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Notes on Distance Dialing 1968

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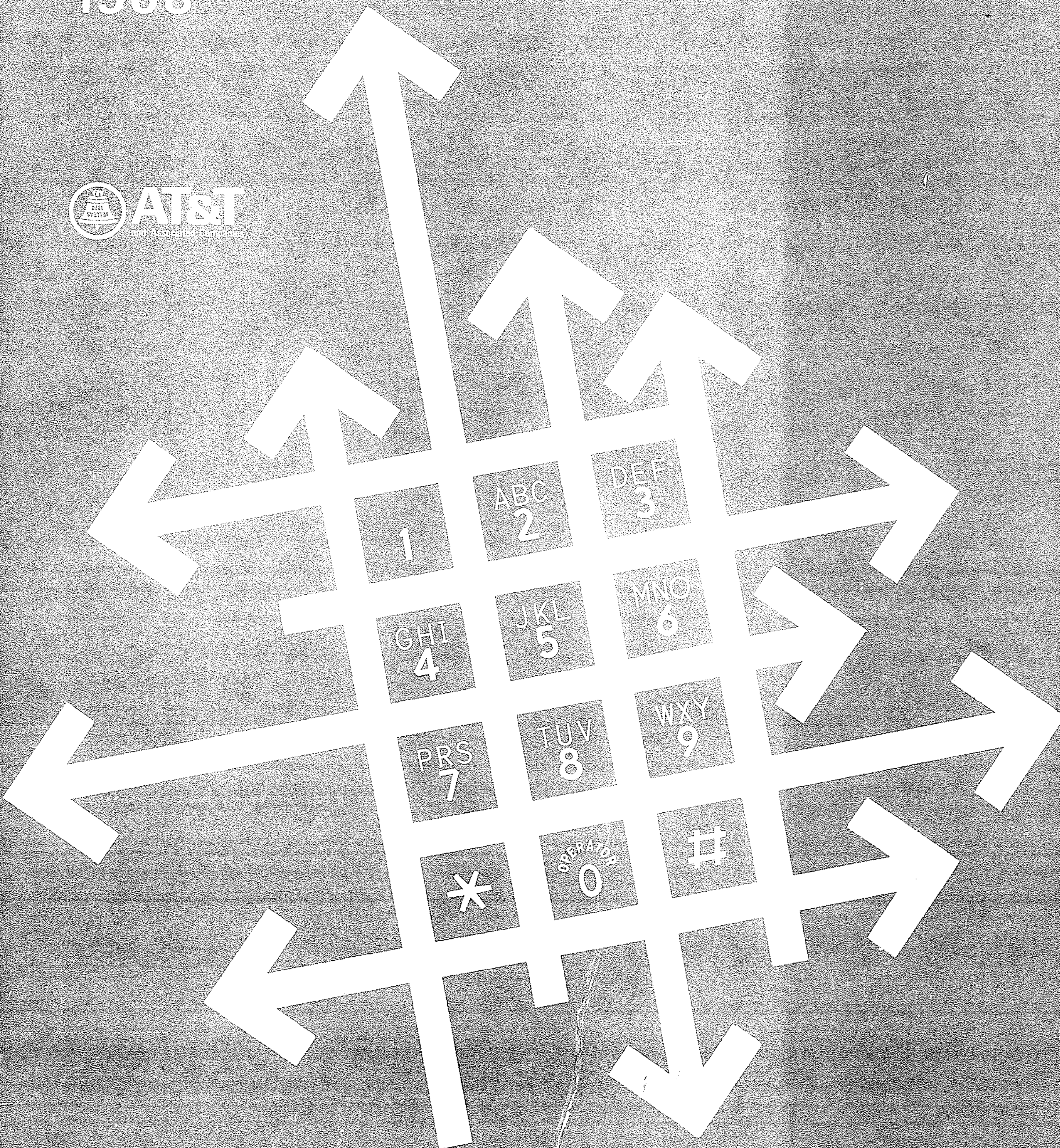


NOTES ON DISTANCE DIALING

AMERICAN TELEPHONE AND TELEGRAPH COMPANY
ENGINEERING DEPARTMENT
SYSTEMS PLANNING SECTION

NOTES ON DISTANCE DIALING

TABLE OF CONTENTS

FOREWORD

SECTION 1

GENERAL

PAGE

SECTION 2

NUMBERING PLAN

SECTION 3

SWITCHING PLAN

SECTION 4

SIGNALING

SECTION 5

EQUIPMENT REQUIREMENTS

SECTION 6

TRANSMISSION CONSIDERATIONS

SECTION 7

MAINTENANCE REQUIREMENTS

SECTION 8

INTERNATIONAL DIALING

SECTION 9

NEW SERVICES UTILIZING DDD NETWORK

SECTION 10

BIBLIOGRAPHY

These Notes outline technical requirements and fundamental principles of operator and direct (customer) distance dialing. They are a revised edition of "Notes on Distance Dialing – 1961," which superseded the earlier "Notes on Distance Dialing – 1956."

This issue of the Notes includes two sections not in previous issues. Section 8 discusses International Dialing and Section 9 covers in general some of the new services that are now being routed on the message network. The remaining sections have been generally updated and revised.

The Notes are confined to matters bearing directly on distance dialing. In addition to technical data required by manufacturing and engineering personnel, discussions are included covering in some detail the Numbering Plan, the Switching Plan, Equipment, Transmission and Maintenance Considerations, etc., which should be of value to operating and maintenance people. For those interested in the overall plan rather than technical details, the "General" section briefly outlines the contents and scope of the other sections in nontechnical terms, and discusses some of the fundamentals that are considered when preparing to incorporate offices into the distance dialing network.

In many instances it has been necessary to specify certain requirements or design objectives without including a discussion of the factors underlying their selection. Also, there are many problems in the Accounting, Commercial, Public Relations and Traffic fields as well as Engineering that relate to distance dialing but are not covered by these Notes. Nevertheless, the Notes do furnish much of the information needed by the telephone industry for the successful coordination of efforts between manufacturing and Operating Companies in furthering distance dialing.

While the Notes describe requirements as visualized today, details will necessarily change as further experience is gained and new instrumentalities are developed. However, the fundamental plan is considered sound and it is believed that changes which may become necessary will have no serious effect on plant designed to meet the requirements outlined in the Notes.

In situations where operator and direct distance dialed traffic items do not reach the nationwide network and where exception to the provisions of the Notes will result in significant industry economy, the requirements shown in the Notes need not be rigidly applied. A book of such general nature as these Notes cannot cover all details of every technical requirement for distance dialing. To care for questions concerning technical matters not discussed in the Notes, direct contact at the local or state level between the Independent and Bell segments of the telephone industry is encouraged.

Planning for distance dialing involves the entire telephone industry. Accordingly, personnel of all Telephone Companies participating in distance dialing have an interest in these Notes. The importance of early and continuous joint planning by Independent and Bell Companies cannot be overemphasized, since the plans of one are bound to affect the plans of others and influence the determination of the most economical industry solution. In this connection, information relative to this issue of these Notes reflects the combined efforts of the U.S.I.T.A. Subcommittee on Network Planning and the American Telephone and Telegraph Company.

Section 1
General

GENERAL

CONTENTS PAGE

1. INTRODUCTION

1.01 Distance dialing (nationwide dialing) as used in these Notes and as commonly understood within the telephone industry, means the completion of long distance calls by either customers or operators dialing from the originating location without any assistance from intermediate operators. CAMA or TSP operators who may enter on the line for momentary assistance are not considered as intermediate operators. To designate calls dialed by customers to points outside their local or extended service area, the phrase "Direct Distance Dialing" is used. When such calls are dialed by operators, the designating phrase "Operator Distance Dialing" is used. Distance dialing has been generally accepted as an industrywide objective, since this method of operation usually provides the fastest, most accurate, and most dependable telephone service, and at the same time results in overall operating economies. The switching plan for distance dialing provides for the handling of long distance traffic within the North American Integrated Network.

1.02 The Notes are intended to serve as a general reference and guide for the Telephone Industry on the principles of distance dialing. They describe minimum requirements and are not intended to provide detailed engineering information. Since the basic plan is designed for both operator and customer dialing, no distinction is made between the two except in instances where requirements differ. Detailed description of circuit operation has been avoided, and the requirements for switching systems are covered only to the extent that they affect distance dialing considerations.

1.03 Generally the Notes describe the requirements that apply when distance dialing has been fully realized, and do not cover interim arrangements which may be both expedient and appropriate during transitional periods. Many things dictated by local conditions must be considered before the methods and equipment arrangements for a given office can be properly determined.

1.04 Some references are made to equipment of Bell System manufacture; however, appropriate equipment of other manufacturers with the necessary operating features could be employed.

2. DESCRIPTION OF SECTIONS

Numbering Plan – (Section 2)

2.01 A primary requisite for distance dialing is that each customer be assigned a distinctive telephone number that does not conflict with the number of any other customer connected to the network. It is essential that these numbers be similar in form, convenient to use, and compatible with local and extended area dialing arrangements.

2.02 Telephone numbers for distance dialing consist of two basic parts:

(1) A 7-digit number consisting of a 3-digit central office code and a 4-digit station number; and

(2) An area code consisting of three numerals to designate the geographical numbering plan area.

2.03 Economical conversions to 7-digit numbering can be accomplished by establishing a careful program for its introduction into all new offices and for orderly, well-planned changes in existing offices.

2.04 Numbering plan arrangements and dialing procedures for the North American Network are discussed in Section 2. International numbering arrangements are discussed in Section 8.

Switching Plan – (Section 3)

2.05 A second requirement for distance dialing is a switching plan that routes traffic automatically, economically and rapidly to its destination. A general switching plan for handling long distance traffic on a manual basis was in operation for more than 20 years. Modifications were made in this plan to develop the switching plan for distance dialing.

2.06 The distance dialing plan takes full advantage of the overall economies offered by alternate routing. The ability of automatic switching systems to rapidly test a number of different routes permits the automatic routing of calls over one or more alternate routes. Trunk plant is used more efficiently than under manual operation, and the plan makes feasible long distance service with essentially no delays.

2.07 Section 3 describes the switching plan for distance dialing in considerable detail and includes in its appendices an explanation of what alternate routing is, why it is used, and how it is used. The routing plan for international dialing is contained in Section 8.

Signaling – (Section 4)

2.08 One of the most important needs for industrywide information about distance dialing is a statement of the signaling operation. Under manual ringdown operation, the requirements were relatively simple; signaling information was passed between switching centers either verbally by the operators or by "ringing" on the line. With automatic switching, however, a complex system of signals is needed to pass information over the dialing network. These signals include digital address information, supervisory and charging conditions, control data, etc. They must be designed to actuate and be recognized by switching and transmission systems of many different types and manufacture, and they must be accurately and rapidly transmitted over many types of transmission facilities.

2.09 Section 4 discusses the signals required for distance dialing and related matters. Considerable technical information is included to illustrate the nature of the signals themselves, as well as the equipment arrangements for their generation and detection. Where necessary, the signaling capabilities and requirements of several types of switching and transmission systems are shown for informational background. A number of charts and schematic diagrams illustrating signaling fundamentals are also included. Since basic signaling requirements are essentially the same for both operator and customer dialed traffic, no distinction has been made between the two except where differences do exist.

Equipment Requirements – (Section 5)

2.10 There are several miscellaneous equipment requirements for distance dialing in addition to the signaling requirements detailed in Section 4. These requirements and brief discussions of the effect of distance dialing on station equipment, switching facilities, long distance switchboards, automatic equipment for recording message billing data, and miscellaneous central office and traffic administrative facilities are summarized in Section 5.

2.11 Section 5 is confined to those specific central office equipment arrangements which need to be provided to interconnect an office with the distance dialing network. No attempt has been made to cover the many other requirements for local and long distance service. The type of equipment employed is not important from the standpoint of distance dialing as long as the minimum requirements outlined in this section and in Section 4 on signaling are met. For this reason, Section 5 covers a number of fundamental considerations regarding miscellaneous and somewhat unrelated items.

Transmission Considerations – (Section 6)

2.12 The switching plan for distance dialing contemplates that most calls are to be completed on direct circuits or over alternate route trunks switched together in tandem. A very small portion of the total number of calls will encounter as many as 9 trunks within Canada or the U.S. In International Dialing as many as 14 circuits could be connected in tandem, with six international circuits and the remainder divided between the terminating countries. This requires careful transmission design as well as concentrated effort in maintaining transmission values close to design objectives.

2.13 Design factors and objectives for trunk plant are covered in some detail in Section 6. In addition, since satisfactory transmission over subscriber loops to local offices is as important to distance dialing as is transmission on trunk plant, subscriber loop design is also discussed. Section 6 also includes a new treatment of the concept of via net loss design. Balance objectives are also described.

2.14 It becomes increasingly important that transmission stability be improved as distance dialing is extended. Improved procedures and techniques are required because with automatic multialternate routing, often involving a number of trunks connected together on a particular call, the problem of identifying a particular trunk having transmission trouble becomes more difficult. Section 6 also discusses maintenance considerations on trunk and loop plant.

Maintenance Considerations – (Section 7)

2.15 A high level of equipment performance is required at the switching centers in the distance dialing network and thus demands superior maintenance effort. This is best accomplished by the use of automatic test and fault recording devices, so that troubles may be promptly detected and corrected before they have any serious impact on service. Unless adequate steps are taken to keep trouble conditions within reasonable limits, they not only react unfavorably on the customers, who normally are the first to detect them, but also result in inefficient use of the network.

2.16 Means have been developed for the automatic detection and recording of troubles so that most trunk and equipment troubles may be cleared before they can cause serious service reactions. Section 7 describes automatic testing equipment, test lines, and various other testing facilities suited to the needs of distance dialing, together with suggestions for their application.

International Dialing – (Section 8)

2.17 Worldwide direct distance dialing will have a major impact on the communications industry in many areas such as numbering, signaling, switching, equipment, transmission, etc. Section 8 has a description of the preliminary plans for International Dialing.

New Services – (Section 9)

2.18 Increasing needs of communications users and the progressing state of the telecommunications art have generated additional services which differ in some respects from ordinary message toll service. Some of the existing new services which employ the distance dialing network are discussed in Section 9.

Bibliography – (Section 10)

2.19 As mentioned in the beginning of Section 1, it is intended to describe in these Notes the minimum requirements to be met in order to connect with the distance dialing network. For those who may wish to explore in more detail subjects related to distance dialing, the Bibliography, Section 10, is furnished for reference.

3. FUNDAMENTAL PLANS

3.01 In addition to the subjects covered in detail in Sections 1 through 9, it may be worthwhile to consider briefly the fundamental plans which are the keystone to the inclusion of any office, large or small, in the distance dialing network. Large sums of money are often required to:

Provide communications services for new customers.

Provide for increased use of services by present customers.

Offer new or improved services.

Achieve desirable economical overall operation.

Replace plant which has become inadequate, obsolete, or worn out.

The plant purchased should best meet the needs enumerated above and be balanced properly among the following:

Capital expenditures.

Annual costs.

Good service.

Improved features.

Conformity with long-range plans and objectives.

Protection of plant and service.

Desirable operating arrangements.

And many more.

Because the sums invested are large, and because the service life of most plant is appreciable, it is important that fundamental plans be made well in advance of the time when something must be done. This will help smooth the transition to mechanized operation and the introduction of new services. New plant and equipment can be provided in an orderly manner without incurring unwise or unnecessary expenditures. Flexible plans fitted to conditions at a given location can be developed which will permit adjustments as necessary to meet changed conditions and advances in technology. Fundamental plans need frequent review to reflect such changes and advances as they occur, in order to be kept current.

3.02 Fundamental planning for distance dialing includes the following broad fields:

(1) Analysis of fundamental traffic data and methods.

(2) Plans for equipment to automatically record and process message billing data for direct (customer) dialed extra-charge traffic.

(3) Design of local central offices and subscriber loops, including local numbering.

(4) Design of plant, including the types of transmission facilities and switching equipment.

3.03 Traffic analysis is an early step in fundamental planning and includes the determination of such items as:

(1) Future routings under the switching plan for distance dialing.

(2) Estimates of future traffic volumes and possible changes in the characteristics of traffic, including:

(a) The effect of future extensions of local area service.

(b) The portion of traffic that can be dialed by customers.

(c) The residual portion of traffic to be handled by operators.

(d) The portion of traffic to be handled by special service networks.

3.04 Because service improvements and operating economies can be obtained from direct dialing of extra-charge traffic, systems for automatically recording and processing message billing data usually receive early and detailed consideration in fundamental planning. Factors pertaining to this phase of planning include:

(1) The type of station identification to be used.

(2) Whether individual recording systems at each local office or one centralized system to serve several offices should be provided.

(3) Whether recording systems for person, credit card and coin traffic should be provided.

(4) Traffic volumes to be dialed and the relative proportions of traffic to be detailed and bulk-billed.

(5) Operating economies which result.

3.05 Fundamental planning for a local exchange to be connected to the distance dialing network includes provision for:

(1) A 7-digit numbering plan.

(2) A 7-digit directory listing of customers' numbers.

(3) Segregation of coin boxes (public or semipublic telephones) in certain recommended thousand series to the extent possible.

(4) Adequate interception of nonworking station numbers and vacant central office codes.

(5) Signaling requirements (as outlined in Section 4).

(6) Subscriber loop design (as described in Section 6) which will establish the lowest loop loss consistent with economy.

(7) Automatic Number Identification, whenever feasible.

3.06 Fundamental planning for switching equipment, outside plant, and terminal facilities takes the following into account:

(1) All plant should be equipped with or arranged for the addition of the features needed to meet the minimum requirements outlined in these Notes.

(2) The most economical transmission facilities which will meet transmission objectives (e.g., carrier, radio, voice-frequency, etc.) should be selected for relief on existing routes and on new routes that may be established. This involves such factors as:

(a) Current and future traffic volumes and trunking requirements for the message network plus requirements for special services.

(b) Transmission design objectives under the switching plan for distance dialing.

(c) Establishment of an approximate but realistic timetable for the programming of the various phases of mechanization for all distance dialed traffic.

(d) Provision of new routes separated from present routes for protection of service.

Section 2

Numbering Plan

NUMBERING PLAN

CONTENTS

1. GENERAL

1.01 An essential element of distance dialing is a numbering system wherein each telephone has a unique number which is convenient to use, readily understandable, and similar in form to that of all other telephones connected to the network. With such a numbering system, operators or customers, wherever located, may use this number to reach the desired telephone through the distance dialing network. This is called "destination code" routing.

A central office serves all or part of a local switching area. With distance dialing, each of these areas becomes a part of one huge multioffice area, each telephone and central office having a distinct identity as part of the distance dialing numbering system.

1.02 Assignment of a unique number to each telephone is a requirement for destination code routing, which is further discussed in Section 3, Part 6.

1.03 The routing codes for distance dialing consist of two basic parts:

(1) A 3-digit numbering plan area (NPA) code.

(2) A 7-digit telephone number made up of a 3-digit central office code plus a 4-digit station number.

Together, these ten digits comprise the network "address" or "destination code" for each telephone. The arrangement is shown in Chart 1 and is described in detail in the following paragraphs. How this plan is being expanded to accommodate worldwide customer dialing is described in Section 8.

1.04 Digit "1" may be prefixed to a number to accomplish one of several purposes:

(1) To switch into the toll networks a call originating in a step-by-step central office.

(2) To distinguish toll calls from local calls.

(3) To reduce the effect of ambiguity between NPA and central office codes when these codes are used interchangeably in the future.

1.05 The succeeding paragraphs describe the basic arrangement used now, and the changes that are necessary to care for future network expansion.

2. NUMBERING PLAN AREA (NPA) CODES

2.01 The entire United States, Bermuda and the Caribbean Islands, Canada, and a portion of Northwest Mexico have been divided geographically into "Numbering Plan Areas," each of which is assigned a distinctive 3-digit designation called an "area code." Calls between numbering plan areas will, in general, require dialing the code of the area in which the called telephone is located, as well as the called customer's 7-digit number. Home area calls, which originate and terminate within the same NPA, ordinarily require the dialing of only the called customer's 7-digit local number.

2.02 As shown in Chart 1, the numbering plan "area code" consists of three digits. At the present time the second digit is always either "0" or "1." With this present format, switching equipment can distinguish area codes from central office codes because the latter never employ "0" or "1" in the second digit, as covered in Paragraph 3.01. Examples of the present type of area codes are 516, 201, 607, etc.

2.03 There are 160 possible N 0/1 X code combinations which are now available for use as NPA codes, where N is any number from 2 through 9, and X is any number from 0 through 9 (8x2x10). Of these, eight codes (211, 311, 411 through 911) are reserved for use as service codes, leaving 152 available as area codes. In May, 1967, 129 area codes were reserved or in use, leaving 23 spare. Chart 2 and Appendix A show the present assignments.

2.04 When the spare NPA codes (N 0/1 X) are exhausted, additional assignments will be made first from NNO codes. Sixty-three NNO codes in their proposed order of assignment as NPA codes are shown in Chart 1. Code 950 is reserved, as noted in Paragraph 3.04, and is not included in the list. When the NNO codes are exhausted, the remaining NXX codes will be used for NPA's. There will then be 800 possible code combinations for use as area codes and/or service codes. (8x10x10 = 800)

2.05 A single NPA for a state or province (Canada) is the most desirable arrangement from a customer dialing viewpoint. For this reason, the NPA boundaries were drawn coincident with existing state or provincial boundaries whenever it appeared that the ultimate central office code capacity for a single NPA would not be exceeded. About half the states and provinces are currently on this basis. In the more populous states, however, two or more areas are required. California is divided into eight different NPA's; New York has seven; Texas has six; Illinois and Ontario have five; Pennsylvania, Ohio and Michigan have four each. Other states have two or three NPA's, depending on the number of central offices to be served.

2.06 In subdividing states and provinces, NPA boundaries are generally drawn so that points generating high volumes of traffic to each other are in the same NPA. This arrangement permits the customer to dial seven digits, exclusive of a prefix (as discussed in Part 4), on most of his calls. Wherever possible, the boundaries are drawn so that a toll center and its tributary offices are in the same NPA. In addition, it is desirable to avoid creation of an NPA boundary between offices with extended area local service to each other. As additional area codes are introduced from time to time, the same principles will apply in fixing the new boundaries. The objectives of keeping the numbering plan as simple as possible for the customer, and enabling him to dial only seven digits on most of his calls, are controlling.

3. CENTRAL OFFICE CODES

3.01 The central office codes that meet the requirements of the distance dialing numbering plan consist of three digits, as shown in Chart 1. There are two main types of central office numbers now in use. The first consists entirely of numbers. This is known as All-Number Calling, or ANC. The other type is the 2L-5N or 2-5 numbering, where the two letters of the prefix are the first and second letters of the central office name and the third digit of the code is a number. Conversions to ANC since 1961 have materially reduced 2L-5N usage. Ultimately, all central office codes will be on an ANC basis.

3.02 All-Number Calling, in conjunction with the interchangeable use of NPA and central office codes (see Part 4), provides a theoretical maximum of 792 central office codes per NPA. This is derived on the basis of 800 NXX code combinations (8x10x10), with the exclusion of the eight N11 combinations which are in use or reserved for service codes.

3.03 At the end of 1965, 73% of all telephones (Bell System and Independent Companies) in the United States and Canada were on an ANC basis. It is estimated that by the end of 1967, 81% of all telephones will be ANC.

3.04 Of the 800 NXX combinations, 202 codes are now reserved for use as area codes, service codes, and for special purposes. The remaining 598 codes may be assigned to central offices. The 202 reserved codes are as follows:

USE	TYPE OF CODE	NO. OF CODES
Area Codes	N 0/1 X	152
Area Codes	NNO (See Chart 1)	27
Area Codes or Future New Services	950-954, 975-979	10
Plant	958-959	2
Time	844	1
Weather	936	1
Toll Information	555	1
Long Distance Operator	211	1
Information	411	1
Repair Service	611	1
Business Office	811	1
Special Services	311, 511, 711, 911	4
		202

4. DIALING PROCEDURES FOR CUSTOMER DISTANCE DIALING

4.01 When the present numbering plan was introduced in 1947, 86 of the available 152 NPA codes were assigned. By 1967, 129 NPA codes were in use or reserved. As early as 1959, it was recognized that the original plan would not care for ultimate code requirements. At that time, some modifications in the ultimate plan were announced. Subsequently, dialing procedures for reaching toll information were added.

4.02 The standard dialing procedures for both step-by-step and common control offices are as follows:

Local Calls			7 digits
Station Paid Toll (including coin)		– HNPA	"1" + 7 digits
		– FNPA	"1" + 10 digits
Person, Special (including coin)		– HNPA	"0" + 7 digits
		– FNPA	"0" + 10 digits
Information	– HNPA Local		411 or "1" + 411
	– HNPA Toll		"1" + 555-1212
	– FNPA Toll		"1" + NPA + 555-1212
Other Service Codes			"N11" or 7 digits
Assistance			"0"
Intercontinental Access			01, 011
Special Codes			00, 10, 11

4.03 The plan provides the following features:

(1) A simple CAMA access code in lieu of "112" in step-by-step offices.

(2) A procedure for customer dialing of person-to-person and other calls requiring operator assistance.

(3) Uniform dialing procedures in both step-by-step and common control type offices.

(4) A simple prefix code in those common control cities where there is a need to reduce toll billing inaccuracies resulting from misdirected local-intended calls reaching toll locations in the home NPA.

(5) A means to reduce the ambiguity brought about by the use of a code as either an area or a central office code.

The plan, in addition to meeting the above considerations, will ultimately increase the available supply of NPA codes from 152 to 792.

4.04 Ultimately, customers will dial the prefix "1" on station paid toll calls, and the prefix "0" on person and other special type calls. In each case, the prefix will be followed by either seven or ten digits, depending on whether the called point is in the home or a distant numbering plan area.

4.05 As indicated, a zero (0) may denote an assistance call or the first digit of a person-to-person or other special type of call. A timing arrangement is provided following the digit "0." If no additional digits are received within three to five seconds, the call will be routed to an assistance operator. If additional digits are received within this time period, the call will be treated as a special type call.

4.06 At present, a given set of three digits following the prefix can be identified by its format as either an area code or a central office code in the home numbering plan area. Ultimately, however, the same set of digits may be either type of code, depending on whether the customer dials seven or ten digits following the prefix. In this case, the equipment cannot determine from the code dialed whether the call is to be a 7-digit or a 10-digit call. The central office equipment will therefore wait for about 3-5 seconds following the seventh digit (exclusive of prefixes). If an eighth digit is received, the equipment will treat the first three digits as an area code and expect a 10-digit address. If no additional digits are dialed within the timing period, the call will be routed to the HNPA destination. In summary, timing applies *only* to "1" + 7 or 10-digit or "0" + 7 or 10-digit calls where the central office code is also assigned as an area code.

4.07 Interchangeable use of NPA and office codes is not expected to occur before 1973, at which time the first of several of the larger NPA's will exhaust the 640 available central office codes, thus requiring NPA codes to be assigned as office codes in these NPA's. When this occurs, local and toll equipment modifications will be required only in the particular NPA assigning NPA codes as office codes.

In other NPA's, equipment modifications for interchangeable codes need be made only in toll switching machines. Blocking of the fifth digit "1" or "0" on 10-digit calls which begin with area codes must be removed at the point where the AMA record is taken and in originating registers of all common control local offices. Other local office modifications can be postponed until area codes are assigned as office codes within the home NPA, or until "NNX" codes are used as area codes.

4.08 While not a part of the standard plan, it may be desirable in the future to institute shortened dialing procedures for reaching toll information, such as "1 + 411" for HNPA toll information and "1 + NPA + 411" for FNPA toll information. Since this change can be made much more economically in conjunction with other work in the various local and toll offices, toll "411" features should be incorporated in the interchangeable area and office code modification "package."

If conditions suggest introducing the toll "411" dialing procedures in one or more NPA's after 1973, the industry would be in position to do so by advancing the local office modifications in the NPA's affected. In any event, "1 + 555-1212" and "1 + NPA + 555-1212" must continue to be accepted in *all offices* indefinitely.

Since it does not appear as though the "1 + 411" code for HNPA toll information will be economically feasible until a sufficient number of central offices are equipped with the new numbering plan modifications, this code may be considered as an optional standard in noncommon control CDO's and small step-by-step offices for reaching *local* information. Thus, those offices which would not be able to abandon their present method of requiring customers to dial "0" for eventual completion to an information bureau because of the trunking penalties involved in rearranging for "411" may use "1 + 411" to route these local information calls. CDO's without DDD facilities would continue to dial "0" for information.

4.09 Not part of the numbering plan, but a necessary part of toll information service, are the operating arrangements for handling the traffic. The preferred arrangement is to terminate the 555-1212 trunks at a centrally located NPA information bureau equipped with records for most, if not all, of the listings in an NPA. Operators may trunk out to a local bureau for certain listings but, economically, these listings should be no more than 30% of the total for the NPA. If the 30% goal cannot be met, then the 555-1212 trunks should be terminated at an inward board where an operator can question the customer and trunk the call to the appropriate local bureau.

5. CONVERSION OF EXISTING NUMBERING PLANS TO 7-DIGIT FORM

5.01 Offices now on a numbering system employing less than seven digits may be converted by building out the existing numbering. Normally it is not necessary to change the "station number" portion of the telephone number unless it is less than four digits.

5.02 In the ultimate plan, all telephone numbers will consist of seven digits. Present design requirements for Bell System toll equipment do not provide for the completion of direct dialed calls to telephones having other than 7-or 10-digit addresses.

5.03 Although 7-digit numbering is needed for distance dialing, local calls may be completed by using the last four digits, the last five digits, or the entire 7-digit number. The choice depends on the number of telephones in the local dialing area, the proximity to a city where the entire 7-digit number is dialed, and other factors. For extended area (local service) dialing, a 7-digit arrangement is desirable; in some multioffice cities, it may be mandatory and in many instances it maybe economically attractive from a trunking standpoint. In small offices, 7-digit local dialing can usually be provided at little additional expense by the use of digit-absorbing, or "drop-back" selectors, or equivalent relay equipment.

5.04 With regard to numbering arrangements, the requirements for direct distance dialing include:

7-digit directory listings.
7-digit numbers on station number cards.

Even though local dialing may be on a 4- or 5-digit basis, it is desirable that arrangements be provided to complete those local calls for which the entire 7-digit listed number is dialed. Digit-absorbing selectors in the first stage of the local train will usually accomplish this quite inexpensively. These selectors may be adjusted to absorb two or three of the office code digits as required, and to trunk on the proper numerical digit, or to trunk at once when the abbreviated local number is dialed. At existing step-by-step offices, digit-absorbing selectors may be installed on all growth projects to provide, on a "stockpiling" basis, the necessary equipment for future conversion to 7-digit listings. The regular selectors thus displaced may be used elsewhere in the switching train. Selection of office codes should be made with due consideration for the digit-absorbing features that will be available.

6. RELATION OF CENTRAL OFFICE CODES TO CENTRAL OFFICE EQUIPMENT

6.01 *Conservation of central office codes is important.* Although interchangeable use of area and central office codes will significantly increase the central office codes in each area and will greatly increase the available NPA codes, it is still important that codes be used prudently.

6.02 In the short term, wise administration of codes can serve to delay the introduction of interchangeable area and office codes in many areas, thus postponing capital expenditures for equipment modifications.

6.03 In the long term, it seems desirable to keep the number of NPA's to a minimum, thus maintaining existing NPA's at maximum size. This will allow the greatest possible percentage of 7-digit dialing and will minimize the number of calls requiring ten digits. To this end, effort should be directed toward achieving a larger number of main stations per central office code.

6.04 A situation which depletes the number of available office codes is the establishment of small local switching centers at new locations. When considering such new centers, proper weight should be given to the numbering plan aspects as well as to other economic and service factors. Use of line concentrators may permit economical service to new groups of telephone customers from existing switching centers. Direct inward dialing of PBX extensions and centrex stations is another situation that must be taken into account when estimating central office code requirements.

6.05 Terminal-per-line equipment (TPL) in step-by-step offices is inefficient in its use of central office codes, because each connector terminal represents 10 telephone numbers. Depending on the ratio of main stations to lines, with TPL equipment it is rarely possible to assign more than 4,000 main stations per central office code. With terminal-per-station equipment, approximately 9,000 stations per code may be achieved, depending on requirements for administrative spare terminals. It is important, therefore, that plans for dial conversions and new offices avoid TPL equipment, because its use will consume an excessive number of central office codes.

7. TOLL CENTER AND OPERATOR CODES

7.01 In addition to the distinctive 3-digit code assigned to every central office, there are two series of codes (0XX and 1XX) that cannot be used by customers. Each toll center (Class 1, 2, 3, or 4C office as defined in Section 3) is given a 3-digit "terminating toll center" (TTC) code. This code is used to enable outward operators in distant cities to reach inward, information, delayed call, and similar operators at that center. (It is also used by maintenance people to reach test lines in distant offices.) Calls to these operators are routed in the same manner as calls to subscriber numbers, except that the assigned TTC code is used instead of a central office code and the "operator" code is used instead of a station number.

7.02 TTC codes consist of three digits. The first digit is normally a "0" (zero), or in some cases a "1." The second and third digits may be any number from 0 to 9. An example of a TTC code is 069. These codes are assigned in this series to prevent DDD calls from reaching terminating toll center operators. The originating equipment used by the customer must be arranged to block calls to distant NPA's containing a "0" or "1" in the fourth digit position.

7.03 Operator codes used for reaching the various auxiliary service operators are:

121 Inward

131 Information

141 Route

181 Toll Station

* 11NX or * 11NXX Leave Word Number

*X = any number from 0 to 9

*N = any number from 2 to 9

7.04 On an operator call to a city in a distant NPA an information bureau in the 216 NPA, for example, could be reached by the code series 216 + 046 + 131 where 216 is the numbering plan area code, 046 the TTC code, and 131 the operator code for information Similarly, on a call to a different information bureau in the 216 NPA, the code series might be 216 + 062 + 131. On calls to operators at centers in the home numbering plan area, the area code would be omitted.

7.05 There is one exception to the practice described above. In order to save on operator and machine work time, the TTC code for one major city in most numbering plan areas is eliminated. For example, there is no TTC code for Des Moines in the central Iowa numbering plan area. To reach the Des Moines information operator from a foreign area, it is merely necessary to dial the area code 515 plus 131. From locations within the home numbering plan area where the destination is reached via a tandem switching system, it is necessary to dial the area code in lieu of the nonexistent TTC code, plus the desired operator code as when calling from a foreign numbering plan area.

8. NUMBERING OF COIN STATIONS

8.01 On a collect call, the outward or originating operator must determine whether or not a coin station (public or semipublic telephone) is being called. If the called telephone number is in the 9000 series (NNX-9XXX), she will determine either from her switchboard bulletin or the route operator whether the called central office has coin stations. On occasion, the operator must call information at the terminating toll center to obtain the status of the number. This check consumes operator work time and slows the service. Greater segregation of coin numbers improves the service and increases operating efficiency. The ideal arrangement is to have all coin stations assigned to the 9000 series, e.g., 225-9XXX. In view of the present operating practices, which provide for checking for coin telephones in the 9000 series only, use of other numbers for coin telephones should be avoided wherever possible.

8.02 The larger Bell and Independent exchanges, for the most part, have their coin numbers segregated in the 9000 or 8000 and 9000 series. In small exchanges employing digit-absorbing selectors, such segregation may make certain office codes unusable or may require another stage of selectors. Nevertheless, segregation of coin numbers in all exchanges is a most desirable ultimate objective.

9. CENTRAL OFFICE NAMES

9.01 In view of the conversion to All–Number Calling (ANC), all newly established central office codes should be in ANC form.

10. NUMBERING FOR AN OFFICE SERVING CUSTOMERS IN TWO NUMBERING PLAN AREAS

10.01 A central office located near the boundary of a numbering plan area may furnish local service to customers located in an adjacent numbering plan area. Chart 3 shows, as an example, an office in Nebraska (402 area) that serves stations located in Kansas (913 area). The assignment of central office codes must be such that all calls, long distance as well as local,to and from these customers will be properly routed and properly charged. There must be no ambiguity. In order to charge correctly, it is necessary to assign a different central office code to subscribers in each state to distinguish between intra- and interstate calls.

10.02 *Outgoing Calls:* Since the Nebraska and Kansas customers are located in different NPA's, they should be segregated on the originating portion of the equipment. Ideally, the Kansas and Nebraska customers should be able to dial each other on a 7-digit basis. This requires that the central office code assigned to the Kansas customers not be used in that portion of the Nebraska NPA that is local to the Kansas customers, and vice versa. For outward DDD, customers would dial offices in their respective NPA's on a 1 + 7-digit,basis and all other areas on a 1 + 10-digit basis.

10.03 *Incoming Calls:* The standard arrangement provides that customers or operators in distant NPA's will dial the proper NPA code and the 7-digit called number to reach either group of customers in this cross-boundary situation.

11. NUMBERING FOR OFFICES SITUATED IN ADJACENT NUMBERING PLAN AREAS WITH EXTENDED AREA SERVICE BETWEEN THEM

11.01 Ideally, all local calls should be dialable on a 7-digit basis. To accomplish this before the "1" prefix was in general use, codes assigned to central offices in a local area which covered part of two NPA's were not assigned elsewhere in either NPA. This is known as "code protection." When the available central office codes in an NPA are depleted, protected codes should be used for further growth which requires that cross-boundary dialing be changed to ten digits. New protected codes should not be established in areas where the supply of central office codes is nearing depletion.

11.02 There are a growing number of EAS offerings which involve flat rate calls to more than one NPA. In addition, there are existing cases of "bulk-billed" message unit calls to more than one NPA. The most desirable plan is uniform 7-digit EAS dialing between the NPA's involved whenever central office code protection can be maintained for the long term, say at least 10 years. The recommended plan for station calls is as follows:

EAS Area – HNPA and FNPA	7 Digits
HNPA – Toll	1 + 7 Digits
FNPA – Toll	1 + 10 Digits

However, if long-term code protection appears impossible due to code growth or additional future expansion of the present EAS boundary, it is recommended that all FNPA points, both EAS and toll, be dialed on a uniform 1 + 10-digit basis. The dialing plan would be as follows:

HNPA – EAS	7 Digits
HNPA – Toll	1 + 7 Digits
FNPA – EAS and Toll	1 + 10 Digits

11.03 *Optional Extended Area Service:* When optional EAS offerings are introduced, calls to certain points are local for customers selecting the optional EAS plan, and toll for the remaining restricted customers.

For simplicity and uniformity, the dialing procedures to optional EAS points should be the same for *all* customers. This provides a uniform dialing plan without a change in dialing instructions for either the "extended" or the "restricted" customers. With this approach it is easier to provide customer instruction, particularly with multioption offerings or those where charging may be dependent on the time of day.

The recommended optional EAS dialing procedure is as follows:

	"Extended" Customer	"Restricted" Customer
Local Exchange Area	7D	7D
Optional EAS – HNPA*	1 + 7D (Local)	1 + 7D (Toll)
– FNPA	1 + 10D (Local)	1 + 10D (Toll)
HNPA Toll	1 + 7D	1 + 7D
FNPA Toll	1 + 10D	1 + 10D

*"1" prefix required on HNPA EAS calls only if now required on HNPA toll calls.

Optional EAS offerings represent the only situations where the "1" prefix code is recommended on HNPA local calls. This may cause some confusion in areas where previous promotion of the "1" prefix has been for toll calls only. This can be overcome with effective instructions and by not promoting the EAS offering as being an extended "local" calling area. The name selected for these offerings should be general in nature, such as "Expanded Metropolitan Area Calling."

Optional plans will usually introduce other problems requiring careful planning, such as determining the scope of the offering, rates, and the selection of boundaries which are as easily identifiable as possible and which will not need to be changed in the near future. In addition, revenue requirements studies should reflect all interdepartmental cost factors of handling this mixed traffic. These studies should compare the advantages of equipping step-by-step areas with common control features, with the economic and service penalties of routing this local traffic over existing toll facilities.

NUMBERING PLAN FOR DISTANCE DIALING

Composition of the Distance Dialing Number

The Distance Dialing Number consists of ten digits, exclusive of prefixes, arranged as follows:

	Area Code	Office Code (Listed Directory Number)	Station Number (Listed Directory Number)
Present	N 0/1 X	N N X	X X X X
Ultimate	N X X	N X X	X X X X

Where X = Any number from 0 to 9

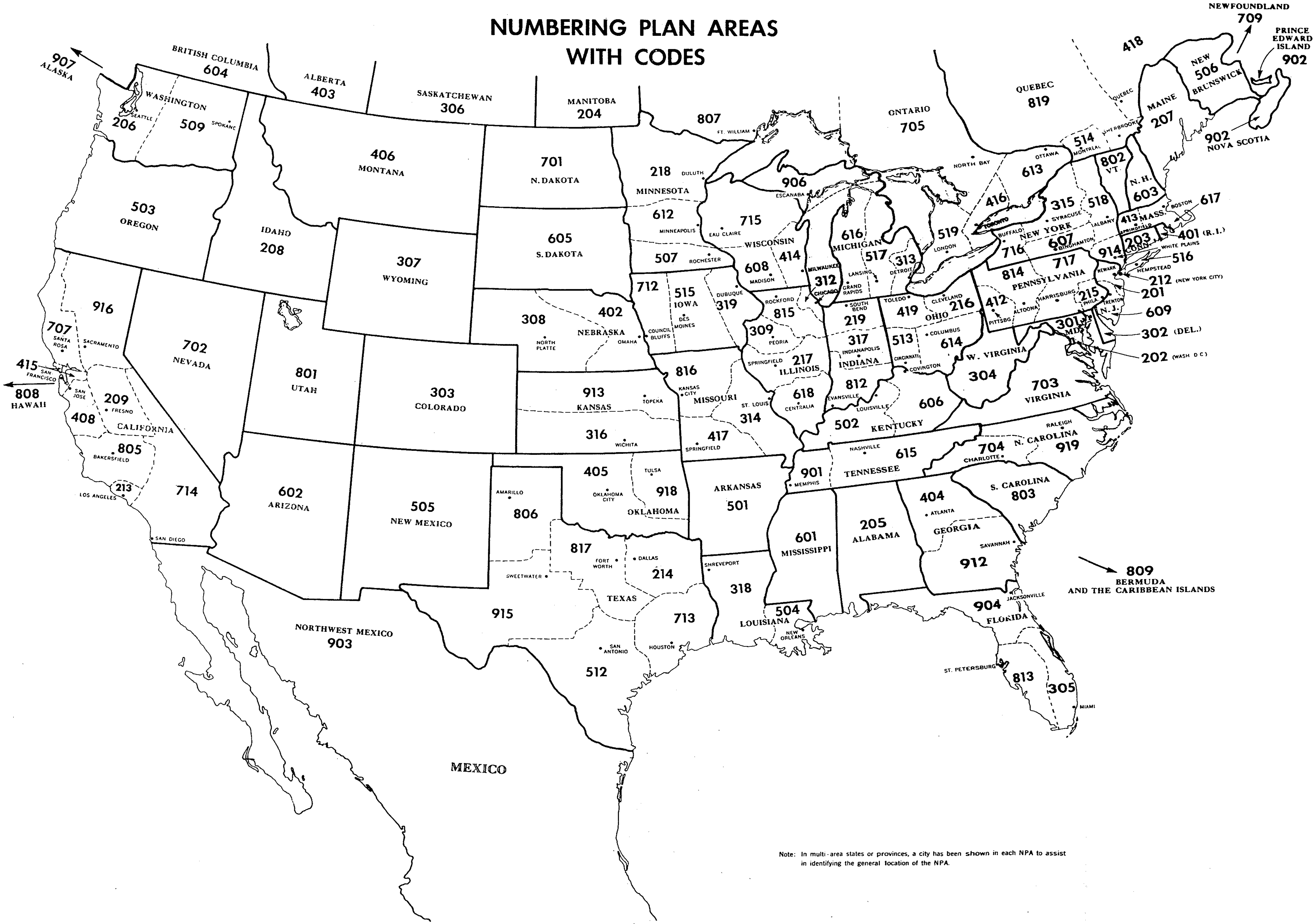
N = Any number from 2 to 9

NNO CODES LISTED IN PROPOSED ORDER OF USE AS NPA CODES

260*	660*	290*	880*	970	320	630	920
480*	680*	470*	570*	350	370	670	360
520*	720*	550*	380*	540	790	560	440
590*	730*	580*	460	820	280	330	780
650*	850*	740*	980	840	640	340	870
220*	940*	930*	860	690	750	390	420
250*	230*	450*	960	770	270	620	530
490*	240*	760*	990	890	430	830	

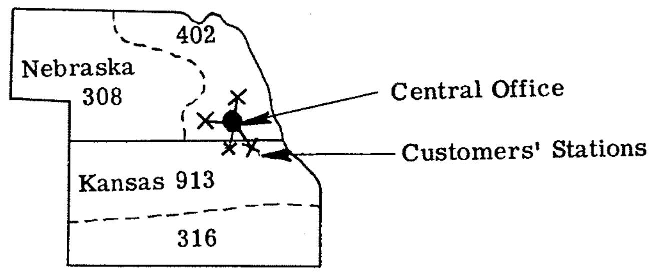
When the supply of N 0/1 X codes is exhausted, the above codes will be assigned as *area codes:* 260 first, 480 second, 520 third, etc., with 530 last. Codes marked with an asterisk (*) are reserved for future NPA codes and should not be assigned as central office codes in any area until all other NNX codes have been exhausted. When the reserved NNO codes must finally be assigned to *central offices*, they will be assigned in reverse order to that shown in the table, i.e., 380 first, 570 second, and so on.

NUMBERING PLAN AREAS WITH CODES



Note: In multi-area states or provinces, a city has been shown in each NPA to assist in identifying the general location of the NPA.

NUMBERING FOR AN OFFICE SERVING CUSTOMERS IN TWO NUMBERING PLAN AREAS



Originating Equipment Arranged:	Nebraska Customer's Office Code Must Be:	Kansas Customer's Office Code Must Be:
To Distinguish Kansas Customers from Nebraska Customers	Protected in local service portion of Kansas (913) area.	Protected in local service portion of Nebraska (402)

NUMBERING PLAN AREAS AND CODES – BY GEOGRAPHICAL LOCATION

Numbering Plan Area	Area Code
Alabama	205
Alaska	907
Arizona	602
Arkansas	501
California	209
"	213
"	408
"	415
"	707
"	714
"	805
"	916
Colorado	303
Connecticut	203
Delaware	302
District of Columbia	202
Florida	305
"	813
"	904
Georgia	404
"	912
Hawaii	808
Idaho	208
Illinois	217
"	309
"	312
"	618
"	815
Indiana	219
"	317
"	812
Inward WATS	800
Iowa	319
"	515
"	712
Kansas	316
"	913
Kentucky	502
"	606
Louisiana	318
"	504
Maine	207
Maryland	301
Massachusetts	413
"	617
Michigan	313
"	517
"	616
"	906
Minnesota	218
"	507
"	612
Mississippi	601
Missouri	314
"	417
"	816
Montana	406
Nebraska	308
"	402
Nevada	702
New Hampshire	603
New Jersey	201
" "	609
New Mexico	505
New York	212
" "	315
" "	516
" "	518
" "	607
" "	716
" "	914
North Carolina	704
" "	919
North Dakota	701
Ohio	216
"	419
"	513
"	614
Oklahoma	405
"	918
Oregon	503
Pennsylvania	215
"	412
"	717
"	814
Rhode Island	401
South Carolina	803
South Dakota	605
Tennessee	615
"	901
Texas	214
"	512
"	713
"	806
"	817
"	915
Utah	801
Vermont	802
Virginia	703
Washington	206
"	509
West Virginia	304
Wisconsin	414
"	608
"	715
Wyoming	307
Canada	
Ontario	416
"	519
"	613
"	705
"	807
Quebec	418
"	514
"	819
British Columbia	604
Alberta	403
Saskatchewan	306
Manitoba	204
Nova Scotia	902
New Brunswick	506
Newfoundland	709
Bermuda and Caribbean Islands	809
Mexico	
Northwest Mexico	903

NUMBERING PLAN AREAS AND CODES – BY AREA CODE NUMBER

Area Code	Location
201	New Jersey
202	District of Columbia
203	Connecticut
204	Manitoba
205	Alabama
206	Washington
207	Maine
208	Idaho
209	California
212	New York
213	California
214	Texas
215	Pennsylvania
216	Ohio
217	Illinois
218	Minnesota
219	Indiana
301	Maryland
302	Delaware
303	Colorado
304	West Virginia
305	Florida
306	Saskatchewan
307	Wyoming
308	Nebraska
309	Illinois
312	Illinois
313	Michigan
314	Missouri
315	New York
316	Kansas
317	Indiana
318	Louisiana
319	Iowa
401	Rhode Island
402	Nebraska
403	Alberta
404	Georgia
405	Oklahoma
406	Montana
407	Unassigned
408	California
409	Unassigned
412	Pennsylvania
413	Massachusetts
414	Wisconsin
415	California
416	Ontario
417	Missouri
418	Quebec
419	Ohio
501	Arkansas
502	Kentucky
503	Oregon

Area Code	Location
504	Louisiana
505	New Mexico
506	New Brunswick
507	Minnesota
508	Unassigned
509	Washington
510	4-Row TWX (U. S.)
512	Texas
513	Ohio
514	Quebec
515	Iowa
516	New York
517	Michigan
518	New York
519	Ontario
601	Mississippi
602	Arizona
603	New Hampshire
604	British Columbia
605	South Dakota
606	Kentucky
607	New York
608	Wisconsin
609	New Jersey
610	4-Row TWX (Canada)
612	Minnesota
613	Ontario
614	Ohio
615	Tennessee
616	Michigan
617	Massachusetts
618	Illinois
619	Unassigned
701	North Dakota
702	Nevada
703	Virginia
704	North Carolina
705	Ontario
706	Unassigned
707	California
708	Unassigned
709	Newfoundland
710	4-Row TWX (U. S.)
712	Iowa
713	Texas
714	California
715	Wisconsin
716	New York
717	Pennsylvania
718	Unassigned
719	Unassigned
800	Inward WATS
801	Utah
802	Vermont

Area Code	Location
803	South Carolina
804	Unassigned
805	California
806	Texas
807	Ontario
*808	Hawaii
*809	Bermuda and Caribbean Islands
810	4-Row TWX (U. S.)
812	Indiana
813	Florida
814	Pennsylvania
815	Illinois
816	Missouri
817	Texas
819	Quebec
901	Tennessee
902	Nova Scotia and Prince Edward Island
903	Northwest Mexico
904	Florida
905	Unassigned
906	Michigan
*907	Alaska
908	Unassigned
909	Unassigned
910	4-Row TWX (U. S.)
912	Georgia
913	Kansas
914	New York
915	Texas
916	California
917	Unassigned
918	Oklahoma
919	North Carolina

*Not reachable by customers – operator dialing only

Section 3
Switching Plan

SWITCHING PLAN

CONTENTS PAGE

1. GENERAL

1.01 The telephone systems in the United States and Canada handle more than fifteen million long distance messages a day. These are routed over a comprehensive network of more than 300,000 long-haul trunks which interconnect about 1,600 long distance switching offices. This network serves, with few exceptions, all of the telephones in these two countries and provides for establishing connections to most other parts of the world, as described in Section 8.

1.02 Large volumes of traffic between any two points are generally routed most economically over direct trunks. When the volume of traffic between two offices is small, however, the use of direct trunks is usually not economical. In these cases the traffic is handled by connecting together, by means of switching equipment at intermediate offices, two or more trunks to build up the required connection. The places where interconnections are made are generally known as "switching centers" and the process is referred to as a "switch." "Built-up" connections may involve several switching centers if the originating and terminating locations are a great distance apart. It is important that telephone plant be designed to provide adequate transmission and service for this multiswitch traffic as well as the large volumes of traffic handled by the less complex direct and single switch connections.

