4												
5												
6												
7												
8*												

* Probe may be resting on bark at this measurement position.

Tip, Ramp Measurements

Tip and Ramp measurements are recorded in inches.

Before Adjustment

After Adjustment

William E. Rote August 6, 2010

Figure 7.7: PerfectaReed Version 2 Measurement Template.
Source: William Rote, "PerfectaReed Measurement Template," The Reed Wizard, accessed November 21, 2019, http://www.reedwizard.com/Images/perfectareedworksheet.pdf.

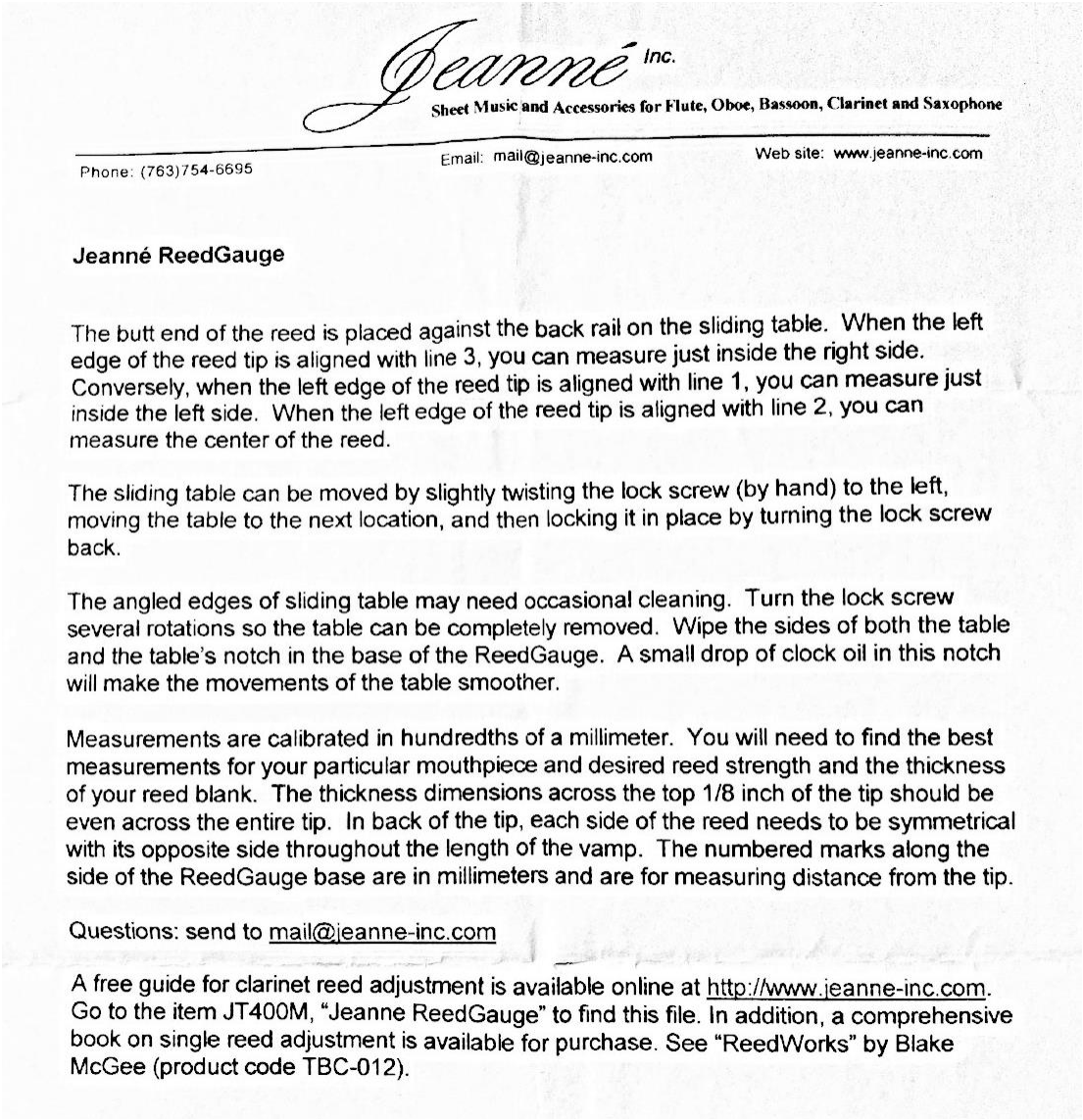
JEANNE REEDGAUGE

The Jeanne ReedGauge tool dimensions are 5 ¼ x 4 x 4 inches. For an additional $27.50, users can purchase the Jeanne Alto Sax-Alto Clar ReedGauge Plate or Jeanne Tenor Sax-Bass Clar ReedGauge Plate to measure reeds of varying sizes. The following product description is quoted directly from Jeanne, Inc.'s website.

> The first step in getting reeds to perform consistently is to make them consistently. Two of the most important measurements in a successful reed are the side to side symmetry, or balance, in the reed vamp, and the relationship of the center dimension to that at the sides. The Jeanne ReedGauge is an accurate, easy way to check these crucial points. Whether you use commercial or hand-made reeds, the balance in the reed vamp will determine much of your tone color and response.
>
> A movable table on the Jeanne ReedGauge, where the reed is placed, is easily locked into place at any position along the reed vamp. The reed can then be measured at any point across the curve by simply sliding the reed from one side to the other under the point of the micrometer. Although no two reeds will - or should - measure the exact same dimension due to differing cell structures, measurements will fall into a "normal" range. After a quick knife adjustment, the reed measurement can be rechecked at precisely the same point.
>
> The Jeanne ReedGauge is made with a heavy, solid aluminum base for maximum stability, allowing you to freely move the adjustable table or the reed. Mitutoyo dial indicators, recognized for their high quality and precision, are installed with the Jeanne ReedGauge. Reed measurements can be made in .01 mm graduations. (Note: The Jeanne ReedGauge with a standard [inches] dial is no longer available.) Interchangeable sliding plates that hold the reeds are available for clarinet, alto saxophone/alto clarinet, and tenor saxophone/bass clarinet.[18]

The following document was included in the product packaging.

[18] "Jeanne ReedGauge, Metric Dial (Millimeters)," Jeanne, Inc.



Jeanné Inc.
Sheet Music and Accessories for Flute, Oboe, Bassoon, Clarinet and Saxophone

Phone: (763)754-6695 Email: mail@jeanne-inc.com Web site: www.jeanne-inc.com

Jeanné ReedGauge

The butt end of the reed is placed against the back rail on the sliding table. When the left edge of the reed tip is aligned with line 3, you can measure just inside the right side. Conversely, when the left edge of the reed tip is aligned with line 1, you can measure just inside the left side. When the left edge of the reed tip is aligned with line 2, you can measure the center of the reed.

The sliding table can be moved by slightly twisting the lock screw (by hand) to the left, moving the table to the next location, and then locking it in place by turning the lock screw back.

The angled edges of sliding table may need occasional cleaning. Turn the lock screw several rotations so the table can be completely removed. Wipe the sides of both the table and the table's notch in the base of the ReedGauge. A small drop of clock oil in this notch will make the movements of the table smoother.

