XIII. *The Solar Spectrum, from* λ 7150 *to* λ 10,000.

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[PLATES 26–28.]

THE accompanying map of the solar spectrum between the limits of λ 7150 and λ 10,000 is made from photographs taken with the diffraction gratings, and is more complete in every respect than the map from λ 7600 to λ 10,000 which appeared in the Phil. Trans. for 1880, under the title of "The Method of Mapping the Least Refrangible End of the Spectrum." In the map which accompanied the paper above referred to the scale numbers attached to the different lines have more accuracy than the wave numbers, and it was to correct the latter that the new series of photographs have been taken. It is my intention at some future and indeterminate time to publish the photographs of this region in connexion with Professor ROWLAND's new photographic spectrum which he has in hand, and these will show the minute features of the spectrum down to a wave-length of nearly double that shown; but as the wave-lengths adopted for the visible spectrum by Professor ROWLAND differ slightly from those given by ÅNGSTRÖM, I have thought it better to publish the part which is to supersede the map of 1880 on the latter scale, leaving the discussion of the true wave-numbers to a later period.

It must be recollected at the time the first map of this region was made that the photographic process employed was comparatively new—that is to say, it had been brought to its true state of perfection but a short time. Four years have elapsed since then, and much experimental work has been undertaken in connexion with it; and moreover the instrumental defects which were then present have been remedied to a large extent, new apparatus having been procured and finer gratings having been employed.

Process employed.

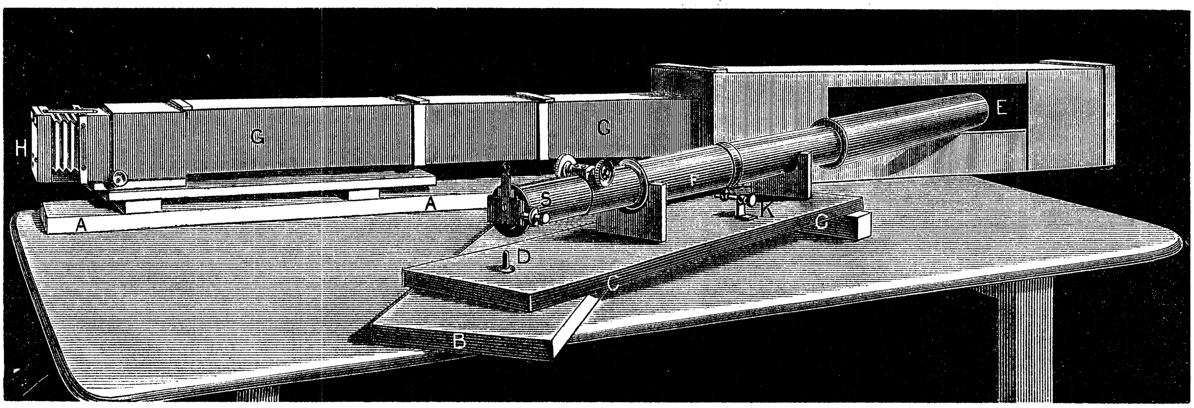
A reference to the paper of 1880 will give the idea of the sensitive salt of silver which I then employed, and as regards its nature I have not found any marked improvement to note; but in the development I have succeeded in effecting an advance. My developer now, as then, is the ferrous oxalate developer, but I have found that by employing a glass plate which is previously coated with gelatine emulsion instead of a bare glass plate to receive the sensitive salt, a more powerful solution of ferrous oxalate, without any large addition of restrainer, is capable of being used. The mode of preparation of the collodion emulsion is nearly the same as that given in the Phil. Trans. for 1880, except that I find the addition of nitric acid is not necessary to be present whilst the emulsion is formed, though in the subsequent washings it is convenient to use it. This may be avoided, however, by washing first with water, and using a dilute solution of iodine to eliminate the veil which is nearly always present after the emulsion is boiled. To the emulsion when prepared I add about $\frac{1}{2}$ per cent. of good soluble cotton; that known as ANTHONY'S No. 1 I find the most satisfactory. A very sensitive gelatine emulsion plate is coated with the collodion emulsion, washed, and then allowed to dry in a warm chamber. The washing causes a minute portion of the underlying gelatine to mingle with the collodion film surrounding the sensitive salt, and to protect it from premature reduction by the ferrous oxalate solution. As I have pointed out in other communications, gelatine acts as a physical restrainer, in contradistinction to a soluble alkaline bromide, which acts as a chemical restrainer. When the former is used there is no partial obliteration of the effect of radiation on the salt, as is the case when the latter is employed; and as a consequence a shorter exposure is necessary.

Apparatus employed.

At first I used the grating with which I had worked for some time previously in my preliminary work. It had a surface of $1\frac{1}{2}$ inches square and about 17,200 wires to the inch, and it is excellent in its performance though with spectra of high orders, ghosts can be traced. Wishing to use less dispersion to obtain a higher wave-length, I secured from Mr. CHAPMAN, of New York, a grating ruled on parallel glass which Mr. A. HILGER had prepared. For the visible spectrum this glass grating gives excellent results, but it is otherwise for the infra-red. When I obtained the grating I backed it with a mercury amalgam, intending to use it as a reflection grating through the glass, but on trying it I found that the spectrum in the first order ceased about λ 8300. This want of success I laid to the metallic backing, and removed it to replace it with one of silver. The glass was carefully cleaned with nitric acid and very dilute potash and alcohol, and silvered by MARTIN'S process. On taking it from the bath I was surprised to find that the layer of silver was so delicate that it took in the grooves formed by the rulings, and that reflection spectra could be taken from both surfaces, *i.e.*, from the silvered surface direct or through the glass. A grating such as this would have proved of the very greatest service, since all that is necessary to have a perfect reflecting surface is to remove the silver film and to re-silver again. Unfortunately the grating thus silvered proved to be useless for my purpose, for there was no infra-red spectrum, probably owing to some peculiarity in the shape of the grooves formed in ruling. That such phenomena are by no means uncommon would now appear to be recognised. Professor ROWLAND most generously gave me several gratings, and amongst them is one ruled on a spherical concave surface, of a radius of 7 feet 9 inches. This grating is so ruled that there is one really bright spectrum, and that one of the first order; all the other spectra are faint. In another grating the spectrum of the third order is brighter than the second order on one side, and the second order brighter than the first order on the other side. This shows that the very greatest care must always be taken in deducing any value for radiation in any particular region unless the constants of the particular grating employed are known. Both of these last-mentioned gratings have been employed for the producing the photographs to which the map is referred. Besides these, Professor ROWLAND sent me for this work two beautiful concave gratings of about 3600 lines to the inch, of 5 feet 7 inches and 4 feet 8 inches radii respectively. These have been employed for the still lower regions of the spectrum.

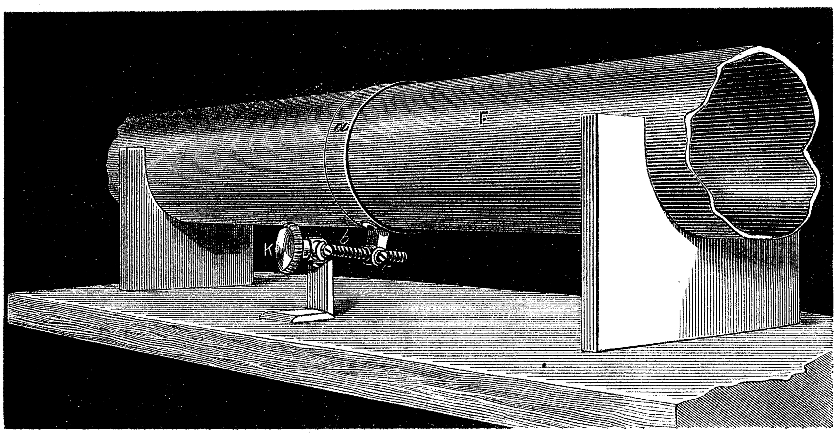
Taking a hint from Professor ROWLAND, I used the concave gratings with their axes perpendicular to the photographic plate, but I adopted a plan which is somewhat different to that proposed and utilised by Professor ROWLAND. The annexed figure will give an idea of a mounting for the 7 feet 6 inches concave grating.

Fig. 1.

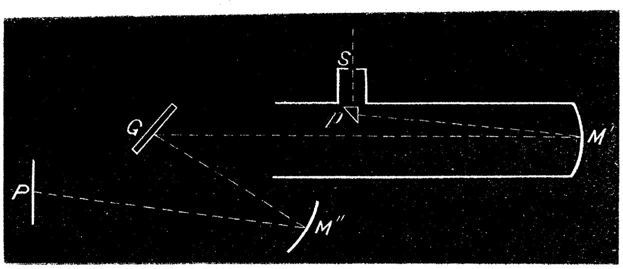


A A is a plank some 8 feet 6 inches long; at one end of it, E, is placed the grating, with its axis lying along the centre of the plank; G G is a camera, as shown, the plate being inserted at H at exactly the distance of the radius of the grating from its centre. At a point bisecting the radius of the grating a pivot is fixed in the plank A, round which the plank B can turn, and another pin or pivot is placed at D, also exactly at a distance of half the radius from the first pivot. Round D the plank C C can turn, which carries a tube, F, with the slit S attached. S is placed exactly over D. By this arrangement the slit S and the tube F can always be made to point towards E, no matter to what angle the plank B is turned away from A; and as D travels on the circumference of a circle in which the plane of the plate and the grating lie, the diffraction spectra are always in focus on H, and the scale of the spectrum is invariable. This plan I adopted for portability's sake, and also because my laboratory is somewhat confined in extent. At K is a slow motion screw, of which Fig. 2 is a representation on a larger scale, which turns the tube bearing the slit, and I found this arrangement better than turning the slit itself: a is a band encircling the brass tube, b is a screw turned by K, which screws into a swivel at c; when K is turned the tube F turns in its bearings with a slow motion. In reference to this I may mention that nearly all friction between the brass tube and the wood is avoided by placing between them pieces of baize or cloth. With a concave grating the necessity of the slit being accurately parallel to the lines of the ruling cannot be too much insisted upon, since the definition very largely depends upon it.

Fig. 2.