1.03 The basic routing arrangements of the Switching Plan make possible systematic and efficient handling of customer and operator dialed long distance traffic. These arrangements are discussed herein.

1.04 The basic principles of the Switching Plan for Distance Dialing were developed from experience gained in handling large traffic volumes between many separate central offices within metropolitan exchange areas. Some similarities in method still exist.

1.05 The needs of distance dialing are met by switching and trunking arrangements that employ hierarchical routing discipline and the principle of Automatic Alternate Routing to provide rapid and accurate connections while making efficient use of the telephone plant. The hierarchical routing discipline provides for the collection and distribution of traffic, and permits complete interconnectability of all offices. With the Automatic Alternate Routing principle, a call which encounters an "all trunks busy" condition on the first route tested is automatically "route advanced" and offered in sequence to one or more alternate routes for completion. Appendix A of this section, titled, "Alternate Routing," discusses these principles.

1.06 With future trends in the telephone industry resulting in materially increased traffic volumes and mechanization of recording and switching, the economical routing of most calls tends to be independent of the location where operator functions are provided. Originating traffic should route directly from the office where billing details are recorded. Concentration at various subsequent switching centers is justified only if overall network economies can be realized. In like fashion, inward traffic should be delivered over trunk groups terminating at, or as close as possible to, the destination.

2. DEFINITIONS

2.01 Under the Switching Plan each office involved in the completion of long distance calls is classified and designated according to its switching function, its interrelationship with other switching offices, and its transmission requirements. The class designations given to the switching centers in the network determine the routing pattern. Chart 1 illustrates how various classes of offices might be grouped. The office classifications, their functions, and the switching areas they serve are described in the following paragraphs.

2.02 The central office equipment entities where telephone loops are terminated for purposes of interconnection to each other are called "End Offices" and are designated as "Class 5" offices. An equipment entity is a subgroup of originating equipment, such as an originating marker group in No. 1 Crossbar, a marker group in No. 5 Crossbar, a decoder group in Panel, or a common intermediate distributing frame in step-by-step.

2.03 The switching centers which provide the first stage of concentration for intertoll traffic from end offices are called Toll Centers or Toll Points and are designated as "Class 4C" and "Class 4P" offices, respectively. The toll center (Class 4C) is an office where assistance in completing incoming calls is provided in addition to other traffic operating functions. The toll point (Class 4P) is an office where operators handle only outward calls or where switching is performed without operator functions. Class 4P includes such switching centers as decentralized outward switchboards, outward and terminating tandem offices, and offices where centralized machine ticketing is provided.

2.04 Offices are designated as traffic "Toll Centers" if inward operator service code functions are provided. This traffic designation is applicable regardless of the classification of the office in the hierarchical arrangement.

Those operating centers without inward assistance functions must be included within the "Toll Center Area" of the higher classed office at which inward services are provided. Appropriate listings in keeping with these basic considerations will appear in traffic routing documents such as: (1) the Operating Rate and Route Guide; (2) the Traffic Routing Guide; and (3) the Distance Dialing Reference Guide.

2.05 Certain switching centers, in addition to connecting end offices to the network, are selected to serve as higher ranking switching centers. These are Primary Centers, designated "Class 3"; Sectional Centers, designated "Class 2"; and Regional Centers, designated "Class 1." Collectively, the Class 1, 2 and 3 offices constitute the Control Switching Points of the distance dialing network.

2.06 A Control Switching Point (CSP) is a switching center at which intertoll trunks are connected to other intertoll trunks. Basic requirements for CSP offices are shown in Chart 2.

2.07 Appendix B – Chart B1 shows, for the general case, the backbone hierarchical network of "final" trunk groups, or final route chain, interconnecting the several classes of office. One final trunk group is always provided from each office to an office of higher rank; (final groups between Regional Centers are discussed in Paragraphs 3.03 and 3.04). That one higher rank switching center to which an office is connected over a final group is called its "home office"; the dependent office is spoken of as "homing" on it. Offices are always assigned the lowest possible classification for the functions provided, i.e., they are classified from the bottom up rather than from the top down.

2.08 The systematic grouping of switching centers results in a similar grouping of the areas they serve. Each Regional Center (RC) serves a large area known as a Region. (There are 10 Regional areas in the United States and two in Canada.)

Each Region is subdivided into smaller areas known as Sections; the principal switching facility in the Section is the Sectional Center (SC). The Section is still rather large and it, too, is further divided into smaller parts known as Primary areas, each of which is served by a Primary Center (PC). The remaining offices that do not fall into these categories are the Toll Centers (TC), Toll Points (TP), and End Offices (EO).

2.09 Each separate switching unit must be assigned its own classification within the hierarchical routing plan. This separate classification is applicable even when more than one unit is located in a single building. The one exception is that switchboards in the same building with, and handling traffic exclusively for, a single toll switching machine are classified as a part of that machine. The switchboard and its trunks must also meet VNL transmission requirements.

3. HOMING ARRANGEMENTS AND THE INTERCONNECTING NETWORK

3.01 It is not necessary that Class 5, 4 or 3 offices must always home on the next higher ranking (lower class number) office. For example, Class 5 offices may be served directly from any higher ranking office. Possible homing arrangements for each class of office are shown in Table 1 below and are illustrated in Chart 1.

TABLE 1

Homing Arrangements

Class of Office	May Home at Offices of the Following Classes
5	Class 4, Class 3, Class 2 or Class 1
4	Class 3, Class 2, or Class 1
3	Class 2 or Class 1
2	Class 1

3.02 Each final trunk group in the network is engineered individually on a low delay basis so that, on the average, no more than a small fraction of the calls offered to such a trunk group in the busy hour will find all trunks busy. Current objectives for final groups call for not more than one call in one hundred being blocked by a no-circuit condition in the busy hour.

3.03 Final trunk groups are required to mutually interconnect the Regional Centers. Such groups are now provided for all Regional Centers except Regina, Canada, which is not yet completely interconnected with all Regional Centers in the United States. For a very small number of calls between the United States and the Regina region, there is RC-RC-RC routing. It is planned that this additional link in the final route will soon be eliminated.

3.04 In addition to the final network, direct high usage trunks are provided between offices of any class wherever the volume of traffic and economics warrant and necessary Automatic Alternate Routing equipment features are available. High usage trunk groups carry most but not all the offered traffic in the busy hour. As discussed in Appendix A, overflow traffic is offered to an alternate route. The proportion of the offered traffic that is carried on a direct high usage trunk group in each case is determined by the relative costs of the direct route and the alternate route (including the additional switching costs on the alternate route). High usage groups are provided when they are shown to be desirable. Due to service or economic considerations, trunk groups which would normally be in the high usage category may in some instances be engineered on a no-overflow basis. This does not change homing arrangements and these groups are called "full groups." Full groups effectively limit the hierarchical final route chain for the items of traffic offered to them.

3.05 In general, trunks in both high usage and final groups are operated 2-way . With usual traffic load characteristics, they are more efficient and fewer trunks are required than with two groups of one-way trunks. However, for large trunk groups there are often economies to be realized in subgrouping facilities into two 1-way segments and one 2-way segment to which the one-way subgroups overflow. In metropolitan areas, trunk groups to and from end offices are usually large and operated one-way. In determining whether one-way trunks should be used, consideration must be given to the possibility of directional noncoincidence of busy period load of the overall traffic.

3.06 Subgrouping is also used to ensure low delay service for traffic overflowed to final trunk groups (particularly RC-RC groups). One subgroup is used exclusively for "first routed" traffic between the terminating locations. Overflow traffic from this subgroup is combined with all other alternate routed traffic which is offered to the second subgroup. This arrangement is used as a service protection feature for first routed traffic between the two terminals.

3.07 The "routing pattern" for a call between any two points is established by the final routing path between the originating and the terminating locations. A call may switch only at offices on the final route. It may be offered to any high usage trunk group which bypasses one or more switching centers in the final chain as long as the call always progresses in the direction toward the destination. Referring to Chart 1, a call originating in one final route chain and entering a second chain, say at Class 2 office, must progress down the second chain to its Class 3, 4, or 5 destination. (A call which could enter a second routing chain and progress up that chain away from its destination or cross from a second chain to a third chain does not follow the standard pattern and is not permissible.) Appendix B, with Charts B 1 and B 2, illustrates typical standard routing patterns within the switching plan. It should be noted that the maximum number of trunks connected in the final route chains from Class 4 office to Class 4 office cannot exceed seven for intracountry calls or eight for a very few United States-Canada calls. These, plus the trunk to the Class 5 office at each end, result in a maximum of 9 trunks in tandem for intracountry calls and occasionally 10 for United States-Canada calls. The probability of a call traversing all possible trunks of the final routing chains is estimated to be only a few calls out of millions. Calls between high volume points are completed on direct trunks regardless of distance; relatively few encounter multiple switches. As traffic growth occurs, a relatively larger portion of the traffic is carried on direct routes. Multiple switching is the rule, however, between infrequently called locations.

4. SELECTION OF CONTROL SWITCHING POINTS

4.01 The use of intermediate switching (CSP's) increases the efficiency of trunk plant. For example, Plan II, shown in Chart 3, will effect savings in transmission facilities as compared to Plan I. However, a CSP requires more switching equipment along with other features that are not ordinarily required if the switching center serves only as a Class 4 office. This tends to offset and may exceed the transmission facility savings. It is, therefore, necessary to weigh these related factors to determine the location and number of CSP's that will result in the most economical overall total layout.

4.02 CSP location studies have been made by the Bell System and Independent Operating Companies, and must be reviewed from time to time as required by changing conditions.

4.03 Future studies may indicate the need for a few additional CSP's. Such studies reflect the relative costs of transmission facilities and switching equipment suitable to do the CSP job. They also recognize the changes in traffic flow, including growth, that develop with the passage of time. The combined effects of these influences will change the number of CSP's that should be provided and alter the classification of some existing offices.

5. EFFECTS ON PLANT LAYOUT

5.01 Alternate routing tends to improve the efficiency of the network and to distribute switching and trunk terminations among the lower ranking offices. Growth of final trunk groups tends to be at a lower rate than the general growth rate for the total area involved. Growth should always manifest itself first in the provision of new high usage trunk groups, secondly, as additions to existing high usage trunk groups and lastly, as additions to the final route path.

5.02 It is essential that these concepts be considered when engineering plant additions. By so doing, the most advantageous plant layout for distance dialing may be obtained, and at the same time the needs during transition periods can be cared for adequately.

5.03 The trunk groups between the end office and its toll center should be engineered for low delay. (In the Bell System, such groups are usually engineered for no more than one delayed call in each 100 busy hour calls offered.) In addition, service requirements and the need for access to an operator for assistance are factors to be considered in determining the base upon which the trunk group is engineered.

5.04 Offices of different classifications may be physically located in the same building. If they are different equipment entities, then each office retains its own classification according to the function it performs.

In other cases, a single equipment entity may be performing several different functions i.e., Class 3 and Class 4, or Class 4 and Class 5. By convention, an equipment entity is referred to by the highest class function which it performs.

5.05 Customer dialed traffic must be provided with automatic recording of call billing details at the originating local office (LAMA) or at a centralized point (CAMA). With centralized operation, each end office must be connected directly to the centralized recording location which serves it. There can be *no* intermediate switch or concentration of facilities to serve more than one local office entity because of transmission and service considerations. Originating operator assistance traffic (dial 0) likewise must be routed over direct trunks from each end office to the switchboard or Traffic Service Position System (TSPS) *without* an intermediate switch or concentration.

6. DESTINATION CODE ROUTING

6.01 By providing flexibility and logic in switching systems and by developing the numbering plan described in Section 2, whereby every telephone connected to the distance dialing network is identified by a unique 10-digit number, a call can be routed from any point on the network to any other point, using the 3-digit NPA code and the 3-digit office code of the called telephone. For a specific called destination, the same address is employed regardless of the location of the originating office. This is called "Destination Code Routing."

6.02 Calls between any two telephones in the same Numbering Plan Area can be completed using only the 3-digit central office plus the 4-digit station number. When the switching system at the originator "toll center" receives the 7 digits from either a customer, an operator, or another switching system, the 3-digit central office code directs the switches to connect to the proper outgoing trunk route to or toward the destination and the full 7 digits, or whatever digits are required by the connected distant switching facility, are sent forward to be registered in and used by that distant machine. The distant switching point, which might be either an intermediate switching point or the terminating "toll center," directs the call to its trunk route for the code received, and spills forward either the full 7 digits on an intertoll route to another switching point, or 4 or more digits, as required, on a toll connecting trunk to the called Class 5 office. This procedure is followed until the call reaches its destination, making use of direct routes, switched routes, or alternate routes as necessary within the routing pattern established for each call. (See Appendix B.)

6.03 Calls between locations in different NPA's are handled similarly, using the full 10-digit destination code. Both originating and intermediate switching points make use of the 3-digit NPA code to direct each call to its particular first choice or alternate route to or toward the called Numbering Plan Area and send forward either the full 10 digits if the next location is an intermediate switching point, or only 7 digits if the trunk route used terminates in the called NPA. Once a call reaches the called NPA, only the last 7 digits are needed to advance the call to its destination, as discussed in Paragraph 6.02 above.

6.04 In cases where an end office (or a group of subscriber lines given a theoretical office designation) is served across an NPA boundary, calls must still be completed to the NPA in which the destinations are located, as discussed in Section 2, Parts 10 and 11. Similarly, originating traffic from each individual end office should be established in accordance with standard dialing procedures in order to maintain uniformity for each entire NPA (7 digits for the Home NPA and 10 digits for Foreign NPA's).

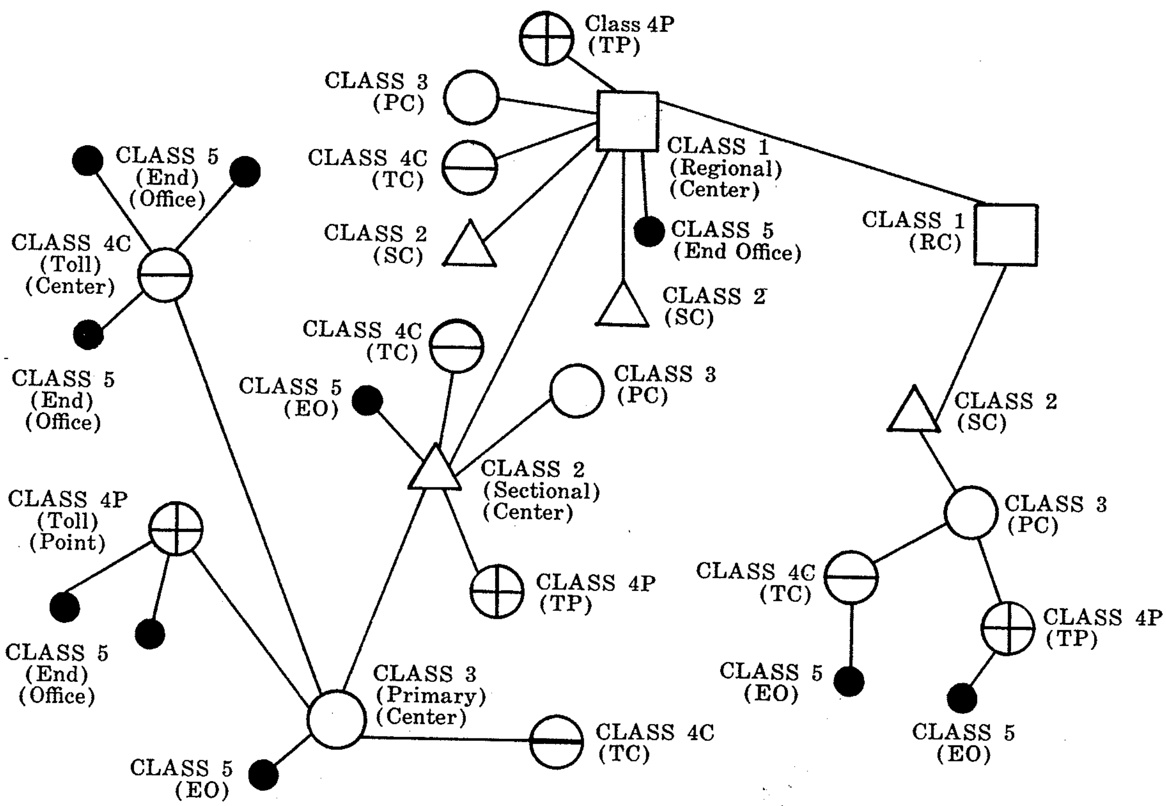
6.05 The code received by a switching system must contain sufficient information to advance the call to or toward its destination. In many instances, a 10-digit call for another NPA can be routed at a switching system on the basis of the NPA code alone; this involves "3-digit translation." In other instances involving calls to another NPA, the first 3 digits do not provide sufficient information. When this occurs, the switching system obtains the additional information it requires by also examining the 3-digit office code, thus using the first 6 digits to properly advance the call; this involves "6-digit translation."

6.06 If from a particular switching system there is one first choice route to reach some points in a given distant NPA and another first choice route to reach other points in that same NPA, the system must 6-digit translate to determine which route to select for each call it switches into that NPA.

6.07 The routing of traffic at a specific office depends upon the trunk groups terminated and the requirements of the distant office to which it connects. For example, extra digits, dialed by the operator or prefixed and sent forward by a preceding switching system, may be required to switch calls through a direct control switching point. Chart 2 of this section outlines digit prefixing, code conversion, and other features required at CSP's for destination code routing. The digit and translation capabilities of various types of switching systems used in the Bell System are discussed in Paragraphs 3.57 to 3.63 of Section 5 and summarized in Charts 8 and 9 of that section.

SWITCHING PLAN

(Basic Principle)



Symbol	Class	Name	Abbreviation
□	1	Regional Center	RC
△	2	Sectional Center	SC
○	3	Primary Center	PC
⊖	4C	Toll Center	TC
⊕	4P	Toll Point	TP
●	5	End Office	EO
—	Final	Trunk Group	

BASIC REQUIREMENTS FOR CONTROL SWITCHING POINTS (CSP'S)

(All Class 1, 2 and 3 Offices)

1. HOMING ARRANGEMENT REQUIREMENTS

There must be at least one office of the next lower rank homing on a CSP, i.e., a Class 2 office must have at least one Class 3 office which homes on it, etc.

(If a given office meets requirements 2 and 3, and long-range plans call for an office of next lower rank to eventually home on it, the office may be considered to be a CSP as its ultimate rank even though requirement 1 is not currently met.)

2. TRANSMISSION REQUIREMENTS FOR A CSP

(a) VNL operation of intertoll trunks.

(b) VNL plus 2.5 dB operation of toll connecting trunks.

(c) Terminal balance objectives must be met by actual measurement on all toll connecting trunks.

(d) Through balance requirements must be met at 2-wire switches between intertoll trunks for through switched traffic. Any "B" factor automatically classifies the CSP as deficient. (See Section 6.)

3. SWITCHING SYSTEM REQUIREMENTS

(a) Storing of digits.

(b) Variable spilling – deletion of certain digits when not required for outpulsing.

(c) Prefixing of digits when required.

(d) Code conversion – a combination of digit deletion and prefixing (also termed substitution).

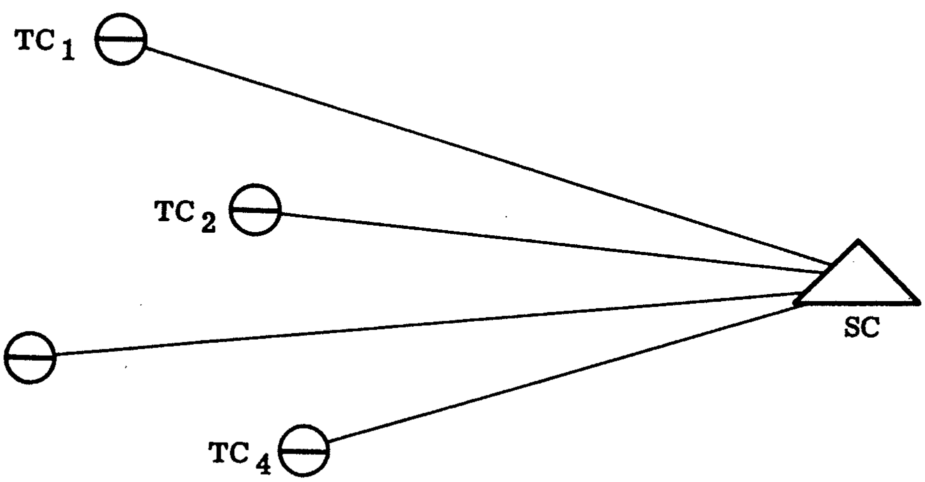
(e) Translation of 3 or 6 digits. (Also translation of 4 or 5 digits for WH calls.)

(f) Automatic alternate routing.

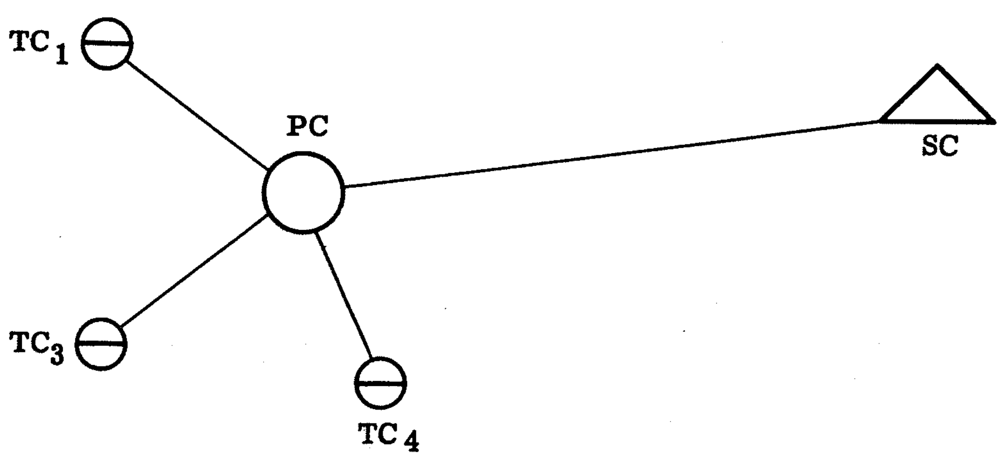
3.01 Where step-by-step equipment is employed at a Class 3 location, requirements of Paragraphs 1 and 2 can be met. The switching system requirements delineated in Paragraph 3 can be provided only with common control equipment. Any Class 3 step-by-step installation therefore, is deficient in these equipment capabilities. It is essential therefore that only equipment with the common control capabilities listed be permitted to route traffic items through, a step-by-step machine providing a Class 3 function.

EFFECT OF ESTABLISHING A CSP

PLAN I



PLAN II



ALTERNATE ROUTING

1. GENERAL

1.01 The successful completion of long distance traffic dialed by operators and customers depends upon a high-speed trunk network so that "all trunks busy" conditions are rarely encountered under engineered conditions. Alternate routing is one of the techniques that makes this possible with reasonable trunk efficiency. It is the purpose of this appendix to explain alternate routing and why it is employed.

1.02 Definitions:

(a) Alternate routing – the procedure at a switching location by which a call, after encountering "all trunks busy" in the first choice route, is offered another route to or toward the ultimate destination.

(b) Multialternate routing – alternate routing with provision for advancing a call to more than one alternate route tested in sequence within the hierarchical routing discipline.

(c) High usage trunk group – a group of trunks for which an engineered alternate route is provided.

(d) Final trunk group – a group of trunks to the next office on the final route and in which the number of trunks is engineered to result in a low probability of calls blocked.

(e) Full trunk group – a group of trunks which ordinarily would be a high usage group but is engineered with low probability of blocking for the traffic offered to it. The normal alternate routing capability is not employed for this traffic.

2. THEORY OF ALTERNATE ROUTING

2.01 Alternate routing is a concept which may best be illustrated by an example. Mr. Jones drives to work over a certain route every morning because he has found it to be the quickest, shortest, most economical route. On a particular morning he finds one of the streets on his accustomed route is congested. He finds another street or streets to take him around the congestion and eventually to his destination. This second route, although satisfactory, takes longer and is farther. Mr. Jones on this particular morning practiced alternate routing instead of being blocked.

2.02 This principle is applied to telephone traffic by providing a first choice (high usage) route for a given item of traffic and a second choice (alternate) route when the call fails to find an idle trunk on the first choice route.

Fundamentals

2.03 Alternate routing is based on two fundamentals: (1) uneven flow of traffic from instant to instant with respect to the average flow of traffic during a stated longer interval, and (2) diminishing trunk efficiency as trunks are added to a trunk group – offered load remaining constant.

Irregularities in the Flow of Traffic

2.04 Traffic volumes reach peaks during certain hours. Facilities are usually provided to care for the average busy hour load in the busy season of the year (see Chart A1). Peaks also occur for shorter intervals within the busy hour, but it is neither practical nor economical to provide facilities for the busiest five-or ten-minute period of the network being engineered.

2.05 When only one outlet (i.e., one trunk group)is provided,these shorter peaks are reflected in lost calls. If more than one route is made available, there is a good possibility that the shorter surges of traffic to which each group is subject, and sometimes even the longer busy hour peaks, will not coincide and the peak load on one route may overflow into an idle condition on its alternate route.

Diminishing Returns from the Provision of Additional Trunks

2.06 The principle of diminishing returns may be illustrated by assuming the case of a step-by-step switching system offering a call to a group of ten one-way outgoing trunks. Tested in order, trunk No. 1 will be selected first, reselected when idle, and thus be kept busy most of the time; trunk No. 2 will be slightly less busy; trunk No. 3 will be used less than No. 2; and so on to the tenth trunk, which is called into use only when all prior trunks are busy. If the tenth trunk were removed, some of the calls would be lost but considerably less than one-tenth of the calls would be affected, because this last trunk does not carry its proportionate share of the total load; it is a low usage trunk. Conversely, if the offered load is very high for ten trunks, the last trunk is kept busier and unless an alternate route is provided the service offered to the entire group will be considerably poorer. It is this principle, applied to trunk groups outside of the final route chain, which makes alternate routing economical.

Advantages

2.07 The ability to alternate route permits improvements in overall trunking economy. High usage trunk groups can be employed to efficiently carry items of traffic which otherwise would have to be carried over low-delay trunk groups or have to be switched. Reducing the number of intermediate switches on a particular call reduces the overall time of connection from completion of dialing to the first ring on the called customer's line. Also, routing and switching economies result from the existence of the alternate routing capability. These economies are a function of the volume of traffic which is directly routed over the high usage trunks – not the volume which is alternate routed. Generally, the actual proportion of traffic alternate routed is small. Practically all traffic offered to high usage routes in the off–peak hours benefits by the advantages of direct routing,since very little or none of it will overflow.

2.08 With a single alternate routing capability, all overflow traffic must be offered to the final route. The provision of multialternate routing capability permits greater economy to be achieved by first offering overflow traffic to another high usage trunk group on a more economical route than the final route. The actual volume of traffic offered to trunk groups beyond a second alternate is very small.

2.09 The relationship between that part of the offered load which is carried by high usage trunk groups and the part which overflows to alternate routes for various trunk group sizes is shown on Chart A2. The nest of curves on this chart indicates this relationship for a series of "cost ratios" (see Paragraph 3.02). The proportion of the offered load carried on a high usage trunk group increases with the size of the group and also with increases in "cost ratio."

3. ECONOMICS OF HIGH USAGE TRUNK GROUP ENGINEERING

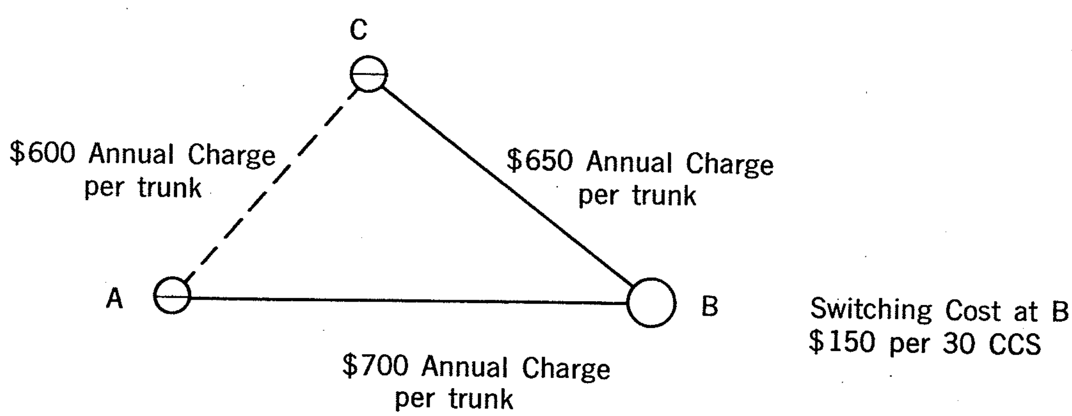
3.01 The number of high usage direct trunks to be provided in a group depends upon the offered load and also upon the ratio of cost (cost ratio) of the alternate route to the direct route.

3.02 The cost ratio applicable to traffic routing considerations is the relationship between the incremental annual charges for transmission and switching facilities for one added trunk path on the alternate route compared to the similar costs of the facilities for a trunk in the high usage route. This relationship can be expressed as follows:

$$\text{Cost ratio} = \text{Trunk efficiency ratio}$$

$$= \frac{\text{Cost for a path in the alternate route}}{\text{Cost per trunk in the high usage route}}$$

A simplified example would be –



$$\text{Cost ratio} = \frac{AB + SW + BC}{AC} = \frac{700 + 150 + 650}{600} = 2.5$$

3.03 Cost ratios are always greater than unity. If the alternate route is almost as cheap as the first route (low cost ratio), fewer trunks will be provided on the first route, they will be kept very busy, and more traffic will overflow. If the alternate route is very much more expensive (high cost ratio), more trunks will be provided on the first route and fewer calls forced to take the more expensive route.

3.04 The following table illustrates this principle, using load figures from standard alternate routing trunk tables.

		First Route				
a	b	c = 30 CCS ÷ b	d	e	f = e ÷ d	g
Offered Load	Cost Ratio	Economical CCS Carried by Last Trunk	No. of Trunks	Load Carried	Average Load per Trunk	Overflow to Alternate Route
200 CCS	1.2	25	4	112 CCS	28 CCS	88 CCS
200 CCS	1.5	20	5	134 CCS	27 CCS	66 CCS
200 CCS	2.0	15	7	169 CCS	24 CCS	31 CCS
200 CCS	2.5	12	8	181 CCS	23 CCS	19 CCS

Notes: (1) a and b are assumed data for this example.
(2) 30 CCS is the approximate load carried per trunk added to the alternate route.
(3) d, e, and g are obtained from standard alternate routing trunk tables.

3.05 Often there are two or more potential alternate routes which could be employed for the same traffic items. Where this is the case, the one having the lowest cost ratio should be used.

4. APPLICATION OF ALTERNATE ROUTING

Local Dialing (Common Control Offices Only)

4.01 In large multioffice cities, direct trunks are provided from each office to every other office where there is sufficient traffic to economically justify such trunks. Also, each office has trunks to and from common tandem points. Calls between offices not directly connected are completed through this tandem center. Since every office is connected to this tandem, the tandem network may be used to provide an alternate route for each of the direct groups. Therefore, fewer direct trunks are needed. Furthermore, with the ability to overflow through this tandem, with growth it becomes economical to establish new direct groups of small size between offices not previously served by direct groups and thus reduce requirements for tandem switching.

4.02 Because alternate routing can be done automatically, it is used extensively to provide economies and service advantages. Calls may be offered in succession to a series of alternate routes via two or more mechanical tandem centers or their equivalent.

4.03 In an emergency situation such as a cable failure, the ability to use alternate routes protects the service. However, if there is a heavy surge of traffic over the entire area (as in an emergency major disaster such as a hurricane), there is little margin for surges in load and the service is not as good as it would be with a less efficient trunk network.

Distance Dialing – Automatic Selection of Alternate Route

4.04 The principle of alternate routing is basic in the design of the distance dialing network. Switching equipment automatically seeks out the alternate routes. The field of application in distance dialing is more extensive than in the case of local dialing, since a call may be subject to routing through more switching centers.

4.05 At each switching center, all of the trunk groups to which a call may be offered, except the last, are kept very busy (high usage), with a portion of the traffic overflowing to other routes. The final groups are fewer in number and are low delay groups so that service is good. The overall chance of completing a call is improved by the fact that it can be offered to more than one group. The switching equipment operates rapidly and there is no significant change in speed of service between direct and alternate routes.

4.06 At some switching points where trunk groups appear in the switchboard multiple, operators can alternate route a call to the final group after manually testing the first choice group.

4.07 In addition to the final groups which connect offices to their home switching points, direct high usage groups to other offices are provided wherever it is economical to do so. However, there is no direct route for calls to many low volume points. The first route for such calls is a switched route over two or more trunk groups of the network, using the cheapest possible routing combination in the standard routing pattern.

4.08 Since the United States, Canada and the Caribbean area are integrated into the switching plan, the employment of an overflow system on such a grand scale requires an orderly and prearranged routing plan. The routing plan is described under "Homing Arrangements and the Interconnecting Network" in the main text of Section 3.

4.09 Appendix B to Section 3, entitled "Routing Patterns Under the Switching Plan," describes how alternate routing is used.

TYPICAL TRAFFIC DISTRIBUTION

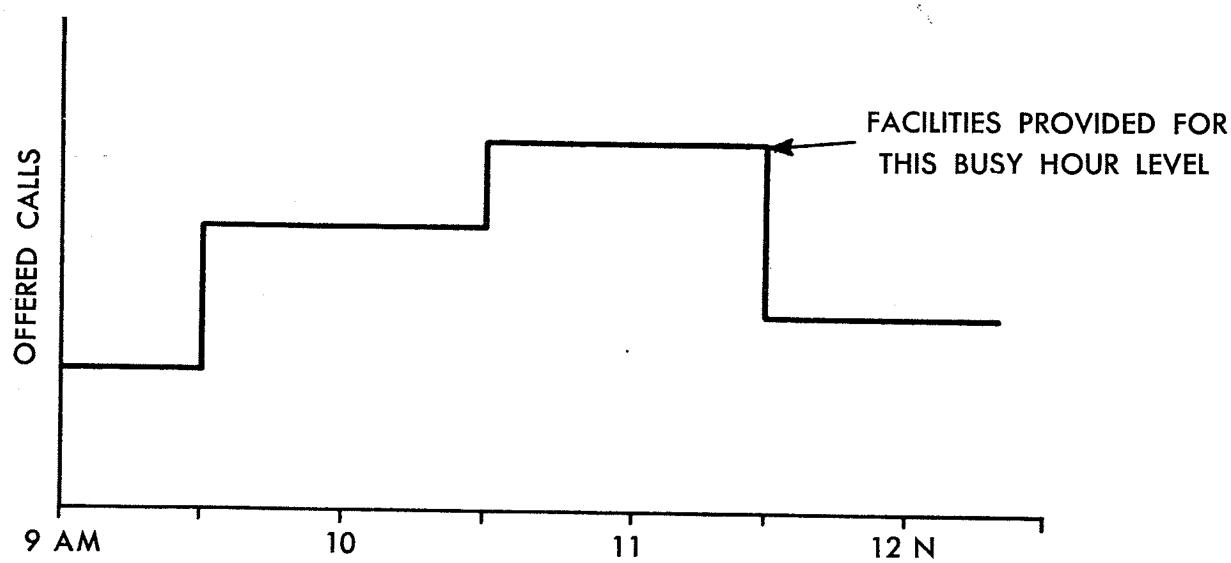


Figure A
Average Hourly Traffic Distribution

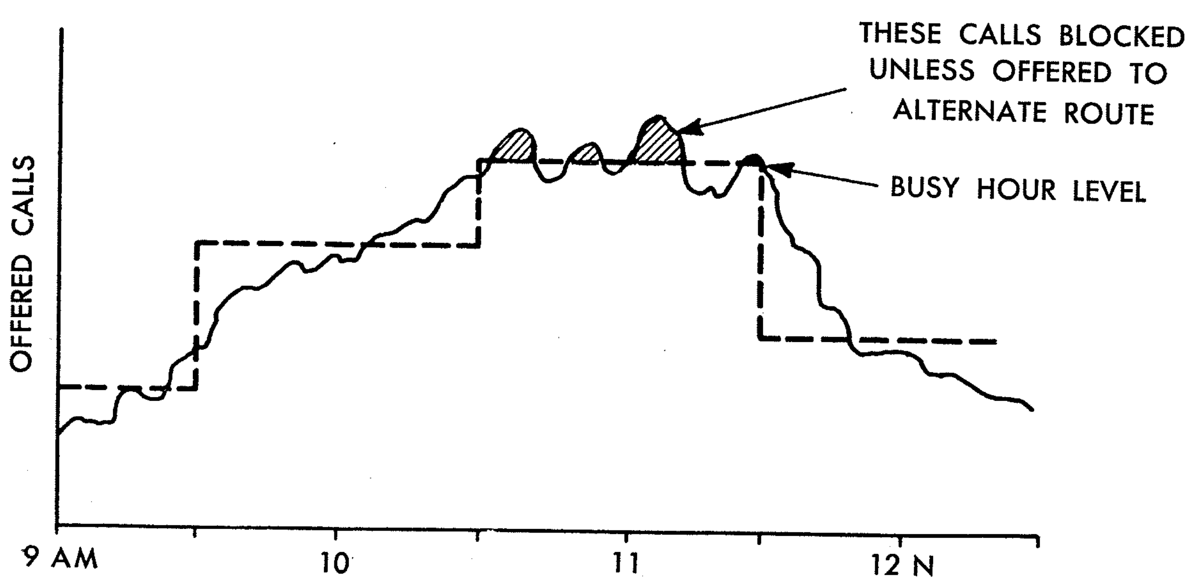
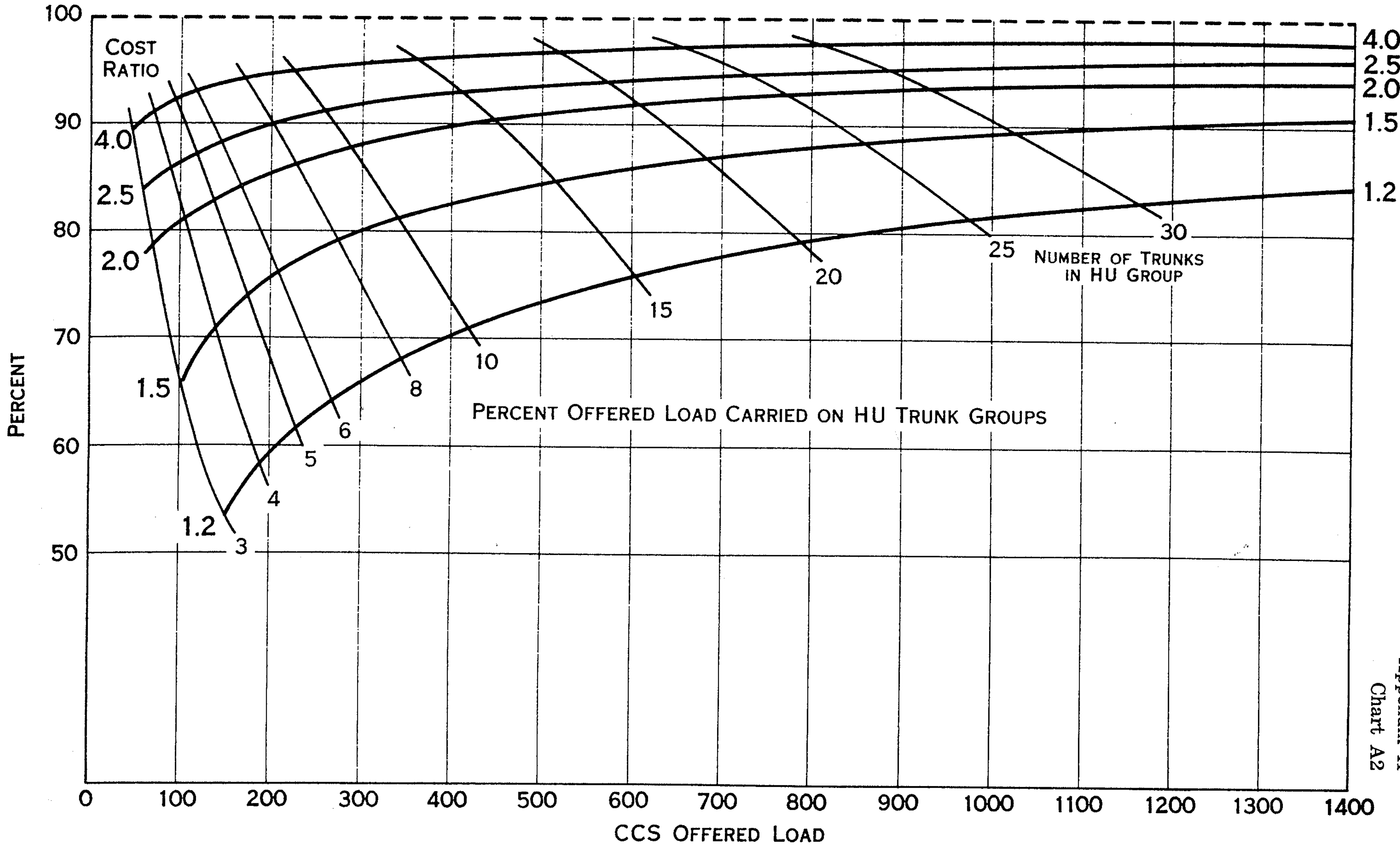


Figure B
Instantaneous Traffic Distribution

DISTRIBUTION OF OFFERED LOAD BETWEEN DIRECT AND ALTERNATE ROUTES



ROUTING PATTERNS UNDER THE SWITCHING PLAN

1. GENERAL

1.01 This appendix discusses routing patterns that are theoretically possible within the framework of the switching plan for distance dialing. Economic and other considerations require various individual patterns. Examples are included.

1.02 Chart B1 illustrates many possibilities for high usage trunking within the framework of the standard routing plan.

2. TYPICAL ROUTING PATTERNS

2.01 Chart B2 and the following discussion illustrate a particular routing pattern that might be involved in completing a call that appears at an end office served from toll center TC_1 destined for an end office served from toll center TC_2. In this example, TC_1 has trunks to PC_1 only; hence the call must be routed to that primary center.

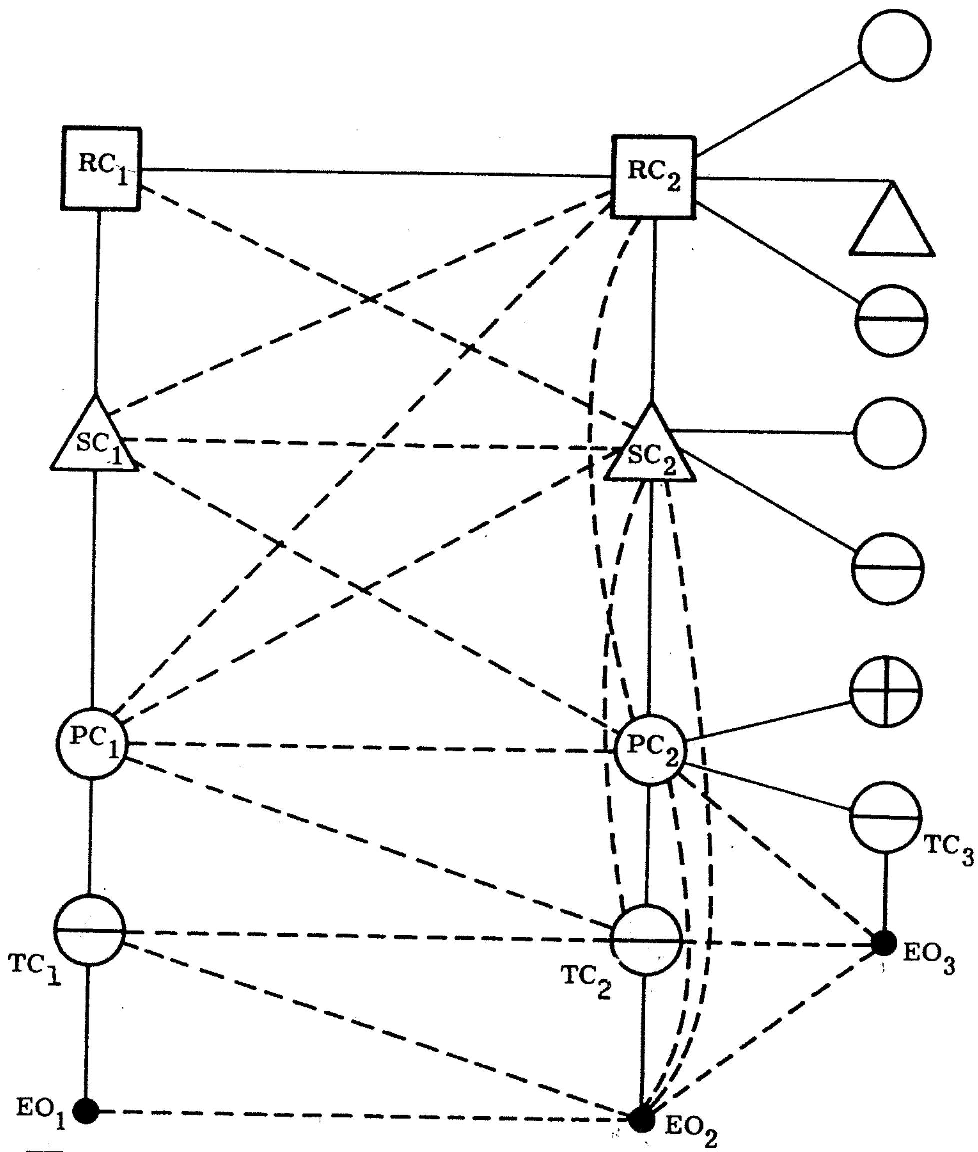
2.02 At PC_1 the call would be offered first to the high usage group to PC_2. At PC_2 the switching equipment would select an idle trunk in the final group to TC_2 and the call would be routed to the called customer in EO_2.

2.03 If, however, all the trunks in the first high usage group (between PC_1 and PC_2) had been busy, the call would next be offered to the high usage group between PC_1 and SC_2 (if PC_1-SC_2-PC_2 is the cheapest alternate route). At SC_2 the call would have a choice of two routings: (1) via direct high usage trunks to TC_2 or if they were all busy, (2) over the two final trunk groups SC_2-PC_2 and PC_2-TC_2.

2.04 In the event all trunks in the group between PC_1 and SC_2 are busy, the call should next be offered to the final group to SC_1. There are available at PC_1 other high usage groups to RC_2 and RC_1. These are intended for terminal and certain other traffic items that must be so routed. Traffic routed via PC_1 should not be offered directly to Regional Centers if there are other lower ranking switching centers in the final route path which have not yet been selected. It is desirable to restrict the switched load to centers of lower rank even though the service advantages of other alternate route possibilities are not realized. At SC_1 the call would have a choice of four routings in the following sequence: (1) via the SC_1-PC_2 high usage group, (2) via the SC_1-SC_2 high usage group, (3) via the SC_1-RC_2 high usage group, and lastly (4) via the final group from SC_1 to RC_1.

2.05 The routing described above is for one set of assumed conditions and could be different in actual practice to the extent that economics and plant layout offer different high usage trunk groups.

SWITCHING PLAN
(Routing Pattern)



CSP'S:
- RC – Class 1 Regional Center
- SC – Class 2 Sectional Center
- PC – Class 3 Primary Center

Other symbols:
- TC – Class 4C Toll Center
- TP – Class 4P Toll Point
- EO – Class 5 End Office

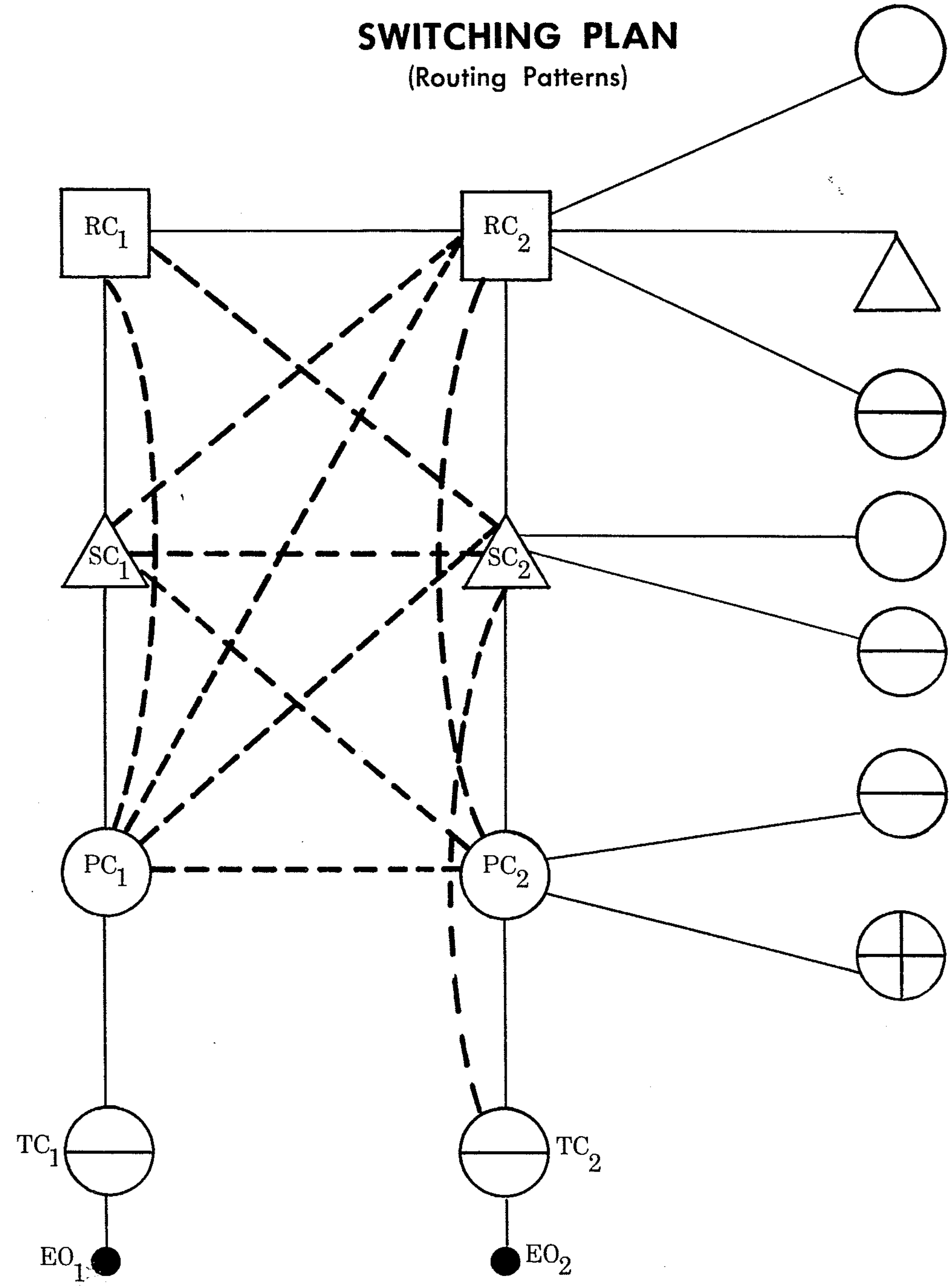
——— Final Group

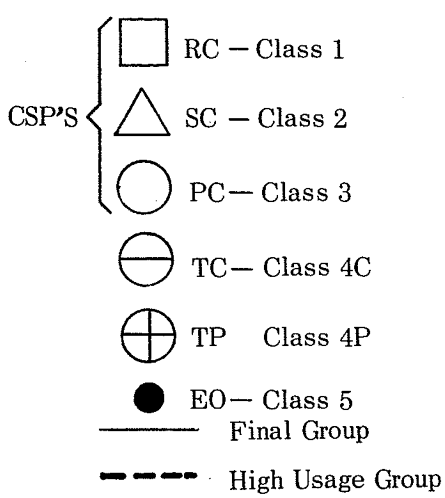
– – – Possible High Usage Group

Note:

An HU trunk group may be established between any two offices, regardless of location or rank, whenever the traffic volume justifies.

