FoMRHI Comm. 2034 **Richard Corran**

Oxford Bodleian MS Mus.Sch.G.621, how long's a piece of string?

The discovery of a stringing table in the flyleaves of a copy of Denis Gaultier's *Pieces de luth* (reproduced on the cover of *Lute News* 107 and further discussed in *Lute News* 108) must rank as one of the most exciting finds in the area of stringing lutes in recent years. We must all be very grateful to Andreas Schlegel for bringing it to our notice. He has given a plausible suggestion that the numbers in the table refer to the number of strands of gut used in each string. I will show below that while this is plausible it isn't the only possible explanation. By taking a somewhat more analytical view I think it becomes possible to establish clearly what this table tells us and perhaps more disappointingly what it may not.

In the table the first aspect to note is that the ratio between the top string, 5, and the 11th course bass, 82, is around 16. If we compare this to a modern string table based entirely on gut, the ratio is too big. Generally a modern table would give a top string of, say 0.44–0.46 mm diameter, with the 11th bass around 1.80 mm diameter, a ratio of around 4. Here the single top course would have a tension of, say, 40 N, while double courses would share 50 N, equally whether unison or octave. If the square root of the ratio is taken, then the agreement would be very close. The square root would indicate that the number in the table is representing the mass per unit length of the string, because the relationship between string diameter, tension, pitch, string length and density is:-

$$f=1/dl \sqrt{(T/\pi\rho)}=1/2l \sqrt{(T/m\rho)}$$

where f is the frequency in hertz
d is the string diameter in metres
l is the string length (nut to bridge) in metres
T is the tension in Newtons
ρ is the density of the string material in kg per cubic metre
m is the mass per unit length of the string kg per metre

Consistent units must be used. It can be seen now that taking the number in the table as the number of strands is a statement about area, and this is directly proportional to mass per unit length. So any interpretation based on the square root of the numbers will give exactly the same ratios between strings as given by Andreas Schlegel.

So why is there further analysis to be done? My suggestion is that the numbers in the table actually refer to the mass of the string, and not to the number of strands. A short search on the internet gives the following standard measures of mass in the 17th century:-

French	mg
Grain	53.11
Gros	3824
Marc	244800
Once	30590
Prime	2.213
Scruple	1275

The unit of interest here is the grain at 53.11 mg. This is a very small mass, but then strings are not massive. The 1st course would be around 265 mg. If this is indeed the case, then it becomes possible to calculate the diameter of the top string once the length is determined. And this is the problem.

We don't know how long the string would be when it was measured. This is clearly not the string length on the instrument because it would have to be longer to allow attachment at peg and bridge. If strings were supplied in a standard length, and I recall hearing they were bought in a hank but can't remember where or when, then presumably they would all have had a standard length, probably in feet. So we could guess 3 feet (0,904 m) or 4 feet (1,205 m) as suitable lengths, but in truth we don't really know. But such lengths would work with lutes and also viols. Probably 3 feet is just too short for a large bass viol of over 800 mm string length, but would fit all likely lute sizes.

I have calculated the attached table of string sizes based on both 3 foot and 4 foot lengths and assuming the number refers to the number of grains mass in each string:[1]

	Length 3', 0.914 m		Length 4', 1.219 m	
Course	Dia. mm	Octave dia., mm	Dia. mm	Octave dia., mm
1	0.53		0.46	
2	0.58		0.51	
3	0.67		0.58	
4	0.79		0.69	
5	0.92		0.8	
6	1.17	0.67	1.01	0.58
7	1.35	0.72	1.17	0.62
8	1.55	0.79	1.34	0.69
9	1.67	0.86	1.45	0.74
10	1.94	0.92	1.68	0.8
11	2.16	1.01	1.87	0.88

The sizes at 4' fit very closely to a modern string table using the tensions above. Clearly the tension on an instrument will depend on the string length. I will assume 0,71 m and then the tensions come out as:-

Course	Tension, N	Tension, Octave, N
1	42.1	
2	36.8	
3	26.6	
4	23.9	
5	22.6	
6	20.2	26.6
7	21.3	24
8	22.5	23.9
9	23.7	24.7
10	25.3	23
11	25.1	22.2

For any other string length the tensions will scale as the square of the string length. It can be seen that although the table in MS Mus.Sch.G.621 must imply equal tension between bass and octave because it gives the unison 3rd as the octave 6th, the unison 4th as the octave 8th and the unison 5th as the octave 10th, the relatively coarse gradation gives only approximately equal tensions in the above table. Within the accuracy of measurement and indeed the uniformity of nominally identical strings, this looks consistent with equal tension bass: octave, equal tension on all double courses, but maybe fractionally higher tension on the top course compared to a single 2nd. The ratio of around 40 N on a single course to 50 N on a double also appears to be supported.

A major practical difficulty with the proposal that the numbers refer to mass is the difficulty of measuring such small masses accurately. Actually with 17th century technology I think it's likely that this could be done more easily than measuring the diameter. Another internet search shows scale and yard arms were were common and indeed in the 17th Century more delicate and accurate scales from China (Dotchin) were introduced with the specific purpose of weighing small masses for precious gems and materials as well as medicinal purposes. An additional factor might be weighing not one but a dozen strings at a time. Use of a yard arm, where the scale is deliberately asymmetric to allow a larger mass to be balanced by a small one combined with weighing several strings at one time would make this a viable method of characterising string sizes.

A further point is the incorporation of treated strings. If the string is modified by including a metal filament or by impregnation or even by helically winding a metal filament around it the key parameter remains the mass per unit length. Today string makers characterise such modified strings by their equivalent plain gut diameters, reflecting the ease with which we can measure diameter using a vernier calipers or micrometer, but it would be just as easy to use mass per unit length except that today we tend not to have the means to make really accurate measurements of small masses in our households. The smallest mass on my kitchen scale is 5 g, and this would be equivalent to about 20 top strings if the proposed mass of 5 grains were true.

So to summarise what can we deduce form this table:-

1. The use of the identical string size from the unison double courses in 3rd, 4th and 5th as the octave for the 6th, 8th and 10th courses implies that the bass/octave split is equal tension.

2. If we accept that the numbers represent area or mass per unit length, then the tensions for double courses come out equal from the 3rd to the 11th course.

3. Given 2. the tension on the top course is fractionally higher than the second course and it looks likely that both are single. A double 2nd course would be very highly tensioned and probably difficult to play.

4. If it is further accepted that the numbers in the table represent mass then depending on the length actual sizes can be deduced assuming the string is made of a single homogenous substance. However such an assumption does not preclude the use of modified strings.

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Note

1 I have taken the density of gut as 1300 kg.m^{-3} but Mimmo Peruffo has pointed out that, as stated in his booklet, *The lute in its historical reality*, 2012, the density of 'ropes' is less than this, say between 1100 and 1200 kg.m^{-3}. So if 'ropes' are used for the bass strings 6-11, they would actually be larger in diameter.