The majority of the photographs which have been measured were taken with the flat grating, and as the apparatus differs slightly in its details from that previously described, I annex a drawing showing how it was employed.



S is the slit; a beam of light falls on the right-angle prism p, which reflects it to the mirror M′, whence it by successive reflections from G and M″ falls on P, the photographic plate. The mirrors M′ and M″ have radii of curvature of about 7 feet each; M′ is so placed that the rays from S are made parallel and fall on the grating G. The spectra thus formed are very bright and the definition excellent, and I can strongly recommend this arrangement for spectrum work, whether gratings or prisms are employed. The object in using this arrangement was to secure the focus of all overlapping rays being in the same plane, thus allowing coincidences between the first and second and the second and third orders to be discussed.

For filling the gratings with light a quartz or glass condensing lens was employed, though a silvered mirror was also utilised. The sunlight was reflected from a heliostat, the mirror being silvered on the front surface. In reference to this I may say that Colonel Festing and myself have examined the reflective power of silver and a variety of other metals for radiation, extending from λ 6600 to 27,000, which we hope to submit shortly to the Royal Society.

Measurement of the negatives.

The negatives, some 30 in number, were all measured by a micrometer by A. HILGER, which was placed at my disposal by the Department of Science and Art. Of the performance of this instrument I cannot speak too highly. It is capable of measuring to the $\frac{1}{100000}$ of an inch, but for any photographs which I have obtained, or which I believe can be obtained, this is too delicate; the $\frac{1}{10000}$ of an inch is the unit which alone is necessary, any readings for a well defined line rarely differing more than 1 or 2 of these units from the mean of a series. In most of the photographs measured, a wave-length on ÅNGSTRÖM'S scale is nearly $\frac{1}{200}$ of an inch; any error in wave-length through bad measurement would therefore only be effected in the second place of decimals: a degree of accuracy which is, for the present, sufficient, since the wave-lengths are only carried to the first place.

In obtaining fiducial wave-lengths the numbers given by ÅNGSTRÖM for the visible spectra of the higher order of spectrum with which the infra red had to be compared have been generally adopted, though in some cases the corrections found in VOGEL'S map have been utilised when it was found that the interpolation formula better agreed with the latter than with the former. CORNU'S map was used for the ultra violet comparisons, together with photographs on the normal scale made by Professor ROWLAND. In many instances the wave-lengths have also been checked by photographs taken on the normal scale, the measures obtained being proportional to the differences in wave-lengths. The labour of mapping the spectrum has been much augmented by this process, as every difference in the first decimal place between ÅNGSTRÖM'S and my own determination had to be discussed.

In the tables the first column shows the number assigned to each line, the second column the measures of the photographs, the third the deduced wave-lengths, and the fourth check measures taken from other photographs.

Atmospheric Lines.

In previous papers by Colonel FESTING and myself we have discussed the effect of water in the atmosphere, and shown that it has a marked effect in shortening the solar spectrum when present in any quantity. We have also shown that the A line is not due to aqueous vapour. It has been asserted by EGGEROFF that this line is due to oxygen. This may be so; but if it be, the absorption by this gas is very intense, since I have found that it does not vary in intensity when observed and photographed at a height of about 9000 feet, at Zermatt at the end of June, from that observed in England at sea level. That many lines are due to aqueous vapour there is no doubt, but there are an equal number of lines which cannot be so disposed of. Part of the group, for instance, extending from A to 8200, alter in appearance at sunset and midday, whilst other lines below it do not appear to vary. Again, $X_{,}$, $X_{,,}$, $X_{,,,}$, are unmistakably not due to ordinary atmospheric absorptions, nor are the pair which I have called Y. There are some metallic lines present which appear to be coincident with certain lines in the spectrum, and as I have before pointed out in the Proceedings of the Royal Society, these are all metals of a low melting-point. My observations have been confirmed recently by HENRI BECQUEREL in an unmistakable manner, since he was, at the time he made his research, I believe, unaware of the paper alluded to.

I have finally to record my thanks to Sergeant H. JACKSON, R.E., and Mr. WALTER BRADFIELD, my two assistants, for the care they have taken in the work, which has been long and arduous, extending over the best of five years to complete.

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave lengths.	Check measures.
1	20542	7146·0	7146·0	45	25016	7234·5	7234·7
2	20691	7148·9		46	25168	7237·5	
3	20829	7151·6		47	25203	7238·1	
4	20843	7153·8		48	25251	7239·1	7239·1
5	21184	7157·9	7157·8	49	25397	7241·8	
6	21277	7160·3		50	25458	7243·0	
7	21375	7162·5		51	25503	7243·8	
8	21430	7163·6		52	25578	7245·4	
9	21527	7165·5	7165·5	53	25664	7247·1	
10	21555	7166·1		54	25735	7248·9	7248·8
11	21772	7170·3		55	25841	7250·6	
12	21802	7170·9		56	25874	7250·9	7251·0
13	21837	7171·6		57	25906	7251·6	7251·8
14	21867	7172·2		58	26091	7255·8	
15	21969	7174·3		59	26123	7256·4	
16	22026	7175·4	7175·3	60	26258	7259·1	7259·1
17	22249	7179·7	7179·8	61	26320	7260·3	
18	22397	7182·7		62	26412	7262·2	
19	22490	7184·6		63	26457	7263·1	
20	22537	7185·4	7185·4	64	26509	7264·1	7264·1
21	22751	7189·6	7189·6	65	26719	7268·3	
22	22856	7191·6		66	26877	7271·4	7271·6
23	22914	7192·8		67	27000	7274·1	
24	22973	7194·0		68	27060	7275·3	7275·4
25	23033	7195·2		69	27108	7276·2	7276·0
26	23070	7195·9		70	27202	7279·2	7279·2
27	23110	7196·7	7196·5	71	27357	7281·0	7281·0
28	23168	7197·9		72	27492	7283·7	7283·7
29	23207	7198·6	7198·7	73	27610	7286·0	
30	23247	7199·4		74	27655	7287·9	
31	23301	7200·2		75	27767	7289·1	7289·3
32	23344	7201·3		76	27883	7291·4	7291·2
33	23377	7201·9		77	27980	7293·3	
34	23409	7202·6	7202·4	78	28061	7294·9	
35	23510	7204·6	7204·7	79	28143	7296·5	
36	23552	7205·5		80	28238	7298·4	7298·6
37	23668	7207·7	7207·9	81	28366	7301·0	
38	24019	7214·7	7214·7	82	28415	7302·0	
39	24379	7221·9		83	28668	7306·7	
40	24576	7225·8	7225·8	84	28695	7307·2	
41	24818	7230·6	7230·7	85	28727	7307·8	7307·2
42	24853	7231·3	7231·3	86	28759	7308·4	7308·4
43	24906	7232·3		87	28790	7309·8	
44	24935	7233·9		88	28877	7311·3	7311·4

Line.	Measures.	Wave-lengths.	Check measures.
89	28974	7313·3	
90	29042	7314·4	7314·3
91	29093	7315·4	
92	29133	7316·5	7316·5
93	29188	7317·6	7317·8
94	29305	7319·9	7319·8
95	29455	7322·9	7323·1
96	29573	7325·2	
97	29627	7326·2	7326·4
98	29810	7327·9	
99	29920	7330·1	
100	29948	7330·6	
101	30052	7332·6	7332·4
102	30297	7338·1	
103	30490	7343·4	7343·1 7343·9
103	3584	7343·4	7343·1 7343·9
104	3802	7348·4	7348·6
105	3876	7350·4	
106	3947	7352·15	
107	4065	7354·9	7354·7
108	4117	7356·2	
109	4251	7359·4	
110	4319	7361·1	
111	4392	7362·9	7563·1
112	4465	7365·0	
113	4604	7368·0	7368·1
114	4707	7370·5	
115	4791	7372·6	
116	4873	7374·6	
117	4921	7375·7	
118	5001	7377·7	7377·6
119	5063	7379·2	
120	5140	7381·0	
121	5175	7381·9	
122	5228	7383·2	
123	5282	7384·5	
124	5334	7385·8	
125	5388	7387·1	
126	5465	7389·0	
127	5497	7389·7	
128	5546	7390·8	7390·8
129	5642	7393·2	
130	5745	7395·5	
131	5910	7399·4	
132	6150	7405·0	
133	6305	7408·7	7408·8
134	6384	7410·6	
135	6530	7413·9	
136	6593	7415·4	7415·4
137	6666	7417·0	
138	6718	7418·2	7418·2

Line.	Measures.	Wave-lengths.	Check measures.
134	5674	7410·7	7410·6
135	5825	7414·1	7413·9
136	5879	7415·4	7415·4
138	6006	7418·4	7418·2
139	6151	7421·8	
140	6212	7423·2	
141	6262	7424·4	
142	6954	7440·6	7440·7
143	7058	7443·0	7443·0
144	7163	7445·4	7445·4
145	7898	7462·2	
146	9179	7491·3	
147	9339	7494·7	7494·9
148	9891	7507·3	
149	10054	7511·0	7511·0
150	10588	7522·5	
151	10701	7524·9	7524·9
152	10816	7528·1	
153	10969	7530·7	
154	11073	7533·0	
155	11658	7545·5	
156	12089	7554·8	7554·8
157	12125	7555·6	
158	12710	7568·3	
159	12932	7573·1	
160	13410	7583·5	
161	13514	7585·8	7585·8
Edge of A . . 162	13875	7593·6	7593·6