Measurements are calibrated in hundredths of a millimeter. You will need to find the best measurements for your particular mouthpiece and desired reed strength and the thickness of your reed blank. The thickness dimensions across the top 1/8 inch of the tip should be even across the entire tip. In back of the tip, each side of the reed needs to be symmetrical with its opposite side throughout the length of the vamp. The numbered marks along the side of the ReedGauge base are in millimeters and are for measuring distance from the tip.

Questions: send to mail@jeanne-inc.com

A free guide for clarinet reed adjustment is available online at http://www.jeanne-inc.com. Go to the item JT400M, "Jeanne ReedGauge" to find this file. In addition, a comprehensive book on single reed adjustment is available for purchase. See "ReedWorks" by Blake McGee (product code TBC-012).

Figure 7.8: Jeanne ReedGauge Product Instructions.
Source: Jeanne, Inc. "Jeanne ReedGauge."
This document was included in the product packaging.

REEDS 'N STUFF DIGITALER MESSPLAZ

This product is the most similar to the Manual Reed Mapper and Digital Reed Mapper. It shares a digital dial tip indicator, two planes of movement which measure vertically and horizontally along the reed without requiring movement and recalibration of the dial, and plate movements in millimeters. The description, as translated by Google,

says, “With the measuring station, you can accurately measure the thickness and symmetry of your finished clarinet and saxophone reeds at any point. The side plates on the left and right sides are adjustable in increments of 1 mm. The stop for the blade tip works in the same way. This can be positioned in 2 mm increments.”[19] As of April 2020, none of Reed ‘n Stuff’s U.S. distributors carried this item. It retails at 398,00 €, approximately $435 (April 2020 exchange rates).

At the company’s request, I will mention that their tool can be ordered from Germany through the U.S. distributor Innoledy.

Innoledy
505 West 54th Street, Suite 1114
New York, NY 10019
+1 646 801 8646
www.innoledy.com

[19] “Reeds 'n Stuff: Digitaler Messplatz,” Reeds 'N Stuff, accessed October 23, 2019, https://www.reedsnstuff.com/Klarinette/Messen-Pruefen-Testen/Digitaler-Messplatz.html.

APPENDIX C: MANUAL REED MAPPER

Table 7.6: Data on degree of wobble using roller ball system in Prototype 4.

	LEGERE 4.25 READING 1				
	L2	L1	C	R1	R2
1	6.5-7	7-7.5	7.5-8	7.5-8	6.5-7
2	15.5-16	18-18.5	19-19.5	18-18.5	15.5-16
3	27.5-28	31-31.5	33-33.5	31.5	27-27.5
4	41-41.5	45.5-46	48-48.5	46.5	40
5	55.5-56	61.5	64.5	61.5-62	53.5-54
6	72-72.5	81-81.5	84	80-80.5	69.5-70
7	95.5-96.5	108-108.5	110-111.5	106-106.5	92.5-93

	LEGERE 4.25 READING 2				
	L2	L1	C	R1	R2
1	6.5-7	7.5-8	8-8.5	7.5-8	7-7.5
2	16-16.5	18-19	19.5-20	18-19	16-17
3	28	31.5	33-33.5	31.5-32	28-28.5
4	41	46-46.5	48-48.5	46.5	41-41.5
5	56	62	64-65	61.5-62	55-55.5
6	72.5	81-81.5	84.5-85	80-81	71-71.5
7	95.5-96	107-108.5	110.5-111.5	105.5.-106	93-94

	LEGERE 4.25 READING 3				
	L2	L1	C	R1	R2
1	6.5-7	7.5-8	8	7.5-8	7-7.5
2	16-17	18-19	19-19.5	18-19	16.5-17
3	28-28.5	31.5-32	33	31.5-32	28-28.5
4	41-41.5	46.5	48-48.5	46-46.5	41-41.5
5	55.5-56	62.5	64.5-65	61.5-62	54.5-55.5
6	72-73	81.5-82	84-85	80-81	71-72
7	96-96.5	107.5-108.5	110-112	106-106.5	93-94

	LEGERE 4.25 READING 4				
	L2	L1	C	R1	R2
1	7	7.5	8	7.5-8	7-7.5
2	16	18-18.5	19.5	18.5	16.5
3	28	31.5-32	33.5	32	28
4	41.5	46.5-47	48-48.5	46-46.5	40.5-41
5	55.5-56	62-62.5	64-65	61.5-62	54.5-55
6	72-73	81-82	83.5-84.5	80-81	71-71.5
7	96-97	106.5-108.5	110.5-112	105.5-107	93.5-94.5

	LEGERE 4.25 READING 5				
	L2	L1	C	R1	R2
1	7	7.5-8	8-8.5	7.5-8	7-7.5
2	16-17	18-19	19-19.5	18-19	16.5-17
3	28	32	33-33.5	32	28-28.5
4	41-41.5	46.5-47	48.5-49	46.5-47	41-41.5
5	55.5-56	62-62.5	64.5-65	62-62.5	54.5-55.5
6	72.5-73	81-82	84-85	80.5-81.5	71-71.5
7	96-97	107-108.5	110.5-112	105.5-106.5	93-94.5

	LEGERE 4.25 READING 6				
	L2	L1	C	R1	R2
1	7	7.5-8	8-8.5	7.5-8	7-7.5
2	16.5-17	18.5-19	19-20	18-19	16-16.5
3	28.5-29	32-32.5	33-34	31.5-32	27.5-28
4	41.5-42	46.5-47	48-48.5	46-46.5	40-40.5
5	56-56.5	62.5-63	64.5-65	61-62	54-54.5
6	73-74	81.5-82.5	84-85	80-80.5	70-71
7	96.5-97.5	107.5-109	110-112	105-107	92.5-93.5

Highlighted areas have a difference of one-thousandth of an inch or more. As the tool was used, the roller balls loosened, leading to increased wobble as readings progressed.
Table produced by Natalie Groom.

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1					
2					
3					
4					
5					
6					
7					

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1					
2					
3					
4					
5					
6					
7					

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1					
2					
3					
4					
5					
6					
7					

Figure 7.9: Data input tables.
This document was provided to participants who recorded test measurements using Mr. Mapper.
Image produced by Natalie Groom.

Table 7.7: Mr. Mapper test measurements.

PARTICIPANT 1: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
1	Y	Timing	5:00	4:00	2:45
		Symmetry	Y	Y	Y
		Zero	0	0	0

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	7	7.5	8	7.5	6.5
2	15.5	19	19.5	17.5	14.5
3	26.5	32	33.5	29.5	23.5
4	39	46.5	47.5	43	34.5
5	52	62	63.5	57.5	45.5
6	67.5	80.5	83	74	59
7	89.5	106.5	109	97.5	73.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	7.5	8.5	7.5	6.5
2	15.5	20	20	18	15
3	26.5	33	34.5	31	24.5
4	38.5	47.5	49.5	45	36
5	51	62.5	65	59.5	48
6	66.5	81	84.5	76.5	61.5
7	87	106.5	111.5	101.5	77.5

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	7	8	8	8	6.5
2	15.5	19	20	18	14.5
3	26	32.5	34	31	24.5
4	38.5	46.5	49	45	35.5
5	51	61.5	64.5	59.5	47
6	67	80.5	84	77	60.5
7	87.5	106.5	111	100.5	75

PARTICIPANT 2: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
2	Y	Timing	6:30	5:00	3:15
		Symmetry	Y	Y	Y
		Zero	0	0	-0.0005

