H 10

FOR OFFICIAL USE

PW—H 10

Post Office Engineering Department

TECHNICAL PAMPHLETS FOR WORKMEN

Subject:

Constants of Conductors used for Telegraph and Telephone Purposes

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ENGINEER-IN-CHIEF'S OFFICE
1919

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FOR OFFICIAL USE

CONSTANTS OF CONDUCTORS

(H 10)

The following pamphlets in this series are of kindred interest :—

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CONSTANTS OF CONDUCTORS USED FOR TELEGRAPH AND TELEPHONE PURPOSES

CONDUCTORS.

Aerial Line Wires.—The mechanical and electrical data of the various iron, copper, and bronze and cadmium copper wires now used for line circuits are given in Tables I., II., III. and IV. respectively.

TABLE I.—IRON WIRE.

Weight.		Approximate Standard Wire Gauge.	Diameter.		Resistance at 60° F.		Minimum Breaking Load in lbs.
lbs. per Mile.	Kilograms. per Kilometre.		Inches.	Mms.	Ohms per Mile.	Ohms per Kilometre.	
400	112·7	7½	0·171	4·343	13·32	8·28	1,200
200	56·4	10½	0·121	3·073	26·64	16·55	600
60	16·9	16	0·066	1·676	88·8	55·2	—

TABLE II.—HARD-DRAWN COPPER WIRE.

800	225·5	4½	0·224	5·683	1·098	0·682	2,400
600	169·1	6	0·194	4·921	1·465	0·910	1,800
400	112·7	8	0·158	4·018	2·202	1·368	1,250
300	84·6	9½	0·137	3·480	2·941	1·827	945
200	56·4	11½	0·112	2·841	4·421	2·747	640
150	42·3	13	0·097	2·461	5·900	3·666	490
100	28·2	14	0·079	2·009	8·858	5·504	330

TABLE III.—BRONZE WIRE.

150	42·3	13	0·097	2·464	12·14	7·54	700
70	19·7	16	0·066	1·676	26·0	16·1	345
40	11·3	18	0·050	1·270	45·5	28·3	200

TABLE IV.—CADMIUM COPPER WIRE.

70	19·7	16	0·066	1·676	15	9·3	345
40	11·3	18	0·050	1·270	26	16·1	200

Two useful formulæ, based on the British Engineering Standards Association's Specification (No. 7–1922) for calculating the resistance of copper wire, are as follows :—

If R = Resistance at 60° F. in ohms per mile of wire

and W = Weight of wire in lbs. per mile,
then

$$R = \frac{860 \cdot 0}{W} \text{ for annealed high conductivity copper}$$

and

$$R = \frac{885 \cdot 8}{W} \text{ for hard-drawn high conductivity copper.}$$

Air-Space, Paper-Core Underground Cable.—The dimensions and electrical data of the conductors for this type of cable are given in Tables V to VIII.

TABLE V.—AIR-SPACE, PAPER-CORE (A.S.P.C.) CABLE, MULTIPLE TWIN.

Nominal weight of Conductor in lbs. per mile.	Diameter in Inches.		Maximum Resistance in ohms per statute mile of cable at 60° F. (Single Wire.)	Mean Electrostatic capacity in microfarads per mile (wire to wire*).	Minimum Insulation Resistance of Cable in Factory Megohms per mile.†
	Minimum.	Maximum.			
20	0·0350	0·0360	43·86	0·062	25,000
40	0·0495	0·0505	21·93	0·062	25,000
70	0·0655	0·0670	12·53	0·062	25,000
100	0·0780	0·0800	8·77	0·062	25,000
150	0·0960	0·0980	5·85	0·062	25,000
200	0·1105	0·1135	4·39	0·062	25,000

* In 90 per cent. of the factory lengths of the cable the average mutual capacity of all pair circuits of each group of each length taken separately is to be within plus or minus 5 per cent. of 0·062 microfarad per mile. In the remaining 10 per cent. of the factory lengths the average mutual capacity of all pair circuits of each group of each length taken separately is to be within plus or minus 8 per cent. of 0·062 microfarad per mile.

In each factory length of cable the average mutual capacity of all phantom circuits of each group taken separately is not to differ by more than 5 per cent. from the value to be determined by multiplying the actual average pair capacity of that group in the same factory length by the factor 1·62.

