Mainspring Gauges

and the

Dennison Combined Gauge

Richard Watkins

Other translations, transcripts and books by Richard Watkins:

Berner, G.A. and E. Audetat: *Pierre Frederic Ingold 1787-1878*, (1962) 2008

Berthoud, Ferdinand and Jacob Auch: *How to make a verge watch,* (1763 and 1827) 2005 (ISBN 0-9581369-6-3) (with E.J. Tyler)

Borsendorff, L.: *The history of a watch followed by a conversation on the horology industry between Mr Trottevite and Mr Vabien*, (1869) 2007 (ISBN 978-0-9581369-9-0)

Buffat, Eugene: *History and design of the Roskopf watch*, (1914) 2007

Camus, C.E.L. and J.I. Hawkins: *A treatise on the Teeth of Wheels*, (1837) 2007 (corrected version of the Google Book copy)

Crespe, François: *Essay on repeater watches*, (1804) 2006 (ISBN 978-0-9581369-8-3)

David, Jacques: *American and swiss watchmaking in 1876, reports to the International Committee of Jura Industries on the manufacture of watches in the United States*, (1877) 2003 (ISBN 0-9581369-2-0)

Favre-Perret, E.: *Philadelphia Exhibition 1876, report presented to the Federal High Council on the Horology Industry*, (1877) 2004

Francillon, André: *History of Longines preceded by an essay on the Agassiz comptoir*, (1947) 2005 (ISBN 0-9581369-7-1)

Graupmann, Emile: *The finishing of the watch case*, (1910) 2004

Grossmann, Moritz: *Prize essay on the construction of a simple and mechanically perfect watch*, (1880) 2002 (ISBN 0-9581369-0-4)

Hillmann, Bruno: *The keyless mechanism, a practical treatise on its design and repair*, (ca1920) 2004

Japy, Frederic: *Patent for 5 years for various horological machines*, (1799) 2006

Lalande, Jerome: *Jerome Lalande, diary of a trip to England 1763*, (1763) 2002 (ISBN 0-9581369-1-2)

Marsh, E.A.: *History of Early Watchmaking in America*, (1890) 2006

Marsh, E.A.: *History*, (1921) 2006

Osterwald, F.S.: *Description of the mountains and valleys of Neuchatel and Valangin*, (1766) 2008

Societe Suisse de Chronometrie: *Some notes on Pierre-Frederic Ingold and the work of E. Haudenschild*, (1932), 2004

Saturday Magazine: *Manufacture of Watches in Switzerland*, (1842) 2008

Waterbury Watch Company: *Ali-Baba and the Forty Thieves*, (1889) 2005

Watkins, Richard: *Mechanical Watches, an Annotated Bibliography of Publications since 1800*, 2004 (ISBN 0-9581369-5-5)

These are available from www.watkinsr.id.au

Articles by Richard Watkins:

Berthoud, Harrison, and Lalande: A Near Myth, NAWCC Bulletin, No. 359 (December 2005): pp. 773-743.

Jacques David—and a Summary of "American and Swiss Watchmaking in 1876" with Emphasis on Interchangeability in Manufacturing, NAWCC Bulletin, No. 350 (June 2004): pp. 294-302.

Confabulations - A Humorous Look at Complications, NAWCC Bulletin, No. 367 (April 2007): pp. 163-172.

The above are also available from www.watkinsr.id.au

Practical Watch Collecting, a Manual for the Beginner: Part 1, NAWCC Bulletin, No. 375 (August 2008): pp. 429-447; Part 2, NAWCC Bulletin, No. 376 (October 2008): pp. 569-577; Part 3, NAWCC Bulletin, No. 377 (December 2008): pp. 679-690.

Contents

Introduction

While researching another aspect of Aaron Dennison's work, I read the following in *Copy of Biographical Sketch in Aaron Lufkin Dennison's Hand Writing Taking the Period up to the Year 1849 of His Life* (available from the NAWCC Library):

> *"One of the first difficulties I encountered in this [watch repair] business was from the lack of any fixed standard of sizes which were in general use; every (different) manufacturer having a gauge of his own ... and no two agreeing ... This led me to devise a gauge upon which all the different parts of a watch could be accurately measured".*

Although I knew of the common *Dennison Mainspring Gauge* I had never come across a gauge to measure "all the different parts of a watch", and I wondered what it looked like.

First I searched through my own library of about 750 books on watches. There were a few vague references to Dennison inventing a gauge about 1840, which was a "Standard Gauge" or "The US Standard", but nowhere was there a description of it. The only concrete statement I found was in a rather obscure book, N. B. Sherwood's *Watch and Chronometer Jeweling*:

> *"We now refer to Dennison's combined gauge, an article indispensable to every watch-maker, who, may by its use, size wire or plate to all the sizes indicated by any Stubb's gauge, also the diameter of wheels and pinions, most perfectly. The prices is [sic] very moderate, when the wide range of sizes is considered."*

But again there was no description.

After that I tried the NAWCC Bulletin index and searching the internet. All I found were a few mentions of Dennison's mainspring gauge and nothing at all relating to the more flexible combined gauge.

My last attempt to find out about it was to post a message on the NAWCC Message Board. I got an instant reply from Dave Coatsworth, who posted photographs of this elusive gauge. And, as luck would have it, a couple of days later I found one for sale and bought it. Because both the mainspring gauge and this other gauge can be signed "US Standard" I will not use that term and, instead, refer to Dennison's *mainspring* and *combined* gauges.

As Dennison knew about European gauges, this article will examine them first. Six mainspring gauges (one with two different scales) will be studied; the Martin, Montandon, Robert, Lepine, Ferret and Prenot gauges. These are the only gauges I know of and I presume they are the ones Dennison was referring to. I will assume the makers were rational people and the gauges they produced were based on sensible scales. However, most published tables indicate the gauges are irrational, having arbitrary scales which do not follow any obvious pattern. As a consequence it has been necessary to carefully examine them and discover the patterns that, in fact, form the basis of their designs. It turns out that these gauges are either *French imperial* (based on the French inch) or *metric*.

I then look at Dennison's combined gauge and his later (and simpler) mainspring gauge and show that both are *English imperial*, based on the English inch.

Acknowledgements

First, this article could not have been written without the help of Dave Coatsworth, Stephen Katchur and Don Ross.

Dave Coatsworth made me aware of the Dennison combined gauge. If he hadn't, this would never have been written.

Stephen Katchur provided photographs and measurements of his "modern" Montandon gauge.

Don Ross has provided an enormous amount of information. He is responsible for all the data and photographs of the Ferret and Prenot gauges. Equally importantly, he provided photographs of different versions of Dennison's gauges with detailed measurements of them, and we have had many stimulating discussions on the topic. Without his contribution this article would be very much poorer.

Second, this article could have been written more easily if I had not used Microsoft Office. I have discovered yet more of the stupid faults and erratic behaviour of these programs, which have made doing simple things, like creating charts, a matter of luck and agony.

However, using Microsoft Office has had two beneficial outcomes. I have become used to saving files every few minutes, to overcome its penchant to crash unexpectedly; and I am much more careful about making backups of all my work.

European Mainspring Gauges

At least six mainspring gauges were used in Europe, but it was hard to find out anything useful about them. The gauges I have information on are:

Montandon: A description of the Montandon gauge (and a mention of the Robert gauge) is in another obscure book, Eugene Buffat's *History and design of the Roskopf watch*. He wrote:

> *"The scales or gauges used for the measurement of mainsprings in the Neuchâtel Mountains and in the Jura do not appear to have a scientific basis. They are measurements created by manufacturers of mainsprings for their customers and consecrated by use. Thus the Montandon gauge (of the Montandon brothers, in Rambouillet, near Paris) is most known; it has 57 numbers above 0, and 9 below 0, for the heights, and 18 numbers (from 0000 to 14) for diameters. The difference between each number in height is 0.08 mm to No. 22, which is = 3 mm, and 0.10 mm for numbers 23 to 57, which is = 6.5 mm. For the diameters, the difference is 1 mm between each number from 0000 to 0 and 0.5 mm from 1 to 14. The Robert scale is just as conventional; in the past it was frequently used at La Chaux-de-Fonds. Currently metric measurements - which are far better - have supplanted these old gauges. It will not be long before they disappear from the scene, but it is good to know them, because many foreign supply houses still give their orders for mainsprings according to the scales Montandon or Robert".*

My Montandon gauge, Figure 1, consists of a piece of steel sandwiched between two pieces of brass. It has mainspring heights from "9/0" to "57" and barrel diameters from "4/0" to "18". It is hand made, with the notches filed out and the engraving done by hand. In contrast, the other gauges I have examined are simple brass plates with the notches cut by machine and regular, punched engraving, as in Figure 3.

The Montandon gauge is obviously old, but I do not know how old. Tardy's *Dictionnaire des Horlogers Français* lists Montandon frères from 1825 and notes that the company registered the trademark on my gauge, Figure 2, in 1863; so that is the earliest possible date.

Stephen Katchur has provided me with photographs and measurements of a more recent Montandon gauge that he owns. It is a simple brass gauge and has heights from "10/0" to "25" and barrel diameters from "1" to "16". The different ranges probably reflect the decreasing sizes of watches over the years. I have not included a photograph of this gauge because it is the same as Figure 3 in appearance.

A third Montandon gauge is illustrated in a Henri Picard & Frère catalogue circa 1885 (reproduced in Ted Crom *Horological Shop Tools 1700 to 1900*). This will be discussed later.

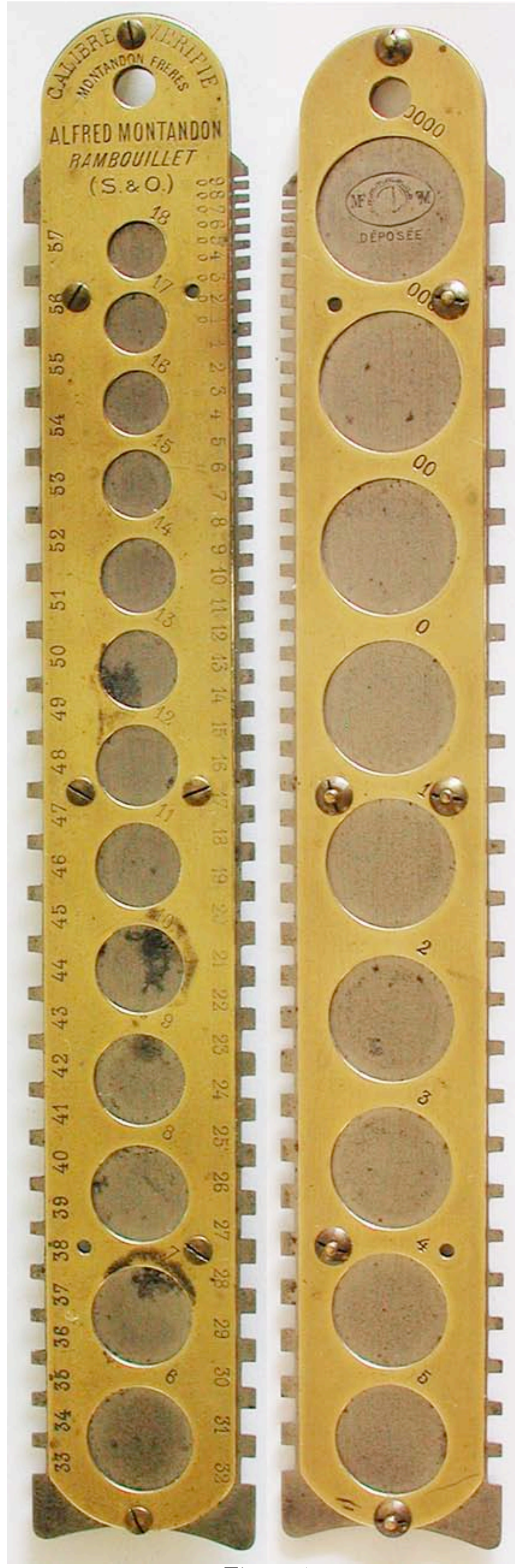


Figure 1

Figure 2

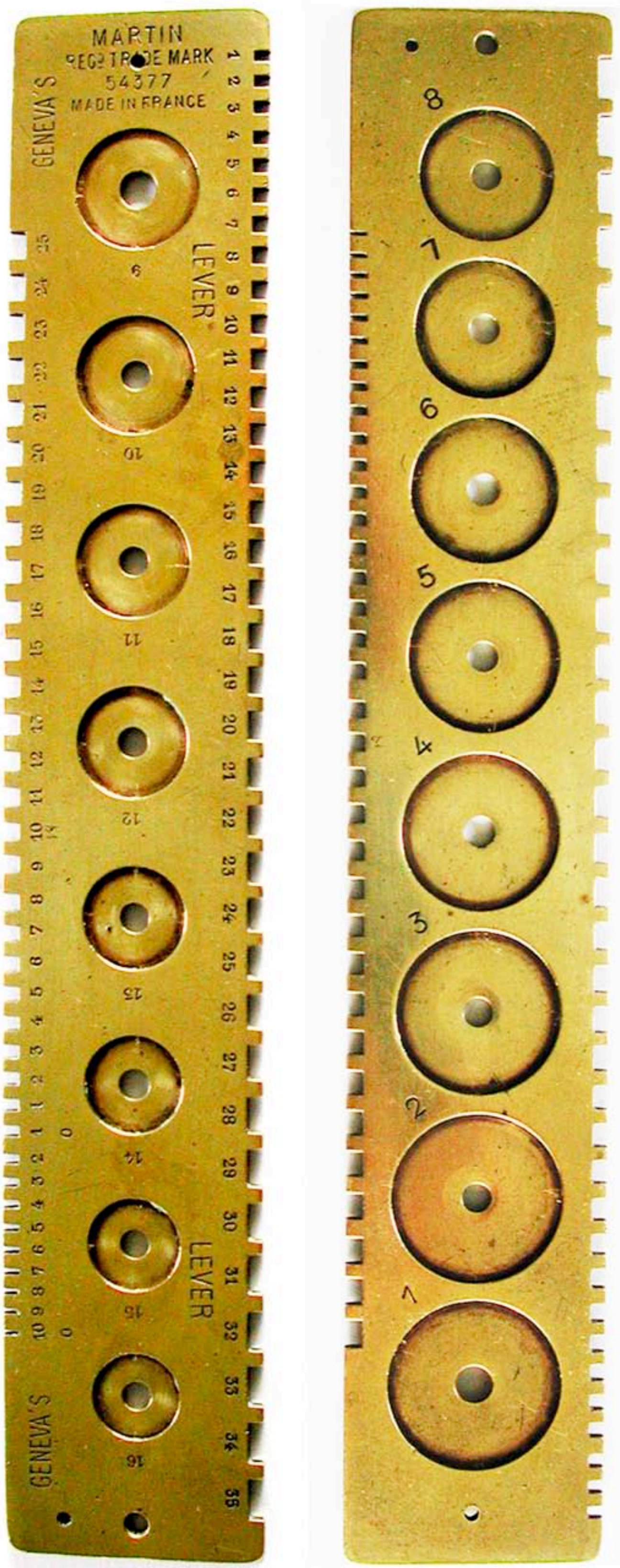


Figure 3

Figure 4

Robert: Unfortunately I have not seen the Robert gauge mentioned by Buffat, but it must be similar to those shown in Figures 1 and 3. It was made by Ulysse Sandoz Robert of La Chaux-de-Fonds, who was still making mainsprings in the 1930s; Figure 3a is an advertisement from the 1932 Swartchild catalogue (B177).

However, my favourite repair book, Jendritzki's *The Swiss Watch Repairer's Manual*, has tables for the Robert gauge (and the Montandon gauge).

Martin: The third gauge, Figure 3, is made by Martin in France, and the only reason I knew of it was because I have two of them in my collection. But then I found an description of it and how to use it in *Watch Cleaning and Repairing* edited by Bernard Jones, a book as obscure as Buffat's:

> *"There are so many different gauges for mainspring widths and thicknesses that it is best to buy a pair of gauges of some recognised standard, such as "Martin" or "Metric", and in ordering quote them distinctly. ... The notches cut in the edges of the Martin gauge indicate the height of the spring, lever one side and Geneva's the other. The sinks correspond with the strength for either lever or Geneva's. For instance, a spring, strength 14, will be found to coincide in diameter with sink 14. Therefore, to find a spring suitable in strength for the barrel, place the latter over the sink which it fits, and select a spring to just fit the sink".*

Nowhere have I found the term "Geneva's" explained, but I assume it means watches with a cylinder escapement. Although hard to read in the photograph, the "scales" for Lever and Geneva's are completely different, the Lever notches ranging from "1" to "35" and the Geneva's from "10/0" (0000000000!) to "25"; for example, a Geneva's "13" is about the same size as a Lever "9", and a Geneva's "25" equates to a lever "20". However both scales have 35 sizes.

Also, there is no size "0", the gauge having sizes "2/0", "1/0", "1", "2"; so "1/0" and "0" are the same thing. I mention this because the use of "1/0" is different in different gauges. If you look at Table 1 you will see that one gauge does not have a"1/0" and one has both a "1/0" and a "0".

Measuring the *strength* (thickness) of a mainspring is very crude. It assumes the barrels in watches make 4 turns in 32 hours and is based on watches using Geneva or Maltese Cross stop work, which only allows 4 turns. In this case the strength is related to the diameter of the barrel.

Lepine: Don Ross replied to my enquiry on the NAWCC Message Board, referring me to an article in the *Jewelers' Circular and Horological Review* (August 27, 1902, page 88). This has another table for the Robert and Montandon gauges, but it also includes the fourth Lepine gauge. (It also mentions a *Boley* decimal gauge without providing any details, but I suspect it is more recent and so not really relevant.)

I then found another table for the Robert, Montandon and Lepine gauges in *Lexikon der Uhrmacherkunst* by Carl Schulte.

Again I have not seen a Lepine gauge, but an advertisement (discussed later) provides some more, but contradictory, information.

Ferret and ***Prenot***: The last additions to the list also came from Don Ross, who provided details of two gauges he owns, marked E. Ferret and Prenot. There is a Ferret mentioned by Buffat:

> *"but they did not do the wheel-cutting and it was to the firm of Ferret, in Corbeil near Paris, that Roskopf sent the discs for the various wheels."*

I do not know if this is the same person, but Don Ross also has a wheel gauge with the same signature.

Unknown: Finally, the Henri Picard & Frère catalogue illustrates another gauge without any identification. This gauge has barrel sinks marked in millimetres and the text "Echelle au 1/10 de millum" (scale of 1/10 mm) referring to the height notches. It is apparent that the barrel sinks are not the same as any of the other gauges. This gauge may be the Boley gauge mentioned in the *Jewelers' Circular* article, but because I have insufficient information I have not included this gauge in the following discussion.

I have discovered nothing more about these gauges. Unlike for watchmakers, there are no lists of tool and parts makers to reference for information. And internet searching has revealed nothing. So we know the names on these gauges but we do not know anything else about their manufacture. In particular, when they were first made is a mystery. Certainly they were used for a long time; as late as 1957, the Lauris *Watchmakers and Instrument Repairers Guide* felt the need to state:

> *"We only stock the metric gauge, as the Geneva gauge is generally considered superceded. ... The Geneva gauges used in Australia in past years were unsatisfactory, because in several important sizes the same reading would cover springs of different dimensions, and because the steps are uneven".*

But which gauges existed in 1840?

In one way it doesn't matter. All six gauges considered here are functionally identical. All have notches on their edges to measure mainspring heights, and four of them have barrel sinks to determine mainspring strengths. So it is sensible to assume that the gauges Dennison saw were basically the same.

Strange Numbers and the Martin Strength Gauge

The *Jewelers' Circular* article also points out that manufacturers had switched to the metric system about 1886, but watchmakers continued to use the old gauges, creating "a deplorable state of affairs" and great confusion by not specifying which gauge they were using! In addition, the writer points out that the French and Rhenish inches were in use, both of which are different from the English inch. Indeed, there were many inches, four of which are:

English inch = 25.340 mm
Prussian inch = 26.148 mm
Rhenish inch = 26.18 mm
French inch = 27.072 mm

Actually, according to the Wikipedia, the French law of 1799 for defining the metre states that one decimal metre is exactly 443.296 French lignes, which means a ligne is 27.06994875 mm, about 0.002 mm smaller than the above figure.

The French inch was divided into 12 *lignes* and each ligne was divided into 12 *douzièmes*, $\frac{1}{144}$th of an inch. Of course it is possible to sub-divide each douzième 12 times giving $\frac{1}{1728}$th of an inch. That is, 1 douzième is about 0.18799 mm and $\frac{1}{12}$ douzième is about 0.01567 mm.

These fractions look strange, but they are perfectly sensible. If I measure something and it is 0.37598 mm you would think it a ridiculous size. But it is exactly 2 douzièmes and perfectly sensible. Likewise the common $\frac{1}{32}$ and $\frac{1}{64}$ inch are sensible even though they are 0.791875 and 0.3959375 mm, and 0.2 mm is sensible although it is 0.00789265982 inch!

Such fractions are not restricted to the French. The common Lancashire watch sizes are based on 1/30 of an English inch, and this fraction was also used for measuring crystals. And the Lancashire pillar gauge, for measuring the heights of pillars, is based on 1/144 of an English inch. (A useful summary of measuring scales can be found in Vaudrey Mercer *The Frodshams, the Story of a Family of Chronometer Makers*)

So a ridiculous number in one measuring system may be a sensible number in another system. Or it may not.

In the following we will need to measure to an accuracy of about 0.01 mm, or about $\frac{1}{2500}$ inch and $\frac{1}{2}$/12 douzième, so don't be surprised when apparently peculiar fractions appear.

The common French imperial measuring gauge is the *douzième* gauge, Figure 5. This is a *magnifying* gauge; the measurement range is ½ French inch and the scale is marked 0 to 72 douzièmes; it is magnified by about 3.7 : 1. As a result it is possible to measure to an accuracy of ½ a douzième. Metric measuring gauges were also made with a measurement range of 12 mm and the scale marked in 0.1 mm divisions which can be read to 0.05 mm.

But these are not accurate enough for the height, let alone the thickness of a mainspring. More accurate measurement requires a much greater magnification.

Figure 5

Figure 6

For example, the ordinary metric micrometer, which has two turns of the thimble for each millimetre and the thimble divided 0 to 50, has a magnification of about 82 : 1 with the scale marked in 0.01 mm divisions which can be read to 0.005 mm.

Although not as convenient, a douzième micrometer is also practical; for example, the thimble makes 3 turns for each ligne and it is divided into 0 to 48 divisions for $\frac{1}{12}$ douzièmes.

Another potentially more accurate measuring gauge is the *slit gauge*, which is often called a *pivot gauge*. For example, Figure 6 shows a Martin *mainspring strength* gauge. In this gauge the range 0.05 mm to 0.30 mm is spread out over 59 mm, or a very large magnification of 236 : 1. This is necessary, because the human eye cannot discriminate between such small distances and it would be impossible to make such narrow notches.

A slit gauge is a linear gauge made of two pieces of metal with perfectly straight edges. These are clamped in position so that the two parts meet at one end and are separated at the other end by M (millimetres or douzièmes).

If the length of the gauge is L then an object m wide will fit at

$$l = (L/M)m$$

from the end.

For example, if L = 100 mm and M = 1 mm then the magnification is 100 : 1 and if the object being measured is 0.17 mm wide it will fit the slit l = 17 mm from the end.

The Martin strength scale is quite regular, but the scale numbers are reversed. The smallest number, “5/0”, corresponds to 0.30 mm and the largest number “21” to 0.05 mm. But there is a simple relationship: the Martin number S corresponds to:

$$M = 0.01(21 - S) + 0.05$$

or

$$M = -0.01S + 0.26 \text{ mm}$$

interpreting “1/0” as 0 and “5/0” as -4.

Interestingly, de Carle’s *Watch and Clock Encyclopedia* has a table for this gauge which is out by one; according to his book Martin number S corresponds to

$$M = -0.01S + 0.27 \text{ mm}$$

Indeed, most tables in books have errors and de Carle is not alone in making mistakes.

Numbers like 0.26 mm seem strange. But this is partly because mathematics favours *zero* whereas people tend to favour *one*. So the above mathematical formula says “starting at *zero*, the size S is 0.26 mm ...”. However, the human who designs a gauge might well think “starting at *one* ...” in which case the correct formula is

$$M = -0.01(S-1) + 0.25 \text{ mm}$$

and 0.25 mm is much more sensible. So what may seem a strange formula can be very practical.

Martin’s slit gauge has probably always been metric and never a douzième gauge, because it is most likely a relatively recent replacement for the original, and very limited barrel diameter gauge.

Such *slit gauges* are of dubious value. When very narrow, damage, caused by forcing a mainspring in, corrosion and dirt reduce its accuracy. And, of course, if it has not been assembled perfectly the scale will be wrong. Even if it is correct the readings can vary. Both my Martin slit gauges are correct, but a size “2” 0.24 mm mainspring (measured with a micrometer) can be pushed down to the size “5” 0.21 mm calibration. So unless the mainspring is inserted with almost no pressure, the reading will be wrong. But if I am too gentle it will record less than 0.24 mm!

Figure 7 is an English imperial slit gauge which measures in $\frac{1}{1000}$th inch to $\frac{250}{1000}$ inch; this illustration is from Henry Abbott’s *American Watchmaker and Jeweler, an Encyclopedia*. A douzième slit gauge is equally simple. For example, a 6 inch gauge with a maximum width of ½ ligne and 72 divisions will accurately measure $\frac{1}{12}$ douzièmes.

The inverse of a slit gauge is also quite common. The obvious examples are the tapered rod used for sizing rings and the much smaller tapered rod used to measure watch jewel holes.

Similarly, it is possible to taper and graduate a piece of flat steel to measure either $\frac{1}{100}$ mm or $\frac{1}{12}$ douzièmes. Such a gauge can be filed into a series of flat sections and used as a go-nogo gauge.

So numbers like 6½/12 and 47/12 douzièmes are not only sensible, but can be measured as easily as 0.08 and 1.24 mm.

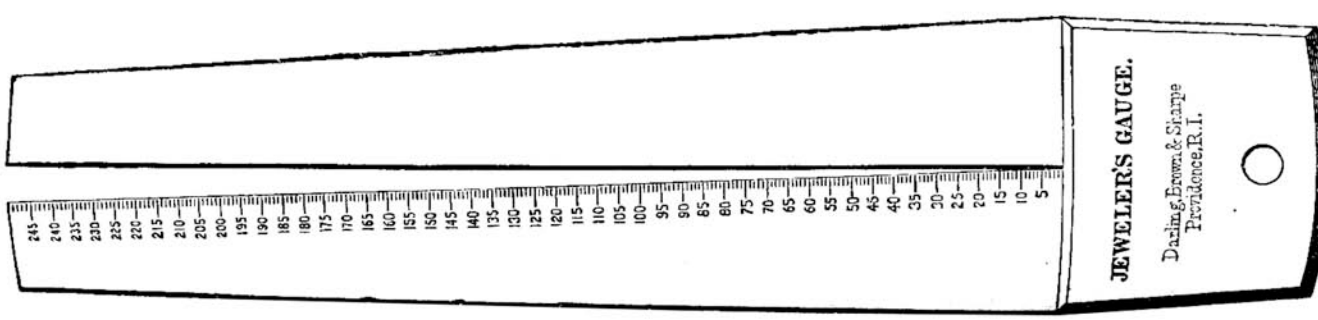


Figure 7

Mainspring Heights: Symbols or Numbers?