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	7.5
2	15	18.5	20	18	14.5
3	25.5	31.5	34	30.5	24
4	37.5	46	48.5	44.5	35
5	50	61	64	59	47.5
6	65.5	79.5	84	77	61.5
7	85.5	104.5	110.5	101	77.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6
2	15	18.5	19.5	18	14.5
3	25.5	31.5	33.5	31	24.5
4	37.5	45.5	48.5	45	36
5	50	60.5	64	59.5	47.5
6	65.5	79	83.5	77	61.5
7	86	104.5	110.5	101.5	77

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6.5
2	15	18.5	19.5	18	15
3	25	31.5	33.5	31	25
4	37	45.5	48.5	45	36
5	49.5	61	64.5	60	48
6	65	78.5	84	77.5	62.5
7	84.5	104	110.5	102	79.5

PARTICIPANT 3: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
3	N	Timing	7:50	5:50	5:50
		Symmetry	Y	tad left	tad right
		Zero	-0.0005	0	-0.0005

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	7.5	7	6.5
2	15.5	19	19	17.5	14.5
3	26	31.5	33.5	30.5	24
4	38	46.5	48	45	35.5
5	50.5	61	63.5	59	47.5
6	65.5	80	83	76.5	61.5
7	85.5	105.5	110.5	101	77.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	7	8	9	7.5	7
2	15.5	19	20	18.5	15.5
3	26.5	32	34.5	31.5	25
4	38.5	46.5	49.5	45.5	36.5
5	51	62	64.5	60	48
6	66	80.5	84.5	77.5	63
7	86	105.5	111	101.5	79

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	7	8	8.5	8.5	7.5
2	15.5	19	20.5	19	15.5
3	26	32	34.5	32.5	26
4	38	46.5	49.5	46.5	37.5
5	50.5	61.5	65	61	49.5
6	65.5	80	85	79	64
7	84.5	105.5	112	103	80.5

PARTICIPANT 4: VOCALIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
4	N	Timing	5:40	4:55	3:20
		Symmetry	Y	Y	tad left
		Zero	0	0	-0.0005

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6.5
2	15	18.5	19.5	17.5	14.5
3	25.5	32	33.5	31	24
4	37	45.5	48.5	44.5	35
5	49.5	61	64.5	59.5	47.5
6	64.5	78.5	84	77	61.5
7	84.5	104.5	110.5	101.5	77.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6.5
2	16	19	19.5	18	14.5
3	26.5	32	33	30.5	24.5
4	37.5	46	48.5	44.5	35.5
5	51	61	64.5	59	48
6	65.5	80	84	76.5	62
7	86	105.5	110.5	101	77.5

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	8	8.5	8	6.5
2	15.5	19	20	18	14.5
3	26	31.5	33.5	31	24.5
4	37.5	46	49	45	35.5
5	50.5	61	64.5	60	47.5
6	65	79.5	84	77.5	62.5
7	85	105	110.5	102	79

PARTICIPANT 5: VOCALIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
5	N	Timing	4:30	3:45	4:00
		Symmetry	tad left	left	Y
		Zero	0	0	0

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7	8	7.5	7
2	15.5	19	20	18.5	14.5
3	26.5	32	34	31.5	24.5
4	38.5	47	49	45.5	36
5	51	61.5	64.5	60	48
6	65.5	80.5	84	78	62
7	85.5	105.5	111	102.5	78

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	7	8	8	7	6.5
2	16	19	20	18	15
3	27	33	34	31	24.5
4	39	47	49	44.5	36
5	52	62.5	65	59	48
6	68	81.5	84.5	76.5	62
7	88.5	107.5	110.5	101	76.5

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7	6.5
2	15.5	19	20	18	15
3	26	32.5	34.5	31.5	24.5
4	38	46.5	49.5	45.5	35.5
5	50.5	61.5	64.5	60.5	48.5
6	65.5	80	84.5	78	62.5
7	85	106	111	103	78.5

PARTICIPANT 6: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
6	Y	Timing	8:10	5:20	4:20
		Symmetry	Y	tad right	Y
		Zero	0	0	-0.0005

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6.5
2	16	18.5	20	17	14
3	27	31.5	33.5	29.5	22
4	37	44.5	49	43.5	33.5
5	51	60	64	57.5	45.5
6	65.5	79.5	83	75	60.5
7	86	102.5	107.5	99	75.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6	9	8	7.5	6.5
2	15	19	20	17.5	14.5
3	24.5	31.5	33	30.5	24
4	35.5	46	47.5	44	34.5
5	49	61.5	65	59	47
6	63	79.5	84.5	76	60.5
7	84	105	107	101	74.5

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	7.5	7.5	8	6.5
2	14.5	18.5	18	20.5	14.5
3	24.5	31.5	33.5	31.5	24.5
4	39	45.5	48.5	43	35.5
5	49.5	61	64.5	60.5	48
6	64.5	79	84	78	62
7	84	105	112	102	78.5

PARTICIPANT 7: STRING PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
7	N	Timing	8:10	5:40	6:10
		Symmetry	Y	Y	left
		Zero	-0.0005	0	0

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	8.5	8	6.5
2	16	19	20.5	17	15
3	26	33	33	31	25
4	37.5	46.5	39	45	36
5	50.5	61.5	65	60.5	48.5
6	66	80.5	85	78	63
7	85.5	105.5	112	103.5	79

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	7	8	8.5	8	7
2	16	19	20.5	18.5	15
3	26.5	32	34	32	25.5
4	37.5	46	48	44.5	36
5	51	62	65	60	48.5
6	66.5	80	84	77.5	62
7	86	106	111	102	78

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	7	7.5	8	8	6
2	15.5	19	20.5	17.5	14
3	25.5	32	34.5	31	23.5
4	38	46	49	44	34
5	51	61	65	59.5	45.5
6	65.5	79.5	84.5	77	60.5
7	85.5	105	110.5	101.5	76.5

PARTICIPANT 8: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
8	Y	Timing	5:30	3:50	4:00
		Symmetry	Y	Y	tad left
		Zero	0	0	-0.0005

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	8	8	8	7
2	14.5	18.5	20	18	15.5
3	25	31.5	34.5	30.5	25
4	36.5	46	49	45	36.5
5	49.5	61	64.5	60	48
6	64.5	79	84	77.5	62.5
7	84	104.5	110.5	102.5	80

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	8	8	8	7
2	15	19	20	18.5	15
3	25.5	31.5	34	31.5	25
4	37	46	48.5	45	36.5
5	49.5	61	64.5	60	48.5
6	64.5	78.5	83.5	78	63
7	84	104	110.5	102.5	80

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	8	8	8	6.5
2	14.5	18.5	19.5	17.5	14.5
3	25.5	31.5	33.5	30.5	24
4	37.5	45.5	48	45	35.5
5	49.5	60.5	64.5	59	47
6	65	79.5	83.5	76	60.5
7	85.5	105	110.5	100.5	75.5

PARTICIPANT 9: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
9	N	Timing	3:15	3:15	3:00
		Symmetry	Y	Y	Y
		Zero	0	0	0

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	8	7.5	8	7.5
2	15	18.5	20	18.5	15.5
3	25.5	32	34	31.5	25.5
4	37	46	49.5	46	37.5
5	49.5	61	65	61	49.5
6	64	79.5	84.5	79	64
7	81.5	104	111.5	104	82

