The Bell System Technical Journal

Vol. XVIII *October, 1939* *No. 4*

Experience in Applying Carrier Telephone Systems to Toll Cables

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THE application of carrier telephone systems to toll cable conductors, particularly those conductors in existing cables, is expected to become an important means of providing additional long distance telephone circuits. Eight hundred and thirty-seven route miles have been equipped in the United States to date, and 17 twelve-channel systems have been placed in service, providing a total of about 58,000 circuit miles. Late in 1939, 200 additional route miles are expected to be completed which, together with additional systems on existing routes, will add nine systems and about 48,000 circuit miles to the above figures.

The type of carrier system which has been installed is that described by Messrs. C. W. Green and E. I. Green before the American Institute of Electrical Engineers in 1938, and which is now designated as type K.[1] The problems incident to the application of this system to toll cable conductors may be of general interest and it is the purpose of this paper to describe some of these. This description will start at the point where traffic needs have indicated that additional circuits should be provided along a given route and economic and other considerations have shown that they should be provided by means of type K cable carrier telephone systems. For specific examples, reference will be made to the New York-Charlotte and Detroit-South Bend projects, in which sections the application of the initial type K carrier systems has been completed. Figure 1 shows the geographical location of these installations, as well as some of those sections where type K carrier systems will probably be installed in the future.

[1] For references see end of paper.

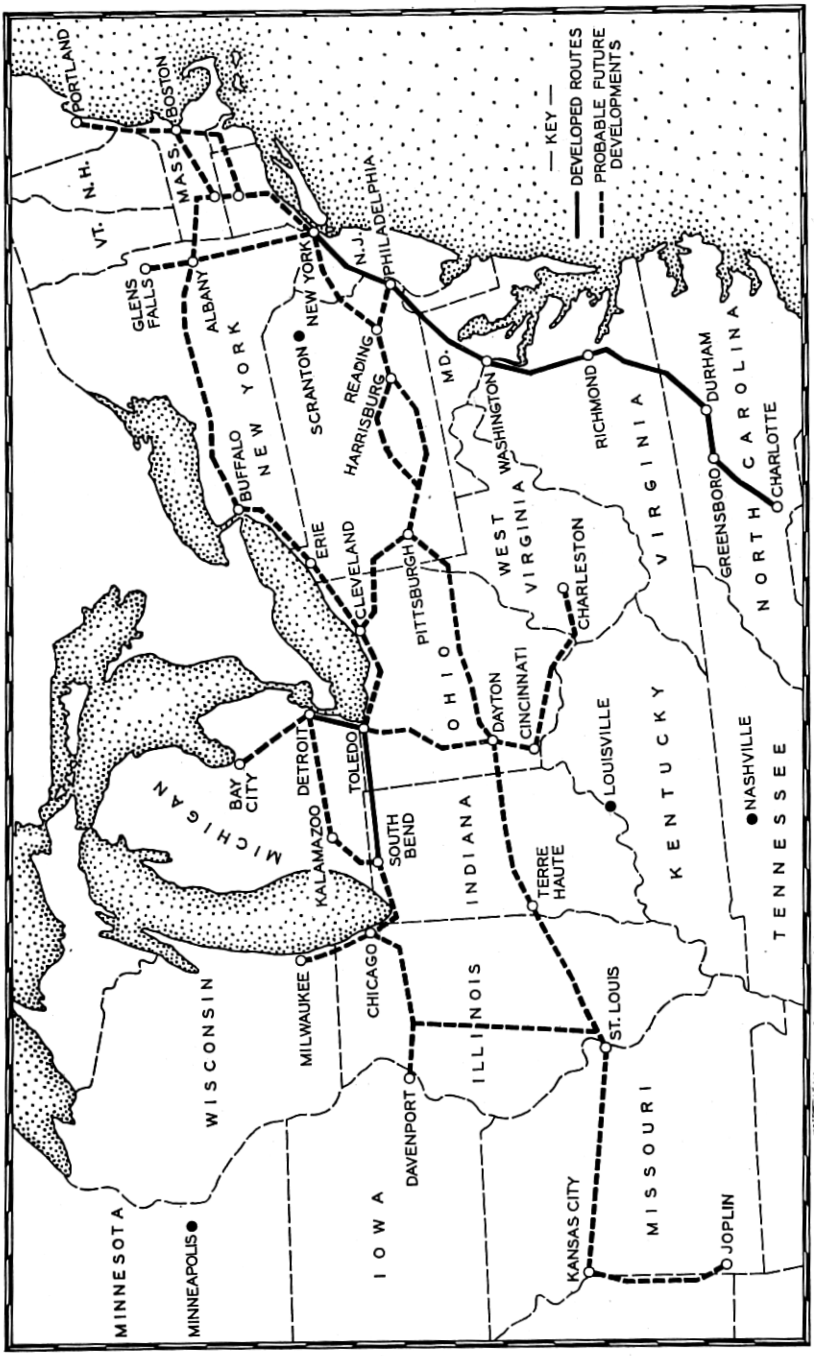

Fig. 1—Routes of existing and probable future type K cable carrier developments.

Selection of Cables to be Equipped

Where more than two cables existed on a route selected for carrier operation, a number of factors influenced the selection of cables to be equipped initially. Among these were the ages of the cables, their makeup, specific route, number of branch cables and open wire junctions, and lengths of underground cable involved. Between Detroit and South Bend there were but two cables on the route selected and hence no selection was necessary. Between New York and Washington on the New York-Charlotte route all cables are underground, and since there were from three to six cables in each repeater section, the two cables which it was decided to employ were selected because they were relatively new and had the smallest number of branches. From Washington to Petersburg, Va., there were two cables, while between Petersburg and Charlotte there was but one cable and it was necessary to install a small second cable chiefly for carrier operation.

The Petersburg-Greensboro section of this second cable was installed one year ahead of the carrier application in order to make use of part of its conductors which were loaded for voice frequency operation. This cable is made up in most sections of 32 quads of 19-gauge conductors, of which 20 are loaded with H-88-50 loading units, leaving 10 quads non-loaded for carrier use and two for maintenance purposes.

The second cable in the Greensboro-Charlotte section was installed coincidentally with the installation of the initial carrier systems. This cable contains 61 non-quadded pairs throughout, except in certain sections where it also contains some loaded conductors for short voice frequency circuits. Paired construction was used because it was expected to be slightly more economical and temporary voice usage of the conductors was not planned.

One additional factor which, in special cases, influences the selection of cables is that of carrier repeater spacing. This is brought about by the fact that on multi-cable routes all of the cables may not follow exactly the same route. For example, one cable may be aerial and the other underground, and the two may be separated in some sections; or underground cables, for conduit reasons, may follow different routes. It is desirable that the two cables used be near each other at repeater points.[2]

One interesting feature in the construction of the Greensboro-Charlotte Cable is the method by which the cable was attached to the messenger. The cable was lashed to the messenger by means of a galvanized steel wire continuous between poles, as shown in Fig. 2. This method of installation is expected to reduce buckling, ring cuts,

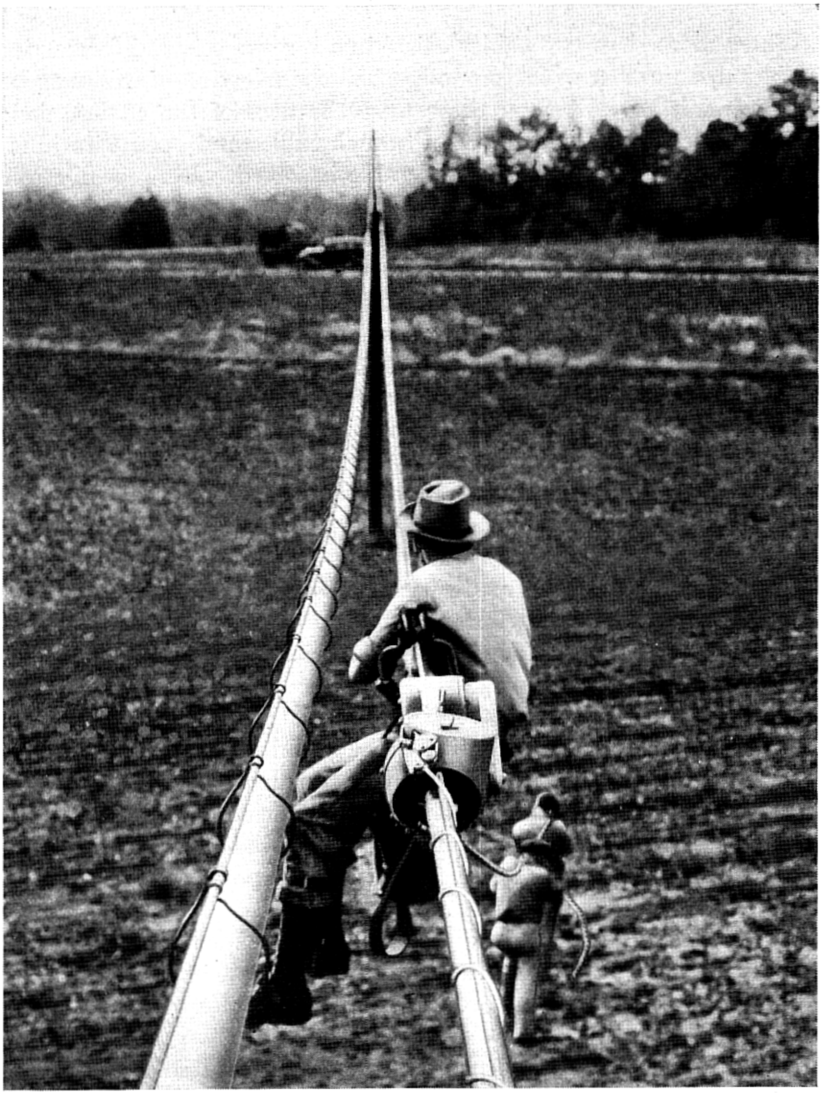

Fig. 2—Method of lashing cable to messenger with galvanized steel wire shown in progress.

and jumping, and avoids the necessity of splicing the cable under tension.

Selection of Conductors for Carrier Use

In general, non-loaded cable pairs are not available in existing cables and it is necessary to remove voice frequency loading from pairs intended for carrier operation. As has been described previously in a paper in this *Journal* [2] the crosstalk mitigation plans in connection with type K carrier are designed on the assumption that cable pairs will be developed in units of 20 pairs for each direction of transmission. Further, the design of this carrier system contemplates the use of 19-gauge pairs.

Ten quads (20 pairs) were, therefore, selected in each cable in which carrier operation was planned. These quads were selected, for crosstalk reasons, from a large voice complement. Two-wire facilities may be used for carrier where a sufficiently large complement exists. This results, however, in the loss of twice as many voice circuits as compared to unloading four-wire quads. In the sections unloaded to date it has been impracticable to unload two-wire facilities.

Where four-wire facilities were used, five quads from the groups designed for each direction of voice frequency transmission in each cable were selected. Over 20,000 circuit miles of four-wire facilities have been unloaded for carrier use. Of this total, H-174-63 loading units were removed from 2,280 circuit miles, and H-44-25 units were removed from the remainder. The H-44-25 loading units removed from 2,475 miles of four-wire circuits were transferred to two-wire 16-gauge quads loaded with H-174-63 units in the same cable, and these latter units released, thus providing at small cost transmission improvement on a total of 4,950 circuit miles.

Preparation of Cable Conductors

Coincidentally with the removal of the loading from the quads selected for carrier operation, special splicing work was performed for crosstalk and transmission reasons. The exact method of making these splices depended upon the layup of the cable involved. For example, if the cable involved concentric segregation, the five former east bound quads were spliced at random to the five former west bound quads and vice versa at each loading point; in cables involving split layer segregation, the ten quads were spliced at each loading point in a planned random manner.

The removal of the loading at the point nearest the center of each carrier repeater section was left until last, so that a special splice, called a poling splice, based on measurements of within-quad admittance unbalances, might be made at each such point.[5] These measurements could not be made until all loading coils on the carrier pairs in the repeater section had been removed. Using these measurements as a guide the quads in one half-section were connected to quads in the other half-section so that the unbalances in the two sections tended to compensate. Table 1 shows for a typical type K repeater section

TABLE 1

Measurements of Mutual Inductance Unbalance (G) and Capacitance Unbalance (C) Before and After Poling on Quads in the Philadelphia-Philadelphia KN Section of the New York-Philadelphia E Cable

Pairs	Before Poling		After Poling	
	G Micromho	C Mmf.	G Micromho	C Mmf.
1–2	.16	110	.12	50
3–4	.12	40	.01	30
5–6	.12	80	.01	45
7–8	.01	40	.02	0
9–10	.07	85	.05	5
11–12	.06	0	0	0
13–14	.10	10	.04	25
15–16	.13	65	0	45
17–18	.11	30	0	20
19–20	.08	25	0	10

the unbalance measurements before poling and the final results after the poling splice was made. These measurements were made at voice frequencies, since as discussed in a previous paper [2] satisfactory results were obtained at these frequencies. It will be noted that poling reduced markedly the unbalances in the quads in the section shown. This is particularly true of the mutual inductance unbalances, indicated in the table by G, the reduction of which is important in reducing crosstalk at carrier frequencies.