† Insulation tests are made with 300 volts. The insulation resistance of each conductor in the cable from every other conductor in the cable and from the lead sheath is not to be less than 25,000 megohms per mile after electrification for one minute at a temperature of not less than 50° F.

TABLE VI.—AIR-SPACE, PAPER-CORE (A.S.P.C.) CABLE, QUAD, TRUNK TYPE.

Nominal weight of Conductor in lbs. per mile.	Diameter in Inches.		Maximum Resistance in ohms per statute mile of cable at 60° F. (Single Wire.)	Mean Electrostatic capacity in microfarads per mile (wire to wire) within ± 5% of :—*	Minimum Insulation Resistance of Cable in Factory. Megohms per mile.
	Minimum.	Maximum.			
10	0·0245	0·0255	87·72	0·072	15,000
20	0·0350	0·0360	43·86	0·066	15,000
40	0·0495	0·0505	21·93	0·066	15,000
70	0·0655	0·0670	12·53	0·066	15,000
100	0·0780	0·0800	8·77	0·066	15,000

TABLE VII.—AIR-SPACE, PAPER-CORE (A.S.P.C.) CABLE, QUAD, SUBSCRIBERS' TYPE.

Nominal weight of Conductor in lbs. per mile.	Diameter in Inches.		Maximum Resistance in ohms per statute mile of cable at 60° F. (Single Wire.)	Mean Electrostatic capacity in microfarads per mile (wire to wire) not to exceed :—	Minimum Insulation Resistance of Cable in Factory. Megohms per mile.
	Minimum.	Maximum.			
6½	0·0195	0·0205	134·96	0·085	5,000
10	0·0245	0·0255	87·72	0·085	5,000

TABLE VIII.—AIR-SPACE, PAPER-CORE (A.S.P.C.) CABLE, TWIN.

6½	0·0195	0·0205	134·96	0·075	5,000
10	0·0245	0·0255	87·72	0·075	5,000
20	0·0350	0·0360	43·86	0·065	5,000
40	0·0495	0·0505	21·93	0·065	5,000

Submarine Cable G.P. Core.—Table IX gives the electrical data for various sizes of core used in connection with the different types of submarine cable.

* 10 per cent. of factory lengths may be within ± 8 per cent. of 0·066 microfarad per mile.

TABLE IX.—SUBMARINE CABLE, G.P. CORE.
Tests made at 75° F.

Type of Core, Standard weight in lbs. per Naut of		Maximum Resistance in Ohms per Naut.	Maximum Product of Resistance and Weight per Naut in ohm-lbs.	Maximum Capacity in Mfds. per Naut.	Insulation Resistance in Megohms per Naut.	
Copper.	Gutta-Percha.				Minimum.	Maximum
$42\frac{1}{4}$	55	28·52	1,205	0·315	400	—
107	150	11·26	1,205	0·305	400	2,000
160	150	7·53	1,205	0·350	400	2,000

Note.—The term "**naut**" is used to represent 2,029 linear yards.

The conductor, of the types of core given in Table IX, is formed of a strand of seven annealed copper wires of equal diameter. The lay of the wires in the strand is left-handed; the minimum conductivity of the wire is specified to be 100 per cent. of that of annealed high conductivity copper, according to the British Engineering Standards Association's standard.

The dielectric of the cores is formed by covering the conductor with three alternate layers of Chatterton's compound and gutta-percha, beginning with a layer of the compound, no more compound being used than is necessary to secure adhesion between the conductor and the gutta-percha.

The test figures given in Table IX are those specified for submarine cable which must have been manufactured at least 14 days, and also kept in water maintained at 75° F. for at least 24 hours previous to test.

Submarine Cable, Paper Core.—Paper is now used as the insulating medium in submarine cables intended for use in waters of not too great a depth. The conductors are covered solidly with paper, little air space being provided. Four such conductors are laid up in quad (as distinct from multiple—twin) formation to form a unit upon which three circuits are worked, namely, one phantom and two side circuits. A number of such units are stranded together to form a cable the whole being lead sheathed and armoured. Sometimes two lead sheaths are used. Such cables are usually loaded by means of a lapping of magnetic material around each of the conductors applied prior to the paper insulating process.