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	7.5	7.5	7.5	6.5
2	18	18.5	19.5	18	14.5
3	25.5	31	33.5	31	25.5
4	36	45	48.5	45	36.5
5	49.5	60.5	64.5	60	48.5
6	64	78.5	84	77.5	63.5
7	83.5	104	110.5	102	81

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	6.5	8	8	8	6.5
2	15	18	20	18	15
3	25	31	33.5	30.5	25
4	36.5	45	48	44	36
5	49	60.5	64	59.5	48
6	64.5	79	84	77.5	62.5
7	84.5	104.5	111	102	79

PARTICIPANT 10: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
10	N	Timing	6:00	4:40	5:30
		Symmetry	Y	Y	Y
		Zero	-0.0005	0	0

LEGERE TEST READING #1					
	L2	L1	C	R1	R2
1	6.5	7.5	7.5	7.5	6.5
2	15	18	20	16.5	14.5
3	27	31.5	33.5	30.5	23.5
4	38	45	47.5	44	36
5	50.5	60.5	64.5	57.5	47.5
6	66	79	83.5	74	60.5
7	86	104.5	110	101	78.5

LEGERE TEST READING #2					
	L2	L1	C	R1	R2
1	6.5	8	8	8	7
2	15.5	17	19.5	17.5	15.5
3	26.5	33	32	31	24.5
4	38	46.5	48.5	44.5	36
5	50.5	62	65	57	49
6	65.5	81.5	85	78	61.5
7	85	105	111.5	101	76

LEGERE TEST READING #3					
	L2	L1	C	R1	R2
1	7	8	8	8	6.5
2	16	19	20	16.5	15.5
3	26.5	32.5	32.5	29	26.5
4	37	45.5	48.5	46	36
5	49.5	61.5	64.5	61.5	50
6	65	80	84	80	64.5
7	84.5	103.5	111	105	83.5

Test measurements were conducted by ten participants.
Table produced by Natalie Groom.

Table 7.8: Mr. Mapper test measurements, group average.

LEGERE TEST READING #1: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.55	7.55	7.9	7.6	6.8
2	15.3	18.65	19.85	17.6	14.7
3	26.05	31.85	33.7	30.6	24.1
4	37.6	45.95	48.55	44.6	35.55
5	50.4	61.05	64.3	59.15	47.5
6	65.45	79.65	83.8	76.6	61.6
7	85.35	104.75	110.3	101.35	77.9

LEGERE TEST READING #2: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.6	7.9	8.15	7.6	6.65
2	15.75	18.8	19.85	18.05	14.9
3	26.05	32.05	33.6	31.1	24.75
4	37.5	46.2	48.6	44.75	35.95
5	50.45	61.55	64.7	59.3	48.1
6	65.5	80	84.2	77.1	62.05
7	85.6	105.35	110.45	101.5	77.7

LEGERE TEST READING #3: GROUP AVERAGE					
	L2	L1	C	R1	R2
1	6.7	7.8	8.05	7.9	6.55
2	15.25	18.75	19.8	18.1	14.8
3	25.6	31.85	33.75	30.95	24.8
4	37.7	45.85	48.75	44.9	35.7
5	50.05	61.1	64.55	60.1	47.9
6	65.25	79.55	84.15	77.75	62.2
7	85.05	105	111	102.15	78.55

Table produced by Natalie Groom.

Table 7.9: Mr. Mapper test measurements, group mode.

LEGERE TEST READING #1: GROUP MODE					
	L2	L1	C	R1	R2
1	6.5	7.5	8	7.5	6.5
2	15	18.5	20	17.5	14.5
3	25.5	31.5	33.5	30.5	24
4	37	46.5	49	45	36
5	50.5	61	64.5	57.5	47.5
6	65.5	80.5	84	74	61.5
7	85.5	104.5	110.5	101	77.5

LEGERE TEST READING #2: GROUP MODE					
	L2	L1	C	R1	R2
1	6.5	8	8	7.5	6.5
2	15.5	19	20	18	15
3	26.5	33	34	31	24.5
4	37.5	46	48.5	45	36
5	51	62	65	60	48
6	65.5	80	84.5	76.5	61.5
7	86	105.5	110.5	101	77.5

LEGERE TEST READING #3: GROUP MODE					
	L2	L1	C	R1	R2
1	6.5	8	8	8	6.5
2	15.5	19	20	18	14.5
3	26	31.5	33.5	31	24.5
4	38	45.5	49	45	35.5
5	49.5	61.5	64.5	59.5	48
6	65	80	84	77.5	62.5
7	84.5	105	111	102	79

Table produced by Natalie Groom.

Table 7.10: Mr. Mapper test measurements, group ranges.

LEGERE TEST READING #1: GROUP RANGE					
	L2	L1	C	R1	R2
1	0.5	1	1	1	1
2	1.5	1	1.5	2	1.5
3	2	1.5	1.5	2	3.5
4	2.5	2.5	2	3	4
5	2.5	2	1.5	3.5	4
6	3.5	2	2	5	5
7	8	4	4.5	6.5	8.5

LEGERE TEST READING #2: GROUP RANGE					
	L2	L1	C	R1	R2
1	1	1.5	1.5	1	1
2	3	3	1	1	1
3	2.5	2	2.5	1.5	1.5
4	3.5	2.5	2	1.5	2
5	3	2	1	3	2
6	5	3	1.5	2	3
7	5	3.5	4.5	1.5	6.5

LEGERE TEST READING #3: GROUP RANGE					
	L2	L1	C	R1	R2
1	0.5	0.5	1	1.5	1.5
2	1.5	1	2.5	4	1.5
3	2	1.5	2	3.5	3
4	2.5	1.5	1.5	3.5	3.5
5	2	1	1	2.5	4.5
6	2.5	2	1.5	4	4
7	3.5	3	1.5	4.5	8.5

LEGERE TEST READING #1-3: GROUP RANGE					
	L2	L1	C	R1	R2
1	1.00	2.00	1.50	1.50	1.50
2	3.50	3.00	2.50	4.00	1.50
3	2.50	2.00	2.50	3.50	4.50
4	3.50	3.00	2.00	3.50	4.00
5	3.00	2.50	1.50	4.50	4.50
6	5.00	3.00	2.00	6.00	5.50
7	8.00	5.00	5.00	7.50	10.00

LEGERE TEST READING #2-3: GROUP RANGE					
	L2	L1	C	R1	R2
1	1.00	1.50	1.50	1.50	1.50
2	3.50	3.00	2.50	4.00	1.50
3	2.50	2.00	2.50	3.50	3.00
4	3.50	2.50	2.00	3.50	3.50
5	3.00	2.00	1.00	4.50	4.50
6	5.00	3.00	1.50	4.00	4.00
7	5.00	4.00	5.00	4.50	9.00

LEGERE TEST READING #2-3: GROUP RANGE DIFFERENCE WHEN DISCARDING ATTEMPT 1					
	L2	L1	C	R1	R2
1	0.00	-0.50	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	-1.50
4	0.00	-0.50	0.00	0.00	-0.50
5	0.00	-0.50	-0.50	0.00	0.00
6	0.00	0.00	-0.50	-2.00	-1.50
7	-3.00	-1.00	0.00	-3.00	-1.00

The yellow cells denote positions at which the group range was greater than two-thousandths of an inch. The green cells denote positions at which the group range improved when data from Attempt 1 was excluded.
Table produced by Natalie Groom.

