



THE STEPHEN PAULELLO PIANO WIRE

Since strings are often missing, broken, rusted or badly replaced, technicians are inevitably confronted to the critical problem of changing strings while rebuilding keyboard instruments.

In order to fit the new stringing in the best way, five types of wire are proposed: type M, type 0, type 1, type 2 and type 3.

INTRODUCTION

Why is it important to propose a choice between several types of wire?

What is the difference between them?

To help you understand our philosophy, let us examine the diverse possible criteria that lead to the right choice for rescaling and stringing, and explain why we favour one versus the others.

Actually, several criteria of graduated pertinence should be considered:

Documentary, but insufficient.

The maker's brand, the manufacturing date and location of the instrument;

Insignificant: the density of the metal.

It is an interesting indication because it is a component of the string tensile strength calculation formula. It is expressed in gr/cm^3 and varies, according to the material in use, between the minimum value of 7.65 gr/cm^3 and the maximum of 7.95 gr/cm^3 for some irons.

Interesting: the modulus of elasticity, or Young modulus.

The module of elasticity has no incidence on the tensile strength but it interferes within the calculation of inharmonicity. According to the material that is used, it can vary from 10% to 15%, which is far from being inconsiderable. Many plots made on ancient string scales in excellent condition allowed us to choose raw materials with similar elastic properties. The risk of splitting on the soundboard, pin-block and bridge pins is reduced, and the tone colour of the instrument is fully respected.

Essential: the stress rate.

It is the criterion we retained in order to choose which type of wire to use. It affects both mechanical and acoustical aspects of strings.

Mechanical: the resistance to strain of the different types of iron rises from 600 to 2600 Newton per mm², according to the diameter and above all to the type of iron. The various bends, loops and twists manhandle it, and that is why the result of the test of nominal breaking strength will have to be reduced by 15 % for type 2 and 3, and by 25 % for the other types, so as to provide the real breaking strength.

The elasticity limit of a string stands at about 80 % of its real breaking strength. Beyond that, it is irreversibly drawn out of shape, does not stay in tune, becomes very inharmonic and finally breaks.

Acoustical: Since Mersenne, until the recent research made at the Laboratory of Acoustics of the School of Physics in the University of Paris on vibrating strings, it has been unanimously admitted that a string, in order to vibrate with the minimum internal amortisement and with a good balance between the fundamental frequency and the upper range partials, should be solicited in a proportion rising from **60 to 75 % of its real breaking load**, that is to say very close to its elastic limit.

Consequently, it is highly advisable to choose a type of steel which fulfils these conditions.

THE FIVE TYPES OF WIRE

Modern:

Type M:

- 500 g or 2 kg coils
- Diameters : from 0.750 to 1.600 mm
- Designed for pianos built between 1880 and today.
- The breaking strength rises from 2000 to 2500 Newton per mm² according to the diameter.
- **PRICE in US \$: \$ 12.00 per 500 gram coil, \$ 34.00 per 2Kg coil**
+ shipping from Ann Arbor, MI to the US or Canada.

Independently from the usually required specificities (diameter tolerances, perfection of the cylinder and polishing, consistency of wiredrawing, resistance and suppleness under crushing etc...), the purpose of the strings designed for instruments built between 1880 and today is to:

- Reduce the internal damping,
- Balance harmoniously the fundamental frequency and the different partials,
- Accelerate the process of stabilisation.

Thanks to the great care taken for the wiredrawing, its low speed, the choice of the number of dies, the choice of the coefficient of deformation, these strings present a beautiful shiny aspect, a spectacular sustain, thanks to a minimal damping rate and an exceptional consistency in their mechanical performances. They are characterized by a long, powerful and well-defined medium.