High Conductivity Annealed Copper Wire.—In Table X the diameter, sectional area, and current carrying capacity are given for high conductivity annealed copper wire. The sizes include all gauges from 0 to 50 S.W.G. The different sizes of electric light cable given in the Rate Book are shown in Table XI.

Table X.—H.C. Annealed Copper Wire.

Size.	Diameter.		Sectional Area.		Current Rating, Ampères, at	
S.W.G.	Inches.	Mms.	Sq. Ins.	Sq. Mms.	1000 amps per sq. in.	I.E.E. Standard.
50	0·0010	0·02539	0·0000007854	0·0005067	0·0007	This column is compiled according to the Standards fixed by the Institution of Electrical Engineers. Gauges smaller than No. 22 are not included.
49	0·0012	0·03048	0·000001131	0·0007296	0·0011	
48	0·0016	0·04064	0·000002011	0·0012972	0·0020	
47	0·0020	0·0508	0·0000031	0·002027	0·0031	
46	0·0024	0·0610	0·0000045	0·002919	0·0045	
45	0·0028	0·0711	0·0000062	0·003973	0·0062	
44	0·0032	0·0813	0·0000080	0·005188	0·0080	
43	0·0036	0·0914	0·0000102	0·006567	0·0102	
42	0·0040	0·1016	0·0000126	0·008109	0·0126	
41	0·0044	0·1118	0·0000152	0·009810	0·0152	
40	0·0048	0·1219	0·0000181	0·011674	0·0181	
39	0·0052	0·1321	0·0000212	0·013701	0·0212	
38	0·0060	0·1524	0·0000283	0·018241	0·0283	
37	0·0068	0·1727	0·0000363	0·023430	0·0363	
36	0·0076	0·1930	0·0000454	0·029267	0·0454	
35	0·0084	0·2134	0·0000554	0·035752	0·0554	
34	0·0092	0·2337	0·0000665	0·042887	0·0665	
33	0·0100	0·2539	0·0000785	0·050670	0·0785	
32	0·0108	0·2743	0·0000916	0·059102	0·0916	
31	0·0116	0·2946	0·0001057	0·068181	0·1057	
30	0·0124	0·3149	0·0001208	0·077910	0·1208	
29	0·0136	0·3454	0·0001453	0·093722	0·1453	
28	0·0148	0·3759	0·0001720	0·11099	0·1720	
27	0·0164	0·4166	0·0002112	0·13628	0·2112	
26	0·018	0·4572	0·0002545	0·1642	0·2545	
25	0·020	0·5080	0·0003142	0·2027	0·3142	
24	0·022	0·5588	0·0003801	0·2453	0·3801	
23	0·024	0·6096	0·0004524	0·2919	0·452	
22	0·028	0·7112	0·0006158	0·3973	0·616	2·5
21	0·032	0·8128	0·0008042	0·5188	0·804	3·3
20	0·036	0·9144	0·001018	0·6567	1·018	4·0
19	0·040	1·016	0·001257	0·8109	1·257	5·3
18	0·048	1·219	0·001810	1·168	1·810	7·2
17	0·056	1·422	0·002463	1·589	2·463	9·8
16	0·064	1·626	0·003217	2·075	3·217	12·9
15	0·072	1·829	0·004072	2·627	4·072	16·3
14	0·080	2·032	0·005027	3·243	5·027	19
13	0·092	2·337	0·006648	4·289	6·648	23
12	0·104	2·642	0·008495	5·480	8·495	28
11	0·116	2·946	0·01057	6·819	10·57	32
10	0·128	3·251	0·01287	8·304	12·87	35
9	0·144	3·658	0·01629	10·51	16·29	38
8	0·160	4·064	0·02011	12·97	20·11	44

TABLE X.—*Continued.*

Size.	Diameter.		Sectional Area.		Current Rating, Ampères, at	
S.W.G.	Inches.	Mms.	Sq. Ins.	Sq. Mms.	1000 amps. per sq. in.	I.E.E. Standard.
7	0·176	4·470	0·02433	15·70	24·33	48
6	0·192	4·877	0·02895	18·68	28·95	53
5	0·212	5·385	0·03530	22·77	35·30	60
4	0·232	5·893	0·04227	27·27	42·27	65
3	0·252	6·401	0·04988	32·18	49·88	74
2	0·276	7·010	0·05983	38·60	59·83	83
1	0·300	7·620	0·07069	45·60	70·69	92
0	0·324	8·230	0·08245	53·19	82·45	102

TABLE XI.—ELECTRIC LIGHT AND POWER CABLES.

