NO. 5 CROSSBAR AUTOMATIC CALL DISTRIBUTOR SYSTEM
TRANSMISSION ENGINEERING CONSIDERATIONS

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1. INTRODUCTION

1.01 Elements similar to those of a No. 5 Crossbar System have been arranged to provide basic switching functions in a system designated as the No. 5 Crossbar Automatic Call Distributor (No. 5 ACD). The No. 5 ACD is designed to satisfy service and economic objectives over a wide range of traffic volumes for number services, including directory assistance and intercept calls.

1.02 The No. 5 ACD is an entity unto itself, capable of providing its own switching functions, and is not part of a No. 5 Crossbar System. It is arranged to distribute calls from a maximum of 2400 incoming trunks and up to 500 new Auxiliary Service Positions (ASPs) for processing. One of the major advantages of the No. 5 ACD is that ASPs need not be located in the same building as the switching machine. All existing types of originating offices, class 5, class 0 (tandem), or class 4 or higher toll offices may be served by this system.

1.03 The basic No. 5 ACD provides operator assistance for the following classes of connection:

(a) Local (411) directory assistance

(b) Intra-NPA (555-1212) directory assistance

(c) Toll or inter-NPA (NPA-555-1212) directory assistance

(d) Intercept service. (In locations capable of supporting a large number of ASPs for intercept traffic, it is expected that the Automatic Intercept System (AIS) will be used instead of No. 5 ACD.)

1.04 Not included in this section are No. 5 ACD Phase II features, such as call transfer to supervisors and distant points involving 3-party conferences, and call origination. This information will be incorporated into future section(s).

1.05 When used only for directory assistance type calls, the transmission requirements on trunk facilities within the No. 5 ACD are not as stringent as they would be if intercept traffic were also routed over the same facilities. The reason for this is that an intercepted call, by its very nature, must enter the operator service systems at the receiving end office, and may have traversed the entire direct distance dialing (DDD) network, before entering the ACD system, whereas a directory assistance call may enter the operator service system at a class 4 or higher position in the hierarchy. In general, then, trunk transmission design objectives for an ACD which handles directory assistance traffic only are similar to, and no more stringent than, regular message network transmission objectives. If intercept service is contemplated, the trunks require a more rigorous design, although, in most cases, not as rigorous as AIS trunks (see BSP Section 852-405-100).

1.06 This section describes basic No. 5 ACD arrangements and presents the transmission engineering considerations and design objectives for trunks within this system. The transmission guidelines given represent reasonable tradeoffs between transmission performance and factors entering from traffic planning, switching systems, and switching development viewpoints. In view of this, and in view of current customer expectations, the use of facility designs of lower quality than those recommended should not be tolerated.

2. SYSTEM DESCRIPTION

2.01 The basic No. 5 ACD system is shown in Fig. 1. The No. 5 ACD acts as a trunk concentrator and call distributor, apportioning traffic to teams of operators who may be remote from the switching machine. Up to 500 operator positions may be served by a single distributor. Operator assistance is provided for the following classes of connection:

(a) Local (411) directory assistance: The links between local offices and the ACD may be concentrated, as shown in Fig. 1.

(b) Intra-NPA (555-1212) directory assistance: Calls enter the ACD system from either a sector tandem office, a toll office, or an end office. Calls from end offices may be concentrated, but calls from sector tandem and toll offices should not be concentrated.

(c) Toll (NPA-555-1212) directory assistance: Incoming calls enter the ACD system from a class 3 or higher class toll office. No trunk concentration should be used.

(d) Intercept service: Links between the intercepting end office and the call distributor may be concentrated.

2.02 During periods of light traffic, selected routes or operator locations may be closed down and traffic transferred to another route. This route is the night closing, or night transfer, link shown in Fig. 1. This facility is used to haul ***unconcentrated*** intercept and directory assistance traffic from one ACD to another. For example, during night operation, the operator positions associated with call distributor I in Fig. 1 would gradually be closed down and traffic would be diverted to distributor II. A second stage of concentration must be avoided. Concentrated local directory assistance and intercept traffic should be diverted under light load at the concentrator and not routed over the night transfer link.

2.03 A modified standard operator telephone circuit (SD-99378-01, Iss. 6A) should be used in all operator positions. The modification consists of a 151B amplifier in the transmit circuit to increase the transmit efficiency by about 4 dB. A new operator telephone circuit that will have universal application in most auxiliary service systems (TSPS, AIS, ACD, etc) is planned for development, and a new design of high quality to improve transmission efficiencies obtained with present operator circuits is anticipated. Successful conclusion of this development will result in significantly less stringent transmission requirements for some ACD system facilities. Until the development is successfully completed, however, the transmission guidelines presented here must be adhered to.

2.04 Trunk concentration in this system can be accomplished with the No. 23 concentrator, with the modifications recommended in paragraph 3.11. The major effects of these modifications are to reduce the 1-kHz insertion loss of the concentrator to 0.6 dB and to increase its echo return loss (ERL) to 26 dB. (If it is desirable to use a concentrator other than the No. 23, its transmission performance should be at least that of the modified No. 23 concentrator.)

3. ENGINEERING CONSIDERATIONS

A. General

3.01 When considering transmission design criteria for a system such as the No. 5 ACD, certain major performance requirements must be satisfied. Among these are

