



STEPHEN PAULELLO PIANO WIRE

Replacing the strings of a piano when they are missing, broken, rusty or not appropriate is part of a technician-restorer's every day life.

In order to complete a real improvement in stability, durability and tone quality on a piano, we develop **4 types** of wire, which differ from each other by the specificity of their alloy and the drawing method:

Type M, Type 0, Type 1 and Type 2.

How to choose the appropriate type(s) of wire for a piano?

The choice between several types of wire provides to the restringing a new dimension: the restorer can now focus his work towards acoustically optimized and historically correct rescaling.

In order to use the Paulello wire properly, it is advisable to plot the speaking lengths and diameters of each note and to write the data in the dedicated column of an Excel spreadsheet, which will be sent to you by request. You will thus know the **stress rate**, note by note, and will be able to model the appropriate stringing in type **M, 0, 1, 2** or a blend thereof. You'll have the possibility to observe the tension distribution, and if you wish, to change certain wire diameters and to determine the type or types which offer the best results.

What is the optimal stress rate of a string?

The *stress rate* is instrumental in the choice of wire type.

As far as the **mechanical behavior** is concerned, the strain of the wire under tension is determined by the stress level applied to the material. An **optimal stress rate range** has been observed, which reduces stabilisation time, improves tuning stability and reduces the risk of breakage.

By choosing type **M, 0, 1 or 2**, you can adjust the stress rate as to reach and remain within this optimal range.

On the other hand, the **acoustical behavior** of a vibrating string also depends on an **ideal** stress rate which allows it to render the fullness of its potential. By using the appropriate type of wire, you'll be able to reach stress rates within this optimum and get the most out of your re-stringing: more power, longer sustain and richer tone quality. This contributes to reducing weaknesses such as transition issues and power losses. The bass range will also gain in depth and legibility.

Regarding both mechanical and acoustical behaviors of the strings, **the optimal stress rate range remains the same**, which is why this criterion is so relevant.

Following the principle of the optimal stress rate, you may find out that you need to use more than one type of wire in the same piano. This practice is quite new in piano technology, however becomes popular among builders and technicians who try it. This is now considered a new standard and a turning point in piano rescaling and scale design.

Understanding the principle of stress rate and interpreting it the right way requires the appropriate terminology: Stress, strain, elastic phase, plastic phase, elastic limit, nominal breaking load, practical breaking load. Further information is provided in the addendum.

Should you want to receive the Excel sheet that will help you choose the proper type of wire, just write to the following address: info@stephenpaulello.com.

Very simple directions for use will guide you, from plotting data in the piano to modelling the tension and the stress of the strings. You will see the tension diagram and be able to even it out by modifying the diameters.

Should you have difficulties the first time you use this method, or if you are not quite sure of your choice, you can send the completed Excel sheet to Stephen Paulello so that he corrects or confirms it.

Where to find Stephen Paulello wire in the U.S ?

Arno Patin Studio LLC
918 Pomona Road
ANN ARBOR MI 48103
www.arnopianos.com Tel: (734) 369 2801

Wound strings with Paulello wire cores :

- Patrice Carrère (France)
- Cédric Cardot (France)
- Bernard Pellerin (France)
- Philippe Jacquemot (France)
- Gregor Heller (Germany)
- Peter Kelemen (Germany)
- B & K. Baumgärtel (Germany)
- J.D. Grandt (Canada)

Nickel-plated wire

Types M and 0 are also available in nickel-plated version. Nickel plating prevents corrosion and features other highly perceptible qualities: reinforcement of fundamental vibration, harmonic richness.

Soft nickel-plate iron bass strings, exclusivity of Stephen Paulello, can be manufactured to order. The acoustical qualities obtained are unmatched by copper wound strings...