After carrying out this and the balancing operations described later for the reduction of crosstalk, it was still necessary to take other steps to reduce the within-quad crosstalk. The recurrence of within-quad coupling between carrier systems which may be assigned to two of the pairs in a 20-pair carrier complement, has been reduced by means of a splicing plan so worked out, that two given carrier systems will operate on the same quad as infrequently as possible. This was accomplished by splitting the quads at the ends of each carrier repeater section on a planned basis. The plan is shown in Table 2. Nineteen types of splices are shown. This table is used as a guide in performing the splice between the balancing bays and the input sealed test terminal. For example, in performing splice type 8, sealed test terminal jacks K-1 are connected to the pair designated 8 at the balancing bay cable terminal, jacks K-2 to the pair designated 16, jacks K-3 to

TABLE 2

DETAILED PLAN FOR SPLITTING QUADS IN NINETEEN CONSECUTIVE CARRIER REPEATER SECTIONS FOR A TEN-QUAD GROUP ARRANGED FOR TYPE K CABLE CARRIER OPERATION

Pair Designation at Sealed Test Terminal Jacks	Planned Splice Type Number																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
K-1	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
K-2	2	3	5	7	9	12	14	16	18	20	1	2	4	6	8	10	13	15	17
K-3	3	4	7	10	14	17	20	3	6	9	19	13	16	19	2	5	8	12	15
K-4	4	5	9	14	18	2	6	10	15	19	3	3	7	12	16	20	4	8	13
K-5	5	6	12	17	2	7	13	18	3	8	17	14	19	4	9	15	20	5	10
K-6	6	7	14	20	6	13	19	5	12	18	5	4	10	17	3	9	16	2	8
K-7	7	8	16	3	10	18	5	13	20	7	15	15	2	9	17	4	12	19	6
K-8	8	9	18	6	15	3	12	20	8	17	7	5	14	2	10	19	7	16	4
K-9	9	10	20	9	19	8	18	7	17	6	13	16	5	15	4	14	3	13	2
K-10	10	11	11	11	11	11	11	11	11	11	9	11	11	11	11	11	11	11	11
K-11	11	12	2	13	3	14	4	15	5	16	14	6	17	7	18	8	19	9	20
K-12	12	13	4	16	7	19	10	2	14	5	8	17	8	20	12	3	15	6	18
K-13	13	14	6	19	12	4	17	9	2	15	16	7	20	13	5	18	10	3	16
K-14	14	15	8	2	16	9	3	17	10	4	6	18	12	5	19	13	6	20	14
K-15	15	16	10	5	20	15	9	4	19	14	18	8	3	18	13	7	2	17	12
K-16	16	17	13	8	4	20	16	12	7	3	4	19	15	10	6	2	18	14	9
K-17	17	18	15	12	8	5	2	19	16	13	20	9	6	3	20	17	14	10	7
K-18	18	19	17	15	13	10	8	6	4	2	2	20	18	16	14	12	9	7	5
K-19	19	20	19	18	17	16	15	14	13	12	12	10	9	8	7	6	5	4	3
K-20	20	1	1	1	1	1	1	1	1	1	10	1	1	1	1	1	1	1	1

Note: Above numbers are pair number designations at balancing bay cable terminals of pairs which are connected to Sealed Test terminal jacks as indicated.

pair 3, etc. Using this plan two systems are exposed to each other on the same quad only once in 19 carrier repeater sections. Beginning with the 20th section the plan is repeated so that between New York and Charlotte two given systems operate together on the same quad in only two repeater sections. Planned splices were made at each end of each carrier repeater section so that after the quads had been split in a definite way at one end of a section, a complementary splice was made at the other end, to rearrange the pairs into a given order as they go through each repeater office. Each carrier pair has been made to appear in the same position at each carrier testboard throughout the 19 types of planned splice sections. This is for convenience in maintaining and identifying them, because carrier systems must be assigned to the same carrier pair in a series throughout the 19 types of planned splice sections if the quad splitting plan is to be completely effective.

The poling splice and the planned splices were, of course, not required in the paired cable placed for carrier operation between Greensboro and Charlotte.

Far-end crosstalk was still further reduced by means of balancing coils installed at the end of each repeater section connected to the repeater inputs.[2, 8] After the splicing operations just discussed were completed and the balancing coils were installed and connected to the carrier pairs, the coupling between each pair and each other pair of the carrier complement was reduced to the lowest value practicable by adjustment of these coils. This was accomplished by sending a disturbing testing tone on one pair, receiving on each other pair in turn, and adjusting the coil which couples each combination of two pairs until a minimum amount of the testing tone was measured on the disturbed pair. Figure 3 shows these adjustments in progress while Table 3 shows a summary of the final crosstalk measurements made after the adjustments. About 19,000 balancing coils have been installed on the carrier routes equipped to date.

At two points on the New York-Charlotte route, retardation coils which are described later were used to increase the attenuation in potential crosstalk paths. At Petersburg, Va., and Burlington, N. C., 60 and 4 voice quads, respectively, connected direct from one carrier cable to the other. These quads, through secondary induction, were likely to serve as crosstalk paths at carrier frequencies between the two cables. Retardation coils were installed in each quad to limit crosstalk currents. Two other situations, where quads connected between the carrier cables, were eliminated by cable rearrangements.

Lateral Cables

At each carrier repeater station four lateral cables were installed to bring the carrier pairs into the repeater building. One of these was required for each direction of transmission for each cable; that is, two input cables and two output cables were required. As a result of the transposition of directions of transmission at each repeater point, the two input cables connect to one toll cable and the two output cables to the other. Figure 4 shows these cables installed at an aerial cable repeater point. All lateral cables were installed for the probable ultimate capacity for carrier systems of the cables being developed; that is, 100 systems on the Detroit-South Bend route, 100 systems north and 60 systems south of Richmond, Va., on the New York-Charlotte route.

The Location of Carrier Repeater Station Sites

The next important step in the development of a route for type K carrier operation is the selection of points at which intermediate

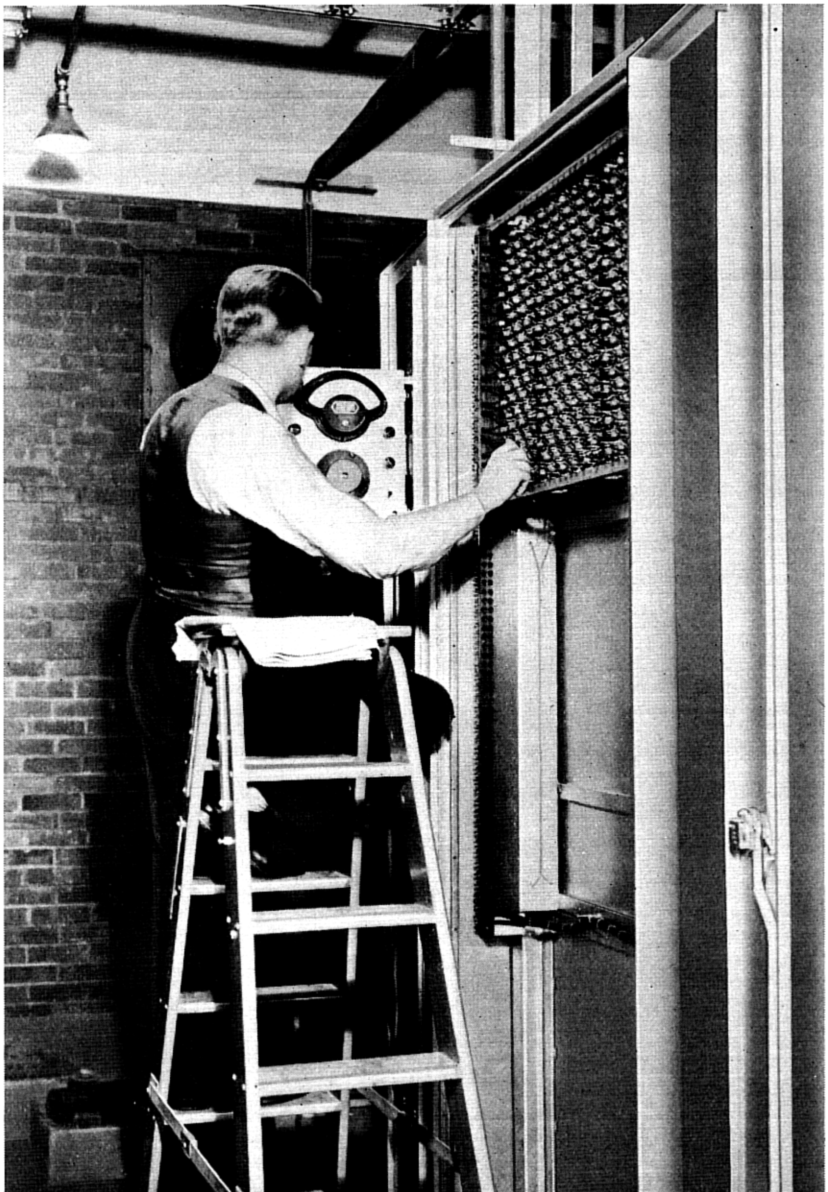

Fig. 3—Adjustment of coils in crosstalk balancing panel.

TABLE 3

FINAL FAR-END CARRIER CROSSTALK MEASUREMENTS AFTER BALANCING COIL ADJUSTMENTS

Section	New York Toward Charlotte					Charlotte Toward New York				
	Ca.	Crosstalk Units 39.85 kc		Crosstalk Units 28.15 kc		Ca.	Crosstalk Units 39.85 kc		Crosstalk Units 28.15 kc	
		R.M.S.	Max.	R.M.S.	Max.		R.M.S.	Max.	R.M.S.	Max.
New York-N. Y. KS....	E	42	283	36	122	F	33	184	31	100
N. Y. KS-Prin. KN.....	F	37	148	36	122	E	29	95	27	92
Prin. KN-Prin..........	E	38	130	36	114	F	40	212	37	155
Prin.-Prin. KS.........	G	37	212	33	130	E	35	132	36	130
Prin. KS-Phila. KN.....	E	35	148	32	164	G	30	100	28	112
Phila. KN-Phila........	G	35	250	31	100	E	29	114	29	127
Phila.-Phila. KS........	D	45	243	44	226	F	37	127	33	122
Phila. KS-Elk. KN......	F	29	116	28	112	D	45	138	45	122
Elk. KN-Elk...........	D	45	161	45	145	F	36	145	36	130
Elk.-Elk. KS...........	F	36	204	36	164	D	42	217	42	176
Elk. KS-Balt. KN......	D	38	126	39	129	F	35	207	33	145
Balt. KN-Balt..........	F	35	107	34	114	D	45	224	45	170
Balt.-Wash. KN........	D	44	241	42	179	E	43	219	38	148
Wash. KN-Wash........	E	39	179	38	195	D	34	100	36	126
Wash.-Wash. KS.......	A	43	184	43	148	B	44	182	48	158
Wash. KS-Fred. KN....	B	43	224	40	167	A	47	141	46	155
Fred. KN-Fred.........	A	54	179	50	163	B	44	170	46	208
Fred.-Fred. KS.........	B	45	173	43	152	A	49	219	48	219
Fred. KS-Rich. KN.....	A	47	167	46	164	B	39	167	39	127
Rich. KN-Rich.........	B	43	167	46	176	A	39	200	38	125
Rich.-Rich. KS.........	A	39	179	40	127	B	30	190	39	158
Rich. KS-McK. KN.....	B	48	138	53	155	A	37	265	35	200
McK. KN-McK.........	A	36	130	34	100	B	56	148	64	167
McK.-McK. KS........	B	57	190	62	174	A	38	152	38	155
McK. KS-Norl. KN.....	A	36	145	35	145	B	56	161	62	187
Norl. KN-Norl.........	B	53	173	56	170	A	41	198	39	190
Norl.-Norl. KS.........	A	34	110	38	134	B	59	167	59	170
Norl. KS-Dur. KN......	B	56	179	56	195	A	39	142	40	142
Dur. KN-Dur..........	A	42	190	38	190	B	65	200	62	187
Dur.-Dur. KS..........	B	61	155	58	145	A	38	114	43	134
Dur. KS-Gbo. KN......	A	42	195	42	118	B	59	205	59	187
Gbo. KN-Gbo..........	B	57	219	58	195	A	37	118	36	107
Gbo.-Gbo. KS..........	A	39	145	37	141	B	55	173	50	155
Gbo. KS-Sal. KN.......	B	57	338	54	346	A	40	224	38	161
Sal. KN-Sal............	A	34	161	35	155	B	43	245	50	300
Sal.-Sal. KS............	B	54	265	52	245	A	35	126	32	107
Sal. KS-Chlot. KN......	A	34	141	32	155	B	53	245	53	286
Chlot. KN-Chlot........	B	43	200	42	155	A	33	167	31	129

Note: These measurements were made in connection with balancing work where relative values are important and do not necessarily represent the absolute magnitude of the crosstalk.