Table 1 gives the scales for mainspring heights for four European gauges. I have used Jendritzki's data for Montandon (**Mont**) and Robert, to which I have added the Martin Geneva's sizes (**MG**) from de Carle's *Watch and Clock Encyclopedia*, Martin Lever sizes (**ML**) measured from my gauges, and Lepine sizes from the *Jewelers' Circular* article.

These are probably *nominal* sizes because they are *go-nogo* gauges. What matters is that a mainspring fits the correct notch and will not fit the next smaller notch; it does not matter if there is a little play. Indeed, my actual gauges produced less attractive figures and I have rounded the Martin Lever sizes.

For example, if the gauge measures 1.84 mm then the size cannot be 1.85 mm because a spring of that size will not fit; and so it should be recorded as 1.80 mm. However, errors in manufacture and measuring of these notches means there is considerable doubt and it is quite likely that such a notch should be recorded as 1.85 mm.

The Lepine sizes have been simplified a bit. For example, the size "7/0" is given for 0.80, 0.85, and 0.95 mm; the *Jewelers' Circular* table does not include 0.90 mm. As this must also be a go-nogo gauge, the notch must be at least 0.95 mm wide to accommodate these sizes, and so I have only included the largest measurement in the table.

In Table 1 I have included all metric sizes from 0.60 to 3.25 in steps of 0.05 mm. Thus the regularity or otherwise of a scale can be seen directly from the spacing of the scale numbers.

What is clear is that the scale "numbers" appear to be *symbols* and not numbers. Numbers follow the rules of arithmetic, and so do metric and imperial measurements: 2 + 2 = 4, 4 mm is twice as long as 2 mm, and so on. But the "numbers" on these mainspring gauges seem not to have any numerical meaning.

Take the Martin Geneva's scale. "1/0" corresponds to 1.15 mm and "1" to 1.25 mm; it is 0.1 mm larger. So "2" should be 0.1 mm larger, or 1.35 mm, which it is. But "3" is not 1.45 mm as we would expect, but only 1.40 mm. A quick look at the table and it becomes obvious that there is no pattern; all five European gauges make arbitrary jumps from one size to another. So we *cannot* describe them as metric gauges. The fundamental principle of a metric gauge is that it measures millimetres and obeys the laws of arithmetic; these gauges do not.

But are they symbols?

Table 2 gives Montandon mainspring heights from Jendritzki (**Jend**), Buffat, the *Jewelers' Circular* article (**JC**), Schulte (**Sch**), Stephen Katchur (**Katch**) and my gauge (**Mine**).

Stephen Katchur, Don Ross and I found it difficult to measure our gauges because some of the notches are not square, and we got different readings depending on what part of the notch we tested. (Which introduces more doubt. If a mainspring fits a notch but

Mainspring Heights					
mm	**M L**	**M G**	**Mont**	**Robert**	**Lepine**
0.60			9/0	3/0	
0.65				2/0	10/0
0.70			8/0	1/0	9/0
0.75			7/0	0	8/0
0.80			6/0	1	
0.85		4/0		2	
0.90			5/0	3	
0.95		3/0		4	7/0
1.00			4/0	5	
1.05		2/0	3/0	6	6/0
1.10			2/0	7	
1.15		1/0		8	5/0
1.20					
1.25		1	1/0	9	4/0
1.30				10	
1.35		2	1	11	3/0
1.40	1	3	2	12	
1.45			3	13	2/0
1.50	2	4			
1.55			4	14	0
1.60	3	5			
1.65		6	5	15	
1.70	4	7	6	16	
1.75				17	1
1.80	5	8	7	18	2
1.85				19	
1.90	6	9	8		3
1.95		10	9	20	4
2.00	7			21	5
2.05		11	10	22	6
2.10	8			23	7
2.15		12			
2.20	9	13	11	24	8
2.25			12	25	
2.30	10	14	13	26	9
2.35				27	
2.40		15	14	28	10
2.45					
2.50	11	16	15	29	11
2.55	12	17	16	30	
2.60	13	18		31	
2.65			17	32	12
2.70	14	19	18	33	
2.75					
2.80	15	20	19	34	13
2.85			20	35	14
2.90	16	21	21	36	
2.95		22		37	15
3.00	17	23	22	38	16
3.05					
3.10	18	24	23	39	
3.15				40	
3.20	19	25	24	41	
3.25				42	
3.30	20				
3.35					
3.40	21				
3.45					

Table 1

will not go to the bottom, is it that size or the next size up?) Note that the table omits Katchur's size "10" because the "10" and "11" notches on his gauge are the same size. Notches "9/0" and "8/0", and "21" and "22" of his gauge are also nearly the same size, but I was able to fit them into the table. So the gauge has been made incorrectly and is unreliable. It is not alone!

It is apparent that all these scales have irregular spacing and they cannot be metric.

But according to Buffat, as quoted above, Montandon's gauge *is* regular, and for numbers S from "9/0" to "22" the mainspring height increases regularly by 0.08 mm. In fact Montandon's "1" should be 1.32 mm, but Jendritzki says it is 1.35 mm. Only a small difference, but for number "15" Buffat's formula gives 2.44 mm, which means Jendritzki has put this number in the wrong row of the table. This applies to several of the irregular entries in Table 2. And the *Jewelers' Circular* article and my gauge give different values again!

All the tables I have seen, including my Table 2, match the scale numbers with nice, convenient numbers of millimetres. But what if an *apparent* irregularity has been introduced simply because *they have been rounded to the nearest convenient number of millimetres*? Perhaps they appear to be irregular when they are not.

Why millimetres anyway?

As we have seen, the Swiss and the French used a perfectly good measuring system based on the French inch. A *douzième*, 1/144th of a French inch is 0.18799 mm. So 5/12 douzième is 0.07833 mm, which is very close to 0.08 mm, differing by only 0.00167 mm. Indeed, the Montandon numbers can just as well be based on douzièmes as on millimetres.

If a scale is regular then the problem is to find the values of a and b in the formula

$$M = aS + b$$

where S is the scale number and M is the corresponding width of the notch in of millimetres or douzièmes.

In general, to do this we need two values from the table which we know are correct. Unfortunately we do not know which these are; indeed none may be correct! But if we can choose two values then we can construct a *uniform* table where a is the *increment*, the difference between consecutive scale numbers and b is the *base*, the size of the scale "0" notch.

Consider the Montandon mainspring heights in Table 2. All the scales are different and all have irregular jumps from one scale size to the next. (Also, the Schulte table has omitted size 8/0 and some of the sizes from 9/0 to 1/0 may be wrong.)

If we choose the values for "9/0" and "24", which are the same for three of the published tables and my gauge, then:

$$3.20 = 24a + b$$
$$0.60 = -8a + b$$

where 1/0 = 0, 2/0 = -1, ... 9/0 = -8. Subtracting we get:

$$2.60 = 32a$$

and so

$$a = 2.6/32 \text{ mm}$$

Substituting this value of a in the second equation gives:

Montandon Mainspring Heights						
mm	**Jend**	**Buffat**	**JC**	**Sch**	**Katch**	**Mine**
0.55					10/0	
0.60	9/0	9/0	9/0		9/0	9/0
0.65			8/0	9/0	8/0	8/0
0.70	8/0	8/0	7/0	7/0		
0.75	7/0	7/0			7/0	7/0
0.80	6/0		6/0	6/0		
0.85		6/0		5/0	6/0	6/0
0.90	5/0	5/0		4/0		5/0
0.95			5/0		5/0	
1.00	4/0	4/0	4/0		4/0	4/0
1.05	3/0			3/0		
1.10	2/0	3/0	3/0	2/0	3/0	3/0
1.15		2/0	2/0		2/0	
1.20					1/0	2/0
1.25	1/0	1/0				1/0
1.30		1	1/0	1/0	1	1
1.35	1		1			
1.40	2	2	2	1	2	2
1.45	3		3	2	3	
1.50		3		3		3
1.55	4	4	4			
1.60				4		4
1.65	5	5		5	4	5
1.70	6	6	5		5	
1.75			6	6	6	6
1.80	7	7		7		7
1.85					7	
1.90	8	8	7	8		8
1.95	9	9	8		8	
2.00				9		9
2.05	10	10	9	10	9	10
2.10		11	10	11	11	11
2.15						
2.20	11	12	11	12	12	12
2.25	12		12			
2.30	13	13	13	13		13
2.35		14				
2.40	14		14	14	13	14
2.45		15			14	15
2.50	15	16	15	15	15	16
2.55	16			16		
2.60		17	16	17	16	17
2.65	17		17			
2.70	18	18		18	17	18
2.75		19				
2.80	19		18	19	18	19
2.85	20	20	19	20	19	20
2.90	21	21	20	21		21
2.95			21		20	
3.00	22	22		22	21	22
3.05					22	
3.10	23	23	22	23		23
3.15			23	24	23	
3.20	24	24	24			24
3.25					24	
3.30						
3.35					25	

Table 2

$$0.6 = -20.8/32 + b$$

and so

$$b = 19.2/32 + 20.8/32 = 40/32 \text{ mm}$$

Therefore

$$M = (2.6/32)\, S + 40/32 \text{ mm}$$

or

$$M = 0.08125S + 1.25 \text{ mm}$$

Graph 1, at the end of this article, shows this formula. What is clear from it is that my gauge, Katchur's gauge (despite its errors), Jendritzki's values and the formula are all very close to each other.

Now a = 0.08125 mm is very close to $\frac{5}{12}$ douzièmes (0.07833 mm, the difference being only 0.0029 mm), and b = 1.25 mm is very close to $\frac{80}{12}$ or $6\frac{8}{12}$ douzièmes. In other words we could use:

$$M = (5/12)S + 80/12 \text{ douzièmes}$$

Alternatively we could choose other values to work out the formula. If we use the values for "1" (1.35 mm) and "22" (3.00 mm) we get:

$$M = 0.07857S + 1.2714 \text{ mm}$$

And other combinations will produce similar but different results. However, all these formulae fit well with the data.

The values of a and of b are important.

As a is the increment from one size to the next it needs to be a sensible number; it would be ridiculous to think that the designer of this gauge used an increment of 0.08125 or 0.07857 mm! However, an increment of $\frac{5}{12}$ douzièmes or 0.08 mm is reasonable.

Likewise, if the gauge is created starting at the scale number "0", then b needs to be a sensible value. Of course, the person who designed the Montandon gauge may have started from any scale number and so some variation in b is possible. In the first equation b is 1.25 mm, which is almost a sensible figure if the scale is metric; but that system does not normally use fractions like ¼. It is also sensible for a douzième scale because $6\frac{8}{12}$ douzièmes is 1.2533 mm. In the second equation b = 1.2714 is not a sensible metric number, but it is very close to $6\frac{9}{12}$ douzièmes.

In principle there is an easier and much better way to determine the values of a and b, the method of *least-squares* curve fitting.

This determines a and b for the straight line that minimises the total deviations of the actual data from the straight line and so produces the line that is the best fit to the data. Spreadsheets include automatic calculation and graphing of least-squares curves. If we use this technique with my gauge in Table 2 we get:

$$M = 0.0809S + 1.3202 \text{ mm}$$

which is near to:

$$M = (5/12)S + 84/12 \text{ douzièmes}$$

But although a might be 0.08 mm, the value of b is definitely not nice and the metric formula is unlikely. When drawn, this least-squares line is almost indistinguishable from the first formula and so I have not included it in Graph 1.

Two points need to be made. First, we should assume the makers of these gauges were rational people and their scales are regular and based on sensible values of a and b. And second, as will become clearer as we examine more cases, the gauges are far from perfect. In Graph 1 we can see small deviations of my gauge from the ideal line which indicate errors in manufacture (or errors in my measurements). Graph 2 shows that the three published tables and my gauge are all different from each other.

These variations mean that both manual calculation of formulae and least-squares curve fitting produce abstract, ideal lines which frequently have irrational values for a and b. However, small changes in the values of a and b are possible while still having formulae that satisfy the gauges, and we can choose values that make sense in the metric or imperial systems, or both.

The value of a is most restricted because it is multiplied by the scale number. For example, in the above formulae changing a by $\frac{1}{100}$ mm from 0.0809 to 0.09 will change size "24" from 3.2618 mm to 3.4802 mm, an increase of about 0.22 mm. This is far too large to be acceptable. So, although we can try "nice" formulae they must be very similar to the abstract ideal.

Montandon Mainspring Heights

The above discussion has been included because it sets out the basic principles. However the formulae are wrong. The problem with them is that they are based on Table 2 which uses an increment of 0.05 mm when, according to Buffat, Montandon's gauge uses two different increments of 0.08 and 0.10 mm. And so the rounding that was necessary to fit the scale numbers into Table 2 has introduced errors leading to the strange values of a and b, causing at least some of the apparent differences between the formula and the published tables.

Table 3 gives the actual sizes of my gauge in millimetres for each scale number. (It has been abbreviated, the scale continuing from "44" to "57".) Graph 3 shows the values in Table 3 and that Buffat is correct. That graph has the values from my gauge with the two least-squares lines necessary to fit the data; they clearly show the change in increment at size "22".

By using Table 3 instead of Table 2, and noting that the gauge is different above and below scale number "22" we get the two formulae:

$M = 0.08(S - 22) + 3.0\ mm$, S = "9/0" to "22"

$M = 0.1(S - 22) + 3.0\ mm$, S = "23" to "57"

Or, to express them more simply:

$M = 0.08S + 1.24\ mm$, S = "9/0" to "22"

$M = 0.1S + 0.80\ mm$, S = "23" to "57"

These formulae give the fifth column in Table 3 (**Buffat mm**) corresponding to the scale numbers in the first column. With the exception of b = 1.24 mm these appear to be sensible metric equations. (Actually we can substitute b = 1.25 without making much difference. Then the scale runs from 0.61 mm to 4.31 mm.)

A French imperial gauge is equally likely. Columns 3 and 4 of Table 3 give the notch sizes corresponding to:

$M = 5/12S + 80/12$ *douzièmes*, S = "9/0" to "22"

$M = 6½/12S + 48/12$ *douzièmes*, S = "23" to "57"

In order to compare the metric and imperial formulae, we need to examine the differences between the ideal formula and my gauge. There are three points:

(a) The average difference between my gauge and the imperial formula is about 1½/12 douzièmes or 0.024 mm. The largest difference, at scale number "56", is about 4½/12 douzièmes or 0.069 mm.

(b) The average difference between my gauge and the metric formula is 0.018 mm. The largest difference is 0.050 mm.

(c) The average difference between the imperial and metric formulae is 0.015 mm. The largest difference is 0.041 mm at scale number "57".

The majority of the differences between my gauge and the two formulae are due to irregularities in the gauge, and there is a high value of 0.069 mm due to the "56" notch being cut too narrow. However, the difference between my gauge and the imperial formula increases from 0.02 to 0.04 mm for scale numbers "45" to "57".

Montandon Mainspring Heights				
Scale	**Gauge mm**	**1⁄12 Douz**	**Douz mm**	**Buffat mm**
9/0	0.58	40	0.63	0.60
8/0	0.64	45	0.71	0.68
7/0	0.73	50	0.78	0.76
6/0	0.83	55	0.86	0.84
5/0	0.89	60	0.94	0.92
4/0	1.02	65	1.02	1.00
3/0	1.08	70	1.10	1.08
2/0	1.18	75	1.18	1.16
1/0	1.25	80	1.25	1.24
1	1.32	85	1.33	1.32
2	1.41	90	1.41	1.40
3	1.49	95	1.49	1.48
4	1.58	100	1.57	1.56
5	1.65	105	1.65	1.64
6	1.74	110	1.72	1.72
7	1.79	115	1.80	1.80
8	1.92	120	1.88	1.88
9	1.98	125	1.96	1.96
10	2.05	130	2.04	2.04
11	2.12	135	2.12	2.12
12	2.22	140	2.19	2.20
13	2.30	145	2.27	2.28
14	2.39	150	2.35	2.36
15	2.45	155	2.43	2.44
16	2.52	160	2.51	2.52
17	2.62	165	2.59	2.60
18	2.72	170	2.66	2.68
19	2.79	175	2.74	2.76
20	2.85	180	2.82	2.84
21	2.91	185	2.90	2.92
22	2.98	190	2.98	3.00
23	3.09	196½	3.08	3.10
24	3.19	203	3.18	3.20
25	3.26	209½	3.28	3.30
26	3.38	216	3.38	3.40
27	3.45	222½	3.49	3.50
28	3.58	229	3.59	3.60
29	3.68	235½	3.69	3.70
30	3.78	242	3.79	3.80
31	3.87	248½	3.89	3.90
32	3.98	255	4.00	4.00
33	4.09	261½	4.10	4.10
34	4.21	268	4.20	4.20
35	4.31	274½	4.30	4.30
36	4.42	281	4.40	4.40
37	4.49	287.5	4.50	4.50
38	4.56	294	4.61	4.60
39	4.69	300.5	4.71	4.70
40	4.80	307	4.81	4.80
41	4.94	313.5	4.91	4.90
42	5.03	320	5.01	5.00
43	5.12	326.5	5.12	5.10
44	5.22	333	5.22	5.20

Table 3

The average differences give a good estimate of the discrepancy between the gauge and the formulae and between the two formulae. These are very small and either formula is a very good fit to the gauge, although the metric formula looks “nicer”.

Graph 4, which includes the full range of sizes from “9/0” to “57”, clearly shows that both formulae fit the gauge very well. However, the graph is too small and interesting detail is hidden. Graph 5 shows a small part of Graph 4 expanded to reveal the variations between my gauge and the formulae.

And so we have no obvious reason to choose between the metric and imperial formulae for the Montandon mainspring heights. Either can be used and the gauge constructed with simple measuring tools.

So is the Montandon gauge metric or imperial?

Figure 8 shows a “Montandon Fusee” gauge (reproduced from the Henri Picard & Frère catalogue circa 1885). This looks like my gauge, having similar scales for the mainspring heights and, as we will see, for the barrel sinks. So it may be the same as the gauge described above, but I have no concrete information about it.

However, except for a few special watches the Swiss rarely used fusees after about the middle of the nineteenth century. So it is very likely that this gauge was first made about the time Dennison devised his gauge, or earlier. In which case it is almost certain that it would use a French imperial scale.

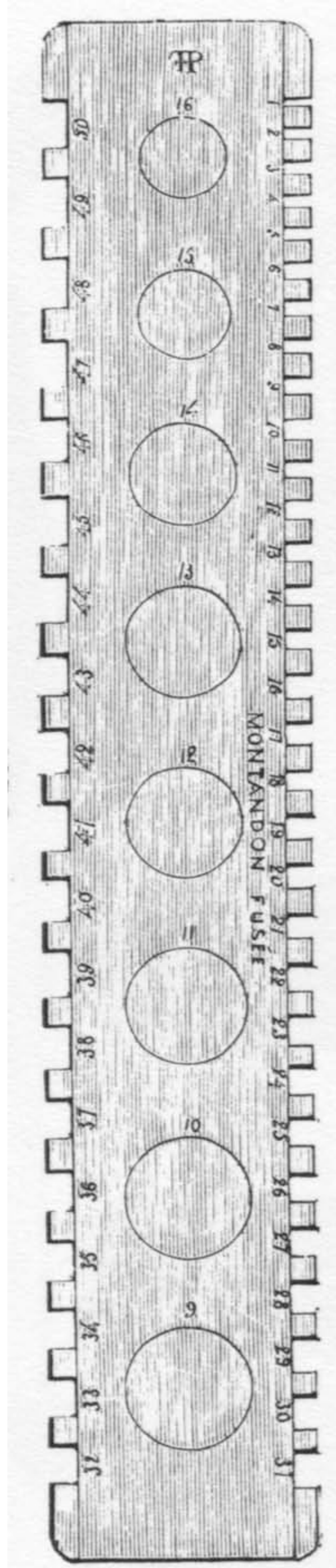


Figure 8

Martin Mainspring Heights

Table 4 gives both the Lever and Geneva's scales from my two Martin gauges, together with de Carle's values for the Geneva's scale.

It is very difficult to measure the width of the notches accurately, in part because it seems they are not exact rectangles, and the table gives my best estimates rounded to the nearest 0.05 mm.

These two gauges provide a cautionary tale. Both have notches which are obviously incorrectly cut and many notches show discrepancies. So it is doubtful if they could be relied upon to any better than 0.1 mm. It is apparent that the gauges were carelessly made and this must cast doubt on all mainspring gauges; at best they will give a rough approximation.

Lever scale: The first gauge, which is also in Table 1, has a large gap between "10" and "11", and "11" to "13" are clumped together. Gauge 2 is much more uniform, but the notches for "21" and "22", and for "23" and "24", are the same size!

After allowing for these obvious errors, the Lever heights appear to be metric:

$$M = 0.1S + 1.3 \text{ mm}$$

fitting within about 0.05 mm throughout the scale.

But the values of a and b are very close to 6½/12 and 83/12 douzièmes:

$$M = (6\tfrac{1}{2}/12)S + 83/12 \text{ douzièmes}$$

and this imperial formula fits almost as well. As the gauges have major errors, there is no obvious reason to choose one formula over the other, although the metric formula is admittedly "nicer".

Graph 6 clearly shows the errors in my gauges, particularly that from size "22" my gauges are almost consistently under size.

Geneva's scale: The Geneva's heights are equally erratic. My gauges are different from each other and both are different from de Carle's scale in Table 1. Also, my second gauge has the notches for "6/0" and "5/0", for "3/0" and "2/0", and for "20" and "21", about the same size. Using the whole range we get for gauge 1:

$$M = 0.08235S + 1.24118 \text{ mm}$$

and for gauge 2:

$$M = 0.07647S + 1.23824 \text{ mm}$$

and for de Carle's data:

$$M = 0.08393S + 1.10179 \text{ mm}$$

Although

$$M = 0.08S + 1.24 \text{ mm}$$

is possible, I think a better option is:

$$M = (5/12)S + 78/12 \text{ douzièmes}$$

which gives as good a fit as the other formulae.

Graph 7 illustrates the fact that the two gauges and de Carle's values deviate considerably from the formula.

Because there is so much latitude in designing suitable formulae, it is easy to miss the obvious. In this case it is that the last formula is almost identical to the formula for the small sizes of the Montandon gauge, the only difference being that b is 78/12 instead of 80/12; but 2/12 douzièmes is only 0.031 mm.

Indeed, it is inevitable that we decide these two gauges are one and the same, especially as the scale values are identical.

Graph 14 compares the mainspring heights of the different gauges. In it, the horizontal scale values are meaningless; the metric sizes of the seven gauges have been aligned with each other and the individual scales have been ignored. The Montandon and Martin Geneva's heights are represented by a single line because they are, despite the 2/12 douzièmes difference, superimposed on each other. The Ferret and Lepine gauges are also identical, as we will see.

Martin Mainspring Heights						
Lever			Geneva's			
Scale	G 1 mm	G 2 mm	Scale	Carle mm	G 1 mm	G 2 mm
1	1.40	1.35	10/0		0.50	0.55
2	1.50	1.45	9/0		0.60	0.60
3	1.60	1.60	8/0		0.65	0.65
4	1.70	1.65	7/0		0.70	0.70
5	1.80	1.80	6/0		0.75	0.80
6	1.90	1.95	5/0		0.80	0.80
7	2.00	2.00	4/0	0.85	0.90	0.90
8	2.10	2.10	3/0	0.95	1.00	0.95
9	2.20	2.20	2/0	1.05	1.10	0.95
10	2.30	2.30	1/0	1.15	1.20	1.10
11	2.50	2.40	1	1.25	1.30	1.25
12	2.55	2.50	2	1.35	1.40	1.35
13	2.60	2.60	3	1.40	1.45	1.45
14	2.70	2.70	4	1.50	1.55	1.50
15	2.80	2.85	5	1.60	1.60	1.60
16	2.90	2.90	6	1.65	1.65	1.65
17	3.00	3.00	7	1.70	1.75	1.70
18	3.10	3.10	8	1.80	1.80	1.80
19	3.20	3.20	9	1.90	1.90	1.85
20	3.30	3.30	10	1.95	1.95	1.95
21	3.40	3.45	11	2.05	2.05	2.00
22	3.50	3.45	12	2.15	2.15	2.05
23	3.60	3.60	13	2.20	2.25	2.20
24	3.70	3.60	14	2.30	2.35	2.30
25	3.75	3.75	15	2.40	2.45	2.40
26	3.85	3.80	16	2.50	2.50	2.45
27	3.95	3.95	17	2.55	2.60	2.50
28	4.05	4.05	18	2.60	2.70	2.60
29	4.20	4.20	19	2.70	2.75	2.70
30	4.25	4.30	20	2.80	2.80	2.80
31	4.45	4.40	21	2.90	2.90	2.80
32	4.50	4.45	22	2.95	3.00	2.90
33	4.60	4.60	23	3.00	3.10	3.00
34	4.70	4.70	24	3.10	3.15	3.10
35	4.80	4.75	25	3.20	3.30	3.15

Table 4

Robert Mainspring Heights

The only information I have found regarding the Robert gauge is in the tables provided by Jendritzki and Schulte, see Table 5.

It is easy to work out a formula:

$$M = 0.05889S + 0.77667 \text{ mm}$$

and from this it is reasonable to choose:

$$M = 0.06S + 0.75 \text{ mm}$$

which fits quite well.

In contrast, there is no obvious imperial formula. The best is:

$$M = (3\tfrac{3}{4}/12)S + 48/12 \text{ douzièmes}$$

Although b = 4 douzièmes is fine, a = 3¾/12 douzièmes seems unlikely.

The formula and how well it fits the Robert gauge, Graph 8, supports the view that it should be considered a metric gauge.

But there is a serious problem. What if Jendritzki's and Schulte's figures are the result of rounding imperial values to suitable metric counterparts? If they have done this, then it is quite possible that the Robert heights are actually French imperial. It is impossible to decide without measuring one or more real gauges.

Robert Mainspring Heights		
Scale	**Jendritzki**	**Schulte**
3/0	0.60	0.65
2/0	0.65	0.70
1/0	0.70	
0	0.75	0.75
1	0.80	0.80
2	0.85	0.85
3	0.90	0.90
4	0.95	1.00
5	1.00	1.05
6	1.05	1.10
7	1.10	1.15
8	1.15	1.20
9	1.25	1.30
10	1.30	1.35
11	1.35	1.40
12	1.40	1.45
13	1.45	1.50
14	1.55	1.60
15	1.65	1.65
16	1.70	1.70
17	1.75	1.75
18	1.80	1.80
19	1.85	1.90
20	1.95	1.95
21	2.00	2.00
22	2.05	2.05
23	2.10	2.10
24	2.20	2.20
25	2.25	2.25
26	2.30	2.30
27	2.35	2.35
28	2.40	2.40
29	2.50	2.50
30	2.55	2.55
31	2.60	2.60
32	2.65	2.65
33	2.70	2.70
34	2.80	2.80
35	2.85	2.85
36	2.90	2.90
37	2.95	2.95
38	3.00	3.00
39	3.10	3.10
40	3.15	3.15
41	3.20	3.20
42	3.25	

Table 5

Lepine and Ferret Mainspring Heights

Initially, the only information about the Lepine gauge came from two published tables of heights. There was no information about barrel sinks, although it is reasonable to assume it would have them.

The Ferret gauge, Figure 9 **a**, is very interesting because it appeared to be closely related to the Lepine gauge. This was then confirmed by Figure 9 **b** which is from the Henri Picard & Frère catalogue circa 1885. The two gauges are identical, but the second one is marked “Montandon Lepine”.