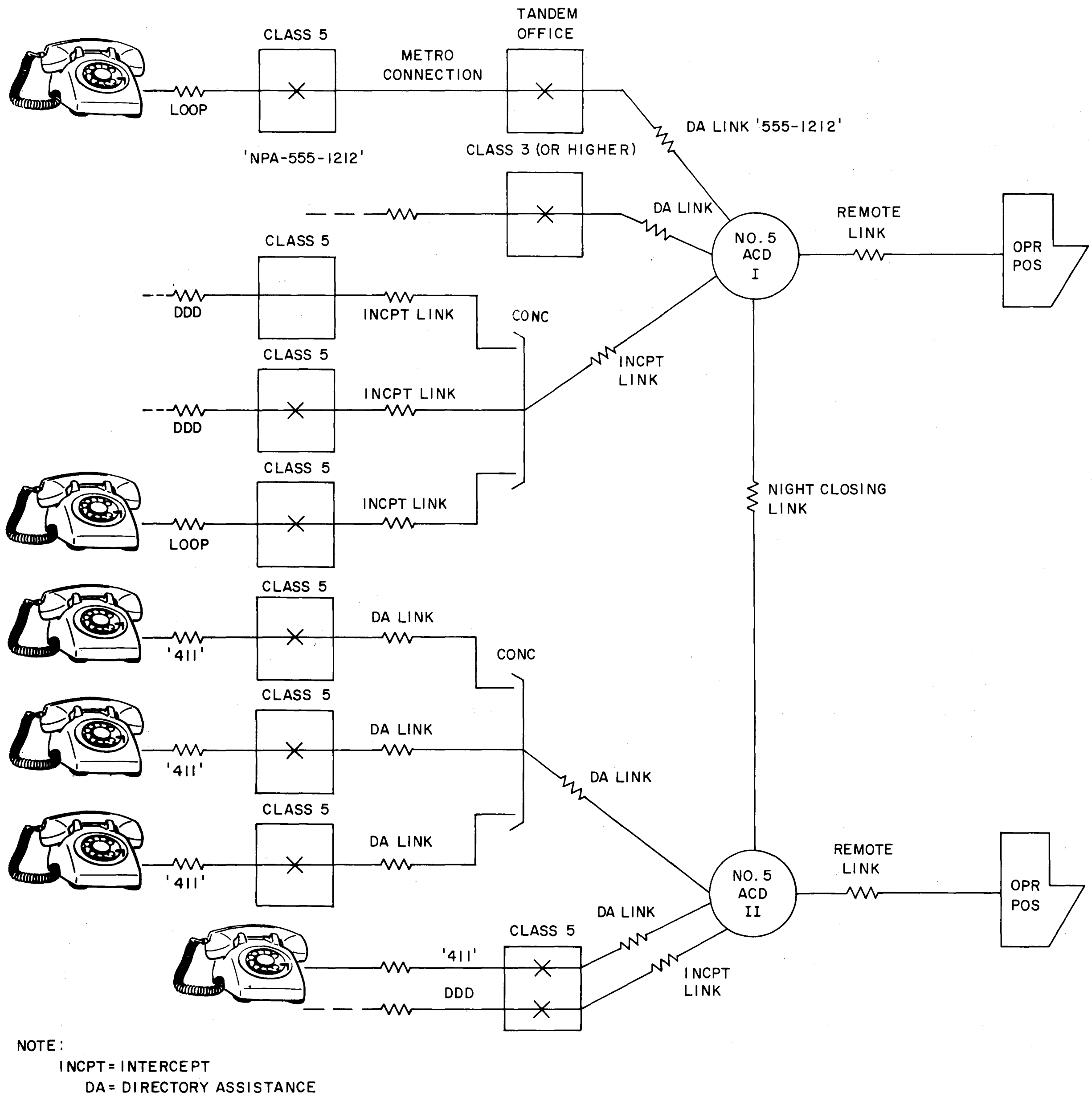


Fig. 1—Basic Call-Distributing System for Combined Intercept and Directory Assistance Service

(a) Adequate transmission between customer and operator,

(b) Adequate operator sidetone levels, and

(c) Operator and customer talker-echo control.

A discussion of these performance criteria is presented in the following paragraphs.

B. Transmission Grade of Service

3.02 The end-to-end performance of a telephone connection is evaluated by means of the transmission grade of service. Grade of service, a major transmission design parameter, combines a distribution of subjective customer opinion with the distribution of plant performance to obtain the expected percentage of customer opinion. As indicated above, the grade-of-service concept is subjective in nature, and it is generally categorized as Good or Better (G), Fair (F), and Poor or Worse (P). (When transmission grade of service is mentioned in this section, noise and loss are assumed to be the parameters of plant performance.)

3.03 For calls between operators and ***nearby*** customers, the grade of service to both parties should be at least that of an average short toll call. A nearby customer is one who is connected to the operator service system by short message network facilities. For example, in Fig. 1, a customer making a 411 directory assistance or local intercept call is considered to be nearby even though the ACD system may carry traffic a considerable distance.

3.04 For calls between operators and ***distant*** customers, the quality should be at least that of the equivalent DDD connection between subscribers. The equivalent DDD connection is one having the same length of regular toll message network facilities between subscribers as the customer-to-operator connection. In Fig. 1, a distant customer is one making an NPA + 555-1212 or a DDD intercept call. Grade-of-service computations have been made and summarized as shown in Fig. 2 which gives transmission grade-of-service "G" performance estimates versus the airline mileage for customer-to-customer connections. Note the degradation of average customer service from 85 percent "G" (6 percent "P") at 10 miles to 52 percent "G" (25 percent "P") at 2000 miles. As discussed above, grade-of-service functions represent a minimum objective for operator-to-customer connections in a number service environment.

C. Operator Sidetone

3.05 Another major transmission design parameter in number service is the operator sidetone path loss. Currently, the estimated acoustic-to-acoustic subscriber sidetone loss distribution is approximately normal with mean = 10 dB and σ = 2 dB, ie, 10 σ 2 dB. There are several reasons why a distribution with a higher mean and smaller deviation would be a desirable objective for operators:

(a) A proposed distribution of sidetone in loop plant is 12 σ 1.5 dB.

(b) The operator experiences sidetone for long periods of time and thus may have problems, eg, fatigue, with higher sidetone levels that probably would not affect a subscriber.

(c) The need for an operator to know she has a "live" connection is not as great as for a subscriber.

(d) Because of the long length of many toll directory assistance (and intercept) connections, it is essential that transmission degradation due to sidetone penalty (ie, a drop in operator transmit volume because of poor sidetone performance) be minimized.

For these reasons, an average acoustic-to-acoustic sidetone path loss objective of 12 dB is given. Sidetone losses in the range 8 through 16 dB are acceptable.