SWITCHING PLAN
(Routing Patterns)





Note:
Of the various alternate routes available, only those high usage groups shown heavy — — — — are employed from TC_1 to TC_2

Section 4
Signaling

SIGNALING

CONTENTS PAGE

1. GENERAL

1.01 The interoffice signals required for operator and Direct Distance Dialing are described in this section. Full dial operation is assumed; therefore, ringdown and straightforward methods are not discussed. Those signals currently in use or about to be put into use are included. In addition, some types of signaling are mentioned briefly for information, although their use may not be significant at present. Some signals, such as revertive pulsing, PCI (panel call indicator) pulsing, and call announcer, are not discussed since distance dialing does not raise any special problems with them, nor does it extend their field of use.

1.02 Chart 1 of this section lists the signals required for distance dialing and explains the function of each. The names given for the signals are those which are well established by general use. A few alternative terms having considerable usage are shown in parentheses. The direction of each signal, the indication given to the customer or operator, and the on-hook or off-hook classification of the signal, where applicable, are also shown.

1.03 Chart 2 shows the tones and announcements recommended for distance dialing.

1.04 Chart 3 shows the application of signals listed in Chart 1 to a direct distance dialed connection switched through three intermediate offices in addition to the originating and terminating end offices. Calls can, of course, be switched through more or fewer offices. However, the number of offices shown should suffice to illustrate the use of the signals.

1.05 Part 2 describes the on-hook and off-hook signals from the technical viewpoint and states the more important technical requirements.

1.06 Parts 3 and 4 describe how these same signals have been combined into signaling systems and presents the general details of these systems.

1.07 Parts 5 and 6 describe other forms of signals that are prevalent in Direct Distance Dialing.

1.08 The digit capacities of the various interconnecting switching systems, of fundamental importance to the subject of signaling, are discussed in Section 5, Part 3.

1.09 Sender and register timing intervals in the various switching systems impose timing requirements on digit pulsing in the calling office and on the attaching of a sender, register, or link in the called office. These requirements are summarized in Part 7 of this section.

1.10 The signaling, carrier, and switching systems referred to in this section are of Bell System manufacture. There are many systems of other manufacture in use throughout the industry. Some of these differ appreciably in design, but for Direct Distance Dialing applications they should be compatible with the equipment herein described.

1.11 Electronic Switching Systems are now coming into use. For the most part, signaling to and from these offices is handled at present (1967) much as it is between electromechanical offices. Specific reference has been made to ESS offices at certain places in this section, as appropriate. In the future, special signaling arrangements between ESS offices may come into being.

1.12 A new kind of signaling system, known as Common Channel Interoffice Signaling (CCIS), is now under consideration for Bell System use. In this system, either all or part of the signaling information of a number of interoffice trunks can be encoded and transmitted over a separate voice channel by digital techniques. Between ESS and possibly crossbar offices with Stored Program Control (SPC), the CCIS system may permit eliminating all per-trunk signaling equipment. In another possible kind of common channel signaling, it is feasible to handle only supervisory signals with numerical signaling provided by other means, such as multifrequency. It is not possible to be more specific on this tentative type of signaling as of now.

1.13 A type of signaling not now used in the distance dialing network is frequency shift pulsing (FSP). This system employs frequencies of 1070 and 1270 Hz and can transmit pulses several times faster than the multifrequency (MF) system described in Part 4. At present it is used only with dial teletypewriter exchange service, some of the line facilities for which are narrowband, making the use of MF pulsing not feasible.

1.14 Signaling on international circuits to points outside the integrated North American Network uses systems different from those in domestic service. At present most such circuits terminating in the United States use a system similar to the CCITT (International Telegraph and Telephone Consultative Committee) #5 system. A new system is now being studied, which will be known as CCITT #6, and will probably be similar in many respects to the CCIS system mentioned in 1.12 above. Reference should be made to Section 8 for more details on the signaling systems used in international dialing.

1.15 Use of the Traffic Service Position System is expected to grow rapidly over the next several years. Signaling to and from this system is different in some ways from the signaling associated with cordboard operation. This has been taken into account at appropriate locations in this section.

1.16 The pulse code modulation carrier systems (e.g., T1) have an integral signaling system which makes use of one of the code bits associated with each channel for conveying the signaling state of the channel. Further discussion of this method of signaling is beyond the scope of this document. They also can use conventional systems discussed in Part 4. Several types of channel units are available for various signaling applications, such as E and M, loop, and foreign exchange.

2. ON-HOOK AND OFF-HOOK SIGNALS

2.01 A number of interoffice signals are classified as on-hook, off-hook, or a series of the two. These terms, on-hook and off-hook, are historically derived from the signals received from a customer's station by the local central office (Class 5 office). If the station is on-hook, the loop is open to dc. If the station is off-hook, there is a dc bridge (shunt) across the line.

2.02 These terms, on-hook and off-hook, have also been found convenient to designate the two signaling conditions of a trunk. Generally, if a trunk is not in use it is signaling on-hook towards both ends. Seizure of the trunk at the calling end usually initiates an off-hook signal transmitted toward the called end. Also, if a trunk is in the condition of awaiting an answer from the called end, the called end normally is signaling on-hook toward the calling end. Answer of the call normally results in the sending of an off-hook signal back toward the calling end.

2.03 Both off-hook and on-hook signals, when not used to convey numerical information, are often referred to as supervisory signals or simply as "Supervision."

2.04 The signals which are on-hook or off-hook or a combination of both are included in Chart 1. The direction of transmission of each of these is also shown. Besides these conditions, one or more of the following factors help in determining the significance of signals.

(a) Duration – The on-hook interval of a dial pulse is relatively short and is thus distinguished from an on-hook disconnect signal which is transmitted in the same direction, but for a longer duration.

(b) Relative Time of Occurrence – A delay dialing off-hook signal occurs before any digits have been sent, while the answer off-hook signal occurs after all digits have been sent.

Although both signals are transmitted in the same direction and both are off-hook, they are distinguished by the relative time of their occurrence.

(c) Frequency of Repetition – Such as: Line Busy, 60 IPM (Interruptions per minute); and No Circuit or Reorder, 120 IPM.

(d) Position in the Connection – It is possible for a delay dialing off-hook signal to be returned to an intermediate switching office from the called office when the originating office is waiting for the answer off-hook signal. However, the trunk circuit in the intermediate office is split (not cut through) and, because of its position in the connection, the delay dialing signal is not transmitted to the originating office, but instead is directed to the intermediate office sender.

2.05 The remainder of Part 2 discusses the on-hook and off-hook types of signals. Some of the other signals included in Chart 1 are covered in other parts of this section. In discussing the technical aspects of each signal, mention will be made of factors (a) thru (d) above which apply.

Connect (Seizure) and Disconnect

2.06 A connect signal is a sustained off-hook signal transmitted toward the called end of a trunk following its seizure. This signal is the means by which the calling end indicates a request for service. It continues as long as the connection is held. Momentary interruptions in the connect signal caused by dial pulses or the ring forward signal are ignored as far as the connect and disconnect functions are concerned. To avoid double seizures, a connect signal must be sent immediately upon seizure of a 2-way trunk in order to make it busy at the other end.

2.07 A disconnect signal is an on-hook signal transmitted toward the called end which exceeds a minimum on-hook interval of about 300 milliseconds for step-by-step office trunk equipments and about 150 milliseconds for other type office trunk equipments. This signal is the means by which the calling end notifies the called end that the established connection is no longer needed and should be released. To insure that ring forward signals (see Paragraph 2.38) do not cause false disconnections, incoming trunk equipments to inward and/or through operators must not release during a maximum interval of 140 milliseconds (a maximum 130-millisecond ring forward pulse plus a 10-millisecond safety margin). In general, any trunk equipment which is connected to inband signaling equipment must also be arranged so that it will not release during an on-hook interval of less than 140 ms.

2.08 Generally, two methods are used to guarantee the minimum disconnect interval necessary between calls. In the first method, the outgoing trunk is guarded by holding it busy for an interval after its release. This prevents a new connect signal from being sent forward until sufficient time has elapsed to effect release of the equipment at the called end. The second method permits the trunk to be reseized immediately, but the sending of the connect signal is delayed by the common control equipment for either a measured interval or until a test of the trunk indicates that disconnection has taken effect. The second method saves trunk equipment, but cannot be used for 2-way trunks because, as explained above, on these the connect signal must be sent immediately.

Answer (Off-Hook) and Hang-up (On-Hook)

2.09 When the called customer answers, an off-hook signal is transmitted toward the calling end (usually repeated by relays) to the outward operator's supervisory lamp or to the office where automatic charging control takes place. For charging purposes, the answer off-hook signal is distinguished from off-hook signals of shorter duration by the requirement that it must be continuous for a minimum interval which ranges from two to five seconds.

2.10 The condition of most trunks when idle or when awaiting the customer's answer is that an on-hook signal is being transmitted from the called end to the calling end. This is true again when the called station hangs up. It is possible to have some one-way loop signaling trunks arranged to signal off-hook toward the calling end when idle.

Immediate Dialing

2.11 There is no specific signal associated with this method of operation. Trunk groups employing common receiving equipment (such as senders or registers) may be equipped at the called end with fast links (or bylinks), with both the links and the common receiving equipment liberally engineered to minimize delays. Such groups are normally ready to receive pulsing in about 1/10 second after trunk seizures. This type of operation is required for direct dialed CAMA traffic from non-senderized SxS offices to avoid the use of second dial tone. In addition, dial pulsing trunks from common control offices to direct control switching systems which are ready to accept digits immediately after seizure need not employ delay dialing. Advantages will be realized, however, if delay dialing is employed for signaling integrity check purposes.

Delay Dialing (Delay Pulsing)

2.12 For pulsing which originates in senders or by operators, economy is obtained by the use of slower links at the called end and by engineering these links and the common equipment for longer delays before pulsing is possible. With these more economical arrangements, variable short delays are encountered sufficiently often to require a signal originating from the called office which indicates a non-readiness to receive digits.

2.13 Most 1-way and all 2-way trunks arranged for delay dialing operation signal on-hook toward each end when in the idle condition. As soon as a connect signal is received from the calling end, the called end returns an off-hook (delay dialing) signal to indicate that it is not ready to receive pulses. The called end maintains the delay dialing off-hook signal until a register (or sender) is attached and ready to receive pulses and at that time sends an on-hook (start dialing) signal to the calling end.

2.14 Other 1-way trunks arranged for delay dialing operation signal off-hook toward the calling end when in the idle condition. With this arrangement, the called office maintains the off-hook signal until a register (or sender) is attached and ready to receive pulses. At that time,the called office changes the off-hook signal to an on-hook signal as a start dialing indication to the calling office.

2.15 The speed with which the called office returns the off-hook (delay dialing) signal is very important when the calling office design is such that the sender (or outgoing trunk equipment) is not required to demand an off-hook signal as well as an on-hook signal before outpulsing. For this type of calling office, the off-hook (delay dialing) signal must be received within 300 milliseconds of transmitting the connect signal. If the calling office does not receive the off-hook signal before 300 milliseconds, it is possible for the calling sender to recognize the on-hook signal representing the idle condition, mistake this signal for an indication that the office is ready to receive signals, and outpulse before a register (or sender) is attached at the called office. A calling office that must receive the off-hook (delay dialing) signal within 300 milliseconds can only operate with a called office arranged for delay dialing operation.

Wink Operation

2.16 With wink operation, the trunk equipments also signal on-hook toward each end when in the idle condition. On receipt of a connect signal, the called office initiates a request for a register (or sender) but the called office does not immediately return an off-hook (delay dialing) signal to the calling office. The idle condition on-hook signal to the calling office is maintained until the register (or sender) is attached at the called office, at which time the idle on-hook signal is changed to off-hook. The register (or sender) maintains the off-hook signal for a timed interval, minimum of 140 milliseconds, and then returns an on-hook (start dialing) signal to the calling office, indicating readiness.

The transition from on-hook to off-hook to on-hook, with the duration of off-hook constrained as indicated, constitutes a wink.

2.17 Regardless of whether delay dialing or wink operation is used, Bell System senders are designed to outpulse only when the called office signals on-hook. In some cases, Bell System senders initiate the connect signal and are in a position to recognize both an off-hook and the following on-hook (start dialing) signal. In other cases, outgoing (or 2 -way) trunk equipments initiate the connect signal and the senders may not be in position to recognize a short off-hook signal before it is changed to on-hook by the called office. In the latter case, the trunk equipments are designed to retain a memory of the off-hook signal and present the off-hook signal to the sender when the sender is ready even though the called office has subsequently changed to an on-hook (start dialing) signal. After the sender recognizes the off-hook, the outgoing trunk equipment presents the actual supervisory state to the sender. In a third case, the trunk equipment initiates the seizure but the sender does not require an off-hook followed by an on-hook before dialing. With this arrangement, the trunk equipment retains a memory of the off-hook signal but does not present it to the sender. The trunk equipment does not permit the sender to recognize any signal until the trunk equipment has received the on-hook (start dialing) signal, and then it permits the sender to recognize the start dialing signal.

2.18 Charts 4, 5, and 6 illustrate the state of the signals (on or off) and the sequence of these signals for delay dialing and wink operation. Method A, shown in Chart 4, is an arbitrary designation given to that operation in which either the sender initiates the connect signal or the outgoing trunk equipment initiates the connect signal and is arranged to retain a memory of the receipt of an off-hook signal. Method A applies only to circuits that do not require the return of an off-hook signal within 300 milliseconds. Method A is preferred when circuit arrangements permit. To extend the use of Method A, a "signaling integrity check" feature has been made available in most outgoing trunk equipments associated with No. 4 type Crossbar offices. This check feature provides the memory referred to above. Chart 4 illustrates the case in which the sender initiates the seizure and indicates how this method applies both to delay dialing and wink operation.

2.19 Method B, shown in Charts 5 and 6, is an arbitrary designation given to that operation in which only the outgoing trunk equipment initiates the connect signal and in which it is *not* arranged to retain a memory of the receipt of an off-hook signal. Method B, therefore, applies only to circuits on which receipt of an off-hook signal within 300 milliseconds is required. Chart 6 illustrates the case where the calling sender is ready to look at the signal from the called office within 300 milliseconds. In this case, the sender recognizes the off-hook signal and withholds dialing until the on-hook signal (start dialing) arrives. If the off-hook signal had not been received within 300 milliseconds, the calling sender would have recognized an on-hook signal representing the idle condition and would have outpulsed prematurely.

Chart 5 illustrates the case where the sender is not in a position to recognize the state of the signal until after the off-hook signal has been removed. Although the off-hook signal was received within 300 milliseconds and was subsequently removed, the calling sender concludes that the on-hook signal received represents a start dialing signal from the called office and proceeds to outpulse.

2.20 The following summarizes the use of delay dialing or wink start pulsing.

DELAY DIALING OR WINK START PULSING*

REQUIRED	NOT REQUIRED
1. Dial pulsing by operators* or senders into distant senders or registers.	1. Dial pulsing by customers into distant senders or registers through bylinks (CAMA).
2. Multifrequency pulsing by operators* or senders.	2. Dial pulsing by customers, operators, or senders into direct control switches.

*Wink start pulsing is not suitable for trunks having switchboard multiple appearances.

Start Dialing (Start Pulsing)

2.21 Start dialing is an on-hook signal transmitted from the called office to the calling office occurring when the receiving office is ready to accept digits. However, a momentary delay of a minimum of 70 milliseconds should be introduced before dial pulsing is started (Charts 4, 5, and 6). This delay is necessary because dial pulsing receiving circuits are sometimes momentarily disabled at the instant of the sending of the start dialing signal to prevent the registration of a false reflected pulse.

70 MS Delay

2.22 Most trunks to direct control switching systems are ready to receive digits without delay and so are normally in the start dialing on-hook condition. However, senders should delay the first dial pulse a minimum of 70 milliseconds after trunk closure to allow time for operating the A relay and soaking the B relay of the distant selector or equivalent circuit. Senders are informed by class marks whether they are operating with this type of trunk or with trunks requiring either a delay dialing or a wink start pulsing signal prior to the start dialing indication.

2.23 In No. 4A Crossbar, a nominal 200-ms delay is introduced after receipt of the start dialing signal on MF outpulsing. This delay helps prevent false operation when certain types of inband signaling equipment are used, and also when senders are on short timing under overload conditions.

Stop

2.24 A stop signal is an off-hook condition transmitted toward the calling end which occurs after some, but not all, of the digits have been received at the called end and which indicates that the called end is not yet ready to receive the remaining digits. It is required on dial pulsing calls which are directed, after some digits have been outpulsed, to trunks terminating in link-type CDO's or common control offices.

Go

2.25 A go signal is an on-hook condition transmitted toward the calling end following a stop signal and indicates that the called end is ready to receive additional digits. It continues until the called party answers when reorder or no-circuit signals are not provided. After receipt of a go signal, senders should delay the first pulse a minimum of 70 milliseconds.

Dial Pulsing

2.26 Dial pulsing is a means for transmitting digital information from a subscriber's dial to the central office equipment. Pulses from a subscriber's dial are momentary openings of the loop which are followed at the switching equipment by a relay. In non-senderized step-by-step systems, the dial pulses are used to actuate directly the switching equipment in the local office. On trunked step-by-step calls, the dial pulses for the distant selectors are relayed forward by an outgoing dial pulse repeater. At the terminating office, the relayed pulses may either operate the switching equipment directly or may again be relayed by an incoming dial pulse repeater. Senders which accept dial pulses from trunks are available, as well as senders which will dial pulse outward.

2.27 Dial pulsing represents the numerical value of each digit by the number of on-hook intervals in a train of pulses. The on-hook intervals of each digit are separated by short off-hook intervals, while the digits themselves are separated by relatively long off-hook intervals. The on-hook signals will not interfere with the function of the disconnect signal, since they fall much below the minimum disconnect times given previously. The off-hook interval between digits is distinguished from the off-hook between pulses by the timing of a slow release relay or by other means. In step-by-step systems, the end of a digit is recognized when the off-hook signal exceeds

90 to 295 milliseconds. In common control systems, the range is in the order of 75 to 210 milliseconds. When the end of a digit is recognized, additional operations must be performed before the next digit can be received. (See "Interdigital Time," Paragraphs 2.34-2.37.)

2.28 Figure 1 shows typical dial pulse signals.

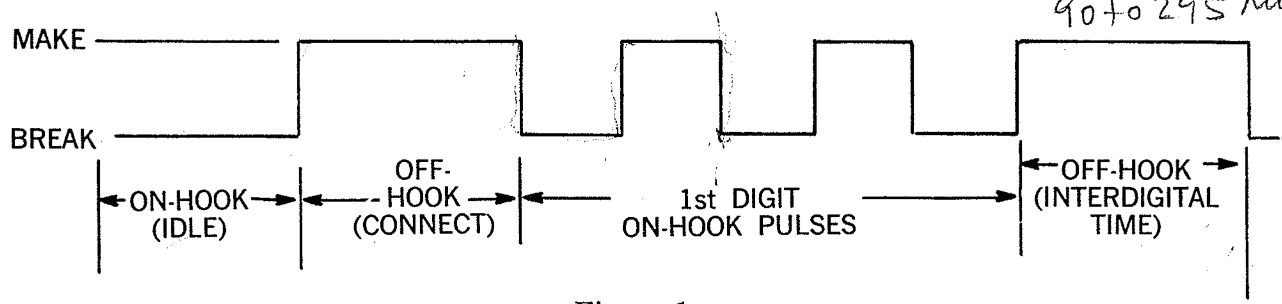


Figure 1
Signaling Conditions During Dialing

2.29 Three important requirements for dial pulsing are: (1) pulse repetition rate, (2) per cent break (sometimes per cent make is used), and (3) interdigital time. The requirements for pulsing speed and per cent break must be considered in relation to (A) the various dial pulse generators, (B) the various signaling, trunk, and repeater circuits used to transmit or regenerate dial pulses, and (C) the receiving circuits such as step-by-step selectors, links, and senders or registers. Per cent break is defined as:

$$100 \times \frac{\text{On-hook interval}}{\text{On-hook} + \text{Off-hook intervals}} \quad ; \text{ or } 100 \times \frac{\text{Break interval}}{\text{Break} + \text{Make intervals}}$$

2.30 The Bell System manufacturing objective for rotary customer dials is a pulse repetition rate of 10 ±0.5 pulses per second (pps) with a 58 to 64 per cent break. Modern dials have essentially constant speed and can be assumed to have an output between 8-11 pps, 58-64 per cent break during any portion of the rundown. Some of the older customer dials, which are still in service, were manufactured to requirements of 8.5-10.5 pps, 59.5-67 per cent break. This requirement is for the average pulse repetition rate, however, and the speed can vary during the rundown. The output of these dials, therefore, can be expected to vary from 7.5 to 12 pps, 59.5 to 67.5 per cent break in service.

Modern 10 pps switchboard dials are held to a requirement of 10 ±0.3 pps, 62-66 per cent break. Older 10 pps switchboard dials, still in service, can vary over the range 10 ±0.5 pps, 59.5-67.5 per cent break.

Twenty pps dials are provided in some switchboards for use over certain metallic trunks. The limit for modern dials is 17-21 pps, 62-66 per cent break.

The objective output for modern senders is 10 ±0.5 pps, 58 ±2 per cent break for E&M lead pulsing and 10 ±0.5 pps, 61 ±2 per cent break for loop pulsing. The majority of senders in service will outpulse within the following limits: E&M – 10 ±1 pps, 57-64 per cent break; Loop

– 10 ±1 pps, 59.5-67.5 per cent break; and Loop (battery and ground) – 10 ±1 pps, 48.5-66 per cent break.

2.31 The nominal dial pulsing speed in the various signaling, trunk, and pulse repeater circuits used in Direct Distance Dialing is 10 pulses per second. Per cent break requirements for these circuits differ, since the per cent break may be shifted in passing through various circuits.

2.32 Signaling and trunk equipments are designed to obtain optimum over-all pulsing results in transmitting the pulses from the dial or sender to the receiving equipment at the incoming office. Each circuit is designed to provide an average or nominal shift in per cent break to deliver pulses best suited to the connecting equipment. As a typical example, Bell System switchboard dials have a nominal 64 per cent break, whereas with some trunk signaling equipment it is desirable to have a nominal 58 per cent break on the transmitting end (M lead). This transformation in per cent break usually occurs in the trunk equipment. For instance, the optimum input, as received from a trunk equipment to a composite (CX) signaling circuit, is 58 per cent break at the transmitting end. A 59 per cent break is the optimum CX signal at the receiving end (E lead) which may be delivered to a variety of circuits, as required by the switching conditions. If the CX signal at the receiving end was switched to an AB toll transmission selector, an incoming trunk equipment would be required between the CX signaling circuit and the AB toll selector. The A relay of this trunk equipment responds to the CX signals and delivers an output pulse in the order of 62 per cent break, which is the optimum signal for the AB toll selector. The A relay and its associated circuitry in the trunk equipment are designed to provide this pulse characteristic. Further examples of the per cent break signal and the typical shifts in per cent break are given in Table 1. The examples shown in Table 1 are illustrative only and are not meant to be all-inclusive. For types not listed, other literature should be consulted.

TABLE 1

TYPE OF TRUNK (BELL SYSTEM)	AVERAGE PER CENT BREAK TESTED AT 12 PPS		
	INPUT	OUTPUT	SHIFT
Outgoing intertoll trunks from switchboard	64*	58	–6 ✓
CX signaling circuit	58	59	+1
Four-wire trunk to toll intermediate selector or intertoll transmission selector	59	59	0
Trunk to AB train	59	62	+3
Trunk to loop toll train	59	64	+5 ✓
Operator office trunk – loop signaling**	59	62	+3
Operator office trunk – CX signaling**	59	58	–1
Selector appearance of intertoll trunk	59	58	–1

*From 10 pps operator dial.

**Repeating relay used from intertoll selector appearance.

2.33 In general the various dial pulse receivers, such as step-by-step selectors and crossbar senders or registers, must have capabilities broader than the requirements of the dial pulse generators and the transmitting and repeating devices to provide a margin for satisfactory service.

Interdigital Time

2.34 The interdigital time is the interval from the end of the last on-hook pulse of one digit train to the beginning of the first on-hook pulse of the next digit train. A slow release relay, which ignores the digit pulses but releases between pulse trains, is used to advance or condition the receiving equipment for the next digit. For customer dialing and operator keying or dialing to a sender, the interdigital time is under human control. See Figure 1.

2.35 The interdigital time delivered by a sender depends on the availability of the succeeding digit. When the next digit is immediately available, the sender must control the *minimum* interdigital interval. The requirements for the minimum interval are:

(a) 300-milliseconds when pulsing into senders or registers of crossbar or ESS #1.

(b) 600–milliseconds when pulsing into step-by-step selectors or the equivalent. This 600 millisecond interval can be, and generally is, used for pulsing into senders or registers. If operator dialing interdigital time is less than 600-milliseconds, failures in completing calls through step-by-step systems may result.

Although senders (incoming) or registers are capable of recognizing interdigital intervals as short as 300 milliseconds, Bell System senders do not in practice use interdigital intervals of less than 500 milliseconds when outpulsing.

2.36 An accuracy of 5 per cent is considered satisfactory for timing this interval. In step-by-step offices, three functions must be completed during the interdigital interval as follows:

(a) Recognition of the end of a digit by the release of the pulse train detector C (or equivalent) slow release relay.

(b) Trunk hunting over as many as nine terminals.

(c) Test idle terminal, cut through, operate A relay, and soak B relay of next switch or equivalent relay circuit.

2.37 A stop dial signal *must be received* 65 milliseconds before the termination of the interdigital interval to allow time for the sender to recognize the signal and stop outpulsing. Thus, to return a useful stop signal when the interdigital time is 600 milliseconds, the total time requirements itemized below, measured from the end of the last pulse of a digit pulse train, must not exceed 535 milliseconds:

(a) The delay due to transit time before a connect seizure is seen at the source of the stop.

(b) The reaction time required to generate a stop.

(c) The delay due to transit time before the stop is seen at the originating end.

Improper adjustment of the digit train detecting slow release relay in a step-by-step selector can, of course, reduce the time available for other interdigital functions.

Ring Forward (Rering)

2.38 This signal is used by an operator at the calling end to recall an operator at the called end on an established connection. It is originated by means of a ringing key in the cord circuit. On trunks arranged for use with E and M lead signaling systems, relays in the outgoing trunk equipment generate a single on-hook pulse for each pull of the ringing key. As applied to distance dialing circuits, ring forward is a momentary on-hook of 100 $\pm$30 milliseconds transmitted toward the called end which is converted at the destination office to a recall signal on the operator's answering cord.

Ringback

2.39 This signal is used by an operator at the called end of an established connection to recall the originating operator. The operation of the called operator's ringing key sends an on-hook pulse back to the calling end which is converted to a recall signal on the originating operator's cord lamp. Ringback continues as long as the called operator's ringing key is operated.

Flashing

2.40 A flashing signal is simply a succession of on-hook and off-hook intervals. These may be irregular when manually generated, but the term is also used to describe reorder, line busy, and no-circuit signals which have a definite repetition rate. Flashing signals are no longer being specified and every effort should be made to eliminate flashing signals between offices at the earliest date.

3. DC SIGNALING SYSTEMS

Loop Signaling

3.01 Signaling methods which use the metallic loop formed by the trunk conductors and terminating bridges are known as loop signaling. The short-range loop signaling methods are not arranged to transmit signals in both directions independently, as are the E and M lead signaling systems which are described later. The loop signaling circuit usually is an integral part of the trunk circuit, rather than a separate assembly of equipment. Loop signals are transmitted by one or more of the following basic methods:

(a) Opening and closing the direct current path through the loop.

(b) Reversing the voltage polarity.

(c) Changing the value of bridged resistance.

The principal loop methods are described in the succeeding paragraphs.

Reverse Battery Signaling

3.02 Reverse battery signaling employs basic methods (a) and (b) described above, but takes its name from the fact that battery and ground are reversed on the tip and ring to change the signal toward the calling end from on-hook to off-hook. This is the preferred and most widely used of loop signaling methods. Figure 2 shows a typical application. Note that the principal elements directly concerned in reverse battery signaling are the CS, T, and A relays and the SW2 switching contacts. On-hook forward (disconnect signal) is an open trunk loop at unoperated SW2 contacts. Off-hook forward (connect signal) is a closed trunk loop by operated SW2 contacts. The backward signals cannot be defined in absolute terms of polarity because of the many variations in practice, but it is always true that on-hook is the polarity existing when awaiting the customer's answer, while off-hook is the polarity when the called customer has answered. The calling end receives signals transmitted by the called end by operation of the CS polar relay. Trunks not requiring the delay dialing signal are in the on-hook condition when idle, whereas trunks requiring the delay dialing signal may be in the off-hook condition when idle. Trunks arranged for the "wink" start dialing signal are in the on-hook condition when idle.

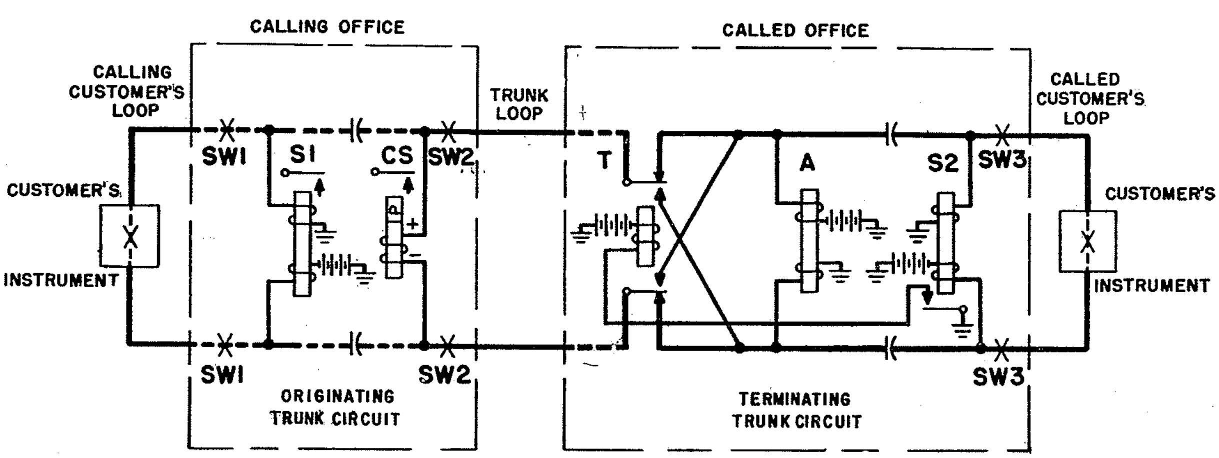


Figure 2

Reverse Battery Signaling

3.03 Figure 3 illustrates repeated reverse battery signaling at a tandem office. The slow release D relay is used to hold the connection through the tandem switches.

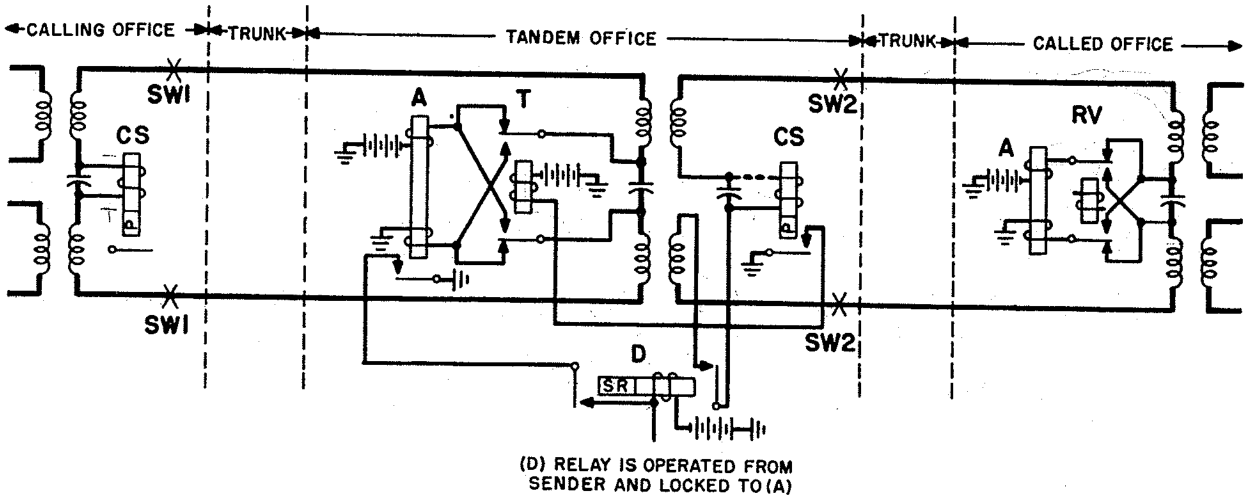


Figure 3

Repeated Reverse Battery Signaling

High-Low, Low-High Signaling

3.04 High-low signaling employs basic methods (a) and (c) described above, but takes its name from the fact that a high resistance shunt is used to indicate on-hook whereas a low resistance shunt indicates off-hook. Low-high signaling operates in the same manner as high-low except that a low resistance shunt signifies on-hook and a high resistance signifies off-hook. *This signaling is not used in the distance dialing network.*

Wet-Dry Signaling

3.05 Wet-dry signaling is so named because of the following commonly used terminology. A trunk is "wet" when battery and ground are connected to the loop at the called end. It is "dry" when battery and ground are removed. "Wet" signifies on-hook and "dry" off-hook. A connect signal (off-hook) forward is a DC bridge across the trunk loop at the calling office. A disconnect is registered by opening the trunk loop at the calling end. However, release of the connection will not take place until the called end is on-hook (wet) and the calling end has disconnected. *This is called joint control of release, and is a disadvantage in distance dialing.* A reversed battery signal is sometimes superimposed on the "wet" or on-hook condition to indicate to the calling end that line seizure has taken place.

Battery and Ground Signaling

3.06 The range of loop signaling can be increased by the employment of battery and ground signaling. This is accomplished by having battery and ground at both ends of the loop, but with opposite polarities at each end. This doubles the current available for signaling. Means are provided to open and close both conductors at the originating end to furnish forward on-hook and off-hook signals. Reverse battery is generally used for supervisory signals from the called end (backward signals). Between digits and at the completion of pulsing, a bridged supervisory relay may be substituted for the pulsing battery and ground to detect the backward signals and to hold the connection regardless of the polarity of these signals. This widely used arrangement is sometimes called "Battery and Ground Pulsing, Loop Holding." When maximum range is required, "Battery and Ground Pulsing, Battery and Ground Holding" may be employed. Caution should be observed in using battery and ground signaling, since in some cases it may result in impulse noise which can cause adverse effects on data service.

E and M Lead Control

3.07 Most signaling systems, other than loop signaling, are separate from the trunk equipment and functionally are normally located between the trunk equipment and the line. The E and M lead signaling systems derive their name from certain historical designations of the signaling leads on the circuit drawings covering these systems. All communications between a trunk equipment and a separate signaling equipment unit are done over two leads, an M lead which transmits battery or ground signals to the signaling equipment and an E lead which receives open or ground signals from the signaling equipment. The near-end condition is reflected by the M lead and the far-end condition by the E lead.

3.08 The input and output signals of E and M lead signaling systems are uniform and are shown in Figure 4.

Signal A to B	Signal B to A	Condition at A		Condition at B	
		M Lead	E Lead	M Lead	E Lead
on-hook	on-hook	GRD	Open	GRD	Open
off-hook	on-hook	BAT	Open	GRD	GRD
on-hook	off-hook	GRD	GRD	BAT	Open
off-hook	off-hook	BAT	GRD	BAT	GRD

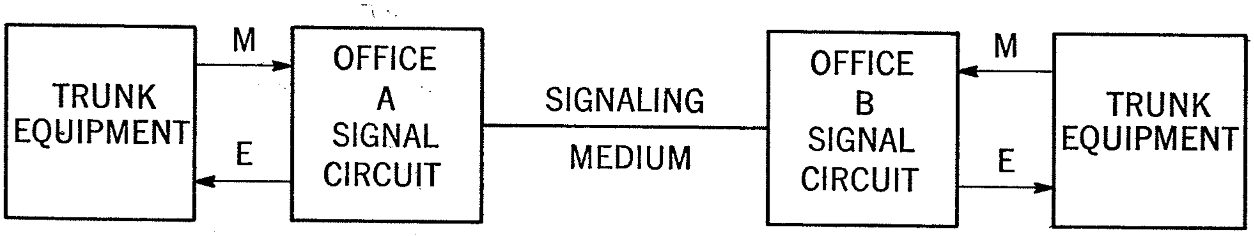


Figure 4

E and M Lead Control Status

3.09 Note that the operation of these systems is "duplex"; that is, signals can be sent simultaneously in both directions without interference.

3.10 Similar signaling circuits should be used at both ends of a signaling section. There are DC types of systems which employ E and M lead signaling, such as duplex (DX) and composite (CX), which are described in this part. Part 4 describes the AC signaling systems which use E and M lead control.

Pulse Links and Converters

3.11 A trunk may be made up of two or more signaling sections connected in tandem, using the same or different types of signaling systems. If the sections have similar signaling arrangements, an auxiliary pulse link is provided to repeat the signals. If the signaling arrangements are different, converters are provided. For example, a trunk equipment may employ loop signaling and the trunk facility may employ signaling with E and M lead control. Converters are required at the terminals of a trunk when the signaling system used differs in signaling arrangements from that of the trunk equipment.

Composite (CX) Signaling

3.12 Composite as well as duplex signaling arrangements were developed to provide means for direct current signaling and dial pulsing beyond the range of loop signaling methods. DX and CX signaling arrangements are duplex in operation; that is, they provide simultaneous 2-way signaling paths. The circuit techniques of CX and DX are fundamentally those used in full duplex telegraph and teletypewriter operation. A sensitive polar relay at each end of the line receives signals from the distant end. Balancing networks are provided and must be adjusted for each circuit according to the impedance of the line conductors.

3.13 Composite (CX) signaling employs a single line conductor for each signaling channel. A balanced polar relay is used at each end of the signaling section as shown in Figure 5 in a symmetrical arrangement which permits full duplex operation. Higher frequency voice currents are separated from the low-frequency signaling currents by a filter arrangement called a CX set. The crossover frequency is about 100 H_z. Two CX legs can be derived from a pair of wires, and four from a phantom group. These four legs can be used to signal independently with a ground return, but in most cases one leg is used as an earth potential compensation path. If the fourth leg is not required for earth potential compensation or for telephone signaling, it can be used for telegraph service. The signaling channels can be assigned independently of the voice channels with which they are physically associated.

3.14 Three types of CX sets (filters) are used in the Bell System and they are coded as follows:

(1) Type C – used for CX signaling on open wire and cable. It can be used at intermediate and terminal points.

(2) Type D – used for CX signaling on open wire and cable but only at terminal points and cannot be used for distance dialing. It is similar to Type C but less expensive.

(3) Type E – used for CX signaling on cable circuits only. It can be used at intermediate and terminal points like Type C, but uses less expensive components.

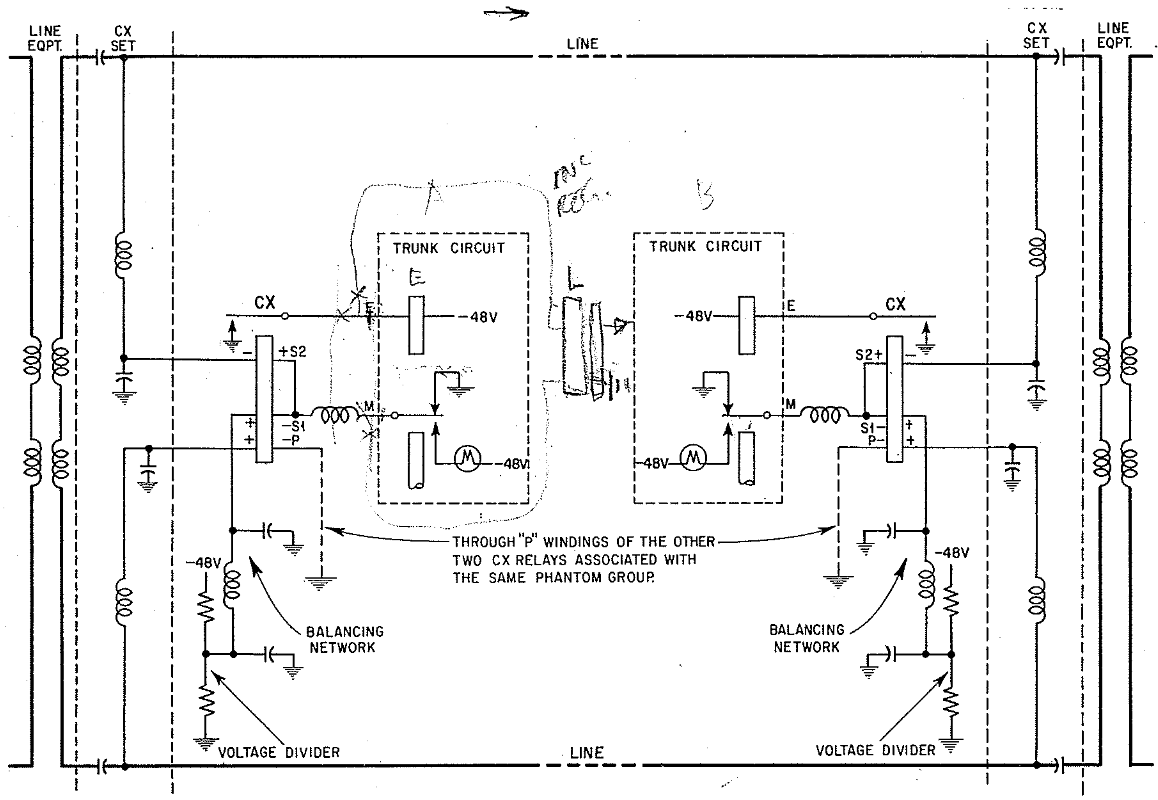


Figure 5

Composite Signaling for One Voice Channel

3.15 A number of CX signaling equipment units are available and are usually classified as either short-haul or long-haul, with the following broad applications:

(a) Short-Haul – Maximum of 4,800 ohms loop resistance on cable circuits or 90-100 miles of open wire.

(b) Long-Haul – Maximum of 12,000 ohms loop resistance. Such circuits usually include one intervening voice repeater around which the signals are bypassed.

3.16 Earth potential compensation is essential to proper performance where earth potential conditions indicate its use. DC earth potential compensation should be used on all intertoll trunks. On toll connecting trunks, its use is optional. One and one-half to four and one-half volts difference in earth potential usually requires compensation depending on the signaling equipment design. Under some conditions, filters may be required to overcome the effect of induced longitudinal alternating current voltages.

3.17 Dial pulsing on CX signaling circuits is normally at a rate of 10 pulses per second. Tests for dial pulse distortion, however, are made at 12 pulses per second, and typical limits for adjusting, testing, and performance, in terms of per cent break at this speed, are as follows:

	PER CENT BREAK		PULSING SPEED
	INPUT	OUTPUT	(PPS)
Adjust	58	59	12
Test	58	57-61	12
Expected Performance	58	55-63	12

The input is at the M lead of one end of a signaling section and the output is at the E lead of the other end.

3.18 The input to CX signaling equipment should be limited to the range of 47 to 67 per cent break or a narrower range under unfavorable conditions. When testing at 12 pulses per second,the output limits into a step-by-step selector are 44 to 72 per cent break.

3.19 Dialing without intermediate senders or registers is not expected to be transmitted through more than four signaling links connected in tandem. This limitation applies to all types of trunk signaling. An example of this would be an N1 carrier channel, a T2 carrier channel, a DX section,and a CX section in tandem.

3.20 The CX signaling circuits have been designed on the basis of total minimum insulation requirements of 160,000 ohms per mile per conductor for open wire circuits less than 25 miles long, and 200,000 ohms per mile per conductor for circuits over 25 miles. The requirements are based upon both the minimum insulation between conductors and a conductor to ground. These values also apply to circuits operating over combinations of cable and open-wire. For cable circuits, the total minimum insulation resistance requirement for conductors is generally 60,000 ohms.

3.21 At an intermediate voice repeater, such as one of the V-type, either two sets of CX equipment and a pulse link may be provided or bypass equipment must be used to provide signaling around the repeater.

Duplex (DX) Signaling

3.22 DX signaling is based upon a balanced and symmetrical circuit that is identical at both ends. It is patterned after CX signaling, but DX does not require a composite set. The simplicity of DX signaling has resulted in trunk circuits which contain the DX features, instead of having a separate signaling unit as is commonly found with other E & M lead control signaling systems. Figure 6 shows a trunk circuit embodying the DX signaling features.

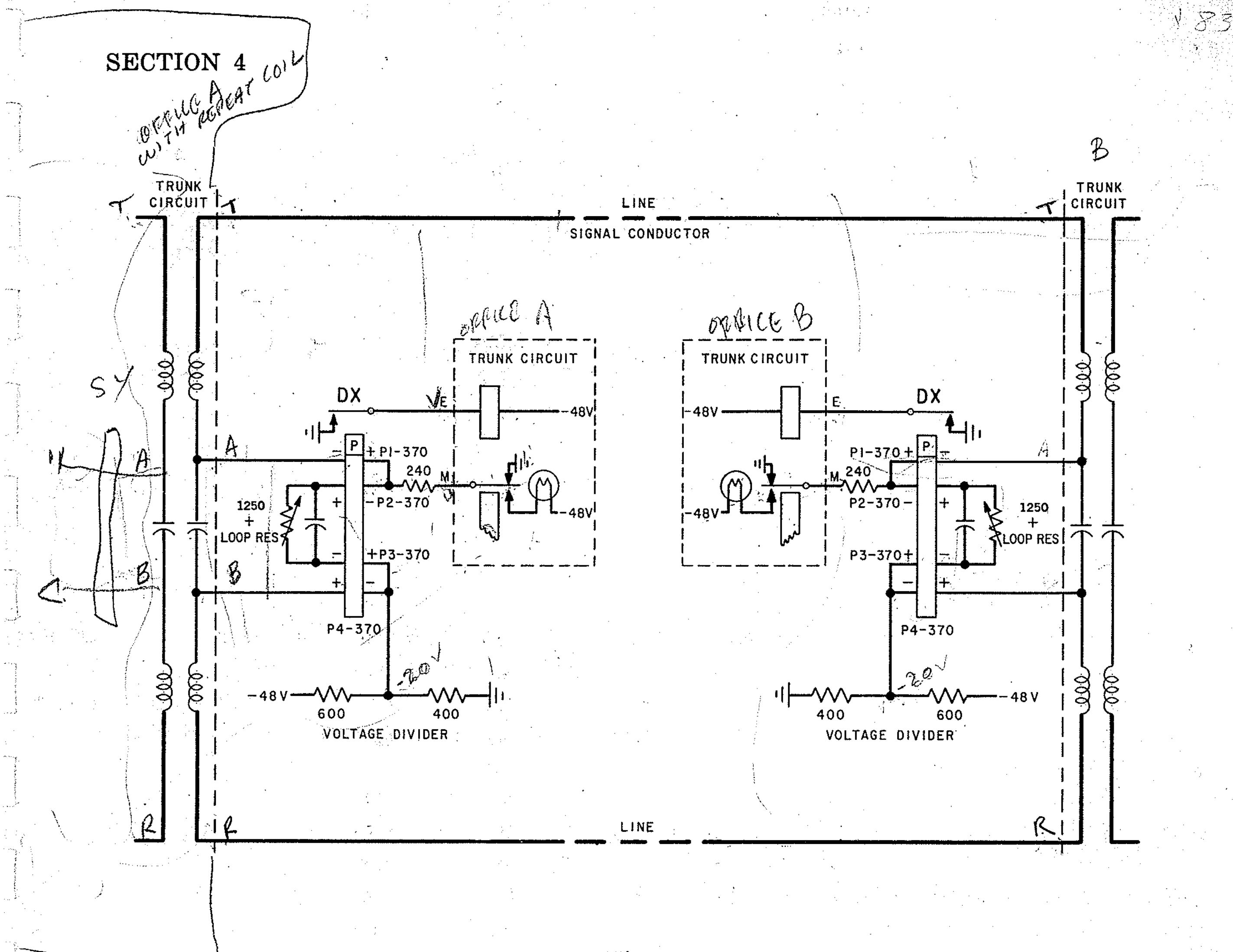


Figure 6

DX Signaling Circuit

3.23 A DX signaling circuit uses the same cable pair as the talking path and, therefore, no filter is required to separate the signaling frequencies from the voice transmission. One conductor of a cable pair in the DX system carries the supervisory and pulsing signals. Both conductors individually carry currents resulting from differences in terminal ground potentials and battery supply voltages, so that current in the second conductor can cancel the effect of this unwanted current in the first conductor. This arrangement allows for self-compensation against differences in ground potential and partial compensation for battery supply variations. It is also balanced against AC induction.

3.24 The DX signaling system may be used on both 10 & 20pps dial pulsing trunks. With proper balancing network adjustment, DX signaling circuits will repeat 12 pulses per second of 58 per cent break with a distortion not exceeding plus or minus 4 per cent break. This performance is better than most loop signaling arrangements and is equal to that of CX signaling. DX signaling is often used instead of loop signaling on longer local and tandem trunks and instead of CX or SX on short intertoll trunks, except where nonphysical or open-wire circuits preclude its use. It can be used through E-type (negative impedance) repeaters, although in many cases the dial pulsing range will be greatly reduced because of balancing difficulties. If V-type repeaters are used, bypass equipment will be required.

3.25 A single DX signaling section is limited to a maximum loop resistance of 5,000 ohms. Although the signaling range of DX is less than that of CX or SX, the signal distortion is so small that two DX circuits can be used in tandem for one trunk. As presently designed, Bell System DX circuits are restricted to line facilities composed of cable pairs equipped at both ends with repeating coils and having a minimum insulation resistance of 100,000 ohms.

3.26 Sometimes it is necessary to extend E & M leads beyond their normal limitations. For this purpose, signal lead extension circuits are used to secure adequate range. In effect, this circuit is a pulse repeater for E & M lead signals. Basically this circuit consists of a DX signaling circuit modified with an additional relay. This circuit converts signals from E-lead conditions to M-lead conditions so that the intermediate circuit can work into another line signaling circuit.

Simplex (SX) Signaling

3.27 Simplex (SX) signaling requires the use of two conductors for a single channel. A center tapped coil or its equivalent is used at both ends of the pair for this purpose. The arrangement may be a one-way signaling scheme suitable for intraoffice use, or the simplex legs may be connected to full duplex signaling circuits which function like the CX signaling circuits with E and M lead control.

3.28 Earth potential compensation requires the use of one conductor of an additional pair for each five signal channels. Thus, only five SX signaling circuits are derived from six physical pairs. The signaling currents in the line side induce no voltage in the equipment, since they flow in opposite directions and, conversely, voice currents in the equipment cause no current flow in the simplex leg. Simplex signaling has been largely superseded for new work by the DX signaling system previously described.