Ferret’s signature, Figure 10, is an “E” overlapping an “F”. It appears on another gauge owned by Don Ross together with the text “A$^{\underline{NE}}$ M$^{\underline{ON}}$ GUERRE FERRET SUCC$^{\underline{R}}$”, but I have not been able to find out anything about either Guerre or his successor Ferret. (The word *echelle* on this gauge is the French word for *scale*.) However we can conclude that Ferret, like Picard, was a tool maker and not a mainspring manufacturer.

Ferret’s gauge has a set of notches on the left side which I first thought were completely different; the scale appears to be reversed with size “0” being the largest notch and scale “14” the smallest. Also, there is no scale “1” notch! However, the Montandon gauge in Figure 9 **b** shows that these sizes are actually “0” (“1/0”) to “14/0” and part of the main set of notches on the other side of the gauge.

Looking at just the Lepine heights given in the books, Table 6 and Graph 9, the *Jewelers’ Circular* table for the Lepine gauge has great irregularity, the increment between two numbers varying from 0.05 to 0.20 mm. However Schulte’s table is much more regular and produces a very nice formula:

$$M = (6/12)S + 96/12 \text{ douzièmes}$$

or

$$M = (1/2)S + 8 \text{ douzièmes}$$

The corresponding metric formula is:

$$M = 0.094S + 1.496 \text{ mm}$$

and so, as far as I can tell, there is nothing to suggest this scale is metric.

Although we can be confident that $a = 6/12$ douzième, the value of b is less certain because both tables are the result of forcing the gauge into a metric table.

Don Ross’s measurements of Ferret’s mainspring heights from “1” to “25”, Table 6, also fit

$$M = (6/12)S + 96/12 \text{ douzièmes}$$

and this is shown on Graph 10. That is, Ferret’s gauge almost exactly fits the Lepine size “1”, “2” ... “16” and beyond. Given the doubt associated with the Lepine tables and the measurement of the Ferret gauge, we can be confident that both use the same scale for heights.

But adding the small sizes from “14/0” to “2/0” creates a problem, because attempting to fit a single line to the values is not satisfactory. However, as with the Montandon heights, two good formulae fit quite well:

$$M = 3/12S + 66 \text{ douzièmes}, S = 14/0 \text{ to } 9/0$$
$$M = 6/12S + 96 \text{ douzièmes}, S = 8/0 \text{ to } 25$$

Lepine Heights			**Ferret Heights**	
Scale	**JC**	**Schulte**	**Scale**	**Gauge**
			14/0	0.42
			13/0	0.44
			12/0	0.49
			11/0	0.55
10/0	0.65	0.65	10/0	0.58
9/0	0.70	0.70	9/0	0.65
8/0	0.75	0.85	8/0	0.79
7/0	0.95	0.90	7/0	0.87
6/0	1.05	1.05	6/0	0.99
5/0	1.15	1.10	5/0	1.07
4/0	1.25	1.20	4/0	1.19
3/0	1.35	1.35	3/0	1.33
2/0	1.45	1.45	2/0	1.40
0	1.55	1.50	0	1.49
1	1.75	1.65	1	1.61
2	1.80	1.70	2	1.72
3	1.90	1.80	3	1.81
4	1.95	1.90	4	1.95
5	2.00	1.95	5	2.00
6	2.05	2.05	6	2.12
7	2.10	2.10	7	2.19
8	2.20	2.25	8	2.28
9	2.30	2.30	9	2.43
10	2.40	2.40	10	2.50
11	2.50	2.50	11	2.55
12	2.65	2.60	12	2.68
13	2.80	2.70	13	2.75
14	2.85	2.80	14	2.87
15	2.95	2.90	15	2.96
16	3.00	2.95	16	3.02
			17	3.15
			18	3.26
			19	3.36
			20	3.47
			21	3.55
			22	3.58
			23	3.68
			24	3.80
			25	3.94

Table 6

However, as is obvious in Graph 11, there is an unacceptable discontinuity between sizes “8” and “9”.

Much to my surprise I found that 3 formulae, as shown in Graph 12, are even better! They are:

$$M = 3/12S + 66 \text{ douzièmes}, S = 14/0 \text{ to } 9/0$$
$$M = 7/12S + 96 \text{ douzièmes}, S = 8/0 \text{ to } 4$$

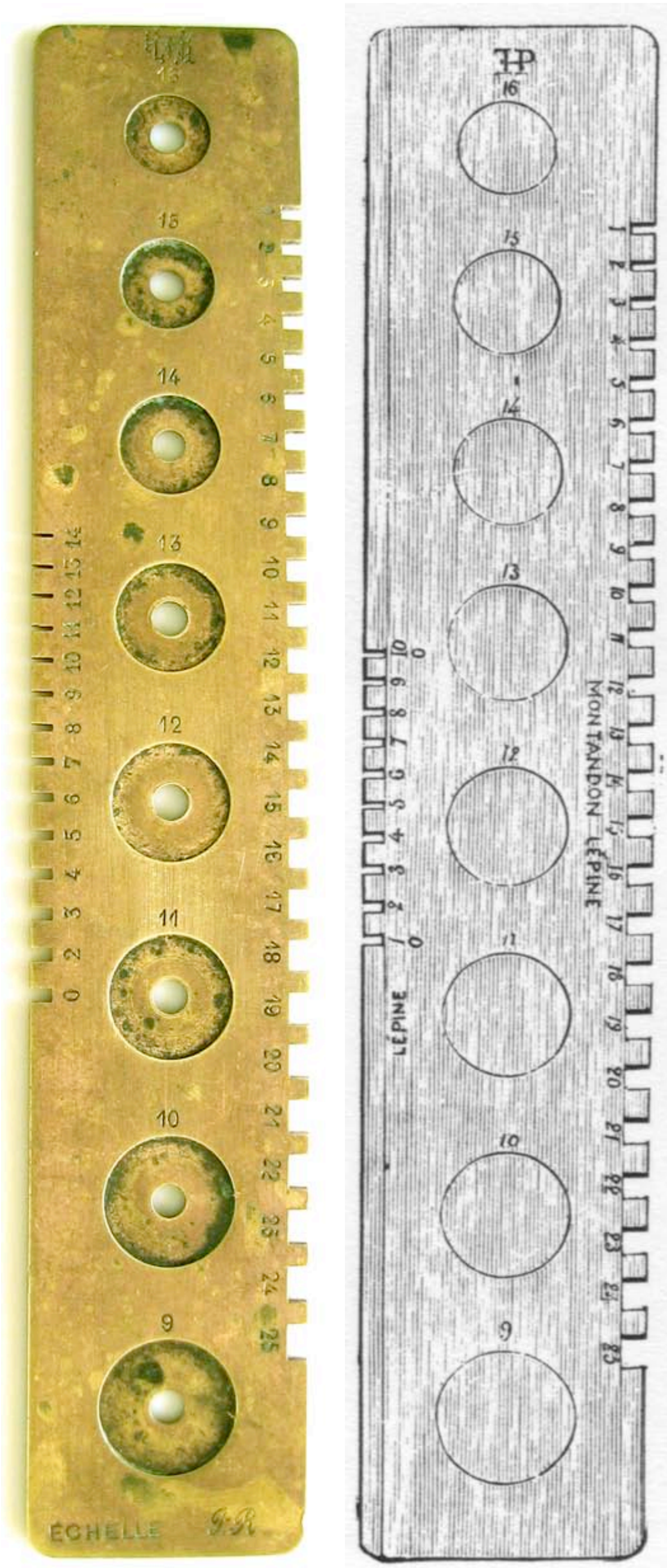
and

$$M = 6/12S + 98 \text{ douzièmes}, S = 5 \text{ to } 25$$

These formulae fit Don Ross’s data to within 0.05 mm throughout the entire scale with an average difference of only 0.02 mm. And no, I did not fiddle it!

So the Lepine gauge is definitely French imperial but, if the Ferret gauge is accurate, it is much more complex than I would have expected.

Figure 10



a **b**

Figure 9

Prenot Mainspring Heights

The gauge signed C Prenot, Figure 11 and Table 7, only has notches on each side, numbered “000” to “40”. The lack of barrel sinks or any other identifying features means it might not be a mainspring gauge. However, the notch sizes and their numbering strongly suggest that was its purpose.

Prenot Mainspring Heights		
Scale	Gauge	Formula
3/0	0.86	0.91
2/0	1.05	1.02
0	1.15	1.13
1	1.23	1.24
2	1.35	1.35
3	1.46	1.46
4	1.59	1.57
5	1.70	1.68
6	1.83	1.79
7	1.98	1.90
8	2.05	2.01
9	2.16	2.12
10	2.24	2.22
11	2.40	2.33
12	2.57	2.44
13	2.62	2.55
14	2.65	2.66
15	2.82	2.77
16	2.96	2.88
17	3.02	2.99
18	3.08	3.10
19	3.17	3.21
20	3.32	3.32
21	3.37	3.42
22	3.51	3.51
23	3.59	3.60
24	3.73	3.70
25	3.83	3.79
26	3.87	3.89
27	3.97	3.98
28	4.12	4.07
29	4.24	4.17
30	4.30	4.26
31	4.44	4.36
32	4.48	4.45
33	4.55	4.54
34	4.64	4.64
35	4.72	4.73
36	4.84	4.83
37	4.92	4.92
38	5.04	5.01
39	5.11	5.11
40	5.24	5.20

Table 7

Although not obvious from Graph 13, this gauge, like the Montandon gauge, uses different increments above and below size “20”:

$$M = 0.1103S + 1.0389 \text{ mm}$$
$$M = 0.0951S + 1.3281 \text{ mm}$$

or

$$M = 7/12S + 72 \text{ douzièmes}$$
$$M = 6/12S + 92 \text{ douzièmes}$$

The maximum difference between the gauge and the formulae is 0.13 at size “12”. But, as can be seen from Graph 12, this is due to the gauge being made incorrectly.

It is clear that the gauge is French imperial.

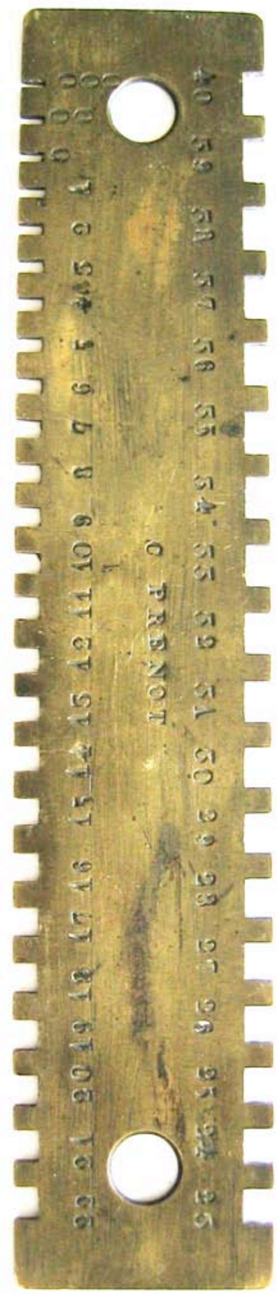


Figure 11

Comparison of Heights

Table 8 and Graph 14 compare the mainspring heights of the different gauges.

To construct this comparison I have arbitrarily chosen the notch width 2.00 mm. That is, I have aligned the heights for each gauge so that the closest sizes to 2.00 mm are in the same row of the table. With the exception of the two known equivalents, Montondon/Martin Geneva and Lepine/Ferret, it is clear that the other scales are different from each other. Thus there are five different gauge types.

Comparison of the Equivalent Scales of Gauges				
Montandon & Martin Geneva	**Martin Lever**	**Robert**	**Lepine & Ferret**	**Prenot**
		3/0		
		2/0		
		1/0		
		0		
		1		
10/0		2		
9/0		3	14/0	
8/0		4	13/0	
7/0		5	12/0	
6/0		6	11/0	
5/0		7	10/0	
4/0		8	9/0	
3/0		9	8/0	
2/0		10	7/0	
1/0		11	6/0	3/0
1		12	5/0	2/0
2		13	4/0	0
3		14	3/0	1
4	1	15	2/0	2
5	2	16	0	3
6	3	17	1	4
7	4	18	2	5
8	5	19	3	6
9	6	20	4	7
10	7	21	5	8
11	8	22	6	9
12	9	23	7	10
13	10	24	8	11
14	11	25	9	12
15	12	26	10	13
16	13	27	11	14
17	14	28	12	15
18	15	29	13	16
19	16	30	14	17
20	17	31	15	18
21	18	32	16	19
22	19	33	17	20
23	20	34	18	21
24	21	35	19	22
25	22	36	20	23
26	23	37	21	24
27	24	38	22	25
28	25	39	23	26
29	26	40	24	27

Table 8

Barrel Diameters

As I have noted, the European gauges determined mainspring thickness from barrel diameters.

However, when the watch repairer used one of these gauges, all that he learned was the scale number for the barrel. To use a scale number he either had to rely on the mainspring manufacturer or use a table to convert it to the thickness. However, I have not seen such a table for any of the gauges.

The only tables I know of were published by Jendritzki and in the *Jewelers' Circular*, and both convert barrel diameters in millimetres to mainspring thicknesses in ⅟₁₀₀ mm. Jendritzki writes:

> *"It is preferable to have a long, weak spring. However, if the watch is so constructed that friction in the gearing and the escapement absorbs a considerable amount of power, a compromise will have to be struck, and a thicker spring chosen."*

Table 9 is from Jendritzki and, other than a few obvious errors, the *Jewelers' Circular* table is the same as the column for weak mainsprings.

In principle this method is fundamentally flawed. The strength of a mainspring depends on the *inside* diameter of the barrel, but barrel sinks measure the *outside* diameter. Thus they are oversize by twice the thickness of the wall of the barrel, which can vary arbitrarily. Clearly the method of determining the mainsprings thickness should take this into account.

Assuming the diameter of the barrel arbor is ⅓ the diameter of the barrel, the formula for the maximum number of turns of a mainspring in a barrel (see for example Reymondin et al *The Theory of Horology*) reduces to:

$$N_{max} = 0.157379R/s$$

where R is the inside radius of the barrel and s is the mainspring strength.

Jendritzki's table generates springs with about 6 turns, although the small barrels with weak springs generate 7 to 8 turns. This fits with the use of stop-work where the first turn is used to set up the spring and the last turn is not used. Of course the barrel diameters are useless for watches that require a different number of turns.

Column 2 of Table 10 shows the number of turns for normal thickness springs. If the barrel diameters are reduced by 1 mm (for a wall thickness of 0.5 mm), as in Column 3 of Table 10, the number of turns is reduced a little, but not enough to seriously affect the validity of the table. So using the outside diameter is acceptable.

As these are go-nogo gauges and actual size of a sink doesn't matter much; in fact, the actual sizes of the sinks in my gauges are not nice, regular numbers of millimetres, but pretty arbitrary values. What is important is that a barrel will fit in the right sink.

The following sections examine the barrel sinks of the Montandon, Martin, Robert and Ferret gauges.

The Lepine gauge is not considered because the

Barrel Diameter mm	**Thickness ⅟₁₀₀ mm**		
	weak	**normal**	**strong**
5.25	5	6	7
6.00	6	7	8
6.75	7	8	9
7.50	8	9	10
8.25	9	10	11
9.00	10	11	12
9.75	11	12	13
10.50	12	13	14
11.25	13	14	15
12.00	14	15	16
12.75	15	16	17
13.50	16	17	18
14.25	17	18	19
15.00	18	19	20
15.75	19	20	21
16.50	20	21	22
17.25	21	22	23
18.00	22	23	24
18.75	23	24	25
19.50	24	25	26
20.25	25	26	27
21.00	26	27	28
21.75	27	28	29

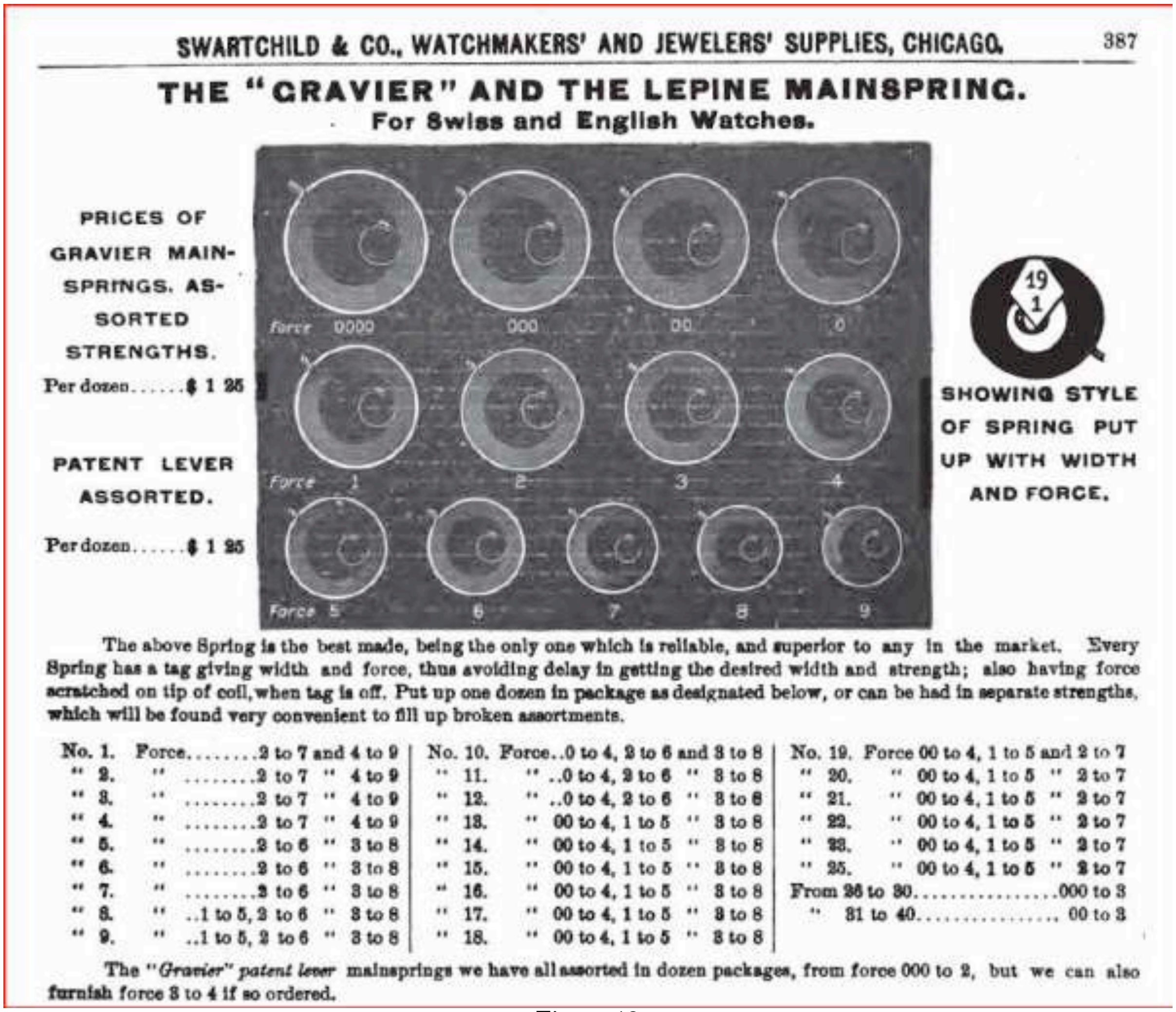
Table 9

Barrel Diameter mm	**Turns outside diameter**	**Turns inside diameter**
5.25	6.89	5.57
6	6.74	5.62
6.75	6.64	5.66
7.5	6.56	5.68
8.25	6.49	5.70
9	6.44	5.72
9.75	6.39	5.74
10.5	6.36	5.75
11.25	6.32	5.76
12	6.30	5.77
12.75	6.27	5.78
13.5	6.25	5.79
14.25	6.23	5.79
15	6.21	5.80
15.75	6.20	5.80
16.5	6.18	5.81
17.25	6.17	5.81
18	6.16	5.82
18.75	6.15	5.82
19.5	6.14	5.82
20.25	6.13	5.83
21	6.12	5.83
21.75	6.11	5.83

Table 10

only information I have on its barrel diameters is from an advertisement in the 1932 Swartchild catalogue, Figure 12. This gauge has at least barrel sizes “4/0” to “9”, but their diameters are not known. However, the table indicates that the Lepine heights had sizes “1” to “40”, whereas the other tables describe 26 sizes from “10/0” to “16”. I do not know which is right.

The advertisement is also interesting because the barrel sink sizes are called *forces*, directly relating them to mainspring strengths.



SWARTCHILD & CO., WATCHMAKERS' AND JEWELERS' SUPPLIES, CHICAGO. 387

THE "GRAVIER" AND THE LEPINE MAINSPRING.

For Swiss and English Watches.

PRICES OF GRAVIER MAIN-SPRINGS, AS-SORTED STRENGTHS.

Per dozen......$ 1 25

PATENT LEVER ASSORTED.

Per dozen......$ 1 25

SHOWING STYLE OF SPRING PUT UP WITH WIDTH AND FORCE.

The above Spring is the best made, being the only one which is reliable, and superior to any in the market. Every Spring has a tag giving width and force, thus avoiding delay in getting the desired width and strength; also having force scratched on tip of coil, when tag is off. Put up one dozen in package as designated below, or can be had in separate strengths, which will be found very convenient to fill up broken assortments.

No. 1.	Force........2 to 7 and 4 to 9	No. 10.	Force..0 to 4, 2 to 6 and 3 to 8	No. 19.	Force 00 to 4, 1 to 5 and 2 to 7
" 2.	" ....2 to 7 " 4 to 9	" 11.	" ..0 to 4, 2 to 6 " 3 to 8	" 20.	" 00 to 4, 1 to 5 " 2 to 7
" 3.	" ....2 to 7 " 4 to 9	" 12.	" ..0 to 4, 2 to 6 " 3 to 8	" 21.	" 00 to 4, 1 to 5 " 2 to 7
" 4.	" ....2 to 7 " 4 to 9	" 13.	" 00 to 4, 1 to 5 " 3 to 8	" 22.	" 00 to 4, 1 to 5 " 2 to 7
" 5.	" ....2 to 6 " 3 to 8	" 14.	" 00 to 4, 1 to 5 " 3 to 8	" 23.	" 00 to 4, 1 to 5 " 2 to 7
" 6.	" ....2 to 6 " 3 to 8	" 15.	" 00 to 4, 1 to 5 " 3 to 8	" 25.	" 00 to 4, 1 to 5 " 2 to 7
" 7.	" ....2 to 6 " 3 to 8	" 16.	" 00 to 4, 1 to 5 " 3 to 8	From 26 to 30	..............000 to 3
" 8.	" ..1 to 5, 2 to 6 " 3 to 8	" 17.	" 00 to 4, 1 to 5 " 3 to 8	" 31 to 40	.... 00 to 3
" 9.	" ..1 to 5, 2 to 6 " 3 to 8	" 18.	" 00 to 4, 1 to 5 " 3 to 8		

The "*Gravier*" *patent lever* mainsprings we have all assorted in dozen packages, from force 000 to 2, but we can also furnish force 3 to 4 if so ordered.

Figure 12

Montandon Barrel Diameters

Table 11 gives the barrel diameters for Montandon gauges. It has the scale from Jendritzki to which I have added my gauge, Stephen Katchur's gauge and the sizes according to Buffat's formula.

Buffat does not specify any actual sizes, only giving the increments. I have assumed that "4/0" is 23.00 mm and calculated the rest, extending them to "25". However, it is clear that Buffat's formula is completely wrong and I will ignore his sizes.

More importantly, Jendritzki omits the scale numbers "8", "11", "20", and "23", but we know, from actual gauges, that at least sizes "8" and "11" exist. So we can be sure that Jendritzki has rounded the values to fit into his neat table (using an increment of 0.75 mm) and, in doing so, has been forced to omit these four scale numbers. Graph 15 shows that Jendritzki's values are definitely peculiar and cannot be used. In contrast, the values from the two actual gauges are consistent.

Although not obvious from Graph 15, my gauge suggests that, like Montandon's heights, the barrel diameters require two formulae with the change occurring at size "9". This becomes clear in Graph 16 where the two least-squares lines are shown. The formulae for sizes "4/0" to "9" and "9" to "18" are:

$M = -0.7127S+20.7432,\ S = 4/0 \text{ to } 9 \text{ mm}$

$M = -0.5758S+19.3568,\ S = 9 \text{ to } 18 \text{ mm}$

The minus sign with a is because the scale numbers are reversed, running from the largest to the smallest barrel diameter; and this applies to all the barrel scales. However it is the magnitude of a which is important.

The first formula might just be metric, but the second most certainly is not. However, both have very good French imperial equivalents:

$M = -48/12S +1324/12$ *douzième*, $S = 4/0$ to 9

$M = -36/12S+1224/12$ *douzième*, $S = 9$ to 18

These look better when simplified to:

$M = -4S +110\frac{4}{12}$ *douzième*, $S = 4/0$ to 9

$M = -3S+102$ *douzième*, $S = 9$ to 18

Graph 17 shows these formulae compared with my gauge. I have also included Jendritzki's values because it is now clear that most of the values in his table are correct, the errors occurring between sizes "9" and "16".

The barrel diameters resolve the question I posed earlier: Is the Montandon gauge metric or imperial? Unless there is a very good reason to think otherwise, I believe the gauges were consistent and that they should be either imperial or metric, but not both. If this is the case, then the Montandon gauge is definitely French imperial.

Montandon Barrel Diameters				
Scale	**Jendritzki**	**My gauge**	**Katchur**	**Buffat**
4/0	23.25	23.00		23.00
3/0	22.50	22.00		22.00
2/0	21.75	21.08		21.00
0	21.00	20.57		20.00
1	20.25	20.07	20.33	19.50
2	19.50	19.51	19.21	19.00
3	18.75	19.00	18.76	18.50
4	18.00	18.03	18.10	18.00
5	17.25	17.50	17.35	17.50
6	16.50	16.52	16.72	17.00
7	15.75	15.54	16.01	16.50
8		15.03	15.24	16.00
9	15.00	14.01	14.58	15.50
10	14.25	13.52	13.79	15.00
11		13.00	13.38	14.50
12	13.50	12.51	12.66	14.00
13	12.75	12.00	11.68	13.50
14	12.00	11.50	11.18	13.00
15	11.25	10.54	10.29	12.50
16	10.50	10.00	9.73	12.00
17	9.75	9.50		11.50
18	9.00	8.96		11.00
19	8.25			10.50
20				10.00
21	7.50			9.50
22	6.75			9.00
23				8.50
24	6.00			8.00
25	5.25			7.50

Table 11

Martin and Ferret Barrel Diameters

Table 12 gives the barrel diameters for my two Martin gauges and Don Ross's Ferret gauge.

There are some discrepancies between the Martin gauges, including the size "15" barrel on the second gauge being almost the same diameter as the size "14" barrel! But most importantly, the values for "15" and "16" are too high on both gauges; Graph 18 shows the average of the two gauges, but that has no effect on the discrepancy.

If I am right about the Martin Lever scale being metric and the Geneva's scale being French imperial, the Martin barrel diameters could be either.

One possibility is:

M = (-46/12)S + 1344/12 douzièmes

This formula is almost identical to

M = -0.7S + 21 mm

which is perhaps more satisfactory.

So it is tempting to conclude that, except for the Geneva's heights which are probably imperial, Martin's gauge is metric.

However, the Ferret gauge changes this. It not only fits the same formula, but fits it better as seen in Graph 18. But the Ferret heights are most likely to be French imperial and the choice of

M = (-46/12)S + 1344/12 douzièmes

is inevitable.