Standard annealed Copper Wires and Cables (British Standards Association's Specifications Nos. 7 and 152—1922).

Number and Diameter of Wires comprising the Conductor.		Sectional Area.		Current Rating in Ampères.		Old S.W.G. sizes
Inches.	Mms.	Sq. Inches.	Sq. Mms.	At 1000 amps. per sq. Inch.	At I.E.E. Standard single V.I.R. Cables run in pairs.	Approximate.
3/·029	3/·736	0·002	1·25	2·0	7·8	3/22
3/·036	3/·914	0·003	1·93	3·0	12·0	3/20
7/·029	7/·736	0·0045	2·932	4·5	18·2	7/22
7/·036	7/·914	0·007	4·519	7	24·0	7/20
7/·044	7/1·117	0·010	6·75	10	31·0	7/18
7/·052	7/1·32	0·0145	9·429	14·5	37·0	7/17
7/·064	7/1·625	0·0225	14·28	22·5	46·0	7/16
19/·052	19/1·32	0·040	25·54	40	64·0	19/17
19/·064	19/1·625	0·060	38·7	60	83·0	19/16
19/·072	19/1·828	0·075	48·98	75	97·0	19/15
19/·083	19/2·108	0·100	65·09	100	118·0	19/14
37/·064	37/1·625	0·120	75·32	120	130·0	37/16
37/·072	37/1·828	0·15	95·33	150	152·0	37/15
37/·083	37/2·108	0·2	126·6	200	184·0	37/14
37/·093	37/2·362	0·25	159	250	214·0	—
37/·103	37/2·616	0·3	195·1	300	240·0	37/12
61/·093	61/2·362	0·4	262·1	400	288·0	—
61/·103	61/2·616	0·5	321·5	500	332·0	—
91/·093	91/2·362	0·6	391	600	384·0	—
91/·103	91/2·616	0·75	479·6	750	461·0	91/12

FUSES.

Fuses are easily replaceable portions of an electric circuit, especially designed to melt when more than a certain electric current passes through them. By this means the circuit is broken and the other apparatus in it is protected from injury by the excessive current.

Any conductor may be used to make the fuse, but certain precautions must be observed.

(1) The terminals, between which the fuse is fixed, must be sufficiently far apart to prevent an arc being formed by the volatilised material of the fuse between the terminals.

(2) The material of the fuse should be of good electrical conductivity, otherwise the fuse must be of large size to carry the current, and a large quantity of metal is volatilised when the fuse blows. This increases the risk of an arc forming and is otherwise objectionable. The voltage drop across a high resistance fuse may be appreciable and in certain cases will give rise to cross-talk.

(3) The fuse should preferably melt at a low temperature, or it will oxidise under its normal current and in time it will become liable to fuse below its rated value.

The metals most commonly used for fuses are tin, lead, alloys of those metals, aluminium, copper, platinoid or German silver.

Fuses are usually rated at some current value which may be from one-third to two-thirds the current which will melt the fuse. The Post Office practice is for the rating current to be about half the fusing current.

Table XII gives the currents which will fuse different sized wires of different materials.

TABLE XII.—FUSING CURRENTS.

Fusing Current Ampères.	Diameter of Wire (Inches).				
	Copper.	Aluminium.	Platinoid.*	Tin.	Lead.
1	0·0021	0·0026	0·0035	0·0072	0·0081
2	·0034	·0041	·0056	·0113	·0128
3	·0044	·0054	·0074	·0149	·0168
4	·0053	·0065	·0089	·0181	·0203
5	·0062	·0076	·0104	·0210	·0236
10	·0098	·0120	·0164	·0334	·0375
15	·0129	·0158	·0215	·0437	·0491
20	·0156	·0191	·0261	·0529	·0595
25	·0181	·0222	·0303	·0614	·0690
30	·0205	·0250	·0342	·0694	·0779
40	·0248	·0303	·0414	·0840	·0944
50	·0288	·0352	·0480	·0975	·1095
60	·0325	·0397	·0542	·1101	·1237
70	·0360	·0440	·0601	·1220	·1371
80	·0394	·0481	·0657	·1334	·1499
90	·0426	·0520	·0711	·1443	·1621
100	·0457	·0558	·0762	·1548	·1739
120	·0516	·0630	·0861	·1748	·1964
140	·0572	·0698	·0954	·1937	·2176
160	·0625	·0763	·1043	·2118	·2379
180	·0676	·0826	·1128	·2291	·2573
200	·0725	·0886	·1210	·2457	·2760

