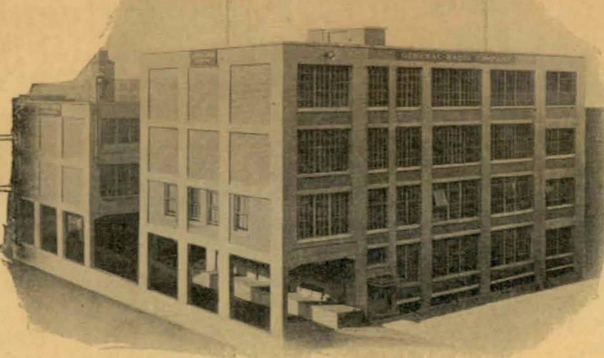
The GENERAL RADIO
EXPERIMENTER



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A Discussion of Condenser Plate Shapes

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Variable air condensers are made with three general types of plate shapes, although there are many modifications of each type.

The first rotary variable condensers were made with "straight line capacity" plates. These plates were semi-circular in shape and are called straight line capacity because the curve of capacity plotted against dial divisions (angle of rotation) is a straight line. The relation between capacity, wavelength, and frequency are such that this plate shape tends to result in crowding of stations at the lower end of the capacity range. That is, there are more transmitting channels for each dial division at the lower end of the scale than the upper. This objectionable feature has led to a widespread use of other plate shapes.

The straight line capacity plates have, however, one distinct advantage when used in single-control setups. Where it is desired to tune several circuits with one control, some form of capacity adjustment is nearly always necessary to compensate for different zero capacitances in the several circuits. If semi-circular, (straight line capacity) units are used, this adjustment can be made by slightly advancing one or more of the units. If this be done with condensers having other plate shapes, the capacities will become unbalanced as the control dial is advanced. This is due to the fact that if the plate shape is not "straight line capacity," the capacity variation per dial division increases as the condenser is turned toward maximum capacity, and the unit which was advanced gains capacity more rapidly than the others. This feature has caused at least one important manufacturer of uni-control receivers to return to the semi-circular plate shape.

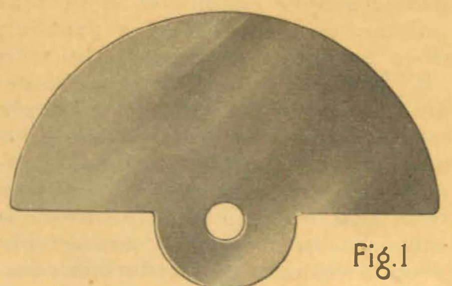


Fig.1

Straight Line Capacity

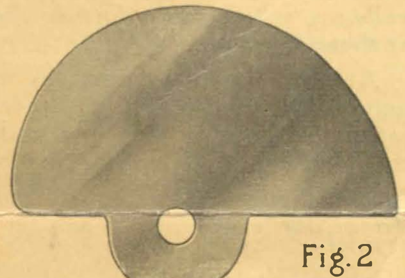


Fig.2

Straight Line Wavelength

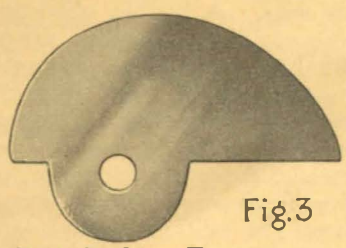
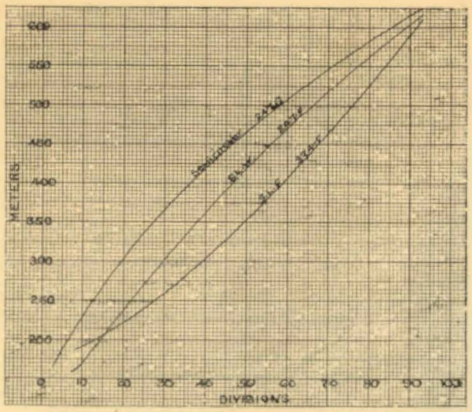


Fig.3

Straight Line Frequency

It may be noted that the effect of "straight line wavelength" and "straight line frequency" condensers is strictly a slow motion action, having a variable reduction, gradually lessening as the condenser is advanced. The same result can be and, in fact, has been accomplished by a slow motion dial so constructed as to automatically vary its reduction ratio to give the effect of a "straight line frequency" plate when used with a "straight line capacity" condenser.