It would be silly to assign a French imperial formula and a metric formula to the same scale simultaneously. And so we must decide that only the Lever heights on the Martin gauge are metric, and the Geneva's heights and the barrel diameters are imperial.

Martin and Ferret Barrel Diameters			
scale	**Martin 1**	**Martin 2**	**Ferret**
1	20.28	20.74	20.15
2	19.83	19.97	19.58
3	18.95	18.78	18.89
4	18.08	18.20	18.34
5	17.34	17.59	17.48
6	16.73	16.58	16.71
7	15.98	16.08	15.91
8	15.34	15.68	15.43
9	14.48	14.48	14.69
10	13.84	13.98	13.94
11	12.98	13.23	13.15
12	12.63	12.62	12.67
13	11.73	12.02	11.74
14	10.98	10.78	10.92
15	10.64	10.58	10.27
16	10.02	10.14	9.54

Table 12

Robert Barrel Diameters

The barrel diameter scale in the *Jewelers' Circular* article is the Robert scale and is identical to Jendritzki's table. I mention this because the scales in different books are sometimes different.

The Robert scale given by Jendritzki, Table 13, is clearly and precisely metric:

$$M = -0.75\ S + 21\ mm$$

However, there is an imperial formula:

$$M = -4S+112\ \textit{douzième}$$

which is as good. Graph 19 shows that the two formulae cannot be distinguished.

Although there must be some doubt, it appears the barrel diameters confirm the Robert scale to be metric. But I am assuming that Jendritzki's figures are not the result of rounding imperial values to their nearest metric counterpart. If he has done this, then it is quite possible that the Robert gauge is actually French imperial. It is impossible to decide without measuring one or more real gauges.

Robert Barrel Diameters	
Scale	**Jendritzki**
2/0	21.75
0	21.00
1	20.25
2	19.50
3	18.75
4	18.00
5	17.25
6	16.50
7	15.75
8	15.00
9	14.25
10	13.50
11	12.75
12	12.00
13	11.25
14	10.50
15	9.75
16	9.00
17	8.25
18	7.50
19	6.75
20	6.00
21	5.25

Table 13

Comparison of Barrel Diameters

Because the four gauges with barrel sinks have almost identical scales, it is possible to compare them directly, and Graph 20 shows that up to size “12” they are very similar, after which the Montandon scale deviates from the other two.

The only significance of barrel diameters is as a means of determining mainspring strengths. Using the formula given earlier, the strength of a mainspring is:

$s = 0.157379R/N$

If we assume $N = 6$ turns, then

$s = 0.157379R/6$

Table 14 and Graph 21 show these nominal strengths.

Rounding the strengths to the nearest 0.01 mm results in the Martin, Ferret and Robert gauges producing identical strengths. And the Montandon gauge now produced the same strengths for sizes “9” and “10”, “12” and “13”, “16” and “17”, “20” and “21”, and “24” and “25”; that is, the difference in barrel diameters is too small.

But this is misleading.

First, if we graph the strengths to the nearest ½ size (0.005 mm), as shown in Graph 22, we get a different picture. Now the Montandon scale makes sense.

Second, we are probably using the wrong dimensions. As three, possibly all four, of the gauges are French imperial, we should be using *douzièmes* not millimetres.

Graph 23 shows the Montandon strengths in ¹⁄₁₂ douzièmes. The barrel sizes in douzièmes were calculated from the formulae, and then the above formula was used to calculate the corresponding mainspring strengths in ¹⁄₁₂ douzièmes. These were then rounded to the nearest ½/12 douzième. The result is quite different from the metric calculation in Graphs 21 and 22!

The reason for the difference is simple. In Graphs 21 and 22 I have rounded the strengths to the nearest 0.01 or 0.005 mm. But in Graph 23 the sizes have been rounded to the nearest ½/12 douzième which is about 0.007833 mm. It is the effects of rounding that have caused the problems with the published tables, and it is clear that careless rounding can produce incorrect results.

In fact, the similarity between the gauges is a necessity. In order to produce sensible mainspring strengths, which must be based on the above formula, the barrel diameters of the different gauges must be almost the same. The only scope for variation is the choice of sizes, but it seems all makers have decided to use the same values for them.

Nominal Mainspring Strengths			
Scale	**Montandon**	**Martin/Ferret**	**Robert**
4/0	0.30		
3/0	0.29		
2/0	0.28		0.29
0	0.27		0.28
1	0.26	0.27	0.27
2	0.25	0.26	0.26
3	0.24	0.25	0.25
4	0.23	0.24	0.24
5	0.22	0.23	0.23
6	0.21	0.22	0.22
7	0.20	0.21	0.21
8	0.19	0.20	0.20
9	0.18	0.19	0.19
10	0.18	0.18	0.18
11	0.17	0.17	0.17
12	0.16	0.16	0.16
13	0.16	0.15	0.15
14	0.15	0.14	0.14
15	0.14	0.13	0.13
16	0.13	0.12	0.12
17	0.13		0.11
18	0.12		0.10
19	0.11		0.09
20	0.10		0.08
21	0.10		0.07
22	0.09		
23	0.08		
24	0.07		
25	0.07		

Table 14

The Dennison Gauges

The history of Dennison's gauges is obscure. The only information we have is Dennison's own statement that he developed a combined gauge about 1840. Since then both the combined gauge and the simpler mainspring gauge have been produced contemporaneously and in a number of different forms.

Assuming the combined gauge came first and the mainspring gauge was a later development, we can recognise at least five versions, as shown in Figure 13:

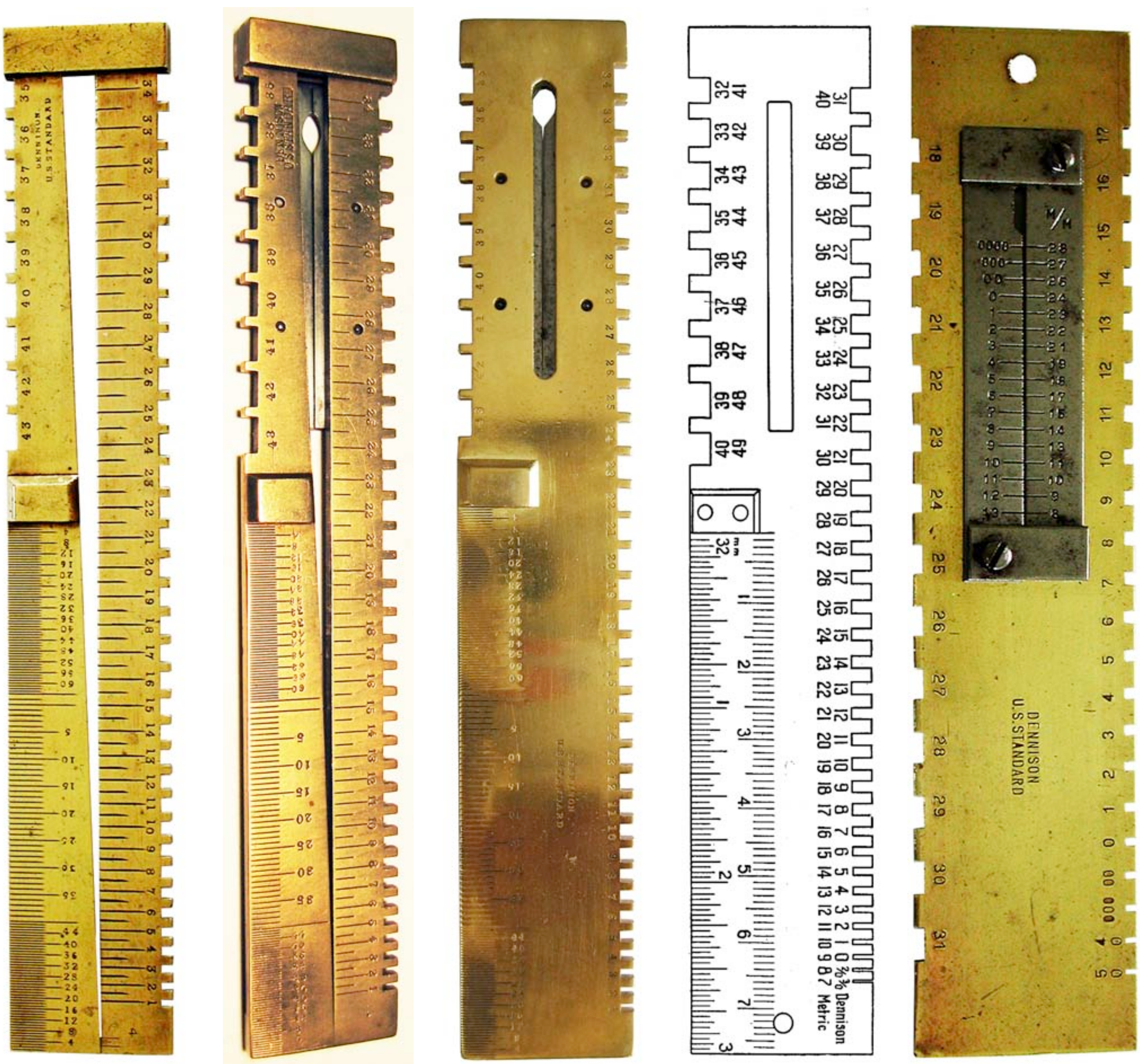
(a) The original form. There are three measuring scales, mainspring height notches and a brass slit running the full length of the gauge. The body is made up of two pieces of brass joined together by brass blocks at both ends. There is no mainspring strength gauge.

(b) This is the same gauge with a mainspring strength slit gauge attached to the bottom (so that it does not obstruct the numbers on the face). It is now difficult to use the widest part of the brass slit gauge.

(c) The brass slit is omitted and the gauge is a single piece of brass. This gauge is illustrated in the Henri Picard & Frère catalogue circa 1885.

(d) The three scales on the original gauge are replaced by a single 3-inch rule with ⅓₂ inch and millimetre markings.

(e) The last remaining measuring scale is removed and the gauge is a simple mainspring gauge.



a b c d e

Figure 13

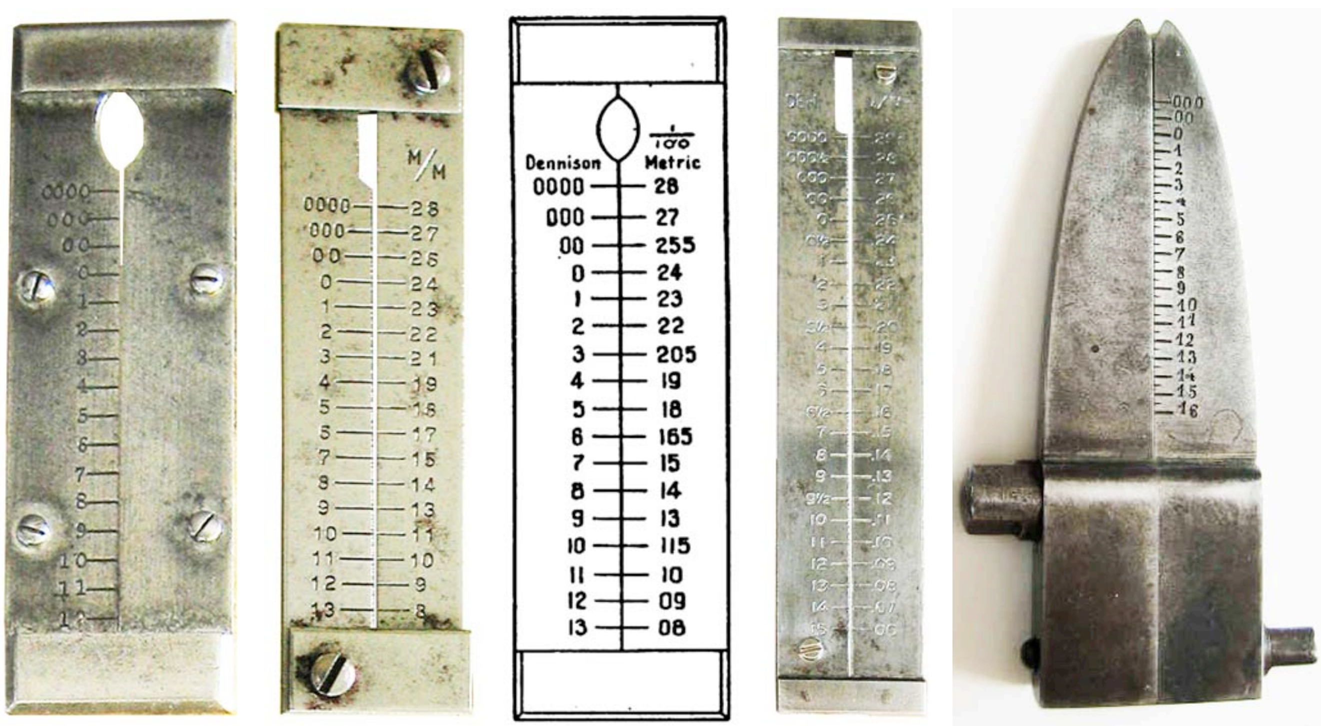
These gauges were not manufactured strictly sequentially, but overlapped each other. For example, both types **b** and **e** appear in the 1932 Swartchild catalogue (B177), but by the 1935 Swartchild catalogue (B-232) type **b** has been replaced by type **d**.

At the same time, the steel slit gauge for mainspring strengths also changed and there were at least four types, as in Figure 14.

(a) Only the Dennison numbers 12 to 4/0.
(b) The Dennison numbers with metric equivalents.
(c) The Dennison numbers with *different* metric equivalents.
(d) The Dennison numbers expanded to include *half* numbers "9½", "6½", "3½", "0½" and "00½", together with metric equivalents.

Figure 14 **e** is a large type **a** gauge, with the Dennison strength numbers from 000 to 16, which came from a supply house in Philadelphia. It would be more reliable than the normal gauges and was probably a standard gauge used to measure mainsprings for orders.

For the reasons given below, I am confident that type **a** was the original design, but it was still available (attached to a Dennison mainspring gauge) in the 1935 Swartchild catalogue. And that same catalogue also illustrates types **b** and **c**! Type **d** is described in the WDMAA catalogue. A very important point to note is that the metric equivalents on gauges **b** and **c** are different and, in fact, both are wrong.



a **b** **c** **d** **e**

Figure 14

Dennison Mainspring Heights

According to the *Official WMDAA Catalog of Genuine Watch Parts* the Dennison mainspring heights are metric, and my mainspring gauge, Figure 13 **e**, appears to confirm this, with the Dennison numbers on the front and metric values, 1/10th millimetre, on the back. So Dennison number S is

$$M = 0.1(S-1) + 1.0 \text{ mm}$$

or

$$M = 0.1S + 0.9 \text{ mm}$$

for every number, interpreting 2/0, 3/0 ... as -1, -2, etc. Note that there is no 1/0, it being the same as 0.

So it seems Dennison was right when he wrote in his biographical sketch:

> *"for this purpose I concluded that it would be best to adopt for a basis the French measure owing to its having a scientific basis, dividing the millimetre into 100ths".*

But is it metric?

Table 15 gives the mainspring heights measured from my combined and mainspring gauges, Figure 13 types **a** and **e**. First, these gauges, like their European counterparts, are badly made; in particular sizes "18" to "22" of the mainspring gauge are too wide, as are sizes "39" to "43" of the combined gauge. Second, *all* the notches are oversize except for size "7" of the mainspring gauge.

Using least-squares curve fitting, the best line for the mainspring gauge is:

$$M = 0.1012S + 0.9311 \text{ mm}$$

and for the combined gauge:

$$M = 0.1015S + 0.9201 \text{ mm}$$

The values of a are near enough to 0.1 mm, but the values of b are not near enough to 0.9 mm for a metric formula to be credible. Of course, it can be argued that these are go-nogo notches and being oversize is not important. However, too many notches are oversize by too much for this to be acceptable.

In contrast, 1/250 inch = 0.10160 mm which is very close to the nominal increment of 0.1 mm and even closer to the values of a above, differing by at most 0.0004 mm. Further 9/250 inch is 0.9144 mm which is much closer to the values of b than is 1.0 mm. So:

$$M = (1/250)S + 9/250 \text{ inch}$$

or

$$M = (1/250)(S - 1) + 1/25 \text{ inch}$$

is a better fit to the gauges than the metric formula given above, and it is most likely that Dennison's mainspring heights are imperial, based on the English inch.

Graph 24 shows these results, particularly that the metric formula is a poorer fit to the actual gauges.

Dennison Mainspring Heights				
Scale	**Mainspring gauge**	**Combined gauge**	**Metric formula**	**Imperial formula**
5/0	0.53		0.50	0.51
4/0	0.67		0.60	0.61
3/0	0.77		0.70	0.71
2/0	0.89		0.80	0.81
0	0.93		0.90	0.91
1	1.04	1.01	1.00	1.02
2	1.11	1.11	1.10	1.12
3	1.22	1.22	1.20	1.22
4	1.31	1.33	1.30	1.32
5	1.41	1.41	1.40	1.42
6	1.53	1.51	1.50	1.52
7	1.58	1.64	1.60	1.63
8	1.70	1.73	1.70	1.73
9	1.80	1.83	1.80	1.83
10	1.92	1.93	1.90	1.93
11	2.02	2.03	2.00	2.03
12	2.12	2.13	2.10	2.13
13	2.20	2.26	2.20	2.24
14	2.35	2.34	2.30	2.34
15	2.43	2.46	2.40	2.44
16	2.55	2.56	2.50	2.54
17	2.64	2.67	2.60	2.64
18	2.83	2.76	2.70	2.74
19	2.92	2.86	2.80	2.84
20	3.01	2.95	2.90	2.95
21	3.17	3.06	3.00	3.05
22	3.22	3.16	3.10	3.15
23	3.26	3.23	3.20	3.25
24	3.36	3.37	3.30	3.35
25	3.44	3.43	3.40	3.45
26	3.53	3.57	3.50	3.56
27	3.64	3.64	3.60	3.66
28	3.71	3.77	3.70	3.76
29	3.85	3.88	3.80	3.86
30	3.96	3.99	3.90	3.96
31	4.07	4.08	4.00	4.06
32		4.17	4.10	4.17
33		4.25	4.20	4.27
34		4.37	4.30	4.37
35		4.43	4.40	4.47
36		4.55	4.50	4.57
37		4.64	4.60	4.67
38		4.76	4.70	4.78
39		4.87	4.80	4.88
40		5.01	4.90	4.98
41		5.08	5.00	5.08
42		5.20	5.10	5.18
43		5.28	5.20	5.28

Table 15

Dennison Strength Gauges

Types a and b: Because slit gauges are simple linear magnifying gauges and types **a**, **b** and **c** in Figure 14 have the same Dennison scale, these three *must* be the same. The only way they could be different is if the widths of the slits were not the same; in which case each type would produce completely different measurements with the one mainspring. However, type **d**, which has a different scale including the "½" sizes, need not be the same.

The only strength gauge I have is attached to my mainspring gauge, Figure 13 **e** and Figure 14 **b**. When I unscrewed it to clean it, I found it was made of two separate parts, Figure 15. This can only be described as utterly stupid! It would be extremely difficult to reassemble it so that the slit was correct. I think I would have to get two bits of mainspring of different but known thicknesses and use them to hold the two halves in their correct positions while I screwed it back together. This would not be easy to do, especially as any error in the strengths of the springs would cause the gauge to be hopelessly inaccurate and, as I explained when discussing the Martin strength gauge, the one spring can register different sizes depending on how hard it is pressed into the slit. However, there is the small consolation this gauge can be taken apart and cleaned.

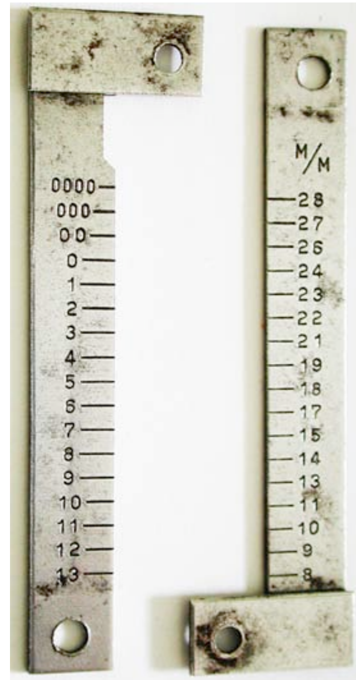


Figure 15

More important are the scales. The M/M scale looks metric but is most certainly is not! One fundamental point is that the scale on a slit gauge *must* be linear; that is, the slit widens by the same amount between any two adjacent marks on the scale. But the metric scale on Dennison's gauge is missing the values "12", "16", "20" and "25". Without them the scale *cannot* be metric and *must* be wrong!

This is shown in Figure 16. Assuming the "8" and "28" mm scale marks are correct, and they might not be, I have added the correct divisions for a metric scale of 1/100 mm. It is clear that only "8", "13, "18", "23" and "28" are close to their correct positions.

Figure 16

A consequence is that it is impossible to assemble the gauge accurately, because I do not know which scale marks are correct and so I do not know how thick the pieces of mainspring need to be to correctly assemble it!

Table 16 and Graph 25 describe this gauge. The least-squares best fit line for type **b** is:

$$M = -0.0127S + 0.2425 \text{ mm}$$

and the formula based on sizes "13" and "000" is:

$$M = -0.0125S + 0.2425 \text{ mm}$$

a trivial difference. So the gauge is obviously not metric, but it is definitely English Imperial:

$$M = (-1/2000)S + 19/2000 \text{ inch}$$

or

$$M = (-1/2000)(S - 1) + 1/100 \text{ inch}$$

What is clear is that the relationship between the Dennison divisions on my gauge and the metric system is very poor. They only agree for 5 divisions, and the other divisions are out by up to 8/10ths of a division! Indeed, it is a waste of time to try and fit this to a metric formula.

Type c: The type **c** gauge is an attempt to resolve these problems and make the gauge more like a metric gauge. Instead of having jumps of 0.02 mm, sizes "2/0", "3", "6" and "10" are reduced by 0.005 mm, which makes the gauge appear more regular. But because the Dennison sizes are the same as those in types **a** and **b**, the same formulae apply and the gauge is English imperial. As can be seen from Graph 25 it partly achieves the goal of evening out the metric equivalents, but it does nothing at all to resolve the fundamental problem: the metric scale is still non-linear and *cannot* be correct.

Table 16 includes the correct, *necessary* metric equivalents to Dennison's sizes and shows that the person who designed the type **c** gauge got it wrong; sizes "3/0", "2", "9" and "13" also should be decreased by 0.005 mm. But then the gauge would be so different from the original as to be ridiculous.

Dennison Strength Gauges Types a, b and c				
Scale	**Type b**	**Type c**	**1/2000 inch**	**Metric equivalent**
13	0.08	0.08	6	0.076
12	0.09	0.09	7	0.089
11	0.10	0.10	8	0.102
10	0.11	0.115	9	0.114
9	0.13	0.13	10	0.127
8	0.14	0.14	11	0.140
7	0.15	0.15	12	0.152
6	0.17	0.165	13	0.165
5	0.18	0.18	14	0.178
4	0.19	0.19	15	0.190
3	0.21	0.205	16	0.203
2	0.22	0.22	17	0.216
1	0.23	0.23	18	0.229
0	0.24	0.24	19	0.241
2/0	0.26	0.255	20	0.254
3/0	0.27	0.27	21	0.267
4/0	0.28	0.28	22	0.279

Table 16

Type d: The *Official WMDAA Catalog of Genuine Watch Parts* provides a table of the new Dennison strengths including the "½" sizes. The first point to note is that these "½" sizes only occur within the range of sizes "4/0" to "13" which are on the strength gauges in Figure 14. The WMDAA has extended the table at both ends, but there are no "½" sizes between "13" and "20", and between "4/0" and "15/0". That is, the scale is precisely metric, based on 0.01 mm, at both extremes.

However, the only way to make the range "4/0" to "13" metric is to *add* sizes to fill in the gaps. Which is what the WMDAA have done by creating "½" sizes, as in Figure 17 and Table 17.

In principle the gauge is now strictly metric:

$M = -0.01S + 0.25$ mm for $S = -15$ to 24

which looks good. But there is a problem.

Up until now I have created formulae of the form:

$M = aS + b$

without stressing one fundamental point. *The values of S are numbers. They are not sizes*. I have been able to gloss over this point because with *every* gauge we have examined until now there has been a simple linear relationship between the gauge sizes and the numbers S so that they have coincided. That is $S = 1$ corresponds to gauge size "1", $S = 2$ to size "2" and so on, interpreting sizes such as 3/0 as negative numbers. For this to be possible the gauge sizes must be complete with no missing and no extra "numbers".

The WMDAA scale fails this requirement. It requires three different formulae:

$M = -0.01(S+4) + 0.25$ mm for sizes = "10" to "20", S being equal to the size as a number

$M = -0.01S + 0.25$ mm for sizes = "4/0" to "15/0", S being equal to the size as a number

$M = -0.01S + 0.25$ mm for sizes = "000½" to "9½", where S must be read from Table 17.

The first two formulae are straightforward; they are simply different! But the last formula can only be used by looking up the value of S from a table; there is no linear relationship between the sizes and S. A linear relationship is only possible if there is a "½" size between *every* full size.

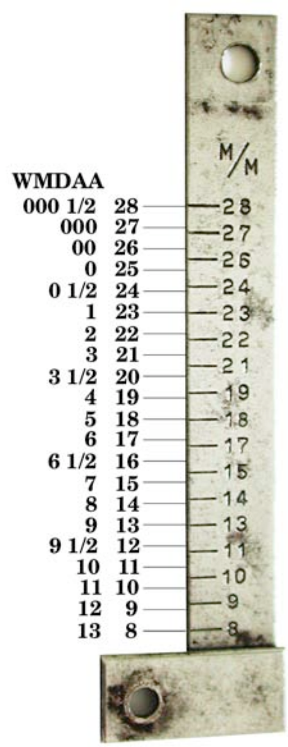


Figure 17

Even worse, if I order a size “0” or “4/0” mainspring I have to specify which strength gauge I am using! The original strengths were 0.24 and 0.28 mm, but the WMDAA has changed these to 0.25 and 0.29 mm.

The WMDAA gauge can only be described as a creation of desperation! Two previous attempts had been tried to convert Dennison’s English imperial gauge to a metric gauge and both, as we have seen, failed. This last attempt is probably worse. Graph 26, based on the third and fourth columns of Table 17 graphically illustrate this. If we try to apply the correct imperial formula to the scale sizes from “20” to “15/0” (type **a**) we find size “20” should be -0.013 mm! There are huge discrepancies at both ends of the range, and smaller but important differences elsewhere.

That is, the WMDAA strength gauge is *not* a Dennison gauge, but an entirely new gauge.