* Platinoid, although of high resistance, is useful for fuses for small currents, when copper or tin wire is mechanically unsuitable.

TRANSMISSION OF CURRENTS ALONG TELEPHONE LINES.

The efficiency with which a telephone circuit will transmit electrical currents of speech frequency, which is usually regarded for telephone purposes as lying between 200 and 2,400 periods per second, depends upon the electrical constants of the circuit, namely, the conductor resistance, leakance, electrostatic capacity, and inductance per mile of circuit. It should be noted that the leakance of a telephone circuit is not determined solely by the insulation resistance as it is affected by the dielectric losses which vary with the type of insulating material.

The resistance of the conductor reduces the voltage of the current as the latter travels along the circuit, while leakance and capacity reduce, by their shunting effect, the strength of the current. Thus the power sent into the circuit is reduced or *attenuated* as it travels along the circuit.

Inductance tends to neutralise the effect of the capacity of the circuit and is therefore often added to circuits in the form of loading coils or by wrapping the conductors with fine iron wire. The latter method is referred to as *continuous* loading and the former method as *coil loading.*

Hitherto, the unit of measurement of the attenuation of speech currents flowing through a telephone circuit has been the attenuation equivalent to that due to one mile of *standard cable.* This unit has now been abandoned and a new unit called the *bel* has been substituted. A circuit is said to have a transmission equivalent of one *bel* if the ratio of the power input at the sending end of the circuit to the power output at the distant end is $\frac{10}{1}$. That is, if 10 milliwatts were sent into the circuit 1 milliwatt would be received at the distant end. If a similar circuit were connected in series with the first, then the power input to the second circuit would be 1 mlliwatt and the power output at the distant end would be $\frac{1}{10}$ or $0 \cdot 1$ milliwatt. Therefore, the ratio of the power input to the first circuit to that received at the distant end of the second circuit would be $\frac{10}{0 \cdot 1} = 100 = 10 \times 10$.

Similarly, if a third circuit having a transmission equivalent of 1 *bel* be added the ratio of the power input to the power output will be $10 \times 10 \times 10 = 1{,}000$ that is the power output would be $\frac{1}{1{,}000}$ of the input power. Such a circuit would be said to have a transmission equivalent of 3 *bels.*

In practice the power ratios would not be so simple and it would be very inconvenient to multiply together the power ratios of a number of circuits to obtain the overall transmission equivalent. Therefore, the common logarithms of the ratios are taken. In the above example the

ratio of $\frac{10}{1}$ may be expressed as $10^1 = 1$ *bel.*

,, $\frac{100}{1}$,, ,, ,, $10^1 \times 10^1 = 10^2 = 2$ *bels.*

,, $\frac{1{,}000}{1}$,, ,, ,, $10^1 \times 10^1 \times 10^1 = 10^3 = 3$ *bels.*

Thus the transmission equivalent expressed in *bels* is the common logarithm of the power ratio.

Take another example, assuming that three circuits connected in series had transmission equivalents of 0·5, 0·8, 0·9 *bels*, respectively. This would represent a total of 2·2 *bels*. 2·2 is therefore the logarithm of the ratio of power input to power output. From a table of logarithms this is found to be a ratio of $\frac{158}{1}$ approximately.

For practical use a unit which is one-tenth of the *bel* is used. This is called the *decibel* for which the abbreviation *db* is used. In the above example, therefore, the transmission equivalent of the three circuits would be expressed as 5 *db*, 8 *db* and 9 *db* respectively.

The power ratio equivalent to one *decibel* is, very nearly, $\frac{1 \cdot 25}{1}$ or $\frac{5}{4}$. Thus if 5 milliwatts were sent into a circuit having an equivalent of one *decibel* the received power would be 4 milliwatts.