4. AC SIGNALING SYSTEMS

4.01 Alternating current signaling systems have been designed to convey the basic trunk supervision and numerical signaling functions required by switching systems. They are used over distance dialing trunks where DC signaling is not feasible or economical, such as long-haul circuits and short-haul circuits equipped with carrier. Two-state AC signaling can handle trunk supervision and numerical signaling where the latter is coded by dial pulsing. Three-state AC signaling has been designed to handle revertive pulsing trunks. Multistate AC signaling, in the form of multifrequency pulses, is used for numerical signaling only and must be coordinated with two-state signaling systems, either AC or DC for supervision.

4.02 Signaling systems using both inband and out-of-band signaling frequencies are in use. Inband systems could use frequencies in the voiceband from about 500 Hz to about 2,600 Hz and signaling equipment is required only at the terminals of a transmission path. In the Bell System, only the upper portion of this range is used. Inband signals are usually of the same order of amplitude as voice currents so as not to overload voice amplifiers or cause crosstalk in adjacent channels.

4.03 Out-of-band signaling systems basically are those which use signals outside the band customarily used for speech transmission on telephone channels. In a sense, this includes DC methods of transmission as discussed in Part 3 of this section, but more usually it is taken to include AC systems such as the type referred to in Paragraph 4.16. It can also be construed to include Common Channel Interoffice Signaling (CCIS) and the T carrier signaling scheme, which were referred to in the general part of this section.

4.04 One of the chief problems with inband signaling is the prevention of mutual interference between voice and signals. Voice-frequency signals are audible and, consequently, signaling should not take place during the time the channel is used for conversation. Signal receiving equipment, however, must remain on the channel during conversation to be ready to respond to incoming signals, and it may thus be subject to false operation from voice sounds which resemble the tones used for signaling. Protection against voice interference can be accomplished in a number of ways:

(1) Signal tones of a character not likely to occur in normal speech may be used.

(2) Time delay may be used to prevent false operation due to voice-frequencies.

(3) Voice-frequency energy, other than the signaling frequency, may be detected and used to prevent the operation of the signaling receiver.

Single Frequency Signaling

4.05 Single frequency (SF) signaling systems are designed to pass the necessary signals for telephone trunks over voice-frequency transmission line facilities without impairing the normal use of these facilities for speech. These systems deliver and accept DC signals to and from the switching trunk equipment in the form of loop or E & M lead controls. The DC signals are transformed to AC on the line side, and vice versa.

4.06 The same frequency is employed in both directions on 4-wire line facilities since these have separate transmission paths between terminals. On 2-wire facilities, different frequencies are used in the two directions. One signal frequency is applied or removed at each end of a line facility to operate or release a relay at the far end. In this way, two alternate signal conditions are provided in both directions of transmission. Normally, speech and signal frequency are not on the line facility at the same time.

4.07 The present standard single frequency inband signaling system employs 2600 Hz for 4-wire trunks, and 2600 and 2400 Hz for 2-wire trunks. The 2600 Hz system provides all of the features of the earlier 1600 Hz system at lower first cost and with more economical maintenance. It can be used on J, K, L, N, O, ON, and T carrier, TD-2, TH, TJ, TL, and TM radio systems, C5 carrier, and 2-wire or 4-wire H-88 or lighter loaded cable facilities. Both the obsolete 1600 Hz system and the early version of the 2600 Hz system used electron tubes, and could operate with E & M lead trunk equipment only. Current 2600 Hz units are transistorized and versions are available to operate with either loop signaling or E & M lead trunk equipments.

4.08 The on-hook and off-hook conditions for all Bell System types of SF signaling systems are as follows:

SIGNAL	TONE	OPERATION	LEAD	CONDITION
ON-HOOK	ON	SENDING	M	GROUND
		RECEIVING	E	OPEN
OFF-HOOK	OFF	SENDING	M	BATTERY
		RECEIVING	E	GROUND

4.09 The simplified schematic Figure 7 illustrates the major features of the E-type transistorized 2600 Hz SF system.

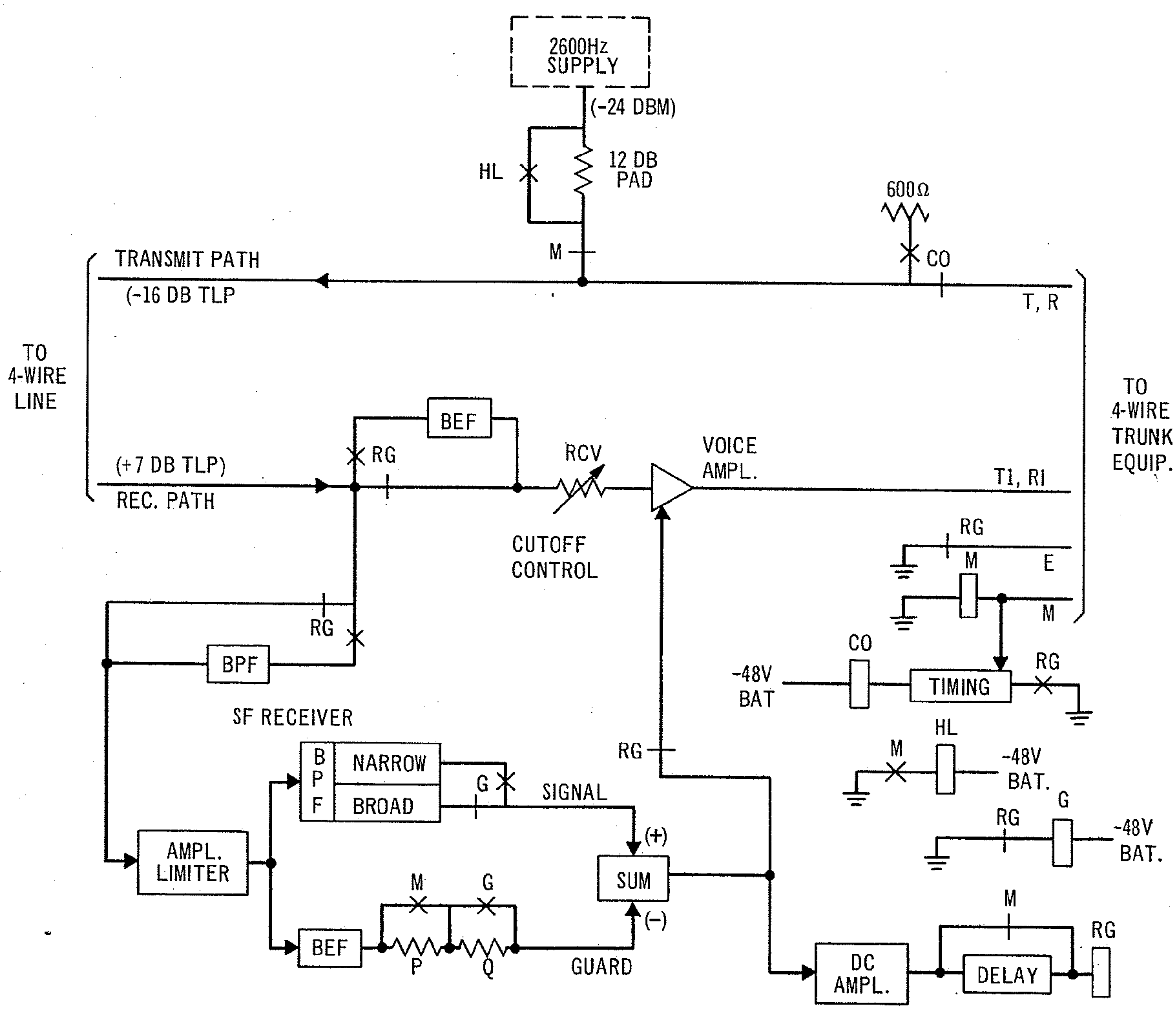


Figure 7

Simplified Diagram of the E-Type 2600 Hz SF Signaling System Connected to a 4-Wire Transmission Channel

4.10 The keyer relay, M, is operated and released by signals on the M lead and alternately removes or applies 2600 Hz to the transmit line of the facility. The M relay operates the high-level relay HL to remove a 12 dB pad in order to permit a high-level initial signal to secure an improved "signal-to-noise" operating environment. The HL relay is slow to release and hence dial pulses, which operate the M relay, are transmitted at an augmented level. In addition, a cutoff relay, CO, operates to block any noise which may be present from the office side of the circuit. The Bell System SF signaling units will accept and transmit dial pulses at speeds from 8 to 12 pulses per second with from 56 to 69 per cent break. If the range of percent break presented to the M lead is outside these limits, means must be provided to bring it within. In general this will be done with an M-lead pulse corrector, but in some cases other means can be used, such as correcting problems in plant where the pulses originate. Limitations in percent break for loop-type SF signaling units are usually overcome by the use of units incorporating a built-in transmitting pulse corrector.

4.11 The receiving portions of the SF unit include a voice amplifier, appropriate band elimination networks, and a signal detection circuit. The voice amplifier's primary function is to block any noise or speech present in the office equipment from interfering with the operation of the signal detector and also to make up for the insertion loss of the SF unit in the receive speech path.

4.12 The signal detector circuit includes an amplifier-limiter, a signal-guard network, appropriate half-wave rectifiers, a DC amplifier, and a pulse-correcting circuit, the output of which operates a relay to repeat signals to the E lead of the trunk relay equipment.

4.13 The receiver sensitivity is –29 dBm at the zero transmission level point for 4-wire line facilities and –32 dBm for 2-wire line facilities, the additional 3 dB being for loss introduced by band elimination filters which are required when two different frequencies are used. The signal-guard network provides the necessary frequency discrimination to separate signal and other than signal (guard) voltages. By combining the voltage outputs of the signal and guard detectors in opposing polarity, protection against false operation from speech and noise is secured. The guard feature efficiency is changed between the dialing and talking conditions to secure optimum overall operation.

4.14 An incoming signal is separated into signal and guard components by the signal and guard detectors. The signal component is a band about 100 Hertz wide, centering on the signal frequency. The guard component is made up of all other frequencies in the voiceband. These components produce opposing voltages with a resultant net voltage in the signal detector. In the talking condition (tone off in both directions), the guard detector sensitivity is such that almost a pure tone is required to operate the receiver since other than signal frequencies will produce a voltage opposing its operation. The guard principle is an important feature in avoiding signaling imitation by speech. It is, however, insufficient by itself to assure that a speech-simulated signal will not cause false operation of the receiver. An additional electronic time delay is therefore provided, so that during the dialing condition the receiver will just operate the RG relay on a tone pulse of 35 milliseconds. When the RG relay operates, it causes a slow relay (G) to release, greatly decreasing the sensitivity of the guard channel and making the signaling channel responsive to a wider band of frequencies.

4.15 On calls for which no charges are made (the called end does not return an off-hook signal), such as business office, repair, or service calls, the tone in the backward direction is not removed, but a band elimination filter prevents the tone from reaching the calling customer. On transmission systems equipped with compandors, the presence of the backward-going tone may reduce the compandor crosstalk and noise advantage. A somewhat similar increase in noise may occur in digital carrier systems, though for other reasons. An important reason for removing the frequency selectivity along with guard sensitivity is the necessity for talking to intercept operators or hearing recorded announcements under tone-on conditions. In addition, the band elimination filter, which is inserted under any on-hook condition, prevents the tone from interfering with voice transmission.

4.16 Certain N, O, and ON carrier channels have built-in signaling capabilities. These employ 3700 Hz as the signaling frequency, and it modulates the channel or twin-channel carrier frequency associated with the voice channel for which it signals. During the trunk-idle condition the 3700 Hz tone is present in both directions of transmission, and supervisory signals are transmitted by interrupting the tone in a fashion similar to that already described for inband SF systems. Since the signaling path is outside of the voiceband, no provision is required for protection against voice operation. In addition, compandors are not affected by the tone, and signaling, if required, can take place during the talking condition.

4.17 Speech and signaling frequencies are separated by filters. A time delay feature is provided in the signal detector circuit to minimize registration of false pulses of short duration due to noise bursts and hits on the line. Means are provided to disconnect called customers, in the event of a carrier failure, to prevent their being held out of service. In addition, after 10 seconds the trunks using the carrier facilities are made busy to prevent lost calls.

4.18 The 3700 Hz signaling system referred to above normally is modulated from DC to tone, and demodulated from 3700 Hz to DC, at the same points where speech modems are located. In some cases, however, carrier channels are connected in tandem. If these channels have conventional channel units, the associated two signaling sections would have to be connected in tandem on a DC basis. To avoid this, "through channel units" should be used at such intermediate points. These units provide demodulation and modulation of the speech channel and the 3700 Hz signaling tone together, and instead of recovering the DC signals the 3700 Hz tone is connected through to the following carrier system on an AC basis.

Multifrequency Pulsing

4.19 The multifrequency pulsing system consists of transmitting and receiving equipment for transferring valid number information over telephone trunks by various combinations of two, and only two of five frequencies in the voiceband. Each combination of two frequencies represents a pulse, and each pulse represents a digit. The pulses are sent over the regular talking channels and, since they are in the voice range, are transmitted as readily as speech. MF receivers detect the pulses and transfer the digital information to control equipment which establishes connections through the switches. MF pulsing is also used to transmit calling number information in CAMA-ANI operation. In this case, the calling number is MF pulsed forward from the originating office to the CAMA office following the forwarding of the called number, whether the called number is transmitted by MF or dial pulsing.

4.20 The MF system transmits only digital information; hence another signaling system, such as DX, SF, or loop, must be provided for supervision.

4.21 Additional signals are provided by combinations using a sixth frequency. The six frequencies are spaced 200 Hz apart. These six frequencies provide fifteen possible two-frequency combinations. Ten combinations are used for the digits 0 to 9 inclusive, and one each for signals indicating the beginning (KP) and end (ST) of pulsing. The remaining three combinations are used for special signals.

4.22 Table 2 shows the digits or other usages, the associated frequencies, and the explanation for the 6-tone MF keypulsing code.

4.23 The principal advantages of MF pulsing are speed, accuracy, and range. Keysets are faster than switchboard dials and similarly, MF senders transmit more rapidly than dial pulse senders. Consequently, MF equipment requires less holding time per call and, as a result, a relatively small number of senders or registers can be used as common equipment for a large number of trunks.

4.24 A typical plan of MF pulsing from a switchboard position to a crossbar office is shown in Figure 8. In such an arrangement, MF pulses are generated by an operator using a keyset, usually keying about two digits per second. In completing a call, the operator first connects the calling cord to the outgoing trunk. By depressing the front KP button, the cord connection is split and the front cord is transferred from the operator's telephone set to the keyset; the KP lamp is lighted; and the keyset circuit is prepared to send the KP signal over the trunk when the distant end signals to start pulsing. Connecting the cord to the trunk gives a connect signal to the distant end which returns off-hook supervision to delay pulsing until a sender or register is attached. When a sender has been found and the pulsing path completed to an idle receiver, the supervision changes to on-hook as a start pulsing signal. The KP pulse is then sent automatically and the positional S (sender) lamp lights. With some switchboards the KP pulse is not sent automatically and the KP key, therefore, is not operated until the sender lamp lights. At the distant end, the KP signal prepares the MF receiver for pulses. The operator now presses a button corresponding to each digit and then the ST key to indicate the end of pulsing. Besides informing the distant sender that no more pulses are to be expected, operating the ST key disconnects the keyset from the cord, reconnects the telephone set under control of the TALK key, restores the connection between the cord pair, and extinguishes the KP and S (sender) lamps.

TABLE 2

FREQUENCIES FOR MF PULSING

DIGIT	FREQUENCIES
1	700 + 900
2	700 + 1100
3	900 + 1100
4	700 + 1300
5	900 + 1300
6	1100 + 1300
7	700 + 1500
8	900 + 1500
9	1100 + 1500
0	1300 + 1500

USE	FREQUENCIES	EXPLANATION	
KP	1100 + 1700	Preparatory for digits	
ST	1500 + 1700	End of pulsing sequence	
STP	900 + 1700	Traffic Service Position System (see below)	
ST2P	1300 + 1700		
ST3P	700 + 1700		
Coin Collect	700 + 1100	Coin Control	
Coin Return	1100 + 1700	Coin Control	
Ring-back	700 + 1700	Coin Control	
Code 11	700 + 1700	Inward Operator	CCITT SIGNALING SYSTEM NO. 5
Code 12	1300 + 1700	Delay Operator	
KP1	1100 + 1700	Terminal Call	
KP2	900 + 1700	Transit Call	

ADDITIONAL EXPLANATION FOR TSPS TRUNK TYPE

	COMBINED COIN	COMBINED NONCOIN	COMBINED COIN AND NON-COIN	DIAL 0, 00 COIN
ST	1 + digits	1 + digits	1 + digits (coin)	0
STP	0 + digits	0 + digits	0 + digits (coin)	00
ST2P			1 + digits (noncoin)	
ST3P			0 + digits (noncoin)	

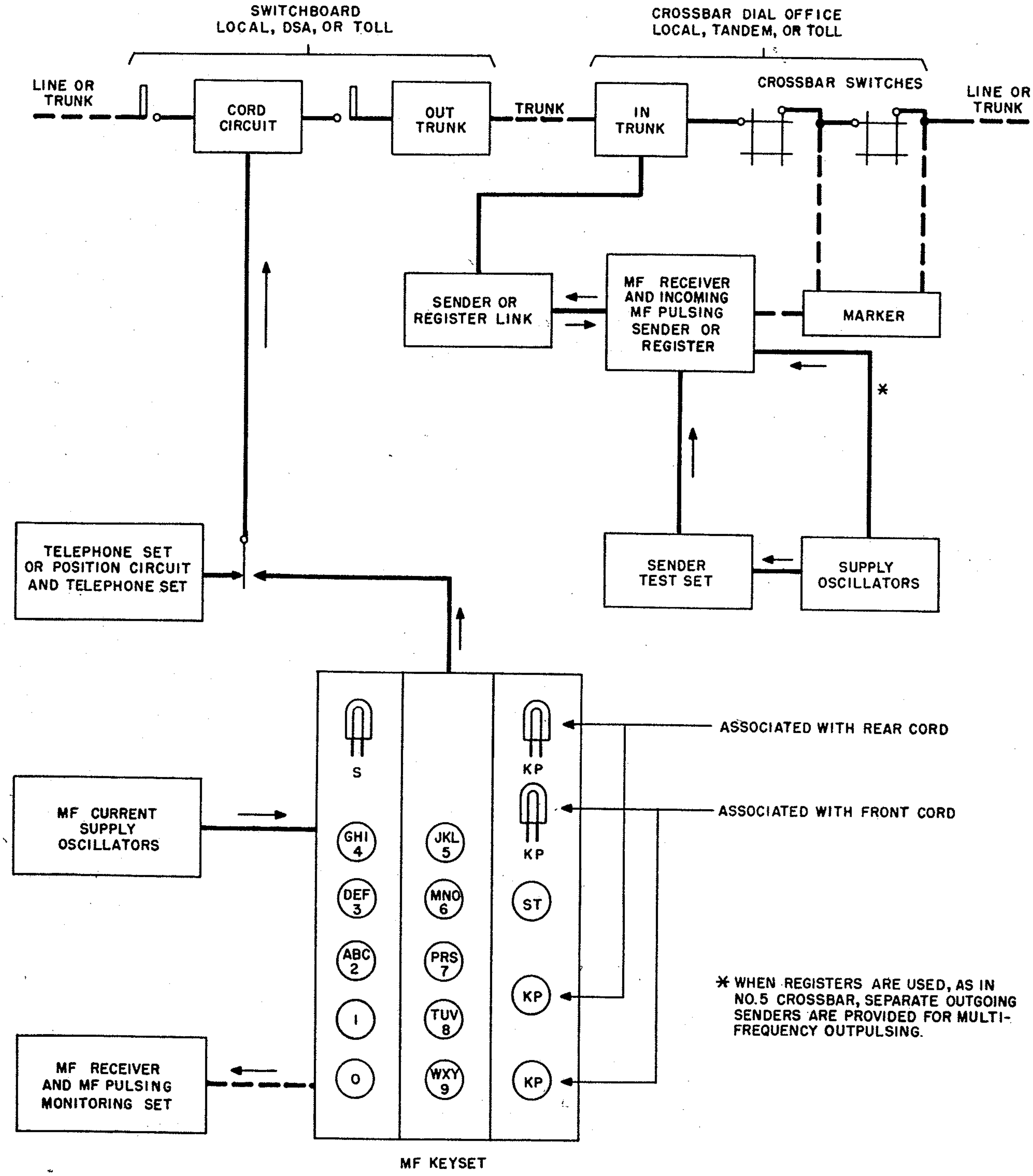


Figure 8

MF Pulsing from a Switchboard to a Crossbar Central Office

4.25 MF pulses are also transmitted by senders. The senders receive numbers from subscribers (DP or PUSHBUTTON) or from operators or other senders (by multifrequency pulsing, or other pulsing basis) and transmit these numbers as MF pulses. MF senders, in general, are arranged to pulse at a rate of approximately 7 digits per second. This rate is increased to 10 per second for intercontinental dialing using CCITT signaling system #5.

4.26 The receiver is connected to a trunk as part of a sender or register as required. It does not respond to voice-frequency currents until it receives the KP signal. The unit then can receive and pass on the number codes and the ST signal to its associated sender or other connected equipment.

4.27 Figure 9 shows the major components of a typical receiver used in electromechanical offices, including an input circuit, a volume-limiting amplifier, a biasing circuit, a signal present and unlocking circuit, and the receiving channel circuits.

4.28 A check circuit in the receiver verifies that two, and only two, channel relays operate for each digit. When an error is detected, a reorder signal is returned.

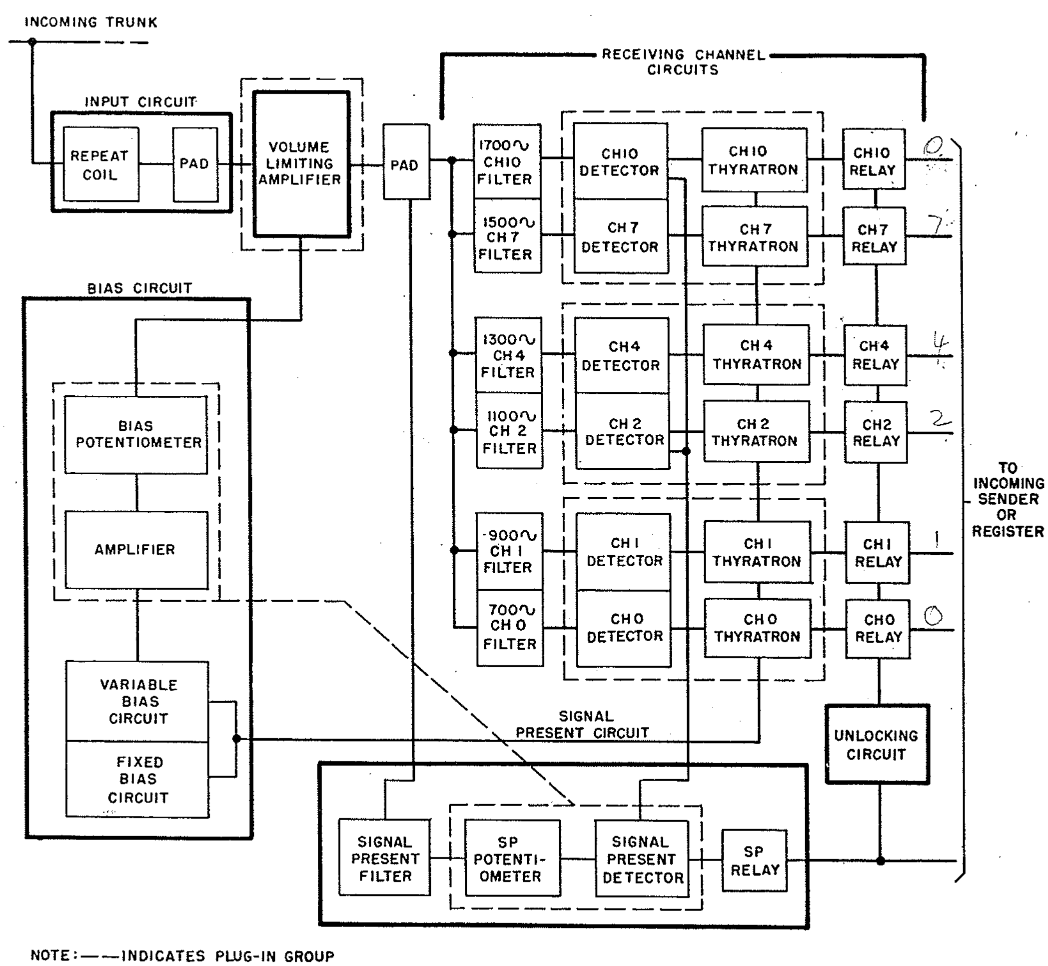


Figure 9
MF Receiver Plan

4.29 At crossbar and ESS offices, MF pulses may be received from operators' keysets or from senders at other offices.

4.30 There are also situations in which operators' keysets MF pulse to senders which, in turn, transmit dial pulses to step-by-step equipment. This permits operators at positions equipped for MF pulsing to establish calls through SxS as well as crossbar equipment.

4.31 The normal power output of MF transmitters presently used in toll switchboards, testboards, test frames, and senders is −6 dBm per frequency at the zero transmission level point. The frequencies of the supply oscillators should be within ±1.5 percent of nominal.

4.32 The engineering limit for operating sensitivity of the MF receiver is −22 dBm per frequency. These margins permit the use of MF pulsing on trunks having switch-to-switch losses of 14 dB, including allowances for trunk variations, etc., when connected to switchboards, testboards, and senders. Little interference from crosstalk, noise, and echo on the line is encountered.

4.33 Senders outpulse MF with pulses and interdigital intervals of 68 ±7 milliseconds.

4.34 In electromechanical offices, MF receivers are tested for slow pulsing at approximately 2 digits per second, with 230 millisecond no-tone and 260 millisecond tone intervals. Fast pulsing is tested at 10 digits per second with intervals of 35 milliseconds tone and 65 milliseconds no-tone. This test is also made with the tone and no-tone intervals interchanged. Receivers are also tested for sensitivity range and for their ability to operate with maximum allowable slope in frequency transmission of 6.5 dB. Tests are also made at high input values to check that false operation of a channel does not result from modulation products. In ESS offices each MF receiver is tested with each MF transmitter through an environmental test circuit. The receiver is checked for sensitivity range, 6.0 dB of slope, false operation resulting from modulation products, timing (speed), and ability to detect operator double-keying.

4.35 The nominal KP signal interval is 100 milliseconds. The receivers are designed to accept a KP pulse of 55 milliseconds minimum, but it is considered good practice for senders to outpulse 100 ±10 milliseconds.

4.36 Delay pulsing and start pulsing signals are always required in connection with multifrequency pulsing, since MF signals are received on a common control basis by senders or registers. However, after pulsing has started, all digits are accepted without delay from the called end. For this reason, stop and go signals are not required after MF pulsing begins.

5. AUDIBLE TONE SIGNALS

5.01 Signals in this category give information regarding the progress or disposition of telephone calls to either operators or subscribers; hence, all signals are either audible or visual. The audible signals must, of course, be easy to interpret and must conform to the transmission system design requirements for signal levels and freedom from interference effects with respect to: (1) voice currents, (2) circuit noise, or (3) other signaling systems.

The maximum benefit to all subscribers will result from uniformity of these signals in all offices of the nationwide network. Calls may be originated to any other office, so each subscriber may be exposed to the full variation of tones and signals. Subscriber confusion is likely to result from tones differing from those employed locally in proportion to the lack of familiarity and degree of difference.

5.02 To better assure consistency in meeting these objectives, the Bell System has recently adopted a Precise Tone Plan consisting of four pure tones which in central office applications will be held to ±0.5 percent frequency tolerance and ±3 dB amplitude variation. These tones are: 350, 440, 480, and 620 Hz. They are assigned singly or in pairs (not modulated) to represent standard audible tone signals, as described in the following paragraphs. In the period of transition to the Precise Tones, the older tones will continue to be used. Except for dial tone, the new and old tones sound nearly alike.

5.03 Standard levels for the Precise Tone Plan have been established and are indicated in the appropriate paragraphs which follow. As before, levels for the old tones should lie in the range of 61 to 71 dBrnc. The tone level should be measured where it is applied to the voice transmission path at the calling subscriber's side of the incoming trunk equipment. Refer to Chart 3 of this section.

Dial Tone

5.04 Dial tone consists of 350 plus 440 Hz at a level of –13 dBm per frequency. The difference in frequency of 90 Hz gives this tone its low-pitched sound. Old dial tone consists of 600 Hz modulated by 120 Hz when supplied by a tone alternator, or by 133 Hz when supplied by an interrupter. In this case, the modulating frequency gives this tone its low-pitched sound. Other combinations were also used.

Low Tone

5.05 Low tone consists of 480 plus 620 Hz at a level of –24 dBm per frequency. Interrupted low tone is used for line busy, reorder, and no-circuit tone signals reached by the customer.

Line Busy

5.06 Line busy is a low tone interrupted at 60 IPM which indicates that the called subscriber line has been reached, but that it is busy.

Reorder, Paths Busy (Overflow, All Trunks Busy), No Circuit

5.07 This is a low tone interrupted at 120 IPM which indicates that the local switching paths to the calling office or equipment serving the called subscriber are busy, or that no toll circuit is available. This signal may indicate a condition such as a timed-out sender or unassigned code dialed. (See also Paragraphs 6.06-6.10.)

5.08 These low tones with the interruption rates that are employed in the Bell System for operator administration of distance dialed call conditions are shown in Table 3. Flashing signals are no longer specified. In those offices where flash is still used, it may not be accompanied by tone in all cases. In such instances it is necessary to furnish tone appliers.

TABLE 3

	LINE BUSY 60 IPM	REORDER 120 IPM	
		LOCAL	TOLL
Tone On	0.5 sec.	0.3 sec.	0.2 sec.
Tone Off	0.5 sec.	0.2 sec.	0.3 sec.

5.09 Tone should be provided at Class 5 offices for 60 and 120 IPM, and at Class 4 and higher ranking offices for 120 IPM.

5.10 For the above conditions, these same tones are received by the calling customer on direct dialed calls. In general, customers are not instructed on the significance of each tone. They try completing their calls again regardless of the tone received. However, detailed instruction concerning tone signals is sometimes given to PBX attendants.

Audible Ringing

5.11 Audible ringing consists of 440 plus 480 Hz at a level of –16 dBm per frequency. This signal indicates that the called line has been reached and ringing has started. It is also used on calls to operators (special service, long distance, information, etc.,) during the "awaiting-operator-answer" interval. Old audible ringing typically consists of 420 Hz modulated by 40 Hz. Other combinations were also used.

High Tone

5.12 High tone consists of 480 Hz at –17 dBm. Old high tone is nominally 500 Hz when supplied from a tone alternator, or 400 Hz from an interrupter.

Class-of-Service Tones

5.13 These tones are used at switchboards to indicate the class of service of the calling subscriber when more than one class is served by the same trunk group. Class of service may be indicated by either a high tone, low tone, or absence of tone.

Coin Denomination Tones

5.14 These tones are produced by gongs or tone pulse generators in a coin telephone as nickels, dimes, and quarters are deposited. The tones are introduced to the line by separate transmitters in the coin box and enable the operator to check the amount deposited. On prepay service, in addition to the tones, a DC signal is sent to the operator showing that coins have been deposited.

Coin Collect Tone

5.15 Coin collect tone is a low tone used to inform the originating operator that the B operator or coin control circuit has collected the coin.

Coin Return Tone

5.16 Coin return tone is a high tone used to inform the originating operator that the B operator or coin control circuit has returned the coin.

Recorder Warning

5.17 When recording equipment is used, a "beep" of 1400 Hz tone is connected to the line every 15 seconds for a 0.5-second interval to inform the distant party that the conversation is being recorded. The tone source is located within the recording equipment and can not be controlled by the party applying the recorder to the line.

6. OTHER SIGNALS

Ringing

6.01 The technical aspects of ringing signals for customers' lines are not discussed, since they are not an interoffice signaling problem.

Ringing Start

6.02 Switching trains designed for controlled ringing require a ringing start signal. These trains, when used for distance dialing, must operate on an automatic ringing basis. To accomplish this, some trunk circuits and senders are arranged to generate a ringing start signal when required.

6.03 Two types of ringing start signals are employed, SX and 20 Hz. SX ringing start consists of +130V applied on a simplex basis to both conductors for a minimum of 0.1 second, whereas 20 Hz ringing start consists of 105V AC ringing current applied on a loop basis for a minimum of 0.35 second. The SX ringing start signal can be applied after the first digit has been sent,(as in trunk circuit design) or after all digits have been sent (as in sender design). The 20 Hz ringing start signal, however, cannot be sent until the line seizure signal has been received.

Coin Collect and Coin Return

6.04 Coin collect is +110 volts (or +130 volts in some systems) negative grounded potential and coin return is –110 volts (or –130 volts in some systems) positive grounded potential. The circuit (in simplified form) for collecting and returning coins over a customer's line is shown in Fig. 10.

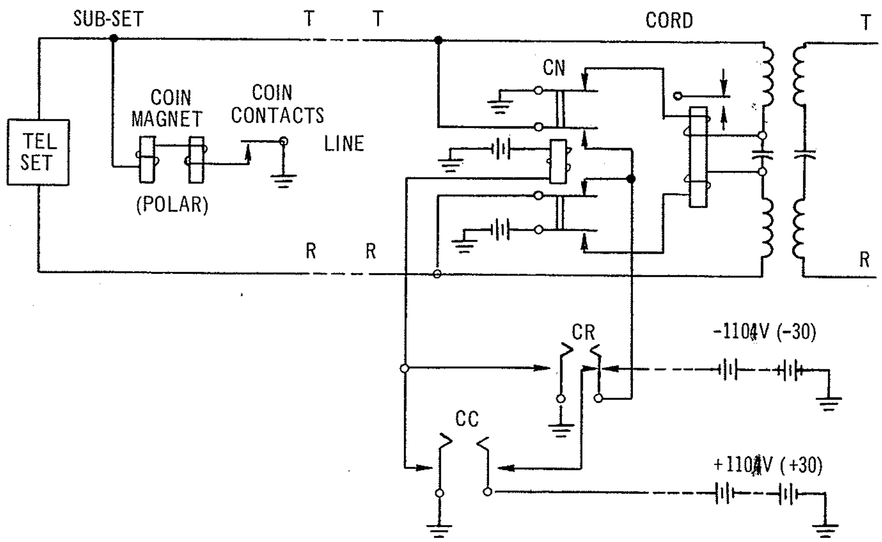


Figure 10

Coin Collect and Return Circuit

6.05 The coin mechanism is polarized and diverts the coins in one direction to collect, and in the other to return. Coin contacts connect the coin magnets to ground when a coin is deposited. Operation of the coin return CR key operates the CN relay which disconnects talking battery and connects T and R together and to –110 volts. The CC key connects +110 volts to T and R. The parallel wires provide a low resistance path. (In some cases it is not possible to use the parallel connection, and the T lead only is used.) In addition to the DC coin control system, there is an AC system using MF signaling frequencies. This system furnishes three basic signals, namely, coin collect, coin return, and ringback.

Announcements and Announcement Machines

6.06 Recording machines are used in the Bell System to provide announcements. A primary use of the recorded announcement machines is to provide an intercepting message to calls reaching vacant or disconnected customer numbers.

6.07 One such machine provides a single channel with an announcement interval, which is usually fixed for a particular installation. It may be set to be one of six intervals ranging from eleven to thirty-six seconds. Means are provided to connect a trunk at the beginning of an announcement interval and repeat from one to nine announcements (two or three is the usual number) and then to connect to an intercepting operator. Two machines are usually provided – one for service and one for standby. If the voice output of the machine in service fails, the standby machine is automatically placed in service. In multioffice cities, the machines are provided in a central location and intercepting trunks may be brought into the center or to sub-centers to which the announcements are transmitted.

6.08 A smaller machine is used in small dial offices where neither operator intercepting nor the larger intercepting machines can be economically justified. In this use, changed numbers, vacant thousands and hundreds levels, as well as all vacant or disconnected numbers are connected to the machine. Normally only one machine is provided. This machine has an announcement interval that may be varied up to a maximum of thirty seconds. The machine operates on a stop-start basis. When once started, all subsequent calls requiring intercept in the announcement interval are cut in immediately to the machine at any stage of the announcement cycle. Provision can be made for subsequent transfer to an operator.

6.09 Direct distance dialed calls will reach these machines when so required. The announcements will be so worded that the customer can understand the proper action to be taken. Also, it is desirable to inform the customer that the announcement is recorded. Connections to announcement machines should not return off-hook (answer) supervision.

6.10 Crossbar tandem and No. 4 type switching systems are to be equipped so that appropriate recorded announcements may be returned on calls which fail to complete because:

(1) All trunks are busy due to heavy traffic or disaster.

(2) A switching system is overloaded.

(3) Vacant codes or unauthorized numbers are dialed.

(4) Operating or equipment irregularities are encountered. Cut-through to an operator is not contemplated under these circumstances.

TOUCH-TONE®

6.11 The Bell System TOUCH-TONE calling system provides a method for pushbutton signaling from subscriber stations using the voice transmission path. The code for this system provides for 16 distinct signals. Each signal is composed of two voiceband frequencies, one from each of two mutually exclusive frequency groups of four frequencies each. The signal frequencies are geometrically spaced and were selected on the basis that the two frequencies of any valid signal combination are not harmonically related.

6.12 The frequency pairs assigned for TOUCH-TONE signaling are as follows:

Low Group Frequencies (H_Z)		High Group Frequencies (H_Z)			
		1209	1336	1477	1633
	697	1	2	3	Spare
	770	4	5	6	Spare
	852	7	8	9	Spare
	941	*	0	#	Spare

6.13 Various features which are provided in the TOUCH-TONE system include the following:

(a) Transistor generator in station set powered from customer loop.

(b) A check by the receiver that two and only two of the tones are present, that one is from each group of four, that they are present for at least 40 milliseconds, and that their levels differ by not more than 18 db.

(c) A guard against false pulsing due to voice signals.

7. SENDER AND REGISTER TIMING AND EFFECT ON SIGNALING

7.01 The senders and registers used in distance dialing are equipped with timing functions to prevent their being held too long. The intervals allowed for the registration of digits, and for a distant sender, register, or link to be attached, have an effect on signaling. If any of the intervals allowed for digit registration are exceeded, the distant sender or register will route the call to recorder and release. If the interval allowed for the attachment of a distant sender, register, or link is exceeded, the call may be routed at the calling end to a mechanical announcement or reorder.

7.02 The requirements for digit pulsing which result from digit registration timing are given for the several systems in Chart 7. Delays exceeding these intervals do not always result in reorder routing, since these limits are necessarily based on minimum timing in the senders and registers. In the No. 5 Crossbar system in the chart, some of the intervals are automatically reduced during periods of heavy traffic in order to conserve common control equipment.

7.03 The requirements for the speed of attachment of a sender, register, or link, following receipt of a connect signal from the calling office, are shown in *Chart 8*. It will be observed that during periods of heavy traffic some of the intervals are automatically reduced. This measure is designed to minimize the effect that delays in one office may have on other offices. Without reduced intervals, mutual delays between offices during periods of heavy traffic can pyramid, seriously impairing service.

NOTES

1. In cordboard operation, the start dialing, delay dialing, stop and go signals are sometimes indicated to the operator on the calling cord lamp instead of the start dial lamp. In TSP operation, these signals are indicated on KP and Start lamps.

2. It will be observed that conditions producing a 120 IPM tone signal apply to facilities that are relatively liberally engineered and, hence, the probability of an immediate subsequent attempt succeeding is reasonably good.

3. Ringing of the called station should be started automatically upon seizure of the called terminal.

4. An ST pulse may not be sent on calls by multiparty customers or if there is an identification failure.

5. Some offices may still be returning flashes in synchronism with tone. Flashing signals should be eliminated and only audible tone signals used.

6. With Traffic Service Position operation, the effect of flashing can depend upon the circumstances, but in most instances a flashing supervisory lamp will result.

SIGNALS REQUIRED IN DISTANCE DIALING

Name of Signal	On-Hook	Off-Hook	Direction: Calling End	Direction: Called End	Use or Meaning	Indication: To Customer	Indication: To Operator	See Note
Connect (Seizure)		✓	——	→	Requests service and holds connection			
Dial Tone			←	——	Equipment ready for dialing	Steady tone	Steady tone	
Disconnect	✓		——	→	No service is desired — Message is completed — Release connection		Calling supv. lamp lighted	
Answer (Off-Hook)		✓	←	——	Called party has answered — Charge timing begins and depends on this signal		Called supv. lamp dark	
Hang Up (On-Hook)	✓		←	——	Called party has not answered — Line idle — Message is completed		Called supv. lamp lighted	
Delay Dialing (Delay Pulsing)		✓	←	——	Called end not ready for digits		Start dial or KP fwd. lamp dark	1
Wink		✓	←	——	Called end ready for digits		Start dial or KP fwd. lamp lighted	1
Start Dialing (Start Pulsing)	✓		←	——	Called end ready for digits		Start dial or KP fwd. lamp lighted	1
Stop		✓	←	——	Some digits received — Called end not ready for further digits		Start dial lamp changes to dark	1
Go	✓		←	——	Called end ready for further digits		Start dial lamp changes to lighted	1
Dial Pulsing (DP)	✓	✓	——	→	Indicates called number			
TOUCH-TONE (Pushbutton)			——	→	Indicates called number			
Multifrequency Pulsing (MFP)								
Keypulse (KP)			——	→	Prepares receiving circuit for digits —			
Digits			——	→	Indicates called number			
Start Pulse (ST)			——	→	Indicates that all necessary digits have been sent			
Start Identification (ANI)		✓	←	——	Indicates that CAMA sender is ready to receive calling number			

SIGNALS REQUIRED IN DISTANCE DIALING

Name of Signal	On-Hook	Off-Hook	Direction (Calling End / Called End)	Use or Meaning	Indication: To Customer	Indication: To Operator	See Note
ANI Outpulsing							
Keypulse (KP)			→	Prepares CAMA sender for digits	———	———	
Identification Digit			→	Indicates if service observed, whether automatic or operator identification and identification failure	———	———	
Digits			→	Indicates calling number if sent	———	———	
Start Pulse (ST)			→	Indicates all digits sent	———	———	4
Line Busy			←	Called line is busy	60 IPM tone	60 IPM tone	5
Reorder			←	All paths busy All trunks busy Blockage in equipment Incomplete registration of digits	120 IPM tone	120 IPM tone	2, 5
Ringing			→	Alerts called customer to an incoming call	Bell rings or other alerting signal	———	3
Audible Ringing			←	Called station is being rung or Awaiting operator answer	Ringing tone	Ringing tone	
Ring Forward	✓		→	Recalls operator forward to the connection	———	Steady or flashing lamp	
Ringback	✓		←	Recalls operator backward to the connection	———	Lighted lamp for duration of ring	
Ringing Start			→	Starts ringing when terminating equipment is of controlled ringing type	———	———	
Flashing	✓	✓	→ ←	Manually recalls operator to the connection	———	Flashing lamp	6
Coin Collect			→ ←	To collect coins deposited in coin box	———	———	

SIGNALS REQUIRED IN DISTANCE DIALING

Name of Signal	On-Hook	Off-Hook	Direction: Calling End	Direction: Called End	Use or Meaning	Indication: To Customer	Indication: To Operator	See Note
Coin Collect Tone			→ ←	→ ←	Indicates that coin collect signal is being sent to coin box		Low tone or no tone	
Coin Return			→ ←	→ ←	To return coins deposited in coin box			
Coin Return Tone			→ ←	→ ←	Indicates that coin return signal is being sent to coin box		High tone or no tone	
Coin Denomination Tones			→ ←	→ ←	Indicates number and denomination of coins deposited in coin box	Tones from gongs or oscillator in coin box		
Class of Service Tone			→	→	Indicates to operator the class of service of the calling customer's line		High, low, or no tone	
Recorder Warning Tone			→ ←	→ ←	Indicates telephone conversation is being recorded	1400 Hz Tone of 0.5-second duration applied every 15 seconds		

TONES AND ANNOUNCEMENTS RECOMMENDED FOR DISTANCE DIALING

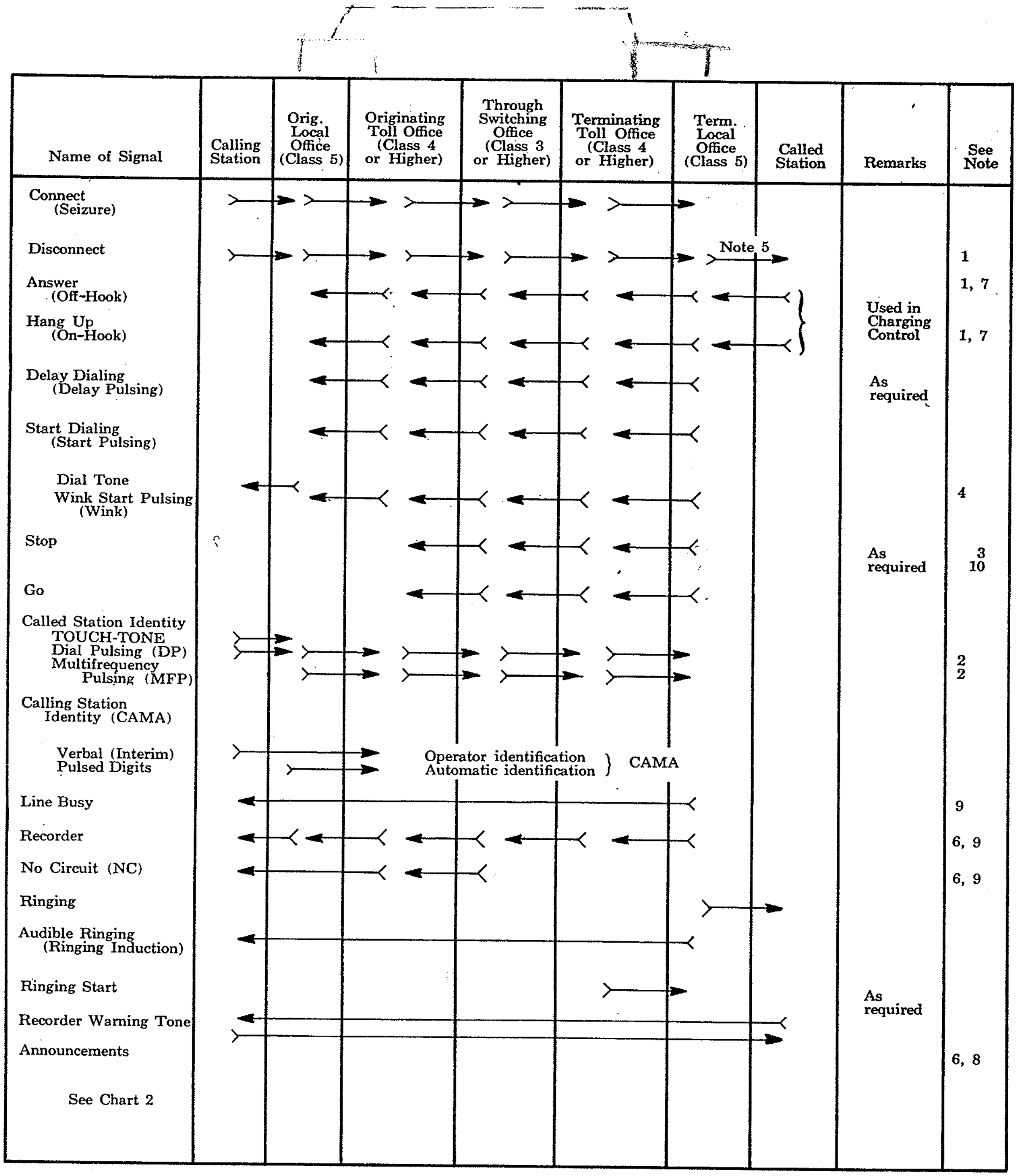
The following table shows the recommended tones and announcements encountered by customers and operators on distance dialed calls. The texts of recommended or typical announcements are shown on succeeding pages.

CUSTOMER AND/OR OPERATOR ENCOUNTERS	RECOMMENDED TONE OR ANNOUNCEMENT
Prior to start of dialing	Dial Tone
On connection to called line or to operator trunk	Audible ringing signal
Line busy	60 IPM Tone
Switching blockages	
Local	120 IPM Tone (Announcement similar to "N" or "X" may be used)
Toll	
(a) #4 & toll XBT	
Switching Paths Busy	Announcement P
Sender Overload	Announcement N
(b) Other	
Switching Paths Busy	120 IPM Tone
Sender Overload	120 IPM Tone
All trunks busy	
Local & Toll Connecting	120 IPM Tone
Intertoll	
Normal	120 IPM Tone
Heavy Calling (#4 & toll XBT)	Announcement N
Disaster (#4 & toll XBT)	Announcement X
Common control equipment irregularity caused by misdialing or trouble	
Local	120 IPM Tone
Toll	
#4 & toll XBT	Announcement P
Other	120 IPM Tone
Vacant Number	Vacant Number Announcement or Operator
Vacant Code	Operator or Announcement L

RECOMMENDED ANNOUNCEMENTS

ANNOUNCEMENT	TEXT
N	I'm sorry, (pause) all circuits are busy now. Will you try your call again later, please? This is a recording.
P	I'm sorry, your call did not go through. Will you please hang up and try again? This is a recording.
L	I'm sorry, we are unable to complete your call as dialed. Please check the number and dial again or ask your operator for assistance. This is a recording.
X	(With flexibility due to situation) I'm sorry, unexpected damage to telephone equipment in Kansas City (or near Kansas City) has delayed your call. Emergency calls may be placed with your operator. This is a recording.
Vacant Number 1.) Announcement machine equipped with operator intercept cut-through.	I'm sorry, the number you have reached is not in service at this time. If you need assistance, please stay on the line and an operator will answer. This is a recording.
2.) Announcement machine not equipped with operator intercept cut-through (CDO's).	I'm sorry, the number you have reached is not in service at this time. If you need assistance, please hang up and dial your operator. This is a recording.

USE OF SIGNALS WITH DIRECT DISTANCE DIALED CALLS



NOTES

(1) This signal is simply relayed from office to office.

(2) Connection must be established before remaining or regenerated digits are sent ahead.

(3) Second off-hook signal causes release of sender and cut-through for talking or flashing.

(4) Second dial tone is used in some cases but is not satisfactory in ultimate.

(5) To stop answering service or to release a locked-in hold condition. This signal is delayed by a timed release feature for an interval of about thirteen to thirty-two seconds in some systems.

(6) May originate at any one of the indicated offices.