3.06 The round-trip delay of reflections in the sidetone path should be short enough that the operator cannot hear an echo. Since studies of listener identification of transmission impairments like echo have not yet been completed, it has been necessary to define a tentative limit on round-trip delay. The objective is stated as follows:

> ***The length and type of facilities in a call-distributor sidetone path should be such that the round-trip midband delay is less than 5 milliseconds.*** This figure corresponds approximately to the delay introduced by three 50-mile links of T1 carrier in tandem. This delay limit, although not an absolute upper limit, is one which is expected to preclude operator talker-echo problems for estimated conditions of loss and noise. Figure 3 gives the round-trip delay for different lengths of various carrier systems for two terminals and the facility.

D. Talker Echo

3.07 The length of transmission facilities associated with the call distributing system is mentioned above as a factor in possible transmission degradation. This quantity also enters into consideration of talker-echo control in a DDD + ACD connection. Operator talker echo is not expected to be a problem if the length, and hence the round-trip delay of the ACD system, is kept within the 5-millisecond limit specified in 3.06.

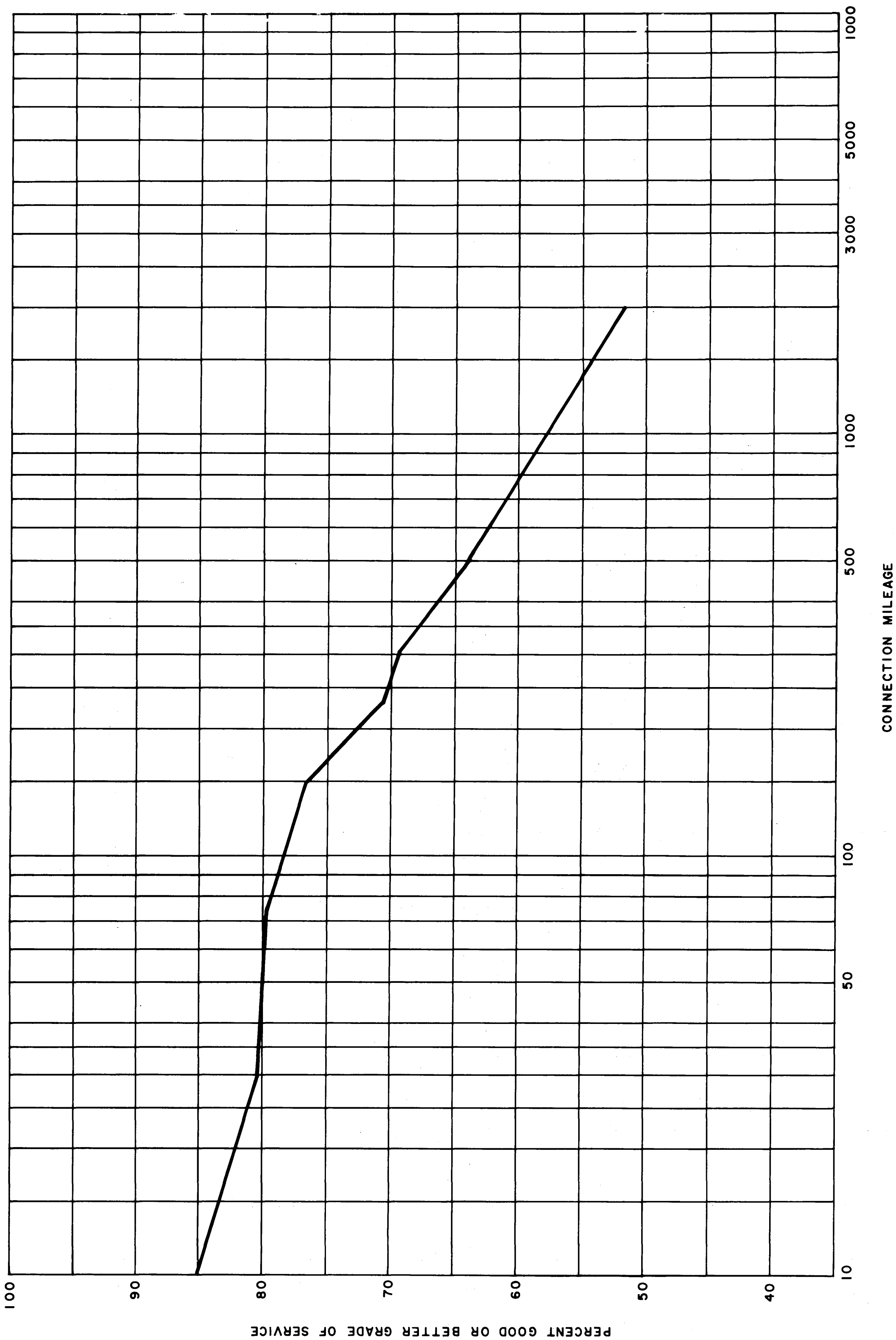


Fig. 2—Low-Noise Grade of Service for NPA Directory Assistance—DDD Customer-to-Customer

