Towards the reconstruction of Wire Gauge Systems for early French Pianos

Paul Poletti, facteur de piano-forte, © 2006

The design of the piano has changed very little since the end of the 19th century; since then, piano manufactures have mostly been repeating a traditional production process. The modern piano maker or technician has thus lost touch with the principles by which early builders designed their instruments. One aspect of this situation is the function of the gauge system used to describe the diameters of the strings. In modern times, these numbers serve as little more than an inventory number, a code specifying which "replacement part" the technician must order from the manufacturer when repairs are needed. In ancient times, however, the situation was completely different, and the gauge system was a fundamental tool in the acoustic design process. In this presentation, Paul Poletti outlines the differences between then and now, describes the technical and acoustic challenges of designing a string plan, and demonstrates how early piano makers approached these issues.

Recent organological research on the pre-industrial piano has focused primarily upon Viennese and south German instruments, and, to a lessor extent, those of English makers. The contributions of French builders have for the most part been sadly neglected. This is particularly unfortunate, because, much like the Alsace/Lorraine region where both Pleyel and Erard began their careers, their work represents a meeting ground between contrasting cultures. These builders were influenced and inspired by both the English and Germanic schools, creating styles of building which bore the traces of both but ultimately were unlike either.

The interpretation of string gauge markings found on early French pianos reflects this duality. While these instruments resembled English pianos in many ways, they bore string markings in the Germanic (Nuremberg and Berlin) tradition. Erard soon adopted the English numbering system, but Pleyel continued using a variation of the German system. How should we interpret these marks? The simplest solution is to assume that the adoption of one or another marking system represented a corresponding dependance upon that particular wire source; were this so, we should simply adopt the generally accepted diameters for German, Austrian and English pianos of the same era. However, it is also quite possible that the disruptions of international commerce caused by the French Revolution and the succeeding Napoleanic Wars may have given impetus to a native French wire industry, which may have adopted one or another numbering system without necessarily adopting the diameters represented thereby.

As we turn our attention to the work of French makers, I would hope that we can avoid making the same mistakes which, in my opinion, have been made regarding the Viennese and south German schools. This assessment is based upon the source which I consider to be the most trustworthy of them all: the comments of historical instrument makers and technicians themselves.

In 1811, the Viennese builder Bleyer stated that the numbers stamped on the spools of wire by the manufacturers could not be trusted, because one often found the same number with different diameters, or the same diameter with different numbers. In 1817, Thon said that it was of no great disadvantage if the builder had neglected to place gauge numbers on an instrument; such numbers were of little value because the various foundries all used different systems. In 1823, von Keeß wrote that "among 12 wire manufacturers, there are hardly 2 which make all sizes according to the same gauge system." Even as late as 1886, the German maker Blüthner warned the student of piano making that different manufacturers used different systems, and that *even the wire from one and the same source was not always consistent because of the wear of the drawplates with which the wire was made*. This significance of this last statement cannot be overemphasized; considering the advances in technology which occurred over the course of the 19th century, how much worse must the problem have been circa 1800?

Despite this overwhelming documentary evidence, many modern organologists persist in seeking solutions for wire gauge markings on musical instruments based upon the historical record of wire manufacture, such as reported reduction ratios or diameter/gauge charts from one or another foundry. Others take what they assume to be a safer route; they measure the diameters found upon old instruments which appear to have original strings. In addition to the fundamental problem of verifying whether or not any surviving set of strings is truly original, there remains another drawback to this approach, which will soon become obvious.

Bleyer, Thon, and Blüthner all recommend the same remedy for this anarchy; the builder must measure the wire himself and assign a known gauge number to each diameter, ignoring whatever may be indicated on the spool. The measuring device was called a "chordometer", and both Bleyer and Blüthner describe the same type: the forked gauge. A forked gauge is simple to construct, and if made carefully, can be extremely accurate. The technical requirements were well within the capabilities of any local precision metal worker of the time: the clockmaker, the locksmith, the gunsmith, the screwmaker. In fact, the tools and techniques are so simple that the average musical instrument maker could have made one himself without the assistance of one of these specialized tradesmen.

The previous quotes indicate that over a longer period of time, musical instrument makers would have encountered an infinite variety of diameters. Each time a builder purchased more wire, he had no idea what he would actually receive. If the spools contained large amounts, the diameter may have increased or decreased slightly even within the same spool. Therefore the challenge was not simply to identify a mislabeled diameter, size 10 mislabeled as 11 for example. Instead, the chordometer would have been used to sort the available diameters into groups which approximated a predetermined graduation scheme. A particular gauge number would not have specified a particular diameter, as it does today, but rather a range of diameters, all of which could be considered to be of one particular gauge.