Table 7.11: Mr. Mapper test measurements, individual participant ranges.

PARTICIPANT 1: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
1	Y	Timing	5:00	4:00	2:45
		Symmetry	Y	Y	Y
		Zero	0	0	0

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0.5	0
2	0	1	0.5	0.5	0.5
3	0.5	1	1	1.5	1
4	0.5	1	2	2	1.5
5	1	1	1.5	2	2.5
6	1	0.5	1.5	3	2.5
7	2.5	0	2.5	4	4

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0.5	0
2	0	1	0	0	0.5
3	0.5	0.5	0.5	0	0
4	0	1	0.5	0	0.5
5	0	1	0.5	0	1
6	0.5	0.5	0.5	0.5	1
7	0.5	0	0.5	1	2.5

PARTICIPANT 2: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
2	Y	Timing	6:30	5:00	3:15
		Symmetry	Y	Y	Y
		Zero	0	0	-0.0005

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0	0	0	0	1.5
2	0	0	0.5	0	0.5
3	0.5	0	0.5	0.5	1
4	0.5	0.5	0	0.5	1
5	0.5	0.5	0.5	1	0.5
6	0.5	1	0.5	0.5	1
7	1.5	0.5	0	1	2.5

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0	0	0	0.5
2	0	0	0	0	0.5
3	0.5	0	0	0	0.5
4	0.5	0	0	0	0
5	0.5	0.5	0.5	0.5	0.5
6	0.5	0.5	0.5	0.5	1
7	1.5	0.5	0	0.5	2.5

PARTICIPANT 3: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
3	N	Timing	7:50	5:50	5:50
		Symmetry	Y	tad left	tad right
		Zero	-0.0005	0	-0.0005

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	0.5	1.5	1.5	1
2	0	0	1.5	1.5	1
3	0.5	0.5	1	2	2
4	0.5	0	1.5	1.5	2
5	0.5	1	1.5	2	2
6	0.5	0.5	2	2.5	2.5
7	1.5	0	1.5	2	3

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0	0.5	1	0.5
2	0	0	0.5	0.5	0
3	0.5	0	0	1	1
4	0.5	0	0	1	1
5	0.5	0.5	0.5	1	1.5
6	0.5	0.5	0.5	1.5	1
7	1.5	0	1	1.5	1.5

PARTICIPANT 4: VOCALIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
4	N	Timing	5:40	4:55	3:20
		Symmetry	Y	Y	tad left
		Zero	0	0	-0.0005

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0	0.5	0.5	0.5	0
2	1	0.5	0.5	0.5	0
3	1	0.5	0.5	0.5	0.5
4	0.5	0.5	0.5	0.5	0.5
5	1.5	0	0	1	0.5
6	1	1.5	0	1	1
7	1.5	1	0	1	1.5

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0.5	0.5	0.5	0
2	0.5	0	0.5	0	0
3	0.5	0.5	0.5	0.5	0
4	0	0	0.5	0.5	0
5	0.5	0	0	1	0.5
6	0.5	0.5	0	1	0.5
7	1	0.5	0	1	1.5

PARTICIPANT 5: VOCALIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
5	N	Timing	4:30	3:45	4:00
		Symmetry	tad left	left	Y
		Zero	0	0	0

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	1	0	0.5	0.5
2	0.5	0	0	0.5	0.5
3	1	1	0.5	0.5	0
4	1	0.5	0.5	1	0.5
5	1.5	1	0.5	1.5	0.5
6	2.5	1.5	0.5	1.5	0.5
7	3.5	2	0.5	2	2

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0.5	0.5	0	0	0
2	0.5	0	0	0	0
3	1	0.5	0.5	0.5	0
4	1	0.5	0.5	1	0.5
5	1.5	1	0.5	1.5	0.5
6	2.5	1.5	0	1.5	0.5
7	3.5	1.5	0.5	2	2

PARTICIPANT 6: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
6	Y	Timing	8:10	5:20	4:20
		Symmetry	Y	tad right	Y
		Zero	0	0	-0.0005

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	1.5	0.5	0.5	0
2	1.5	0.5	2	3.5	0.5
3	2.5	0	0.5	2	2.5
4	3.5	1.5	1.5	1	2
5	2	1.5	1	3	2.5
6	2.5	0.5	1.5	3	1.5
7	2	2.5	5	3	4

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0.5	1.5	0.5	0.5	0
2	0.5	0.5	2	3	0
3	0	0	0.5	1	0.5
4	3.5	0.5	1	1	1
5	0.5	0.5	0.5	1.5	1
6	1.5	0.5	0.5	2	1.5
7	0	0	5	1	4

PARTICIPANT 7: STRING PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
7	N	Timing	8:10	5:40	6:10
		Symmetry	Y	Y	left
		Zero	-0.0005	0	0

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0	1
2	0.5	0	0	1.5	1
3	1	1	1.5	1	2
4	0.5	0.5	1	1	2
5	0.5	1	0	1	3
6	1	1	1	1	2.5
7	0.5	1	1.5	2	2.5

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0.5	0.5	0	1
2	0.5	0	0	1	1
3	1	0	0.5	1	2
4	0.5	0	1	0.5	2
5	0	1	0	0.5	3
6	1	0.5	0.5	0.5	1.5
7	0.5	1	0.5	0.5	1.5

PARTICIPANT 8: CLARINETIST					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
8	Y	Timing	5:30	3:50	4:00
		Symmetry	Y	Y	tad left
		Zero	0	0	-0.0005

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0	0	0	0	0.5
2	0.5	0.5	0.5	1	1
3	0.5	0	1	1	1
4	1	0.5	1	0	1
5	0	0.5	0	1	1.5
6	0.5	1	0.5	2	2.5
7	1.5	1	0	2	4.5

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0	0	0	0.5
2	0.5	0.5	0.5	1	0.5
3	0	0	0.5	1	1
4	0.5	0.5	0.5	0	1
5	0	0.5	0	1	1.5
6	0.5	1	0	2	2.5
7	1.5	1	0	2	4.5

PARTICIPANT 9: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
9	N	Timing	3:15	3:15	3:00
		Symmetry	Y	Y	Y
		Zero	0	0	0

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0	0.5	0.5	0.5	1
2	3	0.5	0.5	0.5	1
3	0.5	1	0.5	1	0.5
4	1	1	1.5	2	1.5
5	0.5	0.5	1	1.5	1.5
6	0.5	1	0.5	1.5	1.5
7	3	0.5	1	2	3

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0	0.5	0.5	0.5	0
2	3	0.5	0.5	0	0.5
3	0.5	0	0	0.5	0.5
4	0.5	0	0.5	1	0.5
5	0.5	0	0.5	0.5	0.5
6	0.5	0.5	0	0	1
7	1	0.5	0.5	0	2

PARTICIPANT 10: WIND PLAYER					
Person ID	Clar Y/N		Attempt 1	Attempt 2	Attempt 3
10	N	Timing	6:00	4:40	5:30
		Symmetry	Y	Y	Y
		Zero	-0.0005	0	0

RANGE ACROSS 3 ATTEMPTS					
	L2	L1	C	R1	R2
1	0.5	0.5	0.5	0.5	0.5
2	1	2	0.5	1	1
3	0.5	1.5	1.5	2	3
4	1	1.5	1	2	0
5	1	1.5	0.5	4.5	2.5
6	1	2.5	1.5	6	4
7	1.5	1.5	1.5	4	7.5

RANGE BETWEEN ATTEMPTS 2 AND 3					
	L2	L1	C	R1	R2
1	0.5	0	0	0	0.5
2	0.5	2	0.5	1	0
3	0	0.5	0.5	2	2
4	1	1	0	1.5	0
5	1	0.5	0.5	4.5	1
6	0.5	1.5	1	2	3
7	0.5	1.5	0.5	4	7.5

Table produced by Natalie Groom.