Line.		Measures.	Wave-lengths.	Check measures.
Edge of A . .	162	31939	7593·6	
Centre of 1st line	163	31952	7593·9	
	164	32010	7595·1	
	165	32053	7596·0	
Edge of 3rd line	166	32079	7596·5	
	167	32123	7597·4	
	168	32176	7598·5	
	169	32255	7600·1	
Several of the lines between 7596·5 and 7616·2 are probably double lines, but too difficult to measure in the micrometer.	170	32328	7601·6	
	171	32403	7603·1	
	172	32448	7604·0	
	173	32508	7605·2	
	174	32558	7606·2	
	175	32627	7607·6	
	176	32692	7609·1	
	177	32740	7610·1	
	178	32827	7611·9	
	179	32872	7612·8	
	180	32968	7614·8	
	181	33009	7615·7	
Edge of band .	. .	33033	7616·2	
Single line . .	182	33257	7620·6	
1st pair . . .	183	33368 }	7622·8	Centre 7623·3
	184	33418 }	7623·8	
2nd pair . . .	185	33553 }	7626·5	Centre 7626·9
	186	33601 }	7627·4	
3rd pair . . .	187	33740 }	7630·2	Centre 7630·7
	188	33798 }	7631·3	
4th pair . . .	189	33947 }	7634·3	Centre 7634·7
	190	33998 }	7635·3	
5th pair . . .	191	34165 }	7638·6	Centre 7639·0
	192	34211 }	7639·5	
6th pair . . .	193	34391 }	7643·1	Centre 7643·5
	194	34432 }	7643·9	
7th pair . . .	195	34627 }	7647·8	Centre 7648·3
	196	34674 }	7648·7	
8th pair . . .	197	34881 }	7652·8	Centre 7653·3
	198	34926 }	7653·7	
	199	35063	7656·4	
9th pair . . .	200	35143 }	7658·0	Centre 7658·5
	201	35191 }	7658·9	
10th pair . . .	202	35420 }	7663·4	Centre 7663·9
	203	35466 }	7664·4	
11th pair . . .	204	35705 }	7669·1	Centre 7669·6
	205	35752 }	7670·0	
12th pair . . .	206	36018 }	7675·2	Centre 7675·5
	207	36057 }	7676·1	
	208	36183	7678·6	
13th pair . . .	209	36318 }	7681·2	Centre 7681·7
	210	36366 }	7682·2	
	211	36640	7685·6	
	212	36760	7689·7	

Line.	Measures.	Wave-lengths.	Check measures.
212	39077	7689·8	7689·7
213	39290	7694·0	
214	39452	7697·0	7696·9
215	40037	7708·2	
216	40239	7712·2	7612·0
217	40931	7724·8	
218	41739	7740·6	7740·6
219	42045	7745·6	7745·6
220	42180	7748·1	
221	42385	7752·0	
222	43195	7767·4	
223	43400	7771·1	
224	43773	7778·2	
225	44246	7787·0	7787·0
226	44514	7792·1	
227	44614	7794·0	
228	45266	7806·4	
229	46695	7831·0	7831·0
230	46865	7833·6	

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave-lengths.	Check measures.
231	23175	7868·6		262	17755	7975·8	
232	22855	7875·1		263	17702	7976·9	
233	22368	7884·9		264	17637	7978·2	
234	21874	7894·4		265	16711	7996·7	
235	21568	7900·5		266	16679	7997·4	
236	21219	7907·3		267	16516	8000·6	
237	21170	7908·2		268	16476	8001·4	
238	21062	7910·3		269	16266	8005·6	
239	20994	7911·7		270	15991	8011·1	
240	20861	7914·3		271	15206	8026·8	8026·8
241	20790	7915·7		272	15028	8030·4	
242	20640	7918·7		273	15041	8032·1	8032·1
243	20455	7922·4		274	14980	8033·3	8033·3
244	20395	7923·5		275	14319	8044·5	8044·3
245	20205	7927·3		276	14112	8048·6	
246	20010	7931·1		277	13643	8058·0	
247	19802	7935·2		278	13125	8068·4	8068·3
248	19587	7939·4		279	12348	8083·8	
249	19361	7944·1		280	11656	8097·6	
250	19243	7946·4		281	11212	8106·5	
251	19065	7949·9		282	10894	8112·4	
252	18950	7952·1		283	10660	8117·6	8117·6
253	18742	7956·3		284	10451	8121·7	8121·3
254	18626	7958·6		285	10268	8125·4	
255	18488	7961·1		286	10052	8129·7	8129·5
256	18325	7966·2		287	9892	8132·6	8132·8
257	18136	7968·2		288	9576	8139·5	
258	18056	7969·8		289	9519	8140·6	
259	17980	7971·3		290	9436	8142·2	
260	17885	7973·2		291	9197	8146·8	
261	17810	7974·7		292	9126	8148·2	

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave-lengths.	Check measures.
289	27042	8140·7	8140·6	329	33075	8260·5	
290	27115	8142·2		330	33138	8261·7	
291	27350	8146·8		331	33561	8270·1	8269·8
292	27423	8148·2		332	33684	8273·2	
293	27548	8150·8		333	33787	8275·2	
294	27666	8153·2		334	33948	8278·4	
295	27830	8156·3		335	34062	8280·4	
296	27980	8159·3		336	34355	8286·2	
297	28025	8160·2		337	34374	8286·8	
298	28120	8162·1		338	34693	8293·0	
299	28412	8167·9		339	34990	8299·0	
300	28808	8175·9		340	35202	8303·2	
301	28874	8177·1		341	35575	8310·7	
302	29038	8180·3		342	35784	8314·5	
303	29088	8181·4		343	35894	8316·4	8316·3
304	29269	8184·9	8184·9	344	36050	8319·6	
305	20425	8188·0		345	36254	8323·6	
306	29610	8191·7		346	36463	8327·7	
307	29694	8193·4		347	36665	8331·7	
308	29830	8196·1		348	36741	8333·2	
309	29982	8199·1	8199·1	349	36948	8337·3	
310	29603	8210·4		350	37015	8338·6	
311	30864	8216·6	8216·5	351	37101	8340·3	8340·3
312	30955	8218·4		352	37313	8344·6	8344·6
313	30996	8219·2		353	37455	8347·4	8347·4
314	31041	8220·1	8220·3	354	37668	8351·7	
315	31160	8222·5	8222·4	355	37865	8355·6	
316	31313	8225·6		356	38085	8360·0	
Z 317	31357	8226·4		357	38320	8364·7	
318	31534	8229·9		358	38693	8372·2	
319	31663	8232·5		359	38828	8374·9	
320	31818	8235·6		360	39207	8382·4	
321	31959	8238·4	8238·4	361	39385	8386·0	
322	32131	8241·8		362	39795	8394·2	8394·3
323	32308	8245·2		363	40453	8407·4	
324	32363	8246·4		364	40799	8414·2	
325	32536	8249·8		365	41811	8434·2	
326	32584	8250·7		366	42388	8445·6	
327	32784	8254·7		367	43450	8466·6	8466·6
328	32938	8257·8		X_i 368	44988	8497·0	

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave-lengths.	Check measures.
369	11185	8497·0	8496·8	420	22020	9041·2	
370	11273	8501·4		421	22126	9046·5	
371	11516	8513·7		422	22233	9051·9	
372	11750	8525·6		423	22384	9059·4	
$X_{ii.}$ 373	12071	8541·8	8541·7	424	22420	9061·2	
374	12355	8556·2		425	22555	9068·0	
375	12901	8583·5		426	22609	9070·7	
376	13427	8609·8		427	22651	9072·8	
377	13611	8619·0		428	22772	9078·8	9078·6
378	14053	8642·0		429	22913	9085·8	
379	14169	8647·8		430	22967	9088·5	
$X_{iii.}$ 380	14441	8661·4	8661·4	431	23058	9093·0	
381	14969	8688·0		432	23168	9098·4	
382	15433	8711·2		433	23315	9105·7	
383	15766	8728·1		434	23419	9110·9	
384	15910	8735·4		435	23540	9116·9	
385	15985	8739·2		436	23668	9123·3	
386	16040	8742·0		437	23782	9128·9	
387	16211	8751·5		438	23907	9135·1	
388	16461	8763·0		439	24240	9151·7	
389	16647	8772·4		440	24292	9153·9	
$X_{iv.}$ 390	17320	8806·1		441	24377	9158·5	
391	17655	8822·9		442	24464	9162·8	
392	17837	8832·0		443	24543	9166·7	9166·6
393	17990	8839·7		444	24661	9172·8	
394	18075	8843·9		445	24722	9175·6	
395	18417	8861·0		446	24876	9183·2	
396	18518	8866·1		447	25092	9193·9	
397	19021	8891·2		448	25297	9204·1	
398	19417	8911·0		449	25452	9211·8	9211·7
399	19743	8927·4		450	25535	9215·9	
400	19975	8939·0		451	25576	9217·9	
401	20111	8945·9		452	25634	9220·8	
402	20163	8948·4		453	25684	9223·3	
403	20221	8951·3		454	25867	9232·4	
404	20265	8953·5		455	25966	9237·3	
405	20434	8961·9		456	26106	9244·2	
406	20496	8964·9		457	26207	9249·2	
407	20603	8970·3	8970·2	458	26302	9253·9	
408	20672	8973·7		459	26359	9256·8	9256·7
409	20787	8979·5		460	26400	9258·8	
Y { 410	{ 20926	8986·5		461	26514	9264·4	
Y { 411	{ 21005	8990·4		462	26591	9268·3	9268·5
412	21181	8999·2		463	26653	9271·3	
413	21245	9002·4	9002·2	464	26777	9277·7	
414	21317	9006·0		465	26900	9283·6	
415	21411	9010·7	9010·6	466	26928	9285·0	
416	21506	9015·5	9015·5	467	26974	9287·2	
417	21629	9021·8	9021·5	468	27021	9289·6	
418	21689	9024·7		469	27095	9293·2	
419	21804	9030·4		470	27153	9296·1	