Post-Romantic:

Type O:

- 500 gram or 2 kg coils
- Diameters : from 0.750 to 1.600 mm
- Designed for French pianos stringed with **Firminy** steel between 1880 and 1920 (according to the vibrating length)
- The breaking strength rises from 1800 to 2200 Newton per mm² according to the diameter.
- **PRICE in US \$: \$ 15.00 per 500 gram coil, \$ 39.00 per 2Kg coil.**
- **+ shipping from Ann Arbor, MI to the US or Canada.**

Romantic:

Type 1:

- 500 gram coils
- Diameters : from 0.575 to 1.600 mm
- Designed for pianos built between 1840 and 1870, (according to the vibrating length).
- The breaking strength rises from 1400 to 1800 Newton per mm² according to the diameter.
- **PRICE in US \$: \$ 20.00 per 500 gram coil**
- **+ shipping from Ann Arbor, MI to the US or Canada.**

Type 2:

- 500 gram coils
- Diameters from 0.525 to 1.400 mm
- Designed for pianofortes built between 1820 and 1840 (according to the vibrating length).
- The breaking strength rises from 1000 to 1400 Newton per mm² according to the diameter.
- **PRICE in US \$: \$ 22.00 per 500 gram coil**
- **+ shipping from Ann Arbor, MI to the US or Canada.**

Classic:

Type 3:

- 125 gram coils
- Diameters from 0.200 to 0.700
- Designed for pianofortes, harpsichords, spinets and clavichords built before 1820 (according to the vibrating length).
- The breaking strength rises from 800 to 1600 Newton per mm² according to the diameter
- **PRICE in US \$: \$ 13.00 per 125 gram coil**
- **+ shipping from Ann Arbor, MI to the US or Canada.**

HOW TO USE THEM

The following instruction will guide your choice within 5 types of strings.

- Plot the vibrating length of each A in the piano from A 49 on, they will be the references.
- Plot the diameters.
- Determine the pitch in which you wish to stabilize the instrument (generally according to its date of building).
- Look up into the different tables which types allow to make all these parameters coincide. The red figure indicates, for a given diameter and pitch, the vibrating length not to be exceeded.

Example: on an Erard model 0 (1.80 m) of 1928 the following datas have been plotted:

- Vibrating length of A 49 : **409 mm**
- diameter : 0.925 mm
- the pitch will remain 440 Hz

Let us look for each A 49 in the tables. On the line « 440Hz », in the column « 0.925mm » we notice that only the 0 Type allows a vibrating length of 409 mm (the limit is **440 mm**). Type 1 ends by 390 mm and type 2 by 349 mm.

Type 0

A 49	0,9	0,925	0,95	0,975	1	1,025
435 Hz	447	445	444	442	441	439
440 Hz	442	440	439	437	436	434
442 Hz	440	438	437	435	433	432

A 61	0,825	0,850	0,875	0,9	0,925	0,95
870 Hz	225	224	224	223	222	221
880 Hz	223	222	222	221	220	219
884 Hz	222	221	221	220	219	218

A 73	0,775	0,8	0,825	0,850	0,875	0,9
1740Hz	115	115	114	114	113	113
1760Hz	114	114	113	113	112	112
1768Hz	113	113	112	112	111	111

A 85	0,725	0,750	0,775	0,8	0,825	0,850
3480Hz	58	58	57,5	57,5	57	57
3520Hz	57	57	57	57	57	57
3536Hz	57	57	57	56,5	56,5	56

Type 1

A 49	0,8	0,825	0,850	0,875	0,9	0,925	0,950	0,975	1
415 Hz	425	423	421	418	416	413	411	408	405
420 Hz	420	418	416	413	411	408	406	403	400
425 Hz	415	413	411	408	406	403	401	398	395
430 Hz	410	408	406	403	401	398	396	393	390
435 Hz	405	403	401	399	396	394	391	389	386
440 Hz	400	399	397	395	392	390	387	385	382