Table 7.12: Mr. Mapper test measurements, group standard deviation.

LEGERE TEST READING #1: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.16	0.28	0.32	0.32	0.42
2	0.48	0.34	0.41	0.66	0.48
3	0.69	0.47	0.42	0.70	0.99
4	0.77	0.76	0.69	0.91	1.12
5	0.81	0.55	0.54	1.29	1.22
6	0.98	0.71	0.67	1.73	1.41
7	1.99	1.09	1.27	1.97	2.32

LEGERE TEST READING #2: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.32	0.46	0.41	0.32	0.34
2	0.89	0.75	0.34	0.37	0.39
3	0.76	0.72	0.77	0.46	0.49
4	1.11	0.71	0.61	0.42	0.60
5	0.93	0.76	0.35	0.92	0.57
6	1.41	1.13	0.48	0.70	0.90
7	1.52	1.11	1.28	0.53	1.92

LEGERE TEST READING #3: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.26	0.26	0.28	0.39	0.37
2	0.49	0.35	0.71	1.05	0.48
3	0.61	0.53	0.63	0.90	0.89
4	0.75	0.53	0.54	1.02	0.86
5	0.72	0.39	0.28	0.77	1.29
6	0.72	0.60	0.41	1.11	1.40
7	0.98	0.88	0.58	1.31	2.49

LEGERE TEST READING #1-3: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.25	0.37	0.35	0.36	0.38
2	0.67	0.50	0.50	0.76	0.45
3	0.70	0.57	0.61	0.72	0.85
4	0.87	0.67	0.60	0.81	0.87
5	0.82	0.61	0.43	1.07	1.07
6	1.05	0.84	0.55	1.30	1.24
7	1.52	1.02	1.10	1.40	2.21

LEGERE TEST READING #2-3: GROUP STANDARD DEVIATION					
	L2	L1	C	R1	R2
1	0.29	0.37	0.35	0.38	0.35
2	0.74	0.57	0.54	0.77	0.43
3	0.71	0.63	0.69	0.70	0.70
4	0.93	0.64	0.57	0.77	0.73
5	0.84	0.63	0.32	0.92	0.97
6	1.10	0.91	0.44	0.96	1.15
7	1.28	0.99	1.01	1.03	2.21

LEGERE TEST READING #2-3: GROUP STANDARD DEVIATION DIFFERENCE WHEN DISCARDING ATTEMPT 1					
	L2	L1	C	R1	R2
1	0.03	0.00	0.00	0.02	-0.03
2	0.08	0.07	0.05	0.01	-0.01
3	0.01	0.05	0.08	-0.02	-0.16
4	0.06	-0.03	-0.03	-0.04	-0.14
5	0.02	0.02	-0.11	-0.15	-0.10
6	0.05	0.07	-0.11	-0.34	-0.10
7	-0.24	-0.03	-0.09	-0.37	0.00

Table produced by Natalie Groom.

GLOSSARY

***Arundo donax*:** a reed species plant harvested for its cane.

Bark: the unfiled portion of the bottom half of a reed.

Cane: a reed species plant manufactured for use on musical instruments.

Clarinet: a single reed musical instrument.

Cosine Error: a measurement error that occurs when an indicator tip is at an angle to the surface being measured. The larger the angle to the surface being measured, the greater the cosine error.

Cut, or Reed Cut: refers to the specific dimensions applied to a finished clarinet reed. One brand may have multiple cuts, such as the Vandoren Traditional, V12, 56 Rue Lepic, or V21. Within a brand, cut variations can include the length of the vamp, slope, proportional thickness, and shape of the heart.

Dial Indicator: the dial face of a micrometer.

Dial Tip: the arm extending from the dial indicator which makes contact with the surface being measured.

Double Reed: a piece of cane known as *Arundo donax* which is curved on both sides. The two sides are fixed together with glue, string, or other adhesives and affixed to instruments such as bassoons and oboes to produce sounds.

Double Reed Micrometer: a micrometer adapted to measure double reeds.

Hardness, or Reed Hardness: the standard by which commercial reeds are graded. Hardness refers to how resistant a reed feels at the player's lips. It is also called "strength."

Heart: the normal parabola-shaped center of a reed.

Heel: the bottommost edge of the reed opposite from the tip.

Ligature: a device which fashions a reed to a mouthpiece.

Micrometer: a precision gauge tool used to measure small distances or thicknesses.

Mouthpiece: the part of an instrument that goes against the player's lips to produce sounds. A ligature and reed are affixed to the mouthpiece.

Rail: the left and right edges of a reed.

Reed: a piece of cane known as *Arundo donax* used to produce sounds on musical instruments.

Single Reed: a piece of cane known as *Arundo donax* which is flat on one side and curved on the other. It fashioned to a mouthpiece to produce sounds on instruments such as clarinets and saxophones.

Single Reed Micrometer: a micrometer adapted to measure single reeds.

Strength: the numeric value assigned to reeds to label their feeling of resistance. It is positively correlated with a reed's thickness and/or hardness. Musicians often use "strength" and "hardness" interchangeably.

Thickness, or Reed Thickness: the objective measurable distance between opposite sides of the reed. In the case of single reeds, it is the distance between the flat backside of the reed and the profiled top of the reed.

Tip: the thinnest part at the uppermost edge of a reed.

BIBLIOGRAPHY

Anderson, John. “Clarinet Reed Adjustment.” Jeanne, Inc. Accessed April 24, 2019. https://www.jeanne-inc.com/mm5/graphics/00000001/Clarinet reed adjustment.pdf.

Anderson explains desirable reed traits such as an even slope, no warpage, uniform color, and straight cane grain from tip to heel. To properly adjust reeds, one should have plexiglass, sandpaper, a reed knife or other scraping mechanism, and a reed clipper. They discuss breaking in reeds, polishing, and finding reed proportions that match a player's mouthpiece.

Armato, Ben. “PerfectaReed.” The Reed Wizard. Accessed April 4, 2019. http://www.reedwizard.com/PerfectaReed Insert.pdf.

This PDF is the product description of the latest version of Ben Armato’s PerfectaReed. It includes general instructions, measuring procedures, tips for best results, and nomenclature of the tool.

Armato, Ben. “PerfectaReed: All You Need for the Perfect Reed.” The Reed Wizard. Accessed April 4, 2019. http://www.reedwizard.com/PerfectAReed.html.

This is the product description of the latest version of Ben Armato’s PerfectaReed. New features include additional markings on the ruler and an engraved name plate.

Armato, Ben. *Perfect a Reed...and Beyond: Reed Adjusting Method*. Ardsley, NY: PerfectaReed, 1996.