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave-lengths.	Check measures.
469	27215	9299·1		524	32034	9537·2	
470	27280	9302·3	9302·5	525	32086	9539·4	
471	27380	9307·3		526	32140	9542·4	
472	27532	9314·9		527	32162	9543·4	
473	27586	9317·6		528	32185	9544·5	9544·4
474	27663	9321·4		529	32230	9546·8	
475	27706	9323·5		530	32275	9549·0	
476	27765	9326·5		531	32333	9551·9	
477	27827	9329·5		532	32401	9555·2	
478	27894	9332·8	9332·8	533	32431	9556·7	
479	27995	9337·8		534	32512	9560·7	9560·5
480	28071	9341·5	9341·5	535	32524	9561·8	
481	28112	9343·6		536	32554	9563·3	
482	28286	9352·2		537	32605	9565·2	
483	28366	9356·1		538	32647	9567·3	
484	28529	9364·2		539	32698	9569·8	
485	28636	9369·4		540	32877	9578·6	
486	28770	9376·1		541	33040	9586·6	
487	28840	9379·5		542	33100	9589·6	
488	28957	9385·3		543	33166	9592·8	
489	29055	9390·1		544	33140	9591·5	
490	29126	9393·7		545	33247	9597·5	
491	29195	9397·1		546	33384	9603·0	9602·8
492	29239	9399·3		547	33488	9608·6	
493	29297	9402 2		548	33576	9612·9	
494	29343	9404·5		549	33631	9615·6	
495	29393	9407·0		550	33680	9618·0	
496	29431	9408·8		551	33792	9623·5	
497	29506	9412·5		552	34043	9635·8	
498	29573	9415·8		553	34202	9643·7	
499	29660	9420·1		554	34559	9661·2	
500	29772	9425·6		555	34711	9668·7	
501	29835	9428·7		556	34916	9678·7	
502	29986	9436·2	9436·3	557	35140	9689·9	
503	30051	9439·4		558	35347	9699·9	
504	31006	9442·1		559	35491	9707·0	
505	30169	9445·2		560	35606	9712·6	9712·6
506	30237	9448·6		561	35696	9717·1	
507	30330	9453·2		562	35782	9721·3	9721·3
508	30350	9454·2		563	35935	9728·3	
509	30443	9458·7		564	36038	9732·8	
510	30616	9467·3		565	36116	9737·7	
511	30742	9473·5		566	36183	9741·0	
512	30859	9479·3		567	36261	9744·8	
513	30980	9485·2		568	36328	9748·1	
514	31120	9492·2		569	36416	9752·4	
515	31189	9495·5		570	36498	9756·5	
516	31269	9499·5		571	36601	9761·5	
517	31517	9511·9		572	36650	9763·9	
518	31584	9515·0		573	36714	9767·1	
519	31694	9520·4		574	36764	9769·8	
520	31746	9523·0		575	36818	9772·6	
521	31826	9526·9		576	36847	9773·5	
522	31850	9529·8		577	36903	9776·3	
523	31978	9534·4					

Line.	Measures.	Wave-lengths.	Check measures.	Line.	Measures.	Wave-lengths.	Check measures.
562	11764	9721·3	9721·3	583	13850	9823·8	
570	12456	9756·4	9756·5	584	14130	9837·3	
575	12785	9772·6		585	14220	9841·6	
578	12958	9780·6		586	14304	9846·6	
579	13163	9790·5	9790·4	587	14441	9853·4	
580	13396	9801·8	9801·7	588	14517	9856·9	
581	13598	9810·7		589	14582	9861·1	9861·2
582	13646	9813·0		590	14725	9867·0	

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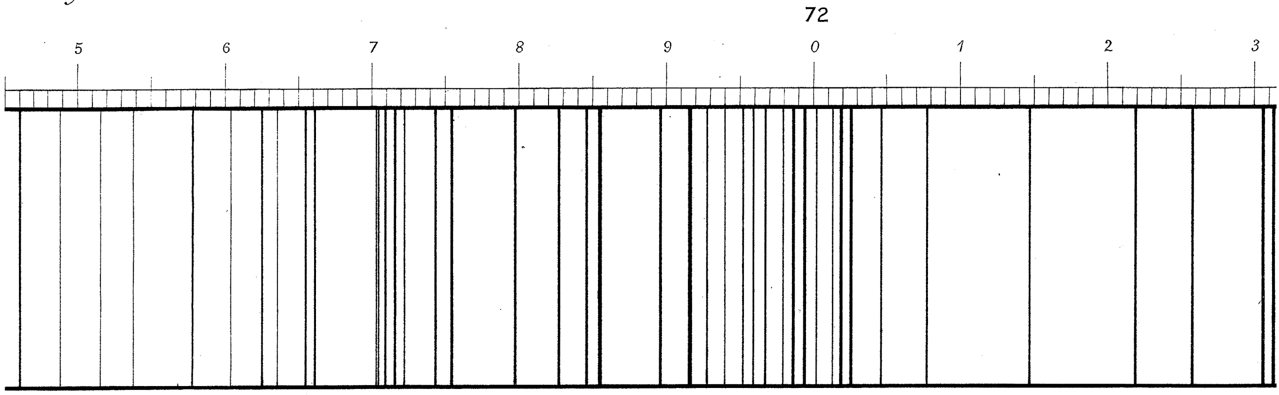