Today, if we measure a piece of wire and find that it is several hundredths of a millimeter too thick or too thin, we call it "out of tolerance"; we would probably reject the wire altogether and try to find "more reliable" source. For the ancient builder, there was no such luxury. A given diameter was never "out of tolerance"; it merely fell into one or another region of diameters as defined by the chordometer. This explains why we often find such a variety of diameters (by modern standards) when we examine old strings which appear to be original, even upon instruments of one and the same builder. At the moment of stringing each instrument, the workers simply used whatever diameters were on hand, sorting them as best they could to more or less agree with the desired reduction scheme. This is precisely why it is unwise to take the diameters of any one set of old strings as absolute indications of gauge sizes; each and every instrument represented nothing more than yet another approach to an ideal, subject to the caprices of the wire supply situation.

Starting therefore from the hypothesis that early French builders also used proprietary chordometers, marked with their own unique graduation systems, how might we go about reconstructing the system used by any given maker? One approach would be to take the diameters found on all surviving instruments and merely take the average for each gauge. This approach would only achieve statistical validity if we had a very large number of such instruments, a situation which sadly is not the case. Naturally, the few bits of evidence we have can act as general guides, but given the variations alluded to in the historical record, we should be wary of taking this evidence on face value.

A better approach would be to use this data as a guide to reconstruct the scale of graduation which was used to mark the original forked gauge. Three possibilities exist:

(a) a linear progression
(b) a logarithmic progression
(c) an arbitrary irregular progression

The limitations of time prevent me from exploring the many arguments for and against each solution. Let it suffice to say that today's modern music wire system, which is linear, is an historical aberration. A clear majority of ancient wire gauge systems were based on regular logarithmic reduction rates. Bleyer stated that a logarithmic reduction was required in order to give the instrument an "even voice". This comes as no surprise, as so many acoustic and psychoacoustic phenomena are based on logarithmic variations of mass, tension, energy, etc.

Therefore it is reasonably safe to assume that the practices of French builders would have been no exception to this overwhelming trend, and we should thus seek a solution using a logarithmic progression. As an instructive example, I would like to examine Pleyel's "Ancien Systeme" using data kindly provided to me by Christopher Clarke. Based on the observations of strings found on several instruments, Clarke has proposed the following solid wire diameters:

Gauge	Diameter
8/0	1.20 mm
7/0	1.12 mm
6/0	1.04 mm
5/0	0,93 mm
4/0	0,86 mm
3/0	0,81 mm
2/0	0,76 mm
0	0,71 mm
0/ ½	0,66 mm
1	0,61 mm

If we plot these diameters, no distinct trend is immediately obvious; the progression appears to be arbitrary. In fact, the S-curved shape of the data set would seem to exclude the possibility of any logarithmic interpretation. However, if we set aside for the moment the thinnest size and take gauges 7/0 and 2/0 as reference values, it is possible to construct a log curve which sufficiently approximates the data set. Only gauges 5/0 and 4/0 deviate by any noticeable amount, though neither is outside of its respective half-gauge limit. Such deviations may be caused by a non representative bias in the limited number of data samples for these two gauges.

The problem with gauge 1 may well lie in the fact that there is only one occurrence of a half gauge. If we extend the theoretical progression by another whole size, we notice that Gauge 0-half is very close to the theoretical Gauge 1, and Gauge 1 is equally close to the theoretical Gauge 2. Therefore it is quite possible that Pleyel marked the *graduations* of his forked gauge following a logarithmic progression, but for some reason chose to *label* these marks in a manner which implied a half step progression. In any event, regardless of what he called the sizes, the actual progression of diameters does in fact follow a logarithmic curve when we space them evenly. The distribution of gauge sizes on the instruments also supports this conclusion: size 0-half almost always occupies a region having the same number of notes as the "whole" sizes, up to and including 4/0.

Having determined a credible ideal series for the solid strings of the Ancien Systeme, we can now turn our attention to a unique aspect of Pleyel's stringing practice: the use of gauge marks for the wrapped strings. On Viennese and south German instruments, wrapped strings are almost without exception *not* labeled in any way, a practice followed by Erard as well. Pleyel, however, used a system which appears to be some sort of a continuation of the solid string method; the numbers continue as we would expect, but the accompanying zero is omitted. What might these number mean?