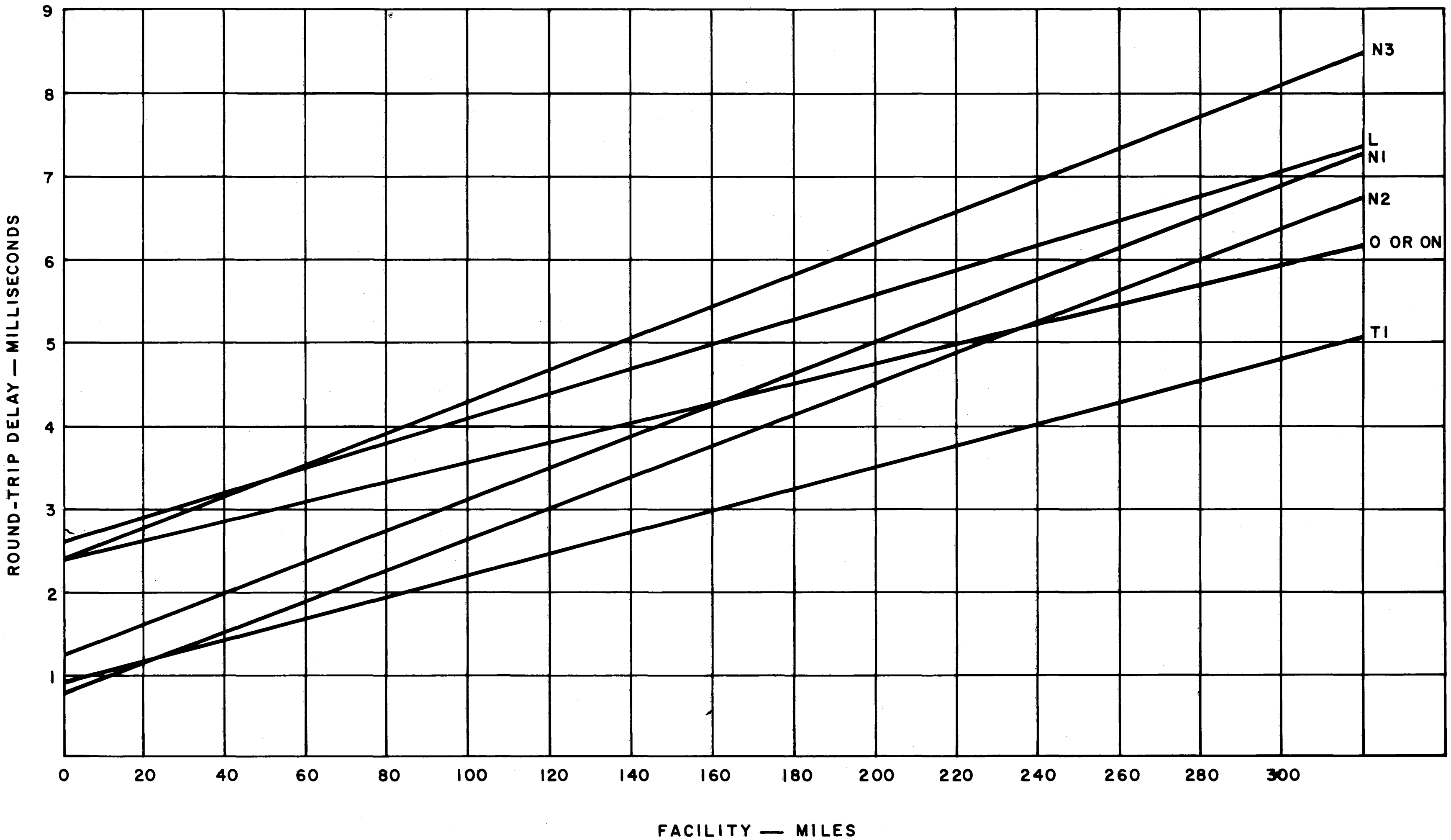


Fig. 3—Round-Trip Delay Versus Length of Carrier Facilities (Two Terminals and Facility)

3.08 There is a possibility of a customer talker-echo problem in a small percentage of NPA directory assistance connections because of the relatively low ERL of the modified operator telephone circuit (SD-99378-01, Iss. 6A) recommended for this system (7.5 σ 0.5 dB compared to 11 σ 3 dB for subscriber loop plant). The reduced echo return loss of the recommended operator telephone circuit is caused primarily by the mismatch between the 150-ohm output impedance of the 151B amplifier used in the transmit circuit and the 50-ohm transmit input impedance of the 181B coil hybrid.

3.09 Calculations under "worst case" conditions, ie, with the maximum number of links allowable in the DDD hierarchy plus 45 milliseconds of round-trip delay (the maximum before echo-suppressor application), indicate that customer talker-echo satisfaction will drop from 94.5 percent, for loop plant, to 89.5 percent. Because of the economic penalty to overcome this degradation, the design is considered to be acceptable on an interim basis. Customer talker echo is expected to be satisfactory for circuits having shorter delay or fewer links.

E. Trunk Concentrator

3.10 As mentioned previously, allowable trunk concentration in this system can be accomplished by use of the No. 23 concentrator. The transmission path through the concentrator consists of two trunk circuits, a battery supply, and a crossbar switch.

3.11 To ensure adequate transmission performance when using the No. 23 concentrator, incoming trunk circuits should be modified to have 120-type repeat coils and 2-μF midpoint capacitors. Also the outgoing trunk circuit must be equipped with 120-type repeat coils and 1-μF midpoint capacitors. With these modifications, the 1-kHz insertion loss should be approximately 0.6 dB and the ERL should be approximately 26 dB.

F. Transmission Testing

3.12 Transmission test calls from the originating offices are routed directly to test lines without operator assistance by use of a portable test set (trunk test set, J94742A, SD-99391-01) at the originating office, or by modification of the master test frame at a No. 5 crossbar originating office. A TOUCH-TONE® frequency indication is provided from the originating office. The No. 5 ACD office recognizes this as a transmission test requirement and prevents completion of the call to a position trunk. Instead, the ACD sets up a linkage to a test connector appearance on a trunk link frame. Subsequent tones indicate the type of test, and the test connector selects the desired test line. Transmission test lines available include the balance, milliwatt, jack-ended, loop-around, and the 104- and 105-type test terminations.