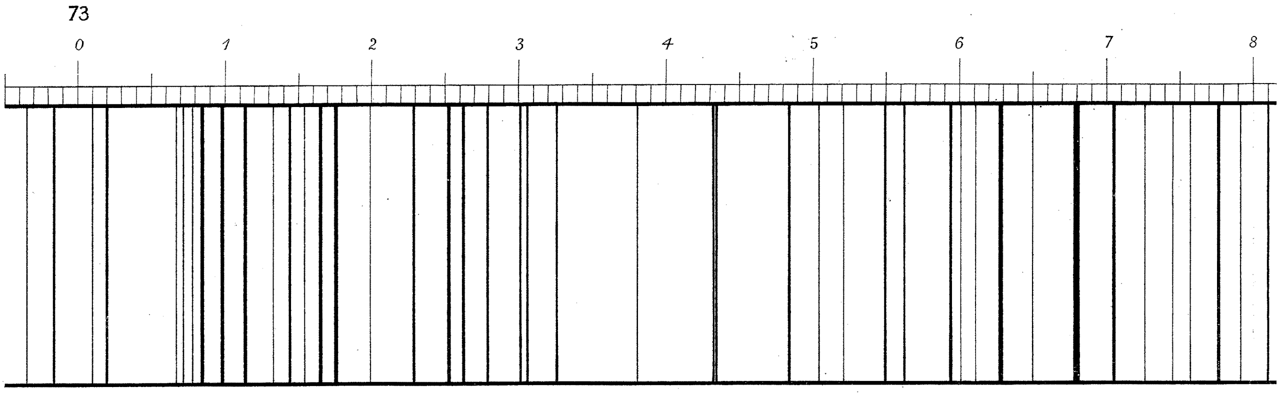

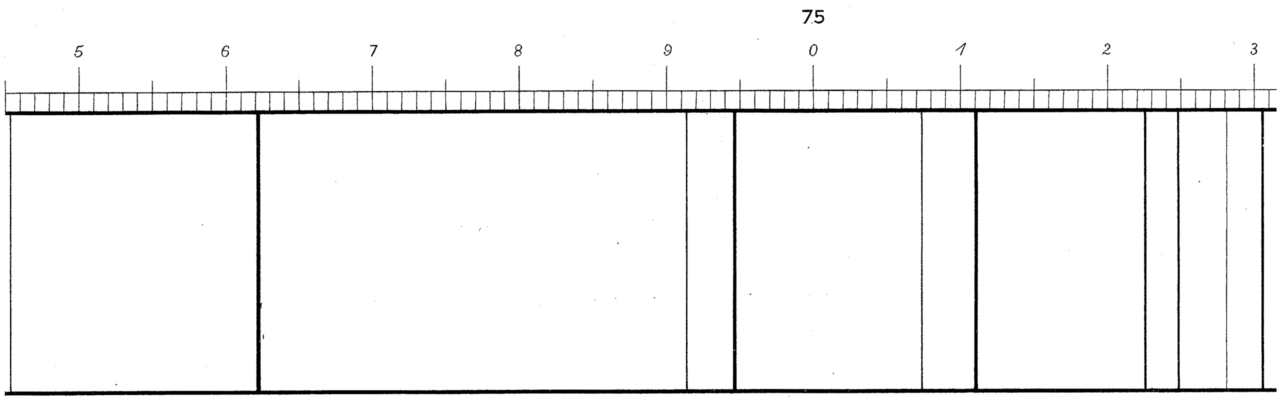

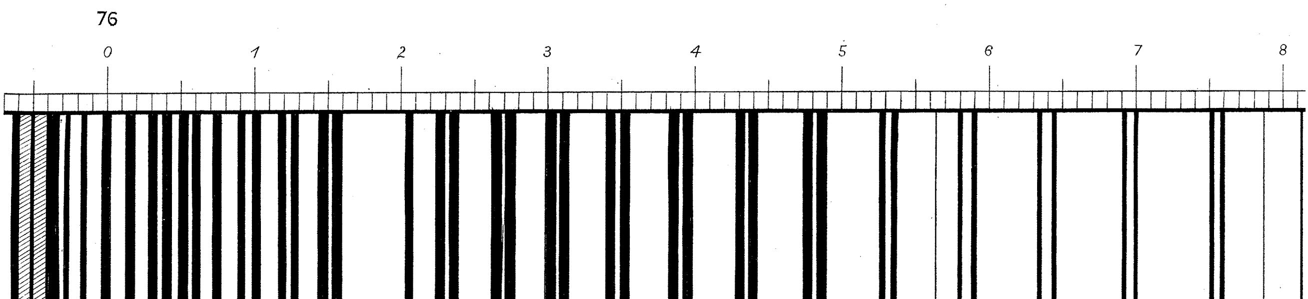

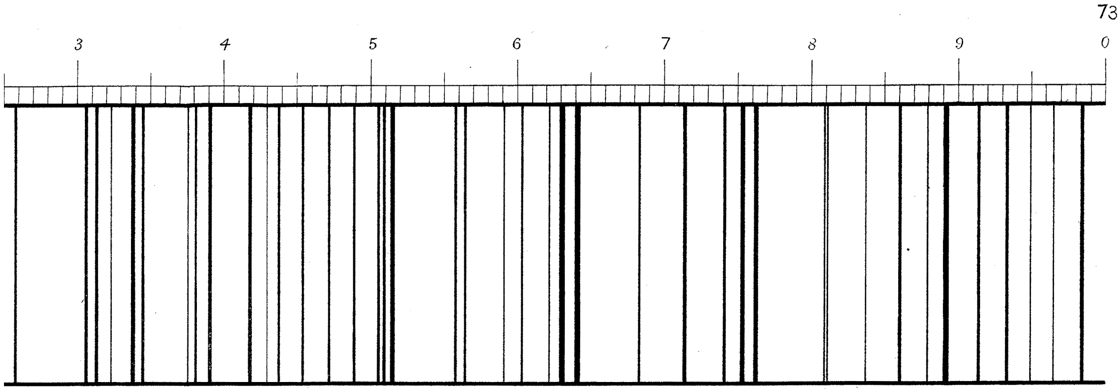
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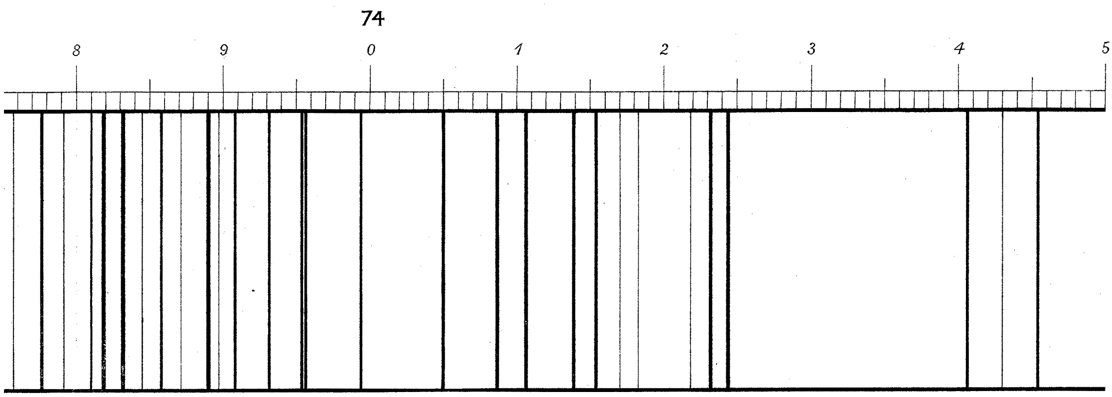
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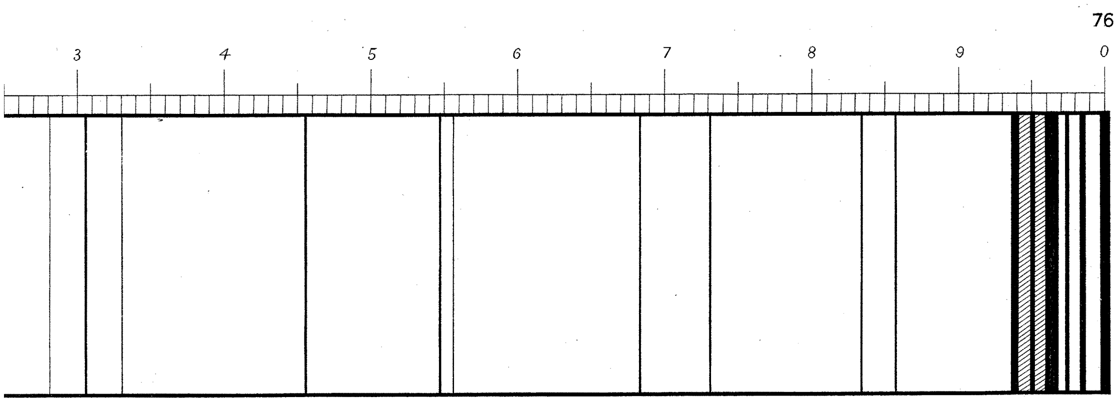
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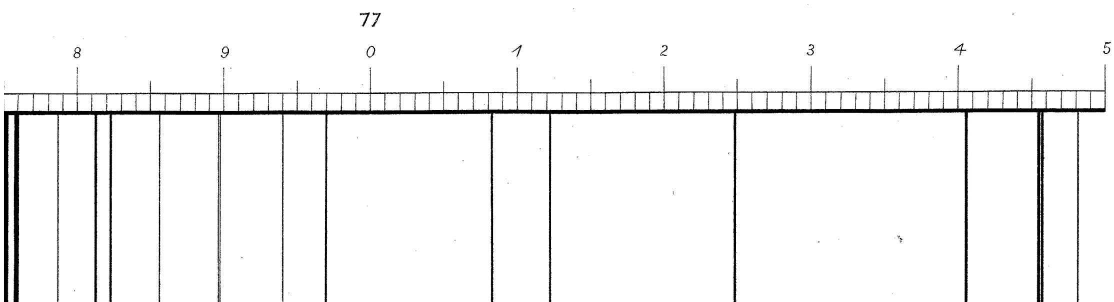
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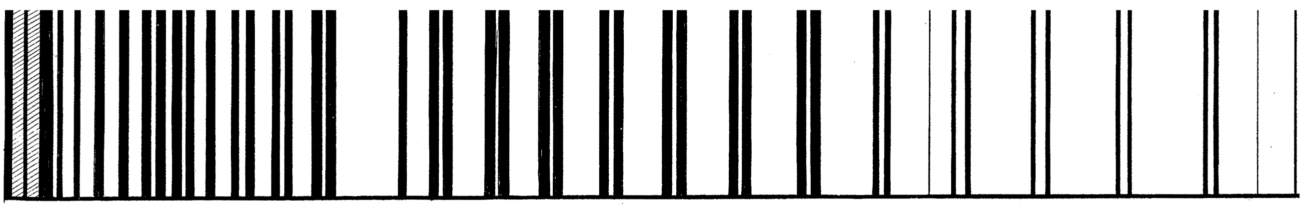

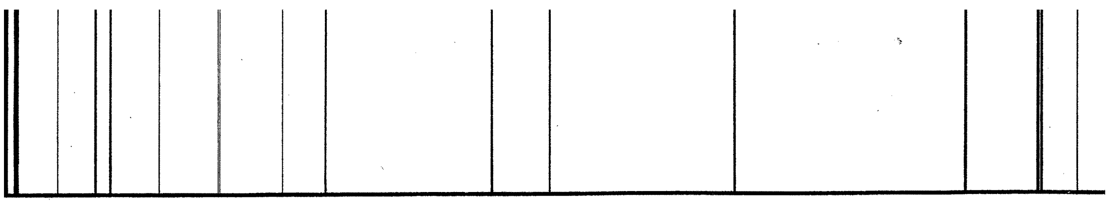

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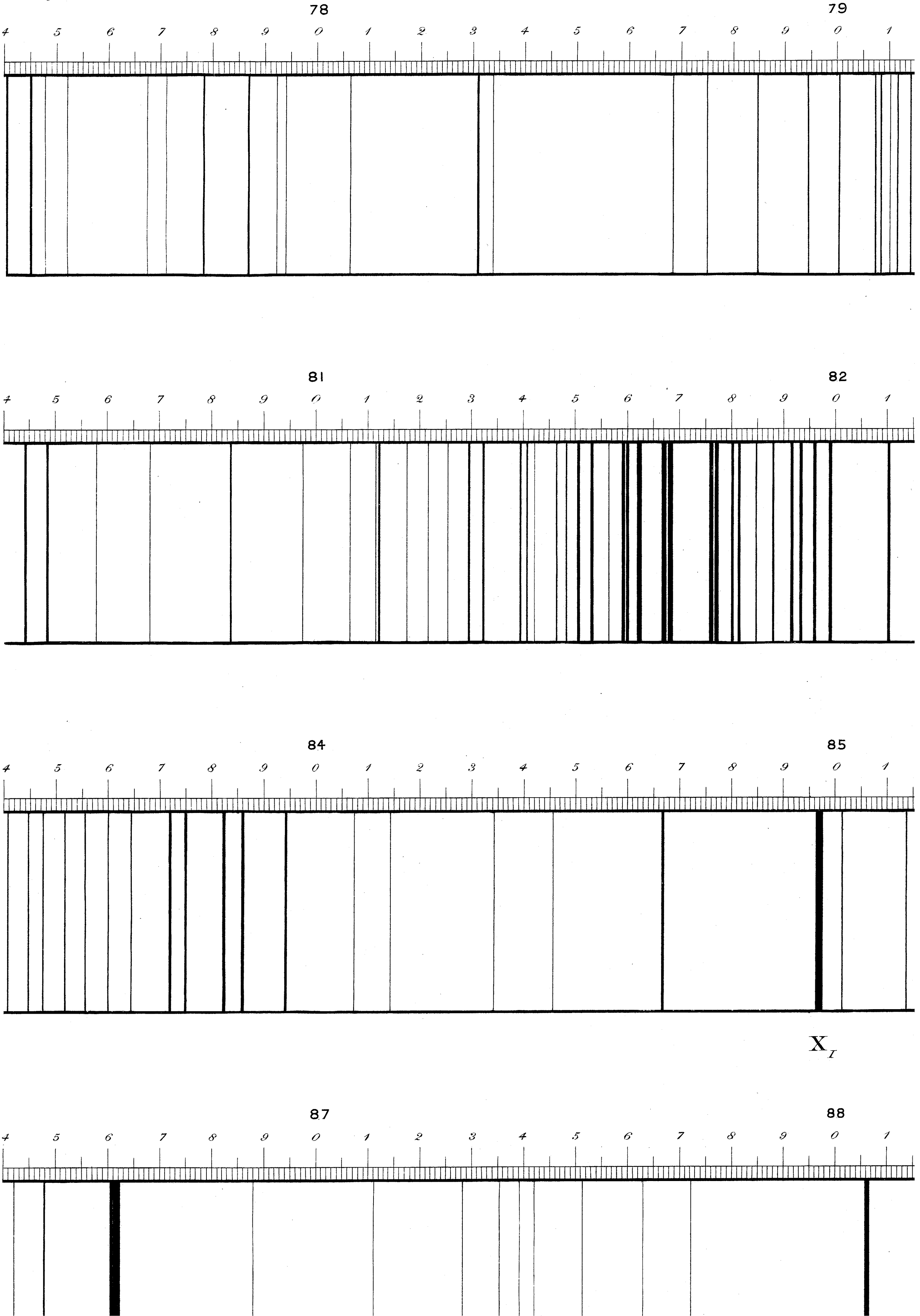