Section one of the book discusses what reed cane is and how it is harvested. Section two talks about equipment and individual player considerations that might affect a reed’s playability, such as a performer’s mouthpiece facing, embouchure, ligature, and clarinet. Section three debunks myths about what makes a good reed, such as “the best cane is grown in France” or mottled reeds will play poorly. Section four takes a scientific approach to understanding the durability of reeds down to the cell level and from a broader view of environmental and weather conditions. Section five discusses play testing, selecting, balancing, and preparing reeds. The final section offers up tips for adjusting a player’s reeds and ways to experiment with adjustments.

D’Addario Woodwinds. “D’Addario Woodwinds: Craftsmanship for the 21st Century. Video last modified September 23, 2016. Accessed February 24, 2019. https://www.youtube.com/watch?v=6UIa5HF806c.

This D’Addario promotional video discussed D’Addario’s acquisition of Rico Reeds. The cane is harvested and dried for two years then laser cut to specification; the

facility switched to digital machinery in 2016. Quality control comes in the form of periodic play tests by individuals. Jonathan Gunn and Richie Hawley provide clarinet reed testimonials. D'Addario emphasizes how their manufacturing process changed after acquiring Rico to produce high quality and consistent reeds.

D'Addario Woodwinds. "How It's Made - Rico Reeds." Video last modified February 11, 2009. Accessed October 11, 2019. https://www.youtube.com/watch?v=MwOUEsdpuI0.

Similar to the popular TV show *How It's Made*, this video describes how reeds are created from cane harvesting to final cuts. This is published by D'Addario Woodwinds but this video was made before D'Addario bought Rico Reeds. The manufacturing processes have changes since the acquisition.

D'Addario Woodwinds. "How to Select a Clarinet Reed." Video last modified September 26, 2013. Accessed February 24, 2019. https://www.youtube.com/watch?v=MQcS78IsUyA.

Richie Hawley describes how to select a clarinet reed. Hawley outlines the differences between each cut (Rico thin blank, traditional Reserve, Reserve Classic thick blank) and what the strength numbers actually mean for choosing a reed cut that is the best fit for a player.

D'Addario Woodwinds. "Humidification System Installed in D'Addario Woodwinds Manufacturing Facility." Last modified January 2014. Accessed February 18, 2019. http://daddario.com/woodwindsNewsDetails.Page?ActiveID=2019&id=1405&sid=193a1857-0c03-44f9-92f1-92baf1e2548a.

D'Addario has installed a reverse osmosis humidification system in its Los Angeles manufacturing facility. This state-of-the-art system constantly regulates the relative humidity in the D'Addario Woodwinds reed factory to ensure a consistent manufacturing environment. A constant humidity level is maintained regardless of the outside ambient conditions with high reliability and energy efficient humidification for the production operation.

Facchinetti, Matteo, Xavier Boutillon, and Andrei Constantinescu. "Numerical and Experimental Modal Analysis of the Reed and Pipe of a Clarinet." *The Journal of the Acoustical Society of America,* 113, no. 5 (May 2003): 2874– 2883.

This is a scientific analysis of reed vibration tendencies. It was tested with a pipe and dry reed, not a player with a wet reed which would introduce humidity from the reed and lips. The article presents a three-dimensional distribution of pressure in the upper half of the clarinet. The authors measured three reeds, which does not seem helpful at all in determining repeatability and large-scale application give the variance in cane quality and reed cuts. They do not state what reeds were used. For the study, the reed is assumed to

be symmetrical along the longitudinal axis (which is not helpful since many reeds are not symmetrical). They consider cane to be a "purely elastic, transversely isotropic, homogenous material," which also does not take into account the variability in this organic material. They replaced the ligature with tape.

Frost, Eberhard. "Reeds." The Clarinets. Accessed October 20, 2019. http://www.the-clarinets.net/english/clarinet-reed.html.

This article gives an informative and easy to understand overview of what reeds are, what they are made of, how they are made, and how to adjust reeds.

Gangl, Manuel, Alex Hofmann, and Alexander Mayer. "Comparison of Characterization Methods for B-flat Clarinet Reeds." Semantics Scholar. Last modified September 22, 2016. Accessed October 23, 2019. https://pdfs.semanticscholar.org/f805/6436a28d6b8829abf622688e462e9269d783.pdf?_ga=2.189194729.31826505.1574130832-1999283873.1574130832.

This document describes how reed strengths are chosen. Hardness is tested by machines which test either reed stiffness or reed hardness. The author specifically compares the hardness of cane and synthetic reeds. The writer concludes that mechanical stiffness is a better indicator of playing ease in both cane and synthetic reeds. Cane reeds are softer than synthetic reeds.

Intravaia, Lawrence J., and Robert S. Resnick. "A Research Study of a Technique for Adjusting Clarinet Reeds." *Journal of Research in Music Education* 16, no. 1 (Spring 1968): 45–58.

This gives an informative and clear description of cane properties, commercial reed production, reed measurements across six brands (the average of 25 reeds per brand), characteristics of an ideal reed, how to break in reeds, and adjusting techniques.

Jeanne, Inc. "Jeanne ReedGauge, Metric Dial (Millimeters)." Accessed April 24, 2019. https://www.jeanne-inc.com/mm5/merchant.mvc?Session_ID=18bb15b6e48aa6f1ca6e73e9a37b4876&Screen=PROD&Store_Code=JI&Product_Code=JT400M&Category_Code=JT-CRG.

This is the product description of the Jeanne ReedGauge provided by Jeanne, Inc.

Jeanne, Inc. "Jeanne ReedGauge Usage and Maintenance PDF." Accessed April 24, 2019. https://www.jeanne-inc.com/mm5/graphics/00000001/Jeanne ReedGauge.pdf.

This is the company description of how to properly use the product. It details how measurements are calculated.

Kawasaki, Masahiro, Tadashi Nobuchi, Yuta Nakafushi, Masateru Nose, Masateru Shibata, Peng Li, and Makoto Shiojiri. “Structural Observations and Biomechanical Measurements of Clarinet Reeds Made from Arundo Donax.” *Microscopy Research and Technique* 80, no. 8 (May 9, 2017).

This article is a highly scientific look at the composition of cane at the cell level. Plant anatomy was examined for two clarinet reeds made from *Arundo donax* by different means of microscopy: light microscopy, low-energy secondary electron scanning electron microscopy (SEM), backscattered electron SEM, and helium ion microscopy (HiM).

Kolesik, Peter, Alan Mills, and Margaret Sedgley. “Anatomical Characteristics Affecting the Musical Performance of Clarinet Reeds Made from Arundo Donax L. (Gramineae).” *Annals of Botany* 81 (June 3, 1997): 151–55.

Though highly technical, this article provides compelling evidence for the ideal anatomy of a reed for it to play well. Reed cane comes from the *Arundo donax* plant, and like all organic material, it has structural variations stalk to stalk. The goal of reed cane growers is to grow plants of uniform quality and consistency across harvests. This study uses confocal imaging analysis to provide precise data on wood anatomy. Reed quality relates to the size of parenchyma cells and vascular bundles, though it is not statistically significant. The test reeds came from the same company in commercial tolerances of ±1.01 mm. All the cane was harvested in the same geographic area of Australia. The results were determined by a human play test which ranked the reed across six playability dimensions. The six dimensions were averaged to rank the reed as grade A, B, or C.