All European countries use internationally, and nearly all use internally, a unit of transmission termed the *néper*. This unit is the natural unit as deduced mathematically from the theory of telephone transmission. The *néper* is equal to 8·686 *decibels*. All international circuits terminating in London are classified and regulated, for transmission purposes, in terms of the *néper*.

The following table gives the approximate power ratio and the equivalent in miles of standard cable (S.M.) and in *népers* of various transmission equivalents expressed in *decibels*.

db.	Ratio.		*Power input* / Power output	S.M.	*Népers.*
1	$10^{\cdot 1}$	=	1·25	1·08	0·115
2	$10^{\cdot 2}$	=	1·6	2·17	0·23
3	$10^{\cdot 3}$	=	2	3·25	0·34
4	$10^{\cdot 4}$	=	2·5	4·34	0·46
5	$10^{\cdot 5}$	=	3·2	5·42	0·58
6	$10^{.6}$	=	4	6·50	0·69
7	$10^{\cdot 7}$	=	5	7·59	0·81
8	$10^{\cdot 8}$	=	6	8·67	0·92
9	$10^{\cdot 9}$	=	8	9·76	1·04
10	$10^{1 \cdot 0}$	=	10	10·84	1·15
20	$10^{2 \cdot 0}$	=	100	21·68	2·30
30	$10^{3 \cdot 0}$	=	1,000	32·52	3·45
40	$10^{4 \cdot 0}$	=	10,000	43·36	4·60

Table XIII gives the various constants of aerial and unloaded cable conductors. The attenuation constant of any particular type of A.S.P.C. cable will depend upon the value of the capacity constant shown in Tables V to VIII ; Table XIII therefore gives representative figures.

A *microfarad* is one millionth part of a farad, the unit of capacity.

A *micromho* is one millionth of a mho, the standard of *leakance*. It is the inverse of resistance, that is to say :—

$$1 \text{ micromho} = \frac{1}{1 \text{ megohm.}} = \frac{1}{1{,}000{,}000 \text{ ohms.}}$$

The leakance, which must be used in telephonic calculations, is the alternating current leakance, which is much greater than the direct current leakance ; for example, a cable with a direct current (Megger) insulation of 2,000 megohms per mile may have an alternating current insulation of less than a megohm per mile.

TABLE XIII.—TELEPHONE TRANSMISSION DATA FOR UNLOADED CABLE AND AERIAL CONDUCTORS.

Type of Circuit.	Constants per mile loop. Resistance Ohms.	Constants per mile loop. Inductance Henrys.	Constants per mile loop. Leakance Micromhos.	Constants per mile loop. Capacity Microfarads.	Transmission Equivalent of 1 mile of Circuit in decibels.	Number of miles of circuit having a Transmission Equivalent of 1 decibel.
(1) AERIAL WIRE.						
40 lb. Bronze ..	91·00	0·00419	1·5	0·0075	0·33	3·05
70 ,, ,, ...	52·00	0·00419	1·5	0·0079	0·23	4·25
100 ,, Copper	17·60	0·00390	1·5	0·0081	0·11	9·38
150 ,, ,, ...	11·73	0·00376	1·5	0·0084	0·08	12·89
200 ,, ,, ...	8·80	0·00366	1·5	0·0086	0·06	16·27
300 ,, ,, ...	5·87	0·00355	1·5	0·0089	0·04	22·72
400 ,, ,, ...	4·40	0·00344	1·5	0·0092	0·04	28·53
600 ,, ,, ...	2·93	0·00331	1·5	0·0096	0·03	39·31
800 ,, ,, ...	2·20	0·00322	1·5	0·0099	0·02	48·83
40 ,, Cadmium Copper	52·00	0·00419	1·5	0·0075	0·23	4·36
70 ,, ,, ,,	30·00	0·00410	1·5	0·0079	0·16	6·32
(2) UNDERGROUND A.S.P.C. CABLE.						
Standard Cable ..	88·00	0·001	1	0·054	0·92	1·08
6½ lb. Cable	270·77	0·001	1	0·075	1·94	0·52
10 ,, ,, ...	176·00	0·001	1	0·075	1·56	0·64
20 ,, ,, ...	88·00	0·001	1	0·065	1·01	0·99
40 ,, ,, ...	44·00	0·001	1	0·065	0·70	1·44
50 ,, ,, ...	35·20	0·001	1	0·065	0·61	1·63
70 ,, ,, ...	25·14	0·001	1	0·065	0·50	1·99
100 ,, ,, ...	17·60	0·001	1	0·065	0·41	2·47
150 ,, ,, ...	11·73	0·001	1	0·065	0·31	3·24
200 ,, ,, ...	8·80	0·001	1	0·065	0·25	3·97
300 ,, ,, ...	5·87	0·001	1	0·065	0·18	5·47
(3) SUBMARINE CABLE.	Representative Constants per naut loop. Resistance Ohms.	Representative Constants per naut loop. Inductance Henrys.	Representative Constants per naut loop. Leakance Micromhos.	Representative Constants per naut loop. Capacity Microfarads.	Transmission Equivalent of 1 naut of Cable in decibels.	Number of nauts of cable having a Transmission Equivalent of 1 decibel.
160 lb. Copper per naut 300 ,, G.P. per naut ..	14·9	0·0019	17	0·138	0·46	2·13
107 lb. Copper per naut 150 ,, G.P. per naut ..	22·5	0·0022	25	0·160	0·67	1·49
160 lb. Copper per naut 150 ,, G.P. per naut ..	14·9	0·0015	5	0·165	0·53	2·13