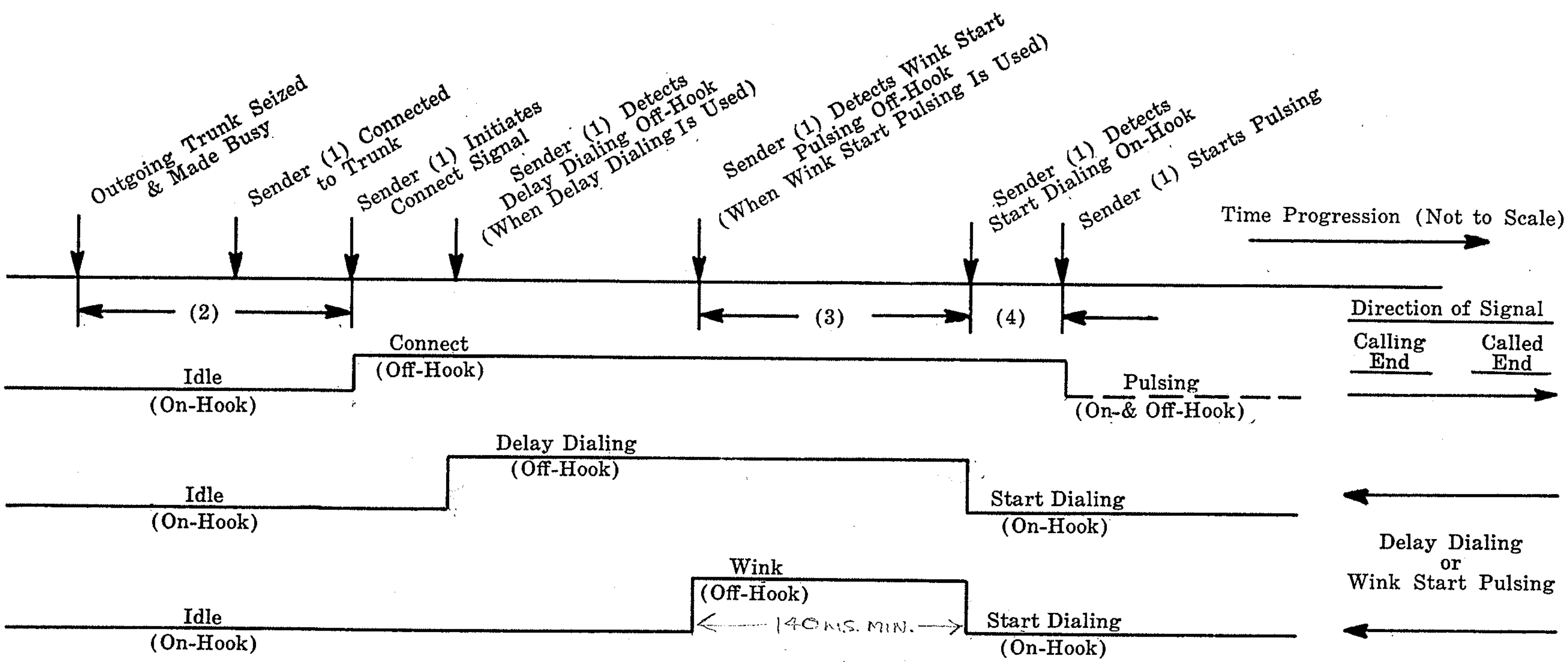
(7) Answer supervision must be returned to the office where charging control is centered. It is desirable to return real or simulated answer supervision to the originating office in all cases, if feasible.

(8) Announcement may be by operator or by machine (recorded announcement).

(9) Some offices may return flashes in synchronism with tone. The ultimate objective is to eliminate flashing signals on a long-term basis and to transmit tone only. However, when certain inband signaling systems are used and either flash only or both flash and tone are transmitted, it may be necessary to use tone appliers to insure that satisfactory tone is returned to the customer.

(10) Stop is returned when selector reaches level having trunks which require this signal.

DELAY DIALING METHOD A AND WINK START PULSING



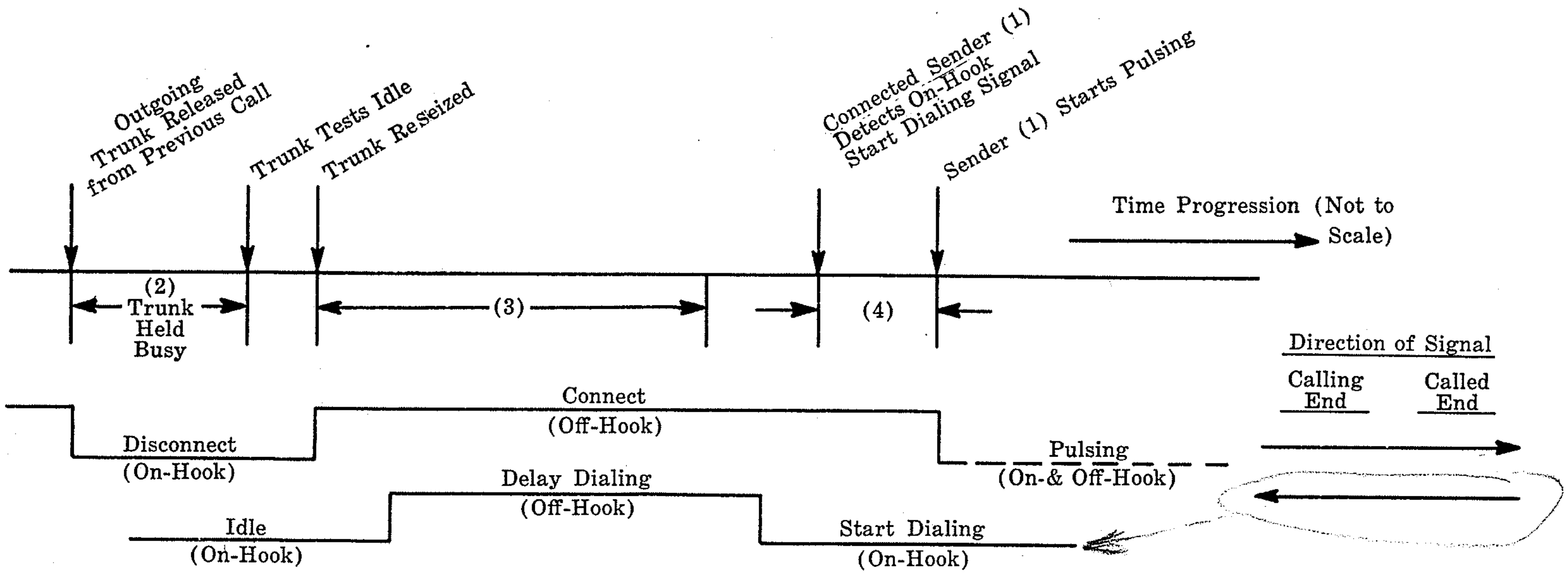
(1) The sender indicated is in the sending office.

(2) This measured delay is provided to insure the minimum interval of 750 milliseconds required for disconnection.

(3) The momentary wink off-hook pulse, nominally 200 milliseconds (140 milliseconds minimum), is transmitted towards the calling end when the called end is ready to receive pulses.

(4) This delay of 70 milliseconds is necessary on dial pulsing trunks because dial pulsing receiving circuits under certain conditions are momentarily disabled to prevent registration of a false reflected pulse caused by the sending of the start dialing on-hook. A similar delay of approximately 200 ms is used on some MF trunks to prevent a false stop dial which can result when certain types of inband signaling are used.

DELAY DIALING METHOD B – SENDER CONNECTED AFTER DELAY DIALING SIGNAL



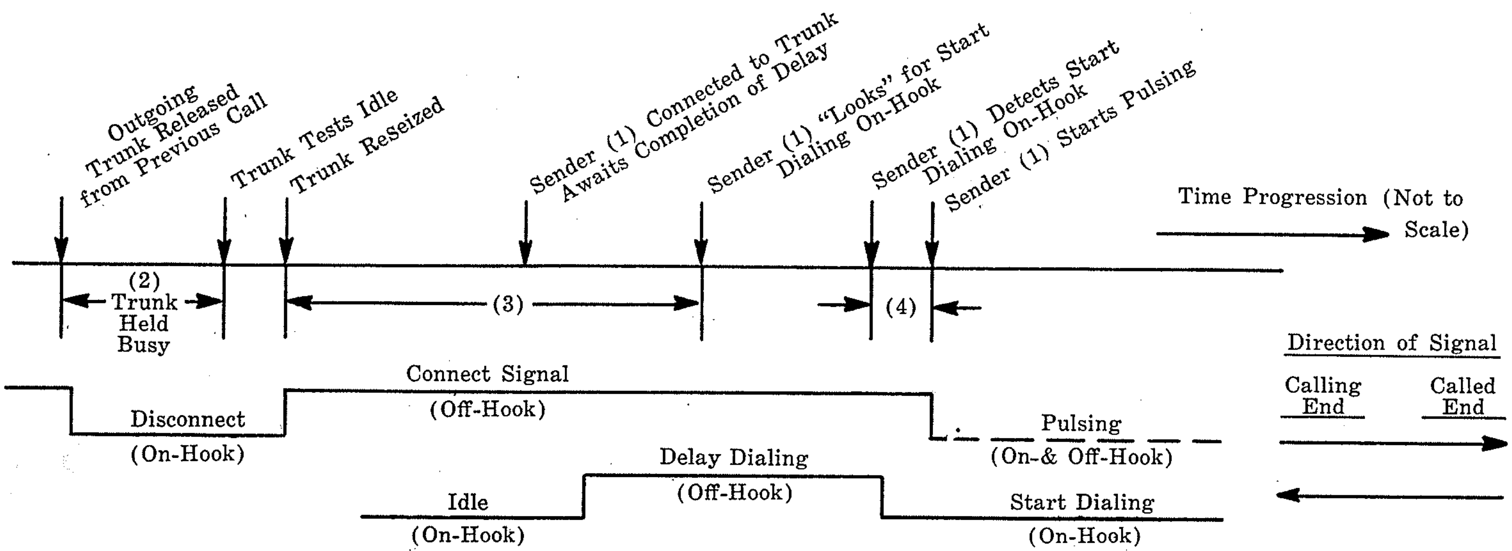
(1) The sender indicated is in the sending office.

(2) The minimum interval required for disconnection of all 2-way and some 1-way trunks is obtained by holding the trunk busy after disconnection for a minimum of 750 milliseconds.

(3) This minimum 300-millisecond interval must elapse before the sender tests for on-hook as the start dialing signal. It insures sufficient time for sending forward the connect signal and the return of the delay dialing signal.

(4) This delay of 70 milliseconds is necessary on dial pulsing trunks because dial pulsing receiving circuits under certain conditions are momentarily disabled to prevent the registration of a false reflected pulse caused by the sending of the start dialing on-hook. A similar delay of approximately 200 ms is used on some MF trunks to prevent a false stop-dial signal which can result when certain types of inband signaling are used.

DELAY DIALING METHOD B – SENDER CONNECTED BEFORE DELAY DIALING SIGNAL



(1) The sender indicated is in the sending office.

(2) The minimum interval required for disconnection of all 2-way and some one-way trunks is obtained by holding the trunk busy after disconnection for a minimum of 750 milliseconds.

(3) This minimum 300-millisecond interval must elapse before the sender tests for on-hook as the start dialing signal. It insures sufficient time for sending forward the connect signal and the return of the delay dialing signal.

(4) This delay of 70 milliseconds is necessary on dial pulsing trunks because dial pulsing receiving circuits under certain conditions are momentarily disabled to prevent the registration of a false reflected pulse caused by the sending of the start dialing on-hook. A similar delay of approximately 200 ms is used on some MF trunks to prevent a false stop-dial signal which can result when certain types of inband signaling are used.

DIGIT TIMING REQUIREMENTS

	4A & 4M			4A & 4M CAMA		Crossbar Tandem (Incl. CAMA)		No. 5 Crossbar (Incl. CAMA)		SxS CAMA		No. 1 ESS	
	DP Sender	DP Reg.	MF	DP	MF	DP ϕ	MF	DP	MF	DP	MF	DP	MF
1st digit must be received in less than______seconds from seizure.	10	16	10	16		15		19 4.4##		15		16 10##	
Both 2nd and 3rd digits must be received in less than______seconds from registration of 1st digit.	10		10										
2nd and 3rd digits must each be received in less than______seconds from registration of previous digit.		16		16		15		19 4.4##		15		16 5##	
4th digit must be received in less than______seconds from registration of 3rd digit.	3*	3		16		15				15		16 5##	
When total number of digits expected is indicated to register by class marks or translation of one or two initial digits, each digit after 3rd digit must be received in less than______seconds from registration of previous digit.								19 4.4##					
When total number of digits expected is not indicated to register, each digit after 3rd digit must be received in less than______seconds from registration of previous digit.		3						3					
Each digit after 4th digit must be received in less than______seconds from registration of previous digit.	3*	3		16#		15#, **				15#		16 5##	
All digits must be received in less than______seconds from seizure.					10		20	19	19		19		16 10##
All remaining digits must be received in less than______seconds from registration of 3rd digit.	10		10										

*Units not incorporating recent changes have comparable but not identical timing.

#In the future the interval following the seventh digit will be subject to 3-second timeout if interchangeable code assignments make this necessary.

ϕIncludes both 3-and 10-digit register operation.

**Assumes discontinuation of timing for stations digit.

##Under overload conditions.

SENDER, REGISTER, OR LINK ATTACHMENT TIMING REQUIREMENTS

		4A & 4M	4A & 4M CAMA	Crossbar Tandem (Incl. CAMA)	No. 5 Crossbar (Incl. CAMA)		SxS CAMA	No. 1 ESS
					DP	MF		
Sender or register in distant office must be attached in less than __ seconds or originating sender in indicated system may time out.	Normal Traffic	30	20	20	19	13	19	16
	Heavy Traffic	5 (Note 1)	5 (Note 1)	3, 5 or 8	4.4	4.4	4.6	4
Link or line finder in distant office must be attached in less than __ seconds or originating sender in indicated system may time out.	Normal Traffic	30 (Note 2)	20	20	19		19	16
	Heavy Traffic	30 (Note 2)	20	3, 5 or 8	4.4		4.6	4

NOTES:

(1) This is present nominal adjusted interval. The range of adjustment is 3-8 seconds.

(2) 20 seconds in 4M.

Section 5
Equipment

EQUIPMENT REQUIREMENTS

CONTENTS PAGE

1. GENERAL

1.01 This section describes equipment arrangements and features used for originating and completing calls through the distance dialing network. These arrangements are described here in three categories:

Station Equipment
Dial Switching Equipment
Miscellaneous Equipment Arrangements

References to equipment herein are based on equipment of Bell System manufacture; however, other equipment may be used if it provides the necessary operational features.

1.02 Section 2 of these Notes describes the Numbering Plan; Section 3, the Switching Plan; and Section 4, the Interoffice Signals. The equipment arrangements described here are designed to operate within the bounds stated in those sections.

2. STATION EQUIPMENT

General

2.01 Station equipment consists of arrangements provided at customer premises to permit the telephone user of the exchange and toll networks to originate and receive communications. Station equipment permits incoming and outgoing signaling, local switching, concentrating and 2-way communication at customer premises.

2.02 Incoming signaling consists of ringing a bell or operating some other device which will make the user aware there is a call coming in, and in addition, on Centrex-CU lines, interpreting the digits being passed forward from the central office so that the call can be routed through the dial private branch exchange to the proper station at the customer location.

2.03 Outgoing signaling consists of an off-hook condition and dialing (pulse or push button signals) on a line to operate central office or PBX equipment to route a call to its destination.

2.04 Local switching and concentration, using key equipment and private branch exchanges, provide flexibility, versatility, and efficient use of telephone lines at customer locations.

2.05 Although to date the station equipment is being used primarily for voice communications, there is a growing family of devices for transmitting other forms of information over the telephone network. However, this section will not be concerned with any devices except those used with voice communications.

Common Battery Operation

2.06 Direct current for signaling the central office and for energizing the station transmitter is supplied over telephone lines from a common battery located in the serving central office.

Lines

2.07 Individual lines are central office lines which serve only one customer. There may be several telephone sets bridged across this line but all are in use by one customer.

2.08 Multiparty lines are central office lines which serve more than one customer. Since the line has only one set of equipment at the central office, only one customer can use the line at one time for separate calls. Each customer may be selectively signaled (up to four parties using superimposed ringing systems or eight parties using frequency timed ringing). Beyond four parties (superimposed) or eight parties (frequency time) either semiselective or code signaling is used. Selectivity is obtained by ringing to ground from either side of the telephone line and by using cold cathode tubes, polarization, or harmonic generator.

Dialing

2.09 Dialing in station equipment may be either rotary dial pulses or push-button signals and is used for generating a signal which permits the central office or PBX equipment to route the call through the switched network to its destination.

2.10 Rotary dials are used to pulse (alternately open and close) a central office or PBX line. Figure C, Chart 1, shows a typical rotary dial number plate. Figures A and B, Chart 1, show two typical 7-digit station number cards used with rotary dial station equipment. The dial speed is controlled to 10 ± 0.5 pulses per second by a governor which maintains a constant speed. The make-break ratio is critical and is controlled to 61 ± 3 percent break. This close control of make and break time extends the dialing range.

2.11 Push-button pads are used to generate tones needed to operate central office or PBX equipment when push-button service is provided. Figure F, Chart 1, shows a typical push-button pad. Figures D and E, Chart 1, show two typical 7-digit station number cards used with push-button station equipment. The pad shown in Figure F is arranged to generate two frequencies whenever one of the buttons is depressed.

Equipment

2.12 Station equipment can be divided into three broad categories; these are: telephone sets, key telephone systems, and private branch exchanges. There are other categories but these three are by far the most numerous and will be the only ones discussed here.

2.13 A telephone set or its equivalent must be used by anyone communicating by voice over the exchange and toll network. A telephone set consists of a transmitter, a receiver, an induction coil (hybrid), a switchhook, a dial, and a ringer. Direct current and ringing current for operating the telephone set are usually supplied from the central office. Two typical telephone sets are shown in Figures A and B, Chart 2. There are many other types, too numerous to be covered here.

2.14 Key telephone systems are station switching systems, located on customer premises, consisting of one or more multibutton telephone sets, similar to those shown in Figures A, B, and C, Chart 3, and associated relay equipment. These permit mutual access to and control of a number of central office lines. A number of telephone sets can be used in key systems. They range from single line pickup through multibutton sets of one, four, six, etc., buttons to a variety of turrets, key boxes, and consoles permitting upwards of 30 lines to be picked up. Systems of this type are assembled for reasons of flexibility and versatility. Key systems permit one or more persons to select any one of a number of lines available to them by depressing a button on the telephone set. Calls can be originated, received, or held and a number of other functions performed by using key systems of various sizes and types.

Private Branch Exchange

2.15 Private branch exchanges (PBX's) are manual or dial systems which basically permit concentration and intercommunication. The concentrating feature permits a large number of telephone stations to share the use of a number of central office lines on a one-at-a-time basis. The intercommunicating feature permits stations on the same PBX to talk to each other without using central office equipment. There are a number of other functions performed by PBX's, but this discussion will be limited to central office and intercommunicating calls.

2.16 Manual PBX switchboards connect central office trunks to stations by the use of jacks, cords, and cord circuits. Cord circuits contain signaling, transmission, dialing, and supervisory equipment. An attendant manually completes all calls (including station-to-station) through a switchboard. Rotary dials or pushbutton pads are used on central office lines terminated in the switchboard.

2.17 Dial PBX equipment can be step-by-step, crossbar, or electronic. The dial equipment usually has an associated manual switchboard or console whose primary purpose is to connect incoming central office calls to stations. With "Centrex-CU" service a central office call can be completed to a station without operator assistance since the dial equipment interprets digits forwarded from the central office equipment and routes the call directly to the station. Outgoing calls to a central office can be made by dialing through the PBX equipment or by placing it through an attendant position.

2.18 The manual switchboard (attendant position) associated with the dial PBX equipment is similar in appearance and operation to the manual PBX switchboard discussed in 2.16. One difference is that station jack appearances are not associated with lamps. This is because the jacks are used for call completion only. When a station wants the attendant position, dialing "0" routes it to a separate set of attendant position jacks rather than to the station jack.

2.19 Consoles serve the same purpose as attendant switchboards. They are used rather than manual switchboards for reasons of appearance, because they occupy less space and because reduced attendant motion in their operation increases speed of call completion. The use of consoles has transferred actual switching into the associated dial apparatus.

2.20 Step-by-step dial PBX's use switches (line finders, selectors, and connectors) to complete calls mechanically. These switches follow dial pulses, climbing vertically to select levels and then moving horizontally, on a level either automatically (selector) or again following dial pulses (connector). The number of switches in a dial PBX are determined by such factors as the number of stations, holding time per call, number of trunks, etc. The equipment for a step-by-step system can vary from one 7-foot frame for 100 lines (2-digit system) to a large number of frames, requiring a separate switchroom, in systems consisting of several thousand lines.

2.21 A crossbar dial PBX is one that uses common control equipment to establish all connections. A typical system contains the following main parts:

(1) A crossbar switch field through which a path is established by the operation of a specific select magnet followed by the operation of two hold magnets. This interconnects two verticals over a selected horizontal path called a link.

(2) A marker, which is the logic element of the system, establishes calls through the switch field in response to signals received from station lines, trunks, registers, etc. A marker

processes one call at a time. Simultaneous bids are sequenced by a gating arrangement. The marker serves each originating register, one trunk bid in each trunk group, and one station bid in each horizontal group sequentially. When all originating registers are in use, the marker stops until a register becomes available.

(3) Originating registers are needed to originate calls. They function as a dial pulse receiver and counter and for digit, class, and group information storage. In addition, the register provides dial tone to calling stations or trunks. The register responds to one-, two-, or three-digit numbers.

(4) A junctor circuit is a double ended circuit required to establish station-to-station calls within the PBX. It provides ringing current to the called station and talking battery and supervision for the calling and called stations.

(5) Various types of lines and trunks to make this system compatible with other systems and equipments.

2.22 One of the new PBX's applies the advantages of electronic switching techniques to station switching. Use of a centralized stored program common control and solid-state devices permits a considerable reduction in the amount of equipment installed on customer premises. The stored program directs all the processing and diagnostic maintenance routines, as well as traffic data collection on switch units – all from the central office.

2.23 The system is organized in two units: a switching unit located on the customer's premises, and a control unit located in the central office. Exchange of information between the control unit and the switch unit is over high-speed data links. One control unit can serve several switch units. A single switch unit may serve several customers. Calls to this system are handled one at a time, under control of the stored program instructions.

2.24 Time division switching, an application of the principle of speech sampling, is used. This permits a number of conversations to use the same transmission path and drastically reduces the number of transmission paths on the customer's premises.

2.25 The electronic PBX has been designed to be compatible with present station equipment and electromechanical central offices. Both push button and rotary dial station sets are served by this system without the need for additional equipment.

2.26 Printed wiring boards are the basic hardware element of the system on which are mounted transistors, diodes, resistors, networks, etc. Infrequent replacement of circuit packs is the basic maintenance routine.

3. DIAL SWITCHING EQUIPMENT

3.01 Distance dialing places no restriction on the type of dial switching system (step-by-step, crossbar, etc.) provided at Class 4 or 5 offices (Section 3 describes office classes); the facilities should, however, send, receive and be actuated by the signals discussed in Section 4. Common control equipment such as registers, senders, directors, etc., are used in many instances to effect economies in switching traffic and to provide uniform dialing procedures. Class 1 and 2 offices are equipped with common control and Class 3 offices with either common or direct control switching facilities, having the control switching point (CSP) features described in Section 3.

3.02 Destination Code routing is used in the Distance Dialing System. This requires 7 or 10 digits to identify the called station. However, the number of digits actually passed between offices may vary. Chart 4 shows the minimum number of digits that all classes of offices must be arranged to receive over incoming trunks. It may be desirable for an office to receive more than this minimum number and such situations should be studied jointly by the Companies involved. In general, the 7-digit number is sent as far as the toll center on which the Class 5 destination office "homes" so that the toll center can route the call properly.

3.03 The following paragraphs describe arrangements and features generally available with local and toll switching systems.

Local Central Offices (Class 5 Offices)

3.04 Local central offices are arranged to process both originating and terminating traffic.

3.05 Originating Traffic – The central office receives dial pulse or push-button signals from stations and routes each call. This may be to complete the call locally to another station, to route the call to the distance dialing network, to an operator, or to a recorded announcement.

3.06 Terminating Traffic – The central office receives signals from other offices (local, tandem, or toll) and uses the received information to complete calls to local stations. When connecting to the station line, it applies ringing voltage to ring the called station. If the called line is busy, busy-tone is returned to the calling party. If the called station is a station on a PBX equipped for in-dialing (Centrex-CU), the local central office is arranged to transmit the dial pulses required to reach the PBX station. Ringing current is then furnished by the PBX.

3.07 Local central office equipment may be categorized as direct control equipment or common control equipment.

Direct Control Equipment (Class 5 Offices)

3.08 Direct control equipment is actuated directly under the control of dial pulses received from local stations or from other central offices. Types of equipment which operate in this manner are:

1. Step-by-Step

2. Relay

3. Motor Switch

3.09 On local calls within the office, or calls completing from distant offices, dial pulses actuate switches or relays in proper sequence to connect the calling party to the called station.

3.10 On local calls to other offices, the central office code dial pulses actuate switches or relays to select a trunk to the distant office. The remainder of the digits are pulsed directly to the distant office which completes the call using the received digits. Some typical trunking plans for completing inward calls in small and medium-sized step-by-step exchanges are discussed in Appendix A. While the arrangements shown are those commonly used in the Bell System and are not necessarily the same as those employed in the Independent industry, the fundamental principles involved in completing inward traffic are applicable in all types of offices.

3.11 On outward toll calls, destination code routing requires that the Class 5 office send the complete 7- or 10-digit called number to the toll center. This requirement is met by having the customer prefix the called number with an access code which connects the calling line to a toll-connecting trunk circuit. The customer-dialed 7 or 10 digits are then sent to and registered in the CAMA office. Where Centralized Automatic Message Accounting (CAMA) arrangements are used, Automatic Number Identification (ANI) equipment at the local office may be used to identify the calling station and transmit its identity to the CAMA equipment by sending multi-frequency pulses over the same trunk after the dial pulsing has ended. The CAMA equipment then records all pertinent information concerning the call. When ANI equipment is not provided, operator identification (ONI) is used to obtain the calling station number. This is keyed into the CAMA equipment by the operator.

3.12 At local offices not equipped for Automatic Message Accounting operation, toll traffic has to be routed to an operator who places the call on the network and records the information necessary for billing. The operator has direct trunks to the toll or tandem switching office and uses multifrequency pulsing (to common control toll offices) or dial pulsing (to direct control toll offices) to advance the call.

3.13 Incoming trunks from common control offices to direct control offices must be arranged for stop-go dial pulsing and usually have an integrity check feature.

Common Control Equipment (Class 5 Offices)

3.14 Common Control Equipment receives dial pulses or push-button signals from calling stations or dial pulses, multifrequency signals, or revertive pulses from other offices. It stores the digits (except on calls terminating in SxS or Panel offices), determines the proper disposition of each call, and routes it accordingly. Types of equipment which are included in this category are:

1. Crossbar
2. Panel
3. Common Control Step-by-Step
4. Electronic

3.15 On local calls within the office or calls completing from other offices, the incoming pulses are used to identify the line associated with the called number. The line is tested. If it is not busy, a connection is established and the ringing signal is applied to the called station line. If the called station is busy, the office returns busy tone to the calling party. If the called number is not a working number, the call is routed to an intercept operator or to a recorded announcement.

3.16 On calls to other offices, the central office stores the digits received from the calling station, translates and routes the call,and outpulses digits as required to the next office. The use of multifrequency pulsing is increasing for calls to common control offices although revertive pulsing still handles a high percentage of the traffic. Dial pulsing is used in routing to direct control offices.

3.17 Some common control offices have the ability to delete or convert digits as required to facilitate routing of calls at succeeding offices. An alternate route may be selected (except from panel) when the direct or most direct trunk group cannot be used.

3.18 Certain types of common control central offices can be arranged with Local Automatic Message Accounting (LAMA) equipment. Other common control equipment types can be equipped with ANI to work into CAMA equipment for recording toll calls.

3.19 Certain types of local common control offices are equipped with message registers which record a cumulative total of the number of message units generated by a calling station. This arrangement may be used for local or EAS calls, in conjunction with CAMA recording for toll calls, where the customer is billed for the number of message units originated by his station.

Local Offices — Miscellaneous Arrangements

3.20 Inward calls may be either operator or customer originated. These calls usually are completed by fully automatic means, but certain calls such as collect to coin stations, requests for busy line verification, etc., require the services of an inward operator. (Calls dialed by either customers or distant operators should not have access to verification and coin control equipment.)

3.21 Neither called operators nor called stations should be signaled until the full complement of digits has been received.

(1) If calls to "operator codes" (Sec. 2) or plant test codes (Sec. 7) reach an outgoing trunk circuit before the complete code has been dialed, provision should be made to wait for any remaining digits before the connection is cut through. Otherwise, off-hook supervision upon fast answers may block sender outpulsing and interfere with the operation of the automatic switching equipment.

(2) Level hunting connectors used on distance dialed calls to reach PBX terminals should be arranged not to trunk hunt until all digits have been received.

(3) Equipment arrangements should be such that selection of the called customer's line will not occur until all digits (including the ST signal on MF pulsing) have been received.

3.22 Outgoing trunks from selector levels that terminate on equipment arranged to return a "stop dial" signal present a special problem. The selector serving such trunks should return a "stop dial" signal before hunting for the outgoing trunk. This requirement is explained in more detail in Chart 5.

Toll Switching Equipment (Class 4, 3, 2, or 1 Offices)

3.23 Toll Switching offices are generally equipped with common control equipment. However, Class 4 and Class 3 offices have been established using direct control equipment. (Class 3 offices can use direct control equipment only where connecting offices are equipped with common control equipment capable of adding, deleting, or converting digits to facilitate switching through the Toll office.) Toll switching offices serve to provide access between local offices and the distance dialing network and to provide economical traffic routing arrangements including alternate routing capability for some trunk groups. Types of equipment are:

1. Crossbar
2. Step-by-Step
3. Electronic (Future)

Direct Control Class 3 and 4 Offices

3.24 These are 2-wire offices which must be balanced to meet transmission objectives. (See Section 6)

3.25 The switching trains must be carefully engineered for compatibility with the numbering plan. Digit-absorbing techniques are frequently used to minimize equipment quantities.

3.26 These offices can be equipped with CAMA equipment to provide Automatic Message Accounting for their tributaries.

3.27 Traffic alternate routing and digit manipulation (deletion, prefixing and substitution) are not feasible with these offices.

3.28 Traffic separation is accomplished by employing separate trunk groups.

Two-wire Common Control Class 2, 3, and 4 Offices

3.29 Crossbar tandem and the tandem portion of No. 5 Crossbar offices are most generally used for tandem switching offices.

3.30 Each office must be balanced to meet transmission objectives. (See Section 6)

3.31 These offices can be arranged to provide CAMA service for their tributaries.

3.32 They may work in connection with the Traffic Service Position System (TSPS).

3.33 These offices have the ability to manipulate digits (delete, prefix, and substitute) as required to maintain uniform numbering arrangements.

3.34 Traffic separations are accomplished through the use of trunk class marks as shown in Chart 6.

3.35 Traffic alternate routing arrangements are used to provide the most economical trunking arrangements. (See Section 3, Appendix A)

Four-wire Common Control Class 3, 2, and 1 Offices

3.36 No. 4 Crossbar is the type of equipment presently used for these offices. In the future, some No. 4 offices will be equipped with an Electronic Translation System (ETS). In addition, 4-wire Toll ESS systems are expected to become available The features described for the 2-wire common control arrangements are all used in the 4-wire toll offices. However, these 4-wire offices do not require through (office) balancing. Pad switching arrangements (high loss operation, see Section 6, Paragraph 4.09) are used. Where it is required, CAMA equipment is incorporated into an office. Alternate routing and extensive translation and digit manipulation features are also available. Trunk class marks are used for traffic separation. (See Chart 6)

Overload Controls

3.37 General – Distance dialing systems are engineered to give a satisfactory grade of service to traffic offered during the busy hour. However, it is expected that there will be occasional surges or peaks of traffic beyond the capacity of the facilities provided. During these overloads the entire network, as well as individual switching systems, needs to maintain maximum call handling capacity even though the offered traffic is far in excess of engineered capacity. Therefore, precautions are taken to ensure that overloads, regardless of cause, do not spread throughout the network and temporarily reduce its call-carrying capacity. Alert administration of the operating plant, early detection of overloads, and immediate application of corrective measures will do much to reduce the effects of isolated overloads. The most effective results are obtained by including in the equipment design, control arrangements which prevent overloads from spreading. (See Section 4, Charts 6 and 7.) For example, trunk circuits from keypulsing switchboards may be arranged to send the "connect" signal forward only after a switchboard sender is attached instead of immediately upon seizure by the operator.* Thus, an "all senders busy" condition in the sending office will not waste the capacity of the incoming equipment in the receiving office; the latter will be called in only when a sender is available to send pulses to it.

* The trunk, if 2-way , is so arranged that an incoming call, received while the operator is waiting for a sender, will take preference.

3.38 Directional Reservation Equipment (DRE) is used at lower ranking offices on a 2 -way final trunk groups to higher ranking offices. When traffic volumes reach a level where only a predetermined number of trunks (1 to 5) are idle, an all trunks busy indication is given to the common control equipment at the lower ranking office. This in effect reserves these 1 to 5 trunks for traffic in the network so that calls can be completed to or via the lower ranking office. In periods of widespread overload conditions, DRE reduces the number of multilink calls originating from lower ranking offices and reduces the number of ineffective call attempts that get into the network.

3.39 Dynamic Overload Controls – During overloads, it is necessary to use all available idle facilities, give priority to single link connections, and inhibit growth of switching congestion. Four controls are now in use in No. 4 type crossbar offices to promote these objectives:

(1) Automatic Cancellation of Short Sender Timing.

This feature conserves decoder usage during periods of decoder congestion by reducing the number of calls routed to sender overload announcement following sender time-out.

(2) Automatic Cancellation of "Follow with Second Trial – All Trunks Busy."

During overloads, the probability that a call which failed on the first attempt will complete on second trial is relatively small. Cancellation of the second trial reduces unproductive decoder and marker seizures.

(3) Automatic Cancellation of Alternate Routing.

When the number of calls waiting for a sender in a high rank office reaches a preset level, signals are sent over telegraph channels to actuate devices in the subtending offices to cancel alternate routing of traffic to the congested office. Also, if desired, first routed traffic may be denied access to the high-usage trunk group to the overloaded office.

(4) Automatic Traffic Overload Reroute Control (TORC).

This feature is being designed for Regional Centers equipped with the electronic translator system. TORC will be actuated when all circuits between two Regional Centers are busy. It permits traffic normally sent direct from one Center to another to be routed via a third Regional Center having switching capacity and spare facilities to the desired Regional Center.

3.40 Network Management Control Centers – The Bell System has established Network Management Control Centers at several locations around the country. These centers automatically receive network status indications which are displayed and used in directing the application of controls to the toll network. This permits the network managers to optimize the use of facilities and to avoid having traffic overloads tie up portions of the network. Network management is particularly useful on known heavy traffic days or in a situation which causes an unexpectedly heavy surge of traffic to any particular location or section of the country.

Dynamic overload control features are also under development for tandem systems in metropolitan trunking networks.

3.41 Line Load Control – Local offices may be arranged so that non-essential subscriber lines can be restrained from originating calls in a general emergency situation. When local calling volumes exceed the capacity of the office and threaten to disrupt service to all subscribers, controls are actuated to discontinue calling from the nonessential type lines until traffic volumes subside and the restraints can be safely removed. This preserves service to the more essential subscribers. A feature known as "intersender timing" is also available for local offices. It operates to limit the amount of traffic switched forward to an overloaded tandem office.

Operator Facilities

3.42 Switchboard positions should be arranged:

(1) To ring forward and ring back over intertoll trunks.

(2) To pulse by means of dials or keysets. Switchboard position and cord circuits should be arranged for pulsing on both front and rear cords and for operation with a "start dial" lamp. (It is desirable that switchboards with MF pulsing not send MF tones back to the customers.)

(3) For switchhook supervision on both front and rear cords.

Trunk Circuits

3.43 Trunk circuits should be arranged to transmit and receive on-hook and off-hook signals as required. The signals are described in Part 2 of Section 4. They are:

(1) Connect and disconnect
(2) Station off-hook and on-hook
(3) Ring forward
(4) Ringback

3.44 Offices receiving traffic over loop signaling trunks from Bell System Crossbar Tandem offices need to have the incoming trunk circuits equipped with balanced windings on the pulse receiving relays to avoid false disconnect upon receipt of a ring forward signal. The ring forward on-hook pulse received over an incoming trunk is converted by the Crossbar Tandem office into a positive 130-volt signal simplexed on the outgoing trunk conductors. When the outgoing trunk from the crossbar tandem uses E&M lead signaling, no problem exists; the simplex signal is merely converted to an on-hook pulse. However, when the outgoing trunk employs loop signaling, the simplexed pulse may cause false disconnect of the distant terminating equipment if windings of the pulse receiving relay are not balanced.

3.45 Toll connecting trunks incoming to Class 5 offices preferably should not be terminated on line circuits or links. However, if this type of termination is used "stop-go" signals must be furnished.

In this connection, it is well to remember that trunking arrangements involving delay dialing and stop-go signals need to conform to the capabilities of dial pulse senders. Senders in No. 4 and No. 5 Crossbar systems, when connected to a particular dial outpulsing trunk group, can be set to expect only one of the following combinations of signals:

(1) No delay dialing and no stop-go.

(2) Only delay dialing.

(3) Only one stop-go.

(4) Both delay dialing and one stop-go.

Some crossbar tandem senders presently in operation, on a particular dial outpulsing trunk group, can be set to expect only one of the following combinations of signals:

(1) No delay dialing and one stop-go.

(2) Only delay dialing.

More recent crossbar tandem 11-digit senders permit operation with the following signals:

(1) No delay dialing and one stop-go.

(2) Both delay dialing and one stop-go.

3.46 Dial back operator office trunks provide facilities over which a calling customer in a community dial office (CDO) may reach the operator at the operator office, who, in turn, may dial back over the same trunk to connect the calling customer to a called customer served from the same CDO. Dial back operator office trunks may be used as toll connecting trunks for completing inward dialed calls, provided they return the standard supervisory and control signals discussed in Section 4 and conform to VNL + 2.5 dB design as discussed in Section 6. If these trunks have other signaling characteristics, inward traffic to the CDO's should be handled through the inward operator, or separate toll connecting trunk groups should be established to each CDO. It is not contemplated that dial back type trunks will be used for customers to gain access to Bell System CAMA equipment.

3.47 It is desirable that all operator trunks, except dial-automatic or multifrequency-automatic, be arranged to return audible ringing signal to the calling end. In addition, trunks to "121" (inward) operators and leave-word operators (11XX) should be arranged to ring back and to receive ring forward.

3.48 Joint Control Trunks – Although the distance dialing network operates on the basis of "calling party control," it may sometimes be necessary to complete calls to Class 5 offices over trunks which are arranged for control by either end (joint control). This is permissible if the joint control trunks are arranged to:

(1) have the "toll center" office end of the trunk release its switching equipment upon calling party disconnect, and then

(2) make the trunk appear busy until the called party disconnects.

Note: Trunk busy should not be released if called party flashes.

3.49 Two-Way Trunks – If these trunks are not arranged for joint control, they should have the following operating characteristics:

(1) The calling end of a 2-way trunk should be held busy a minimum of 750 milliseconds after sending the disconnect signal forward to the called end. During this "guard" interval, off-hook supervision from the called end should not start a new call at the calling end.

(2) After the called end recognizes the disconnect signal (140 milliseconds on-hook), it should time for an additional interval of not less than 610 milliseconds to permit the switches to release before giving an idle indication for calls in the opposite direction.

3.50 Glare – Two-way trunks are subject to occasional simultaneous seizures at both ends because of the unguarded interval between the seizure of the trunk at one end and the consequent making busy of the trunk at the other end. This is called Glare. These simultaneous seizures cause each end of the trunk to receive an immediate and sustained off-hook signal. When delay dialing signals are used, the blocking condition is assumed to exist if the off-hook condition persists longer than the intervals shown in Chart 7 of Section 4. When delay dialing signals are not used, the blocking condition can be detected immediately upon trunk seizure. Equipment at each end should be arranged to: (1) prevent the off-hook signal from reaching the charging control equipment and (2) disengage from this mutually blocking condition. To disengage from the blocking condition, some types of common control equipment are arranged to flash forward at the reorder rate when the blocked condition is recognized. The flash is sent after the expiration of the intervals shown in Chart 7 of Section 4 on MF pulsing trunks; it is sent immediately on dial pulsing trunks which do not require delay dialing. The trunk circuits are so arranged that the flash brings about the release of the connection at the distant end. The near end is also arranged to release and route to reorder or, alternatively to complete the call over the same trunk after a 2-second pause (if the start pulsing signal is received from the distant end).

3.51 Tone Appliers – When satisfactory tone cannot be returned to the calling customer from the point at which a call is blocked, a locally generated tone, synchronized with the flashing signal that is returned, must be supplied. The Bell System arranges certain trunks incoming to the various switching systems to supply this locally generated tone toward the calling office. (Some Independent companies supply this tone through an element of the switching system.) Any tone or tones that may appear at the trunk circuit along with flashes are blocked so that they cannot be confused with the locally applied tone. The following suggestions, illustrated in Chart 7, may serve as a guide for determining which trunk circuits should be arranged for tone application.

(1) In general, tone appliers should be provided at the first Class 4, 3, 2,or 1 office encountered by customer dialed traffic. Included in this group are the incoming trunk circuits at offices arranged for centralized recording of automatic message billing data.

(2) Tone appliers are required on trunks outgoing from Class 5 offices equipped with LAMA when these trunks terminate on step-by-step intertoll selectors not arranged to return busy tones, or usually when single-frequency (SF) signaling of the types found in the Bell System are used. (If tone appliers are provided at the Class 5 office on trunks using SF signaling, they are not required with the incoming trunk circuits as noted above.)

Special Requirements

3.52 The distance dialing network imposes special requirements on signals and features sometimes found in local central offices as covered in Paragraphs 3.53 through 3.56.

3.53 Dial tone should not be applied to any incoming toll connecting or intertoll trunk. If for circuit reasons dial tone cannot be removed from incoming trunks, provision should be made for blocking the tone at the connecting office.

3.54 Second dial tone is not desirable. Equipment arrangements precluding its use are preferred.

3.55 Control of the connection:

(1) On customer dialed calls, the connection should be under the immediate control of the calling party and under delayed control (timed disconnect) of the called party. The timed disconnect period ranges from 13 to 32 seconds in most Bell System designed equipment.

(2) On operator dialed calls, the connection between the operator and the calling customer should be under joint control; the equipment from the operator to the called station should be under control of the operator.

3.56 Timed cutoff arrangements in local offices (to limit conversation time on local calls) are undesirable. Where they are used, provision should be made to disable the feature on both inward and outward DDD calls.

CONN CTRL

Digit Capabilities and Translation

3.57 Digit Capacities – Chart 8 is a summary of both dial pulsing and multifrequency digit and translation capacities for various switching systems. Any particular installation may not be equipped for the full capacity shown.

3.58 Direct Distance Dialing is currently based on the use of 7- or 10-digit called station numbers and the more recently designed equipment is not arranged to handle more than 10 digits. If operator dialing is used to complete calls to some locations which have an eighth local number, a minimum capacity of 11 digits is required in the intermediate equipment.

3.59 Six-Digit Translation – When a foreign area can be reached by more than one route, the first six digits of the 10-digit number (area and office codes) of each call to that area are examined (translated) to select the preferred route. (See Section 3, Part 6)

3.60 Digit Deletion – The number of digits which can be deleted is independent of the number of digits translated for routing. Any equipped combination of digits translated and digits deleted may be used. Digit deletion always begins with the first digit received.

Some of the more important uses of the digit deletion features are:

(1) Send forward all digits received when they are required in the next office. (Delete 0)

(2) Drop an area code when pulsing into that area. (Delete 3)

(3) Drop an office code when pulsing into that office. (Delete 3)

(4) Drop both area and office code when pulsing into that office and both were received. (Delete 6)

(5) Drop an area and/or office code when other digits are to be substituted for them. (Delete 3 or 6) This is called code conversion. (See Paragraph 3.62)

(6) Drop part of an office code when the remaining code digits are all that is required to route the call to that office. (Delete 1 or 2)

3.61 Prefixing – One, two, or three digits may be prefixed to the routing digits (Chart 8). An example is the prefixing of the extra digits required for switching through a step-by-step primary center. Another example is the prefixing of the home area code to the office code and numericals received. This latter is necessary to bring the call back to the home area, when it is routed via an office in an adjacent NPA.

3.62 Code Conversion – Digits may be substituted in some systems (Chart 8) for some or all of the routing digits received. This feature, which is called code conversion, provides flexibility for meeting numbering plan requirements by furnishing routing digits for certain systems in the network. For example, an established step-by-step train may require routing digits which differ from those provided by the 7-digit numbering plan. The last preceding CSP can delete some of the 7 digits and furnish instead digits which fit the switching train.

3.63 Chart 9 lists the outpulsing capabilities of various switching systems. The permissible combinations of digit deletion and prefixing are indicated for each system. For each combination, the digits outpulsed are shown in order from left to right. The terminology and mechanics for digit deletion and prefixing vary somewhat among the systems. For this reason, the compromise terminology used here may not agree with the specific terms of a system's literature, and no inferences should be made from these data as to the mechanics of performing these functions.

4. MISCELLANEOUS CENTRAL OFFICE AND TRAFFIC ADMINISTRATION FACILITIES

Intercepting Facilities

4.01 Adequate facilities should be provided to intercept calls which cannot be completed due to the following conditions:

(a) Unassigned numbers including those on a terminal-per-line arrangement.

(b) Changed numbers.

(c) Vacant levels in step-by-step offices.

(d) Unassigned numbering plan area codes or central office codes. (Vacant Codes)

4.02 Intercepted calls should be routed to an operator or to a recorded announcement. The use of busy, audible ringback, "no such number tone," or no tone at all is considered unsatisfactory.

4.03. Recorded announcements are adequate to intercept disconnected numbers, unassigned numbers, vacant codes, and vacant levels, but it is most desirable that arrangements be provided for cut-through to an operator. Calls to changed numbers may be handled by operators, or by a recorded announcement which should be arranged for cut-through to an operator.

4.04 With large scale number change projects, such as changes to a 7-digit numbering plan where the change is uniform and easily explainable, recorded announcements may be used. In many cases, this may be the only practical method of handling the large volume of traffic. At step-by-step offices, previously working selector levels can be supplied with this announcement to provide better service during and immediately following the number change.

4.05 Blocked thousand levels on step-by-step incoming toll trains should be minimized by building out the incoming train as much as practicable in order that calls to these levels may be properly intercepted.

4.06 Idle circuit terminations on incoming trunks must be removed when they are connected to intercepting trunks. (The transmission loss of intercepting trunks to either an announcement machine or to manual positions at a centralized location should not exceed 2.5 dB including equipment losses at both ends. The volume level of the output from the announcement machine ought to be adjusted so that the level at the incoming (customer's) side of the bridging trunk circuit is about -8 VU.)

4.07 To avoid false charging on distance dialed traffic, intercepting equipment needs to be arranged so that it will:

(a) Return neither answer supervision nor flash.

(b) Not differentiate between local and toll calls.

(c) Not recall originating operator (flashing key should not be provided).

Information Service

4.08 The incoming trunks to dial switching equipment at each toll center (Class 4C or higher rank office) should have access to the information board serving that location. Here up-to-date listings should be maintained for each Class 5 or 4P dial office homed on that location. At present, customers in areas equipped for Direct Distance Dialing can dial directly to distant points for information service by dialing 555-1212 for home NPA points and the appropriate NPA plus 555-1212 for foreign NPA locations. Under this arrangement, the customer will be connected directly to a centralized information bureau in the called NPA containing number information for the entire numbering plan area, or to an inward operator in the called NPA who will connect the customer with the proper information bureau. The ultimate objective is to establish centralized information bureaus for each NPA. (See Section 2, Paragraphs 4.02 and 4.08 for further information on dialing procedures.) To avoid charges to the customer any 131 (operator information) trunks associated with this arrangement should not return off-hook supervision, even though used alternatively by operators and customers. Also, on 131 trunks used exclusively by operators, the return of off-hook supervision upon operator answer is no longer required.

Verification Facilities

4.09 Verification—For security, customers must not be permitted access to verification facilities. In addition, operator access should be limited to the regular verification positions unless the cost is prohibitive.

4.10 Busy Line Cut-In – If verification arrangements are not provided, it may be desirable to employ Busy Line Cut-In equipment on those few important lines, i.e., police and fire department lines, that should have means for being apprised of an emergency call while busy with an existing call.

Service Observing Facilities

4.11 It is desirable that suitable service observing facilities be installed with equipment for distance dialing. In this way, an up-to-date record of the performance of both operating personnel and automatic switching equipment can be obtained. Also, the resulting record of customer dialing irregularities is useful. Service observing information, in addition to facilitating the administration of operating forces and telephone plant, serves as a measurement of the effectiveness of training programs for operators and of instructional material furnished the customer.

4.12 Service observing facilities, if they are to be effective, should produce an adequate sample in a predetermined period of time and should be capable of determining (where applicable):

(1) Speed of operation: Recorded as the time required for significant events to occur during establishment of the telephone connection such as:
   (a) speed of answer to trunk signals
   (b) speed of attention to cord signals
   (c) speed of advancement
   (d) speed of service

(2) Quality of service: Measured in terms of errors, irregularities, and other significant qualities of performance of equipment, operators, and customers, except speed.

(3) Call disposal: Recorded as calls completed and uncompleted, or in terms of other final disposition of the calls, irrespective of speed and other qualities of the service.

Operator Training Equipment

4.13 Facilities for training operators are desirable and should be provided wherever feasible. Two types of training units, in-board and energized, are generally used. In-board training units are those installed in the regular commercial switchboard. Those which do not use regular positions are referred to as energized training units. If regular switchboard positions are available for the scheduling of an efficient training program, in-board units may be used. If, however, shortages of regular positions would cause unsatisfactory arrangements for training or interfere with commercial traffic handling, energized units are desirable. Either type of equipment should provide adequate facilities for giving operators controlled practice on each call taught in the initial and subsequent training courses.

Traffic Separation Facilities

4.14 Registers – Traffic separation registers are used to give an indication of the number of intrastate and interstate connections through No. 4-type and crossbar tandem switching offices. These numbers of connections are used as bases to which corresponding usage is related for the purpose of apportioning book costs of plant and related expenses between interstate and intrastate services.

4.15 Class Marks – The diversified sources of traffic having access to certain switching locations and the variation in characteristics among these sources make it desirable to incorporate in the traffic separation register equipment additional features to provide a more detailed classification of connections than merely "interstate" or "intrastate." Thus, the No. 4-type and crossbar tandem systems are provided with incoming and outgoing class marks. These class marks are scored in different combinations in the traffic separation registers to indicate the volume of separate classes of traffic. The 4A and 4M systems are provided with four incoming and seven outgoing class marks for a total of 28 separate classes. The crossbar tandem system has four incoming and four outgoing marks, with a maximum capability of scoring ten separate classes. The class marks and illustrative traffic separation assignments for these systems are shown in Chart 6.

Single Channel Operation

4.16 Most Bell System central office equipment and trunking facilities are arranged so that customers gain access to an operator by dialing "Operator" (Zero). This operator handles assistance calls, operator-handled long distance calls, etc. (Separate codes are used to reach Information, Repair Service, and the Telephone Company Business Office.) This grouping of operator functions is referred to as "single channel" operation. Such arrangements afford simplicity from the customer's standpoint, eliminate misdirection of calls, and result in uniform procedures for the traveling public. However, arrangements are currently being implemented to allow customers to dial person-to-person calls and collect calls directly. This will minimize the use of "Zero" Operator facilities.

AUTOMATIC RECORDING OF MESSAGE BILLING DATA

4.17 General – Direct dialing of station-to-station, sent-paid messages by customers requires that certain data be obtained automatically in order that chargeable calls may be billed. Two widely used billing plans are "detail billing" and "bulk billing." Detail billing furnishes the customer with detailed information for each extra charge call completed during the billing month. Bulk billing, which may be used for single and multiunit short-haul calls, charges the customer on the basis of the total message units used during the billing month. Although more items of message billing data are required for detail billing than for bulk billing, detail billing can be used for all extra charge calls.