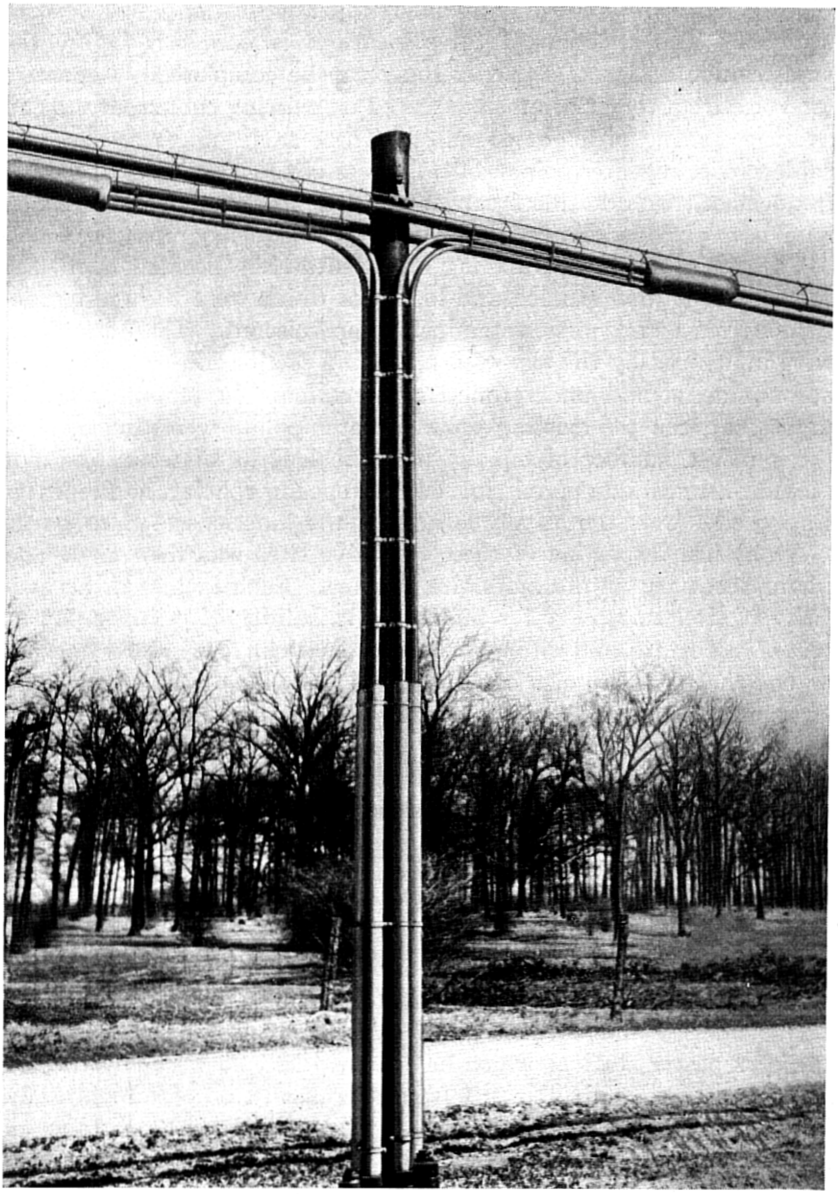

Fig. 4—The four lateral cables containing carrier pairs shown as installed at an auxiliary repeater point on aerial cables.

repeater stations, known as auxiliary repeater stations, will be constructed. The selection of these locations is necessary before the transmission design of a carrier route can be completed. Repeaters for voice frequency circuits are located on existing cable routes at an average spacing of about 45 miles. These same offices are used as cable carrier repeater points, but, because of the high losses at carrier frequencies, two additional carrier repeater stations, on the average, have been provided between each two voice frequency repeater offices.

The cables and routes having been tentatively decided upon, the route records were studied and locations which were the most practicable from a transmission standpoint were selected. These selections were influenced by the expected maximum section losses, taking into account aerial and underground construction. In general, the distances between the existing voice repeater points were divided into the smallest number of equal parts, the lengths of which did not exceed the maximum permissible carrier repeater spacing, and repeater station sites were tentatively located at the junctions of these parts.

A physical inspection of these tentative sites was then made and where necessary an alternate site selected. Such factors as accessibility of site, suitability for building, availability of primary power, cost of real estate, and willingness of owners to sell determined whether or not the tentative site could be used and, if not, what alternate location might be used. Where a suitable existing telephone building happened to be located near a proposed repeater station location, the possibility of using such building was studied. It has been practicable, however, in only one instance to use an existing building in installing the 34 auxiliary stations provided to date. The sites which were considered satisfactory after the physical inspection were then examined to check their suitability from a carrier transmission standpoint. In cases where transmission limits had been exceeded, the sites were reinspected and compromise locations finally agreed upon. In most cases it has not been difficult to find sites which are suitable both from a transmission and a construction standpoint. Of the 34 type K carrier repeater stations which have been built, 20 were constructed at the sites originally selected from a transmission standpoint. In most of the other cases the final sites were within a short distance of the originally selected locations. In a few cases, however, where ideal sites fell in populous centers or comparatively inaccessible wilds, it was necessary to take unusual steps.

In one case the site which had been selected from a transmission standpoint fell at a location where the two cables which had been selected followed different conduit runs and were separated by more than $2\frac{1}{2}$ miles. Two lateral cables, each of that length, would have been required in order to make use of this site. Moving the location back to the point where the cables came together would have resulted in an excessively long carrier repeater section and would have located the station within the business section of Wilmington, Del. The problem was to find a compromise site between these two points where the lengths of lateral cables would not be excessive and the repeater section could be kept within desirable limits. A tide water stream between these two points complicated the problem.

Nine sites were inspected and four of them studied in detail. Flood and fire hazards, as well as high prices of real estate, were added to the other factors governing the choice. None of the locations was entirely desirable, but a compromise choice was finally made of a location which resulted in the longest repeater spacing in the New York-Charlotte project, but the lengths of the lateral cables were reduced to between eleven and twelve hundred feet.

Table 4 shows the theoretical spacings which, considering the fixed

TABLE 4

COMPARISON OF THE ORIGINALLY SPECIFIED CARRIER REPEATER SPACINGS AND ACTUAL SPACINGS ON THE NEW YORK-CHARLOTTE AND DETROIT-SOUTH BEND CABLE ROUTES

Project	No. of Re-peater Sections	Theoretically Best Spacings			Actual Spacings Used		
		Min.	Ave.	Max.	Min.	Ave.	Max.
New York-Charlotte...	38	13.5	16.5	18.8	13.2	16.5	20.2
Detroit-South Bend...	13	14.9	16.1	17.6	13.6	16.1	18.4

location of existing repeater points, were selected as best from a transmission standpoint, and the actual spacings which it was found necessary to use. The theoretically best spacings for the two routes differed because of the difference in spacings of the existing voice frequency repeater points of which use has been made as carrier repeater points. Figure 5 shows the repeater office locations as they are distributed on the New York-Charlotte project. The various types of repeater offices shown are discussed later in this paper.

DIRECTION OF TRANSMISSION

The circuits used for the two directions of transmission of type K carrier systems operate in separate cables on the projects so far completed and, for crosstalk reasons, these two directions of transmission have been transposed between the two cables at each carrier repeater point.[2] The location of branch cables and taps to open wire have an

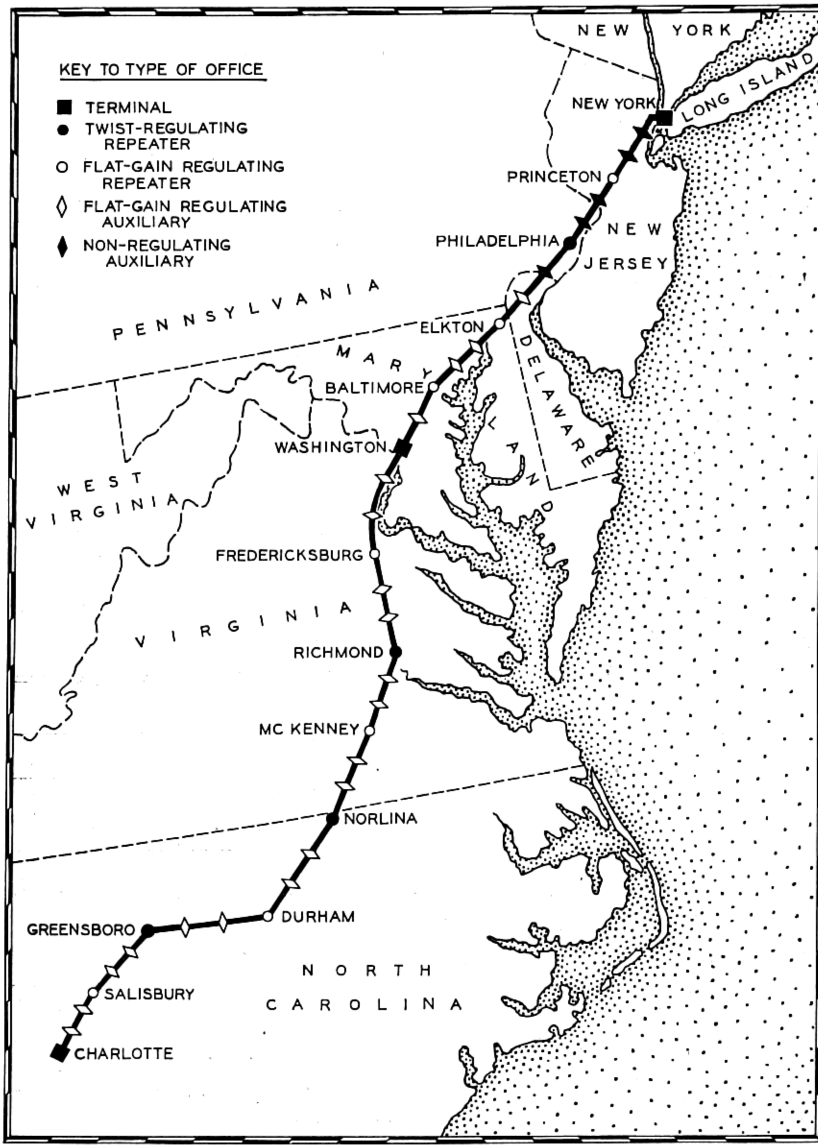

Fig. 5—Route of New York-Charlotte cable carrier development.

important bearing on the selection of the direction of transmission, since it is desirable to assign directions of transmission which will result in a minimum number of taps to open wire and branch cables occurring near carrier repeater inputs. Where the lengths of underground construction adjacent to a repeater station differ on the two cables, it is preferable to have pairs in the cable having the longer section of underground connected to repeater inputs. With these and other factors in mind, tentative directions of transmission were assigned to the cable conductors and computations of expected noise currents made and checked with computations which assumed the directions reversed. The total overall noise currents computed to be 1.25 db better when assuming the directions of transmission finally selected for the New York-Charlotte project than when assuming these directions reversed. This was largely due to the fact that south of Petersburg, where but one cable had existed, a small cable was added to permit carrier operation. Pairs in this cable, because of its small size, are more susceptible to static induction directly into the cable than pairs in larger cables. The effect, therefore, of the greater contribution to overall noise currents, which this small cable tends to cause, was reduced by selecting the directions of transmission so as to take advantage of the increased shielding resulting from underground construction adjacent to repeaters. Tables 5 and 6 show the final noise level computations for the 1000-cycle point of channel 12 (57 kc on the line) of a New York-Charlotte system. It will be noted that the longer repeater sections contribute a great deal of noise as compared to average or shorter sections. Noise measurements which have been made indicate that noise conditions compare favorably with those which it was calculated might be expected.

Non-Regulating Repeater Points

Examination of the carrier repeater sections on the New York-Charlotte route showed seven to be unusually short and involving all underground cable construction. The usual plan would have been to provide flat gain regulation at each carrier repeater point, but since these seven sections averaged but 14.8 miles in length and the theoretical transmission variation might be but $\pm$ 1.42 db, it was obvious that the regulators having a normal range of $\pm$ 7.15 db would be required to operate only over a small part of their range. However, the real limitation is not the regulating mechanism but the lower levels to which the line currents without regulated gain would drop during periods of high cable temperature with corresponding impairments in noise levels. In this layout, omission of regulation at one station increases the noise level about the same as lengthening the following repeater section about $\frac{3}{4}$ of a mile. Omission of two successive regulators is approximately equivalent to increasing the second repeater section about $\frac{3}{4}$ of a mile and the third about $1\frac{1}{2}$ miles. Repeater

TABLE 5

NEW YORK-CHARLOTTE TYPE K CARRIER NOISE COMPUTATIONS

Section	Cable	Miles			57 kc Loss Max. Temp.[1]	Estimated 57 kc Noise Level[2] at Rept. Output
		U.G.	Aerial	Total		
New York-New York KS	E	15.45	—	15.45	58.09	− 8.91
New York KS-Princeton KN	F	14.45	—	14.45	54.33	− 9.71
Princeton KN-Princeton	E	16.59	—	16.59	62.38	+ 1.10
Princeton-Princeton KS	G	13.22	—	13.22	49.71	−13.29
Princeton KS-Philadelphia KN	E	13.92	—	13.92	52.34	−10.75
Philadelphia KN-Philadelphia	G	14.79	—	14.79	55.61	− 2.19
Philadelphia-Philadelphia KS	D	15.14	—	15.14	56.93	−10.07
Philadelphia KS-Elkton KN	F	13.49	—	13.49	50.72	− 9.38
Elkton KN-Elkton	D	19.70	—	19.70	74.07	+ 8.57
Elkton-Elkton KS	F	17.28	—	17.28	64.97	− 2.03
Elkton KS-Baltimore KN	D	16.89	—	16.89	63.51	− 3.49
Baltimore KN-Baltimore	F	16.91	—	16.91	63.58	− 3.42
Baltimore-Washington KN	D	18.61	—	18.61	69.97	+ 2.97
Washington KN-Washington	E	18.95	—	18.95	71.25	+ 4.25
Washington-Washington KS	A	7.31	11.28	18.59	71.93	+ 5.93
Washington KS-Fredericksburg KN	B	—	18.45	18.45	72.69	+ 6.69
Fredericksburg KN-Fredericksburg	A	.10	16.54	16.64	65.55	+ 2.95
Fredericksburg-Fredericksburg KS	B	.11	18.23	18.34	72.24	+ 6.24
Fredericksburg KS-Richmond KN	A	—	18.26	18.26	71.94	+ 5.94
Richmond KN-Richmond	B	7.64	10.99	18.63	72.03	+ 5.03
Richmond-Richmond KS	A	9.82	7.09	16.91	64.85	− 1.15
Richmond KS-McKenney KN	B	10.13	5.85	15.98	61.14	+ 8.54
McKenney KN-McKenney	A	.08	15.43	15.51	61.09	− 1.51
McKenney-McKenney KS	B	.11	16.87	16.98	66.88	+14.08
McKenney KS-Norlina KN	A	—	15.23	15.23	60.01	− 2.59
Norlina KN-Norlina	B	.06	14.28	14.34	56.49	+ 3.89
Norlina-Norlina KS	A	—	16.36	16.36	64.46	+ 3.66
Norlina KS-Durham KN	B	—	16.68	16.68	65.72	+13.12
Durham KN-Durham	A	.12	17.62	17.74	69.87	+ 3.87
Durham-Durham KS	B	.05	18.05	18.10	71.31	+18.51
Durham KS-Greensboro KN	A	—	17.79	17.79	70.09	+ 4.09
Greensboro KN-Greensboro	B	2.38	16.25	18.63	72.98	+12.18
Greensboro-Greensboro KS	A	5.64	12.18	17.82	69.20	+ 3.20
Greensboro KS-Salisbury KN	B	—	16.41	16.41	64.66	+12.06
Salisbury KN-Salisbury	A	1.85	14.84	16.69	65.43	− 2.53
Salisbury-Salisbury KS	B	1.82	11.92	13.74	53.80	+ 1.2
Salisbury KS-Charlotte KN	A	—	14.47	14.47	57.01	− 4.09
Charlotte KN-Charlotte	B	3.78	9.96	13.74	53.45	− 8.35
New York-Charlotte Totals				627.42		+23.27[3]

[1] Attenuation figures used: 3.76 for U.G. at 73° and 3.94 for Aerial at 110°.
[2] For top channel, referred to − 9 db switchboard level.
[3] Computed on a root-sum-square basis.

sections adjacent to New York and Philadelphia are short and it was decided, therefore, to omit regulation from the two auxiliary stations between New York and Princeton, N. J., two between Princeton and Philadelphia, and one between Philadelphia and Wilmington, Del.