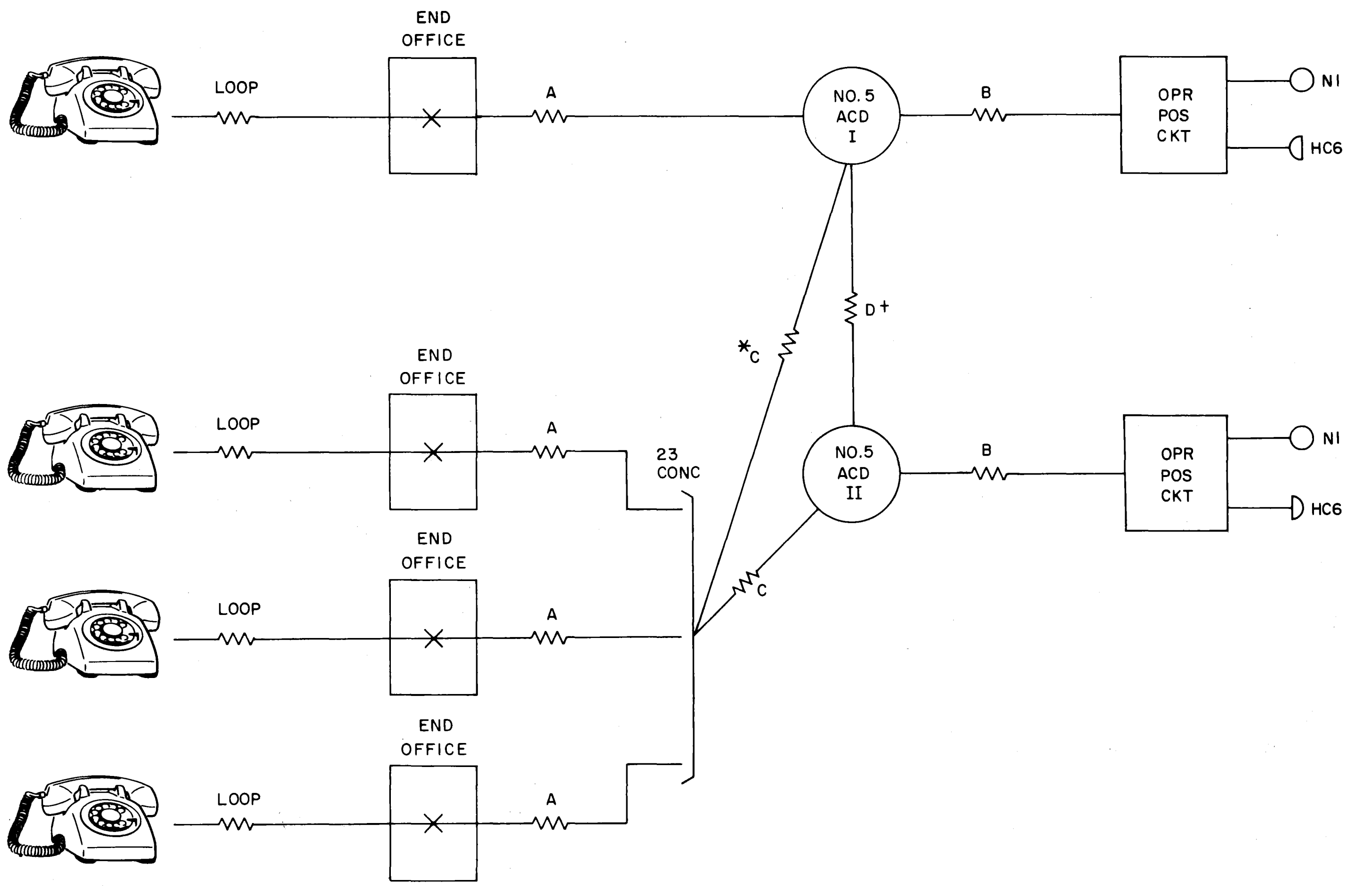
4. TRANSMISSION PLAN AND OBJECTIVES

A. Local Directory Assistance

4.01 Local directory assistance (411) calls are placed from within the NPA for which assistance is required. Figure 4 depicts typical trunking arrangements for 411-type service. In Fig. 4, a customer places a 411 call through his serving central office, which enters the ACD system over link A. If concentrated, the call reaches the ACD over link C and the operator over remote link B. Table A provides objectives for insertion loss and ERL for links A, B, C, and D.

4.02 The objectives of Table A call for the use of tandem trunk type facilities in link A, meeting a nominal 3-dB 1-kHz insertion-loss objective and a 13-dB average, 10-dB minimum, return-loss objective at the operator end. Link B requires facilities that meet toll connecting trunk insertion-loss requirements, and return-loss requirements ***at the operator end.*** Furthermore, 4-wire facilities meeting intertandem trunk insertion-loss requirements should be used in links C and D. The customer-to-operator connections on these 411 calls are analogous to the "local only" metropolitan network plan where the concentrator and ACDs are effectively the tandem locations and the operator locations are the terminating end offices. The built-up connection ACDB should not be allowed in this system.

4.03 These objectives provide a nearly optimum end-to-end loss of 12 dB for an average 411 connection. With the above objectives, the customer transmission grade of service is 90.6 percent "G" without concentration and 90.2 percent "G" with a stage of concentration included. Corresponding operator grade-of-service percentages for "G" performance are 88 percent and 90 percent. "P" performance is less than 5 percent in all these connections. The mean end-to-end loss for the operator is slightly below optimum in unconcentrated connections, resulting in the small degradation in



* NIGHT CLOSING LINK FOR CONCENTRATED TRAFFIC.
+ NIGHT CLOSING LINK FOR UNCONCENTRATED TRAFFIC.

Fig. 4—Trunking for Local Directory Assistance

TABLE A

RECOMMENDED DESIGN FOR LOCAL DIRECTORY ASSISTANCE

LINK[1]	LOSS[2] (in dB)	ERL[3] (in dB)
A	3 Nom., 4 Max.	13 Avg., 10 Min.
B	3 Nom., 4 Max.	18 Avg., 15 Min.
C,D	1.5 Nom.	25 Min.

Notes: 1. See Fig. 4 for link definitions.
2. "Loss" = 900Ω, 1-kHz insertion loss.
3. "ERL" as measured at end nearest ACD operator, with reference and terminating impedances of 900Ω + 2.16 μF.

performance. This suggests that the 3-dB nominal loss recommended for the tandem (link A) facilities, as well as for the toll connecting (link B) facilities, be obtained by adding 2-dB pads to the trunk design for those facilities with less than 2-dB insertion loss.