The disadvantage of the semi-circular plate shape was first realized in connection with the construction of wavemeters. This was long before there were enough broadcast stations for the problem of station separation to be serious. As the relation between capacity and wavelength is not a direct proportion, a dial calibrated in wavelengths will not have equal divisions over its scale if a semi-circular plate shape is used. This not only makes the instrument more difficult to read, particularly as to the estimation of readings which fall between divisions, but involves difficulty in calibration, as the space between two points ten meters apart for instance, could not be divided into ten equal one-meter divisions. A plate shape which would give equal divisions for equal wave-lengths, i.e., "straight line wavelengths," was highly desirable, and a condenser with such a plate shape was first used commercially in the General Radio 124 wavemeter, introduced in 1916. When the multiplication of broadcast stations began, the straight line wavelength plate was introduced for condensers used in receivers, and became very popular, due to the better separation of stations resulting from its use.

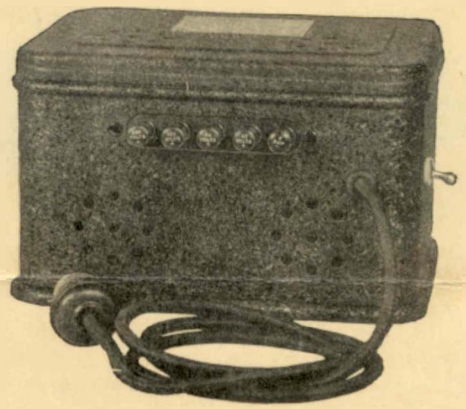


The above chart shows the calibration curves for the three distinct types of General Radio condensers, the maximum capacity of each type being 500 MMF

Broadcast stations continued to multiply, however, until all channels in the wavelength range allotted to broadcasting were filled. The transmission channels were assigned on the basis of uniform frequency rather than uniform wavelength separation, and, as they all became occupied, the difficulty of crowding a great many more than half the stations into the lower half of the dial again rose. The obvious step was, of course, the "straight line frequency plate" shaped to give equal frequency divisions over the dial. This plate shape not only improves the distribution of stations over the dial, but is the only type of condenser which can be used in a single-control superheterodyne, where there is a constant difference of frequency between the two circuits being tuned.

Certain objections, however, have prevented this type of condenser from achieving the wide popularity which was promised for it. In order to obtain a "straight line frequency" variation, an extremely low minimum capacity is required. The stray or "zero" capacity of most receivers is so large as to defeat this requirement and to prevent the realization of a true straight line frequency variation. Another objection was the large physical dimensions of most of the straight line frequency condensers, due to the fact that this plate shape is very inefficient in its use of space. Then, too, there is the fact that in the conventional type of condenser, there is a rotation of but 180° in which all stations must be included. Spreading out stations on the lower portion of the dial necessarily results in crowding them closer together on the upper. It so happened that the policy of the government in assigning channels was to give the high powered stations channels in the upper portion of the wave band, and the crowding together of these stations, generally having the better programs, proved disadvantageous.

Voltage Regulation of Plate Supply Units



One of the most bothersome problems in connection with the design of power supply equipment is that of voltage regulation. This problem does not arise in connection with "B" batteries as their internal resistance is quite low and a relatively large current may be drawn without appreciable drop in terminal voltage. The resistance of the rectifier tube and filter circuit, however, is sufficient to cause an appreciable drop in voltage. This is further complicated by the fact that resistances must be used to get intermediate voltages, which cause further drops at these terminals.