Available gauges

500g coils	Available Gauges	Breaking Load (Newton / mm ²)	Recommended for: (to be confirmed by stress rate)
Type M « Modern »	12½ to 27 i.e. 0,725 à 1,7 mm	2 000 to 2 500	For modern pianos since 1880
Type M <i>Nickel plated</i>	13½ to 26 in 2 Kg i.e. 0,8 à 1,6 mm 13½ to 16½ in 500g i.e. 0,8 to 0,95 mm	2 000 to 2 500	<ul style="list-style-type: none">• Protects from corrosion,• longer and purer sustain, with more fundamental partial,• beautiful aspect
Type 0 « Post romantic »	12 to 27 i.e. 0,725 to 1,7 mm	1 700 to 2 200	<ul style="list-style-type: none">• Pianos around 1880 to about 1890• Or for modern pianos, blended with type M
Type 0 <i>Nickel plated</i>	17 to 26 i.e. 0,975 to 1,6 mm	1 700 to 2 200	Blended with nickel plated Type M
Type 1 « Romantic 1 »	9 to 26 i.e. 0,575 to 1,6 mm	1 400 to 1 800	<ul style="list-style-type: none">• Pianos from 1840 to about 1870• Or for modern pianos, blended with type M and type 0.
Type 2 « Romantic 2 »	5 to 24 i.e. 0,4 to 1,4 mm	1 000 to 1 400	Instruments from 1820 to about 1840

Addendum: Why focus on stress rate ? What are its critical values?

When it comes to deciding on the replacement wire for the re-stringing, one can rely on several criteria to help choosing the appropriate material. In order to understand our philosophy, let us examine the diverse possible criteria that lead to the correct choice, and see why we favour one versus the other.

The piano make or manufacturing location and date, for example, are of a documentary interest but far from being sufficient as a guide for optimal string replacement. In the 19th century, there were actually so many different materials depending on geographic origins and stage of metal technology that it is impossible to know the characteristics of the original material. It would be very complicated to copy and produce so many different qualities of wires.

The density of the metal is not of major importance either: according to the alloy, the density actually varies between the minimum value of 7.65 gr/cm³ for iron and the maximum of 7.95 gr/cm³ for some steels. Considering that between these extremes, one gets a discrepancy of tensile strength of only about 4 %, this information can be held as irrelevant.

The modulus of elasticity is a major feature of the vibrating string inharmonicity and as such is an interesting criterion. Many measurements made on original string scales from antique instruments in excellent condition allowed us to recreate raw materials with similar elastic properties. It allows retaining the original inharmonicity rates and fully respecting the tone colour of the piano while reducing the risks of bridge splitting at the pins due to too much stiffness when using regular modern wire.

The stress rate, as mentioned earlier, is the most relevant criterion.

The nominal breaking loads of Paulello wires rise from 1000 for type 2 to 2600 Newton per mm² for type M. The various bends, loops and twists applied to the wire while re-stringing make it necessary to reduce these theoretical values by 25 % as a safety margin for types M, 0 and 1 and by 15 % safety margin for type 2. What we call the practical breaking load is the nominal breaking load with this safety margin subtracted.

The elastic limit of a steel wire stands at about 80 % of its practical breaking load. This means that when put under tension, the string stretches (elastic phase). Then, beyond a stress rate of 80 %, it turns into plastic phase and strains irreversibly, so that, even when tension is reduced, it doesn't return to its original shape. A string which is stressed over its elastic limit won't hold tuning anymore; it becomes very inharmonic and ultimately breaks.

Since Mersenne's work about gut strings until the recent researches by Claude Valette and Christian Cuesta in their book dedicated to vibrating strings, it is generally accepted that a string provides the fullness of its vibrating power when it is stressed to around 60 to 75% of its practical breaking load, or close to its elastic limit (Re). Stressing a string in this way actually limits internal damping and offers the best balance between the fundamental frequency and higher partials.

It is also at the end of the elastic phase that the material restores its internal structure most rapidly and that the stringing stability is reached in a shorter time. Later, if you maintain this piano, you'll observe that tuning is more durable and that string breakage is reduced.