B. Intra-NPA Directory Assistance

4.04 Intra-NPA directory assistance (555-1212) calls can enter the ACD system from an end office, a sector tandem office, or a toll office. Calls from end offices may be concentrated, but calls from sector tandems or toll offices should not be concentrated. Calls entering the ACD directly from an end office should follow the plan given in Part 4A. For calls entering the ACD from the toll network, the ACD should be considered a class 4 switching point and the trunk design should follow the transmission plan covered in Part 4C. Figure 5 is a diagram of the trunking involved in calls entering the ACD system from a sector tandem office. The objectives for inserted connection loss and echo return loss for each link in the ACD system are given in Table B.

4.05 The facility between the sector tandem office and the ACD (link A) should be 4-wire and meet intertandem trunk inserted connection loss requirements for trunks terminated in tandem offices. In addition, these trunks should meet 4-wire toll connecting trunk terminal balance ERL objectives as measured from the end of the trunk nearest the ACD operator. Link B requires facilities that meet toll connecting trunk inserted connection loss requirements and ERL requirements at the operator end if access from a night transfer link is not allowed. Otherwise, link B should meet toll connecting trunk requirements ***at both ends.*** Link C requires the use of 4-wire facilities designed to an inserted connection loss of 0-dB nominal, 1-dB maximum. Through balance requirements to night transfer links should be met at the first ACD.

C. Toll Directory Assistance

4.06 Toll directory assistance (NPA + 555-1212) calls are generally placed from outside the numbering plan area (NPA) for which directory assistance is required, and thus tend to be longer than the average DDD connection. (More than 50 percent of all toll calls span an airline distance of 45 miles or less). A directory assistance call enters the ACD system for an NPA at one of the NPA's class 3 or higher toll offices, as shown in Fig. 6, and is routed over link A to the ACD. The ACD identifies the class of call and passes it over remote link B to an appropriate operator. Table C gives the recommended objectives for each link in this arrangement.

4.07 Via net loss (VNL) designed trunks of intertoll grade should be used between toll offices and the ACD (link A in Fig. 6). The night transfer link should be designed for 0-dB loss using 4-wire facilities. The ACD should be treated as a class 4 switching point in that terminal balance is required to the operator positions. However, in order that night transfer will not perceptibly degrade service, through-balance requirements from the first ACD to night transfer links should be met.

4.08 One might wonder why the ACD assumes the position of a class 4 office in the DDD hierarchy rather than that of a class 5 office: in the class 5 position, the ACD would be connected to a class 4 toll office by a toll connecting link, whereas in the class 4 position, the ACD would home on a class 3 or higher office for toll directory assistance (link A in Fig. 6) and would be connected to the toll office by a trunk of intertoll grade; in either situation, the connection might be further extended over link B in Fig. 6 to a remote operator position. In order to attempt an answer to this basic question, three remote operator toll connecting trunk loss allocations were analyzed:

(a) Minimum loss (2 dB),

(b) Average loss (3 dB), and

(c) Maximum loss (4 dB).

Based on these conditions, computations of transmission grade of service for the customer indicated that

(a) Class 4 operation of the ACD results in less sensitivity to loss in the remote links than that encountered in the class 5 plan,

(b) Customer grade of service is better overall with class 4 operation, and

(c) With class 5 operation, customer grade of service is below the acceptable minimum (average customer service as shown in Fig. 2) for the 3- and 4-dB remote link plans. The 3-dB

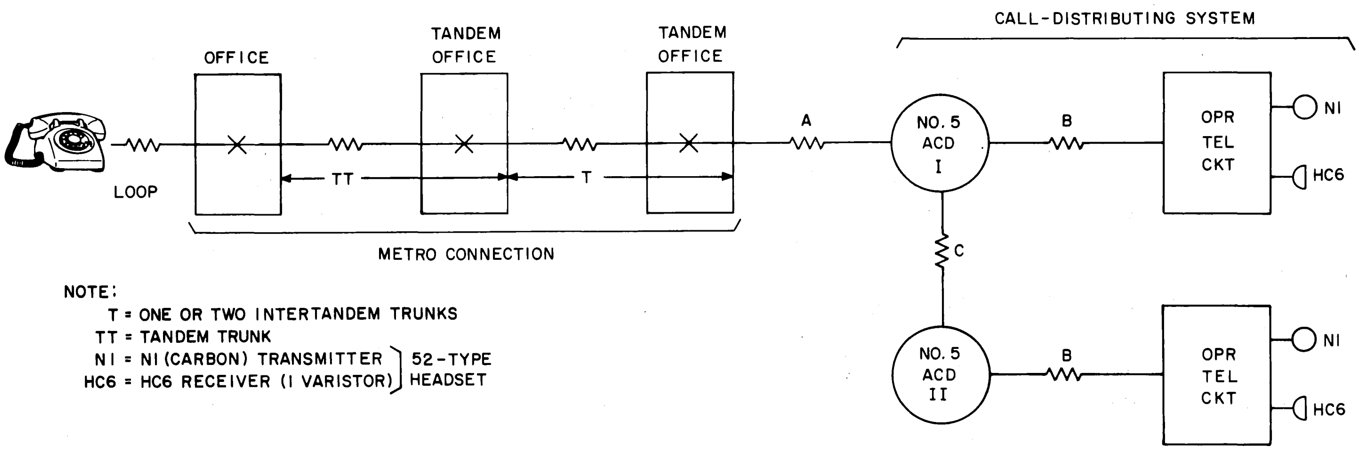


Fig. 5—Trunking for Intra-NPA Directory Assistance

TABLE B

RECOMMENDED DESIGN FOR INTRA-NPA DIRECTORY ASSISTANCE — ACCESS FROM SECTOR TANDEM OFFICE

LINK[1]	LOSS[2] (in dB)	ERL[3] (in dB)
A	1.5 Nom.	22 Avg., 16 Min.
B	3 Nom., 4 Max.	18 Avg., 15 Min.[4]
C	0 Nom., 1 Max.	25 Min.

Notes:
1. See Fig. 5 for link definitions.
2. "Loss" = 900Ω, 1-kHz insertion loss.
3. "ERL" as measured at end nearest ACD operator, with reference and terminating impedances of 900Ω + 2.16 μF.
4. If a night closing link (link C) can be switched to link B, then ERL requirements should be met at both ends of link B.