TABLE 6

CHARLOTTE-NEW YORK TYPE K CARRIER NOISE COMPUTATIONS

Section	Cable	Miles			57 kc Loss Max. Temp.[1]	Estimated 57 kc Noise Level[2] at Rept. Output
		U.G.	Aerial	Total		
Charlotte-Charlotte KN	A	3.78	9.96	13.74	53.45	− 9.15
Charlotte KN-Salisbury KS	B	—	14.47	14.47	57.01	+ 5.91
Salisbury KS-Salisbury	A	1.82	11.92	13.74	53.80	− 7.60
Salisbury-Salisbury KN	B	1.85	14.84	16.69	65.43	+14.13
Salisbury KN-Greensboro KS	A	—	16.41	16.41	64.66	+ 2.06
Greensboro KS-Greensboro	B	5.64	12.18	17.82	69.20	+ 4.70
Greensboro-Greensboro KN	A	1.66	16.97	18.63	73.10	+ 7.10
Greensboro KN-Durham KS	B	—	17.79	17.79	70.09	+17.29
Durham KS-Durham	A	.05	18.05	18.10	71.31	+ 5.31
Durham-Durham KN	B	.12	17.62	17.74	69.87	+17.07
Durham KN-Norlina KS	A	—	16.68	16.68	65.72	+ 3.12
Norlina KS-Norlina	B	—	16.36	16.36	64.46	+11.86
Norlina-Norlina KN	A	.06	14.28	14.34	56.49	− 6.11
Norlina KN-McKenney KS	B	—	15.23	15.23	60.01	+ 8.91
McKenney KS-McKenney	A	.11	16.87	16.98	66.88	+ .78
McKenney-McKenney KN	B	.08	15.43	15.51	61.09	+ 8.49
McKenney KN-Richmond KS	A	6.18	9.81	15.99	61.89	− .71
Richmond KS-Richmond	B	16.84	.07	16.91	63.60	+ .60
Richmond-Richmond KN	A	7.52	11.08	18.60	71.94	+ 5.94
Richmond KN-Fredericksburg KS	B	—	18.26	18.26	71.94	+ 5.94
Fredericksburg KS-Fredericksburg	A	.10	18.23	18.33	72.21	+ 6.11
Fredericksburg-Fredericksburg KN	B	.10	16.54	16.64	65.55	+ 2.95
Fredericksburg KN-Washington KS	A	—	18.45	18.45	72.69	+ 6.69
Washington KS-Washington	B	8.69	9.91	18.60	71.72	+ 4.72
Washington-Washington KN	D	18.90	—	18.90	71.06	+ 4.06
Washington KN-Baltimore	E	18.64	—	18.64	70.09	+ 3.09
Baltimore-Baltimore KN	D	16.89	—	16.89	63.51	− 3.49
Baltimore KN-Elkton KS	F	16.86	—	16.86	63.39	− 3.61
Elkton KS-Elkton	D	17.33	—	17.33	65.16	− 1.84
Elkton-Elkton KN	F	20.21	—	20.21	75.99	+ 8.99
Elkton KN-Philadelphia KS	D	13.51	—	13.51	50.80	−12.20
Philadelphia KS-Philadelphia	F	16.00	—	16.00	60.16	− 1.34
Philadelphia-Philadelphia KN	E	13.36	—	13.36	50.23	−12.77
Philadelphia KN-Princeton KS	G	13.93	—	13.93	52.38	− 9.34
Princeton KS-Princeton	E	13.49	—	13.49	50.72	− 9.67
Princeton-Princeton KN	F	16.69	—	16.69	62.75	− 2.75
Princeton KN-New York KS	E	14.50	—	14.50	54.52	− 5.38
New York KS-New York	F	15.38	—	15.38	57.88	− .69
Charlotte-New York Totals				627.70		+23.46[3]

[1] Attenuation figures used: 3.76 for U.G. at 73° and 3.94 for Aerial at 110°.
[2] For top channel, referred to − 9 db switchboard level.
[3] Computed on a root-sum-square basis.

Figure 6 shows a comparison of the computed levels for maximum cable temperature conditions in the New York-Philadelphia Cable under conditions of both regulation and non-regulation. Omitting the regulation from a carrier repeater office where noise conditions and gain requirements are favorable has the advantage of economy in saving the cost of the regulating apparatus and in an expected saving in maintenance.

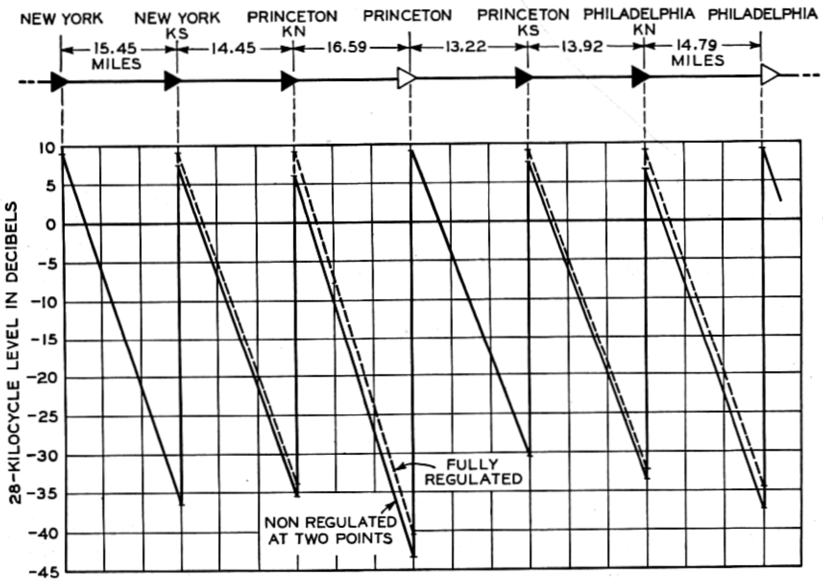

Fig. 6—Level diagram of New York-Philadelphia section, showing theoretical maximum effect on 28 kc levels of omitting regulation at the auxiliary repeater stations.

Noise Suppression Devices

Two types of noise suppression devices were used on voice frequency circuits to limit noise currents which might enter the cables used for carrier.[2] The first of these is a retardation coil designed to suppress longitudinal currents but to have a negligible effect on the metallic currents on the side and phantom circuits. These were installed at voice frequency repeater points, in all voice quads in cables which contained carrier pairs connected to carrier repeater inputs. These coils attenuate longitudinal noise currents at carrier frequencies generated in the voice repeater office which might enter the cable over the pairs used for voice circuits and be induced into the carrier pairs. A total of 3,000 retardation coils was installed along the New York-Charlotte route for this purpose. The coils are connected into the cable conductors on the office side of the point at which the carrier lateral cable is connected to the main cable. These coils were installed in the office cable vault or manhole. Figure 7-A shows a number of

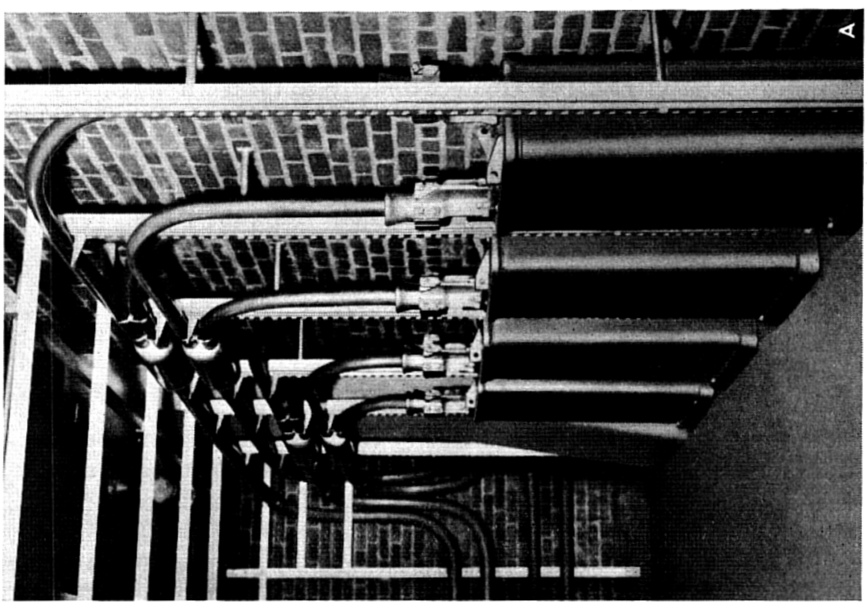

Fig. 7-A—Retardation coil cases installed in cable vault at West Unity, Ohio.

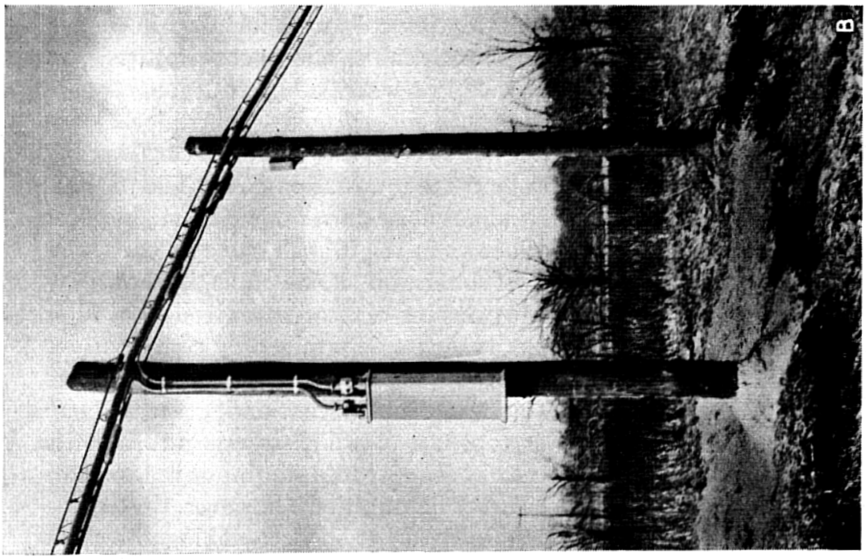

Fig. 7-B—Installation of filters on aerial cable.

apparatus cases containing these retardation coils installed in the cable vault at West Unity, Ohio.

In addition to this usage, retardation coils were installed in certain instances in the conductors of branch cables and open wire taps. In other branch cables and open wire taps where a higher degree of noise current suppression was required the second noise suppression device was used.[6] This second device is a filter which provides a considerably greater degree of suppression than the retardation coil. The purpose of these is to attenuate longitudinal noise currents which might enter the main cable over the conductors in the branch cable or open wire tap. A typical installation of filters on aerial cable is shown by Fig. 7-B. The question as to whether a retardation coil or a filter was required in each particular case was determined by computations of expected noise which might be contributed by the conductors entering the main cable. This was done by considering the makeup and length of the branch or tap, use to which it was put, and its location with respect to the nearest carrier repeater input in the cable to which it was connected. These computations, however, were made coincidentally with those described earlier in determining the most desirable directions of transmission.

Five hundred fifty-one retardation coils and 132 filters were installed in the 26 branch cables and open wire taps along the New York-Charlotte route, 11 of which connect directly to open wire. On the Detroit-South Bend project, 12 branch cables and open wire taps were equipped with 44 retardation coils and 124 filters. Nine of the 12 are taps connected directly to open wire.

As a further step toward prevention of noise currents in the carrier pairs, the shielding furnished by the lead sheaths of the cables has been kept effective by maintaining continuous the electrical path through these sheaths by means of shunts consisting of large condensers placed across each insulating joint.[4]

Auxiliary Repeater Station Buildings

Small buildings to house the auxiliary repeaters have been erected at the sites determined to be acceptable from transmission and construction standpoints. These structures are of fire resistive construction with concrete foundations, brick walls, and slate roofs. Since these buildings house equipment which is expected to operate for long periods of time without attention, no openings have been provided in the walls except for an entrance door and ventilating units. Thermal insulation has been provided over the ceiling. Two sizes of buildings have been used. The larger one which is 24 ft. × 24 ft., inside dimensions, is used on routes where an ultimate of 100 systems is expected, while the smaller one, 21 ft. × 24 ft., is used on a route to be developed for a maximum of 60 systems. The ceiling height in these buildings is sufficient to care for 11′-6″ relay racks. Eleven of the small buildings and 22 of the larger ones have been built on the carrier projects so far completed.