Mechanical specificities :

TYPE M

Average density (av. ρ) = 7,85 gr/cm³
Modulus of elasticity (E) = 202 Gpa

N°	Ø (mm)	Mr / mm ²	Mr	PBL(NBL- 25 %)	Re
12	0,725	2462	1016,37	762,281	632,7
12,5	0,75	2447	1081,05	810,789	664,8
13	0,775	2437	1149,61	862,204	698,4
13,5	0,8	2427	1219,94	914,957	732
14	0,825	2417,5	1292,30	969,227	765,7
14,5	0,85	2398,5	1361,03	1020,77	796,2
15	0,875	2388,5	1436,25	1077,19	829,4
15,5	0,9	2378,5	1513,14	1134,85	862,5
16	0,925	2369	1591,98	1193,99	895,5
16,5	0,95	2364	1675,65	1256,74	930
17	0,975	2349,5	1754,18	1315,64	960,4
17,5	1	2339,5	1837,44	1378,08	992,2
18	1,025	2329,5	1922,21	1441,66	1024
18,5	1,05	2320	2008,89	1506,67	1055
19	1,075	2310,5	2097,07	1572,8	1101
19,5	1,1	2310,5	2195,74	1646,81	1153
20	1,125	2300,5	2286,74	1715,06	1201
20,5	1,15	2300,5	2389,50	1792,13	1254
21	1,175	2280,5	2472,84	1854,63	1298
21,5	1,2	2280,5	2579,18	1934,39	1354
22	1,225	2271	2676,57	2007,43	1405
22,5	1,25	2261,5	2775,28	2081,46	1457
23	1,3	2246,5	2981,83	2236,37	1565
23,5	1,35	2232	3194,86	2396,14	1677
24	1,4	2217	3412,81	2559,6	1792
24,5	1,45	2207,5	3645,24	2733,93	1914
25	1,5	2192,5	3874,47	2905,85	2034
25,5	1,55	2168	4090,84	3068,13	2148
26	1,6	2158	4338,92	3254,19	2278
27	1,7	2133,5	4842,62	3631,96	2542

TYPE 0

Average density (av. ρ) = 7,81 gr/cm³
Modulus of elasticity (E) = 202 Gpa

N°	Ø (mm)	Mr / mm ²	Mr	PBL (NBL-25%)	Re
12	0,725	2179	899,5	674,659	560
12,5	0,75	2163	955,6	716,688	587,7
13	0,775	2147	1013	759,603	615,3
13,5	0,8	2131	1071	803,368	642,7
14	0,825	2115	1131	847,948	669,9
14,5	0,85	2099	1191	893,308	696,8
15	0,875	2083	1253	939,413	723,3
15,5	0,9	2067	1315	986,226	749,5
16	0,925	2051	1378	1033,71	775,3
16,5	0,95	2035	1442	1081,84	800,6
17	0,975	2019	1507	1130,57	825,3
17,5	1	2003	1573	1179,86	849,5
18	1,025	1987	1640	1229,69	873,1
18,5	1,05	1971	1707	1280,02	896
19	1,075	1955	1774	1330,81	931,6
19,5	1,1	1939	1843	1382,02	967,4
20	1,125	1923	1911	1433,62	1004
20,5	1,15	1907	1981	1485,59	1040
21	1,175	1891	2050	1537,87	1077
21,5	1,2	1875	2121	1590,43	1113
22	1,225	1859	2191	1643,25	1150
22,5	1,25	1843	2262	1696,28	1187
23	1,3	1827	2425	1818,76	1273
23,5	1,35	1811	2592	1944,18	1361
24	1,4	1795	2763	2072,39	1451
24,5	1,45	1779	2938	2203,25	1542
25	1,5	1763	3115	2336,61	1636
25,5	1,55	1747	3296	2472,34	1731
26	1,6	1731	3480	2610,29	1827
27	1,7	1715	3893	2919,53	2044