Type d (WMDAA) Strength Gauge			
Scale	**Scale number**	**Type d**	**Type a**
20	24	0.01	-0.013
19	23	0.02	0.000
18	22	0.03	0.013
17	21	0.04	0.025
16	20	0.05	0.038
15	19	0.06	0.051
14	18	0.07	0.063
13	17	0.08	0.076
12	16	0.09	0.089
11	15	0.10	0.102
10	14	0.11	0.114
9 1/2	13	0.12	
9	12	0.13	0.127
8	11	0.14	0.140
7	10	0.15	0.152
6 1/2	9	0.16	
6	8	0.17	0.165
5	7	0.18	0.178
4	6	0.19	0.190
3 1/2	5	0.20	
3	4	0.21	0.203
2	3	0.22	0.216
1	2	0.23	0.229
0 1/2	1	0.24	
0	0	0.25	0.241
00	-1	0.26	0.254
000	-2	0.27	0.267
000 1/2	-3	0.28	
0000	-4	0.29	0.279
5/0	-5	0.30	0.292
6/0	-6	0.31	0.305
7/0	-7	0.32	0.317
8/0	-8	0.33	0.330
9/0	-9	0.34	0.343
10/0	-10	0.35	0.356
11/0	-11	0.36	0.368
12/0	-12	0.37	0.381
13/0	-13	0.38	0.394
14/0	-14	0.39	0.406
15/0	-15	0.40	0.419

Table 17

The Dennison Combined Gauge

Except for the mainspring height notches on both side, this gauge is completely different from Dennison's mainspring gauge. On the left-hand side, Figures 18 and 19, there is a brass block acting as a stop and three separate scales, **A**, **B** and **C**. In the middle there is a long slit, but the only scale that can be used with it is **E**, the set of numbers 1 to 34 which mark the mainspring height notches. These have "half" markers which are meaningless for mainspring heights, but may be useful if they are used with the slit. Finally, there is a tiny scale **D**, consisting of only 4 lines, in a position where it could not be used. It clearly refers to the slit, but the slit is so narrow at this point that it cannot be used because of dirt, corrosion or damage. (This scale is not on the gauges of Dave Coatsworth and Don Ross, and it may be just a test marking. It measures about 0.05 or 1/20th inch, and has 4 divisions of about 0.0125 or 1/80th inch. Which might make sense, but it cannot be used.)

The three scales are:

A This is a ¾ inch long scale measuring $\frac{1}{64}$ inch from 0 to 48. It is used for measuring from the end of the gauge.

B This is a 1 inch long scale measuring $\frac{1}{64}$ inch from 0 to 64. It is used for measuring from the stop.

C This is strange because it runs from -2 to 40. Although it looks metric, it is in fact $\frac{1}{32}$ inch, so it runs from $-\frac{2}{32}$ to $\frac{40}{32}$.

The three scales together are $\frac{200}{64}$ inches long, 3⅛ inches, but I do not know if this is significant.

Scale **C** could be interpreted as sizes running from "3/0" to "40", but its purpose is obscure.

One possible use for it is to measure watch diameters. If it was intended for this purpose, the plate would be held against the stop and the watch size read off the scale: "3/0" (1 inch), "2/0" ($1\frac{1}{32}$ inch), "1/0" or "0" ($1\frac{2}{32}$ inch), up to size "40" ($2\frac{10}{32}$ inch).

However, this scale is neither the Lancashire nor the Dennison scale used for American watch movements. The Lancashire scale increments by $\frac{1}{30}$ inch and 1 inch is "6/0". Dennison's scale increments by $\frac{1}{16}$ inch and uses letters; A is 1 inch, B is $1\frac{1}{16}$ inch, and so on.

It has also been suggested that the scale is used as above, but for watch crystals; however the same problem arises. Vaudrey Mercer *The Frodshams, the Story of a Family of Chronometer Makers* gives details of the three crystal gauges. These are:

(a) *1/4 scale*, the English or Lancashire gauge. Full sizes differ by $\frac{1}{30}$ inch and ¼ sizes increment by $\frac{1}{120}$ inch or 0.212 mm. Size "0" is $1\frac{1}{30}$ inch, so "0¼" = $1\frac{5}{120}$, "0½" = $1\frac{6}{120}$, and so on. The scale goes from "12/0" to "29¾".

(b) *1/16 scale*, based on the ligne. Full sizes are lignes and $\frac{1}{16}$ sizes increment by $\frac{1}{16}$ ligne or 0.141 mm. Size "10" = 10 lignes, so "$10\frac{1}{16}$" = $10\frac{1}{16}$ ligne, $10\frac{2}{16}$" = $10\frac{2}{16}$ ligne, and so on. The scale goes from "7" to "$23\frac{2}{16}$".

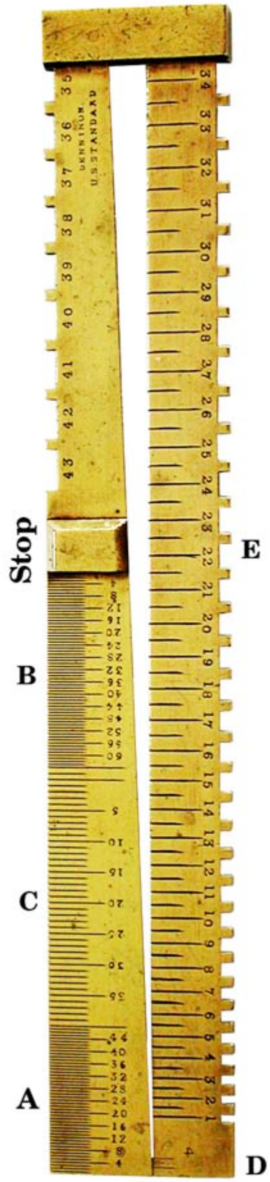


Figure 18

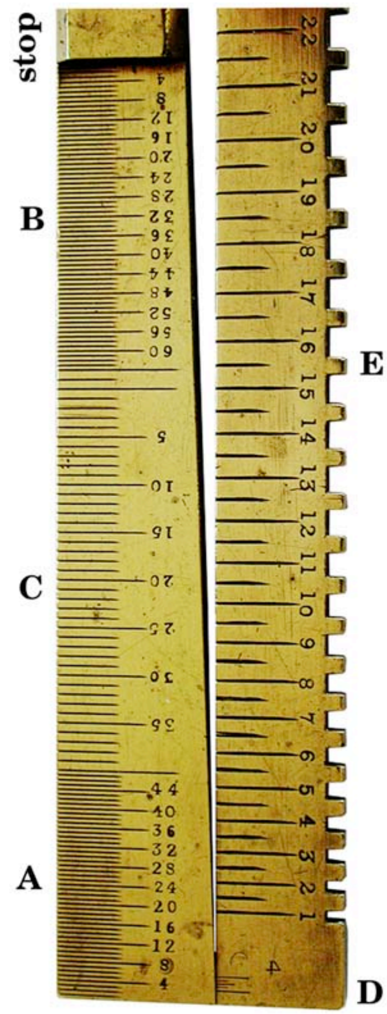


Figure 19

(c) *1/8 scale*, based on ½ lignes. Full sizes are ½ lignes and ⅛ sizes increment by $\frac{1}{16}$ ligne or 0.141 mm. Size "1" is 10½ lignes, so "1⅛" = $10\frac{9}{16}$ lignes, "1$\frac{2}{8}$" = $10\frac{10}{16}$ lignes, and so on. The scale goes from "12/0" to "26$\frac{2}{8}$".

These three gauges use completely different scales, 1/4 size "1", 1/16 size "12" and 1/8 size "4" being equivalent.

Dennison's scale also has a different scale, size "0" corresponding to the above. But it has an increment of $\frac{1}{30}$ inch or 0.794 mm which is far too coarse for crystal sizes. Even if we read to half sizes, such as "1½", the increment of 0.397 mm is still too coarse. So it cannot be used for cystals.

So we must assume Dennison devised a scale for something, but it may never have been used by other people.

Note that in the later version, type **d** Figure 13, the metric scale is not against an edge and can only be used with the stop.

The mainspring height notches are the same as those on the Dennison mainspring gauge described earlier and given in Table 16.

This confirms my opinion that the height notches are English imperial based on 1⁄250th inch, and they were later adapted to the metric system, an easy thing to do because the scales agree very well and little manipulation is required. It would be stupid to imagine the combined gauge had three imperial scales and one metric scale.

Finally, the slit running the length of the gauge creates a serious problem. The only scale that can be used with it is scale **E**, but that is simply ridiculous.

As I have noted, the scale for a slit must be linear. For example, the width of this slit at scale number "34" is about 4.8 mm, so width at scale number "17" should be half that or 2.4 mm. But it is about 1.9 mm. So if we measure something in the slit there is no simple way to determine what that number represents in inches or millimetres.

It is difficult to measure the width of the slit accurately at any point. But as it runs the whole length of the gauge, and it is possible to measure the width at the end reasonably accurately, we can calculate the width W a distance L from the narrow end to be about:

$$W = 0.034L$$

This applies to both metric and imperial units. As it is quite easy to measure L for each of the scale **E** divisions, Graph 24 provides a good picture of this scale; I have chosen imperial units to be consistent with the rest of the gauge. The line curves up showing the scale to be non-linear.

Note that it appears that the scale numbers align with the middle of the corresponding notch for full numbers and with the middle of the corresponding block for half numbers. That is, L depends on the width of each notch *and* the width of each block. The first block, from the end of the gauge to notch "1", is 7.09 mm and the other blocks are about 1.37 mm, but they vary from 1.34 to 1.39 mm. None of these numbers make sense and it must be concluded that the values of L, and hence the values of W, are arbitrary. Thus something can be measured in the slit, but the scale number produced is meaningless.

This is very embarrassing because it means Dennison created a gauge with an utterly useless feature! The only explanation, other than saying Dennison was an idiot, is if the original combined gauge had another scale on it; the back of the gauge is blank, so there is plenty of room for one.

If we assume this scale was marked in 1⁄64 inch, the finest possible, then each division would correspond to 0.0005312 inch, solving the problem.

As my measurements are rough, we can assume the correct relationship is:

$$W = 0.032L$$

and the scale then measures in units of 1⁄2000 inch.

Of course this is a guess. We can only know whether I am right or not if someone produces a combined gauge with such a scale on it.

Two other points need to be made.

First, I have never seen or heard of a Dennison gauge with barrel sinks for measuring mainspring strengths. So did he always use a slit gauge? I think the answer is no, he didn't. My reason is that scale **B** on the gauge can be used to measure the outside diameter of barrels. As this method was common it is not unreasonable to think Dennison employed it. So he had no need of a separate gauge to measure strengths.

Second, when Sherwood described this gauge he wrote that watchmakers:

> *"may by its use, size wire or plate to all the sizes indicated by any Stubb's gauge, also the diameter of wheels and pinions, most perfectly".*

Unfortunately, this is not true.

There is no suitable scale on the gauge to measure Stubbs wire. In fact there are two different Stubbs wire gauges, one for steel and one for iron wire. The steel wire gauge runs from size "1" (largest) to "80" (smallest), but according to the table in Kendrick & Davis *Staking Tools and How to Use Them* the gauge is erratic and the difference from one size to the next varies. Abbott's *The American Watchmaker and Jeweler, an Encyclopedia* has a table for wire gauges that includes the Stubbs or Birmingham iron wire gauge which is quite different, but again the difference from one size to the next varies. This gauge runs from "4/0" to "36".

So the Stubbs sizes cannot be measured by a slit gauge and a plate with individual holes is necessary.

Neither can the diameter of wheels and pinions be measured.

A wheel could be measured using scale **B** provided it was not mounted on its arbor; if it were it would not be possible to accurately align the wheel with the stop. Which is why wheel gauges were like barrel gauges; round sinks with holes in the middle to take the arbor.

Pinions can be measured in slit gauges or calipers, but there are serious problems when there are no leaves diametrically opposite each other; then the measurement is necessarily under-size. Anyway, the combined gauge has no suitable scale, unless the missing scale for the slit existed.

Thus either Sherwood was completely wrong or he was describing some other, unknown gauge. The later is possible but unlikely.

Conclusions

The first thing to point out is that I am not implying the makers of mainspring gauges spent a lot of time developing formulae. Indeed, I am sure it never occurred to them to study the mathematic foundations of their work, and my use of formulae has been to discover *what* they made, not *how* they made them.

I am sure people like Montandon arbitrarily chose a convenient size and then made other sizes "so much" bigger or smaller. That is, it is the *increment a* in the formulae that is vital.

Equally, if Montandon found he had too many sizes to be convenient, he just changed the increment to suit. The process was practical, informal, but *based on units of measurement*; the ligne, the inch or, much later, the millimetre.

Unfortunately we do not know how these people went about their work, although some insight can be found in *L'art de Faire les Ressorts de Montres suivi de la Maniere de Faire les Petits Ressorts de Repetitions et les Ressorts Spiraux* by Blakey, an English translation of which appears in yet another obscure publication, *The Ferrous Metallurgy of Early Clocks and Watches, Studies in Post Medieval Steel* by Wayman. But we do not know how they *sized* mainsprings. So I have worked backwards, using least-squares curve fitting because it enabled me to deduce what they might have done, even if they did it differently.

Perhaps more importantly, we do not know *who* these people were. Some names on gauges are simply those of tool makers, like Vigor or Fitrite. Others like Ferret almost certainly fall in this class. So who actually designed them? Montandon probably. Martin may be. As I have noted, information on the people and companies that made tools and parts is almost non-existent, and we can do little more than guess.

The second point to be made is that the errors in mainspring gauges make them very unreliable. Even in such a small sample the frequency of errors is simply staggering, and I have no doubt that the gauges were made without any real care.

In one way this doesn't matter. The watchmaker who ordered a mainspring and got one of the wrong size probably did not even notice. Or, if it would not fit, being too high, returned it assuming he had been sent the wrong one. After all, if he used a Dennison strength gauge and ordered in millimetres, it is inevitable that the spring would be wrong!

Did anyone care? I doubt it. These gauges are inherently dubious even if well made, and I am sure "good enough" was the prevailing sentiment with very few people demanding "right".

All of which depends on another unanswerable question: When were the gauges made? Unfortunately, other than patina, strips of brass don't reveal their age. Even when incorporated in watches they can be difficult to date; My rule when I see a nondescript Swiss watch is to say "1880" simply because it is impossible to tell the age within about 40 or 50 years. So dating mainspring gauges is almost impossible.

At first I had thought Dennison's combined gauge was rare. Now we know it was probably made for 100 years, from about 1840 to about 1940, and it is quite common. Indeed, all the gauges we have examined are almost certainly from the twentieth century. (The Montandon gauge in Figure 1 is probably an exception; I think it was made when craftsmanship was as important as price and so is earlier.)

Which leads to the next unanswered question: Did the quality of mainspring gauges deteriorate over time? I can imagine that in the 1920s these gauges, although still commonly used, were regarded more as obsolete rather than practical tools. And so there may have no longer been any desire (or need) to make them with due care.

Consider Dennison's strength gauge, originally a practical, sensible gauge measuring small fractions of an inch. At some stage someone, probably a tool company, decided to pervert it by making it metric. After which there is a sorry saga of ill-conceived, incorrect gauges foisted upon watchmakers.

Perhaps the later tool makers made gauges by copying one, without understanding the underlying measurement system, and so replicated errors?

In contrast, this article has been based on an assumption: *the people who designed the gauges were sensible*. That is, there should be recognisable relationships between the sizes of notches, sinks and slits, and metric, imperial or other units of measurement. In other words, the tables for gauges should be uniform with each size differing from the next size by a constant increment. And the starting point, the base size, should be a sensible number in the appropriate unit of measurement.

Although open to criticism, I believe I have demonstrated that the gauges examined fit this principle.

However, I have not mentioned one aspect of them. I believe all these gauges were created *before* the adoption, let alone the *acceptance*, of the metric system in watchmaking. Watchmaking is renowned for being a very conservative profession, clinging to outdated ideas long past their use-by date. So that even after the general application of the metric system, the old French and English imperial systems were used, to the rather ridiculous extent that American watches have always been measured in Lancashire sizes and, even today, Swiss watch sizes are still quoted in lignes.

Which is to say, without any evidence at all, I still believe mainspring gauges should be based on imperial measurements and a metric one should be viewed with great suspicion. With possibly one and a bit exceptions, this article supports that view:

Montandon:

> The gauge I have examined has French imperial heights and barrel diameters, and I am confident that Montandon was a mainspring maker.

Lepine:

The heights scale, the only scale I know of, is French imperial.

Who created this gauge is a mystery. We have Lepine heights listed in books, and gauges made by Montandon and Ferret (presumably a tool maker). But the only comparable barrel sizes (on the Ferret gauge) match Martin's gauge which does not have Lepine heights!

It is possible that Lepine heights are a "generic" scale related to a type of watch, which would have to be standardised and made in large quantities; quite possibly the common Swiss barred movement of the 1880s.

Martin:

This gauge is confusing, because of the two different height scales. I am confident that the Geneva's heights and the barrel diameters are French imperial; which means the Ferret barrel diameters are also French imperial. But the Lever heights could be metric. Certainly, there can be no doubt that the Martin slit gauge is metric.

The term "Geneva's", like "Lepine", is probably generic, referring to watches made in Geneva and, as I have noted, these probably use the cylinder escapement. Which is why the other scale is called "Lever".

I assume Martin was a mainspring maker, but I have no evidence for this.

Robert:

I first thought the Robert gauge was the exception that proves the rule, and that it is purely metric; certainly the published tables support this view. But, as we have seen, tables can be misleading and the French imperial scales are possible.

An alternative is that Robert, a mainspring maker, may have begun using French imperial measurements and then changed to metric. As I have noted, we will not know unless some gauges are found and measured.

Ferret:

This gauge is French imperial. Because it is a mix of Lepine and Martin scales, and made by a tool maker, it is not possible to be sure why it exists.

Prenot:

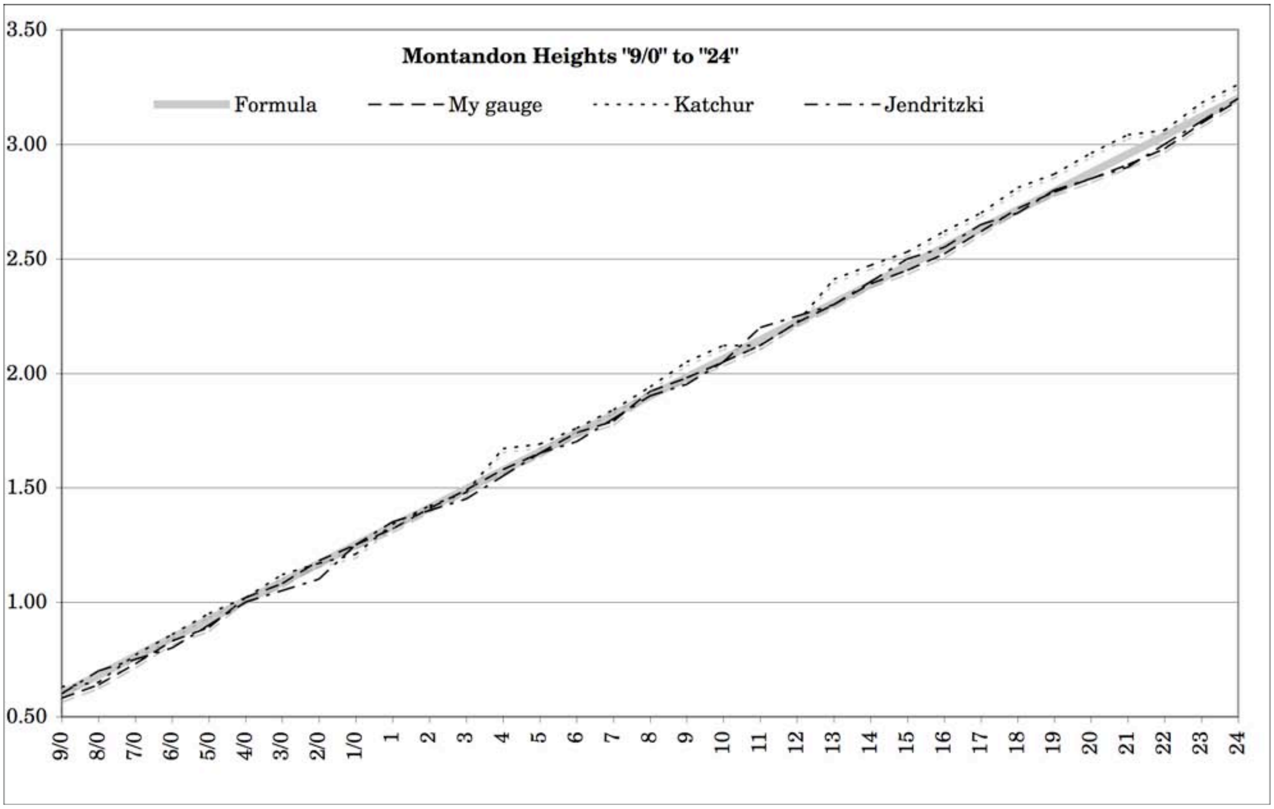
This gauge is French imperial. Although the mainspring heights scale is different from other gauges, the lack of barrel sinks means it is hard to relate this gauge to the others. Who Prenot was and what he did is unknown.

Dennison:

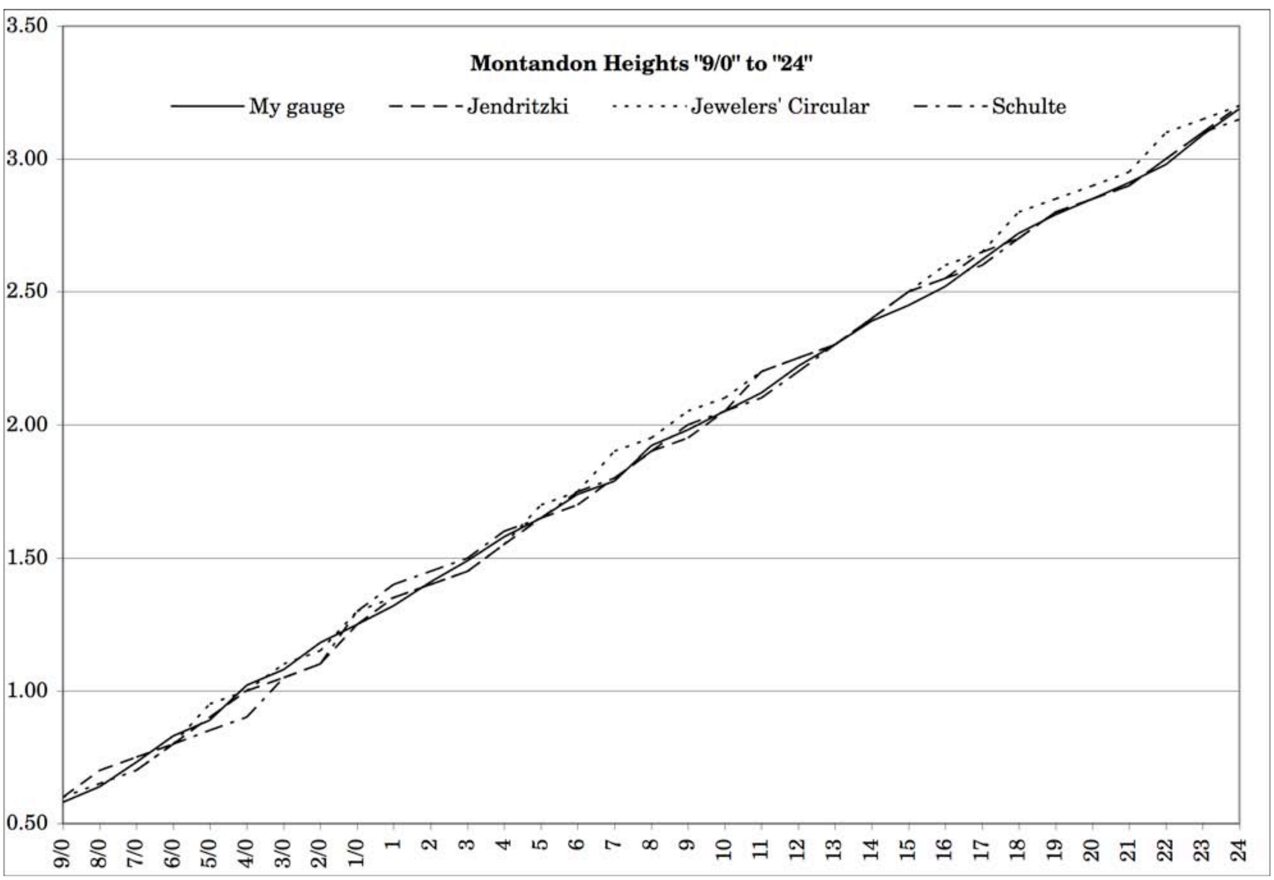
All Dennison gauges are English imperial.

Finally, it would have been better if I had been able to examine more gauges, but time and opportunity has precluded that. I began by planning to write four or five pages on Dennison's combined gauges and I have ended up with ten times that amount, which is enough. May be this might stimulate someone else to go further with these curious bits of brass.