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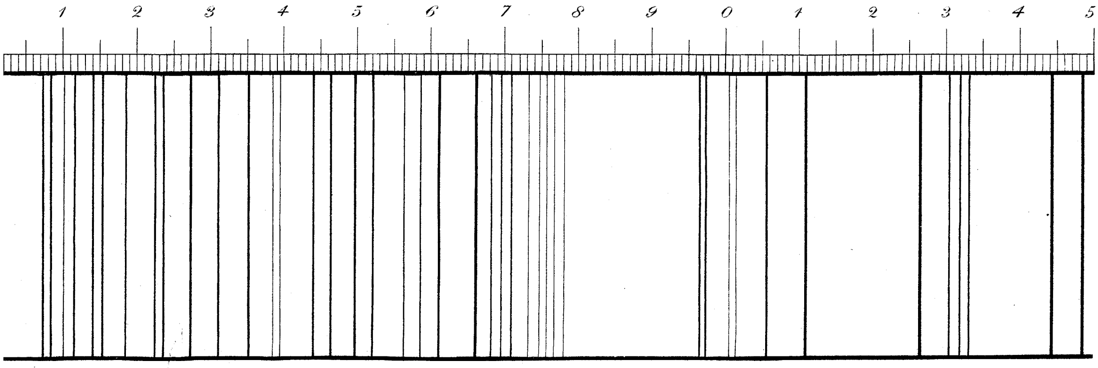

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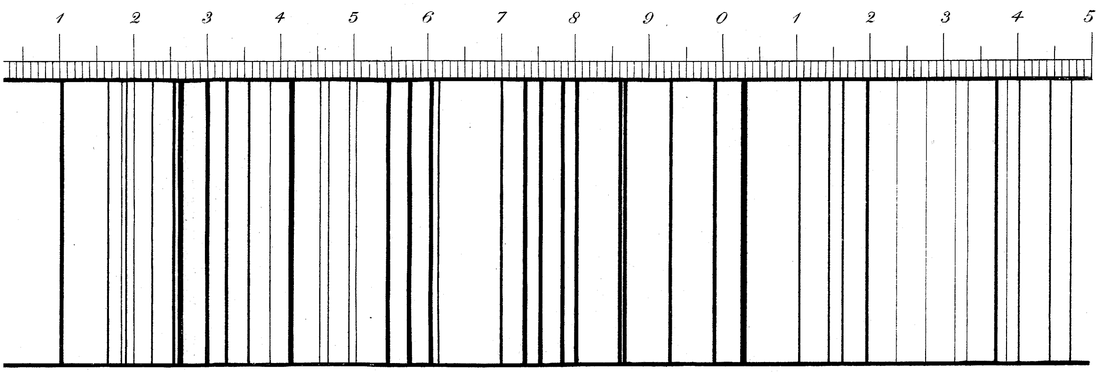

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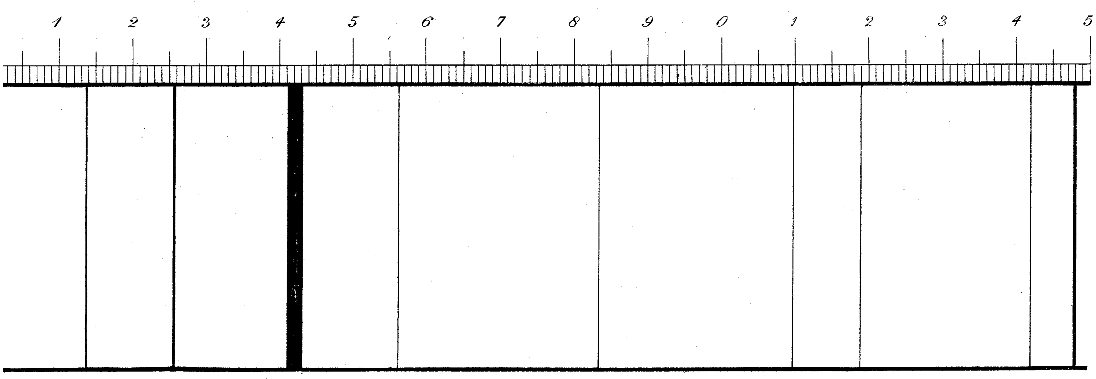

$\mathbf{X}_{II}$

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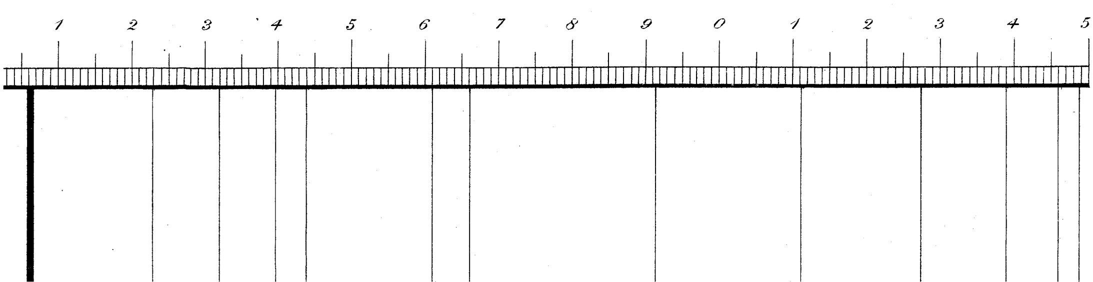
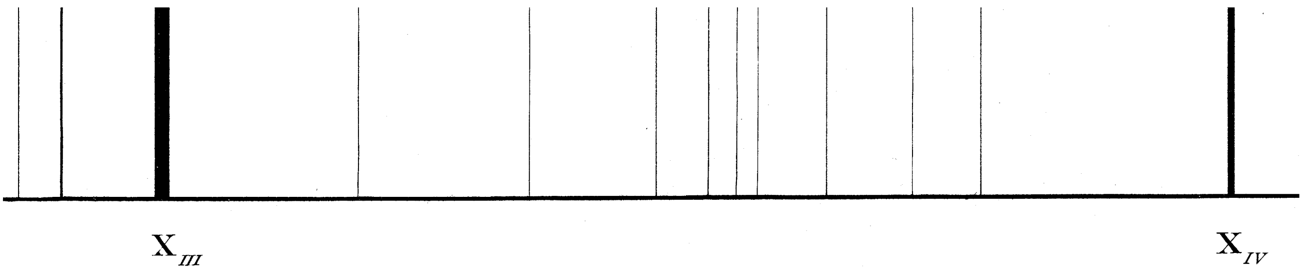
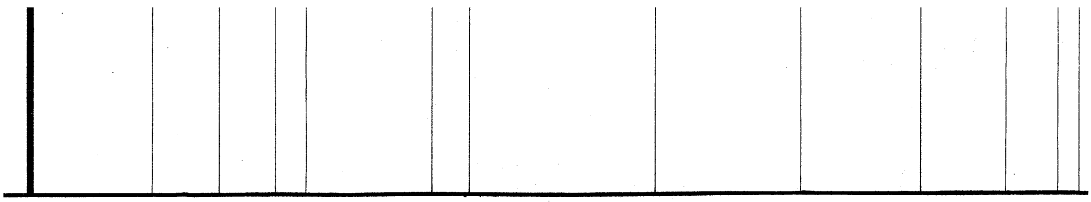