The architectural treatment of the exterior of these buildings varies somewhat, depending upon the location of the site selected and the character of the buildings in the immediate neighborhood. The present designs may be classified as three types; i.e., plain brick with no trim, plain brick with limestone trim, and plain brick with limestone trim and artificial windows. In the latter type the window arrangements are obtained by the use of a wooden frame and sash with rough wire glass, backed by the interior brick wall. The brick portion behind the window is painted buff on the upper half facing the window, and black on the lower half, to simulate a true window with the shade half drawn. Typical examples of these types may be seen in Fig. 8. The type of building selected for each station depended upon the locality.

Arrangements have been provided in these buildings for automatically controlling the heating and ventilation by the use of thermostatically controlled electric heater and fan units. Although experience was generally lacking on the heating and ventilating problem for these stations, tentative requirements were set up. A minimum temperature of 40° F. has been considered satisfactory for the operation of the equipment in these stations and the thermostat has been set to turn on the heater unit if the inside temperature drops below that point.

Ventilating equipment consisting of intake and exhaust ventilators, exhaust fan and control equipment has been provided so that advantage may be taken of the effect of cooler outside air when the temperature inside the buildings rises to about 90° F. Consideration was given to the direction of the prevailing winds in locating these units in the building walls. The room side of the intake ventilator unit is equipped with a spun glass filter. These ventilators are equipped with rigid and movable louvers. The movable louvers are actuated by solenoids which are connected to the exhaust fan control which functions by means of a thermostat and a differential temperature control. The latter includes outside and inside temperature compensating elements. The thermostat is set at 90° which, with the differential feature of the control, will cause the louvers to open and the exhaust fan to start only when the inside temperature is more than 10° above that prevailing outside the building. When the inside temperature has been reduced to within 10° of that outside, the control circuit is opened to shut off the fan and close the louvers.

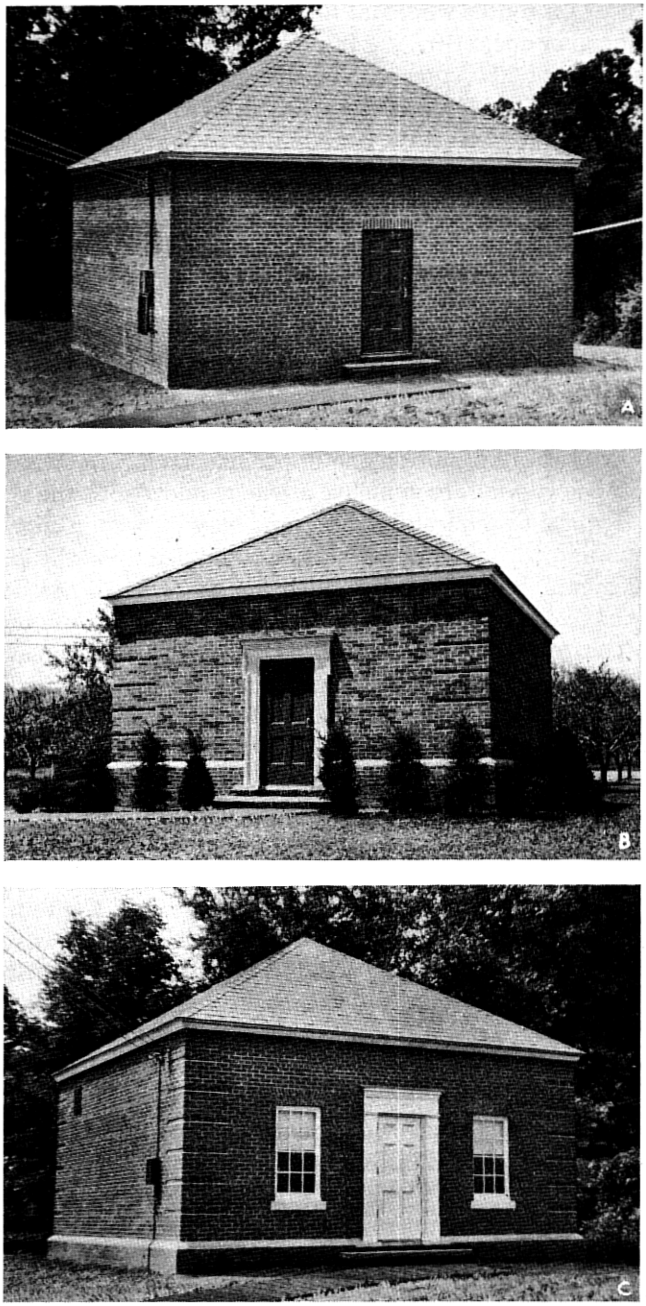

Fig. 8—Auxiliary repeater station buildings: A, without trim; B, with limestone trim; C, with limestone trim and artificial windows.

Terminal Office Equipment

The various major items of equipment which are provided at a terminal office are shown schematically by Fig. 9. Two bays of sealed test terminals—one input and one output—are associated with the pair of cables which bring the carrier pairs into the office and are equipped initially to terminate 40 pairs. The input high-frequency jacks are mounted in high-frequency patching bays adjacent to the input sealed test terminal bays and the output jacks in bays adjacent to the output sealed test terminal bays. At points where more than 50 terminals are expected to be required at some future date plans have been made for one input and two output high-frequency patching bays. The input and output high-frequency patching and sealed test terminal bays for two cable routes, together with a high-frequency transmission measuring bay, are grouped so as to form a desirable arrangement for testing and maintenance purposes. This group of bays serves somewhat the same purpose as a primary testboard on voice frequency facilities. The arrangement of these bays as installed at New York is shown in Figs. 10-A and 10-B.

A portable transmission measuring set has been provided and may be placed on a writing shelf mounted in the high-frequency transmission measuring bay. This set may be connected to the various circuits by means of patching cords.

Line and twist amplifiers with associated flat and twist gain master controller equipment and crosstalk balancing bays also are installed at each terminal office. The arrangement of the amplifier equipment and controllers as installed at New York is shown in Fig. 11.

The terminal equipment for one system consists of six channel modem (modulator plus demodulator) panels, each of which mounts the sending and receiving apparatus for two channels.[3] Channel modem equipment for three systems is mounted in two adjacent bays with the first two systems occupying separate bays. One bay of carrier supply equipment for each ten systems provides both regular and emergency units for generating carrier frequencies for the operation of the channel and group modem units and pilot channel equipment. The group modem units, one of which is required for each system, are mounted nine in one bay. Figures 12 and 13, respectively, show the method in which these bays are installed at New York.

The d-c power supply for the carrier equipment at terminal and main repeater offices is obtained from the existing 24-volt and 130-volt office power plants. Two sets of main distributing leads have been provided for each filament and plate power supply. Odd numbered circuits are

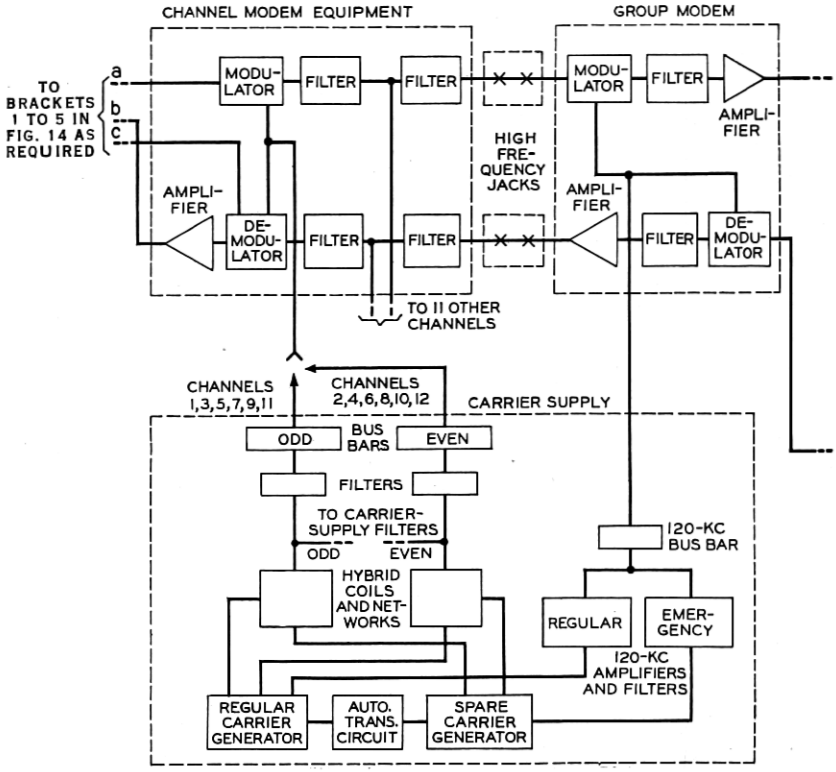

Fig. 9—Schematic showing the order of equipment at a terminal office.

connected to one set of leads for each type of power, and even circuits to another set.

The voice frequency sides of the channel modem units have been terminated in jacks which are located in a four-wire jack field mounted in a voice frequency patching bay. From this point the four-wire jack circuits are connected to the distributing frame for interconnection on a four-wire basis with other channel equipment, voice frequency repeater equipment, or terminating apparatus, as shown schematically in Fig. 14. Voice frequency patching bays shown in Fig. 10-B may be considered the equivalent of a secondary testboard.

Voice frequency transmission measuring apparatus has been mounted with the voice frequency patching bays.

Main Repeater Office Equipment

There are two types of installations at main repeater offices: (*a*) flat gain regulation only, and (*b*) both flat and twist gain regulation

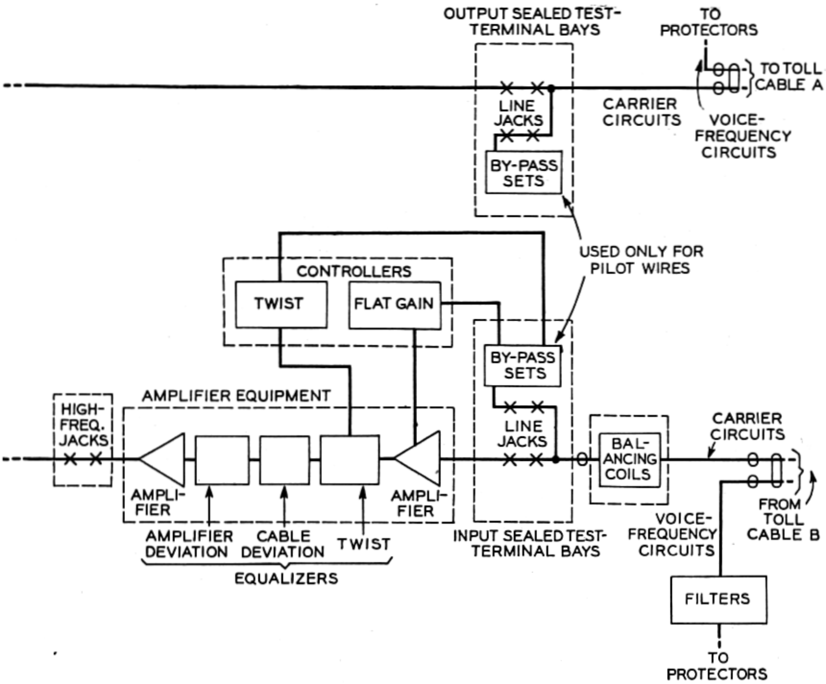

Fig. 9—Continued from page 570.

In general, these offices are attended regularly by maintenance forces. They serve in some cases as control or supervisory points for the auxiliary repeater stations. Since the installations at main stations have been made in existing voice frequency repeater offices, the available power plant is used to furnish filament and plate current for the amplifier equipment.

The input and output sealed test terminal bays with a high-frequency transmission measuring bay have been installed adjacent to each other to form a five-bay unit for testing and patching purposes.

Line amplifiers for each direction of transmission have been grouped together in adjacent relay rack bays. Each bay has a capacity of 20 amplifiers, except the first, in which is mounted the test amplifier associated with the high-frequency measuring system and 19 line amplifiers. Associated with the line amplifiers are the flat gain master controllers and power supply and cable balancing equipment. A schematic arrangement of circuits in a flat gain repeater office is shown in Fig. 15.

Repeater offices giving both flat and twist gain regulation have been

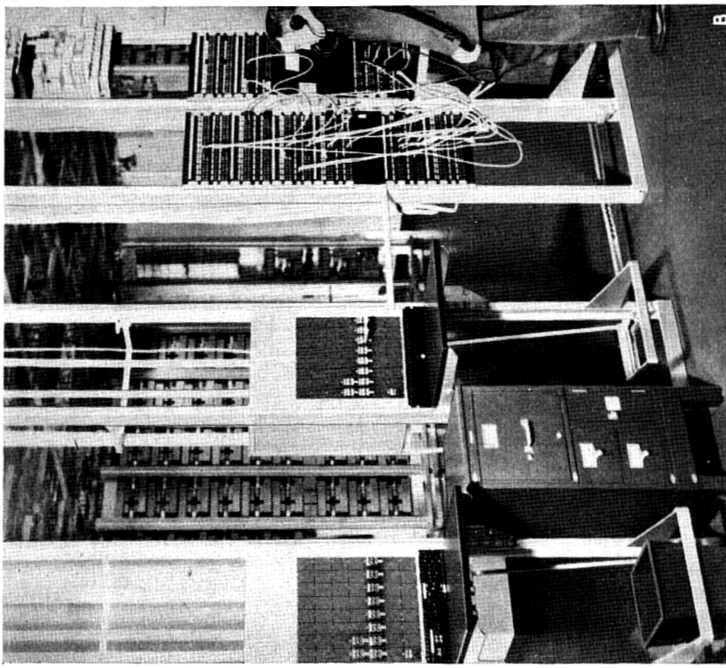

Fig. 10B—High frequency and voice frequency patching bays at New York, N. Y.