A 61	0,725	0,75	0,775	0,8	0,825	0,85	0,875	0,9
830Hz	216	215	214	212	211	210	209	207
840 Hz	213	212	211	209	208	207	206	204
850 Hz	210	209	208	206	205	204	203	202
860 Hz	208	206	205	204	203	202	201	200
870Hz	206	204	203	202	201	200	199	198
880 Hz	204	202	201	200	199	198	197	196

A 73	0,7	0,725	0,75	0,775	0,8	0,825	0,85	0,875
1660 Hz	108	107	107	106	106	105	105	104
1680 Hz	107	106	105	104	104	103	103	102
1700 Hz	106	105	104	103	103	102	102	101
1720 Hz	105	104	103	102	102	101	101	100
1740 Hz	104	103	102	101	101	100	100	99
1760 Hz	103	102	101	100	100	99	99	98

A 85	0,575	0,6	0,625	0,65	0,675	0,7	0,725	0,75	0,775	0,8	0,825	0,850
3320 Hz	57	56,5	56	55,5	55,5	55,5	55	54,5	54	54	53,5	53,5
3360 Hz	56	55,5	55,5	55	55	54,5	54	53,5	53	53	53	53
3400 Hz	55	55	55	54,5	54,5	54	53,5	53	52,5	52,5	52,5	52,5
3440 Hz	54,5	54,5	54,5	54	54	53,5	53	52,5	52	52	52	52
3480 Hz	54	54	54	53,5	53,5	53	52,5	52	51,5	51,5	51,5	51,5
3520 Hz	53,5	53,5	53,5	53	53	52,5	52	51,5	51	51	51	51

Type 2

A 49	0,725	0,75	0,775	0,8	0,825	0,850	0,875	0,9	0,925	0,950
415 Hz	394	391	388	385	382	379	376	373	370	367
420 Hz	389	386	384	381	377	374	371	368	365	362
425 Hz	385	382	379	376	373	370	367	364	361	358
430 Hz	381	378	375	372	369	366	363	360	357	354
435 Hz	376	373	370	367	364	361	358	355	353	350
440 Hz	372	369	366	363	360	357	354	351	349	346

A 61	0,7	0,725	0,75	0,775	0,8	0,825	0,850	0,875	0,9
830Hz	198	197	196	194	192	191	189	188	186
840 Hz	196	195	194	191	190	188	187	185	184
850 Hz	194	193	191	189	188	186	185	183	182
860 Hz	192	191	189	187	186	184	183	181	180
870Hz	190	189	187	185	184	182	181	179	178
880 Hz	187	186	184	183	182	180	179	177	176

A 73	0,625	0,65	0,675	0,7	0,725	0,750	0,775	0,800	0,825	0,85
1660 Hz	99	99	99	99	98	97	97	96	95	94
1680 Hz	98	98	97	97	97	96	95	94	94	93
1700 Hz	97	97	96	96	96	95	94	93	93	92
1720 Hz	96	96	95	95	95	94	93	92	92	91
1740 Hz	95	95	94	94	94	93	92	91	91	90
1760 Hz	94	94	93	93	93	92	91	90	90	89

F 81	0,525	0,550	0,575	0,60	0,625	0,65	0,675	0,7	0,725	0,750	0,775	0,800
2635 Hz	65	64,5	64,5	64	64	63	63	63	63	62	62	61
2666 Hz	64	64	63,5	63	63	63	62	62	62	61	61	60
2698 Hz	63	63	62,5	62	62	62	62	61	61	61	60	60
2730 Hz	62,5	62,5	62	62	61	61	61	61	60	60	60	59
2762 Hz	62	61,5	61,5	61	61	61	61	60	60	59	59	58
2793 Hz	61	61	61	60	60	60	60	60	59	58	58	58

THE PHILOSOPHY OF RESCALING

While rebuilding a piano, it is possible to improve the sound quality of the instrument and, for example, to redesign the transition from steel strings to covered strings, by playing with the different diameters and types of wire, in order to optimize the stress of the string scale.