Légère Reeds. “The Légère Reeds Story.” Video last modified November 28, 2016. Accessed November 1, 2019. https://www.youtube.com/watch?list=PLhet0rWzbzYOG90Ufyn9ejktqpi1FFSvK&v=2jzRj4Sk9jQ.

Guy Légère discusses the foundation of Légère and how it has developed since its inception. The product idea was to have a reed with the personality of cane but with the ability to repeat an identical product. A synthetic reed option is impervious to external factors such as humidity and temperature that can negatively affect cane reeds.

Muncy Winds. “Perfecta Reed.” Video last modified November 4, 2011. Accessed April 11, 2019. https://www.youtube.com/watch?v=aloA0I5eyAA.

Muncy Winds demonstrates how to use the PerfectaReed. First, calibrate the device to zero it out. Measure the left and right sides. Unlock the carriage via the lock pin to move the dial position to points A–E to collect all reed measurements.

Pàmies-Vilà, Montserrat, Alexander Mayer, Alex Hofmann, and Vasileios Chatziioannou. “Measurement of Dynamic Bending and Displacement of Clarinet Reeds.” Paper presented at the 7th Alps Adria Acoustics Association Congress on Sound and Vibration, Ljubljana, Slovenia, September 22–23, 2016.

https://pdfs.semanticscholar.org/b327/7c34c3c4040a4539e5c3294f86a3bb5adea1.pdf.

This lecture analyzes reed behavior inside a player's mouth during performance. The measurements were performed on two German cut Légère reeds (strengths 2.75 and 3.5) on a Bb clarinet mouthpiece (Maxton Na-1). They placed a pressure transducer inside the mouthpiece, a strain gauge on the reed surface close to where a player's lip goes, and vibrated the reed using a Laser Doppler Vibrometer. The excitation of the reed was achieved artificially.

Paul, Randall Stewart. "A Study and Comparison of Four Prominent Clarinet Reed Making Methods." Ph.D. diss., University of Oklahoma, 2001.

This is a description of the reed making method of Stanley Hasty, Christopher Sereque, Daniel Gilbert, and Robert DiLutis. Descriptions include tube cane selection, cane aging and storage, cane splitting, rough blank to finished blank, making the finished blank flat, cutting the vamp, finishing the vamp, and final finishing. They use Version 2 of Ben Armato's PerfectaReed to produce metric measurements which they then convert to inches. The author summarizes the four reed making methods and then provides their own approach at the end.

Perdue, Robert E. "Arundo Donax-Source of Musical Reeds and Industrial Cellulose." *Economic Botany* 12, no. 4 (October 1958): 368–404.

The history of reed cane can be traced back 5000 years to ancient Egypt. Somehow, even with modern technology humans have been unable to create an adequate substitute for *Arundo donax*. Written by a botanist, the article looks at the scientific characteristics of *Arundo donax*. A large part of the article is dedicated to describing how it was used to make various primitive instruments, tracing the evolution to modern instruments. Perdue circles back to cane production. At the end, Perdue discusses other uses of *Arundo donax*.

Pieczynski, Joe. "Cosine Error Demonstrated and Challenged." Video last modified January 17, 2018. Accessed October 10, 2019. https://www.youtube.com/watch?v=dsWSxpwCPUg.

This video puts some mechanics to the term "Cosine Error" and offers up a different point of view versus the popular belief of indicator to tip positioning for accuracy.

Reeds 'n Stuff. "Reeds 'n Stuff: Digitaler Messplatz." Accessed October 23, 2019. https://www.reedsnstuff.com/Klarinette/Messen-Pruefen-Testen/Digitaler-Messplatz.html.

This micrometer is sold by a German company and shares numerous features with the Manual Reed Mapper.

The Reed Wizard. “About Mr. Ben Armato.” Accessed October 23, 2019. http://www.reedwizard.com/AboutArmato.html.

This provides biographical information about Ben Armato. Armato studied with Daniel Bonade and worked for the Metropolitan Opera Orchestra. Armato invented the PerfectaReed in 1969. In 1980, Armato wrote “Perfect a Reed,” a scientific method of adjusting single reeds. Armato invented and patented The Reed Wizard, a profiling tool.

Rote, William. “PerfectaReed Measurement Template.” The Reed Wizard. Accessed November 21, 2019. http://www.reedwizard.com/Images/perfectareedworksheet.pdf.

This measurement table by Bill Rote includes Positions A left and right through F left and right across the reed. If measuring a B♭ clarinet reed, this leads to 84 data points (6 x 2 x 7).

Schmidt, Karen F. “Good Vibrations.” *Science News* 140, no. 24 (December 14, 1991): 392–394.

Schmidt interviews a clarinet and oboe student from the University of Reading in England about their research on reed cane. *Arundo donax* has been the primary reed cane source for thousands of years because it diffuses vibrations efficiently. Researches have yet to discover or produce a favorable substitute. Reeds deteriorate because of bacteria, chemical decomposition, carbon-oxygen double bonds which prevent reeds from retaining moisture, and repeated stress of playing.

Starrett. “General Micrometer Information.” Last modified July 16, 2011. Accessed December 6, 2019. https://web.archive.org/web/20110716132738/http://www.starrett.com/download/222_p1_5.pdf.

This outlines Starrett’s micrometer design and manufacturing features.

Taillard, Pierre-André, Franck Laloë, Michel Gross, Jean-Pierre Dalmont, and Jean Kergomard. “Measurements of Resonance Frequencies of Clarinet Reeds and Simulations.” Last modified May 6, 2014. Accessed February 21, 2019. https://hal.archives-ouvertes.fr/hal-00668277v1.

This article is a highly scientific look at resonance frequencies of clarinet reeds, specifically as it relates to sensitivity to moisture. A set of 55 clarinet reeds is observed by holography, collecting 2 series of measurements made under 2 different moisture contents. Statistical analysis shows good correlations, but also significant differences between the series. Within a given series, flexural modes are not strongly correlated. The authors use a Principal Component Analysis to show that the measurements of each series can be described with 3 factors capturing more than 90% of the variance:

transverse modes, flexural modes of high order and the first flexural mode. In order to account for individual sensitivity to moisture content, another factor becomes necessary.

Vandoren Paris. “Reeds Technical Elements: The Different Cuts of Clarinet Reeds.” Accessed February 18, 2019. https://vandoren.fr/en/reeds-technical-elements/.

This is a topographical diagram of each cut. All points on the same level curve have the same thickness. The more pointed the arch, the thicker the spine and heart, and conversely, the thinner the side bevels.

Wissmuller, Christian. “D’Addario’s Robert Polan on the Rico Acquisition.” Last modified January 23, 2014. Accessed December 5, 2019. https://mmrmagazine.com/issue/upfront-q-a/d-addario-s-robert-polan-on-the-rico-acquisition/.

D’Addario acquired Rico in 2004 after Rico’s parent company, The Rutland Group, sought out D’Addario’s interest. First acquisition preference was given to Vandoren, but Vandoren was not interested in the partnership.

Wolfe, Joe. “Clarinet Acoustics: An Introduction.” University of New South Wales Music Acoustics. Accessed October 23, 2019. https://newt.phys.unsw.edu.au/jw/clarinetacoustics.html.

This is a wonderful introduction to the science of clarinet acoustic. The list of resources, articles, conference papers, and books at the end is immensely helpful and informative. Numerous images illustrate the author’s points, and it is technical in nature. It is written so that non experts can understand.