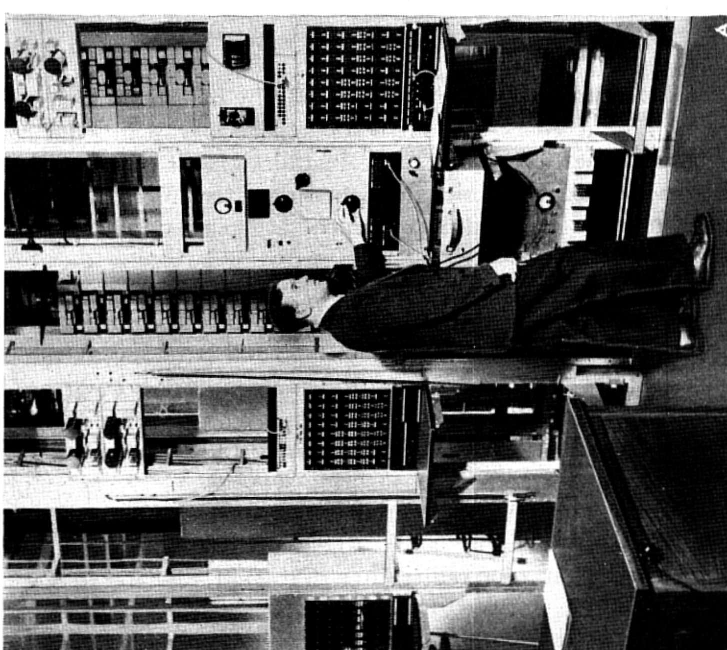

Fig. 10A—High frequency test bays at New York, N. Y.

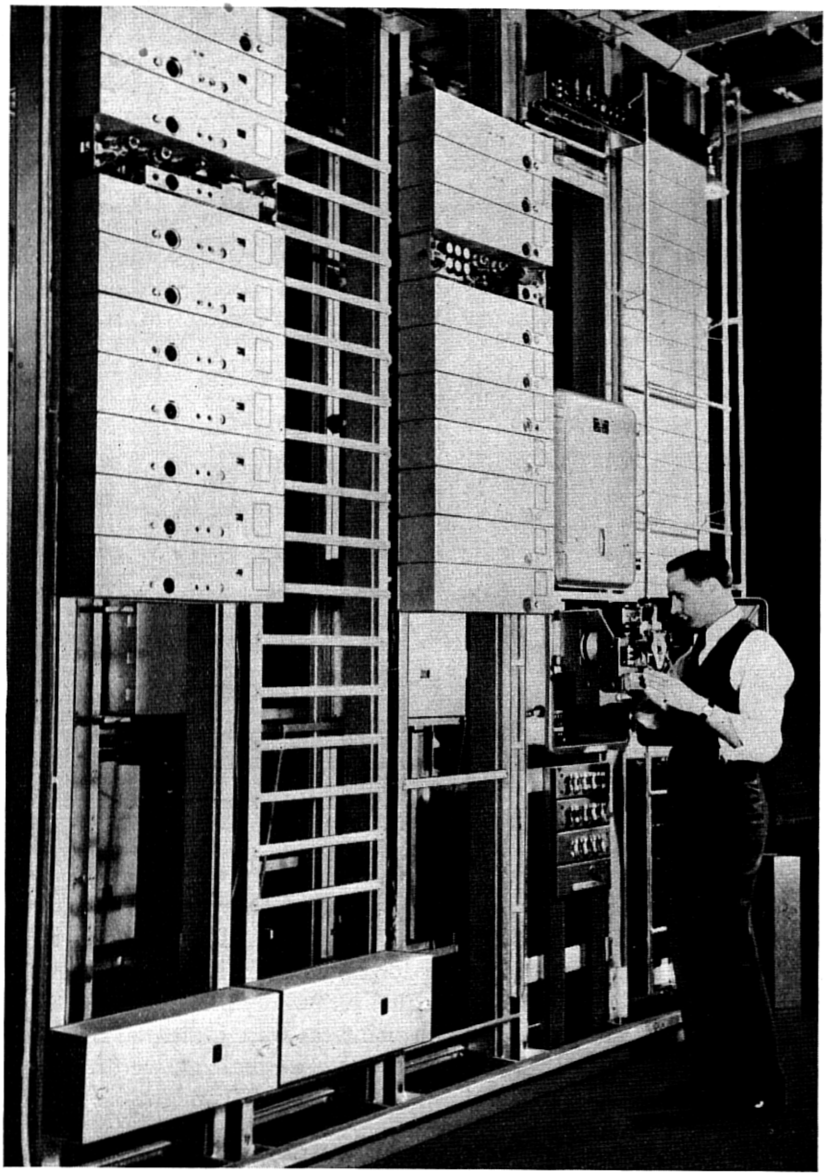

Fig. 11—Line and twist amplifier and controller equipment bays as installed at New York.

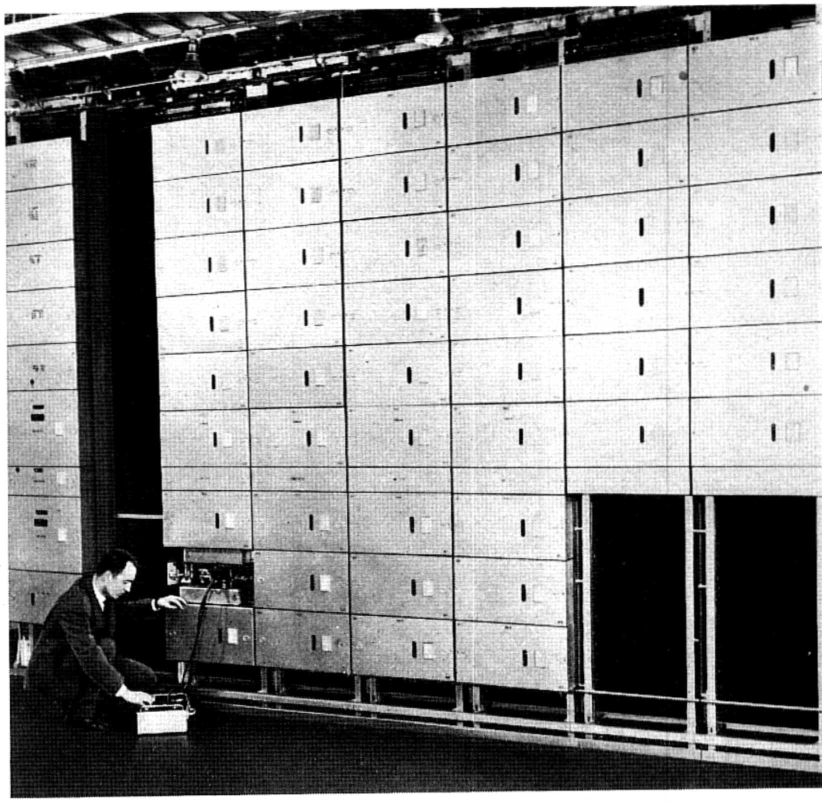

Fig. 12—Arrangement of carrier supply and channel modem equipment at New York, N. Y.

provided at intervals of about 100 miles. They differ from the flat gain regulating repeater office chiefly in that they include twist correction regulation [1] and its associated amplifiers. Provision was made at each twist gain regulating office for the installation of amplifier and cable deviation equalizers. The equalizers were actually connected to the circuits, however, only at such points as were indicated by lineup tests. To permit lineup without delay, spare equalizers were available at points where computations had indicated they might be needed. Amplifier deviation equalizers were required at South Bend, Toledo, Philadelphia, Richmond, and Greensboro on completed projects. It was not found necessary to install cable deviation equalizers at any point. Equalizer, flat gain, and twist gain amplifiers were installed in three-bay groups with the equalizer equipment occupying the center bay, and controller equipment in the fourth bay, similar to the ar-

Fig. 13—Bay arrangement for group modem equipment as installed at New York.

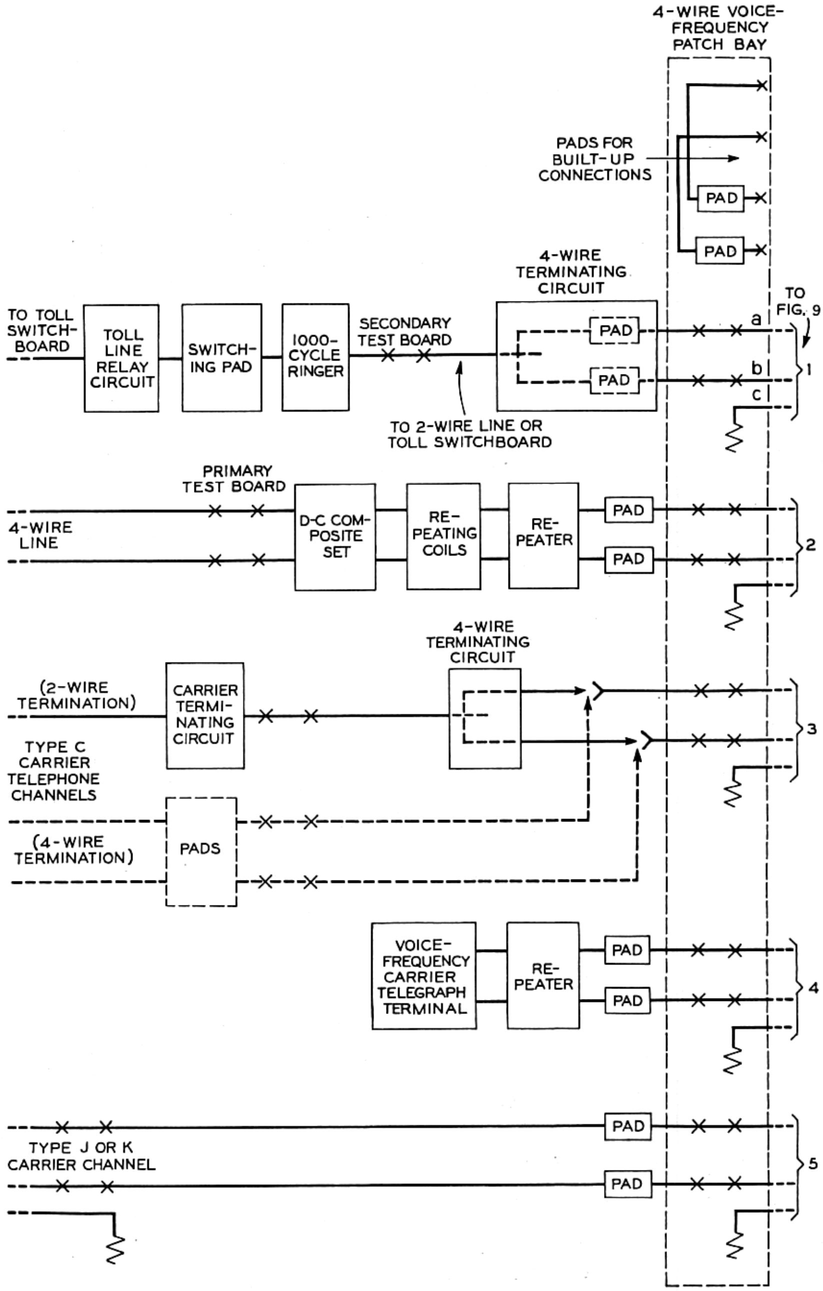

Fig. 14—Schematic showing the various circuit arrangements on the office side voice frequency patching bay.

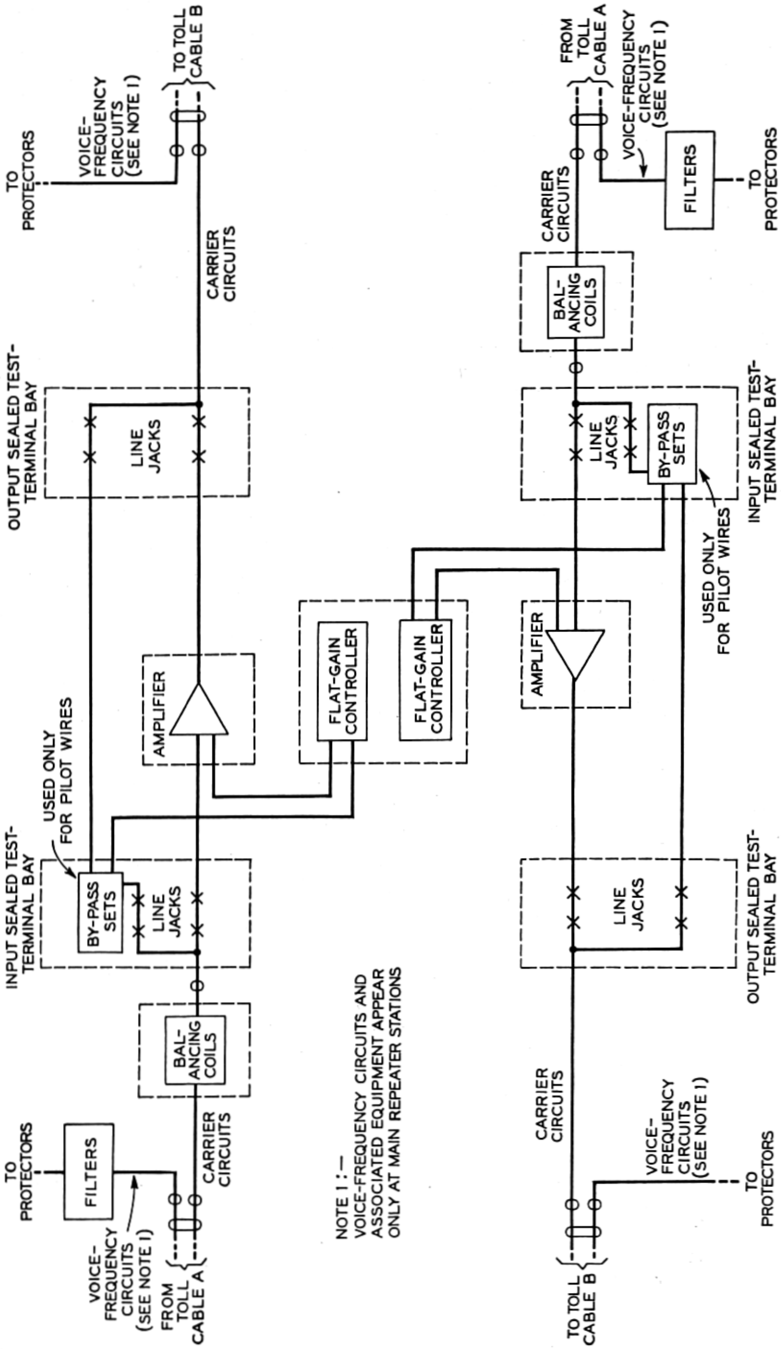

Fig. 15—Schematic showing the order of equipment at a flat gain repeater office.

rangement shown in Fig. 11. Each group of three bays mounts equipment for one direction of transmission for 17 systems. A schematic arrangement of equipment in a twist and flat gain regulating repeater office is shown in Fig. 16.