X_{III}
X_{IV}



$\mathbf{X}_{IV}$

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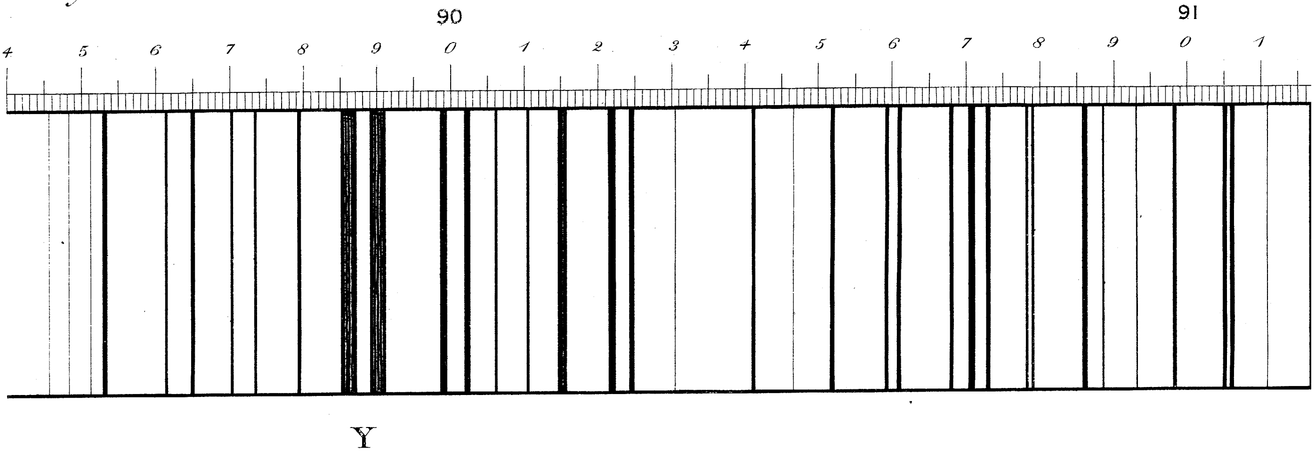
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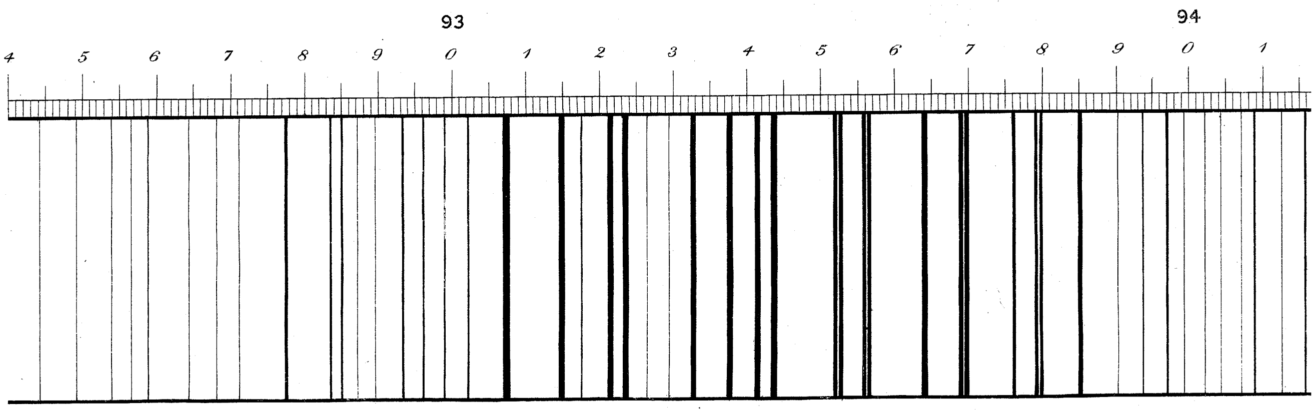
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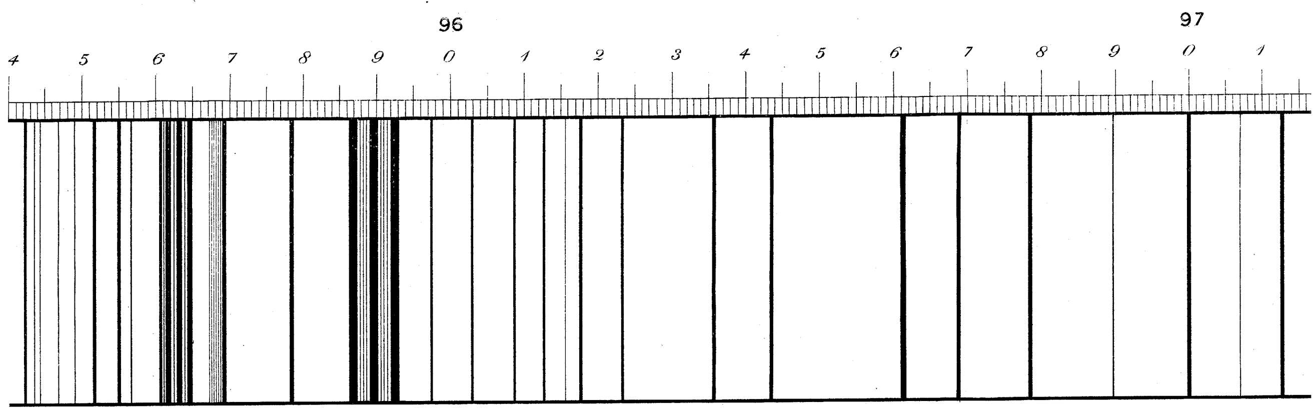
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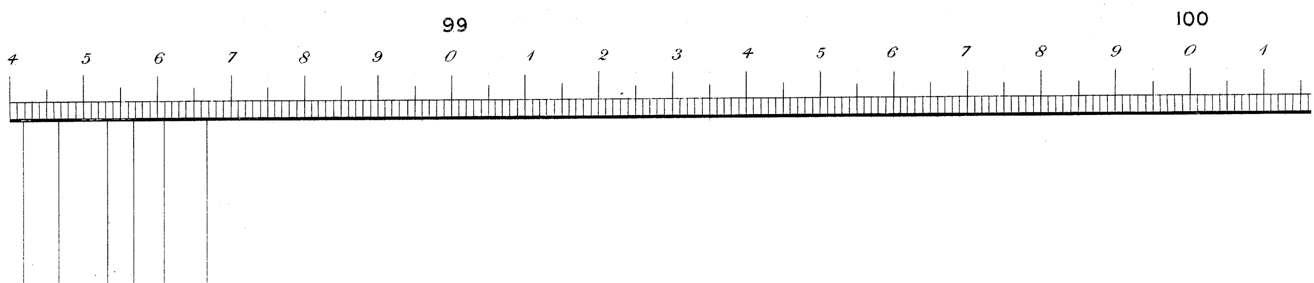
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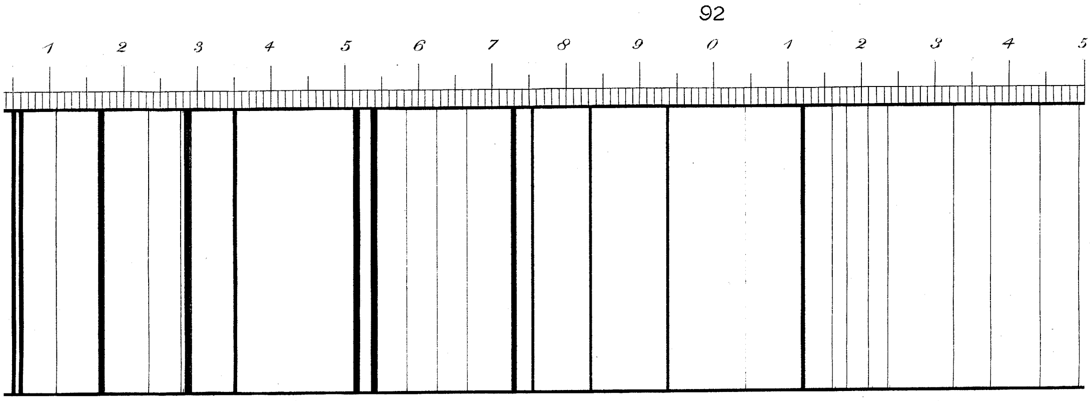
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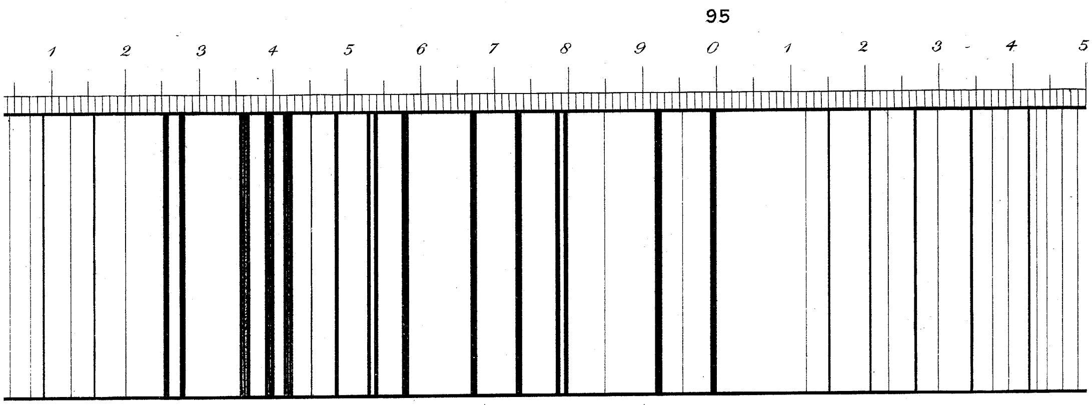
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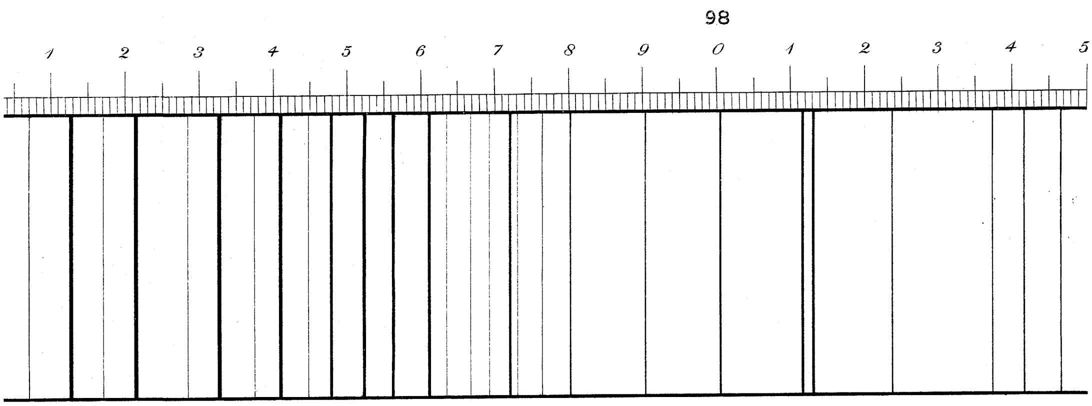
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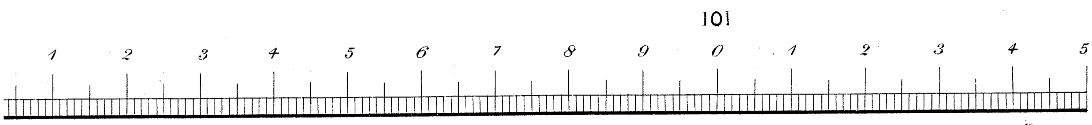
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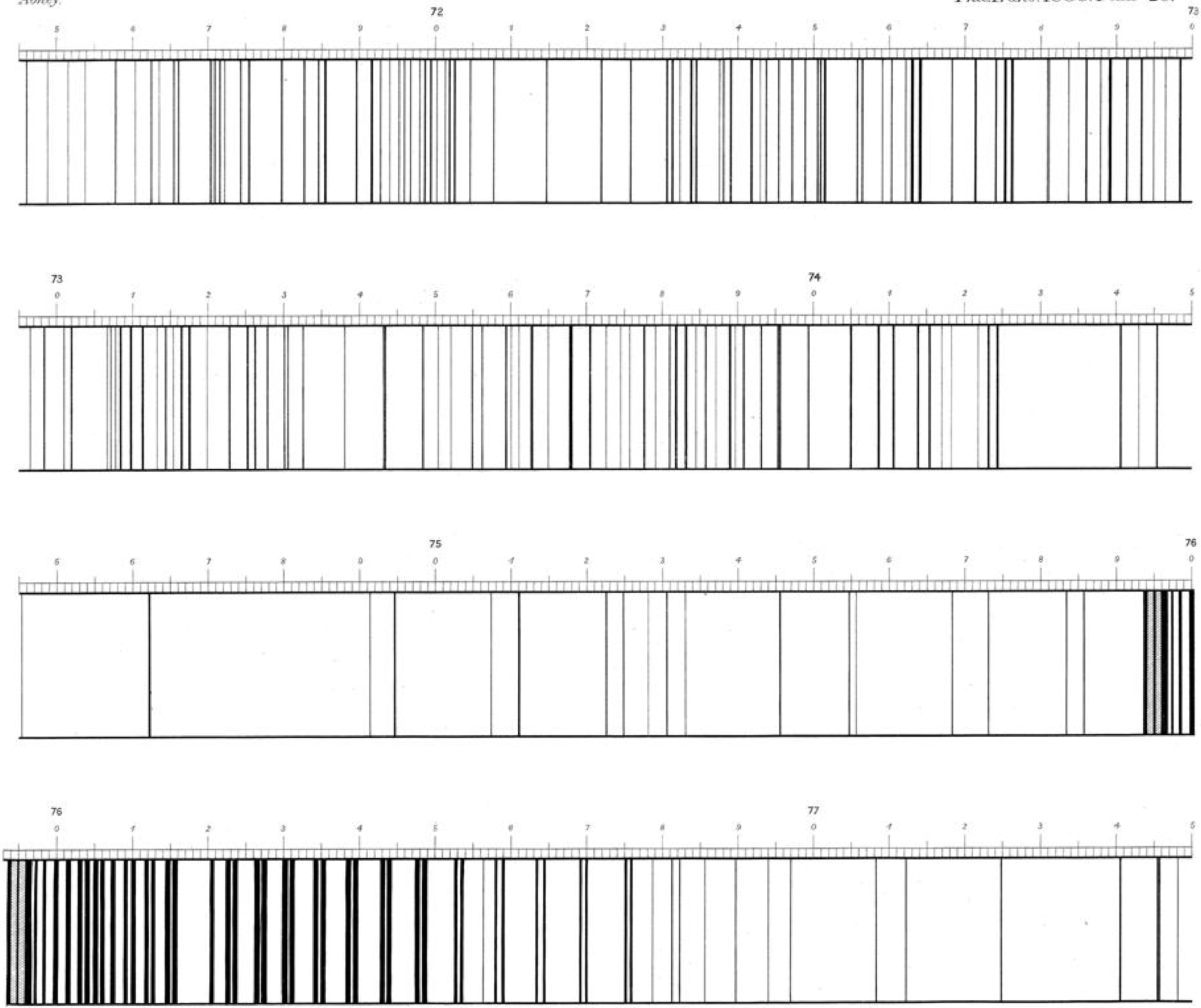