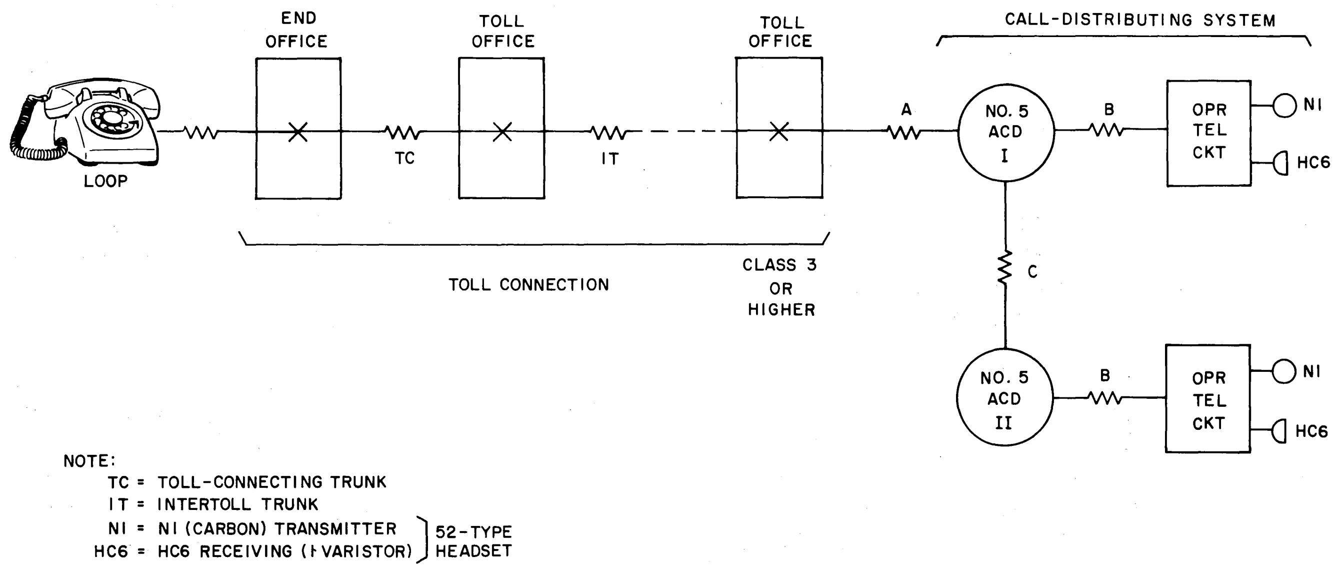


Fig. 6—Trunking for Toll Directory Assistance

TABLE C

RECOMMENDED DESIGN FOR TOLL DIRECTORY ASSISTANCE

LINK[1]	LOSS[2] (in dB)	ERL[3] (in dB)
A	VNL, 2.6 Max.	25 Min.
B	3 Min., 4 Max.	18 Avg., 15 Min.[4]
C	0 Min., 1 Max.	25 Min.

Notes: 1. See Fig. 6 for link definitions.
2. "Loss" = 900Ω, 1-kHz insertion loss.
3. "ERL" as measured at end nearest ACD operator, with terminating reference impedances of 900Ω + 2.16 μF.
4. Facility should meet ERL requirements at ***both*** ends.

plan averages 1.5 percent worse and the 4-dB plan averages 5.5 percent worse grade of service than average customer service.

The first two conclusions were also indicated for operator grade-of-service computations. These results, plus the degradation of grade of service because of the night closing links, make it clear that the class 4 plan for the No. 5 ACD when serving toll directory assistance customers is advised. Furthermore, facilities meeting toll connecting trunk inserted connection loss requirements and return-loss requirements ***at both ends*** are recommended for use in the remote operator links, since impedance compensation at both ends of 2-wire facilities must be employed to attain acceptable operator sidetone and customer talker-echo levels.

4.09 In order to maintain the grade of service delivered by the system during night transfer operation, zero-loss 4-wire facilities should be used in link C of Fig. 6. If carrier is employed, the use of T carrier facilities is preferred to analog carrier facilities because of the superior, and distance-independent, noise performance of T carrier.

D. Intercept Service

4.10 A relatively small part of the capacity of the No. 5 ACD may be used to centralize intercept service in areas which do not generate enough traffic to prove in AIS. However, although the bulk of call distributor traffic will be in directory assistance, the limiting case in transmission will be intercept.

4.11 The recommended transmission plan calls for the requirements outlined in Table D for the facilities depicted in Fig. 7. With these guidelines assumed, customer and operator transmission grade-of-service computations provide the following data:

(a) At a connection length (exclusive of the ACD system) of 100 miles, the ACD operator receives about 2 percent poorer "G" service and the customer receives about 6 percent poorer "G" service than on an average customer connection (see Fig. 2).

(b) For connection lengths from 10 to 2000 miles, customer service ranges from approximately 5 percent to 8 percent worse than DDD service and ACD operator service is about 2 percent worse.

The primary cause of the poor grade-of-service results is the low transmit efficiency of the operator circuit compared with the AIS operator circuit. AIS operator circuits use a 24V4-type arrangement to overcome the inherent inefficiency of the operator transmitter and to allow for three links of 2 dB each from the intercept end office to the AIS operator. However, the extra gain in the AIS telephone circuit forces the need for very stringent ERL requirements on the AIS facilities to control operator sidetone. By using the ACD telephone circuits and designing link C to 0-loss 4-wire, the facility requirements on links A and B of Fig. 7 can be reduced while acceptable performance is maintained.

4.12 Because operator sidetone on ACD intercept connections includes a significant structural reflection returned from the toll connecting facility or subscriber loop connected at the intercepting end office, the length of the call distributing system must be restricted as discussed in paragraph 3.06.