Auxiliary Repeater Station Equipment

Each auxiliary repeater station houses crosstalk balancing equipment, sealed test terminals, line amplifiers, pilot wire regulators, and a power plant. A typical floor plan arrangement of the equipment required in one of these stations for a maximum of 100 systems is shown in Fig. 17. The equipment arrangement for a 60-system route is practically the same, except that provision has been made for a smaller number of amplifiers and crosstalk balancing bays. A schematic arrangement of equipment circuits is shown in Fig. 15.

Four bays of sealed test terminals have been installed, one input and one output for each direction of transmission. Initially each unit contains carrier line and equipment jacks for testing or patching purposes for 40 carrier and eight miscellaneous circuits. In addition, miscellaneous auxiliary equipment is mounted in these bays.

Twenty-one amplifier panels for one direction of transmission may be mounted in a bay. Two bays are required for the flat gain master controllers and the associated controller power supply equipment. Figure 18-B shows amplifier, controller, and testing bays.

High-frequency testing apparatus consisting of a variable test oscillator and a portable transmission measuring set mounted in a mobile relay rack bay has been provided at each auxiliary station. This unit may be connected to the jacks in the sealed test terminals as required by means of patch cords.

Since auxiliary stations are designed to operate for considerable periods of time without attention, the power plant is of the automatic type.[7] It consists of a 70-cell, 152-volt storage battery which is continuously floated across regulated tube rectifiers fed from a commercial power supply. Figure 18-A shows a typical installation. Two rectifiers are provided initially, one which floats the battery, and the other which is connected automatically into the charging circuit in case of failure of the first unit or to increase the charging rate after a prolonged failure of the outside power. Arrangements are available in the power service cabinet to terminate leads from a portable emergency engine driven alternator set which may be set up outside the building. It is expected that the battery installed initially will be of sufficient size to provide a minimum of 24 hours reserve throughout its life, taking

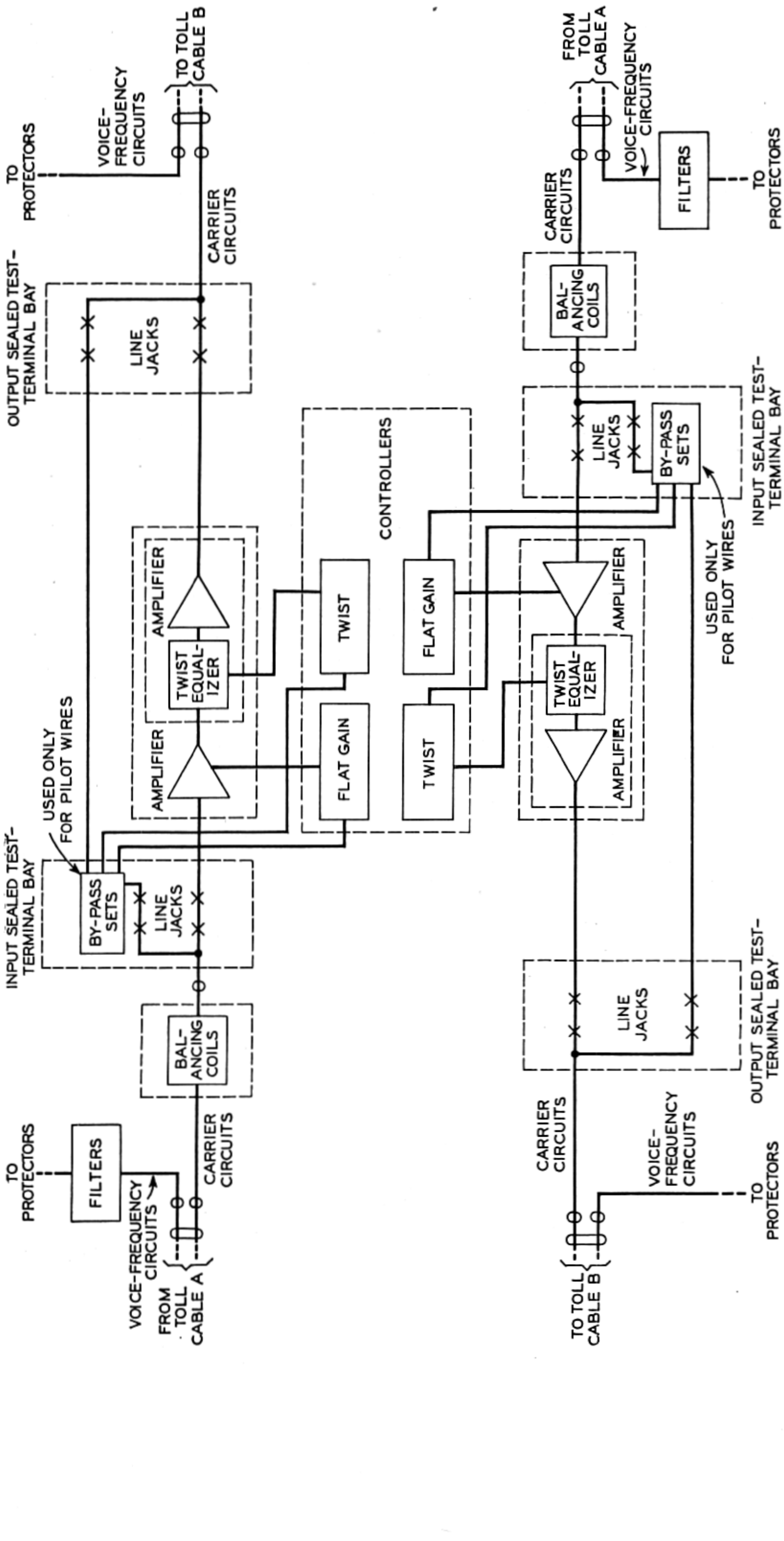

Fig. 16—Schematic showing the order of equipment at a twist and flat gain office.

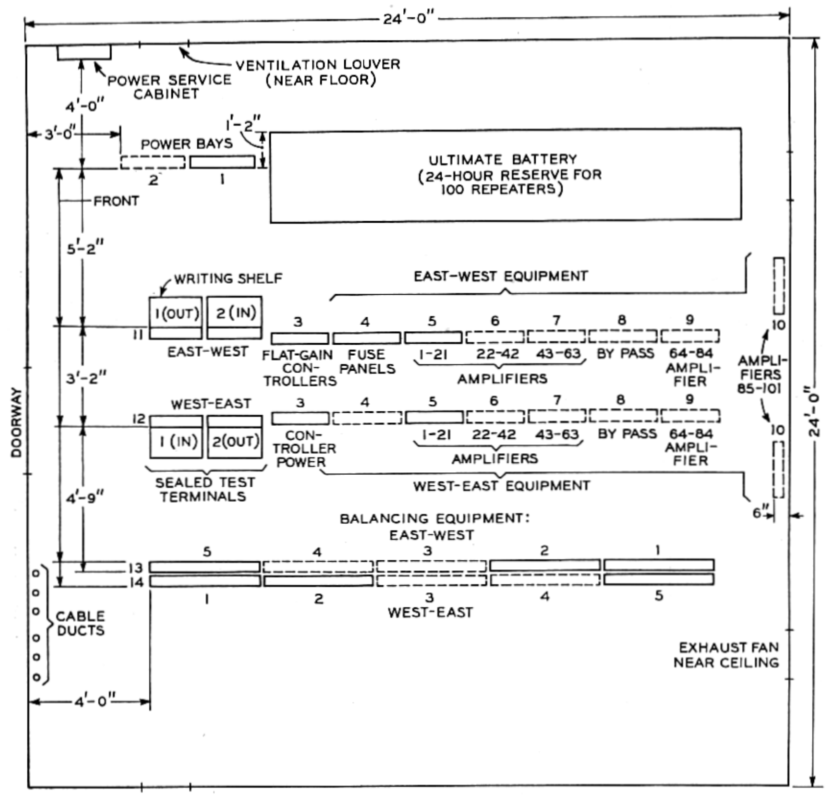

Fig. 17—Floor plan arrangement of equipment for 100 systems at an auxiliary repeater station.

into account the estimated growth of carrier amplifier equipment requirements for that period.

The entire voltage of the battery is used to furnish plate supply for the amplifier tubes. The 70-cell battery is arranged in seven groups of 10 cells each and taps are taken from each group to supply current for the heaters of the tubes of each amplifier. To prevent an uneven drain, amplifiers are connected across the battery in multiples of seven. In case the number of amplifiers installed is not an even multiple of seven, dummy load resistances are connected as required, in lieu of amplifiers to fill out the unequipped multiple.

The controller power supply bay contains apparatus for the 140-volt d-c pilot wire bridge supply and 55-volt, 60-cycle a-c supply. An emergency rotary converter, which automatically provides 110-volt, 60-cycle a-c supply during outside power failure, and operates intermittently from the battery, also is mounted in this bay.

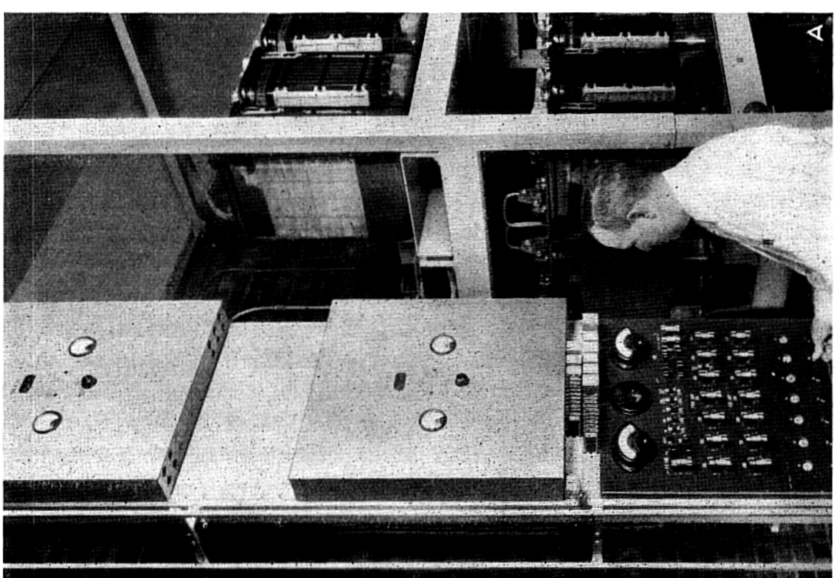

Fig. 18A—Auxiliary repeater station power plant.

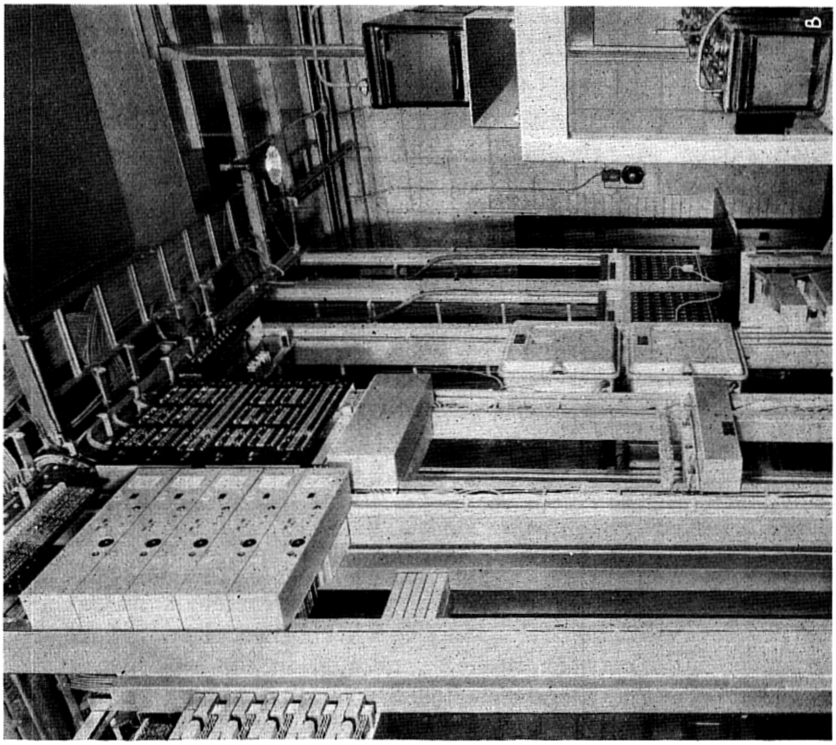

Fig. 18B—Amplifier, controller, and testboard equipment arrangement at an auxiliary repeater station.