4.18 Data Requirements – Automatic equipment for recording message billing data may be arranged to care for both bulk billed and detailed billed calls. The data listed in Chart 10 shows the items needed to render a detailed bill under Direct Distance Dialing and also what is needed for bulk billing.

4.19 Automatic Message Accounting – The industry has developed a number of systems for automatically recording the required message billing data. These may be broadly divided into "local" and "centralized" systems.

(1) Local automatic message accounting (LAMA) data recording systems have the recording equipment located at the Class 5 office where the extra-charge calls are originated.

(2) Centralized automatic message accounting (CAMA) data recording systems are those in which the recording equipment is installed at a centralized location so that extra-charge calls from a number of Class 5 offices may be concentrated and recorded there. Centralized recording may prove more economical than local recording depending on specific local considerations.

4.20 CAMA at Class 4 and Higher Ranking Offices – Centralized recording equipment may be provided at Class 4 or higher ranking offices. Extra-charge traffic from Class 5 offices not equipped with local recording facilities, and extra-charge traffic that cannot be served by local recording equipment, when provided, is trunked to the centralized location where the required billing data is recorded.

4.21 Data Processing Equipment – In addition to the central office equipment mentioned above, suitable data processing equipment is required to process the message billing data into the form needed for billing the customer.

4.22 Common Control Features – Several types of equipment for the automatic recording of billing information are currently being manufactured by the Bell System and by independent suppliers to work with both common control and direct control switching equipment. When the automatic equipment provided to record billing data includes a director or sender, common control features are available even though switching may be on a step-by-step basis.

4.23 ANI Timing –

(1) Some equipments that automatically record billing information may require a substantial interval for calling number identification. This interval should not result in a delay between the sending of a connect signal forward on an outgoing trunk to a common control system and the subsequent outpulsing of digits over the trunk nor should it result in an extended interdigital time interval. Such delays could result in time-outs in the common control office and consequent failure to complete calls.

(2) When identification of the calling number is made after the calling subscriber dials the called number, arrangements should be made so that selection of the called line does not occur prior to identification of the calling number.

Typical Station Number Cards

FIGURE A

FIGURE B

A Typical Dial Number Plate

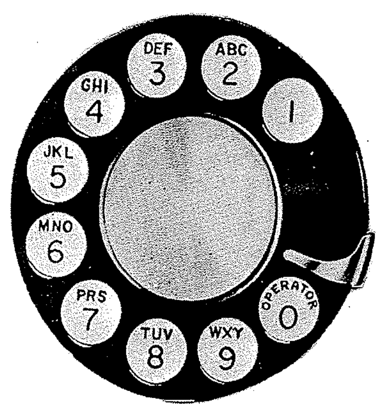


FIGURE C

Typical Station Number Cards

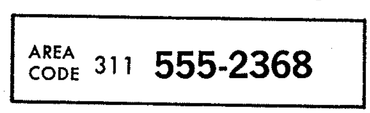


FIGURE D

FIGURE E

A Typical Push-Button Dial

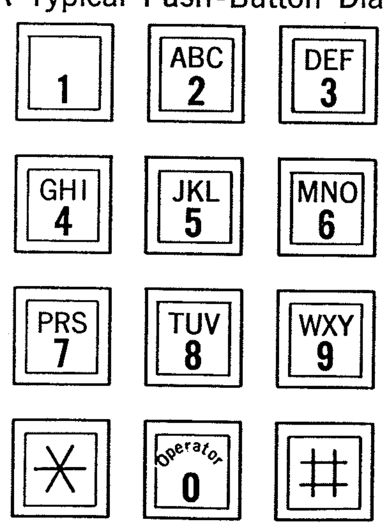


FIGURE F

Typical Rotary Dial Telephone Set

FIGURE A

Typical Push-Button Dial Telephone Set

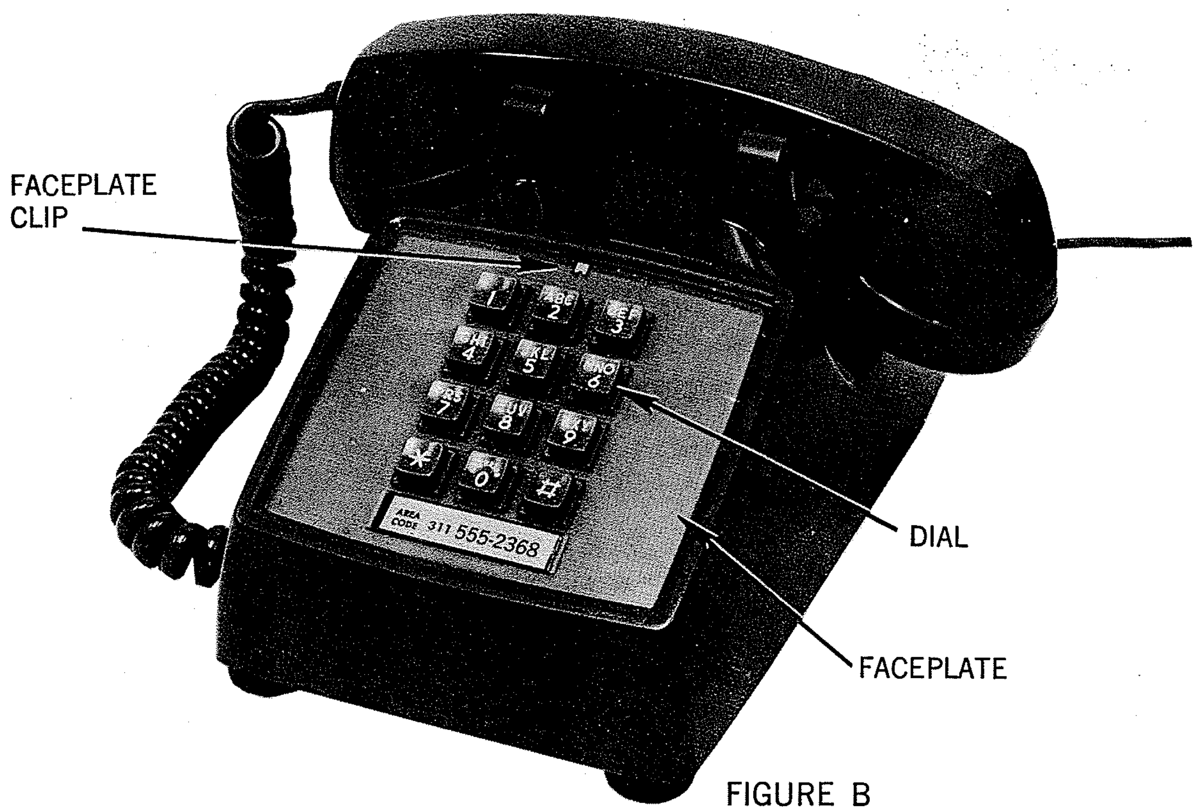


FIGURE B

Typical Multibutton Telephone Sets

FIGURE A

FIGURE B

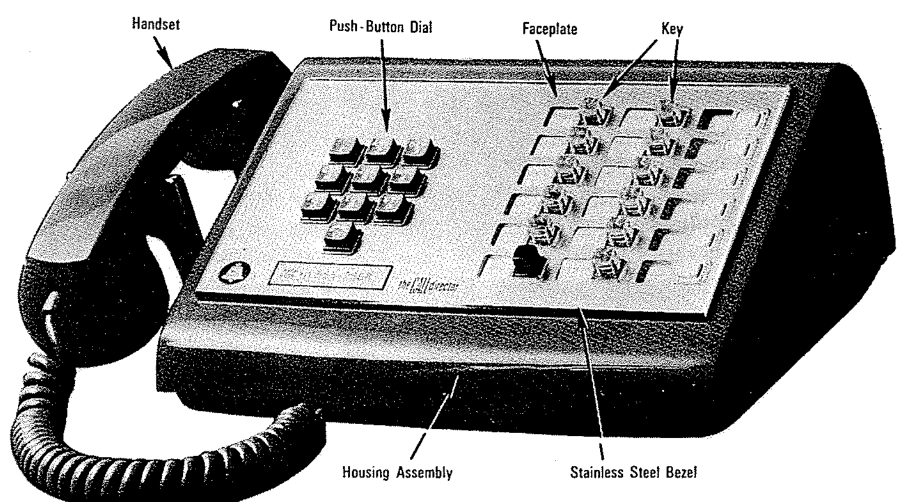


FIGURE C

MINIMUM NUMBER OF DIGITS CENTRAL OFFICE EQUIPMENT SHOULD BE ARRANGED TO RECEIVE FROM THE DISTANCE DIALING NETWORK

CLASS OF OFFICE	MINIMUM DIGITS INCOMING	EXAMPLE*
5	4	(625) 1234
4P	5 (See Note 1)	(62) 51234
4C	5 (See Note 2)	625 1234
3 (or higher)	7	See Note 3

*Numbers in parentheses ordinarily need not be received.

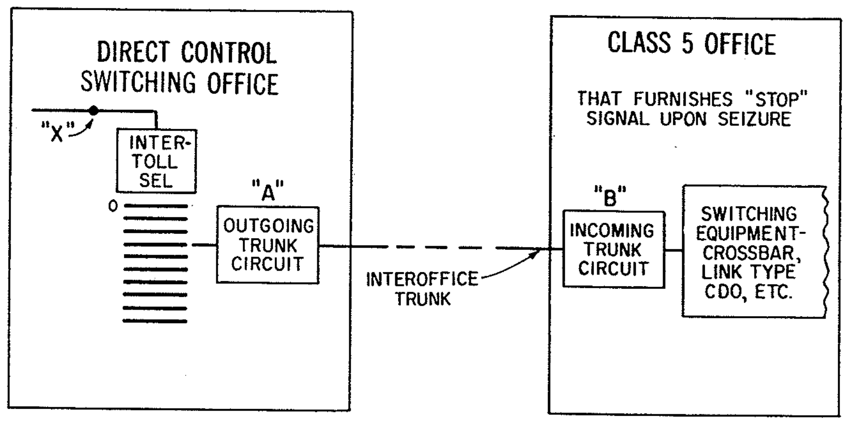
Note 1: Class 4P offices homed on switching centers equipped with common control equipment generally need the number of digits indicated. Class 4P offices homed on Class 3 offices equipped with direct control switching equipment will frequently require 7 digits.

Note 2: Most 4C offices will be arranged to receive 7 digits. An exception to this requirement may be made where the cost of arranging the equipment at the 4C office for full 7-digit dialing appears excessive in comparison with the advantages offered by uniform operating procedures. Such exception should be limited to the deletion of the AB or ABX digits on groups (intra-company or inter-company Intrastate) which will not be reached from the nationwide network. This is a matter for local decision.

Note 3: If the Class 3 office is of the common control type, 7 digits may be sufficient; if of the direct control type, one or more digits will be required to switch through the Class 3 office so that the full 7-digit number may be delivered to the Class 4C office. Not more than 7 digits are needed at the home switching point on calls to Class 5 offices that home directly at the switching office.

STOP DIAL SIGNALS

A Typical Application



General

1. Pulsing proceeds normally when the condition on the circuit at Point "X" is "on-hook".
2. Pulsing should *stop* when condition on the circuit at Point "X" changes to "off-hook".
3. Pulsing should *resume* when condition on the circuit at Point "X" returns to "on-hook".

Analysis of Conditions and Requirements

Steps in the Progress of the Call	Conditions At Point "X"	Remarks
1. Intertoll selector being pulsed up to desired level.	"on-hook"	
2. Intertoll selector reaches level that trunks to distant office.	"off-hook"	"Off-hook" condition returned from the intertoll selector (or equivalent) as soon as the marked level is selected and before rotary hunting has begun.
3. Rotary hunting results in selection and seizure of outgoing trunk circuit "A".	"off-hook"	"Off-hook" condition is maintained by the intertoll selector (or equivalent).
4. Trunk circuit "A" seized, sends seizure signal forward to incoming trunk circuit "B".	"off-hook"	"Off-hook" condition is maintained by the intertoll selector.
5. Incoming trunk circuit "B" immediately upon seizure. (A) Originates a request for a sender, incoming register, link, etc. (B) Returns a "stop dial" signal (off-hook condition) toward trunk circuit "A".	"off-hook"	"Off-hook" condition is maintained by intertoll selector.
6. "Off-hook" condition received at trunk circuit "A" causes trunk circuit "A" to present "off-hook" condition toward intertoll selector.	"off-hook"	"Off-hook" condition still maintained by intertoll selector.
7. "Off-hook" condition within intertoll selector is removed as a result of release of slow release relay.	"off-hook"	But condition at Point "X" remains unchanged because of "off-hook" condition existing on trunk due to operation of trunk "B".
8. Distant central office equipment ready to receive digits.	"on-hook"	Incoming trunk circuit "B" returns "on-hook" signal toward originating end as an indication that pulsing may proceed.

TRAFFIC SEPARATIONS AVAILABLE WITH No. 4–TYPE AND CROSSBAR TANDEM SYSTEMS

4A and 4M Systems

Incoming Trunk Class Marks	Outgoing Trunk Class Marks 0	1	2	3	4	5	6
	Possible Combinations						
A	A-0	A-1	A-2	A-3	A-4	A-5	A-6
B	B-0	B-1	B-2	B-3	B-4	B-5	B-6
C	C-0	C-1	C-2	C-3	C-4	C-5	C-6
D	D-0	D-1	D-2	D-3	D-4	D-5	D-6

Crossbar Tandem Systems

Incoming Trunk Class Marks	Outgoing Trunk Class Marks A	B	C	D
	Possible Combinations			
A	A-A	A-B	A-C	A-D
B	*B-A	B-B	B-C	B-D
C	C-A	C-B	C-C	C-D
D	D-A	D-B	D-C	D-D

*The combinations B-A, C-A, C-B, D-A, D-B, and D-C are scored respectively as A-B, A-C, B-C, A-D, B-D, and C-D.

TONE APPLIERS

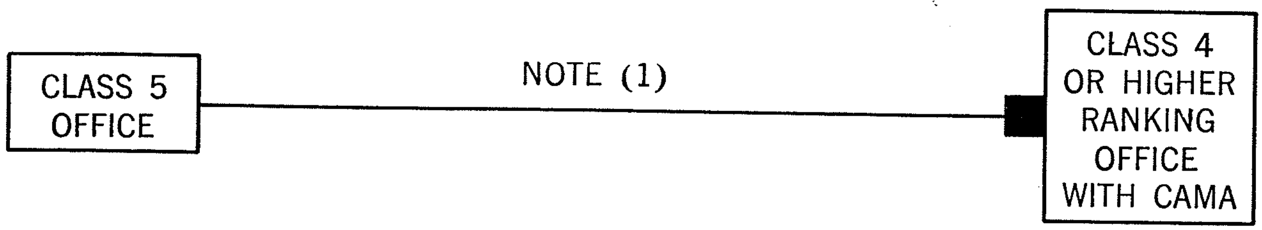


Figure 1

Location When Centralized Message Billing Data Recording Equipment Is Used

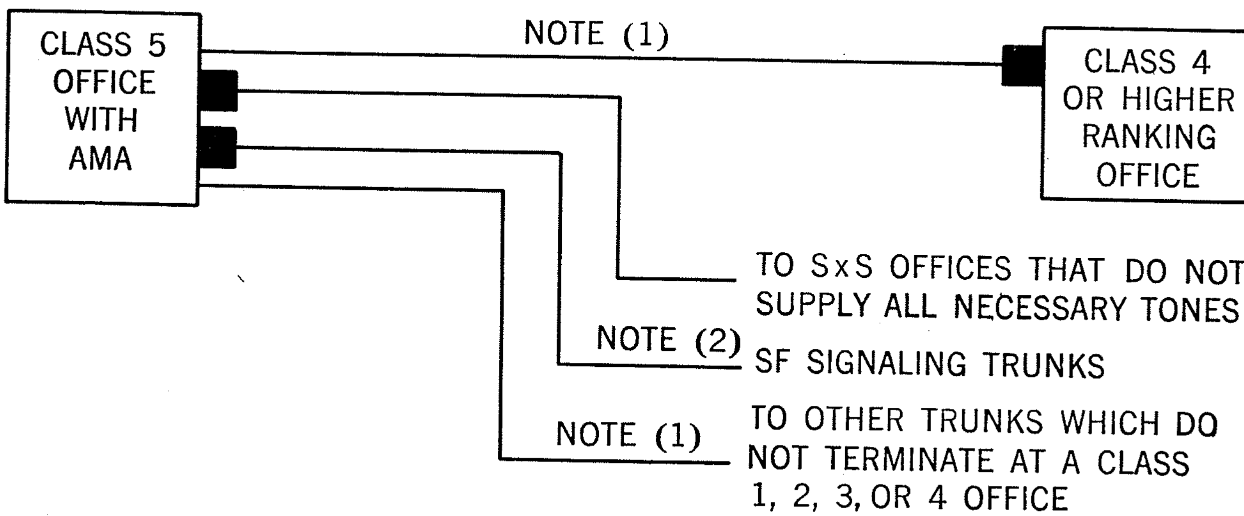


Figure 2

Location When Local Message Billing Data Recording Equipment Is Used

(Tone applier can be either individual equipment or part of trunk circuit)

Note (1) Interoffice trunk (a) not employing Bell System-type single-frequency signaling; or (b) equipped with the proper type of transistorized SF unit at the CAMA end when the CAMA office is 2-wire.

Note (2) Or arranged per Figure 1, if the Class 4 or higher ranking office is 2-wire and the proper type of SF unit is used, as in condition (b) of Note (1).

DIGIT CAPACITIES OF VARIOUS SWITCHING SYSTEMS

	4A & 4M	4A & 4M CAMA	CROSSBAR TANDEM (INCL. CAMA)	NO. 5 CROSSBAR	NO. 5 CROSSBAR CAMA	S x S CAMA
Max. No. of Digits Received (Required Capacity)	11	10	11	11	10	10
Max. No. of Digits Outpulsed (Required Capacity)	11 (Note 1)	10 (Note 1)	11 (Note 1)	11 (Note 1)	10 (Note 1)	12 (Note 1)
No. of Digits Translated for Routing	3, 4, 5, 6 (Note 4)	3, 6	3, 6 (Note 3)	3, 6 (Note 2)	3, 6	3, 6
No. of Digits Received Which Can be Deleted	0, 3, 6 (Note 5)	0, 3, 6	0, 1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	0, 1, 2, 3, 4, 5, 6	0, 3, 6
No. of Digits Which Can be Prefixed or Substituted for Routing Digits Received	0, 1, 2, 3	0, 1, 2, 3	0, 1, 2, 3	0, 1, 2, 3 (Note 6)	0, 1, 2, 3	0, 1, 2, 3, 4, 5 (Note 7)

NOTES:

1. Technically, these systems can outpulse a maximum of 13, 14, or 15 digits. However, there is usually no need for outpulsing more than 10, 11, or 12 digits.
2. Also translates 3 and 4 digits for TX calls.
3. Also translates 4 and 5 digits for TX calls.
4. 4-and 5-digit translation, although fully flexible in these systems, is used at present principally for TX codes.
5. Equivalents for the deletion of 1, 2, 4, and 5 digits are shown in Chart 9.
6. See Note 3 in Chart 9.
7. Includes 1 or 2 exit digits.
8. Early XB tandem designs do not include all items listed in table.

OUTPULSING CAPABILITIES OF SWITCHING SYSTEM SENDERS

Note 4)

Item No.	Number of Digits Deleted	Number of Digits Pre-fixed or Sub-stituted	DIGITS OUTPULSED: Digits Prefixed or Sub-stituted (NOTE 1)	Digits A-L Registered (NOTE 2) ("I" Desig. Not Used): A	B	C	D	E	F	G	H	J	K	L	SYSTEMS: 4A & 4M (Incl. CAMA NOTE 4)	XB TDM (Incl. CAMA)	No. 5 XB (Incl. CAMA NOTE 3)	S x S (CAMA NOTE 4)
1	0	0		x	x	x	x	x	x	x	x	x	x	x	#	#	#	#
2	1	0		0	x	x	x	x	x	x	x	x	x	x	(Note 5)	#	#	(Note 5)
3	2	0		0	0	x	x	x	x	x	x	x	x	x	(Note 5)	#	#	(Note 5)
4	3	0		0	0	0	x	x	x	x	x	x	x	x	#	#	#	#
5	4	0		0	0	0	0	x	x	x	x	x	x	x	(Note 5)	#	#	(Note 5)
6	5	0		0	0	0	0	0	x	x	x	x	x	x	(Note 5)	#	#	(Note 5)
7	6	0		0	0	0	0	0	0	x	x	x	x	x	#	#	#	#
8	0	1	+	x	x	x	x	x	x	x	x	x	x	x	#	#	#	#
9	1	1	+	0	x	x	x	x	x	x	x	x	x	x	#	(Note 6)	#	(Note 6)
10	2	1	+	0	0	x	x	x	x	x	x	x	x	x	#	(Note 6)	#	(Note 6
11	3	1	+	0	0	0	x	x	x	x	x	x	x	x	#	#	#	#
12	4	1	+	0	0	0	0	x	x	x	x	x	x	x	#	(Note 6)	#	(Note 6)
13	5	1	+	0	0	0	0	0	x	x	x	x	x	x	#	(Note 6)	#	(Note 6)
14	6	1	+	0	0	0	0	0	0	x	x	x	x	x	#	#	#	#
15	0	2	+ +	x	x	x	x	x	x	x	x	x	x	x	#	#	#	#
16	1	2	+ +	0	x	x	x	x	x	x	x	x	x	x			#	
17	2	2	+ +	0	0	x	x	x	x	x	x	x	x	x	#	(Note 6)	#	(Note 6)
18	3	2	+ +	0	0	0	x	x	x	x	x	x	x	x	#	#	#	#
19	4	2	+ +	0	0	0	0	x	x	x	x	x	x	x			#	
20	5	2	+ +	0	0	0	0	0	x	x	x	x	x	x	#	(Note 6)	#	(Note 6)
21	6	2	+ +	0	0	0	0	0	0	x	x	x	x	x	#	#	#	#
22	0	3	+ + +	x	x	x	x	x	x	x	x	x	x	x	#	#	#	#
23	1	3	+ + +	0	x	x	x	x	x	x	x	x	x	x			#	
24	2	3	+ + +	0	0	x	x	x	x	x	x	x	x	x			#	
25	3	3	+ + +	0	0	0	x	x	x	x	x	x	x	x	#	#	#	#
26	4	3	+ + +	0	0	0	0	x	x	x	x	x	x	x			#	
27	5	3	+ + +	0	0	0	0	0	x	x	x	x	x	x			#	
28	6	3	+ + +	0	0	0	0	0	0	x	x	x	x	x	#	#	#	#
29	0	4	+ + + +	x	x	x	x	x	x	x	x	x	x	x				*
30	3	4	+ + + +	0	0	0	x	x	x	x	x	x	x	x				*
31	6	4	+ + + +	0	0	0	0	0	0	x	x	x	x	x				*
32	0	5	+ + + + +	x	x	x	x	x	x	x	x	x	x	x				*
33	3	5	+ + + + +	0	0	0	x	x	x	x	x	x	x	x				*
34	6	5	+ + + + +	0	0	0	0	0	0	x	x	x	x	x				*

LEGEND AND NOTES ON NEXT PAGE.

LEGEND

0 0 0	Digits Deleted (Registered but not outpulsed).	Each digit may be any digit 0-9.
X X X	Digits Registered and Outpulsed.	
+ + +	Digits Prefixed or Substituted in accordance with instructions previously given to the machine.	
#	System has capability for this item.	
*	Only 3 Prefixed Digits if MF, and 4 if DP may be transmitted. At least one and possibly 2 Prefixed Digits must be dial pulsed exit digits.	

NOTES:

1. Substituted digits may be identical to those that are deleted.
2. These Digits are Outpulsed only if registered.
3. All No. 5 XB systems may be equipped for items 15 through 28 for Dial Pulsing but only the later design may be so equipped for Multifrequency Pulsing. However, restricted 2-and 3-Digit Prefixing for MF pulsing is now available for the earlier design.
4. SxS CAMA and the 4A and 4M CAMA Systems will accept only 7 or 10 Digits
5. Items 2, 3, 5, and 6 are provided by the means used to obtain items 18, 11, 21, and 14, respectively.
6. Items 9, 10, 12, 13, 17, and 20 are provided by the means used to obtain items 25, 18, 28, 21, 25, and 28, respectively.

DATA REQUIRED FOR RECORDING BILLED MESSAGES

DETAIL-BILLED CALLS

1. Called Customer's Telephone Number

   This may be either a 10-digit or a 7-digit number, i.e.,
   NXX + 7 digits, if the call terminates in a foreign area, or
   7 digits, if the call terminates in the home area.
   In the recording process, a single digit is often substituted for the NPA code of each of ten of the most frequently called areas.

2. Calling Customer's Telephone Number, 7 digits

3. Date.

4. Time of Day.

5. Duration of Conversation.

BULK-BILLED CALLS

1. Calling Customer's Telephone Number, 7 digits

2. Message Units Chargeable to Calling Telephone.
   This quantity is determined from the following data that needs to be available to the recording equipment:

   2a. Office code of called telephone.
   2b. Duration of conversation.

   (An indication of the initial period rate or a code designating the appropriate charging plan may be substituted for information called for in Item 2a. It may also be desirable to record the date and time of day.)

TYPICAL TRUNKING DIAGRAMS FOR STEP-BY-STEP OFFICES

1. GENERAL

1.01 Every office has individual requirements that must be met when establishing trunking arrangements for distance dialing. The sketches shown in Charts A1, A2, AND A3 and the following discussion are intended to illustrate some of the fundamental principles of automatic switching. Specific trunking, signaling, and pulsing arrangements should be worked out jointly by the Companies whose offices are involved.

1.02 Chart A1 covers numbering and trunking considerations in Class 3 and 4 offices and shows how digit-absorbing selectors may be used to hold the required ranks of selectors to a minimum. The relationship between office code assignments and operating characteristics of digit-absorbing selectors is also pointed out. Chart A2 shows how toll and local trains may be integrated in an end office.

1.03 Chart A3 shows the use of one switching train in Class 5 offices having prepay coin and free service (official) lines.

2. OFFICE NUMBERING – TRUNKING PLAN CONSIDERATIONS

2.01 Substantial savings in switching equipment and uniform operating procedures at distant offices can frequently be had by the use of digit-absorbing facilities in direct control offices. The capabilities and limitations of available digit-absorbing equipment need to be kept in mind, however, when developing office trunking and numbering plans. The attached Charts A1 and A2 show some applications of the digit-absorbing principle. The left-hand portion of Chart A1 shows, in simplified form, a step-by-step office that serves as a primary center, (Class 3 office) and, in addition, has Class 5 offices homed on it. The primary center is homed on a sectional center (Class 2 office) which is a CSP provided with common control–type switching equipment. A method is shown for switching through traffic to the Class 4C offices by means of arbitrary digits prefixed by the CSP. In this example, the arbitrary code "00" is used to switch through the Class 3 office to reach the Class 4C office shown on the right-hand side of the figure. In addition to its through switching functions, the primary center also serves as the "toll center" for the following end offices:

(a) "625," "626," "627," and "628" Class 5 offices located in the same building.

(b) "232," "233," . . . "239" Class 5 offices in the same exchange but in a different building.

(c) "445" and "437" Class 5 offices, each of which requires only four effective digits for switching purposes.

(d) "33" building which houses several Class 5 offices "332," "333," etc., and, therefore, requires five effective switching digits.

2.02 By arranging the intertoll first selectors to absorb "4" repeatedly (AR4) and to absorb "6" once and unlock all levels (A6), the desired operational features are obtained.

2.03 To reach the Class 5 offices homed on the Class 4C office, the Class 2 sectional center pulses "00" to switch through the primary center and follows this with the seven digits of the called number. Digit-absorbing intertoll first selectors or the equivalent in the Class 4C office provide the necessary trunking in an economical manner.

2.04 Since inward and delayed operation is cared for at Class 3 offices,the auxiliary train is also provided.

2.05 Chart A 2, Figure A shows a local office (about 3000 numbers) with office code "437." The local customers may make local calls by dialing either the listed 7-digit number or the abbreviated 5-or 4-digit number, as desired. It will be noted that the incoming toll connecting trunks are terminated on three-wire local switches arranged to return tone only busy signals. (See Paragraph 3.04 on planned elimination of flashing signals.)

2.06 Chart A2, Figure B, shows a somewhat larger installation, the four units of the "79X" offices. For this installation,a regular toll train using toll transmission selectors is provided for inward distance dialed traffic.

3. SINGLE SWITCHING TRAINS IN CLASS 5 OFFICES

3.01 The Bell System now combines local and incoming distance-dialed traffic on one switching train in new step-by-step offices. Separate toll trains are no longer provided for Class 5 offices. Toll trains were originally provided for transmission reasons, and such features as flashing signals, controlled ringing, and coin control were added later. With present-day engineering and operating practices,it is felt that all requirements may be satisfied on a single local-type train as outlined in the following.

Transmission Considerations

3.02 With the introduction of improved station instruments, toll grade battery as provided by toll trains is no longer required to meet transmission objectives.

3.03 Other transmission requirements such as proper impedance matching, suitable return loss, and minimizing noise resulting from inductive interference can generally be met on a single train arrangement by the provision of incoming trunk circuits which include appropriate repeating coils.

Flashing Signals

3.04 As an objective, it is planned to eliminate flashing signals and use tone only signals such as are available on a local train. In the interim, flash or tone only (or both flash and tone) is acceptable. Where flashing signals are not received, the operator should stay in on connections until some audible evidence of call progress is received.

Controlled Ringing

3.05 Elimination of the toll train results in the loss of controlled start of ringing and the ability to rering. Although this imposes some operating penalties, Traffic Operating Practices have been revised to cover the handling of delayed calls over facilities with immediate ringing.

Coin Control Arrangements

3.06 For prepaid coin service, the line number method of coin control may be used in some offices, particularly the smaller ones.

3.07 For prepaid coin service in offices associated with switchboards requiring positional coin control operation, a partial toll train with access to coin lines only may be used. Equipment arrangements are shown in Chart A3.

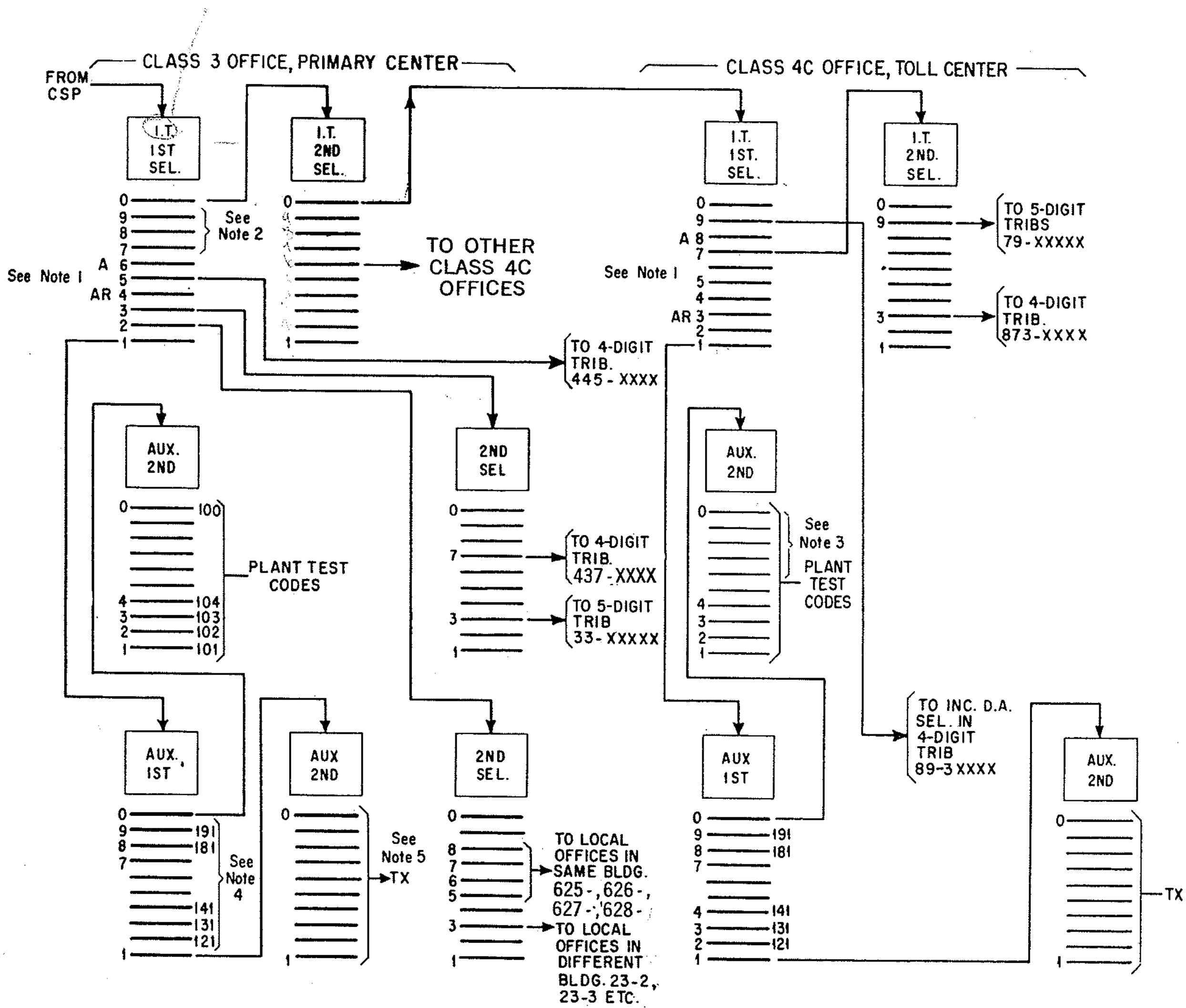
(a) Only incoming collect to and delay outward traffic from coin lines would be routed over this train, thereby permitting the train to be relatively small. All other incoming traffic would be routed over the local-type train. For example, in an office requiring 4-digit in-dialing and having less than a thousand coin lines, the arrangements described in (b) would be used.

(b) Terminate incoming trunks on toll transmission selectors and provide combination connectors in the group or groups serving the coin lines. Mark all the levels of the transmission selector for blocking except the level which represents the thousand digit assigned to coin and have this level marked for once-only digit absorption. Assign as many of these levels as required (equivalent to the number of coin connector groups) and connect other levels to intercept or recorded announcement. With this arrangement, the hundreds series of numbers of the coin thousand not required for coin may still be assigned to noncoin lines, but access to the noncoin lines will be over the local train only.

Charge Supervision on Distance Dialed Calls to Free Numbers

3.08 The provision of a 4-wire incoming local train is suggested where requirements exist for charging on distance dialed calls to official numbers which are free service within the local dialing area. Connector groups or connector levels serving free lines would return an off-hook supervisory signal via the fourth wire, through the selectors, to the incoming trunk from the switching office.

SIMPLIFIED HYPOTHETICAL TRUNKING PLAN



Notes:

1. Digit-absorbing by selectors having levels designated A and AR:
   A = Absorb digit once only, on next digit trunk on all levels.
   AR = Absorb digit repeatedly unless a digit has been absorbed previously on a level designated A.
2. By provision of additional groups of 2nd selectors from other levels of the 1st selectors, access may be obtained to any required number of local offices, Tribs and intertoll groups. The local office and Trib office codes determine the assignment of levels and digit-absorbing arrangements. Intertoll groups may be assigned to any groups of 2nd selectors not required for other purposes.
3. Unused levels should be intercepted.
4. Final "1" should be absorbed in the trunk circuit before operator is signaled.
5. This method involves use of 11XX TX codes. The "11" is used to reach this auxiliary second selector which absorbs the first "X" and switches on the second "X".

DIAGRAM SHOWING RELATION BETWEEN LOCAL AND TOLL TRAINS

3000 TERMINAL OFFICE

437 - OFFICE

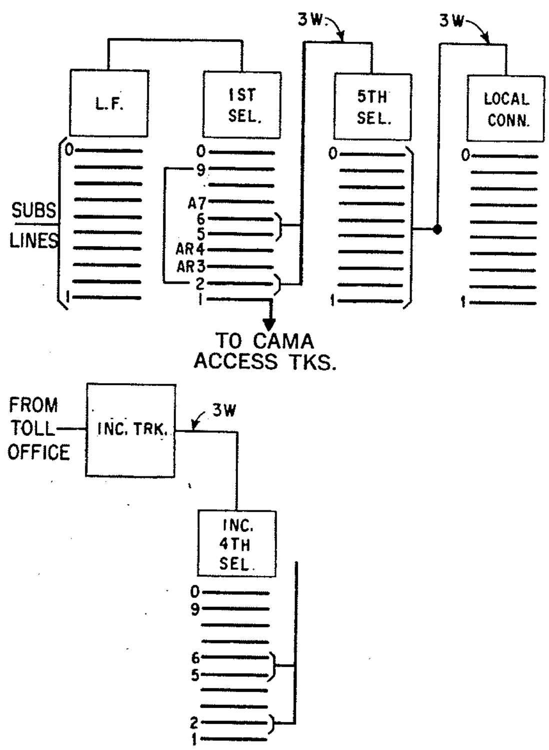


FIG. A
FOUR EFFECTIVE DIGIT OFFICE WITHOUT TOLL TRAIN

40,000 TERMINAL OFFICE

79X - OFFICES

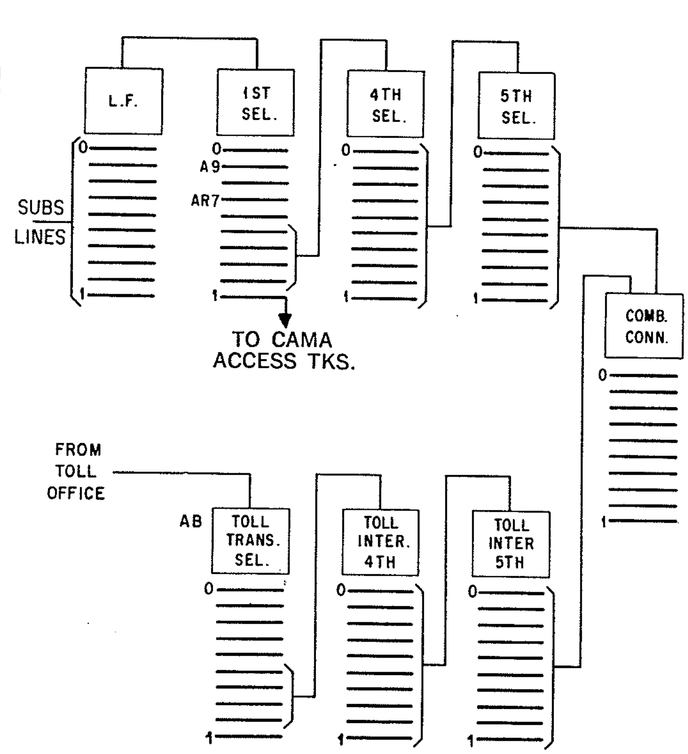
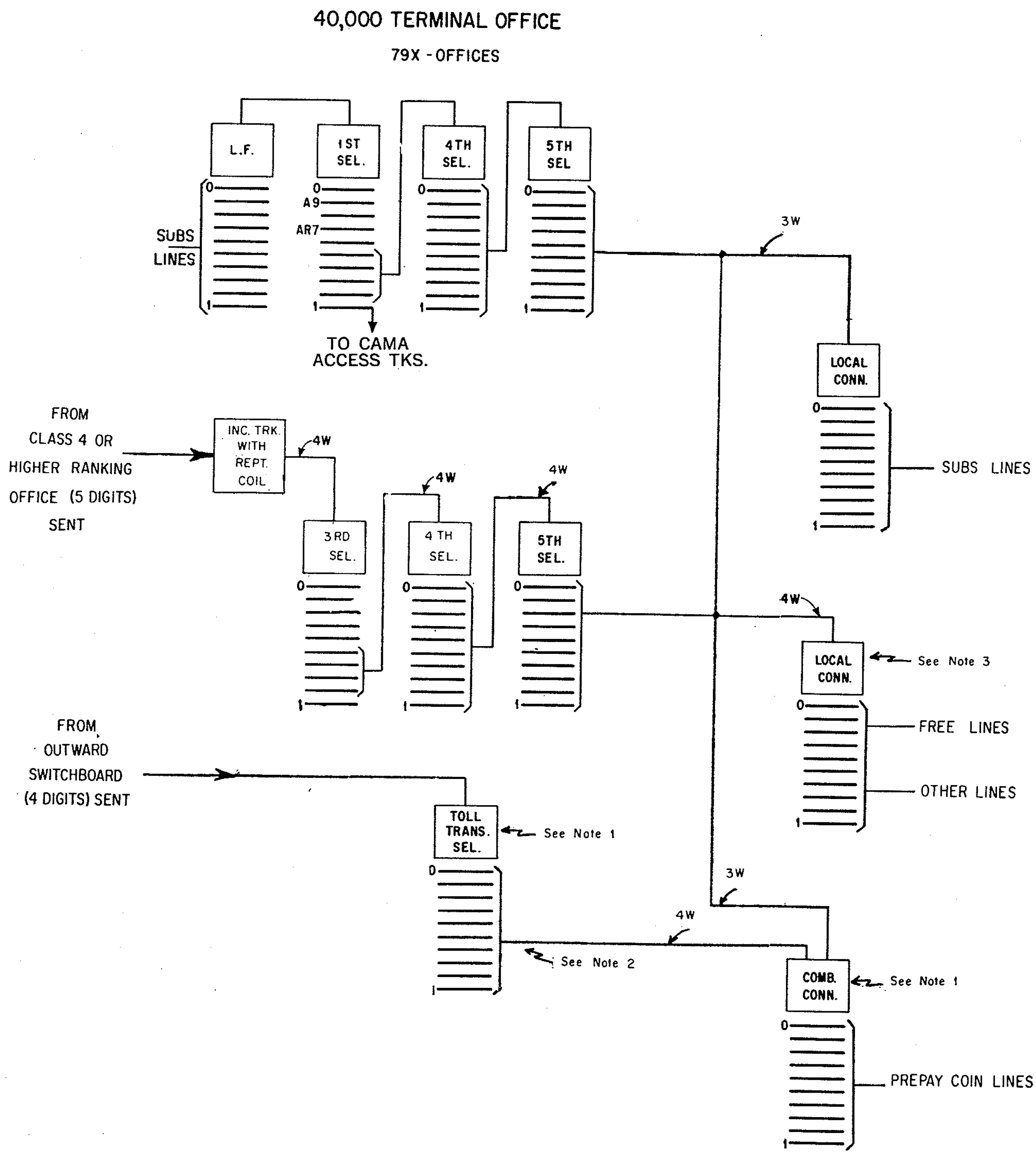


FIG. B
FIVE EFFECTIVE DIGIT OFFICE WITH TOLL TRAIN

SINGLE SWITCHING TRAIN IN CLASS 5 OFFICE

(Diagram showing local–type train used for both local and incoming distance dialed calls and with partial toll train for coin lines.)



Notes:

1. Provide for office with prepay coin lines.
2. Arrange to block on all levels except thousands digit of coin box series. Arrange this level for once-only digit absorption.
3. Provide for end office with free lines. On free line levels, arrange for nonreversal on local calls and 4th wire supervision on incoming calls from Class 4 or higher ranking office.

Section 6
Transmission

TRANSMISSION CONSIDERATIONS

CONTENTS PAGE

5. Typical Connections of Two Intermediate (Intertoll) Trunks at a 2-Wire Switching Office

6. Impedance Compensator – 837A Network

7. Impedance Compensator – 837B Network

8. Impedance Compensator – (SD-95756)

9. Fixed 2 dB Pad Arrangements

1. GENERAL

1.01 From the transmission standpoint, the principal impact of the toll switching plan is that even though a large part of the total traffic is handled with a minimum of switching, a maximum of nine trunks may be connected together on any given call within the North American continent. This maximum includes the toll connecting trunks, one at each end, between the serving end offices and their home toll centers. Furthermore, as a result of alternate routings under the switching plan, different numbers and makeups of trunks may be encountered on successive calls between the same two telephones.

1.02 The transmission engineer must therefore restrict the transmission characteristics of each trunk which may be used in a connection in order to provide adequate transmission on all calls and to avoid large differences in transmission on successive calls between the same two places.

1.03 The ideal would be to operate all trunks at zero loss and very low noise levels, making overall transmission independent of the number of trunks used in a connection. However, current technology requires operation of transmission facilities at some finite loss in order to provide suitable overall transmission characteristics. Also, the plan must provide for the most effective utilization of all kinds of carrier and voice-frequency facilities, each with its own particular transmission capabilities.

1.04 The practical approach to the transmission problem, therefore, is to:

(a) Operate every trunk at the lowest loss and noise level practicable, considering its length and the type of facilities used.

(b) Assign trunks with different transmission capabilities in accordance with their particular place in the overall network.

1.05 It is clear that no matter how carefully plant design is carried out, success depends on how closely trunk losses can be maintained to their assigned values. This is important because:

(a) Expected trunk loss variations have an important bearing on the extent to which trunks can be operated near zero loss.

(b) Unless trunk losses are maintained within expected variations, large positive or negative losses can accumulate on multiswitched connections, adversely affecting transmission from the standpoint of either low volume (high loss), excessive echo, hollowness, or singing.

1.06 The importance of close maintenance stems from two characteristics of distance dialing:

(a) Today on most toll message network connections, there is no operator to observe the quality of transmission.

(b) When direct dialed calls encounter trouble, it is next to impossible to identify and locate the trouble since the customer must release the connection in order to reuse his telephone to report the unsatisfactory condition.

1.07 The extensive use of repeaters and carrier systems in the trunk plant has created an entirely new concept of maintenance. It is not enough to insure that the physical components of transmission systems are trouble-free; the loss and noise level at which an individual trunk operates depends on the care and understanding with which the various adjustments at terminals and intermediate points have been made. A further important feature of electronic transmission systems is that adjustments made at any one point may have an important reaction on adjustments made at other points.

1.08 A successful approach to the transmission maintenance job involves:

(a) The closest cooperation between the engineers who design the trunks and the plant forces who establish and maintain them.

(b) Training plant maintenance people in the "why" as well as the "how" of transmission maintenance procedures.

(c) Providing maintenance people with good tools to do their job — adequate records and instructions, test equipment that is in good condition, is well understood, simple to operate, and frequently calibrated and checked for accuracy. Automatic testing facilities should be provided wherever they are economically justified.

(d) More frequent testing to assure trouble-free operation of the toll switching network.

(e) A follow-up program to correct trunks not meeting objectives.

2. TOLL SWITCHING PLAN

2.01 With automatic interconnection of trunks by switching machines, it is necessary to obtain the best economic balance between trunk cost and switching costs which results in good transmission performance. The switching plan for distance dialing provides for a definite hierarchical arrangement of switching offices for the final routing pattern as shown in Chart 1. Illustrated are the maximum nine trunks (two toll connecting and seven intertoll) which can be connected together within the United States, when a call is handled entirely by switching machines or by a Traffic Service Position System (TSPS) operator. Calls handled by cord switchboard operators sometimes involve an additional one or two intertoll trunks. One additional intertoll trunk may also be required temporarily in some RC-RC-RC routing between the United States and Canada, and also with the use of Traffic Overload Reroute Control (TORC). Ultimately, TSPS will handle practically all calls requiring an operator, and therefore transmission design is based on a maximum of about ten trunks being interconnected between end offices on the North American Continent.

2.02 Also shown on Chart 1 are the objective losses for trunks in the switching plan. These objectives are intended to provide a satisfactory compromise between: (1) the need for sufficiently low loss to provide natural received volumes and minimum contrast in received volumes on different calls, and (2) the need for sufficiently high losses to ensure adequate performance from the standpoint of talker echo and near singing. These objectives are obtained by Via Net Loss (VNL) design considerations as discussed in Part 3 of this section.

2.03 Any switching plan and its associated transmission design requirements must necessarily depend on the current state of the art and, therefore, requires continuous review as new and improved instrumentalities become available. In order to provide satisfactory transmission regardless of the routing selected to complete a call, it is necessary to operate each trunk which might be involved at as low a loss and noise level as its inherent capabilities permit. The widespread use of carrier systems, with their high velocity of propagation and instrinsic stability, has been of outstanding importance in meeting the transmission objectives of the switching plan.

2.04 The best transmission performance is obtained at switching points where the terminal equipment, testboards, dial switching system, and associated switchboards are in the same or adjacent buildings. Multi-building layouts introduce tie cables between buildings resulting in special transmission problems. Transmission through such centers is inferior to single building layouts and should be avoided. Recognition of this fact in the early stages of planning by the people concerned with traffic, buildings, equipment, transmission, outside plant, and maintenance will insure that all cost elements are properly evaluated and weighed against the possibly lower cost of a building at a new location. It is important that cost advantages of a separate building location be substantial — not merely marginal — to justify layouts of less desirable service performance. Testboard problems involving more than one operating company should be worked out locally to provide the best possible maintenance arrangements for good transmission performance. Divided responsibility should be avoided wherever possible.

3. VIA NET LOSS CONCEPTS

Design Factors

3.01 The following transmission considerations are important in determining the lowest practicable losses at which trunks may be operated:

(a) Echo

(b) Tolerance to Echo

(c) Singing

(d) Noise and Crosstalk

Echo

3.02 Echo is the sum of all the transmitted energy which has been reflected back to its source. Chart 2 shows how an echo arises on a telephone connection. This chart shows the relatively simple case of a 4-wire trunk connected by means of 4-wire terminating sets to a 2-wire termination through the switches at each end. The 2-wire terminations may be anything from nearby telephone sets to sets on a wide variety of customer loop lengths on loaded or non-loaded facilities, or on carrier systems. There may also be intervening trunks on cable (either loaded or non-loaded) or on carrier systems. The range of impedance presented by these terminations varies widely, being different for each connection. The best that can be done under such circumstances in selecting a balancing network for a 4-wire terminating set is to choose one which is the best compromise for the range of conditions encountered. This is known as a compromise network. It consists of a resistor and capacitor in series whose values are determined by the general level of impedance of the particular office. Understandably, the balance in any given connection might not be ideal.

3.03 When the customer at Point A talks, his speech energy (the heavy solid line) travels along the circuit to Point B and on to the distant customer. However, because of the impedance mismatch between the local plant and the compromise network at Point B, some of this energy (the dash-dot line) is reflected back across the 4-wire terminating set and is transmitted back to the talker's receiver. Thus he hears his own voice and, if the time required for his speech to travel to Point B and back is long enough, the returned energy appears as a distinct echo; hence, the term "talker echo." In addition to causing possible hollowness, talker echo interferes with the talkers thought process.

3.04 At Point A, the same kind of impedance is present as at Point B. Consequently, some of the talker echo arriving at Point A is again reflected back across the 4-wire terminating set at that point and is transmitted back (the dotted line) to the subscriber at Point B. This is known as "lisener echo." However, the extra loss across the 4-wire terminating set at Point A and the added loss encountered in the additional trip down the circuit so attenuates the listener echo that it is usually not controlling in this type of connection.

3.05 The magnitude of the reflected currents at Points A and B depends on the degree of impedance mismatch between the compromise network and the 2-wire plant. This is conveniently expressed by the term "return loss," and is equal in dB to 20 log 10 $(Z_N + Z_L / (Z_N - Z_L)$, where Z_N is the impedance of the compromise network and Z_L is the impedance of the 2-wire plant. Since the impedance of the 2-wire plant varies over the frequency band, the return loss also varies with frequency. Echo Return Loss (ERL) is a single weighted figure of the return losses in the frequency band important from the echo standpoint (500 to 2500 Hertz). As discussed in Paragraph 3.21, ERL is used in developing the Via Net Loss design concept.