TYPE 1

Average density (av. ρ) = 7,85 gr/cm³
 Modulus of elasticity (E) = 202 Gpa

N°	Ø (mm)	Mr / mm ²	Mr	PBL(NBL- 25 %)	Re
9	0,575	1920	498,6	373,928	299,14
9,5	0,6	1900	537,2	402,909	322,33
10	0,625	1880	576,8	432,583	341,74
10,5	0,65	1860	617,2	462,904	365,69
11	0,675	1840	658,4	493,829	385,19
11,5	0,7	1820	700,4	525,314	409,74
12	0,725	1800	743,1	557,314	429,13
12,5	0,75	1780	786,4	589,785	454,13
13	0,775	1760	830,2	622,683	473,24
13,5	0,8	1740	874,6	655,965	498,53
14	0,825	1720	919,4	689,584	517,19
14,5	0,85	1700	964,7	723,499	542,62
15	0,875	1680	1010	757,664	560,67
15,5	0,9	1660	1056	792,035	586,11
16	0,925	1640	1102	826,568	603,39
16,5	0,95	1620	1148	861,219	628,69
17	0,975	1600	1195	895,943	645,08
17,5	1	1580	1241	930,697	670,10
18	1,025	1560	1287	965,436	685,46
18,5	1,05	1540	1333	1000,12	710,08
19	1,075	1520	1380	1034,69	724,29
19,5	1,1	1500	1425	1069,12	748,39
20	1,125	1480	1471	1103,36	772,35
20,5	1,15	1460	1516	1137,36	796,16
21	1,175	1440	1561	1171,09	819,76
21,5	1,2	1420	1606	1204,49	843,14
22	1,225	1400	1650	1237,52	866,26
22,5	1,25	1380	1694	1270,14	889,10
23	1,3	1360	1805	1353,87	947,71
23,5	1,35	1340	1918	1438,55	1006,98
24	1,4	1320	2032	1523,99	1066,79
24,5	1,45	1300	2147	1610,02	1127,01
25	1,5	1280	2262	1696,46	1187,52
25,5	1,55	1260	2378	1783,14	1248,20
26	1,6	1240	2493	1869,88	1308,91

TYPE 2

Average density (av. ρ) = 7,82 gr/cm³
 Modulus of elasticity (E) = 202 Gpa

N°	Ø	Mr / mm ²	Mr	PBL(NBL- 15 %)	Re
5	0,4	1479,20	185,88	158,00	121,66
5,5	0,425	1467,87	208,24	177,00	136,29
6	0,45	1457,24	231,76	197,00	151,69
6,5	0,475	1440,67	255,29	217,00	167,09
7	0,5	1426,03	280	238,00	183,26
8	0,525	1418,45	307,06	261,00	200,97
8,5	0,55	1401,37	332,94	283,00	217,91
9	0,575	1390,89	361,18	307,00	233,32
9,5	0,6	1377,26	389,41	331,00	251,56
10	0,625	1365,15	418,82	356,00	267,00
10,5	0,65	1350,79	448,24	381,00	285,75
11	0,675	1338,07	478,82	407,00	301,18
11,5	0,7	1323,68	509,41	433,00	320,42
12	0,725	1310,91	541,18	460,00	335,80
12,5	0,75	1299,54	574,12	488,00	356,24
13	0,775	1286,88	607,06	516,00	371,52
13,5	0,8	1273,24	640	544,00	391,68
14	0,825	1261,07	674,12	573,00	406,83
14,5	0,85	1246,03	707,06	601,00	426,71
15	0,875	1234,54	742,35	631,00	441,70
15,5	0,9	1220,53	776,47	660,00	462,00
16	0,925	1207,97	811,76	690,00	483,00
16,5	0,95	1195,02	847,06	720,00	504,00
17	0,975	1181,80	882,35	750,00	525,00
17,5	1	1168,38	917,65	780,00	546,00
18	1,025	1156,28	954,12	811,00	567,70
18,5	1,05	1142,64	989,41	841,00	588,70
19	1,075	1130,29	1025,9	872,00	610,40
19,5	1,1	1116,64	1061,2	902,00	631,40
20	1,125	1104,25	1097,6	933,00	653,10
20,5	1,15	1090,74	1132,9	963,00	674,10
21	1,175	1078,45	1169,4	994,00	695,80
21,5	1,2	1065,19	1204,7	1024,00	716,80
22	1,225	1052,11	1240	1054,00	737,80
22,5	1,25	1039,20	1275,3	1084,00	758,80
23	1,3	1026,39	1362,4	1158,00	810,60

Mr = Mechanical Resistance
 PBL = Practical Breacking Load
 Re = Elastic Limit



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