Table XIV gives the approximate transmission equivalents, characteristic impedance and cut-off frequency of various types of coil loaded underground cable. The figures for 1·136 mile spacing may be taken to apply approximately to 1·125 mile spacing. For 1·4 mile spacing increase 1·136 mile transmission equivalents by 11 per cent.

Table XV gives representative transmission data for coil loaded and continuously loaded submarine cables.

TABLE XIV.—TRANSMISSION EQUIVALENTS OF COIL-LOADED UNDERGROUND CIRCUITS.

	Inductance of Side Circuit Loading Coils (mH)	Inductance of Phantom Circuit Loading Coils (mH)	Spacing between Coils in miles.	Loading Code.	Weight of Conductor lbs. per mile single wire. Transmission Equivalent of 1 mile of circuit in decibels. 20	40	70	Approximate Characteristic Impedance.	Approximate Cut-Off Frequency p.p.s.
Side Circuits only Loaded	253	—	1·136	253/1·136	·25	·145	·10	1860	2320
	177	—	1·136	177/1·136	·28	·155	·102	1560	2770
	136	—	1·136	136/1·136	·31	·165	·107	1370	3170
	120	—	1·136	120/1·136	·33	·175	—	1260	3340
	89	—	1·136	89/1·136	·36	·195	·12	1110	3920
	44	—	1·136	44/1·136	·49	·26	·155	800	5570
	177	—	1·6	177/1·6	·32	·17	·11	1310	2340
	136	—	2·272	136/2·272	·41	·22	·13	980	2240
	136	—	2·6	136/2·6	·43	·23	·14	920	2090
	22	—	1·136	22/1·136		·36		540	7800
	16	—	1·136	16/1·136		·41		460	9100
	22	—	0·568	22/0·568		·27		760	10900
Side and Phantom Circuits Loaded *Side Circuits*	253	—	1·136	253 S/1·136	·25	·155	·112	1860	2320
	177	—	1·136	177 S/1·136	·29	·165	·113	1560	2770
	136	—	1·136	136 S/1·136	·32	·175	·117	1370	3170
	120	—	1·136	120 S/1·136	·33			1300	3400
	89	—	1·136	89 S/1·136	·37	·20	·125	1110	3920
	44	—	1·136	44 S/1·136	·50	·26	·16	800	5570
	177	—	1·6	177 S/1·6	·33	·18	·12	1310	2340
	136	—	2·272	136 S/2·272	·42	·22	·14	980	2240
	136	—	2·6	136 S/2·6	·44	·23	·145	920	2090
Side and Phantom Circuits Loaded *Phantom Circuits*	253	156	1·136	156 P/1·136	·195	·12	·086	1240	2520
	177	107	1·136	107 P/1·136	·22	·125	·087	1030	3040
	136	82	1·136	82 P/1·136	·23	·135	·092	900	3480
	120	40	1·136	40 P/1·136	·35	—	—	590	4700
	89	54	1·136	54 P/1·136	·28	·155	·098	740	4280
	88	32	1·136	32 P/1·136	·38	·21	—	530	5270
	44	25	1·136	25 P/1·136	·39	·21	·125	510	6300
	177	107	1·6	107 P/1·6	·25	·14	·091	870	2560
	136	82	2·272	92 P/2·272	·32	·17	·107	645	2460
	136	82	2·6	82 P/2·6	·34	·18	·11	600	2290