At first, variable resistances were universally resorted to in order to set the voltage at each terminal to the desired value. This arrangement proved open to several objections. In the first place, it added several controls to those already on the receiver, a distinct disadvantage at a time when the trend is toward simplification and elimination of adjustments. A further objection was that very few users of the power units had a suitable voltmeter for adjusting the voltage. A very high resistance voltmeter is required for this purpose, as the ordinary voltmeter used for checking "B" battery voltages, draws sufficient current to change the voltage of the plate supply greatly. As a result, the voltage of these instruments having adjustments was in most cases set at the wrong value. This is not so serious of itself, as present day tubes do not usually require a particularly critical adjustment of plate current.. There was a strong temptation, however, to make excessive use of the voltage control in an effort to clear up trouble having its source elsewhere. It proved, unfortunately, that many of the variable resistances offered for this work were not equal to the strain of almost continual adjustment, and trouble developed due to the noisy action of these devices.

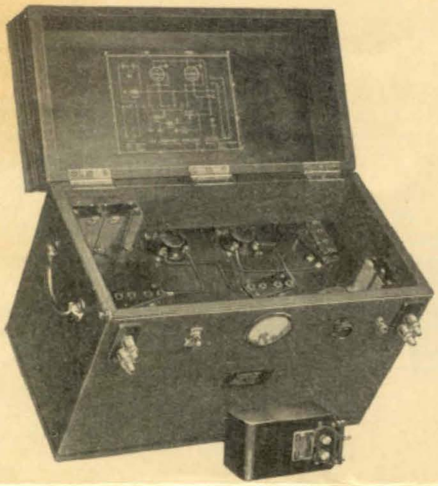
These considerations made the elimination of the variable resistance highly desirable. While this arrangement does not permit an exact adjustment of voltage, if the resistances are properly proportioned, it is possible to hold the voltage at any terminal within fairly narrow limits over the range of current likely to be drawn from it.

In a plate supply designed for this purpose, the resistance across the output circuit is relatively low, so that a considerable current is drawn from the rectifier when no tubes are connected. When tubes are connected to the plate supply, the series-parallel circuit resulting, consisting of tubes and the output resistance of the filter, is very complicated. Briefly, however, as tubes are inserted into the circuit the "bleed" current through the low tap resistance decreases, and part of it flows through the tubes. Thus the drain on the rectifier and its output voltages does not change as much as it would were the variable high resistance system used. The result is greatly improved regulation. In fact, it is possible to have a lower voltage drop per mil at the lowest tap than occurs in the overall voltage, despite the greater resistance of the circuit from which it is drawn.

A plate supply designed along this line will fit the needs of a great number of cases without adjustments of any kind. In the few cases which it does not fit, the adjustable factor may easily be added.

Another advantage of the low output resistance is that it limits the rise in voltage when the load is turned off, lessening the possibility of damage to filter condensers. This design, combined with a judicious choice of condensers, has practically eliminated the problem of condenser puncture.

The Type 415 Laboratory Amplifier



The sensitivity of a great many laboratory measurements can be increased by the use of a properly designed amplifier. An amplifier also makes possible the substitution of a visual for an auditory balance of bridge circuits operating at 800 to 1,000 cycles. This feature is of advantage, for example, in connection with the 383 capacity bridge. When this instrument is set up for factory test work, a vacuum tube voltmeter may be used as an indicator, which greatly simplifies the setting of tolerances. An amplifier is necessary also in making observation by means of an oscillograph such as the General Radio Type 338, where the circuit conditions must not be disturbed by the measuring equipment.

In the Type 415 amplifier, the necessary equipment and batteries are contained in a single cabinet of stout construction. The audio coupling units are mounted on our Type 274 plugs so that any type of coupling unit desired may be used. This feature makes possible a quick determination of the relative merits of different types of amplifying systems. The output of the second tube may be connected directly to the output terminals or by means of a plug base to any form of output coupling device desired. Four-plug plates may be obtained which may be used for mounting various types of coupling units.

The battery space is sufficient for four 22-volt "B" batteries, one 4.5-volt "C" battery and three 1.5-volt "A" cells. The amplifier is designed for use with WX-12 or UX-199 (C X-12 or CX-299) tubes. A voltmeter in the panel provides for proper adjustment of the filament voltages.