3.06 In the case of 2-wire trunks, echo currents arise at the terminals just as in the 4-wire case, but in addition there are echo paths at each intermediate repeater and impedance irregularity. These are compensated for in the design factors for 2-wire facilities discussed in Paragraph 3.31.

Tolerance to Echo

3.07 Extensive tests under controlled conditions have shown that people's tolerance to talker echo depends on the loudness of the echo and the time delay in arriving at the talker's ear. There is also a very wide difference between individuals as to the relative loudness and delay which they will tolerate. Table 1 and Chart 3 show the echo path loss for different echo path (round trip circuit) delays at which the volume of echo can be just tolerated by the average observer.

TABLE 1

Echo Path Delay (Milliseconds)	Echo Path Loss-dB (Satisfactory to Average Observer)
0	1.4
20	11.1
40	17.7
60	22.7
80	27.2
100	30.9

Note: More recent tests made to review these values indicate that customers may be somewhat less tolerant to talker echo, particularly at the longer delays, than the above figures indicate. However, there is some echo margin introduced by the straight line method of selecting via net loss factors as outlined in Paragraph 3.28 (see also Chart 4.) The net effect is that the present factors will be retained until further studies indicate otherwise.

3.08 The range of tolerance to echo for individual observers is such that on the more critical side some 34% require losses ranging from the averages shown in Table 1 to about 2.5 dB greater than the average, and 49.86% to 7.5 dB above the average. On the more tolerant side 34% were satisfied with losses ranging from these averages to values 2.5 dB less, and 49.86% to 7.5 dB below the average. In statistical terms, therefore, the variation among people in tolerance to echo can be expressed as a standard deviation of 2.5 dB.

Note: Standard deviation is the root-mean-square of the individual deviations from the average. In mathematical form, the standard deviation, $=\sqrt{(a^2 + b^2 + \ldots)/n}$ where a, b, etc., are individual variations from the average and n is the total number of variations.

3.09 Referring again to Chart 2, the loss in the talker echo path for a talker at A is equal to the circuit loss from A to B, plus the return loss between the compromise network in the 4-wire terminating set and the 2-wire plant at B, plus the circuit loss from B to A. The round trip delay (usually expressed in milliseconds) is the time it takes the energy from the speaker's voice waves to travel to the distant end of the circuit and back again.

3.10 The echo characteristic of a connection as discussed above imposes a lower limit on the loss at which a trunk can be operated. The return loss is a fact of life—there it stands, its value being set by a large bulk of existing plant. It can and should be improved by use of the techniques to be discussed later. It is recognized that further return loss improvement will depend on advances in the state of the art, which may extend over a long period of time. Thus it is the trunk loss itself to which we must look to control echo. Fortunately, high-speed carrier circuits permit a lower net loss for a given length of circuit than voice-frequency circuits, because the round trip delay is so much shorter. In addition, echo suppressors may be employed on the longer connections to block effectively the returned energy, thus stopping echo. However, they cannot be considered for general use in controlling echo on every trunk of a multiswitched connection as discussed in Paragraph 3.33.

The performance objective for talker echo (customer to customer) is as follows: The design of trunks should be such that talker echo will be satisfactorily low on more than 99 percent of all telephone connections which encounter the maximum delay likely to be experienced.

Singing

3.11 Referring to Chart 2 again, it can be seen that if the current returned to Point B by the "listener echo" path is greater than the original current arriving at that point, a condition is set up which sustains a circulating current around the loop consisting of the two sides of the circuits and the terminating sets at the ends. This condition can arise at any frequency due to low return losses at Points A and B and higher gains in line repeaters or carrier channels. Stated in another way, singing occurs when, at any one frequency, the sum of all the gains in the transmission paths exceeds the sum of all the losses. Singing can be prevented by limiting repeater and carrier-system gains and, preferably, by improving the terminal return losses. Singing in built-up connections can occur at any frequency in the voiceband. However, since ERL is controlled in the 500 – 2500 Hertz range, it occurs most often in the frequency ranges 200 to 500 Hertz and 2500 to about 3200 Hertz.

3.12 One of the interesting aspects of singing phenomena is that impairment of transmission occurs somewhat before actual singing takes place. This is particularly true if the instability occurs at low frequencies, below or in the lower part of the echo band. The "near-sing" or "hollow" effect is likened to talking into an empty barrel. To avoid this effect in built-up connections, the design of trunks should be such that the singing margin is 10 db or more in 95 per cent of all cases. The average singing margin is considerably higher. *Singing Margin* can be thought of as the gain which, when added to a given connection, will just start singing.

3.13 As developed later, VNL trunk design is based on factors derived from the echo requirements. With the return losses in the singing frequency ranges also maintained to the objective, trunk design will then be adequate for both singing and echo.

3.14 In using 2-wire voice frequency facilities, it is important to pay close attention to layout and design to obtain optimum singing performance and still achieve low losses. In particular, care should be taken to avoid repeater sections of excessive length and to use facilities with a minimum of impedance irregularities to permit realizing singing point objectives.

Noise and Crosstalk

3.15 Noise and crosstalk are best controlled by the design of the individual transmission systems and in the layout and construction of associated outside plant, rather than by increasing losses. In other words, the preferable approach is to get at the basic causes of noise and crosstalk instead of only masking their symptoms.

3.16 Noise and crosstalk control in carrier, repeatered voice, and radio systems requires care in locating repeaters and terminals; provision of suppression devices to nullify disturbances; and coordination with other facilities, not only other telephone systems but also power company and radio services.

3.17 In voice-frequency cables and subscriber loops, it is also necessary to use cables that are well balanced and to employ sound splicing practices. In open-wire systems, both voice-frequency and carrier, it is necessary to employ transposition layouts adequate for the frequencies employed and to maintain adequate clearances with power lines.

Via Net Loss Design Plan

3.18 With adequate control of singing incorporated in basic trunk design, talker echo is then the controlling requirement on trunks which can be involved in end-to-end connections having appreciable absolute transmission delays. Intertoll, secondary intertoll, toll connecting, and long-haul direct trunks are of this type. For these trunks, the loss objectives are specified in terms of the Via Net Loss (VNL) design plan. This plan was arrived at by first considering the tolerance of customers to talker echo, then taking into account the statistical variations of the elements involved, and from this determining the loss required between Class 5 offices in an overall connection. Loss per trunk requirements are finally obtained by allocating this overall connection loss among all the trunks in the connection.

Overall Connection Loss Requirement

3.19 Overall Connection Loss is defined as the total design loss (one-way) of a toll connection from the outgoing switch of the originating Class 5 office through the outgoing switch of the terminating Class 5 office. It is primarily determined by the talker echo requirement. Whether a given amount of talker echo is objectionable or not to a given customer will depend upon: (1) the delay in the echo path, (2) the loss of the echo path, and (3) the customer's particular talker echo tolerance. Without considering variations, the Overall Connection Loss can be expressed for a given echo path delay by the expression:

Overall Connection Loss = ½ (the echo tolerance for the average observer minus the average return loss of customer loops at the distant Class 5 office)

The echo tolerance comes from Table 1 (or Chart 3), and has a normal distribution among observers with a standard deviation of 2.5 dB.

3.20 The return loss component in the above formula considers only the major reflection which causes annoying echo. This reflection occurs at the distant Class 5 office at the junction between the toll connecting trunks and customer loops. Reflections at intermediate toll offices *must* be controlled by specified *through* and *terminal balance* requirements, since a basic assumption of the VNL plan is that no appreciable echo occurs at any point in the overall connection between Class 5 offices.

3.21 As discussed in Paragraph 3.05, return loss in the echo range is not a single value but consists of a wide spread of values. The figures for return loss which have been used in deriving net loss design factors are based on field tests of a large number of calls. The design factors therefore assume that the average return loss at Class 5 offices is 11 dB and its standard deviation is 3 dB. Hence, practically all of the return losses could be expected to fall in the range from 2 to 20 dB; i.e., three standard deviations on either side of the average.

3.22 Another factor to be considered is the variation of trunk losses from their assigned values. These variations directly affect the loss in the echo path. Present maintenance procedures allow trunk stability to be maintained at a standard deviation of 1 dB in each direction. For practical purposes, it is assumed that this is equivalent to a standard deviation of 2 dB in the round trip echo path. This variation applies to each trunk in a connection.

3.23 To take these distributions into account, it is necessary to state our service requirement: The customer should seldom get objectionable echo. This can be realized if the determination of trunk loss is based on assuring satisfactory echo performance in 99 percent of all connections. The 99 percent point on a distribution curve is equivalent to 2.33 standard deviations. However, by the judicious use of echo suppressors and by the margins included in the simplified design methods discussed below, satisfactory echo performance is actually achieved in more than 99 percent of all connections.

3.24 We are now ready to rewrite the formula for one-way loss of an overall connection by adding to the average losses in the echo path a quantity equal to 2.33 times the combined standard deviations of all the variables, as follows:

$$\text{Overall Connection Loss} = \frac{\text{Avg. Echo Tol.} - \text{Avg. Ret. Loss} + 2.33\sqrt{D_T^2 + D_R^2 + ND_L^2}}{2}$$

Where Avg. Echo Tol. = Echo Tolerance for average observer, in dB as a function of delay (Table 1)

Avg. Ret. Loss = Average Return Loss of subscriber loops or 11 dB (Paragraph 3.21)

D_T = Standard Deviation of echo tolerance distribution among observers, or 2.5 dB (Paragraph 3.08)

D_{RL} = Standard deviation of return loss distribution, or 3.0 dB (Paragraph 3.21)

D_L = Standard deviation of distribution of round trip circuit loss variation per trunk, or 2.0 dB (Paragraph 3.22)

N = Number of trunks in the connection between Class 5 offices

3.25 As an illustration, taking the condition for one trunk with 20 milliseconds round trip delay, the overall connection loss becomes:

$$\frac{11.1 - 11 + 2.33\sqrt{2.5^2 + 3^2 + 2^2 - 5.0\text{ db}}}{2} = \frac{.1 + 2.33\sqrt{14.25}}{2} = \frac{.1 + 2.33 \times 3.8}{2} = \frac{8.9}{2} = 4.5$$

3.26 By using the required losses for the various values of round trip delay from Table 1, the trunk losses shown in Table 2 are obtained for various numbers of trunks in tandem. Using these values, curves of the required overall connection loss (Class 5 to Class 5 office) as a function of delay and number of trunks are plotted on Chart 4.

TABLE 2

Round Trip Delay (Milliseconds)	Overall Connection Loss (dB) Which Results in Satisfactory Echo Condition in 99% of Cases			
	1 Trunk	2 Trunks	4 Trunks	6 Trunks
0	0.3	0.8	1.7	2.5
20	5.0	5.6	6.5	7.4
40	8.5	9.0	9.8	10.6
60	10.9	11.4	12.3	13.1
80	13.2	13.7	14.6	15.4
100	15.1	15.6	16.5	17.2

3.27 By using the values of Table 2, curves of the required overall connection loss as a function of delay and number of trunks are obtained as shown in Chart 4. Inspection of Table 2 or Chart 4 indicates that as the number of trunks is increased, an increase of approximately 0.4 dB per trunk is required. This is compensation for the increased loss variability with increased number of trunks. Actually a series of linear approximations to these curves is used to simplify the VNL design calculation. The approximation is derived by considering:

(a) The need for increased loss at low delays to prevent near-singing. Singing requirements dictate a minimum one-way loss of 4 dB between reflection points. Therefore, the approximate curve for one trunk is drawn to intersect the 0 delay axis at 4.4 dB (4 dB protection against singing and 0.4 dB against negative variation of trunk loss).

(b) The need for control of noise, crosstalk, and carrier system overloading.

(c) The need to limit the maximum trunk loss to provide satisfactory transmission. This is accomplished by drawing the linear approximate curve so that it intersects the exact curve at 45 milliseconds, and only using VNL design rules below 45 ms. Above 45 ms delay, one of the trunks will be equipped with an echo suppressor in accordance with application rules for the plan, and operated at zero loss.

3.28 The linear approximate curves for more than one trunk are derived by adding 0.4 dB for each additional trunk to the loss required for a single trunk. This loss is approximately the difference between the exact loss curves (Chart 4) at 45 milliseconds. The 0.4 dB loss can be thought of as an additional constant that is needed to protect against possible negative variations of trunk losses. The linear approximate curves are then given by the equation:

$$\text{Overall Connection Loss} = 0.10 \times (\text{echo path delay, ms}) + 4.0 + 0.4 \times (\text{number of trunks})$$

where the constant 0.10 is the slope of the linear approximate curve in Chart 4, in dB/ms.

Via Net Loss and Via Net Loss Factors

3.29 In the preceding discussion, the overall loss of a connection between Class 5 offices was determined. It is desirable to assign this loss so that each trunk of a connection operates at the lowest loss practicable considering its length and type of facilities. The procedure is to assigned 2 dB of the constant in the equation of Paragraph 3.28 to each toll connecting trunk (4 dB total on each connection) and to assign the remainder to all trunks, including toll connecting trunks, in proportion to the echo path delay of each trunk. This remainder is called via net loss (VNL), which is defined as the lowest loss value in dB which must be assigned to the trunk(s) in the connection to satisfy the echo requirement. Now:

$$\text{Overall Connection Loss} = \text{VNL} + 4 \text{ dB}$$

where $\text{VNL} = 0.10 \times (\text{echo path delay}) + 0.4 \text{ dB}$

3.30 Since the echo path delay of a trunk is related to its length, the above equation is usually given in terms of length and a via net loss factor (VNLF) as:

$$\text{VNL} = \text{VNLF} \times (\text{one-way distance}) + 0.4 \text{ dB}$$

where $$\text{VNLF} = \frac{2 \times 0.10}{\text{velocity of propagation}} \text{ in dB/mile}$$

The factor "2" appears in this derivation because the loss (in dB) in the slope of the linear approximate curve in Chart 4 is one-way, while the delay is round trip. The velocity of propagation used in the above equation must allow for the delay in an average number of terminals, repeaters, and intermediate modulation equipments, as well as the velocity of propagation of the carrier, radio, or voice-frequency facilities. The accepted values for the via net loss factors of typical facilities are given in Table 3.

TABLE 3
VIA NET LOSS FACTORS

	Via Net Loss Factor — 2-Wire Circuits (dB per mile)	Via Net Loss Factor — 4-Wire Circuits (dB per mile)
Toll Cable (quadded Low Capacity)		
19H172-63, 16H172-63	0.04	0.020
19B88-50 (side and phantom)	0.04	0.020
19H88-50 (side and phantom)	0.03	0.014
19H44-25, 16H44-25	0.02	0.010
VF Open Wire (Side and Phantom)	0.01	—
Carrier (all types, including microwave radio)	—	0.0015
Exchange Cable, H88, D88, or other VF loading and NonLoaded	.04	.017

3.31 The Via Net Loss Factors for 4-wire trunks are derived from the lowest losses permitted from a talker echo standpoint which, together with other VNL design rules discussed, also meet the current objectives for singing, crosstalk, noise, and carrier system overloading. The factors for 2-wire trunks have been increased over the echo requirements on a judgment basis to allow for the effect on singing as well as on talker echo of additional return loss paths at intermediate repeater points. In 2-wire voice frequency facilities it is necessary to support the required repeater gains by adequate impedance matching to permit working at the losses determined by the Via Net Loss Factors. It should be noted that 2-wire trunks are not equivalent in terms of loss, echo, and delay to high velocity 4-wire trunks even though the 2-wire trunk is operating at "Via Net Loss."

Application of Echo Suppressors

3.32 At about 45 milliseconds (ms) of round trip delay in a connection, the amount of overall loss required for echo control becomes sufficiently high to degrade the received volume. Echo suppressors (E/S) are then used to eliminate the need for any loss in the trunk to which they are assigned. Echo suppressors are 4-wire voice-activated devices which insert high loss in the return echo path during the time a customer is talking. However, since they produce some degradation in the received speech, the application rules are designed normally to permit only one suppressor in a connection. This is easily accomplished because of the hierarchical nature of the network and the limited size of the Regional Center areas. The maximum echo path delay within any Regional Center area is usually sufficiently short so that echo suppressors are not required for intraregional trunks. In contrast, there is a possibility of greater than 45 ms delay in connections routed between Regional Center Areas. Echo suppressors are therefore applied to all Regional Center to Regional Center trunks, and of course are required on all circuits routed via an earth satellite.

3.33 In addition, echo suppressors are applied to any interregional intertoll trunks (other than RC-RC) whose design loss is greater than 2.6 dB. A 2.6 dB design loss equates to a delay of 22ms ($0.10 \times 22 + 0.4 = 2.6$ dB) and allows an additional 23ms delay for the other trunks in the connection. Since intertoll trunks are tested with 2 dB pads at each end, a design loss of 2.6 dB corresponds to an assigned class mark for Automatic Transmission Measuring Systems of 6.6 dB. If the trunk utilizes all carrier facilities, the length at which an E/S is provided is 1565 miles. It is recommended that interregional intertoll trunks equipped with E/S be operated at 0.0 dB loss (4 dB EML). 2db + 0db + 2db = 4db. two pads

3.34 An end office toll trunk between two Class 5 offices is permitted the maximum 45 ms round trip delay. As can be seen from Chart 4, the loss required to prevent echo for a circuit with this delay is 9 dB. However, in the interest of minimizing contrast, the maximum loss is restricted to 8 dB, which includes 0.5 dB battery supply loss at each Class 5 office. Thus, the longest direct trunk permitted without using echo suppressors is 1730 miles. $8.0 - (4.0 + 0.5 + 0.5 + 0.4) = 2.6$ dB; 2.6 dB/.0015 dB/mi = 1730 miles). Trunks longer than this should employ echo suppressors and be assigned a loss of 6 dB.

3.35 Foreign toll connecting trunks (toll connecting trunks between different toll center areas) should be designed at VNL +2.5 dB, with a maximum of 5.5 dB. This will also result in a permissible length of 1,730 miles. Trunks which exceed this length should employ echo suppressors and be assigned a loss of 3.0 dB.

3.36 It will be noted from Chart 1 that echo suppressors are installed on each RC-RC trunk. They are installed either as full echo suppressors at one end or as split echo suppressors at both ends of the trunk. On this basis, every connection involving an RC-RC route contains the equivalent of one echo suppressor. By the use of only carrier facilities on the chain of final trunk groups, echo suppressors are avoided on final route trunks other than RC-RC. The trunks in final routes must be designed so that a call from any end office to another end office in the same region routed via their regional center is satisfactory from an echo standpoint without the aid of an echo suppressor. This is achieved if the trunks are designed in accordance with the above described plan and the necessary maintenance attention is applied to ensure that the deviations from the 1000-Hertz expected measured loss (EML) of the individual trunks are kept within established objectives.

4. TRUNK LOSS OBJECTIVES

4.01 With the background of VNL concepts discussed in Part 3, we are now ready to summarize by stating the design loss objectives for the various trunks included in the switching plan (Chart 1). The basic design loss objectives are applied to these trunks in accordance with their place in the overall plan, so that the net effect of any connection in the network results in an overall connection loss of VNL+4 between Class 5 offices.

(Note: The VNL+4 value does not include switching and battery supply losses at the Class 5 offices.) ✓

4.02 Trunk administration from a design standpoint is complicated by switching pad arrangements in 4-wire toll offices which permit economies through "High Loss" trunk design, and also by various test pad arrangements. For these reasons the basic design objectives for each major trunk category cannot be expressed in terms of the *Expected Measured Loss* (EML). Therefore, a new term of *Inserted Connection Loss* (ICL), has been adopted to enable direct comparisons with the basic design objectives (which will be known as ICL Objectives). Both EML and ICL values are required on circuit layout records for Plant and Engineering administrative purposes, respectively. NOTE

Expected Measured Loss (EML)

4.03 The Expected Measured Loss of a trunk is the 1,000 Hertz loss that is expected to be measured between specified test points. EML is the "calculated" loss that will be measured between the outgoing switch appearance at the outgoing end of the trunk and the outgoing switch appearance to which the trunk is connected at the incoming end, and includes test pad losses when specified in the measuring circuits. The value of the Actual Measured Loss (AML) can be directly compared to the EML for Plant administrative purposes.

Inserted Connection Loss (ICL)

4.04 The Inserted Connection Loss is the net equivalent 1,000 Hertz loss inserted by *switching* the trunk into an actual operating connection. It is the sum of all gains and losses from the originating outgoing switch appearance to the terminating outgoing switch appearance to which the trunk is connected. The ICL is calculated by subtracting the test pad losses from the EML. In addition, with High Loss trunk design, the value of the A-pad must also be subtracted from the EML of the high loss trunk to obtain the ICL (refer to Paragraph 4.09). The value of the ICL of a trunk can be directly compared to the basic ICL design objective for Engineering administrative purposes.

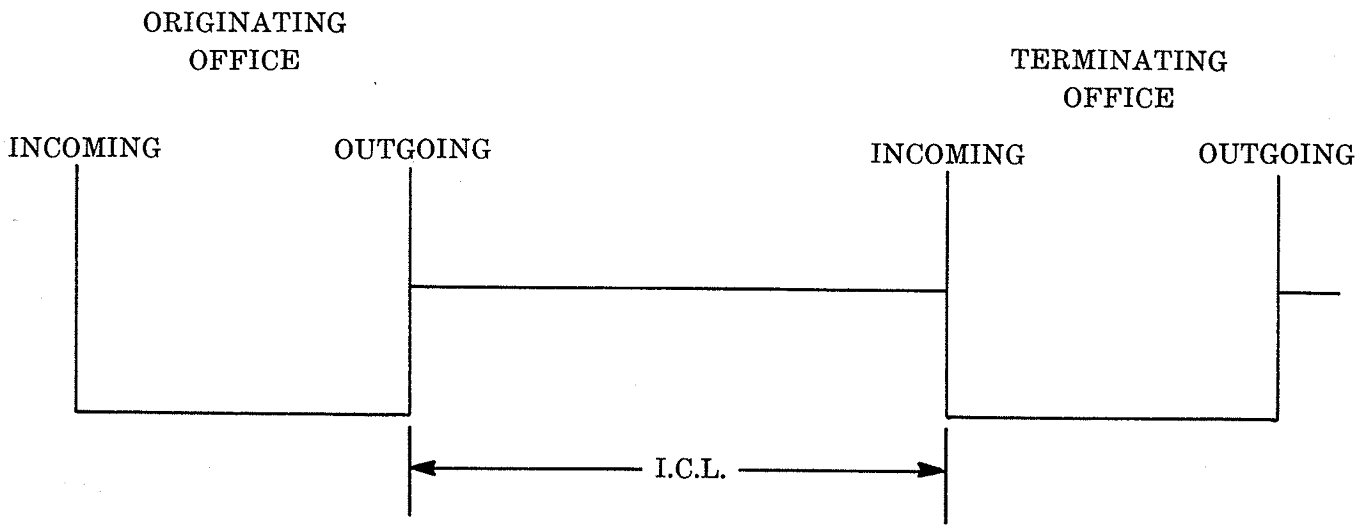


Figure 1
INSERTED CONNECTION LOSS

4.05 With the concept of ICL design available, it is possible to clarify and purify the concept of "VNL." In the past it has not always been clear whether a trunk can or cannot be classified as "operating at VNL" when its loss calculation included "penalty" losses such as those associated with operating on uncompensated temperature variation (UTV) facilities, or "B" Factors associated with trunks between nonbalanced offices as discussed in Paragraph 5.09. As developed in Part 3, VNL *is* a theoretical derivation, and does *not* include any penalty losses. However, by definition, ICL is the actual operating loss assigned by the designer to a trunk, and therefore can and should include penalty losses if required.

Inserted Connection Loss (ICL) Objectives

Intertoll Trunks

4.06 An *intertoll trunk* connects any Class 1 through 4 toll switching system to any other Class 1 through 4 office. Intertoll trunks should always be designed to be 4-wire whenever there is a requirement for gain devices to be provided in the trunk, for reasons given in Paragraph 3.31.

Design Objective ICL of Intertoll Trunks:

	Objective	Maximum
Final Group	VNL dB	1.4 dB
High Usage and Full Groups	VNL dB	2.6 dB
Trunks with E/S	0 dB	0.5 dB

Since most intertoll trunks operate on carrier and are tested with a 2 dB test pad (TP2) at each end, the following Table 4 has been provided as a convenient reference for these conditions. Note that Table 4 assumes that the intertoll trunks are operating without any penalty losses due to uncompensated temperature variation facilities or nonbalanced offices.

TABLE 4

ICL AND EML VALUES TO BE ASSIGNED TO ANY INTERTOLL TRUNK OPERATING ON ALL CARRIER FACILITIES

Trunk Length (Note a) (miles)	Inserted Connection Loss ICL = Via Net Loss (0.0015 × Avg Length + 0.4 dB) (dB)	Expected Measured Loss EML = TP2 + ICL + TP2 (Note b) (dB)
0-165	0.5	4.5
166-365	0.8	4.8
366-565	1.1	5.1
566-765	1.4	5.4
766-965	1.7	5.7
966-1165	2.0	6.0
1166-1365	2.3	6.3
1366-1565	2.6	6.6
Any length with echo suppressor (Note c)	0.0	4.0

Notes:

(a) The average or midlength in each interval corresponds to the class mark of the ATTC or test frame associated with the ATMS.

Example: Midlength point of 166-365 mi. is 266 mi.

$$ICL = VNL = (0.0015 \times 266) + 0.4 = 0.8 \text{ dB}$$

$$EML = TP2 + ICL + TP2 = 2.0 + 0.8 + 2.0 = 4.8 \text{ (class mark)}.$$

(b) EML values correspond to class marks. The loss values actually measured are 4 dB greater than the ICL loss of the trunk because of the 2 dB pads in the measuring facilities at each end.

(c) In 4-wire toll offices employing 7 dB A-pads on intertoll trunks, the additional loss of 1.8 dB for 1A–type Echo Suppressor plus office cabling and equipment losses greater than about 0.3 dB may be too high to permit the trunk to operate at 0.0 dB. In such cases, the ICL should be 0.5 dB and the EML 4.5 dB. However, provision of 3-type E/S will allow the 0.0 dB objective to be met in all cases.

Secondary Intertoll Trunks

4.07 A *Secondary Intertoll* Trunk is used to connect a toll switching machine and its associated manually operated assistance switchboard in the same or adjacent building (such as operator tandems, operator junctors, operator service, 121, 131, TX, etc.). These trunks are separately identified because they are "extra" trunks in the hierarchical plan. They also differ in that they can and should be operated at zero dB loss when designed without gain devices in association with 4-wire toll machines (by switching out the A-pad of connected trunks).

Design Objective ICL for Secondary Intertoll Trunks:

	Objective	Maximum
Without Gain Devices	VNL dB	0.5 dB
With Gain Devices	0.0 dB	0.5 dB

Toll Connecting Trunks

4.08 A *Toll Connecting Trunk* connects a Class 5 local office to any higher ranking toll office. As originally established in Part 3, the theoretical design loss of these trunks is VNL + 2 dB. However, the test points established with the more recent ICL concept now include additional battery supply equipment, which was previously assigned to the loop from a design standpoint. This additional loss is about 0.5 dB, and results in the following:

Design Objective ICL for Toll Connecting Trunks:

	Objective	Maximum
Basic	VNL + 2.5 dB	4.0 dB
Alternate*	3.0 dB min.	4.0 dB

*For cable facilities less than 15 miles and carrier facilities less than 100 miles.

4.09 Intertoll trunks in four-wire switching systems generally have additional gain available which, if added to a connection, will make it possible to increase the loss of toll connecting trunks by an amount equal to the available gain. The method of accomplishing this is reffered to as "High Loss Design". Switchable pads (A Pads) are included in the intertoll trunks, and the loss of toll connecting trunks is increased by an amount equal to the value of the A Pad in the intertoll trunk. When the intertoll trunk is switched to the High Loss trunk, the machine switches out the A Pad. This effectively transfers available gain from the intertoll trunk to the toll connecting trunk. Steps must be taken to insure that "High Loss" designed trunks are never switched to other "High Loss" designed trunks.

End Office Toll Trunk (Direct Long-Haul)

4.10 A *Direct Trunk* interconnects two Class 5 offices and normally is considered as a local trunk. However, if a direct trunk is provided over distances involving appreciable echo path delays (in the order of 100 miles), it should also be designed in accordance with VNL concepts.

Design Objective ICL for end office toll trunks:

Objective	Maximum
VNL + 5	8.0 dB

CONTROL SWITCHING POINT

5. THROUGH BALANCE AT 2-WIRE CSP'S

5.01 The regional centers (Class 1), a majority of the sectional centers (Class 2), and some of the larger primary centers (Class 3) situated within the United States are equipped with 4-wire switching systems. The remainder of the Control Switching Points (CSP's) employ 2-wire systems at the present time. The use of 2-wire switching systems at primary (Class 3) and the smaller sectional (Class 2) centers has been made possible by careful balancing procedures, and by the extensive application of high-speed carrier systems. By providing the equivalent of 4-wire circuits, carrier facilities eliminate the intermediate singing and echo problems present with 2-wire voice facilities. The echo paths at the 2-wire switching points can be effectively minimized by providing a high through balance at the switching offices. To provide adequate margin against singing and unsatisfactory echo conditions, the 4-wire terminating sets employed on trunks at 2-wire switching offices are designed to have an input impedance (viewed from the 2-wire side) that, over the transmitted frequency band, closely resembles the impedance of the compromise network (with allowance for average office cable resistance) of other trunks to which they switch.

5.02 The via net loss factors shown in Table 3 assume that all interconnections of intertoll trunks will encounter no appreciable echo paths at the CSP (Class 1, 2, and 3) offices. In 4-wire switching offices, such an echo path is automatically eliminated by retaining 4-wire operation on through switched connections. By careful engineering installation and maintenance, 2-wire switching systems can be made to give satisfactory transmission performance. The best transmission results are obtained if the switching system, the terminal equipment (carrier terminals or voice-frequency terminal repeaters), and the associated switchboards and testboards are in the same or adjacent buildings. Where these conditions do not exist, a complete review of the overall switching layout is necessary to determine the steps to be taken to insure satisfactory transmission performance.

5.03 On connections through a 2-wire CSP system, return currents (echo and singing) arise due to unbalance between the office equipment and wiring and the balancing network in the 4-wire terminating sets. By using capacitors for balancing office cabling as outlined in later paragraphs, these return currents can be held to such small values as to cause little impairment on the switched connections.

5.04 *Through balance* is required whenever intertoll trunks are switched together for a connection "through" to another toll office. It is defined as the procedure of measuring and adjusting all intertoll trunks in a CSP to enable meeting the echo return loss and singing point objectives:

Through Balance Objectives	50% of Intertoll Trunks Equal to or Exceeding	Minimum
Echo Return Loss (ERL)	27 dB	21 dB
Singing Point (SP)	20 dB	14 dB

5.05 In order to interconnect trunks at random at 2-wire switching points, a single type of compromise network must balance any of the trunks in the office. It follows that the impedance of all the trunks terminating in the office must be equal to that of the network within fairly precise limits. A nominal office impedance of 600 ohms was originally selected because of the impedance characteristic of open-wire lines. It is currently used in the trunk circuits terminating at step-by-step, No. 5 crossbar, and most manual toll switchboards while the crossbar tandem system and certain toll switchboards are designed for a 900-ohm impedance. The trunk terminal impedance is designed to match the nominal impedance of the office. However, since supervisory signals are often transmitted over the talking path conductors, capacitors are required in certain locations to isolate parts of the signaling circuit. Consequently, the office impedance is assumed to be 600 or 900 ohms (depending on the type of office) in series with a 2.16 μF capacitor, and trunk terminal impedances are so designed.

5.06 Chart 5 shows a typical connection of two intertoll trunks in a 2-wire toll office. The input impedance of the 4-wire terminating sets is modified by the office cabling required to extend the trunk to the switching point (switches or switchboard), by switchboard multiple, and by any permanently connected testboard appearances. Also, there are different amounts of cable in different trunks. This difference impairs the office return loss; therefore, the capacitance of each switching path is adjusted to a uniform value by means of the drop building-out (DBO) capacitors shown in Chart 5. DBO capacitors are generally part of the trunk circuit. Having restored uniformity to the terminal impedance, the network building–out (NBO) capacitors shown in Chart 5 are adjusted to a value such that the compromise network balances the trunk terminal impedance as modified by the office cabling and DBO capacitance of the two trunks that are interconnected.

5.07 Since office cable has a distributed shunt capacitance and series resistance, it is practically impossible to balance its effects perfectly. The shunt impedance resulting from the distributed capacitance of the office cabling can be satisfactorily balanced by the adjustable NBO capacitor. It is necessary to limit the series resistance of office cabling in 2-wire CSP offices in order to obtain satisfactory balances on through connections by means of simple balancing networks. The desired return losses can be obtained by limiting the value of series resistance introduced by the wiring between the 2-wire sides of any interconnected 4-wire terminating sets to a maximum of 65 ohms in 900-ohm impedance offices and 45 ohms in 600-ohm impedance offices. Such limitations involve consideration of office layouts, use of 22-gauge (instead of 24-gauge) wiring in transmission leads wherever possible, and provision of direct cabling (rather than cross-connections) between 4-wire terminating sets and trunk relay equipments. Also, it is desirable to limit the length of office cabling (both series and bridged), because aside from balance considerations, the relatively high shunt capacitance of office cables tends to cause attenuation-frequency distortion on through switched connections. "Office cabling capacitance" includes the capacitance of switchbank multiple, switchboard and testboard multiple (if present), as well as all of the cabling from terminal equipment to the switches. This distortion is controlled by limiting the total 2-wire shunt capacitance to a maximum of 0.08 μF in both 600-and 900-ohm CSP offices.

5.08 It is necessary to employ an adjustable DBO capacitor on each trunk as shown in Chart 5. In switching systems having several different paths through the switches, this may require more than one capacitor in each trunk circuit. When these capacitors are employed, the capacitance of each path is built out by means of the adjustable DBO capacitor to be equal to the capacitance of the longest path in the office. The value of the NBO capacitor is made about equal to the value of the capacitance of the longest path through the office. Its actual value is determined by connecting two trunks together which follow this path and adjusting the NBO to give the maximum return loss at 2000 Hertz. This value of capacitance is then employed as the value of the NBO capacitor in each terminating set in the office. The actual values of the DBO capacitor adjustments are then obtained by connecting each trunk to a properly built-out test termination and adjusting for the best return loss at 2000 Hertz.

5.09 After adjustment at 2000 Hertz, measurements of ERL on all intertoll trunks should be made using a noise generator whose output is properly weighted from an echo standpoint, together with a receiving transmission measuring set also weighted for echo. Singing point measurements are also made on all trunks, and if these tests meet the objectives of Paragraph 5.04, the 2-wire switching office has adequately approached the transmission performance of 4-wire switching. Thus, the office may be used without a penalty being assigned. If this degree of balance is not achieved, a "B" factor is temporarily assigned to the switching office, and the office is considered a "deficient CSP". "B" factor is the additional loss assigned to each intertoll trunk terminating at a deficient 2-wire CSP to provide the same echo performance as if 4-wire switching was provided. In other words, there is a transmission penalty whenever switching is done on a

2-wire basis unless the office is properly balanced. The "B" factors are in steps of 0.3 dB (to conform to class marks) as follows:

Median Office Balance	"B" Factor (dB)	Median Office Balance	"B" Factor (dB)
27	0	16	0.9
21	0.3	15	1.2
18	0.6	14	1.5

5.10 Every effort should be made in the design of a CSP office to avoid the need of assigning a "B" factor inasmuch as this adds loss in every switched connection and, if occurring at a number of offices on a connection, increases the number of calls that are unsatisfactory due to the overall transmission loss being too high. Because the added loss represented by the "B" factor is assigned to each intertoll trunk, the switching penalty through an office requiring such assignment is equal to twice the value of the "B" factor.

5.11 This discussion has concerned itself primarily with balancing the office paths through the switches. There are other paths for assistance traffic through associated switchboards which also need to be taken into account in the through balance job. Techniques depend on types of equipment, office layout, etc., but the same broad principles apply as for the paths through the switches.

6. TERMINAL BALANCE AND TOLL CONNECTING TRUNK DESIGN

Terminal Balance Objectives

6.01 Terminal balance testing is required in each toll switching office (Class 4 and higher, both 2-wire and 4-wire) having trunks to or from a class 5 office.

6.02 Via net loss operation of trunks is based on having adequate balance at all points where trunks are connected (switched) together. When two intertoll trunks are switched together, the resultant balance is called through balance. When an intertoll trunk is switched to a toll connecting trunk, the resultant balance is called terminal balance. Terminal balance is defined as the balance between the impedance of the compromise network in the intertoll trunk 4-wire terminating set (or its equivalent) and the impedances of the toll connecting trunks which connect to subscriber loops.

6.03 The basic terminal balance objectives necessary to support VNL operation of intertoll trunks assume a specific method of measuring from a test hybrid coil (simulating an intertoll trunk) through each toll connecting trunk to a 900-ohm plus 2.16 μF termination in the Class 5 office. These objectives are:

Terminal Balance Objectives (2-Wire Trunks at 2-Wire Offices)	50% of Toll Conn. Tks. Equal to or Exceeding	Minimum
✓ Echo Return Loss (ERL)	18 dB	13 dB
✓ Singing Point (SP)	10 dB	6 dB

6.04 The objectives shown above are the *basic* terminal balance objectives which apply to 2-wire toll connecting trunks in a 2-wire toll office. When 4-wire toll connecting trunks appear at the 2-wire switching point with properly selected 4-wire terminating sets not requiring repeating coils to derive signaling leads, the input impedance of this equipment is substantially the same as that of the compromise network on the intertoll trunk. The resulting ERL and SP are quite good, and therefore the balance objectives are increased 3 to 5 dB as a troubleshooting tool. These higher objectives can also be met when a repeating coil is encountered in the path from the 4-wire terminal to the switches, with certain exceptions involving built-in hybrids and older trunk circuits. Layouts involving more than one repeating coil in the path to the switches can and should be avoided, as they will not meet the basic objectives.

6.05 Because of the A-pad, hybrid coil, and testing arrangements in 4-wire toll offices, different test objectives have been established which are higher but equivalent in principle to those discussed above.

Terminal Return Losses

6.06 Terminal return losses affect both echo and singing conditions. Their magnitudes express the measure of similarity at various frequencies between the impedance of the toll connecting trunk plant and that of a compromise impedance.

While considerable emphasis has been given to echo return losses, it is important also to recognize those return losses affecting the singing margins below and above the echo frequency range. Frequently, both the low and high frequency singing points may be quite low and about equal in magnitude. A sizable improvement engineered for one may have little or no effect on the other, resulting in only a small improvement in overall singing stability. It may merely shift the singing to the other end of the frequency range.

Echo Frequency Improvement

6.07 The echo range is considered to extend between 500 to 2500 Hertz and the echo return loss is the composite of the return losses over this range. In the determination of via net loss factors for design of trunks, the echo return losses presented at the Class 5 office by the wide variety of customer loop plant conditions against a compromise network are described as a distribution having an average of 11 dB with a standard deviation of 3 dB. The lower portion of this distribution presents the hazards to service from an echo standpoint.

6.08 In the broader picture it would, of course, be desirable to improve the loop plant, either by reducing the standard deviation of the distribution or by improving its average with the same standard deviation. Until such advances are made, terminal balance improvement can only be achieved by careful design of the toll connecting trunks. Since the bulk of toll connecting trunks involve 2-wire loaded cable plant having low return losses against a compromise network at the upper frequencies, some of the desired improvement can be obtained over the upper section of the frequency range by the use of impedance compensators.

Singing Frequency Improvement

6.09 The lowest return losses, those that tend to cause singing, as a rule fall outside of the echo range. On the low frequency side they may be below 500 Hertz, and on the high frequency side are usually above 2500 Hertz. The poor return loss at the low frequencies, which may be as low as 2 to 3 dB, usually results from the poor impedance characteristic of the repeating coil circuits at those frequencies. Past practice generally specified 4 μF capacitors in both the line and drop sides of repeating coils associated with the toll connecting trunks at a switching point. It has been found that an improvement of as much as 6 dB in return loss at 300 Hertz can be obtained in some cases by the substitution of a 1 μF instead of the 4 μF capacitor on the drop side of certain of the commonly used repeating coils without appreciable effect on transmission or signaling. This modification has been adopted in the Bell System for applications of these repeating coils on toll connecting trunks.

6.10 The above arrangement applies specifically to types of apparatus normally used in the Bell System. It is an important consideration which needs to be checked for each type of trunk circuit likely to be encountered, to determine what improvement in low frequency return losses can be obtained. As a guide to selecting the value of capacitance applicable to various coil inductance values, the following table can be used:

SHUNT INDUCTANCE LOOKING INTO DROP SIDE OF COIL		CAPACITANCE
Low	(0.5 to 1.0 Henry)	1 μF
Medium	(1.0 to 1.5 Henry)	2 μF
High	(1.5 to 3.0 Henry)	3 μF

Information on the shunt inductance of particular coils should be obtained from the manufacturer.

6.11 At the high end of the frequency range, very low return losses result from the extreme variation of the line impedance from the midband values as the facility approaches cutoff. The impedance compensator used for improvement in the echo range also gives some benefit to the singing margin at frequencies just below cutoff on 2-wire loaded trunks.

Toll Connecting Trunk Design

6.12 As developed in Parts 3 and 4, the objective ICL for toll connecting trunks is VNL + 2.5 dB, which lies in the range of 3 dB (minimum) to 4 dB (maximum). The design loss of each trunk should be checked by measurement before the terminal balance tests are made.

6.13 4-wire trunks require no special terminal balance treatment other than that covered in Paragraph 6.04.

6.14 The design loss value for each toll connecting trunk is determined by the facilities to be used, as shown in the following example:

Example: 2-Wire Cable Circuit, 4.5 Miles of 24H88

Actual Loss $= (4.5 \text{ mi.})\ (1.2 \text{ dB/mi.}) + \text{Office Losses}$

$= 5.4 + 1.0 = 6.4 \text{ dB}$

Objective ICL $= \text{VNL} + 2.5$

$= (\text{VNLF} \times \text{Mi} + 0.4 \text{ var.}) + 2.5$

$= (0.4 \text{ dB/mi.} \times 4.5 \text{ mi.} + 0.4) + 2.5$

$= 0.2 + 0.4 + 2.5 = 3.1 \text{ dB}$

Required Repeater Gain $= 6.4 - 3.1 = 3.3 \text{ dB}$

Expected Measured Loss (calculated, assuming 2 dB Test Pad at Toll Office):

EML $= \text{ICL} + \text{TP2} = 3.1 + 2.0 = 5.1 \text{ dB}$

Circuit Layout Record EML (to the nearest ATTC class mark) $= 5.1 \text{ dB}$

Note that it is recommended that the EML value for the Circuit Layout Record be calculated to the nearest class mark of automatic test frames, even though they may not presently be installed in the particular office involved.

6.15 For trunks on 2-wire loaded facilities, repeaters (V-type, E-type, etc.) should preferably be located at the Class 5 office on a short trunk, or at an intermediate point on a long trunk. If the repeater is located at the toll office, it is difficult to meet terminal balance objectives because the structural irregularities of the cable are amplified by the repeater gain.

6.16 With load spacing accuracies of 2 or 3 percent repeatered voice-frequency facilities are stable (do not sing) in the idle condition for VNL + 2.5 dB design. Inasmuch as many of these trunks are associated with loop signaling facilities where no special incoming or outgoing trunk circuit is involved, they operate satisfactorily without the provision of an idle circuit termination. With other types of signaling where a trunk circuit is provided, an idle circuit termination is incorporated in the trunk circuit design, and this feature should be used where available.

Impedance Compensation

6.17 Loaded 2-wire trunks will require impedance compensators at the toll office. Impedance compensation is used to make the sending end impedance of a loaded cable pair remain substantially uniform and predominantly resistive in the frequency range from about 1000 Hertz up to about 85% of its cutoff frequency.

6.18 It is common practice to use half section termination for loaded pairs at the switching point. The impedance characteristic of a loaded pair at half end section has a resistance component (which increases with frequency), but a very small negative reactance component. The compromise network in the intertoll trunk circuit has a fixed resistance which retains the same magnitude at all frequencies. Since the resistance component of the trunk impedance increases with frequency, the return loss against the same fixed value of the compromise network deteriorates with increasing frequency, the extent depending on the cutoff frequency of the loading system. With H88 loading, the 3000 Hertz return loss is in the order of 9 dB. To improve this return loss substantially, it is necessary to keep the cable pair impedance from changing appreciably over the frequency range from the 1000 Hertz magnitude for which the basic impedance ratios were selected. The impedance compensator does this.

6.19 The compensator is a simple circuit arrangement consisting of a bridged adjustable capacitor, high frequency corrector circuit, and a low frequency corrector circuit connected in tandem as shown in Chart 6. The capacitor is used to build out the loading end section of the cable to approximately 0.8 section, for which the resistance component of the impedance is substantially uniform over the frequency range up to a high fraction of the cutoff frequency, and the reactive component becomes increasingly negative with frequency. Since the high frequency corrector has a positive reactance proportional to frequency, the addition of this circuit at this point in the loading end section tends to cancel the negative reactance over the frequency range in question. This results in an impedance substantially resistive and of fairly uniform value between 1000 Hertz and 85% of the cutoff frequency.

6.20 The adjustable capacitor should be located adjacent to the cable pair, so that it will directly augment the cable pair end section capacitance. The compensator normally is crossconnected between the main distributing frame and the incoming or outgoing trunk circuit, or the switches, if no trunk circuit is provided.

6.21 Impedance compensators should be provided on all loading systems having cutoffs equivalent to or less than that of standard H88 loading on exchange-type cable (approximately 3500 Hertz). This includes high capacitance D88 loaded cables. It excludes (1) B88, H44 on low or high-capacitance cable, and D88 on low-capacitance cable; and (2) open-wire entrance loading, since the higher the cutoff of the loading, the less the 3000 Hertz impedance departs from the nominal 1000-Hertz value. Where the phantom is not used on H88-50 loading, the impedance compensator may be used to provide return loss improvement.

6.22 The 837A impedance compensator (Chart 6) is the standard for most applications. The 837B (Chart 7) has, in addition to the components found in the 837A, build-out resistors and drop build-out capacitors. The 837B is used primarily for TWX and DATA-PHONE loops but may also be used on trunk circuits that require DBO's but which do not have them built into the trunk circuit equipment. If the largely obsolete heavy loading systems, such as H135 and H175, are to be compensated, the older type impedance compensator (Chart 8), which contains a 2000-ohm resistor in series with the line build-out capacitor, must be used.

6.23 A compensator is not required on any toll connecting trunks which use 4-wire voice-frequency or carrier facilities.

Fixed 2 dB Pads

6.24 Nonrepeatered toll connecting trunks whose ICL would be less than 2 dB must be provided with 2 dB pads at the toll office, to meet terminal balance requirements. Fixed 2 dB pads must also be provided on nonloaded trunks. Other means of designing the trunks, such as operation on coarser gauges or 4-wire, must be used if the 2 dB fixed pad results in an ICL greater than the 4 dB maximum.

6.25 Generally the 2 dB fixed pads, when used in toll connecting trunks, are resistances arranged in a balanced H configuration with a small capacitor in the shunt branch. The capacitor is required to avoid a DC path between the two wires of the line circuit, and its capacitance is small to prevent excess distortion of DC signals transmitted over the trunk.

6.26 The pad should be located in or adjacent to the trunk circuit and should be of either 600 or 900 ohms impedance, depending on the circuit into which it is connected and its position with respect to the repeating coil, if the repeating coil is not a 1:1 type. In a number of trunk circuit types an arrangement of a pad associated with the repeating coil and relay wiring is provided to avoid the effect of the series resistance components on the signaling system. This and other pad arrangements are shown in Chart 9.

2db pads

6.27 In order to obtain maximum return loss benefit when the 2 dB pad is required in the toll connecting trunks, it is preferable to install the pad on the drop side of the repeating coil. However, from a signaling standpoint, it may sometimes be necessary to locate it on the opposite side.

Drop Building-Out

6.28 Occasions may arise where meeting terminal balance objectives requires the addition of a drop building-out (DBO) capacitor to the toll connecting trunks. This generally occurs in offices where drop balancing has been applied to the intertoll trunks for through balancing purposes, or when a larger office network building out (NBO) is required due to long central office cable runs.

6.29 In Chart 5 the magnitude of the NBO usually is about equal to the sum of the total capacitance of the longest 2-wire path through the office, plus a 10% growth factor. However, when either intertoll trunk is switched to a toll connecting trunk which has considerably less office wiring and multiple and no drop building-out, the magnitude of the NBO may be too great and a low return loss may result at the higher frequencies. This can be corrected by the use of a DBO capacitor on the toll connecting trunks adjusted to make up this deficiency of capacitance.

Matching Office Impedances

6.30 With the exception of a few isolated cases, the following summarizes the nominal switching office impedances used in the Bell System: All local Class 5 offices are 900 ohms, and all toll offices are 600 ohms, with the exception of the 900-ohm Crossbar Tandem office. These values of impedance do not reflect actual central office switching equipment impedance, but are standardized values which are based on average impedances of trunk and subscriber facilities connected to the office.

6.31 Proper termination of trunks to match both local and toll office impedances is absolutely necessary to meet terminal balance requirements. At Class 1, 2, 3 and 4 offices, all intertoll and toll connecting trunks must be brought to the common office impedance. At local Class 5 offices, incoming and outgoing trunk circuits must also be arranged to terminate on the subscriber side at a 900-ohm impedance. Since the crossbar tandem switching system has no repeating coil in the outgoing trunk circuits, the impedance at the switches of this system was selected to be most representative of the type of facilities used for outgoing trunks. In the majority of metropolitan areas, the facility most commonly used for outgoing trunks is H88. Therefore, the nominal impedance of 900 ohms was selected for crossbar tandem.

6.32 The office impedance determines the selection of suitable ratio repeating coils or 4-wire terminating sets so that at the point of switching a common impedance is presented by all trunks. This matching of impedance is necessary to obtain the desired return loss conditions. When coils are required at local offices for signaling purposes, the use of the optimum ratio substantially eliminates any reflection loss which would result from dissimilar impedances. Care should be taken to avoid design layouts involving more than one repeating coil in the possible paths through a toll office.

Switchboard Operator's Telephone Set

6.33 With VNL switching, switchboard operators may have access to the outgoing trunks at the VNL point. Normally the low frequency end of the operator's telephone set circuit produces a very poor return loss when connected at the VNL point, and approaches instability from a singing standpoint around 200 to 300 Hertz. It is possible to improve this low frequency return loss by about 6 dB, by adding a 2 μF capacitor in series with the receiver. (Newer sets are equipped with this capacitor.)

6.34 On the average, operator talking volume at the VNL point in the toll office is about the same as that of the average subscriber volume at the toll office on a VNL + 2.5 dB toll connecting trunk. The improvement in return loss derived from the 2 μF capacitor makes it possible to operate at VNL without a pad in the operator telephone circuit, thereby maintaining operator transmit and receive volumes.

6.35 The above arrangements apply specifically to operators' telephone set circuits normally used in the Bell System. It is an important consideration which needs to be checked for each type of operator's telephone set circuit likely to be encountered to determine what improvement in low frequency return losses can be obtained by a similar procedure.