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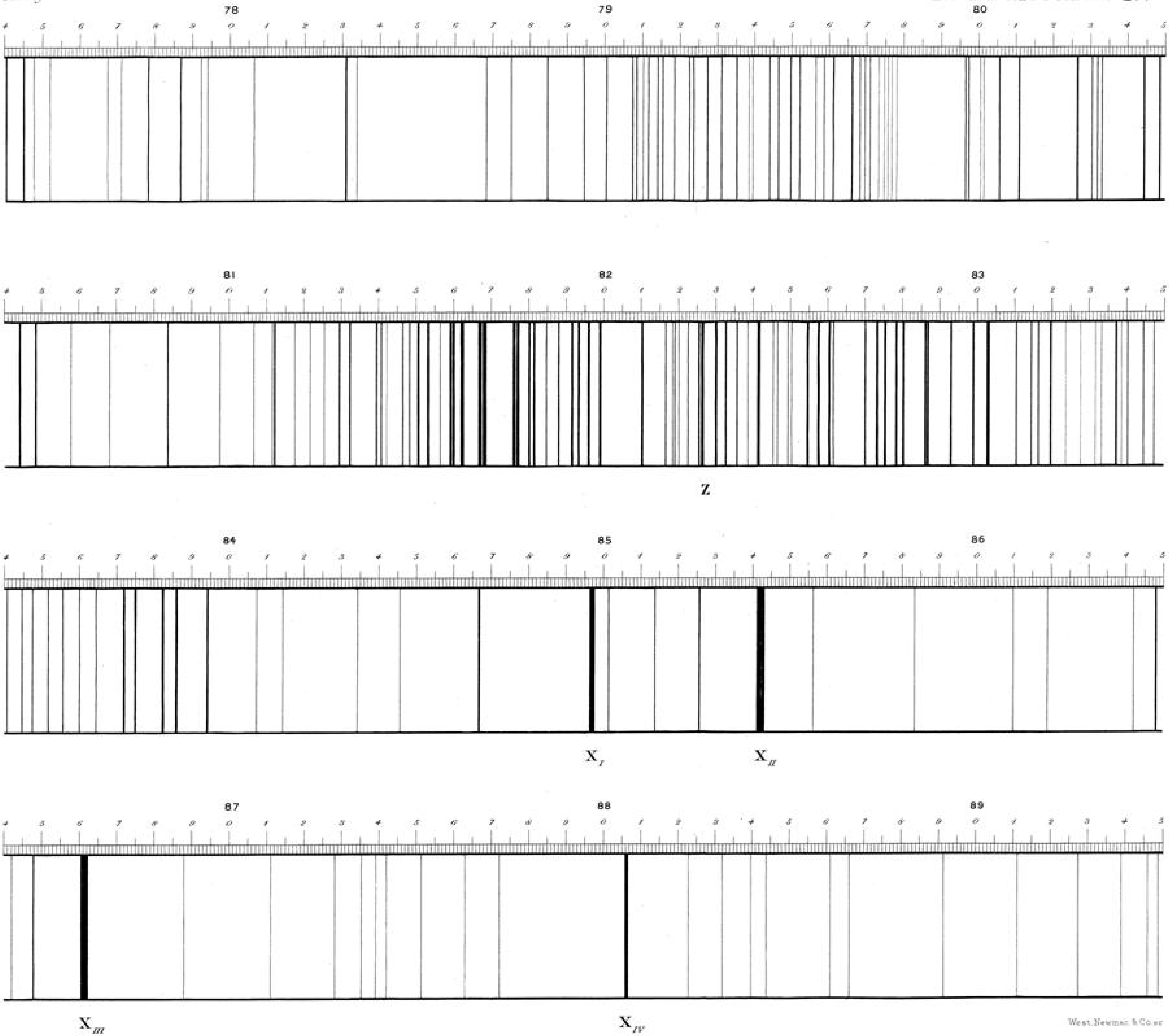

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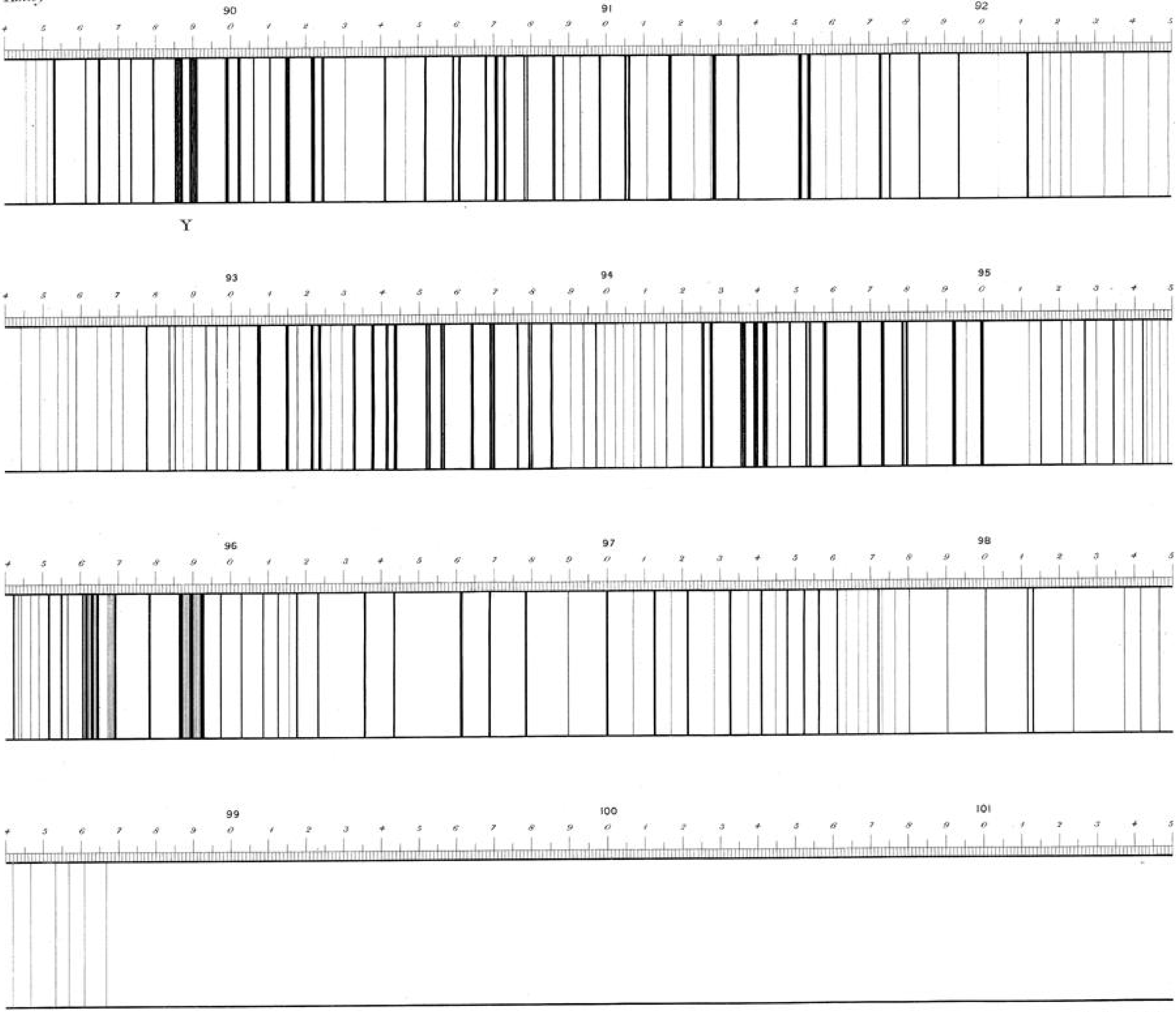
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