The price of the Type 415 Laboratory Amplifier, exclusive of tubes, batteries and transformers, is $40.

How Good Is "GOOD"?

How good is "good"? What are the requirements of a good amplifier?

It will be readily conceded by all that a perfect amplifier is one which will cause a reproducer to set up in a room exactly the same combination of sound waves as existed in the room where the transmitter microphone was placed. The reproduced sounds depend on a great many factors beside the amplifier, and the original sound may be changed either before it enters or after it leaves the amplifier. Before reaching the receiving audio amplifier, the sound passes through a microphone, several amplifiers, often several hundred miles of telephone line, a few or hundreds of miles of space, the radio frequency amplifier and detector. Each successive element of the system has an opportunity to alter the characteristic of the original sound, and most of them take advantage of it to a greater or less degree. The composite effect of these elements in the system includes both addition and subtraction.

In considering the amplifier, we are then confronted by the fact that the product delivered at the amplifier input terminals is no longer capable of reproducing the sound waves existing at the microphone. Even a "perfect" amplifier per se, then, can not deliver a perfect output. The amplifier cannot replace that which has been lost. Possibly, however, it can partially remove the sounds which have been added, without removing any of the original sound. Many of the noises added to the signal as it traverses the transmitting and receiving systems occur at relatively high frequencies, above 5,000 cycles. The experiments of Dr. Harvey Fletcher of the Bell Telephone Laboratories have demonstrated the fact that frequencies above 4,000 or 5,000 cycles may be eliminated from speech and music without noticeable effect. It seems then desirable that the amplifier be so designed as to cut off at about 5,000 cycles, and that such an amplifier would give more nearly perfect results than a "perfect" amplifier.

Under present conditions, the signal probably suffers more between the time it leaves the amplifier and the time it strikes the ear than it does before reaching the amplifier. That is to say, the loudspeaker is probably a greater source of frequency distortion than all the rest of the system.

The loss of the lower frequencies is due principally to the inability of many loudspeakers to reproduce frequencies much lower than 200 cycles. It does not seem to be generally realized how high this actually is, in many cases around 200 cycles. The sensitivity at low frequencies of two of the best types of present day speakers was checked at 60 cycles, by means of an oscillograph. The oscillograph was first connected to the input and the input signal adjusted for an exactly sinusoidal wave form. The oscillograph was then switched to a pickup and the sound wave in the room was seen to be of 120 cycles frequency. A stiff connection was made between the speaker and the pickup, and a 60 cycle wave appeared, showing that while the speaker was vibrating at 60 cycles, no measurable energy was being radiated at that frequency. Another test with a different type of speaker showed that the full output of a UX-210 tube was required to get an audible sound at 60 cycles.

Someone has made the suggestion that since reproducers are more or less peaked at the middle or upper frequencies, transformers should be designed to have a corresponding hollow. This is upsetting the perfect amplifier with a vengeance. It would seem more logical, however, for the loudspeaker manufacturer to equip his instrument with a filter to cut off the peaks of the curve in somewhat the same manner as telephone lines are "equalized." If the amplifier were made to match the speaker, it would be necessary to discard the entire amplifier every time an improvement was made in reproducers.

To the manufacturer of coupling units, the problem of "how good is good" presents itself in a very practical manner. How far down in the low frequency region is it reasonable to go? How much of this band, which does not now exist in the input to the amplifier, and could not be reproduced if delivered to the speaker, should the amplifier be capable of passing? It boils down to: "Is the public willing, and justifiably so, to pay more for a transformer that will amplify as low as 30 cycles than for a transformer capable of amplifying frequencies of the order of 100 cycles, when no actual gain in quality of reproduction results from the higher cost?"

Fortunately, the low frequencies that our present reproducers will not radiate are not lost. These frequencies are reproduced in the ear from their harmonics and the fundamental pitch of the note is not lost, although if the cut-off of the amplifying and reproducing systems is too high, it loses "naturalness." It is to the detector action of the ear that most of the bass notes we hear are due, and they come from no farther out the "vasty" ether than the ear of the listener.