Example: On a Steinway model O, the first steel string being B 27:

Note	Type	vibrating length	Diameter	Tension (Newton)	Stress %
B 27	Modern	1110 mm	1.025	491.1 N	34.46
B 27	Type 1	1110 mm	1.025	491.1 N	44.89
B 27	Type 2	1110 mm	1.025	491.1 N	63.65

According to the wire type, **we always obtain the same tension**, but **the stress varies**.

The most interesting solution is to use type 2 because the stress rate will be 63.65%: this is profitable for the tuning stability as well as for the sound quality.

This operation requires a little calculation, but you will be rewarded by a better sound result and a tremendous time saving when voicing the piano.

Thanks to the following table you will be able to do these calculations:

Type M			Type 0			Type 1			Type 2		
N°	Diam	Real breaking point	N°	Diam.	Real breaking point	N°	Diam.	Real breaking point	N°	Diam.	Real breaking point
12	0,725	790	12	0,725	681,2	9	0,575	373,92	8	0,525	263,12
12,5	0,75	840	12,5	0,75	724,2	9,5	0,6	402,9	8,5	0,55	286,76
13	0,775	890	13	0,775	768,2	10	0,625	432,58	9	0,575	311,21
13,5	0,8	940	13,5	0,8	813,2	10,5	0,65	462,9	9,5	0,6	336,46
14	0,825	990	14	0,825	859,1	11	0,675	493,83	10	0,625	362,47
14,5	0,85	1040	14,5	0,85	905,9	11,5	0,7	525,31	10,5	0,65	389,23
15	0,875	1090	15	0,875	953,5	12	0,725	557,31	11	0,675	416,71
15,5	0,9	1140	15,5	0,9	1002	12,5	0,75	589,78	11,5	0,7	444,88
16	0,925	1200	16	0,925	1051	13	0,775	622,68	12	0,725	470,2
16,5	0,95	1255	16,5	0,95	1101	13,5	0,8	655,96	12,5	0,75	495,68
17	0,975	1310	17	0,975	1152	14	0,825	689,58	13	0,775	521,26
17,5	1	1365	17,5	1	1203	14,5	0,85	723,5	13,5	0,8	546,88
18	1,025	1425	18	1,025	1255	15	0,875	757,65	14	0,825	572,51
18,5	1,05	1480	18,5	1,05	1308	15,5	0,9	792	14,5	0,85	598,09
19	1,075	1540	19	1,075	1361	16	0,925	826,57	15	0,875	623,56
19,5	1,1	1610	19,5	1,1	1415	16,5	0,95	861,22	15,5	0,9	648,89
20	1,125	1685	20	1,125	1470	17	0,975	895,95	16	0,925	674,02
20,5	1,15	1760	20,5	1,15	1525	17,5	1	930,67	16,5	0,95	698,89
21	1,175	1840	21	1,175	1580	18	1,025	965,4	17	0,975	723,47
21,5	1,2	1915	21,5	1,2	1636	18,5	1,05	1000,1	17,5	1	747,69
22	1,225	1995	22	1,225	1692	19	1,075	1034,7	18	1,025	771,52
22,5	1,25	2070	22,5	1,25	1749	19,5	1,1	1069,12	18,5	1,05	794,89
23	1,3	2175	23	1,3	1877	20	1,125	1103,32	19	1,075	817,77
23,5	1,35	2290	23,5	1,35	2009	20,5	1,15	1137,37	19,5	1,1	840,09
24	1,4	2420	24	1,4	2144	21	1,175	1171,12	20	1,125	861,81
24,5	1,45	2590	24,5	1,45	2282	21,5	1,2	1204,5	20,5	1,15	882,88
25	1,5	2770	25	1,5	2424	22	1,225	1237,5	21	1,175	903,25
25,5	1,55	3000	25,5	1,55	2568	22,5	1,25	1270,12			
26	1,6	3300	26	1,6	2714	23	1,3	1353,9			

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