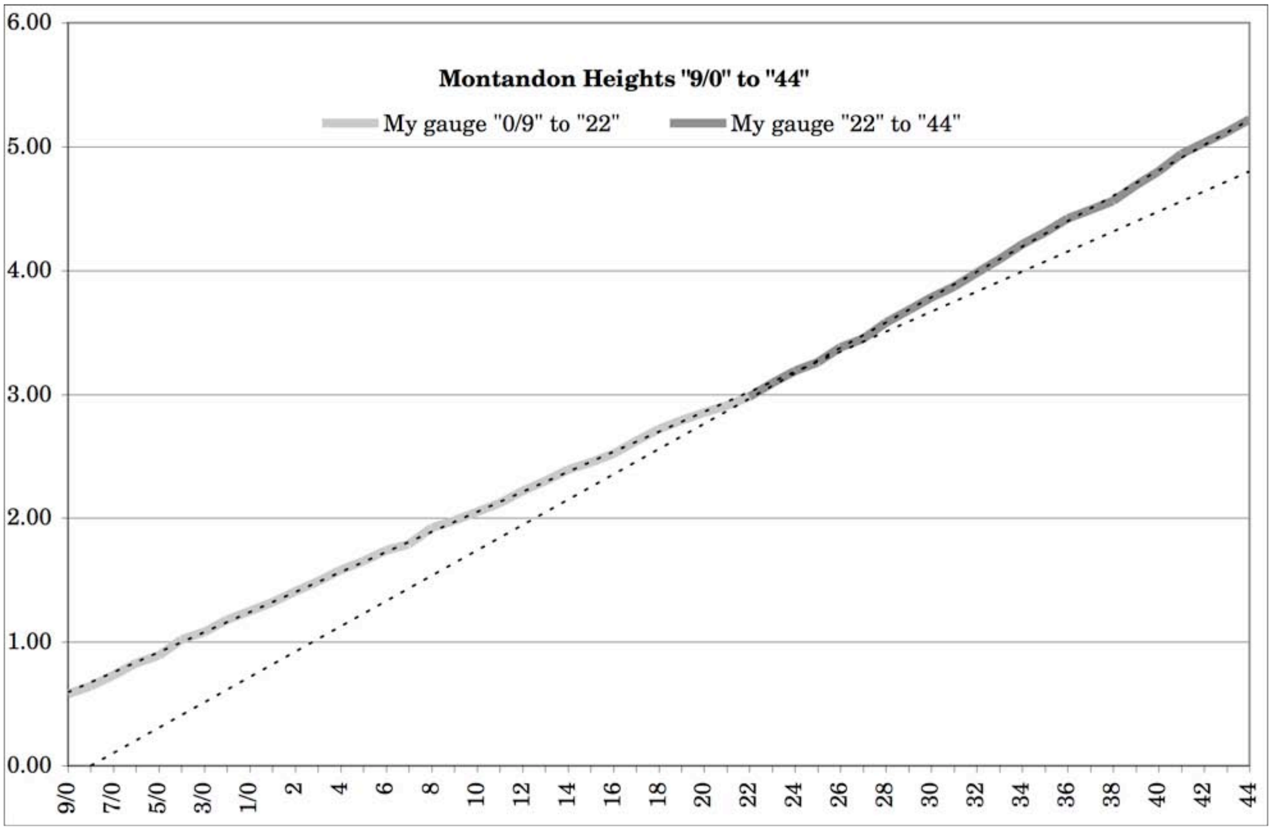
Graphs



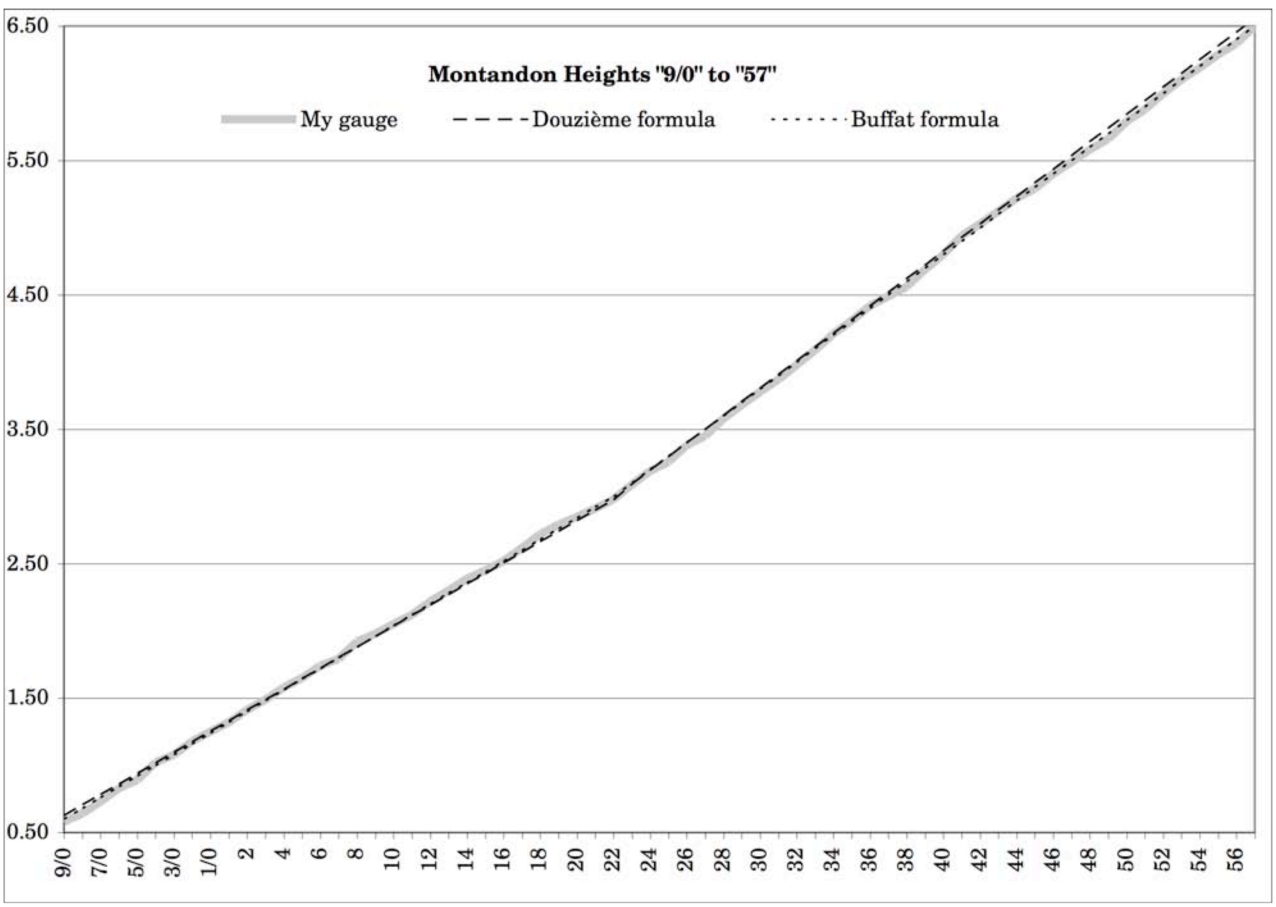
Graph 1



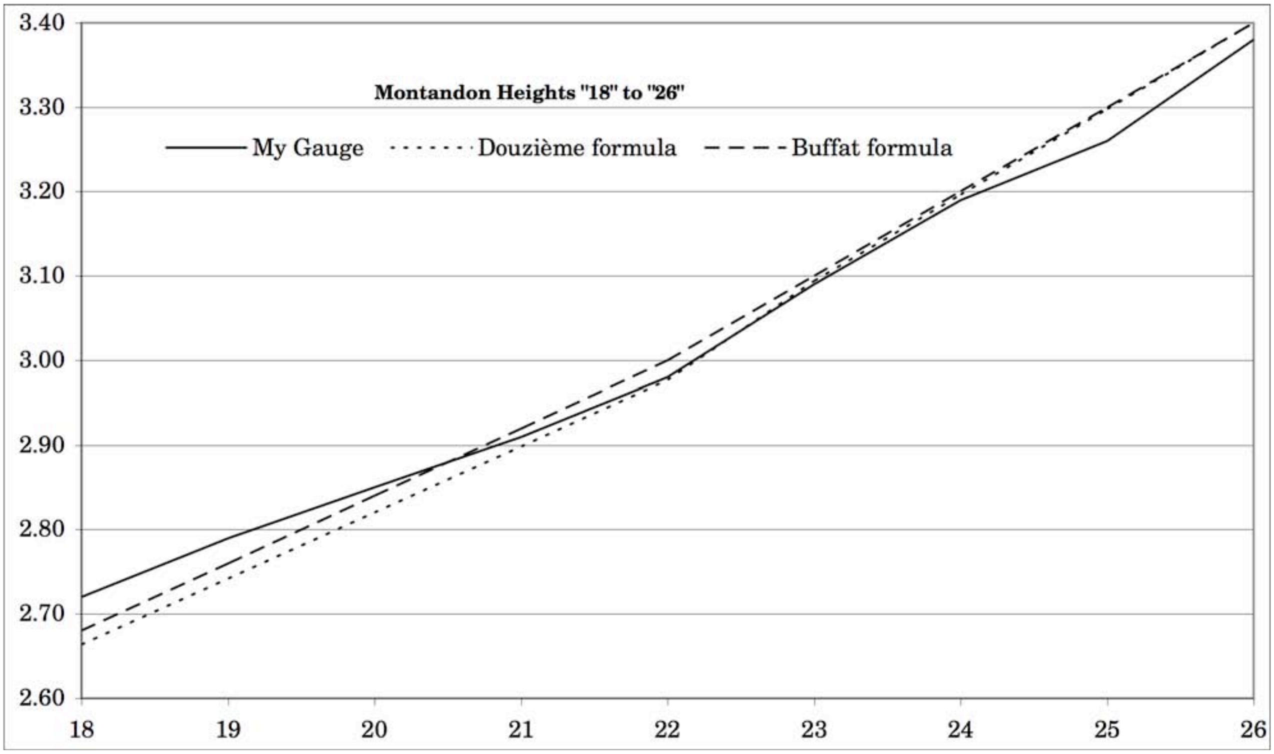
Graph 2



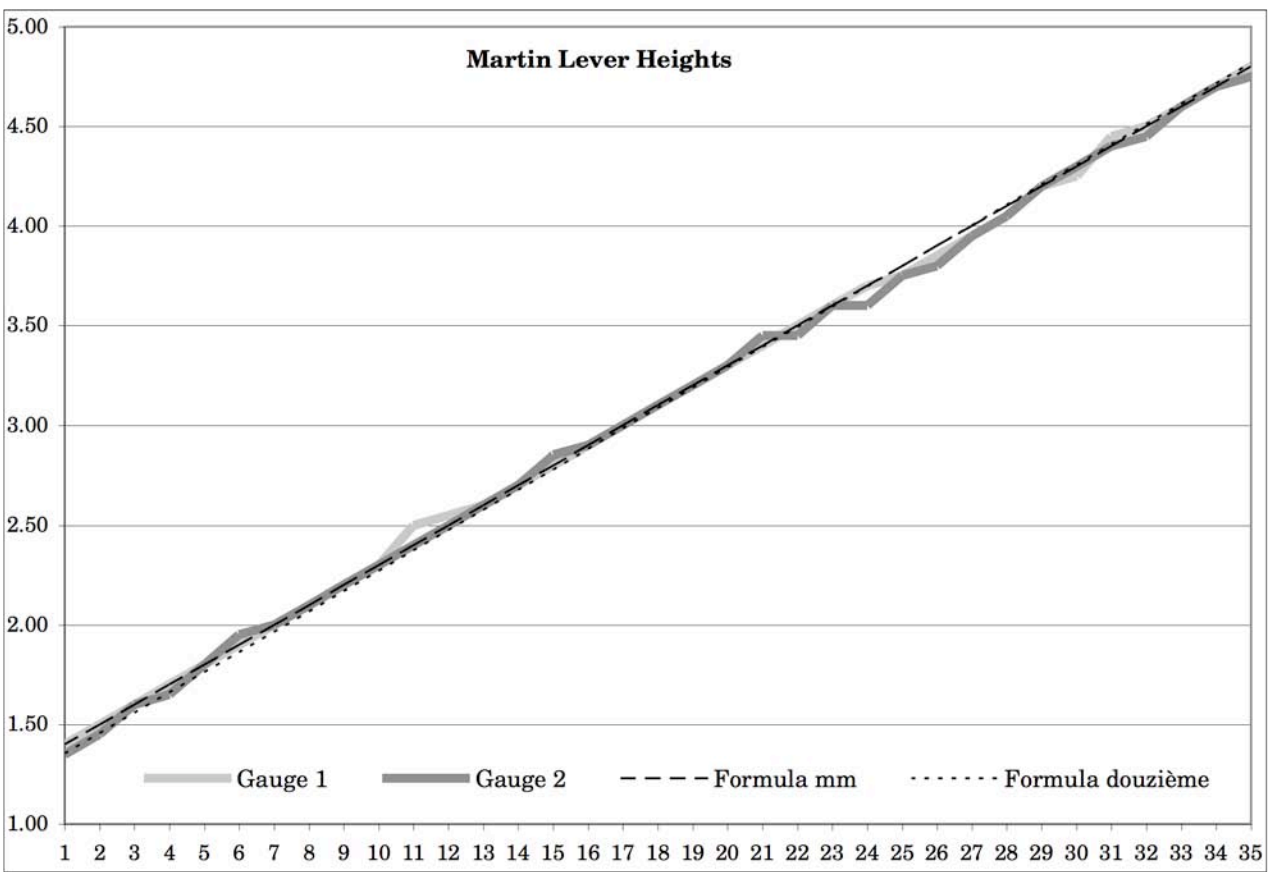
Graph 3



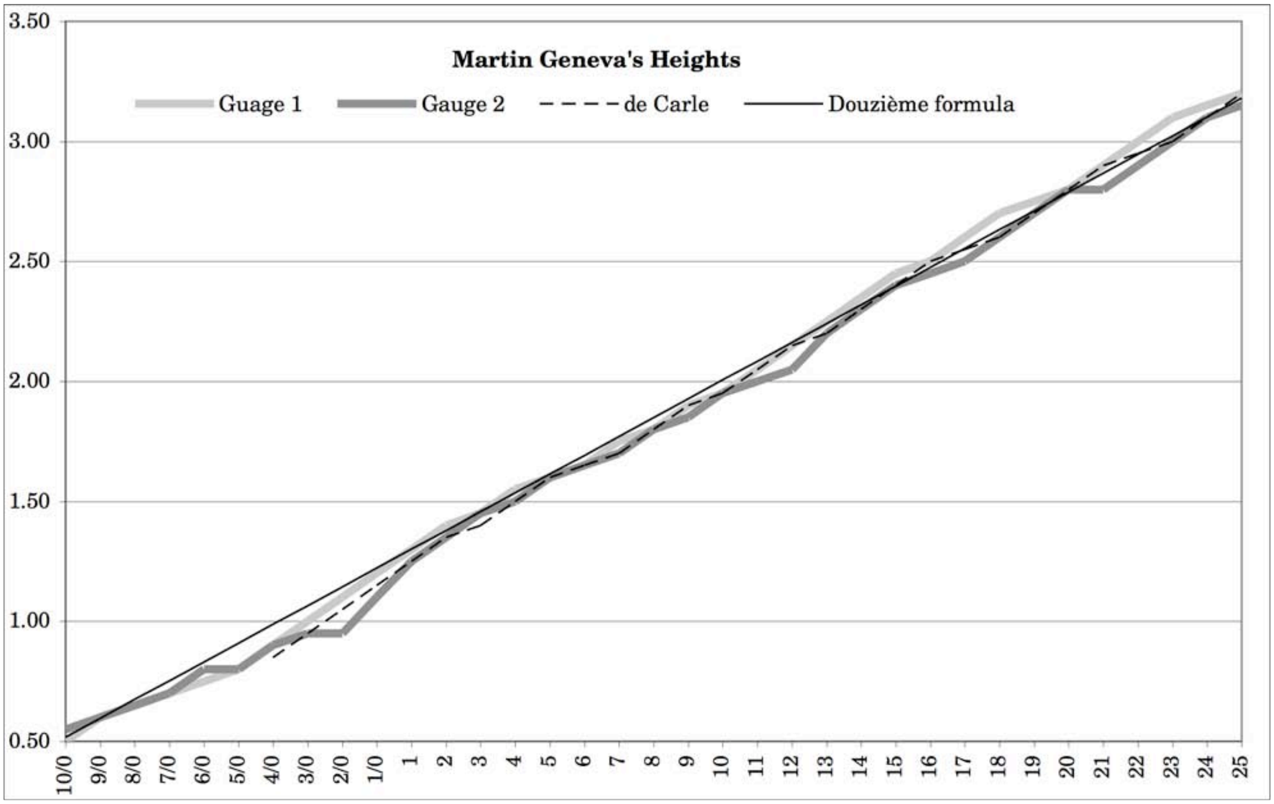
Graph 4



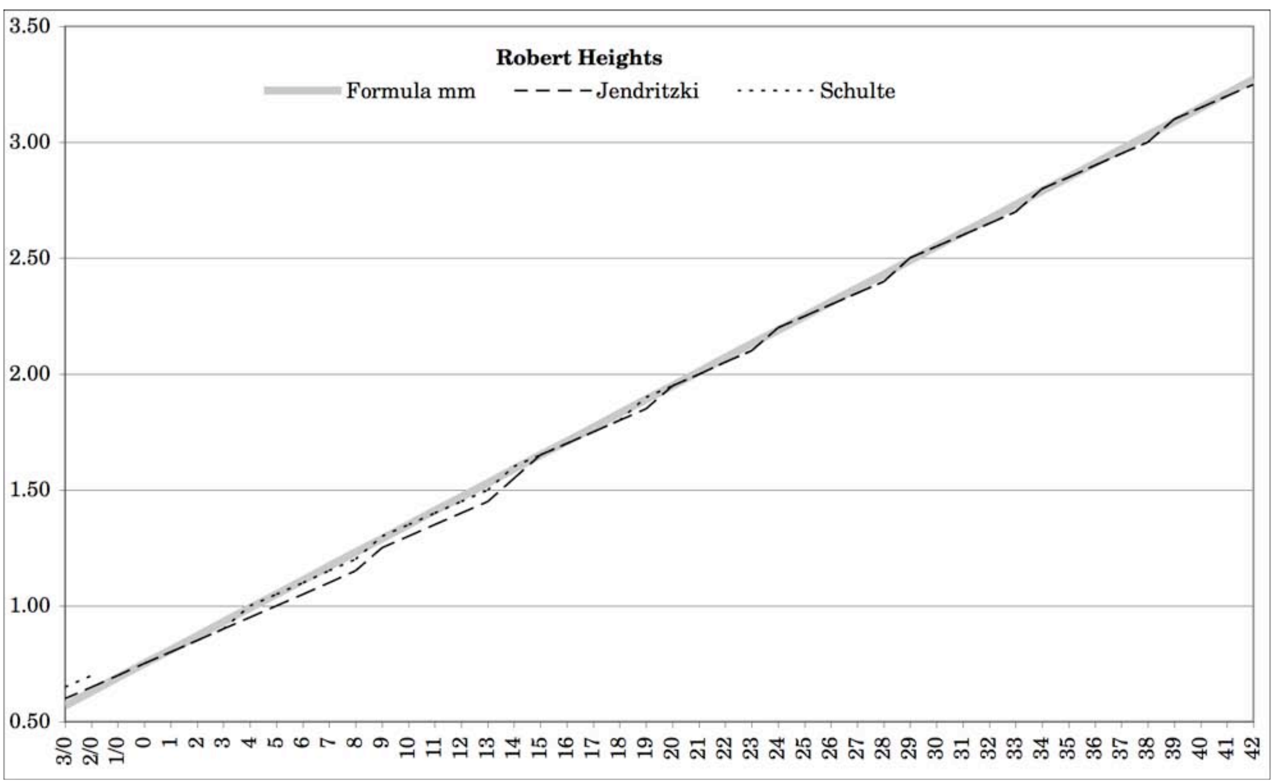
Graph 5



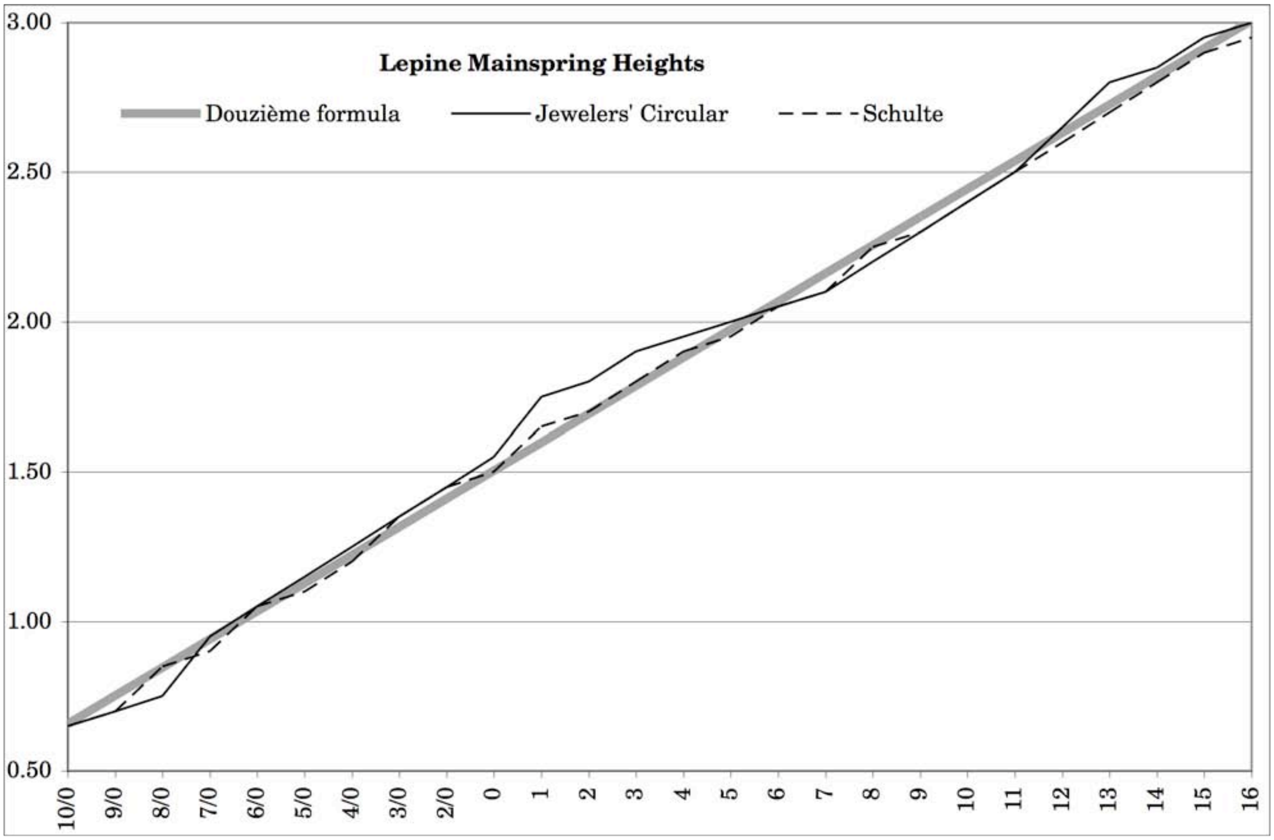
Graph 6



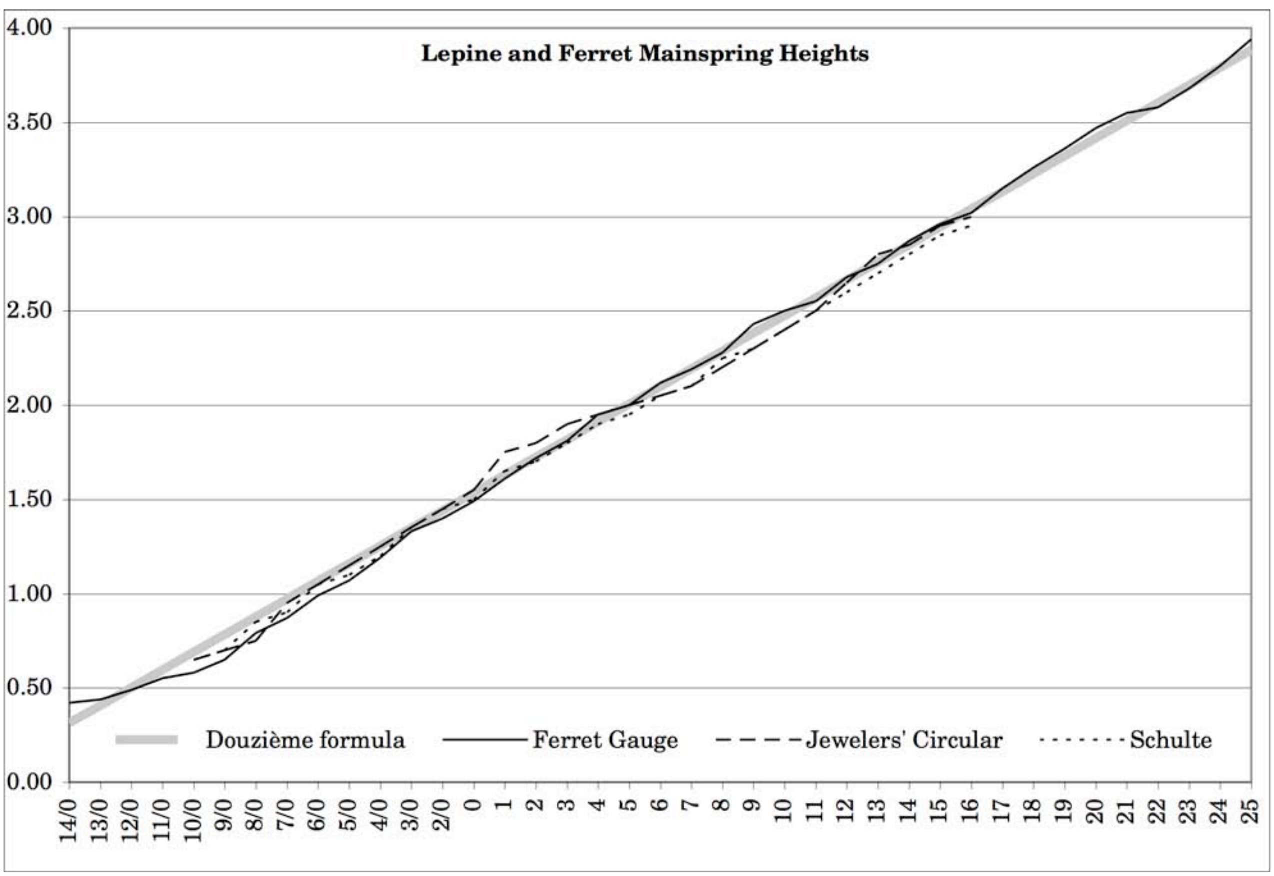
Graph 7



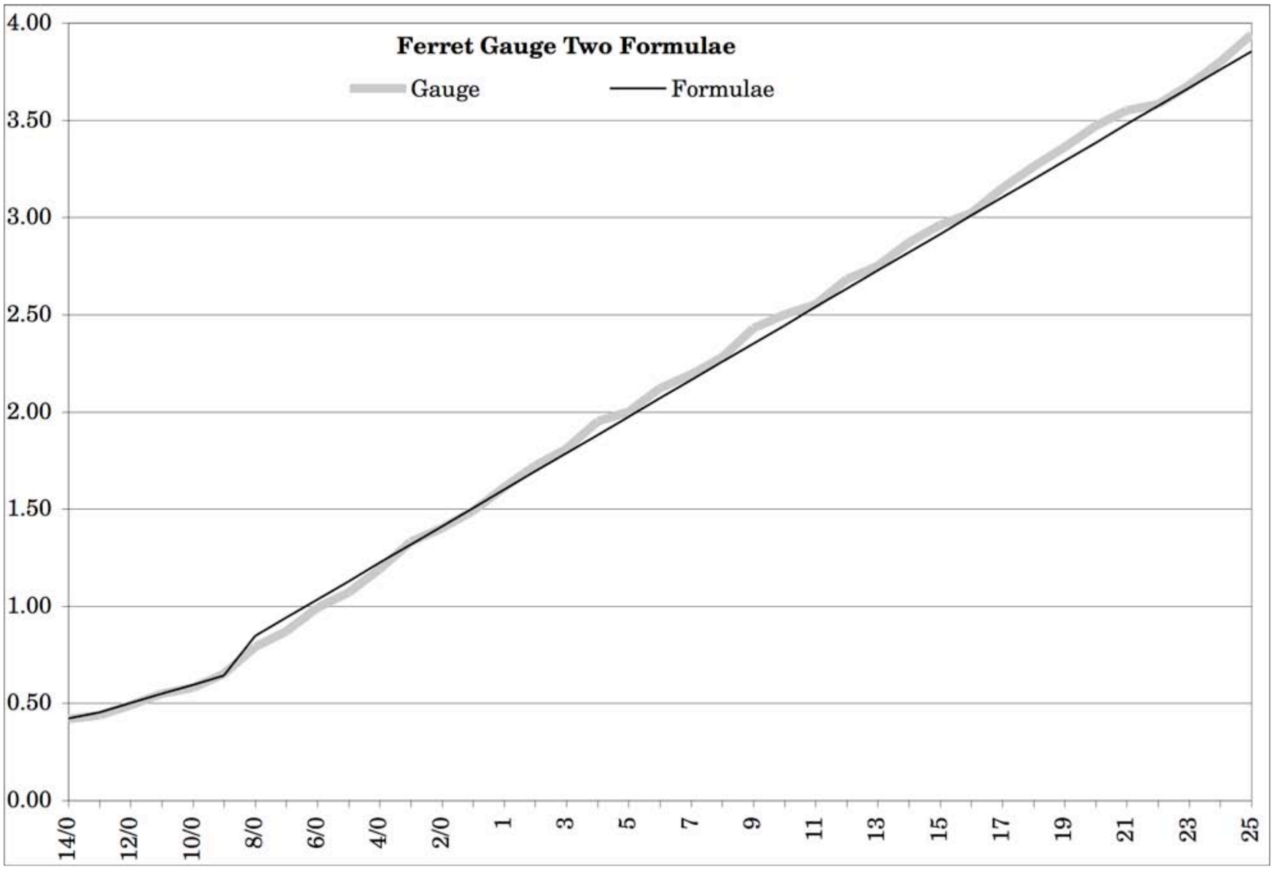
Graph 8



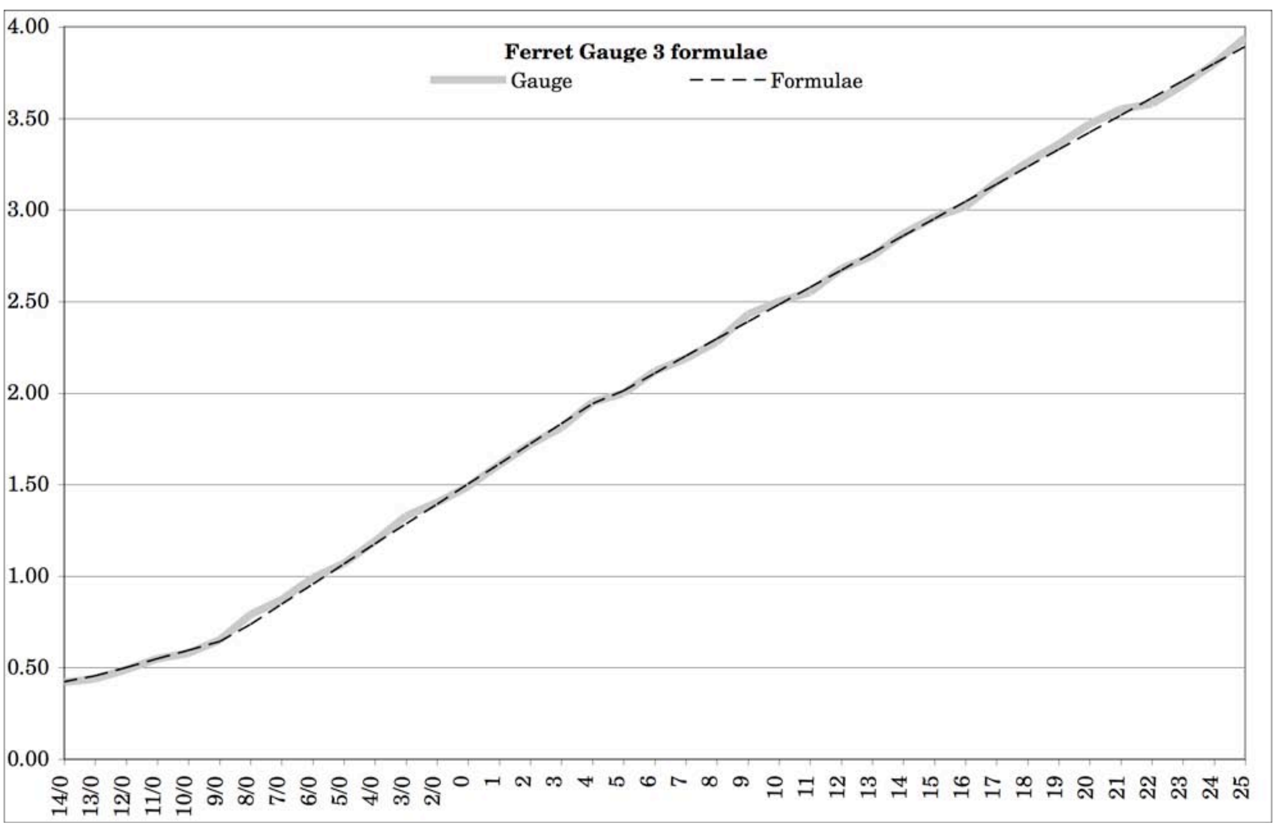