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SIZE B. & S.	DIAMETER - MILS	AREA IN CIR. MILS	TENSILE STRENGTH IN LBS. - HARD	TENSILE STRENGTH IN LBS. - SOFT	FEET PER OHM	FEET PER POUND					OHMS PER POUND 68°F					OHMS PER 1000 FT 68°F	FUSING POINT IN AIR	TURNS PER INCH						POUNDS PER 1000 FEET						COST PER POUND IN CTS.					
						BARE	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON			BARE	ENAMEL	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	ENAMEL	SINGLE SILK	DOUBLE SILK	SINGLE COTTON	DOUBLE COTTON	BARE	ENAMEL	SINGLE SILK (White)	DOUBLE SILK (White)	SINGLE COTTON	DOUBLE COTTON
1	289	83700	3746	2234	8062	3.95					.0005					.126								253											
2	258	66400	3127	1772	6394	4.98					.00078					.159								201											
3	229	52600	2480	1405	5070	6.28					.00124					.201								159											
4	204	41700	1967	1114	4021	7.91					.00197					.253								126											
5	182	33100	1559	883	3189	9.98					.00314					.319								100											
6	162	26300	1237	700	2529	12.6					.00499					.403								79.5											
7	144	20800	980	555	2005	15.9					.0079					.508								63											
8	128	16500	778	440	1590	20					.0126					.641								50											
9	114	13100	617	349	1261	25.2					.02					.808								39.6											
10	102	10400	489	277	1000	31.8					.0314					1.02	333							31.4											
11	91	8230	388	219	793	40.1					.0507					1.28	284							24.9										21	22
12	81	6530	307	174	629	50.6					.0806					1.62	235							19.8										21	22
13	72	5180	244	138	499	63.8					.1284					2.04	200							15.7										22	23
14	64	4100	193	109	396	80.4					.2032					2.58	166	15.6	14			14	13	12.4	12.68			12.68	12.92		21			23	24
15	57	3260	153	87	321	101.4					.3166					3.25	139	17.5	16			15	14	9.86	10.05			10.08	10.27		22			24	26
16	51	2580	133	69	249	127.9					.515					4.09	117	19.6	18			17	16	7.82	7.97			8.01	8.18		22	38	50	25	28
17	45	2050	97	55	197	161.3					.819					5.16	99	22	21			20	18	6.20	6.32			6.37	6.51		23	39	52	27	29
18	40	1620	77	43	156.5	203.4					1.302					6.51	82.8	25	23			22	20	4.92	5.01			5.08	5.19		23	39	55	28	31
19	36	1290	61	34	124	256.5					2.076					8.21	66.7	27.8	27			25	22	3.90	3.97			4.04	4.13		24	42	62	30	33
20	32	1020	48	27	98.4	323.4	319	312	311	298	3.293	3.23	3.175	3.15	3.02	10.4	58.3	31	29	27	25	27	25	3.09	3.14	3.13	3.20	3.22	3.29		25	47	67	31	36
21	28.5	810	38	21.5	78.1	407.8	398	389	389	370	5.235	5.125	5.025	4.97	4.72	13.1	49.3	35	32	30	27	30	27	2.45	2.475	2.49	2.56	2.57	2.63		27	51	73	34	39
22	25.3	642	30.2	17.1	61.91	514	504	493	491	461	8.321	8.12	7.96	7.81	7.44	16.5	41.2	39	36	34	30.5	34	30	1.94	1.970	1.98	2.03	2.05	2.11		26	52	83	34	42
23	22.6	509	24	13.6	49.09	648	645	631	624	584	13.24	12.9	12.6	12.4	11.7	20.8	34.5	44	40	38	34	37	32	1.54	1.555	1.573	1.604	1.63	1.68		27	54	89	35	47