The transmission equivalent, characteristic impedance and cut-off frequency of conductors loaded with 120 mH coils spaced at 1·136 miles not included in the table are :—

10 lb. conductors 0·65 db 1,210 ohms 3220 p.p.s.
25 ,, ,, 0·26 db 1,260 ,, 3340 ,,

TABLE XV.—TRANSMISSION DATA FOR COIL-LOADED SUBMARINE CABLES.

Weight of Conductor lbs. per naut.	Weight of Gp. lbs. per naut.	Inductance of Loading Coil. Henrys.	Spacing.	Characterisic Impedance. at w = 5000.	Approx. Cut-off Frequency.	Transmission Equivalent of 1 naut of Cable in decibels
310	200	Side ·08 Phantom ·04	1 naut ,,	709 338	2400 2400	·10 ·10
160	150	Side ·100 Phantom ·050	,, ,,	800 400	2230 2230	·15 ·15
46	L.C.P.C.	Side ·044 Phantom not loaded	1760 yds.	Side 815 Phantom 159	5620	·376 1·05
		Continuously Loaded Submarine Cables.				
300	300	Side ·0124 Phantom ·0062	Inductance per naut Henrys.	266 130	— —	·15 ·15
165	L.C.P.C.	Side ·0186 Phantom ·0091		422 172	— —	·17 ·20
161	,,	Side ·0162 Phantom ·0080		439 186	— —	·16 ·18
118	,,	Side ·00126 Phantom ·0059		397 162	— —	·24 ·29
118 Blackpool Isle of Man.	,,	Side ·0118 Phantom ·0055		374 153	— —	·25 ·30

Table XVI.—Inductance and Direct Current Resistance of Loading Coils.

Sides only loaded.

Code Number of Coil.	Nominal Inductance Millihenrys.	Average Loop Resistance.	Code Number of Coil.	Nominal Inductance Millihenrys.	Average Loop Resistance.
506	250	5·6	588	88	3·8
582		10·5	688		·3·7
508	176	4·0	788		3·1
584		7·4	A88		3·0
684		7·3	678	60	2·8
784		5·9	A60		2·1
400		7·0	590	44	2·0
A176		6·2	690		2·0
507	136	3·3	790		1·7
535		3·0	A44		1·7
586		6·2	694	22	1·4
786		4·4	794		1·3
401		5·5	A22		1·0
A136		4·8	676	16	1·5
696	120	4·9	776		·9
796		4·9	AM22	22	2·1
A120		4·1	AM16	16	1·5
			AM11	11	1·1
			AM 8	8	·9

Sides and Phantoms loaded.

Code No. of Loading Unit.	Nominal Inductance Millihenrys. Side.	Nominal Inductance Millihenrys. Phantom.	Average Loop Resistance including Side and Phantom Coils.	Code No. of Loading Unit.	Nominal Inductance Millihenrys. Side.	Nominal Inductance Millihenrys. Phantom.	Average Loop Resistance including Side and Phantom Coils.
582 + 581	250	155	15·6	788 + 787 A88 + 32	88	32	5·1 5·5
584 + 583	176	106	11·0	A60 + 20	60	20	3·8
535 + 536 586 + 585 786 + 785	136	82	4·6 9·2 9·7	590 + 589 690 + 689 790 + 789 A44 + 24	44	24	3·2 3·8 3·2 3·2
796 + 795 A120 + 40	120	40	7·0 7·0	A44 + 16	44	16	2·8
588 + 587	88	54	6·0	A22 + 22	22	12	1·8

Note.—Code numbers, unless preceded by one or more letters, are preceded by a digit indicating the manufacturer.

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