Graph 9



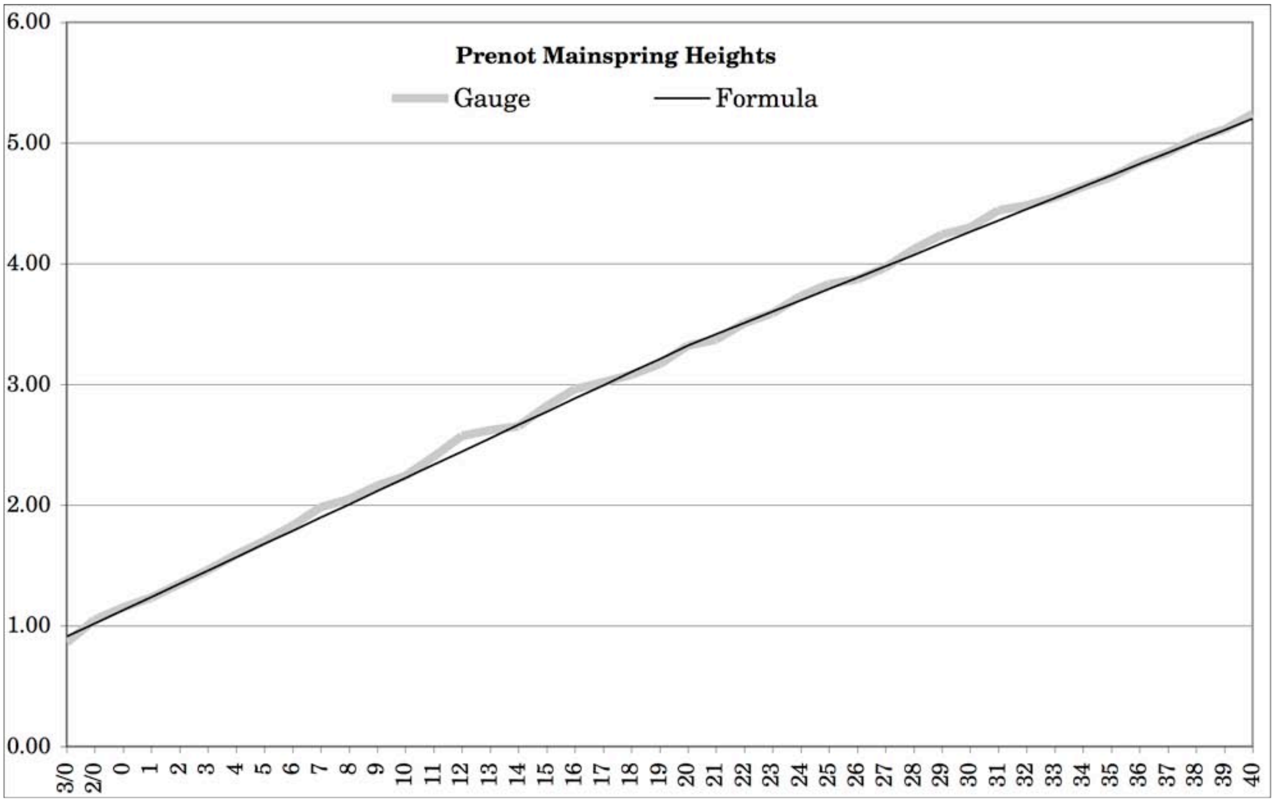
Graph 10



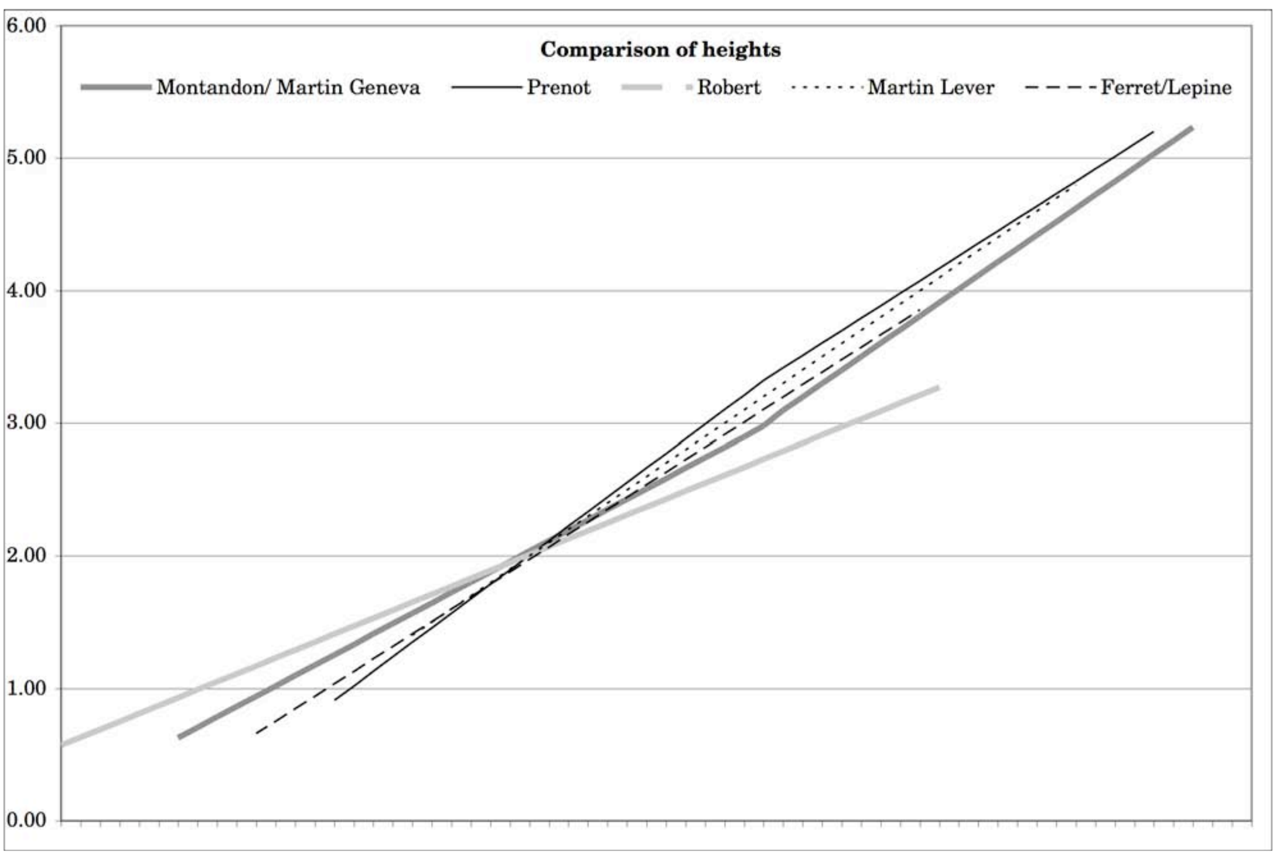
Graph 11



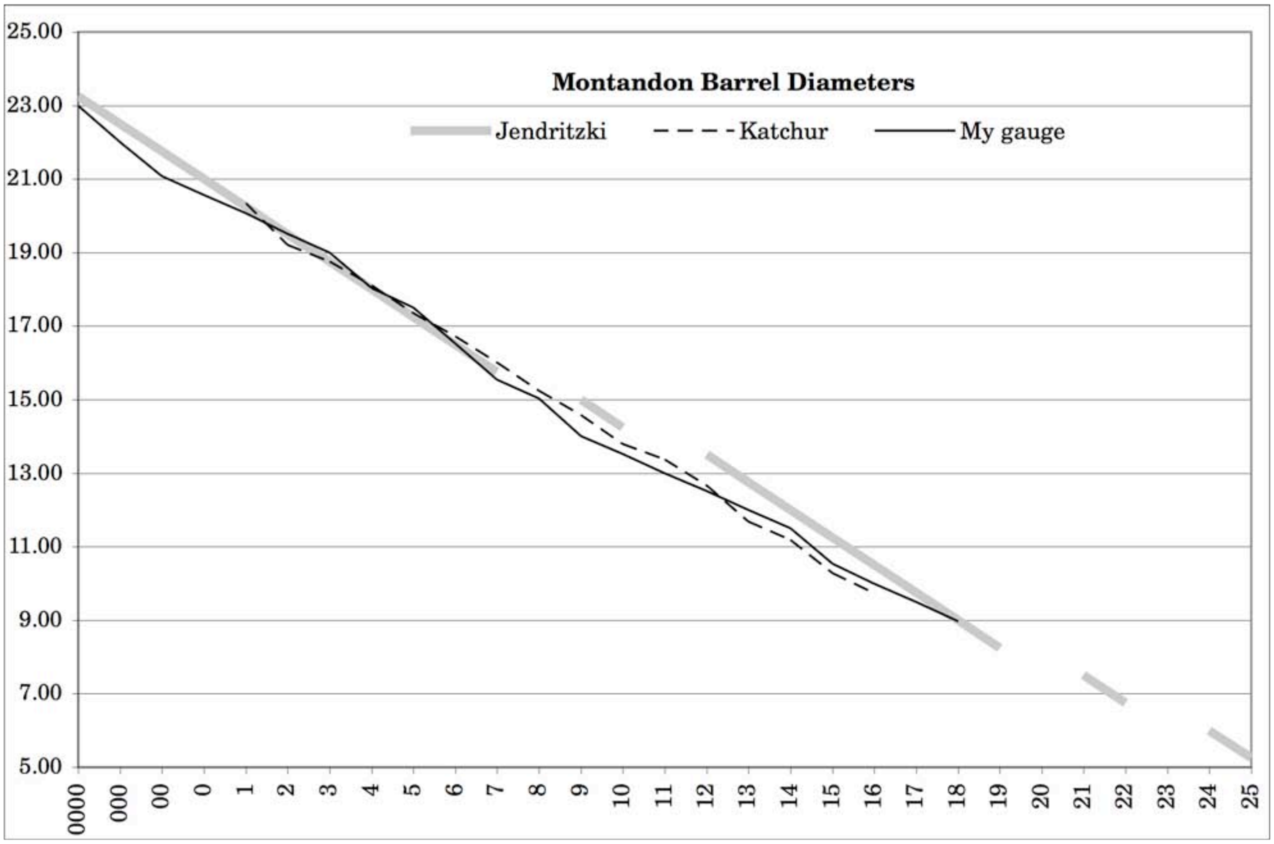
Graph 12



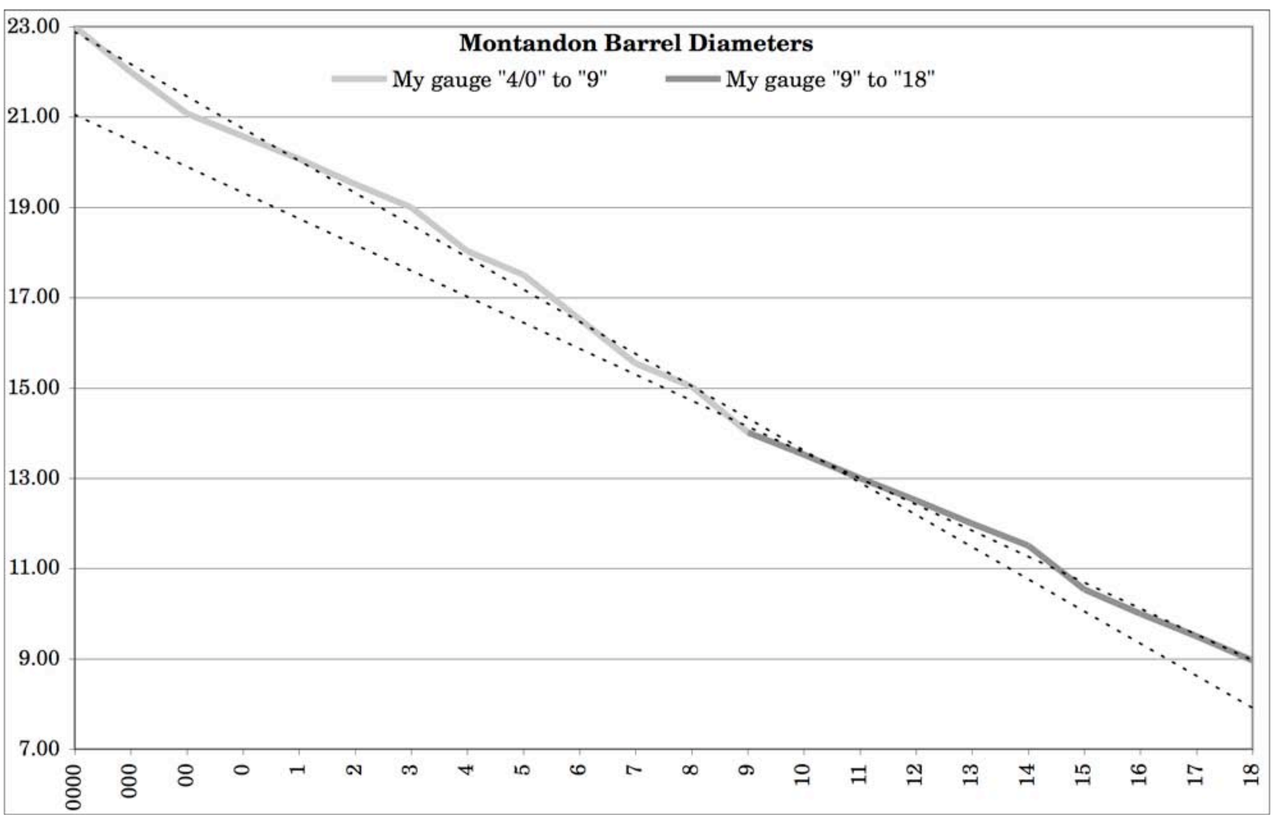
Graph 13



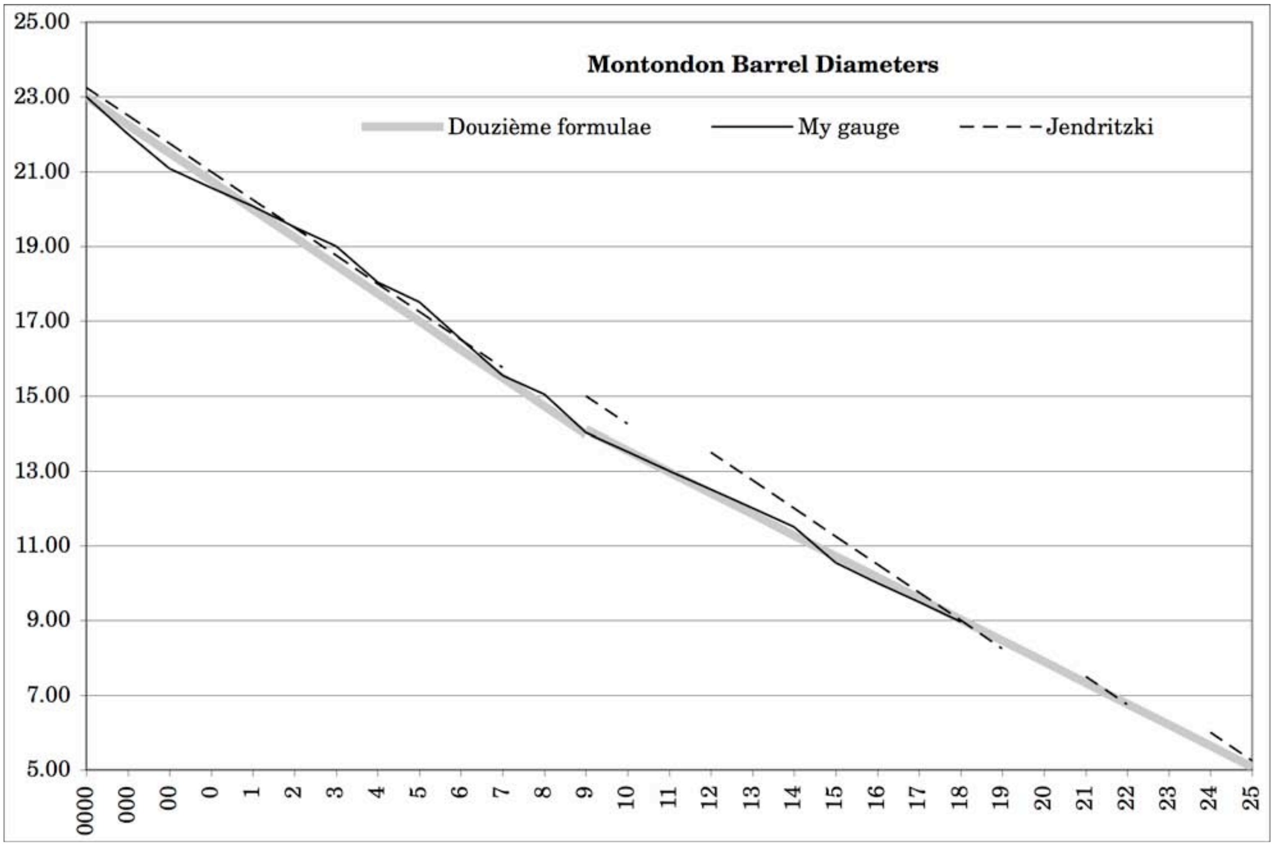
Graph 14



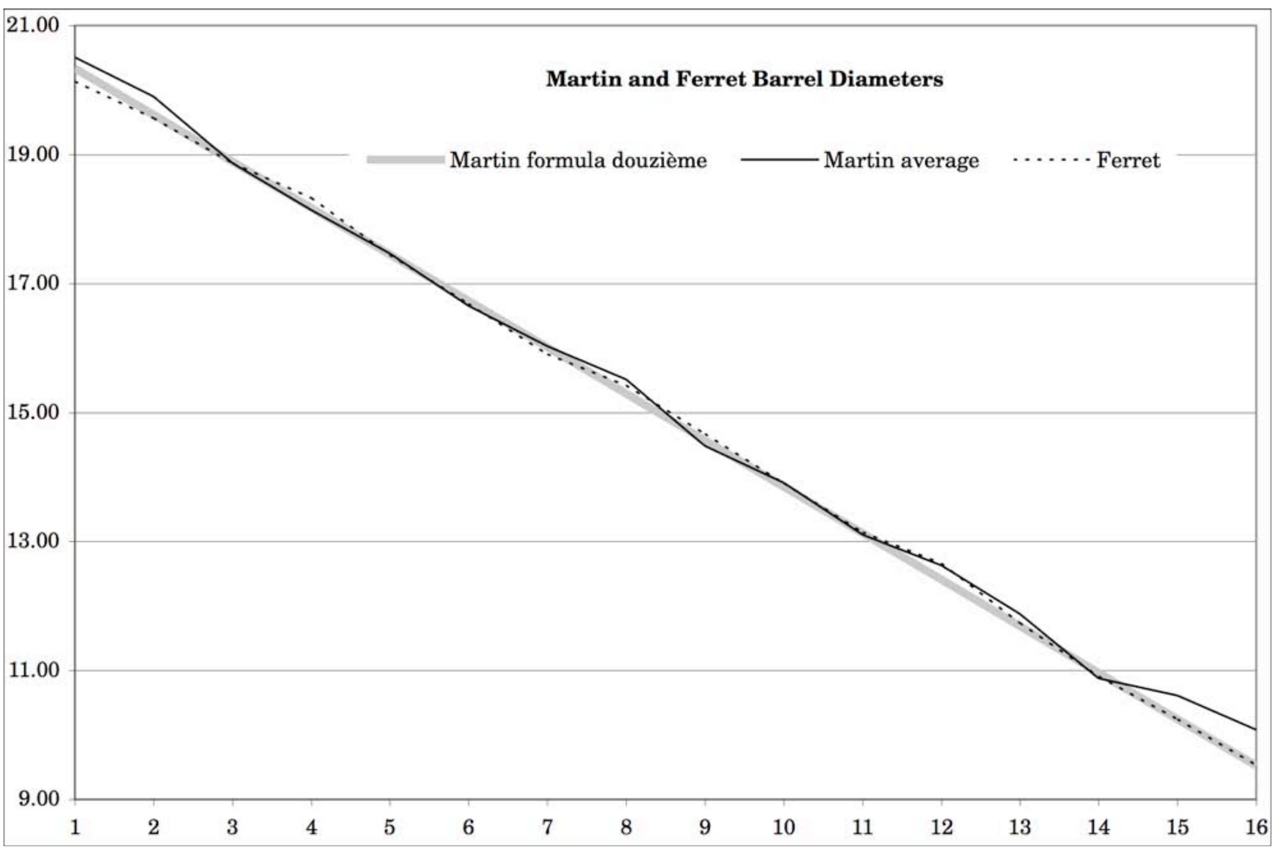
Graph 15



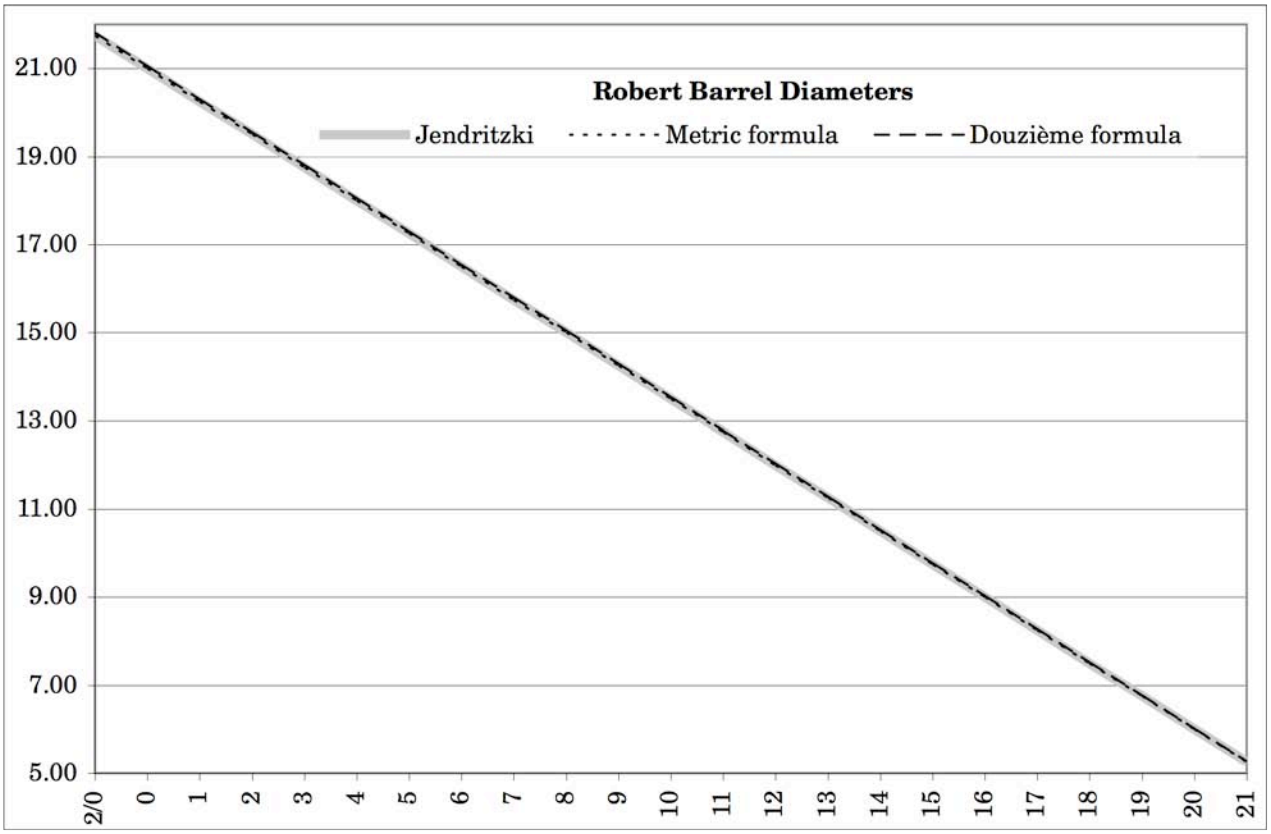
Graph 16



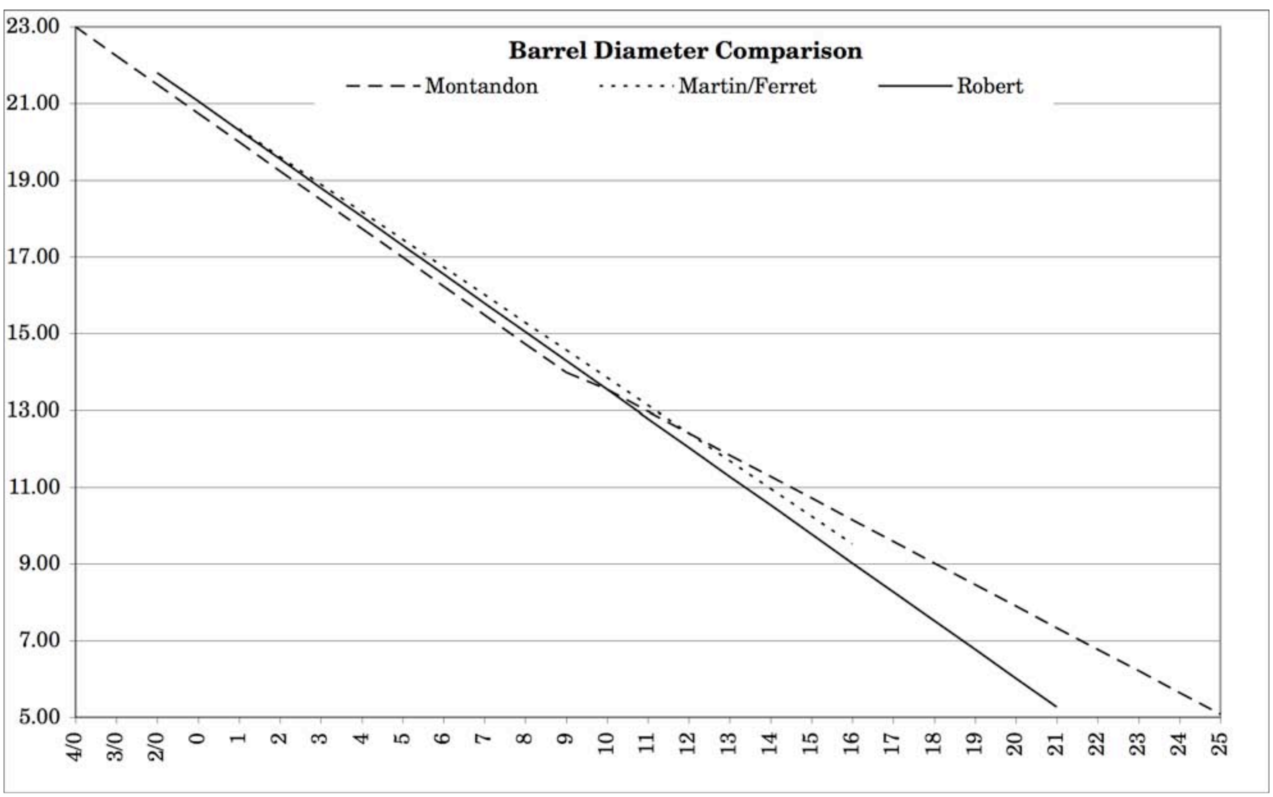
Graph 17



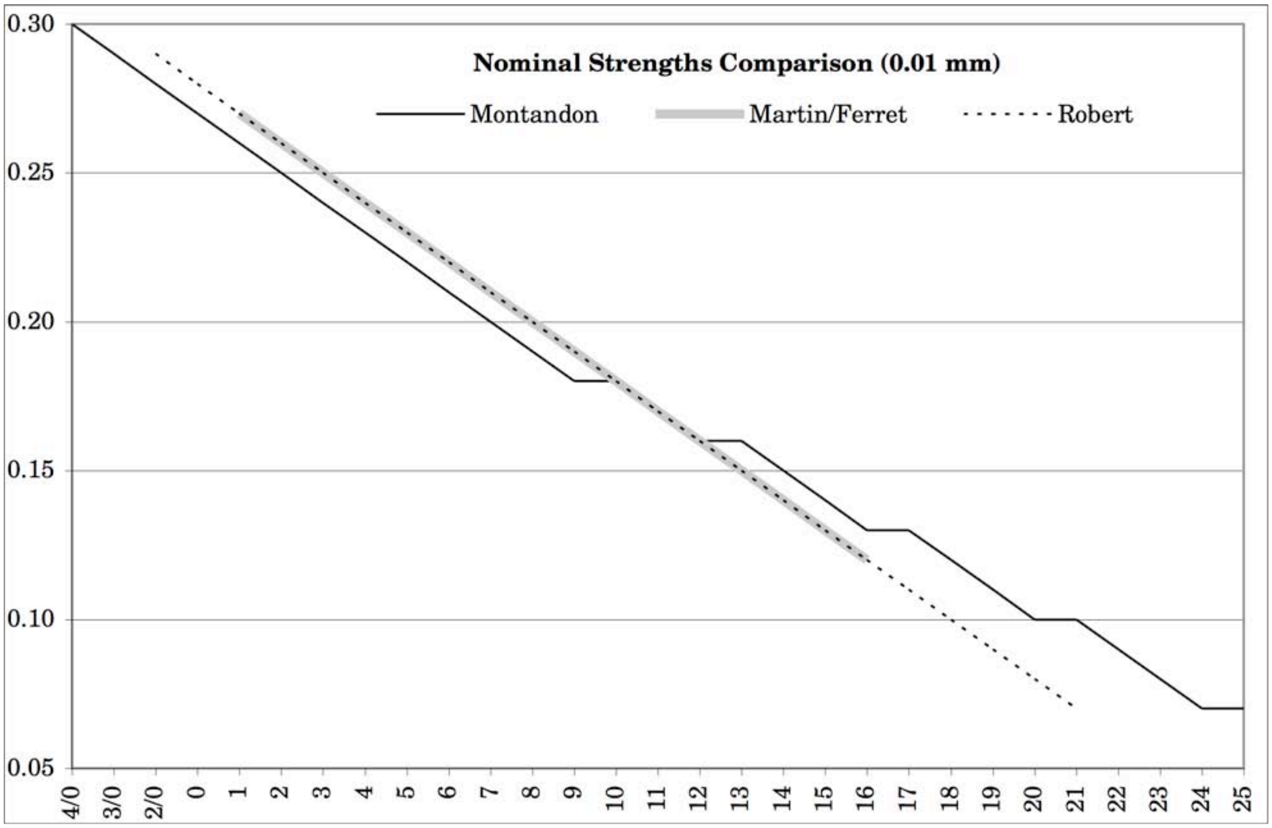