Based on the sampling of diameters found on several surviving instruments, Christopher Clarke has pointed out that in the region where the wrapped and solid systems overlap, the diameters of the wrapped strings almost coincide with the diameters of the solid strings. This lead him to suspect that the wrapped string system may have been a direct continuation of the solid system. However, if we plot Clarke's proposed wrap diameters against the ideal solid diameter curve, we see that the wrapped diameters follow their own separate logarithmic progression. This implies that Pleyel had a separate gauge for measuring wrapped strings, which would also explain the difference in numbering; one gauge with zeros for solid strings, another without zeros for wrapped strings. What purpose might this have served?

Wrapped strings are used whenever a solid string would be too thick - that is, too stiff - to sound good. It is therefore logical to expect that the mass of a wrapped string should duplicate the mass of the solid string it replaces. The total mass of a wrapped string is provided by two different materials, iron and copper. Iron is slightly lighter than brass, and copper slightly heavier. We might therefore think that a combination of the two in roughly equal proportions would more or less equal the mass of a solid brass string, given identical diameters. However, this overlooks one major aspect of wrapped strings; a significant part of the area described by the total diameter is occupied by empty space between the component strings. Therefore, any wrapped string will always be somewhat thicker than a solid brass string of the same mass.

The hidden advantage to Playel's second string gauge becomes obvious only when we examine the relationship between the actual wrapped strings and the hypothetical brass strings they replaced. Taking an average of the mass per unit length of the wrapped strings from three Pleyel pianos, we can convert these values into equivalent solid brass diameters. As we might expect, these virtual brass diameters agree almost perfectly with the hypothetical solid string diameter curve. In other words, Pleyel's wrapped string gauge appears to have been designed to produce composite strings which duplicated the mass of solid strings. How would this have worked?

The most important aspect of designing a wrapped string is the choice of the core diameter, for the strength of the string is completely dependent upon the solid iron core. A core diameter which is too small will produce a string which cannot withstand the tension; a core which is too large will defeat the purpose of making a flexible string. Determining the minimum safe core diameter would have been relatively easy. Mersenne had explained the basic relationships between string length, diameter, mass, tension, and pitch in 1636; makers probably had an empirical understanding of the topic long before this. Since the string maker was attempting to duplicate the mass of a known brass string, he knew that the eventual wrapped string would be under the same tension. Therefore he could find the smallest possible iron core values by comparing the known load of each bass note as strung in solid brass against known maximum safe tension levels for the different diameters of his iron wire.

Given a core diameter, monochord tests could determine the wrap diameter required to produce any desired mass. The test strings did not have to be full length, since everything is proportional. One merely needed to find a combination of core and wrap diameters which produced the same pitch as the original brass string under any given tension on the monochord.

The difficulty arises when we remember that this entire process would have been subject to the same unpredictable supply of diameters already mentioned. In other words, the builder had to deal with variations in the available diameters for both the core and wrap strings. Any solution arrived at by trial and error today might not be available next month, or next week, because the diameters at hand were slightly different. This is where the forked gauge offers a distinct advantage. Whatever core diameter was available at any given moment, the best available wrapping diameter could quickly be determined by merely holding two pieces of wrapping string on either side of a piece of core string and checking their combined width in the forked gauge. In less than minute, the string maker could find a combination which came as close as possible to total diameter indicated on the gauge.

The surprising thing about this system is that it produces a consistency which we might not expect from something so simple as merely checking the total diameter of a composite string. It might seem that the almost infinite number of possible combinations of core and wrap diameters for any given total diameter would produce markedly different mass values. However, as this chart shows, even with different solutions for the same wrapped gauge number, Pleyel was able to design strings which produced the desired mass per unit length with amazing consistency.

In closing, I would be the first to admit that all of this is merely hypothesis suggested by what little data we have. Before we can determine with any certainty whether or not such methods were indeed used by the Pleyel firm, or any of the early French makers for that matter, we need to collect far more data and analyze it carefully. My intent today has primarily been to encourage us all to set aside modern assumptions and thought patterns as we turn our attention to this previously neglected school of instrument making, to both confront the real challenges faced by the ancient builders and to imagine practical solutions using their tools and techniques. It is only through such a process that I feel we can best prepare ourselves to approach the restoration and reproduction of these instruments with the wisdom and respect which such cultural artifacts deserve.