5. CONSIDERATIONS FOR A UNIFIED DIRECTORY ASSISTANCE AND INTERCEPT SERVICE SYSTEM

5.01 Part 4 of this section discussed the use of the No. 5 ACD as an intercept system. Directory assistance, of course, will form the bulk of the call distributor service, but, as mentioned previously, if intercept traffic is handled over certain links, this traffic will be the limiting case for transmission purposes. Some economies could be realized if the facilities in the remote links (links B) could be designed to meet objectives similar to those for link B in the toll directory assistance plan (see Part 4C).

5.02 A proposed intercept system having objectives similar to the toll directory assistance plan was evaluated. This plan, called the "2-0-3" system, had 2-dB trunks in link A, 0-dB 4-wire trunks in link C, and 3-dB facilities in link B. The results of this evaluation showed that at 100 miles, ACD operator grade of service on concentrated intercept connections is approximately 6 percent below the DDD objective of Fig. 2 and customer service is about 14 percent lower. Customer service in particular worsens as connection length increases and is 16 percent below the DDD objective at 2000 miles.

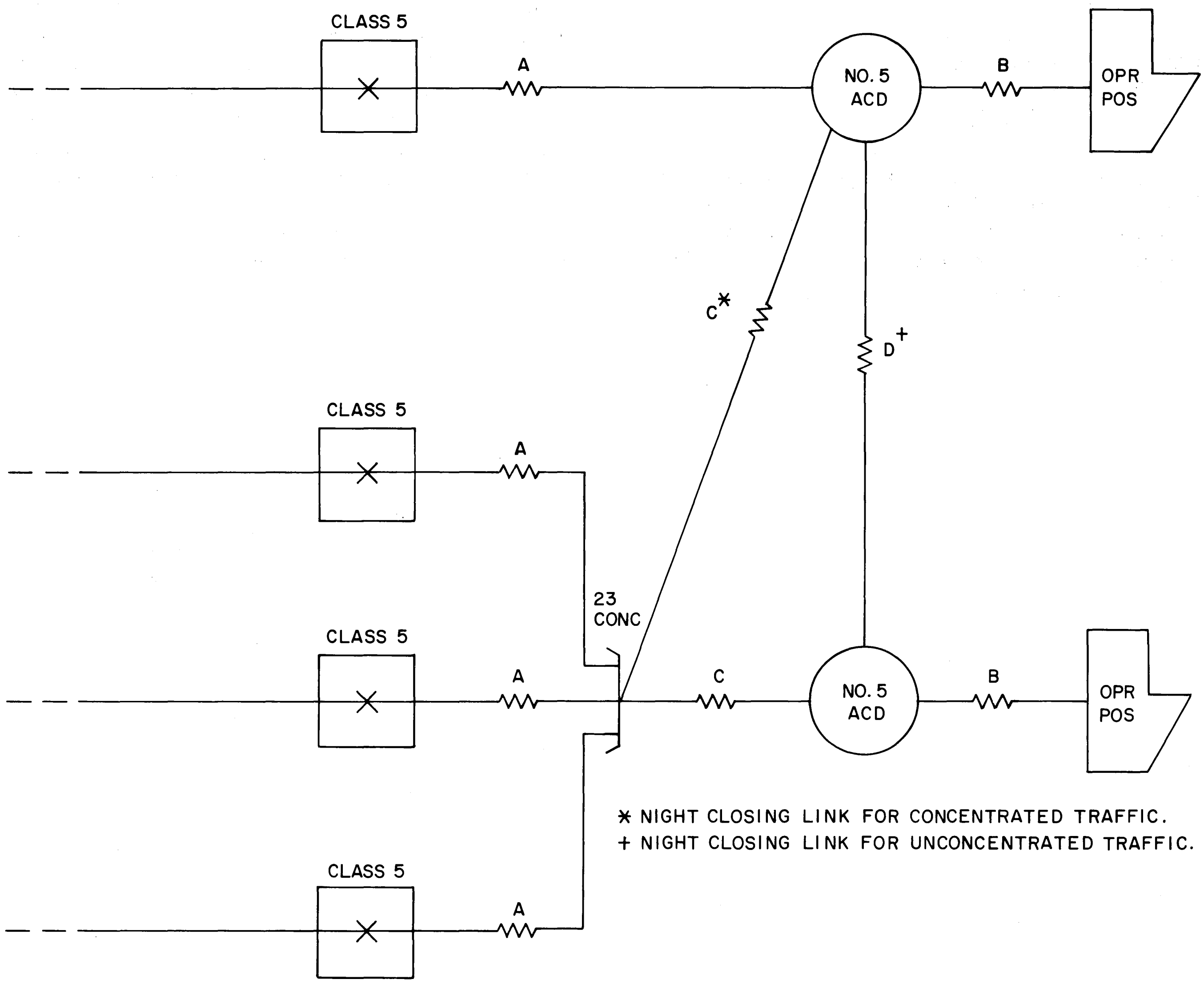


Fig. 7—Trunking for Intercept Service in a Call-Distributing System

TABLE D

RECOMMENDED DESIGN FOR INTERCEPT SERVICE

LINK[1]	LOSS[2] (in dB)	ERL[3] (in dB)
A	2 ± 0.5	15 Min.
B	2 ± 0.5	15 Min.
C,D	0 Min., 1 Max.	25 Min.

Notes: 1. See Fig. 7 for link definitions.
2. "Loss" = 900Ω, 1-kHz insertion loss.
3. "ERL" as measured at end nearest ACD operator, with reference and terminating impedances of 900Ω + 2.16 μF.

5.03 The thought may occur to temporarily accept less stringent grade-of-service objectives while awaiting transmission improvements in operator telephone circuits or standard trunk facilities. However, a comparison of the transmission quality for ACD operators and customers with that for AIS operators and customers argues against accepting less stringent objectives. Furthermore, operator-to-customer connections should not deliver substantially worse service than ordinary DDD customer connections. This is especially true in view of the recognition among some personnel concerned with transmission objectives and planning that even DDD service, as summarized in Fig. 2, is not as good as it should be. Another objection is that, even on an interim basis, the "creeping degradation" introduced by successive plans for operator service is objectionable. In view of these considerations, the "2-0-3" plan for intercept connections is untenable and the recommended guidelines given in Part 4D should be used.