Graph 18



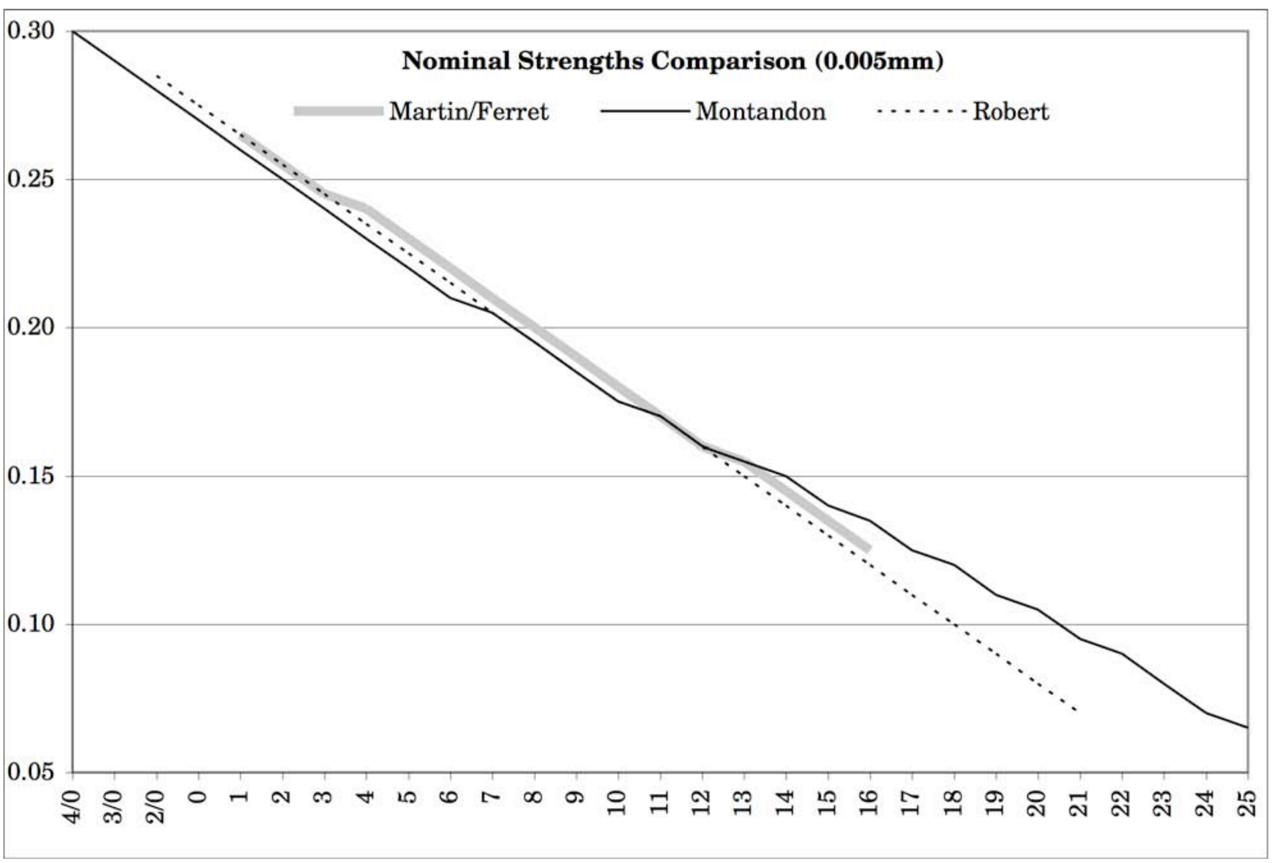
Graph 19



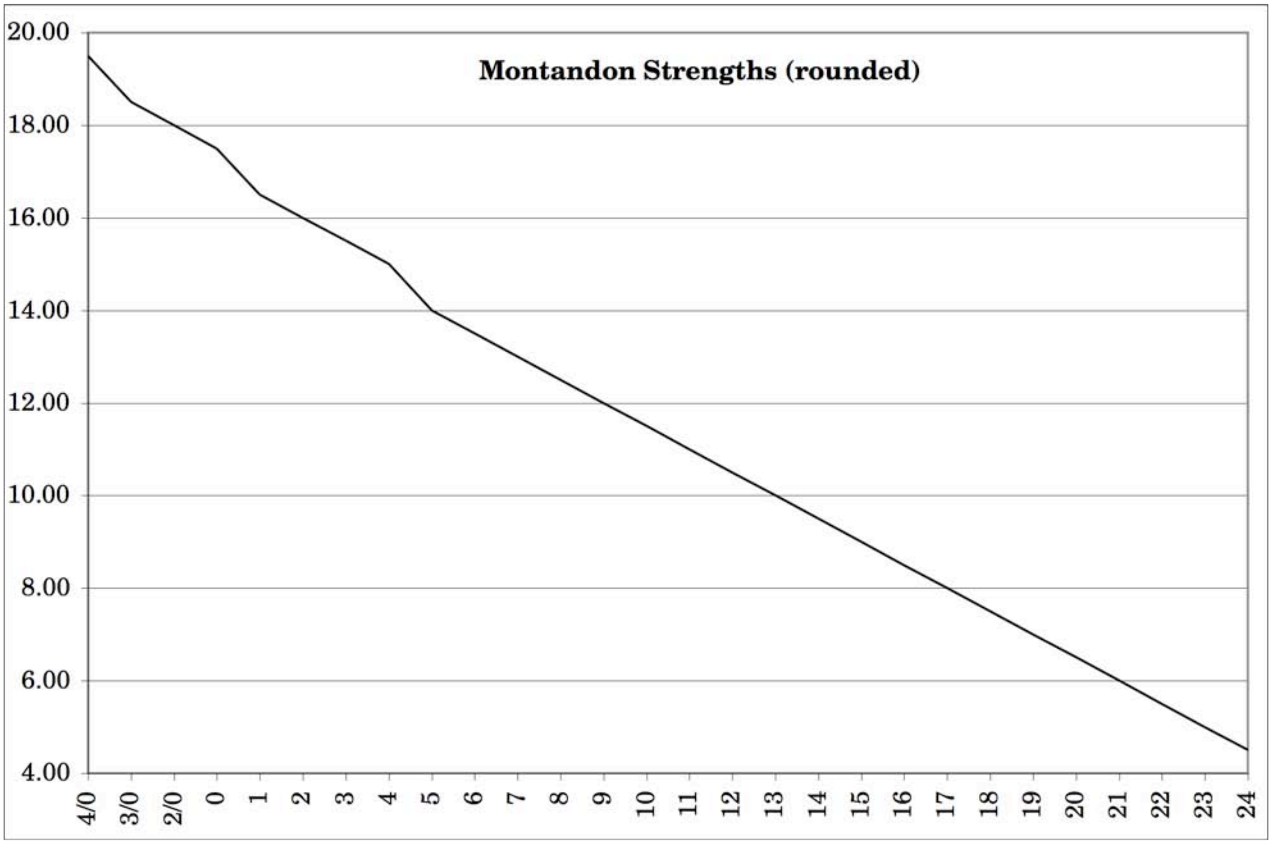
Graph 20



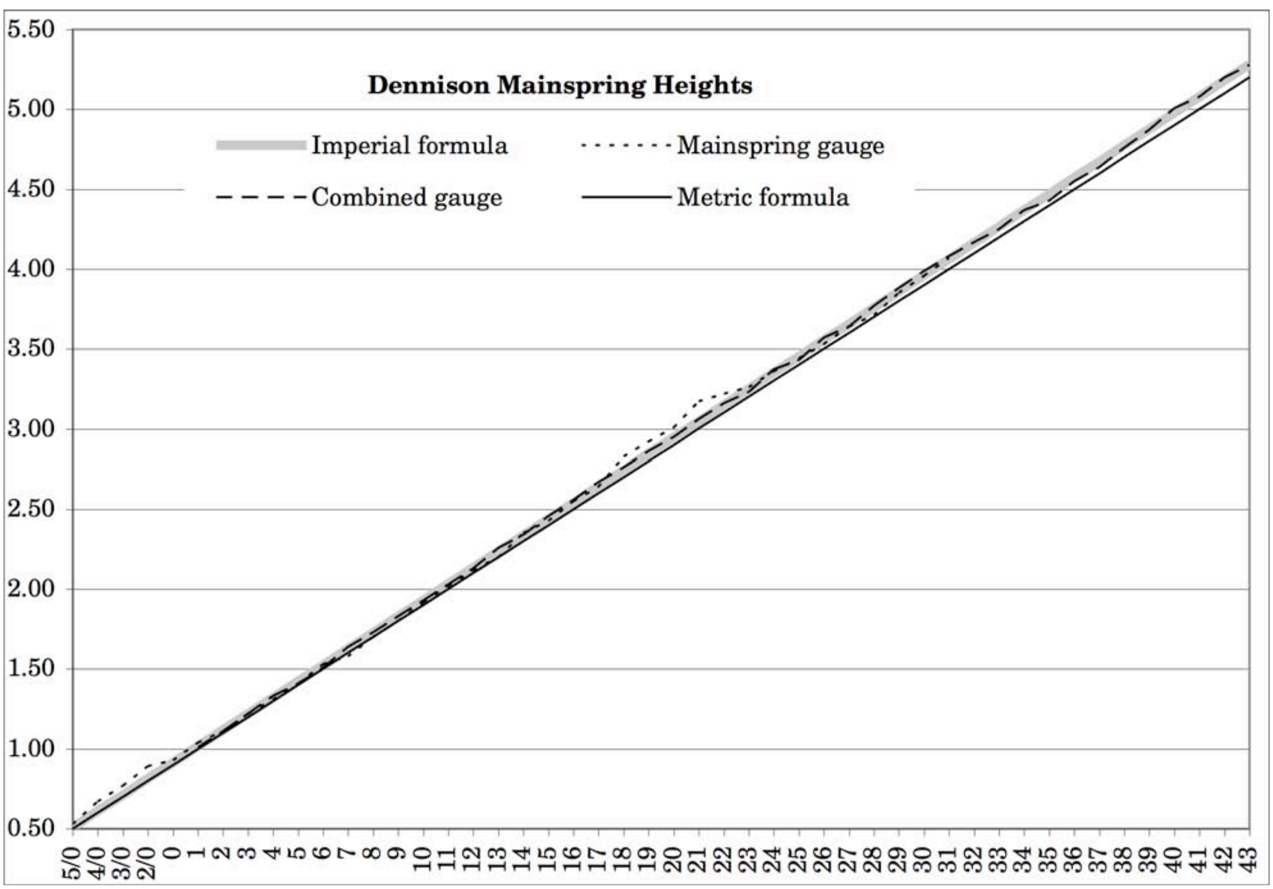
Graph 21



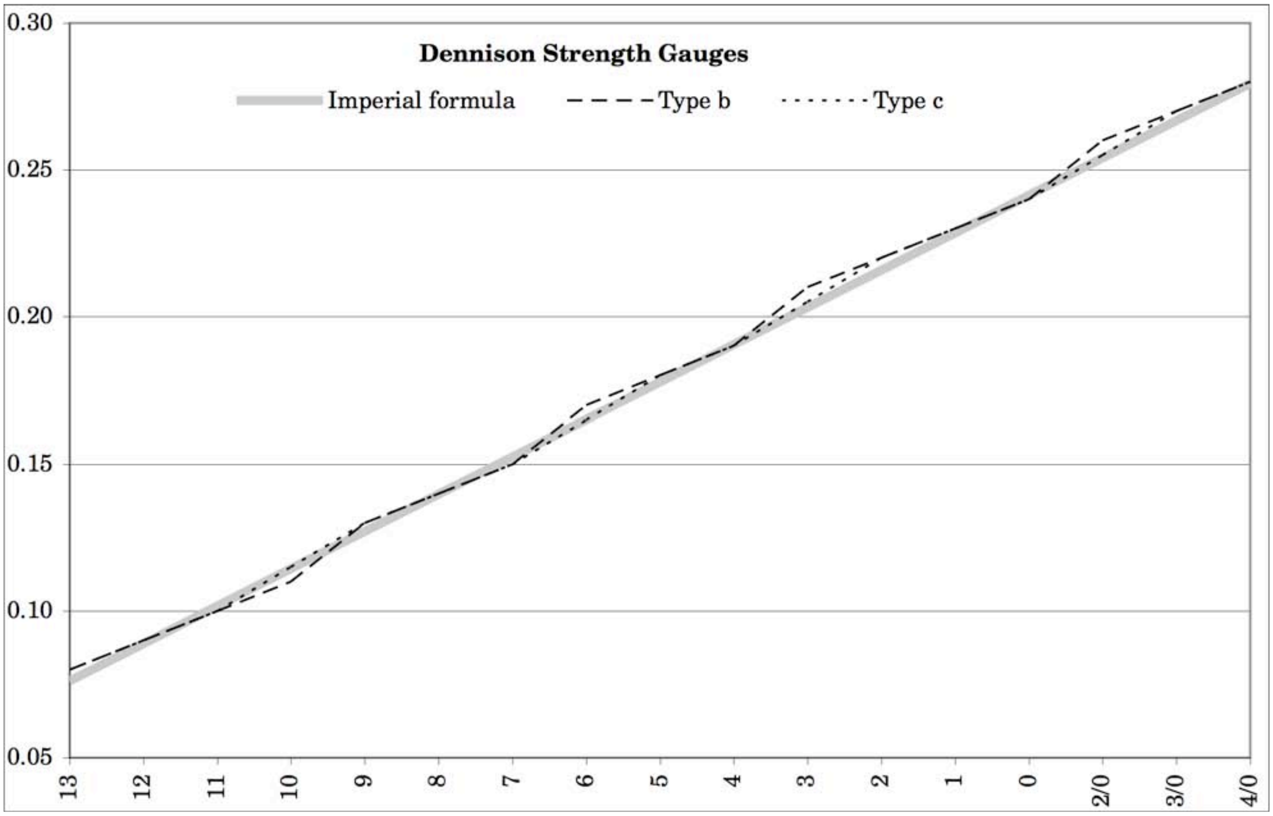
Graph 22



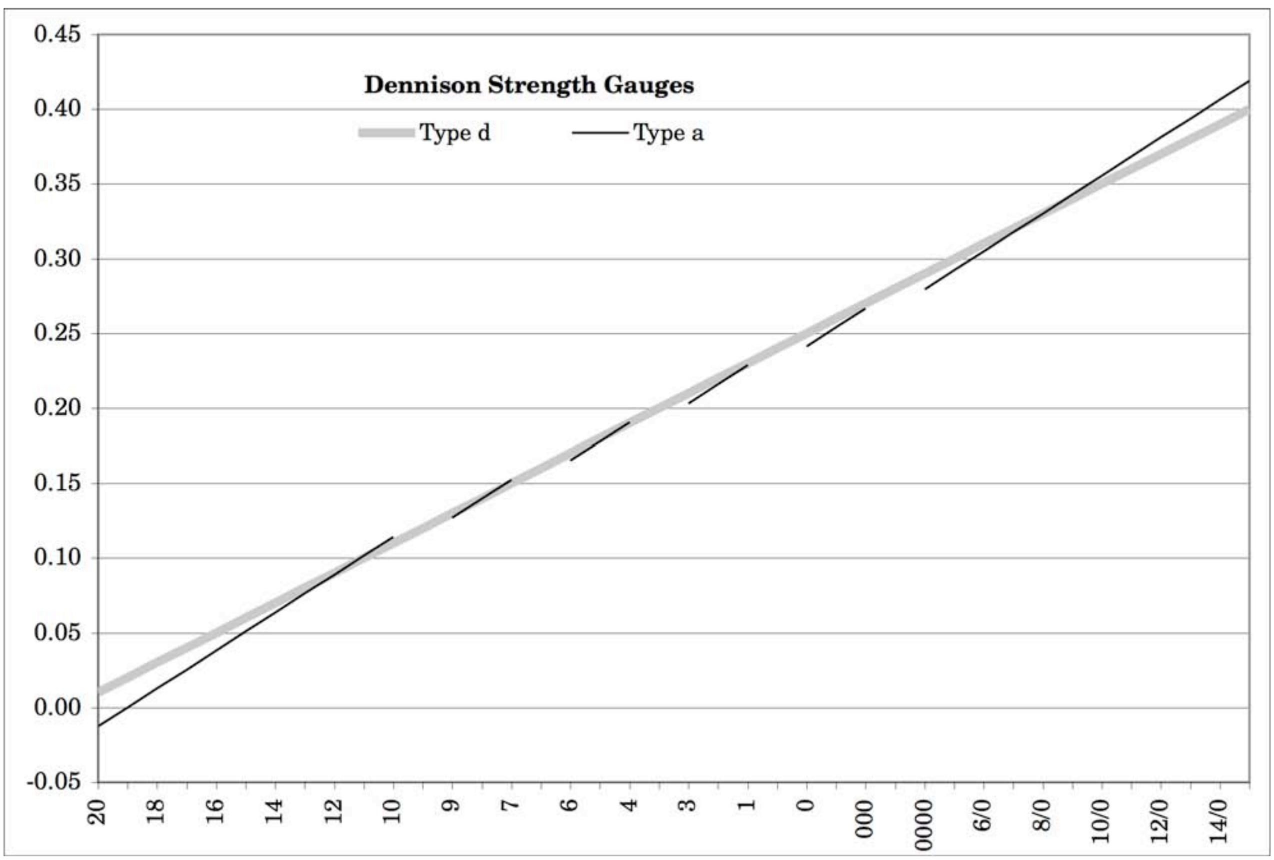
Graph 23



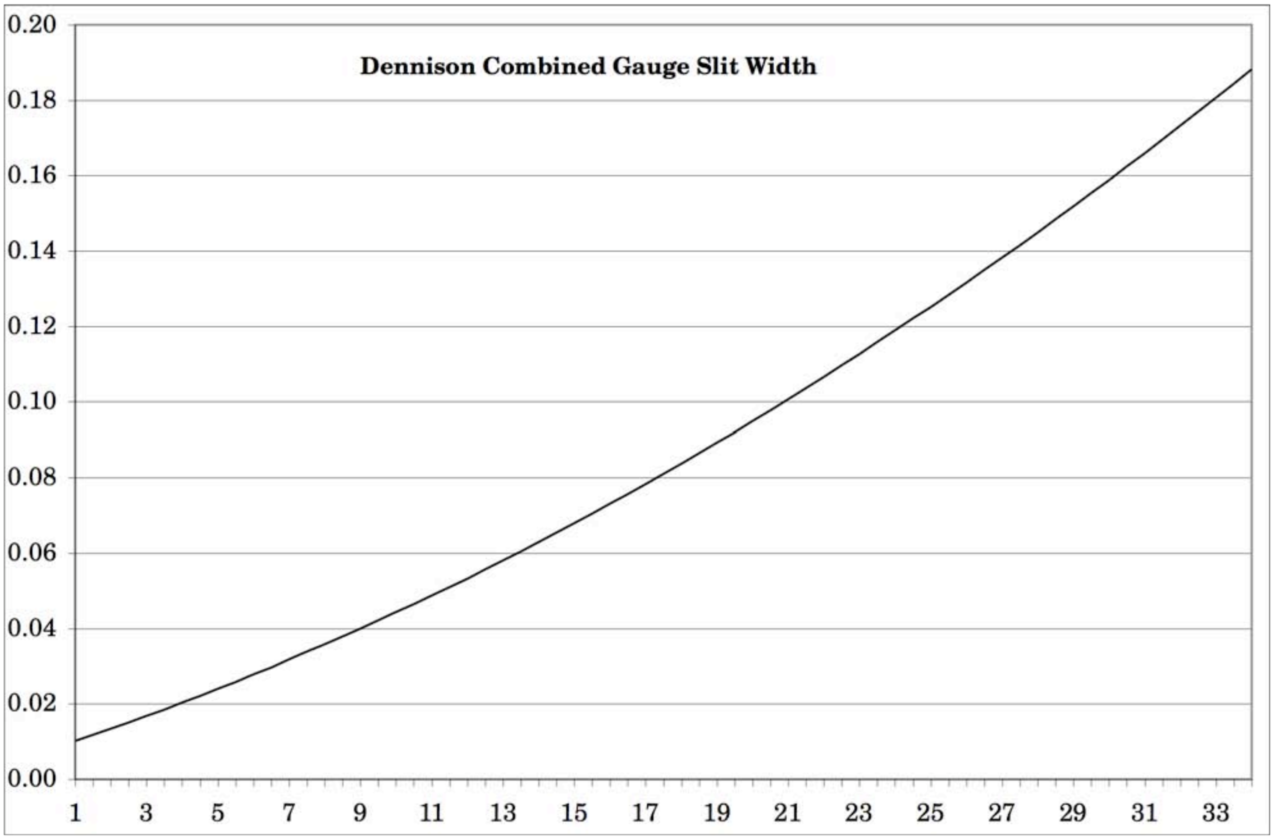
Graph 24



Graph 25



Graph 26


Dennison Combined Gauge Slit Width
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1
3
5
7
9
11
13
15
17
19
21
23
25
27
29
31
33

Graph 27