Cabling Problems and Floor Plan Layouts

The floor plan arrangements for type K carrier equipment have been controlled to a considerable extent by transmission requirements, with consideration also being given to satisfactory operating and maintenance layouts both for the initial installation and for the future. The first consideration of any space which is to be used for carrier equipment is that the various units of equipment can be so located, with respect to each other, that the established maximum wiring lengths, as determined by transmission, operating, and economic requirements, will not be exceeded. For example, the length of shielded pair cable between the jacks in the input sealed test terminal bay and the input side of the line amplifier has been limited to about 50 feet and the potentiometer lead between the voice frequency patching bay and the channel modem units has been kept short in order not to limit the adjustment range of the potentiometer and a limit of 150 feet has been set. These limits were set in the design of the type K systems. Two types of cabling were installed in the transmission part of the carrier circuit; i.e., standard lead covered cable and shielded pair cable.

In cabling the carrier equipment the input leads were not run on the same cable racks with voice frequency cables. Due to the difference in transmission level between cabling connected to the input sides of carrier amplifiers and that connected to the output sides, these two groups of cabling have been segregated by running them over separate cable racks. The input leads were spaced not closer than two feet to any leads carrying interrupted direct current or power supply leads which might possibly carry high-frequency noise currents. Output leads were run on the same cable racks with voice frequency cabling where necessary, but were kept six or more inches away from possible disturbing leads such as those just mentioned. Cabling from the voice frequency side of the channel modem equipment was installed without greater precautions than are used when installing other voice frequency cabling. Crosstalk balancing bays were installed in any convenient location without special limitations in the lengths of lead covered cables between these and the input sealed test terminal bays.

All cable racks carrying the rubber covered shielded cables from the amplifier and group modem bays to the sealed test terminal and high-frequency patching bays were arranged so that these leads were run loosely and without sewing. This arrangement provides a ready means for switching cables for circuit layout purposes, particularly at terminal offices or at junctions of carrier cables.

In existing offices the high-frequency jack and testing equipment has been located as close as practicable to the existing toll testboard positions. Separate testboard lines have been established in several offices opening off, or convenient to, the main operating aisle in front of the toll testboards. The voice frequency patching jack bays at carrier terminals have been located, where practicable, near the secondary toll testboard equipment. These arrangements have been made in order to facilitate operating and maintenance, particularly during light load periods when a small force is on duty.

The amplifiers and group modems have been closely associated with the high-frequency patching bays and sealed test terminals in order to limit cabling lengths. Channel modems and carrier supply have been located convenient to the other equipment but within wiring limitations to the voice frequency patching bays.

The adequacy of all floor plan layouts, in providing for ultimate requirements, particularly at large terminal offices, was studied. This problem was given special consideration where it is expected that routes in addition to the initial one may be developed later for carrier operation. For example; at New York it was necessary to plan for the development of K carrier and other broad band facilities on four separate routes requiring a considerable amount of space for the necessary terminal equipment. The installation of carrier equipment at this office, therefore, has been made in space separate from the existing voice equipment. A floor plan arrangement of the equipment layout at New York is shown in Fig. 19.

Order Wires and Alarm Circuits

One or more auxiliary stations have been associated with an adjacent main or terminal office for maintenance control. Interoffice trunk and alarm equipment provide talking and signaling facilities between each auxiliary and main repeater station over a loaded cable pair. The various alarm signals are terminated in lamps which are mounted in the sealed test terminal bay at the controlling main office. These alarms are arranged to indicate such happenings as fire, open door, high-low battery voltage, main discharge fuse operation, a-c power failures, etc. When an alarm signal is received at the main station, it is rechecked and upon its reappearance an attendant may be dispatched at once or later to the auxiliary station involved, depending upon whether the signal is of major or minor importance.

The auxiliary stations are not always controlled by the nearest attended station. For example, in several cases it has been thought better to have them controlled by a station located in a small town rather than a city, because in cases of necessity an attendant should be able to drive to the auxiliary station in less time than required to drive

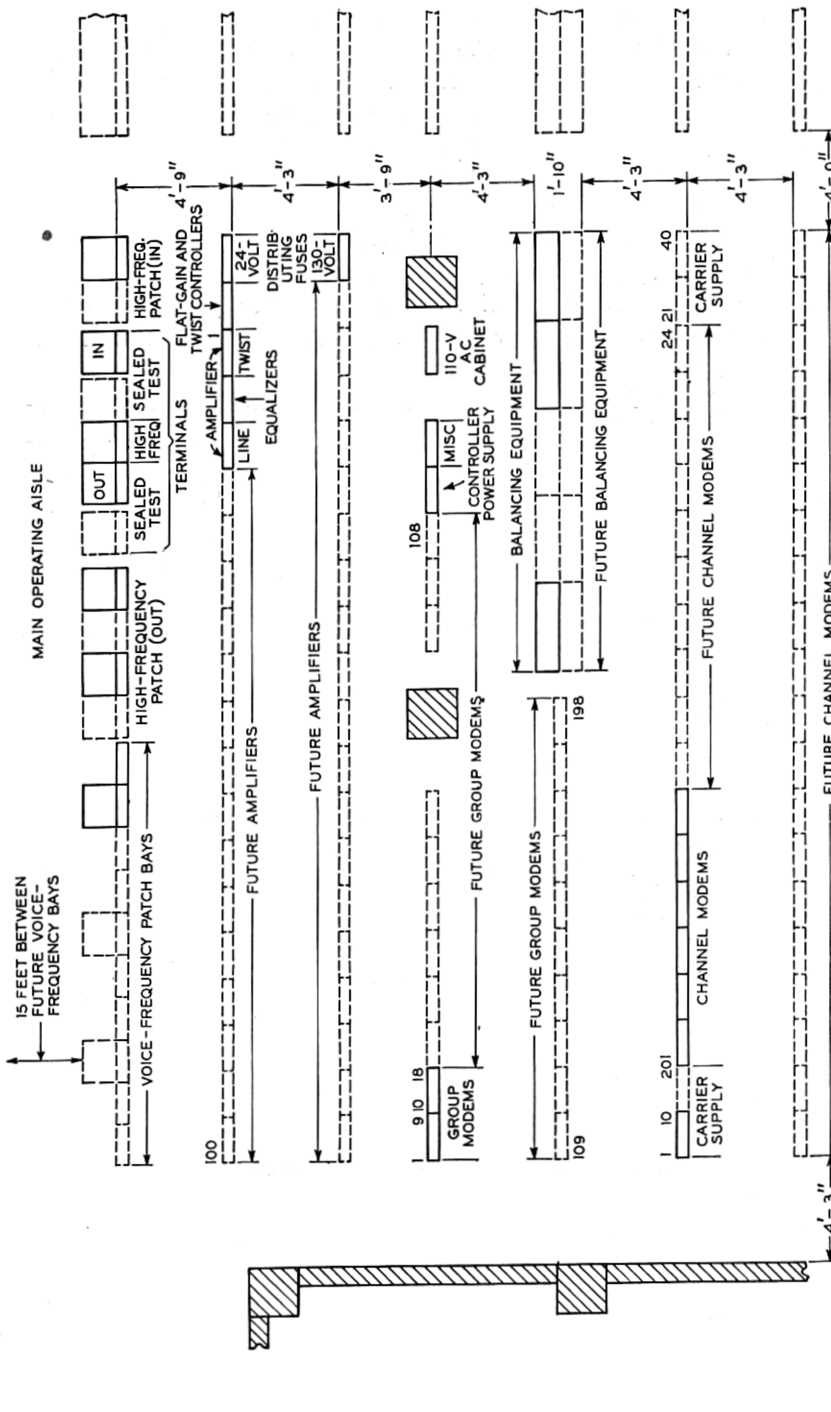

Fig. 19—Floor plan arrangement of equipment installed at New York, N. Y.

through a city area. In other cases certain main stations are not manned 24 hours per day and control and alarm circuits have not been terminated at such points. In one case a main repeater station has terminated in it the control leads from eight auxiliary stations. Four of these are connected through the partially attended main stations on either side.

Completion Tests and Overall System Adjustments

The usual completion tests were made on each unit of equipment after it was installed and on each cable pair between repeater stations after it was unloaded, in order to insure readiness of each item to be connected to form the overall carrier system. The gains of the repeaters were given a final adjustment by connecting each repeater input to the cable pair with which it was installed to work, then sending a predetermined amount of power at 28 kc into the cable pair at the adjacent office and adjusting the gain of the repeater until it delivered the desired output level. The flat gain master regulator was adjusted with respect to its pilot wire so that it would adjust the gain of the amplifier to maintain the desired output level at 28 kc at all cable temperatures.

The repeater sections beginning at one end of each twist regulating section were measured progressively at the output of each repeater. In each case transmission was checked at ten frequencies throughout the range from 12 to 60 kc. In this way a check was obtained to determine whether proper equalization was being provided at each line amplifier. It was necessary in some cases to change the type of equalizer provided because the transmission characteristics of specific cable pairs differed from the average which had been assumed in providing equalizers. Measurements were also made on the overall twist regulating section and transmission checked at ten frequencies throughout the 12 to 60 kc range, since the output of a perfectly corrected twist section would be the same at all frequencies within this band.

Overall measurements similar to these were made on the high-frequency line between terminal points and Fig. 20 shows the results for typical New York-Charlotte and New York-Washington systems. The most desirable characteristic would be a straight line and it will be noted that this curve differs materially from such an ideal. This difference is due to inadequate compensation by means of equalizers for small deviations from linearity in the individual line amplifiers. This lack of linearity in the overall high-frequency line has not materially affected the systems being operated at present but might be-

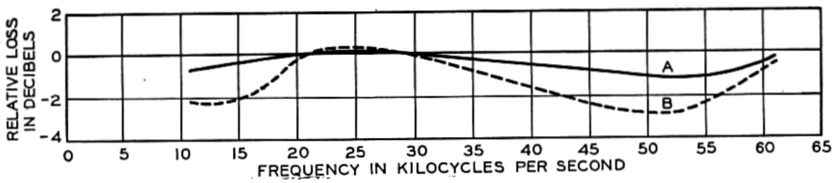

Fig. 20—Typical overall transmission frequency characteristic of high frequency line between New York and Charlotte, N. C. (B), and New York-Washington (A).

come objectionable on future long systems and it is planned to improve this characteristic by means of different equalizers.

The overall transmission frequency characteristic of a channel on a New York-Charlotte type K system is shown by Fig. 21. Measurements for this characteristic were made between the two-wire sides of hybrid coils connected to the two directions of carrier transmission of the channel concerned.

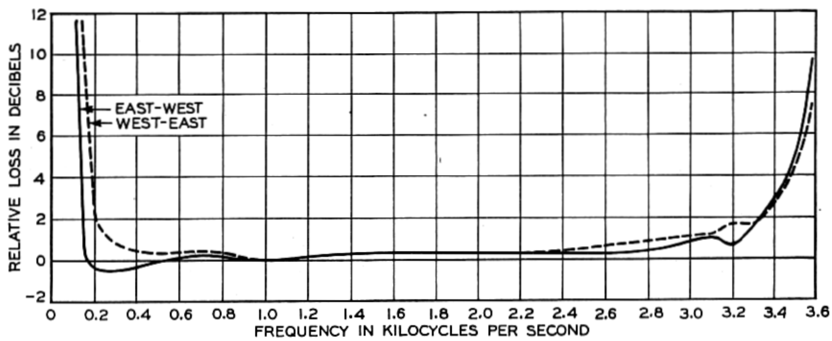

Fig. 21—Overall transmission frequency characteristic of a type K carrier channel between New York and Charlotte, N. C., as measured between two-wire voice frequency lines.

Use of Initial Systems

Telephone message circuits are being operated over most of the type K channels now available for use. In most cases the channels are used as parts of circuits which are longer than the carrier systems. For example, most of the 60 channels between New York and Charlotte, N. C., are used for circuits between New York and southern cities beyond Charlotte. Some of these circuits are obtained by connecting type K carrier channels at Charlotte to channels of type J open wire carrier systems which operate between Charlotte and West Palm Beach, Fla. Of the 204 channels available for use, only 21 are used as all carrier message circuits between the system terminals. This is not necessarily typical of what the usage of type K channels will be, but is brought about by their relatively limited application to date and demonstrates the flexibility of the type K carrier circuit in fitting in with the other types of circuit facilities.

Conclusions

Although experience with type K systems in service is rather limited, they are providing circuits of excellent quality and performance. The band width of the individual channels slightly exceeds the original estimates. Such instabilities of transmission as have been experienced have, in most cases, been corrected before service was interrupted and have been caused largely by non-recurring troubles inherent to most installations of new equipment. In brief, the operating experience with type K cable carrier systems confirms the view that they are expected to become an important means of providing additional long distance telephone circuits over cable facilities.

References

1. C. W. Green and E. I. Green, "A Carrier Telephone System for Toll Cables," *Bell System Technical Journal*, Vol. 17, No. 1, January, 1938.
2. M. A. Weaver, R. S. Tucker and P. S. Darnell, "Crosstalk and Noise Features of Cable Carrier Telephone System," *Bell System Technical Journal*, Vol. 17, No. 1, January, 1938.
3. R. W. Chesnut, L. M. Ilgenfritz and A. Kenner, "Cable Carrier Telephone Terminals," *Bell System Technical Journal*, Vol. 17, No. 1, January, 1938.
4. A. J. Aikens, "Suppressing Noise and Crosstalk on the Type K Carrier System," *Bell Laboratories Record*, Vol. 17, No. 7, March, 1939.
5. F. W. Amberg, "Crosstalk Poling for Cable Carrier System," *Bell Laboratories Record*, Vol. 17, No. 6, February, 1939.
6. P. W. Rounds, "A Longitudinal Noise Filter for the Type K Carrier System," *Bell Laboratories Record*, Vol. 17, No. 9, May, 1939.
7. H. H. Spencer, "Power Plant for Broadband Repeater Stations," *Bell Laboratories Record*, Vol. 17, No. 8, April, 1939.
8. L. Hochgraf, "Crosstalk Balancing for the Type K Carrier System," *Bell Laboratories Record*, Vol. 17, No. 6, February, 1939.