24	20.1	404	19.1	10.8	38.92	818	795	779	778	745	21.05	20.4	19.9	19.6	18.2	26.2	28.9	50	45	43	38	41	35	1.22	1.232	1.241	1.298	1.30	1.34		28	61	98	38	51
25	17.9	320	15.1	8.55	30.86	1031	1004	966	958	903	33.47	32.4	31.5	30.9	28.4	33	24.6	56	50	47	41	45	38	.97	.980	.991	1.04	1.04	1.08		29	67	109	42	58
26	15.9	254	12	6.8	24.47	1300	1240	1202	1188	1118	53.23	51.3	49.7	48.5	44.3	41.6	20.6	63	57	52	45	50	41	.769	.777	.791	.833	.828	.873		31	75	121	45	62
27	14.2	202	9.45	5.35	19.41	1639	1615	1542	1533	1422	84.64	81.4	78.3	76.5	68.8	52.5	17.7	70	64	58	50	55	45	.61	.616	.631	.666	.661	.703		33	81	139	50	71
28	12.6	160	7.5	4.25	15.39	2067	2023	1917	1903	1759	134.6	129	123	120	106	66.2	14.7	79	71	64	53	60	48	.484	.485	.499	.521	.524	.562		35	94	149	85	85
29	11.3	127	6	3.4	12.21	2607	2625	2485	2461	2207	214	204	194	190	164	83.4	12.5	88	81	71	58	65	51	.384	.384	.397	.416	.421	.457		37	105	167	61	93
30	10	101	4.75	2.7	9.68	3287	3325	2909	2893	2534	340.2	322	306	294	252	105	10.25	100	88	80	66	71	55	.304	.303	.315	.332	.336	.372		40	115	200	68	109
31	8.9	79.7	3.75	2.12	7.86	4145	3820	3683	3483	2768	528.4	510	477	461	384	133	8.75	112	104	87	71	76	58	.241	.242	.254	.267	.271	.307		43	133	219	89	124
32	8	63.2	2.97	1.68	6.09	5227	4876	4654	4414	3737	860.3	803	747	717	585	167	7.26	125	120	95	76	84	62	.191	.192	.203	.214	.215	.248		43	149	259	94	148
33	7.1	50.1	2.36	1.33	4.83	6591	6243	5689	5688	4697	1367	1265	1165	1195	880	211	6.19	141	130	105	83	90	66	.152	.152	.161	.172	.174	.201		45	174	304	107	168
34	6.3	39.8	1.87	1.06	3.83	8311	7757	7111	6400	6168	2175	1995	1810	1715	1315	266	5.12	159	140	110	88	97	69	.120	.121	.130	.140	.141	.161		47	211	345	127	203
35	5.6	31.5	1.49	.84	3.04	10480	9660	8534	8393	6737	3458	3140	2820	2640	1960	335	4.37	179	160	130	104	104	73	.0954	.101	.110	.119	.120	.137		51	242	405	152	236
36	5	25	1.18	.67	2.41	13210	11907	10040	9846	7877	5497	4880	4340	4070	2890	423	3.62	200	190	140	110	117	82	.0757	.081	.089	.096	.099	.112		58	294	488	176	268
37	4.5	19.8	.93	.53	1.91	16660	13474	10670	11636	9309	8742	7680	6660	6180	4230	533	3.08	222	205	150	115	123	85	.060	.07	.077	.082	.084	.096		68	344	590	208	292
38	4	15.7	.74	.42	1.51	21010	16516	14220	13848	10660	13772	12100	10250	9430	6150	673	2.55	250	225	160	120	130	88	.0476	.051	.058	.065	.071	.088		83	464	746	243	353
39	3.5	12.5	.59	.33	1.2	26500	22260	16520	18286	11910	21896	18850	15600	14200	8850	848	2.2	285	255	180	130	142	90	.0377	.039	.045	.053	.058	.081		102	548	891	289	399
40	3.1	9.9	.47	.26	.95	33410	26950	21330	24381	14220	34823	29300	23650	21300	12500	1070	1.86	321	280	200	140	151	92	.0299	.031	.037	.040	.046	.072		139	693	1149	346	452

Add 5% to this price, for Green Silk Wire

For those who are keeping a continuous file of the various issues of the "Experimenter" and who would like a copy of the Copper Wire Table to mount on a piece of stiff cardboard