Summary of Equipment Requirements

6.36 Certain equipment in the toll switching office is required if satisfactory terminal balance is to be obtained. Visual checks (on a sampling basis where possible) should be made, to insure that equipment affecting terminal balance is properly installed and cross-connected into the trunks. The following list shows the items most commonly in need of checking:

(a) Impedance compensators for 2-wire loaded toll connecting trunks.

(b) Fixed 2 dB pads in toll connecting trunks with less than 2 dB Inserted Connection Loss and in nonloaded trunks of any length.

(c) 1 μF capacitors in the midpoints of the drop side of the trunk circuit repeating coils. (These capacitors are required to improve the low frequency return losses.)

(d) Impedance ratio of trunk circuit repeating coils. (A reversed or wrong ratio repeating coil will reduce return losses and degrade transmission.)

(e) Modified operator telephone set circuits. (This is required to improve the low frequency return losses.)

(f) Network and (when required) drop building-out capacitors.

(g) Test pads (TP2) in various test circuits such as testboards, test frames, and test lines.

7. CUSTOMER LOOP PLANT DESIGN

7.01 The loop between the customer's telephone and the local central office is always the first (and the last) part of any telephone connection. Satisfactory transmission design of this loop is as important to the toll switching plan as is the design of intertoll and toll connecting trunks.

7.02 More recent telephone sets (Western Electric 500-type or equivalent) permit extension of the loop range and simplification of loop plant design methods. With the transmission performance of these sets, the controlling limitation on customer loops is not the loss of the loop but is generally the conductor resistance ranges set by supervision and pulsing limitations. This loop plant design method is termed "resistance design." As long as the principles of resistance design are adhered to, adequate transmission will be obtained.

7.03 Resistance design is applied by using the following simple guides (for additional discussion see Reference No. 97 in Bibliography, Section 10 of these Notes):

(a) Select the most economical gauge or combination of two adjacent gauges permitted by the conductor resistance range of the central office, but not to exceed the Resistance Design Limit of 1300 ohms.

(b) Use 500-type sets or equivalent on cable loops over 10,000 feet. (Zone 5).

(c) Fully load all cable loops over 18,000 feet.

(d) Limit the length of bridged cable on nonloaded loops to 6000 feet.

(e) For loaded loops, the customer end section plus bridged tap should be at least 0.5 of a load section and no more than 2.0 sections.

(f) There should be no bridged tap between load coils and no loaded bridged tap.

(g) Loops falling beyond the resistance design limits are classified as long loops and require both supervision and transmission review.

7.04 Under resistance design principles, the choice of gauge depends only on the total cable resistance. Detailed knowledge of the transmission art is not required. If the above procedures are followed, the transmission results will be good. Hence, loop design can, in general, be performed by field engineers.

7.05 Resistance design is the standard for loop plant design by the Bell System. Application of resistance design principles provides good transmission and simplified engineering, as well as plant economies.

8. MAINTENANCE CONSIDERATIONS

Trunks

8.01 Good service with distance dialing requires that all trunks be correctly designed, correctly installed, and well maintained. Good design can be defeated unless trunks are maintained close to their transmission design objectives. Although separate requirements and methods of testing were provided for intertoll and toll connecting trunks in the past, there is no longer any difference in dealing with them from a transmission maintenance standpoint. Many types of toll connecting trunks are more complex than some intertoll trunks. From the service standpoint, all the trunks in a given connection are equally important and should receive the same quality of maintenance. Since intertoll trunks are generally longer and more costly, more sophisticated maintenance facilities and procedures are often justified economically, but this does not mean that the intertoll trunks have any more importance in the functioning of the distance dialing network.

8.02 Maintenance of trunks in the distance dialing network consists of:

Circuit order tests

Routine or periodic tests

Correction of troubles found by tests and investigations

8.03 Trunks should not be turned up for service unless they meet all of the applicable circuit order requirements. Failure to observe this rule will only lead to future trouble which could otherwise be avoided. All too often, in the rush to provide service on time and with the intent to save manpower and maintenance money, circuits have been placed in service with one or more defects. These troubles have to be corrected eventually, usually at higher cost and after degradation of service.

8.04 Depending on their complexity, all trunks should be measured at sufficiently frequent intervals to assure that transmission difficulties are detected before they can have a significant effect on the performance of the network. Where periodic tests of large numbers of trunks would require considerable time and manpower, the use of automatic transmission measuring equipment may be economical.

8.05 Testing is of little value unless the detected troubles are corrected promptly. Trunks exceeding specified limits beyond which they would be considered unserviceable should be removed from service as soon as the trouble is detected. After transmission troubles have been corrected, sufficient tests should be made to assure that a trunk meets all of the transmission requirements for a new trunk before placing it back in service.

Types of Transmission Measurements

8.06 Until recently, the most important transmission characteristic considered in maintenance was the 1000 Hertz loss. Although this is still important, other characteristics must now be considered. With the continual reduction in transmission losses of trunks and loops over the years, the increased efficiency of telephone sets, and the more critical attitudes of the customers, noise is increasing in importance in its effect on the performance of distance dialing. In some cases, customer complaints of noise exceed those due to excessive loss and echo or near singing. It is therefore important to measure both loss and noise on circuit order, periodic and trouble tests.

8.07 The distance dialing network is now being used with increasing frequency for the transmission of data and other nonvoice signals. Transmission of these signals is affected by characteristics which affect voice transmission to only a minor degree. Therefore, it will be necessary to check trunks to measure their data handling capability. The characteristics which are important from this standpoint in addition to loss and noise are:

Attenuation distortion (frequency response)

Delay distortion

Impulse noise

Frequency shift

Nonlinearity – change in loss with strength of the signal

Objectives for these parameters are presently under study.

8.08 In the testing of trunks for transmission purposes, some of the above characteristics can be evaluated in combination by a single test called PAR. PAR stands for *P*eak to *A*verage

Ratio. In this case, a pulse of known magnitude and shape is transmitted over the trunk, and the ratio of its peak to average power is measured and compared to the known ratio of the transmitted pulse. This test is expected to be required on a circuit order test and later, if found necessary, as a periodic test.

<u>Test Equipment and Test Power Sources</u>

8.09 A wrong measurement is often worse than no measurement at all, since it can result in wasted effort and degraded performance. All test equipment must be kept in good condition at all times, and simple means must be provided for its calibration at frequent intervals or before each use. It should be simple to operate and read and have the stability and accuracy required for the purpose for which it is used. The need for corrections to meter readings and for computations by the Plant personnel should be avoided wherever possible. The right set should be used for each type of measurement, and the set should be able to measure at the required impedance and level point.

8.10 The accuracy of test power sources is one of the more important requirements for good transmission maintenance. These sources are used not only for the transmission of test power during transmission measurements, but also for the calibration of test equipment. All appearances of test power output, including coded transmission test lines, should be extremely stable, accurately adjusted, and available for use whenever they are needed. It should be remembered that in a large number of cases, an office depends on the accuracy and availability of test power from a distant office for the veracity of its own trunk measurements. Failure to provide accurate test power can place the effectiveness of the entire maintenance job in jeopardy.

<u>Access to Trunks for Transmission Maintenance Purposes</u>

8.11 To make meaningful transmission measurements on trunks, it is necessary that simple access be provided at each end for the connection of test equipment or application of test power. It is also important that the whole trunk be included in the measurement. For the purpose of transmission maintenance, a trunk is considered to extend from its outgoing switch appearance at the outgoing end to the outgoing switch appearance of a test line or test trunk to which it is connected at the incoming end. The path through the switching equipment at the incoming end is, therefore, considered as part of the loss of the trunk. Failure to include the whole trunk in a measurement will result in part of the trunk never being tested. If a trouble develops or is introduced by an omission of this nature, the customer would be the only one who would encounter it.

8.12 Some trunks can be accessed in service at either or both ends in several ways. For example, a trunk may be accessed from a manual switchboard as well as directly from the switching machine. In another case, it may have the capability of being connected at either end to a subscriber loop or another trunk. Two-way trunks can be accessed at either end. In each of these different modes of operation, different transmission paths, and sometimes different equipment, are involved. Maintenance of these trunks must include measurements in all possible modes of operation so that it can be assured that the trunk is satisfactory for all of its intended uses.

8.13 Access for transmission maintenance at the outgoing end of a trunk may be in some cases via a test multiple of the trunk which appears at a testboard or test frame. In other cases, it may be through the normal switching equipment, or a separate switching path to a test connector multiple. In order that the measured loss of the trunk will be the equivalent of its loss in actual service and to avoid the need for making corrections to the results of measurements, the transmission level point where test equipment or test power is connected must be electrically equivalent to the level point at the outgoing switch appearance. If the physical location of the testboard or test frame cannot be placed sufficiently close to the outgoing switch appearance of the trunks, it is necessary to compensate for the difference in level. Where a test pad is used in connection with transmission measurements, this can be done by increasing or decreasing the loss of the test pad from its nominal value by the average amount of level difference involved.

8.14 At the incoming end, all trunks are accessed for two-man manual transmission testing through a jack-ended test line which is connected to the trunk to be tested by dialing or signaling from the outgoing end of the trunk. If the loss of this trunk from its own outgoing switch appearance to the jack appearance in the testboard or other maintenance area is appreciable, this loss must be compensated as discussed above.

8:15 In either of the above cases where test pads are not employed, it is possible, if dedicated test equipment is used, to arrange for special calibrations and adjustable pads to compensate for the losses or differences in level.

8.16 One-man manual and automatic tests normally make use of test lines and associated equipment at the incoming end. It is important that these test lines be adjusted so that the measurements are made effectively at the outgoing switch appearance of the test lines.

Evaluation of the Results of Transmission Maintenance

8.17 It is desirable to be able to evaluate the results of transmission maintenance activities, to determine the quality of the job being done and to point out weak spots that need attention. This is done by summarizing the results of loss and noise measurements made on periodic tests.

8.18 For loss measurements, the actual measured loss (AML) is compared to the expected measured loss (EML) and the difference (or deviation), either positive or negative, is computed. For noise measurements, the actual measured noise is compared to the maintenance limit and the percentage of measurements which exceed the limit is computed.

8.19 In earlier days, all transmission maintenance was done by the so-called limit method, in which any trunk whose AML did not exceed a given deviation from the EML was considered satisfactory. This method was not entirely suitable because a trunk whose AML was equal to the EML was considered no better than one whose deviation of AML from EML was equal to the limit. Later, a method called "Distribution Grade and Bias" was adopted and was used for many years. This recognized that trunks whose losses are kept close to the design values provide better service than those which hover near the outer limits. However, since this method required complex computations not always understood in field use, and for other reasons outlined below, a new method has now been adopted.

8.20 In the distribution grade and bias method, the deviations of AML from EML were averaged algebraically and the result was called "bias." The standard deviation of these deviations about the average was called "distribution grade." An objective of 1.0 dB for "distribution grade" and ±0.25 dB for bias was originally established. Later, the objective for bias was reduced to ±0.2 dB. Increase in maintenance effort and the improvement of carrier systems and transmission measuring equipment have resulted in meeting or exceeding these objectives in many cases. However, it appeared necessary to improve the results of transmission maintenance still further to meet the requirements of distance dialing. A tightening of the distribution grade and bias objectives did not seem to be the best method of accomplishing this, however, since it was found that although the objectives could be met, a significant percentage of the trunks could still exceed desirable deviations because of nonnormal distributions. This occurred in spite of the fact that the percentage of trunks exceeding deviations of 3.7 dB from EML were included in the overall evaluation of transmission maintenance effort. In addition, as indicated above, the process of computing averages and standard deviations was complex and time-consuming and it was felt that a simpler method which would give the desired results would be preferable.

8.21 The present method for evaluating transmission maintenance effort is to compute the percentages of deviations which exceed two values. The objectives have been established in such a way that the distribution should approach normality, but it is not necessary to compute the distribution. At the same time, reasonable control is exercised over those trunks which may have excessive deviations. The present maintenance objectives are:

Not more than 30% of the deviations should exceed 0.7 dB.

Not more than 4.5% of the deviations should exceed 1.7 dB.

8.22 The above objectives are being applied to all trunks except those using only E repeaters or passive equipment. Because of the inherent stability of E repeaters and passive equipment, it is convenient to simplify the required objectives for trunks using this equipment. Therefore, for such trunks which make use of outside plant, the present maintenance objective is:

Not more than 12.0% of the deviations should exceed 0.7 dB.

8.23 It has not been considered necessary to evaluate maintenance effort on passive trunks which do not use outside plant facilities, because there is little that can affect their performance provided they meet circuit order requirements before being placed in service.

8.24 Noise maintenance limits have been established which are dependent on trunk length. This recognizes the fact that higher noise is inherent in the longer trunks. Two limits are provided, one which should not be exceeded on circuit order and which indicates that corrective action may be necessary if exceeded on periodic test, and the other which indicates the trunk is unserviceable and should be removed from service and corrected immediately. In evaluating the results of maintenance effort, the percentage of trunks on which the noise exceeds the circuit order and maintenance limit is computed. The objective is that not more than 5% should exceed this limit.

<u>Correction of Transmission Troubles</u>

8.25 To point to the need for corrective action to reduce deviations from EML, guides have been established which indicate when such action will be profitable. These guides vary with the complexity of the trunk, and are based on past experience. They do not indicate when performance is satisfactory, since this is covered by the evaluation procedures discussed above. Judgment is required in the application of the guides so that the objectives listed above will be met or bettered.

8.26 When a transmission difficulty is corrected, it is desirable to reduce the deviation from EML to the lowest possible amount and to reduce the noise as far as possible considering the capabilities of the transmission facilities involved. When this is done, it is necessary that the actual cause of trouble be found and corrected rather than make adjustments which correct the symptoms only. Correction of symptoms merely breeds more trouble, since a later correction of the real trouble will introduce the need for still further action.

<u>Through and Terminal Balance</u>

8.27 Through balancing must be accomplished in all two-wire switching offices which are Class 3 or higher ranking, i.e., offices which interconnect intertoll trunks, as discussed in Paragraph 5.01. This involves measuring the return loss encountered by every intertoll trunk when connected to any other intertoll trunk in the office. Both incoming and outgoing trunks and both branches of two-way trunks must be included. A common value compromise network and network building-out capacitor (NBO) are used in the 4-wire terminating sets of all the trunks in the office. The 2-wire paths between interconnected trunks are built out to a common value of capacitance. Through balance is measured by connecting two trunks via the machine and disconnecting the transmission facilities from the terminating sets in each one. The echo return loss and singing point are measured at the 4-wire appearances of the terminating set on one of the trunks, with the 4-wire appearances of the terminating set of the other terminated in 600 ohms. This is repeated until all combinations have been tested.

8.28 In terminal balancing, all toll offices of Class 4 and higher rank must be included. As in through balancing, each intertoll trunk in a 2-wire switching office of Class 3 or higher rank is provided with a common value compromise network and NBO and the 2-wire paths to the switching machine are built out to a common value of capacitance. In Class 4 offices, a compromise value of NBO is used, based on an average of the actual office capacitances. If wide variations in office capacitance are encountered, some of the toll connecting trunks are built out to reduce the range. Toll connecting trunks using loaded cable facilities are equipped with impedance compensators to bring their impedance as closely as possible to 900 ohms plus 2 μF over the echo frequency band.

8.29 In measuring terminal balance, it is convenient to provide two test circuits comprised of a 4-wire terminating set, trunk circuit, and build-out capacitors. One test circuit simulates an incoming intertoll trunk, while the other simulates an outgoing intertoll trunk. The NBO and drop building-out capacitors are adjusted to the same values as those on the intertoll trunks in the office. The balance to outgoing toll connecting trunks is obtained by switching the first test circuit through the machine to each outgoing toll connecting trunk in turn. The toll connecting trunk is terminated in a 900 ohms plus 2.16 μF termination at the Class 5 office. For incoming toll connecting trunks, the Class 5 office dials Code 970-xxxx and then places the termination on the trunk at its end. At the toll office, the test line reached by the 970 code is terminated in a jack at the outgoing trunk test frame or equivalent, where it can be patched to the 2-wire appearance of the second test circuit. The wiring involved in the 2-wire path of 970 code test arrangement must be short, or its capacitance must be compensated when building out the 2-wire path of the test circuit.

8.30 Balance tests consist of echo return loss and singing point measurements. For the former, a thermal noise generator with proper weighting for the echo band is used as a source of test power, while a 3-type noise measuring set with C- message weighting is used as the detector. For singing point tests, a singing point test set is used.

8.31 It is desirable to have the 4-wire appearances of the test circuits at a convenient location, such as the outgoing trunk test frame where the patching to the 970 code jack appearance is done. These 4-wire appearances are used for connection of the test equipment mentioned above, when terminal balance measurements are made on the toll connecting trunks. Through balance tests and balance tests for terminal balance on intertoll trunks in Class 4 offices require a 4-wire test point in each intertoll trunk for connection of the test equipment. Formerly, the circuit patch bay provided such a test point. However, with the discontinuance of circuit patch bays, other arrangements must be made. Jack access can be provided with the newer terminating sets at the bays where the sets are mounted. Also, the voice-frequency patching bay can be used, provided any single frequency signaling units in the 4-wire path are effectively bypassed.

8.32 In 4-wire switching offices, terminal balance tests are made on the toll connecting trunks at the 4-wire terminals of the trunks. The 4-wire terminating sets on these trunks may be located at the distant Class 5 office or at the toll office. In the latter case, precision-type balancing networks are used and adjusted for the best return loss. Access to the 4-wire appearances of outgoing toll connecting trunks is made through the trunk test frame normally provided in these offices and the 4-wire switching equipment. A termination of 900 ohms plus 2 μF is placed on the trunk at the Class 5 office. For incoming trunks, the Class 5 office dials Code 970-xxxx and then places the termination at its end. In this case, the 970 code consists of a 4-wire jack-ended trunk to which the measuring equipment can be connected.

Loop Plant Maintenance

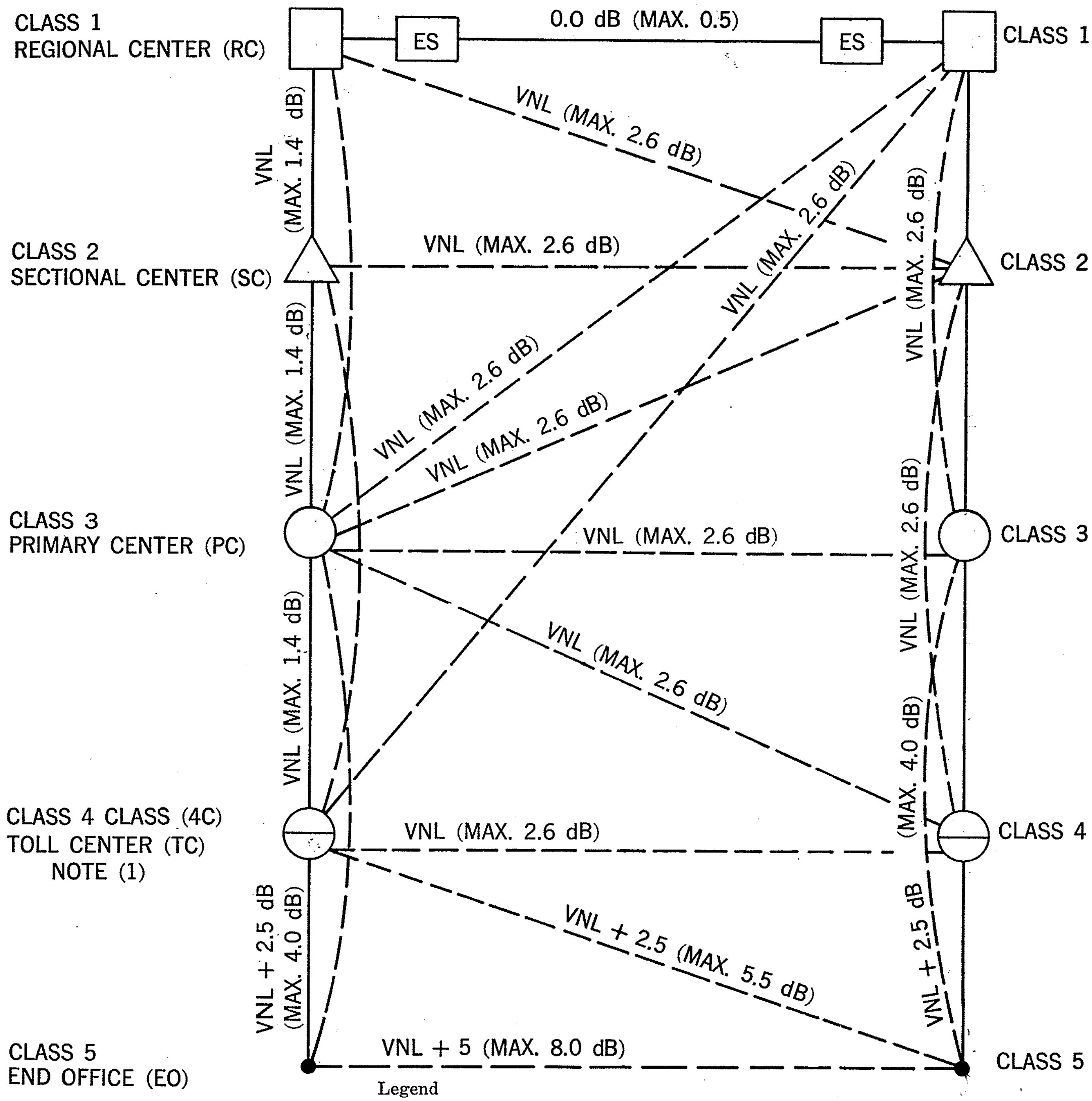
8.33 Connections between the Class 5 offices and the customer locations consist of several categories: PBX-Central Office trunks, foreign exchange lines and trunks, and customer loops. The maintenance of each is handled differently.

8.34 Since PBX-CO trunks and foreign exchange lines and trunks are designed to loss and noise objectives, it is necessary to measure the losses and noise upon installation and at periodic intervals thereafter in a manner similar to trunks between switching offices. In the case of the larger PBX's, transmission test lines similar to those used at central offices can be justified so that one man at the central office can measure the losses and noise.

8.35 Customer loops, on the other hand, are designed differently and it is necessary to check that they have been installed in accordance with the rules governing their design. Two methods are presently in use: (1) a check at the customer end to a source of test power at the central office and (2) a measurement of the impedance at the central office to an on-hook instrument at the distant end. In the first case, the source of power consists of a tone whose frequency is swept over a portion of the voiceband at a level which is dependent on the frequency. The detector is adjusted for the length and type of loop, and its resistance. The swept signal received is then compared with a specified value. In the second case, the source of test power is a swept frequency of constant magnitude and the results are displayed on an oscilloscope. Requirements are based on the pattern displayed for the particular type of facility making up the loop.

8.36 Noise measurements should be made on customer loops, to assure that the noise is within the proper requirements. The most accurate method is to measure the noise with a noise measuring set at the customer end, with the central office end terminated in 900 ohms plus 2 μF. However, it is possible to make noise measurements at the central office end to an on-hook instrument and to decide whether or not definite noise difficulties exist, or to indicate that tests should be made at the customer end for further evaluation.

TRUNK LOSSES WITH VIA NET LOSS (VNL) DESIGN



Legend

ES Echo Suppressor Notes (2) and (3)

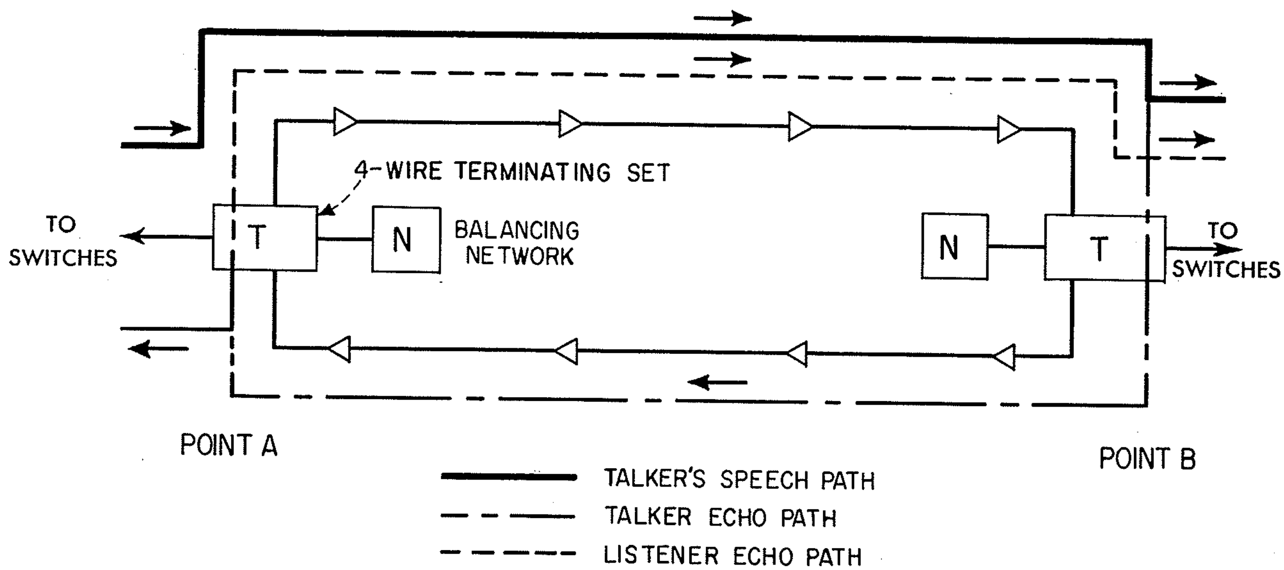
– – – – High Usage and Full Route

——— Final Route

Notes:

1. Also ⊕ Toll Point (TP) Class 4 (Class 4P)
2. For possible application of ES to *interregional high usage* and full trunks, see paragraph 3.33. Where ES is used, the trunk should be operated at 0.0 db, where possible.
3. All losses shown are the VNL *Inserted Connection Loss* (ICL). ICL = *Expected Measured Loss* minus the test pad loss at each end of the intertoll circuit.

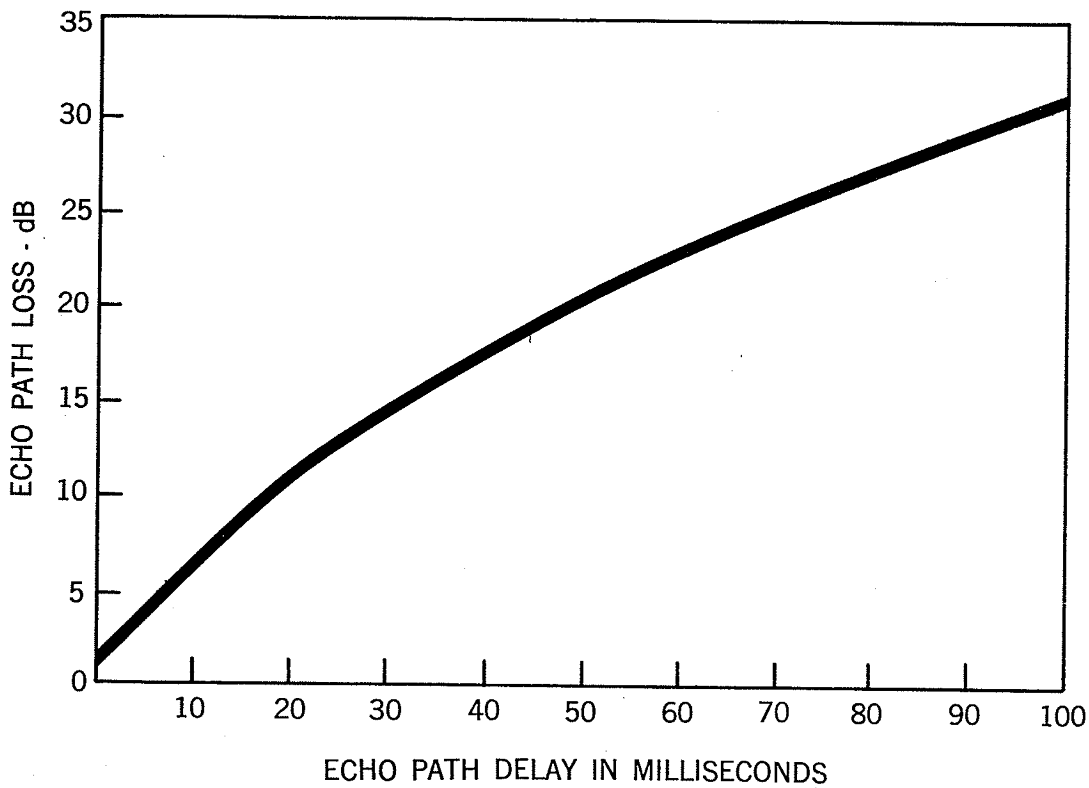
ECHO PATHS



Notes.

1. ▷ = Amplifier
2. [T] = Term. Set
3. Hybrid Arrangements are a part of the 4-wire terminating set

TALKER ECHO TOLERANCE FOR THE AVERAGE OBSERVER

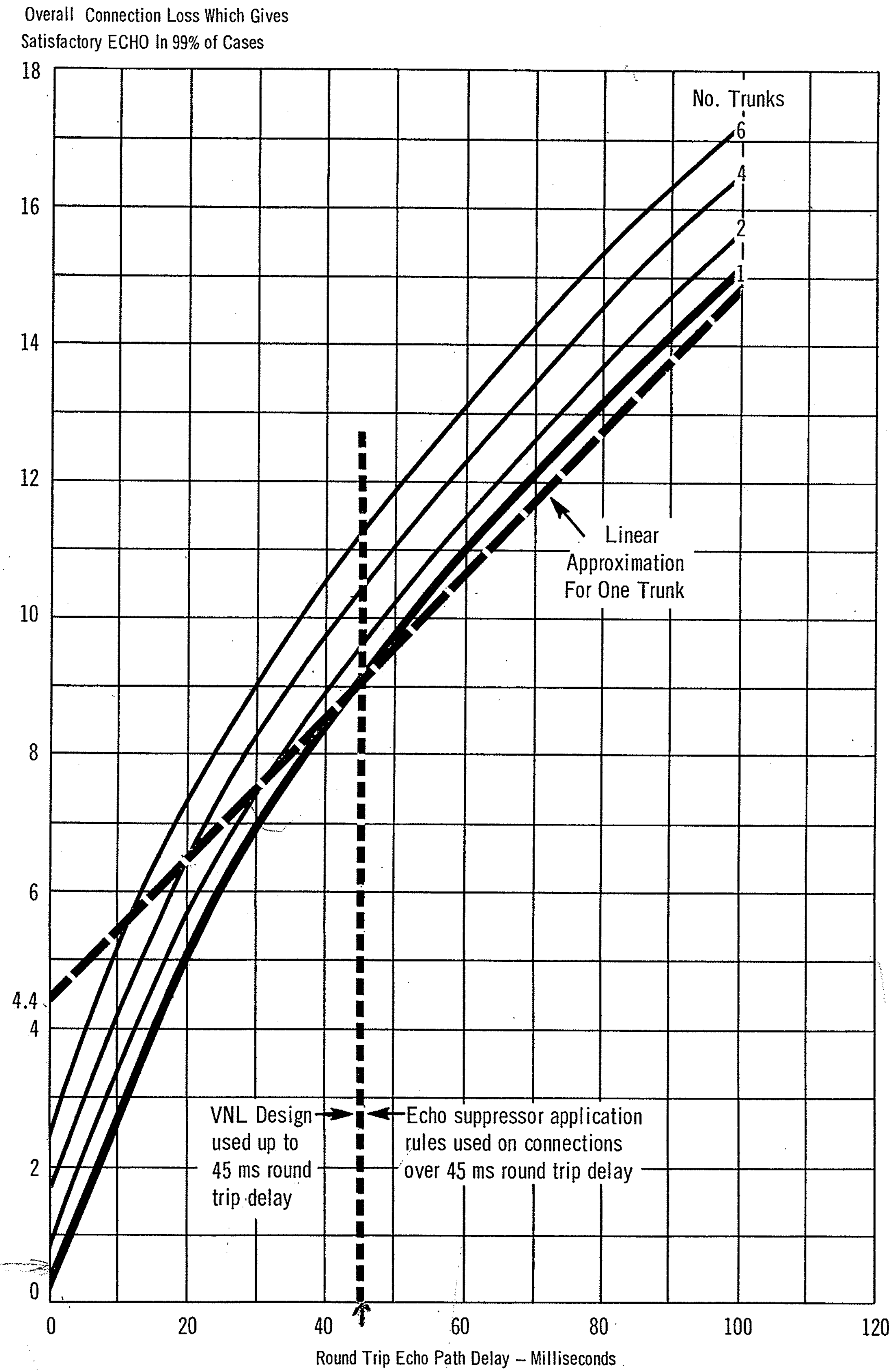


General Notes:

1. Echo path loss equals twice the one-way loss plus far-end return loss.
2. Curve represents study results used in formula for the calculation of overall connection loss (from Class 5 to Class 5 office in toll network).
3. Distribution of echo tolerance observer judgments for a given delay is normal with a standard deviation of 2.5 db.

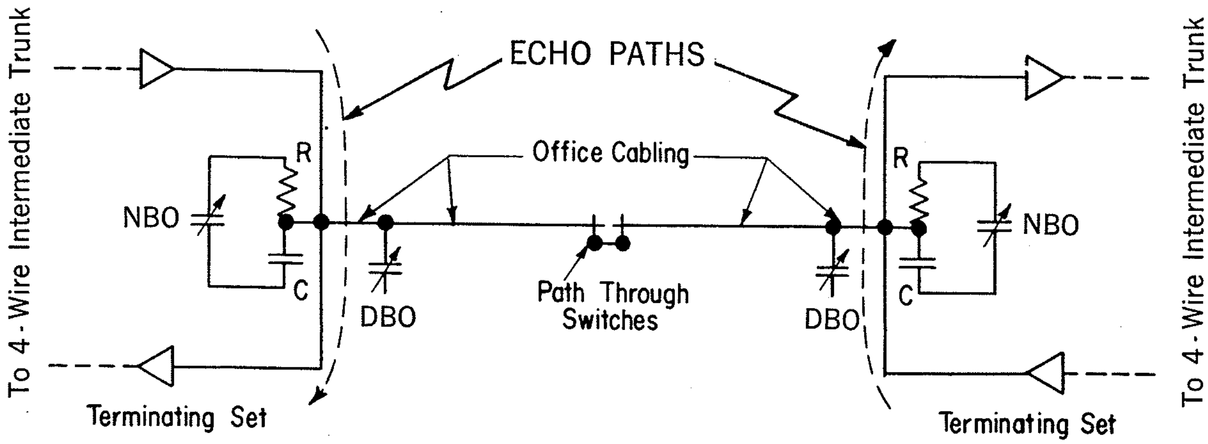
Relationship between Overall Connection Loss and Echo Path Delay

(Class 5 to Class 5 Office)



Note: These curves assume control of all intermediate reflections within the connection (through 4-wire circuits and 4-wire switching, or their equivalents in 2-wire toll offices meeting through and terminal balance objectives for VNL operation).

TYPICAL CONNECTIONS OF TWO INTERMEDIATE (INTERTOLL) TRUNKS AT A 2-WIRE SWITCHING OFFICE



Legend:

Compromise Network

R = Resistor, either 600 or 900 ohms

C = Capacitor, 2.16 μF

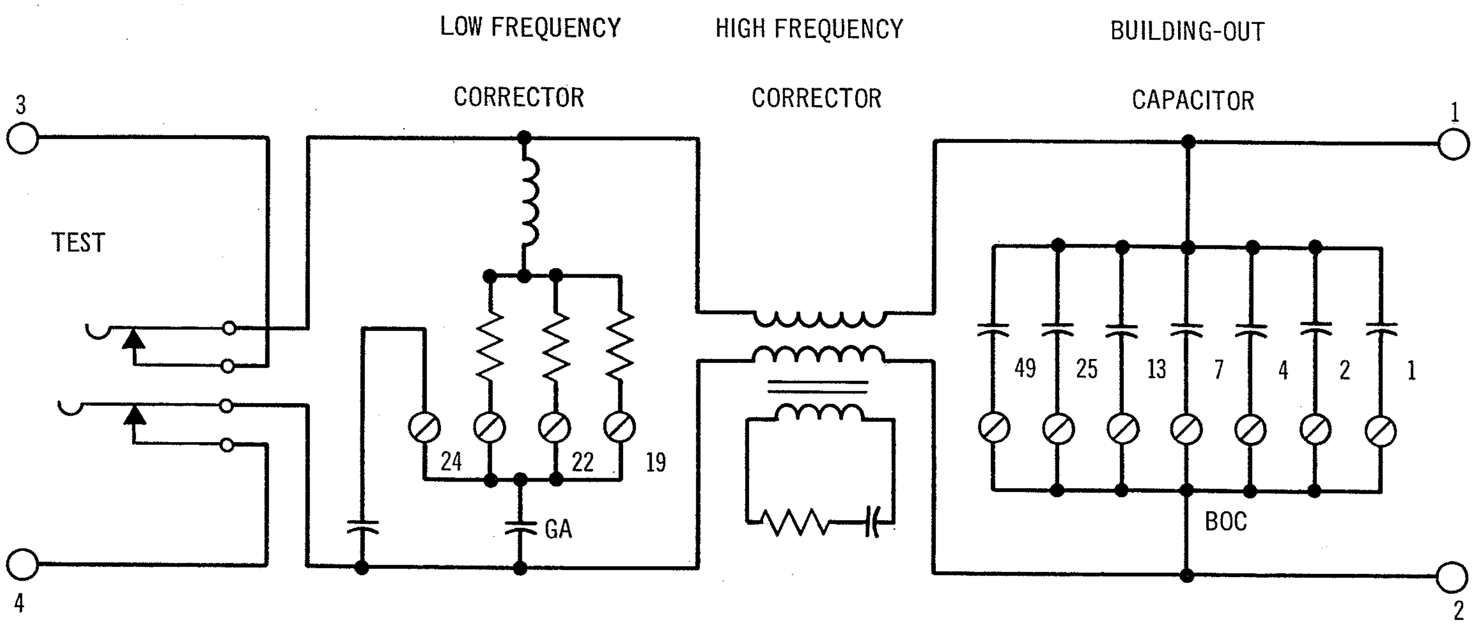
NBO = Network Building-Out Capacitor

DBO = Drop Building-Out Capacitor

▷ = Repeater or Carrier Channel Equipment

IMPEDANCE COMPENSATOR

837A NETWORK



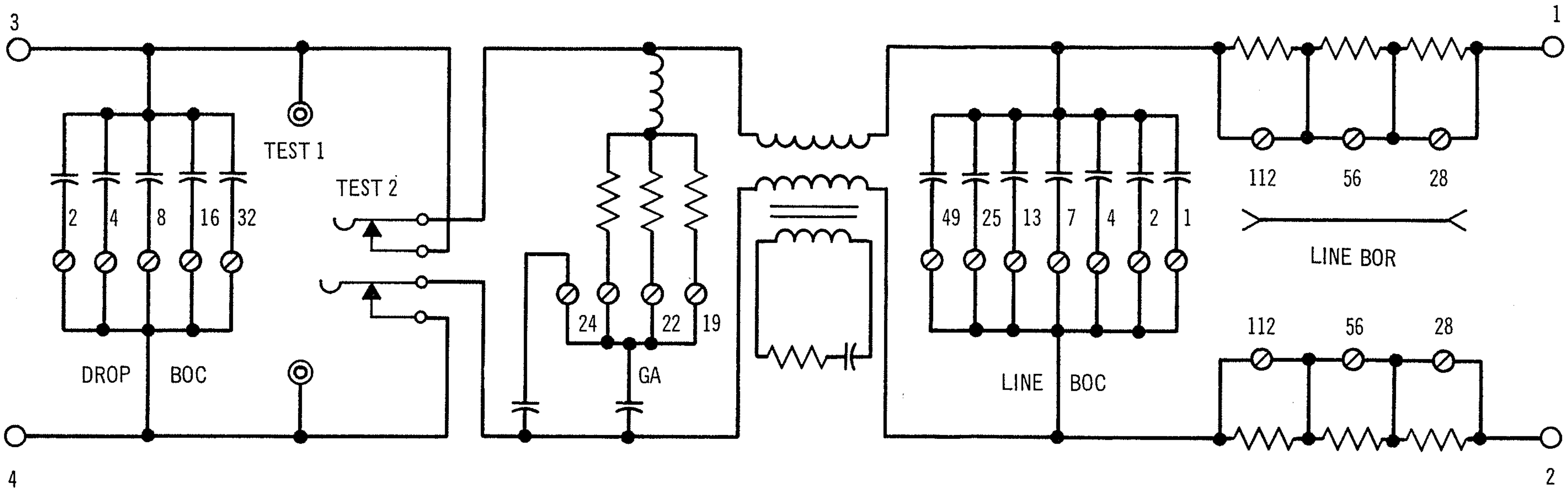
LEGEND
⊘ SCREW
TIGHTENED – ELEMENT IN
LOOSENED – ELEMENT OUT

BOC VALUE

1 – .001 μF
2 – .002 μF
4 – .004 μF
7 – .007 μF
13 – .013 μF
25 – .025 μF
49 – .049 μF

IMPEDANCE COMPENSATOR

837B NETWORK



LEGEND FOR LINE AND DROP BOC

⊘ SCREW

TIGHTENED – ELEMENT IN
LOOSENED – ELEMENT OUT

DROP
BOC VALUE

2 -.002 µF 8 - .008 µF
4 -.004 µF 16 - .016 µF
32 - .032 µF

LINE
BOC VALUE

1 - .001 µF 7 - .007 µF
2 - .002 µF 13 - .013 µF
4 - .004 µF 25 - .025 µF
49 - .049 µF

LEGEND FOR LINE BOR

⊘ SCREW

TIGHTENED – ELEMENT OUT
LOOSENED – ELEMENT IN

DROP
BOR VALUE

28 - 14 ohms
56 - 28 ohms
112 - 56 ohms

IMPEDANCE COMPENSATOR
(SD-95756)

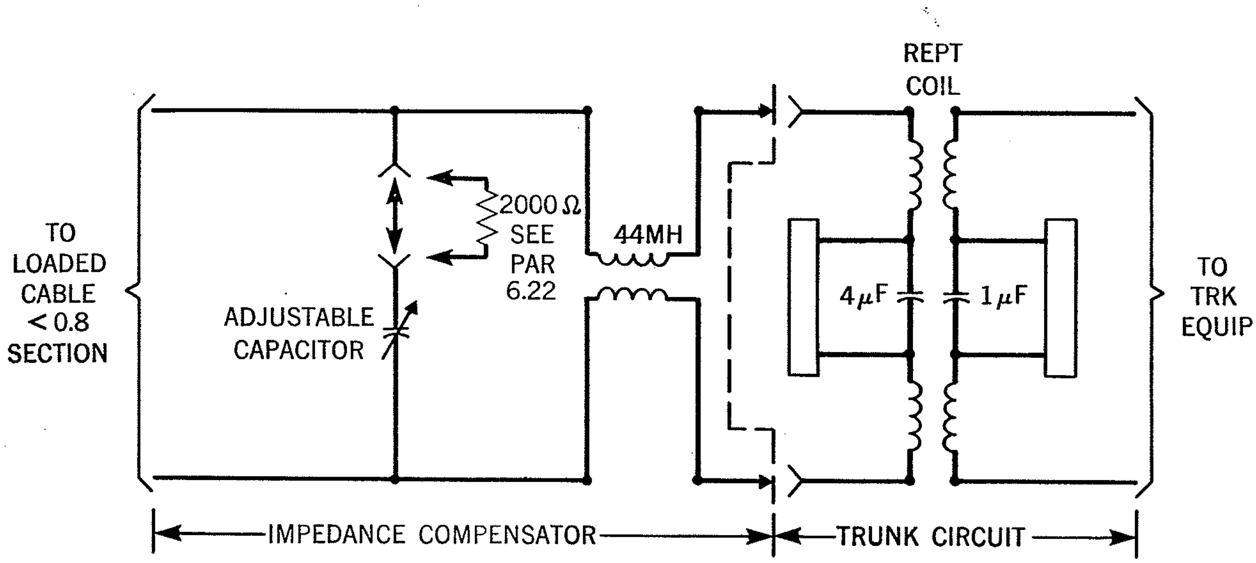


Figure A
Impedance Compensator

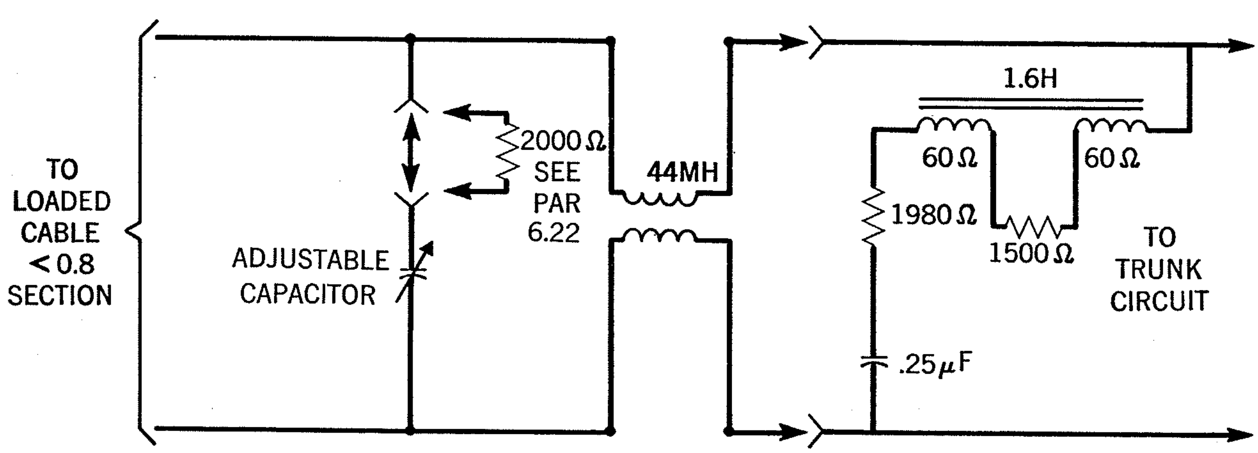


Figure B
Low-Frequency Impedance Corrector

FIXED 2db PAD ARRANGEMENTS

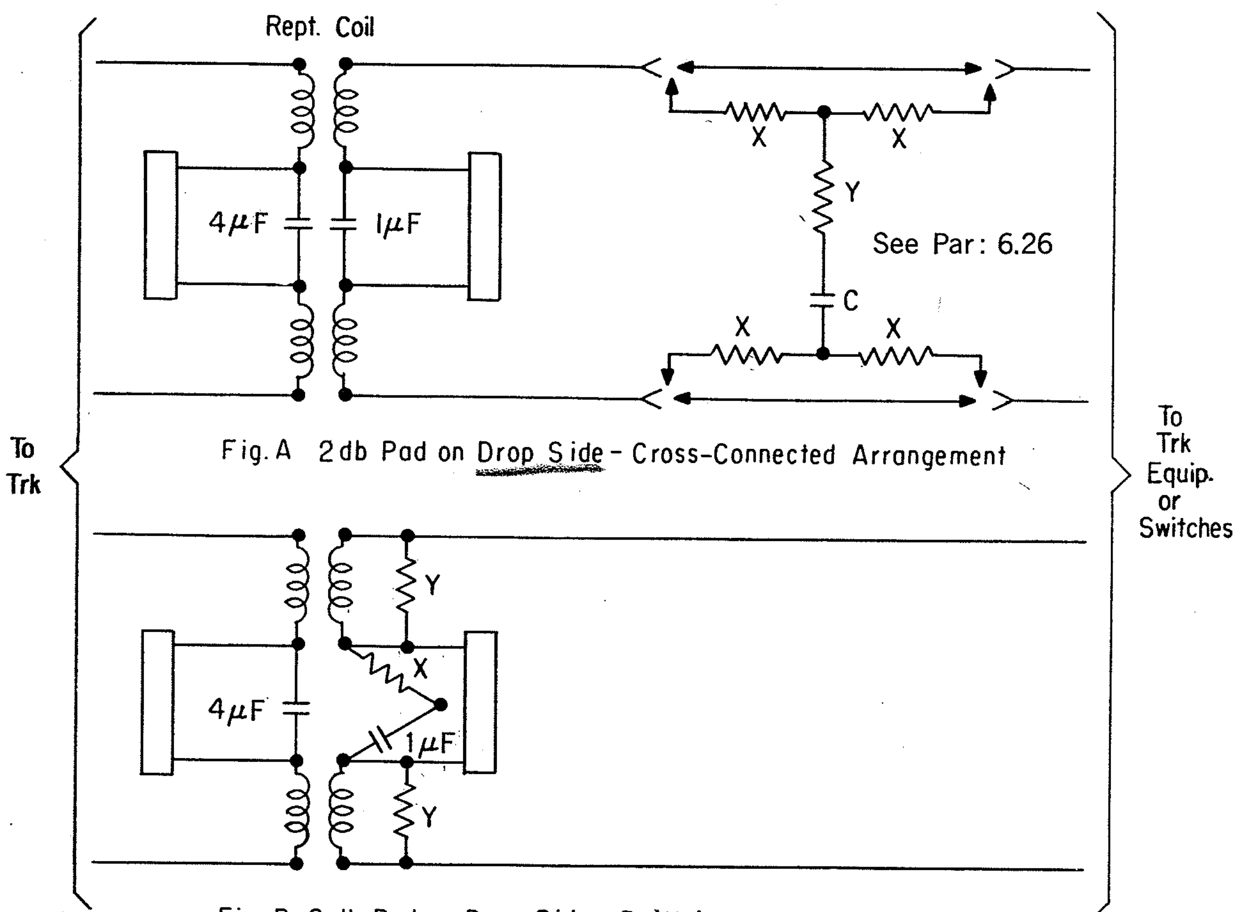


Fig. A 2db Pad on Drop Side - Cross-Connected Arrangement

Fig B 2 db Pad on Drop Side - Built into Reptg Coil Cct.

DESIGN VALUES FOR PADS

Fig.	Imped.	Resist. Ohms (± 2%) X	Resist. Ohms (± 2%) Y	C - mf (± 10%)
A	600ω	34	2560	0.25
	900	51	3855	0.25
B	600	123	1160	1.0 } Assoc. with Rept. Coil
	900	185	1740	1.0 } Assoc. with Rept. Coil

Section 7
Maintenance

MAINTENANCE REQUIREMENTS

CONTENTS PAGE

1. GENERAL

1.01 Distance dialing arrangements are predicated on rapid and dependable switching, supplemented by a maintenance plan that assures a high level of performance, promoting the optimum use of plant, and resulting in customer satisfaction.

1.02 For distance dialing, the personnel, test equipment, methods, and organization of the maintenance job should be of a high quality in order to maintain the precision and stability required of the network of interconnecting switching systems. Trouble detection is more difficult with direct (customer) distance dialing, because operators can no longer supervise connections. Employment of automatic alternate routing adds to the difficulty of identifying trunks in trouble. Accordingly, maintenance methods and facilities based on requirements for automatic switching have to be provided, rather than attempting to use older techniques based on manual switching, inasmuch as most of the trouble indicators under manual switching no longer exist.

1.03 With automatic switching, poor maintenance at one office can result not only in excessive trouble at that office, but also in adverse reaction elsewhere in the switching network. It is essential that each Company have a well-organized maintenance plan at all locations. Intercompany cooperation should be maintained between all operating companies of the North American Integrated Network for the coordination and exchange of maintenance information and results. Maintenance plans should clearly define the responsibility among forces, departments, and telephone companies , along with organized procedures for reporting and analyzing trouble to insure prompt action. Service measurement plans are also important.

1.04 Evolutionary development of maintenance procedures will continue as experience is gained in direct distance dialing and as new switching techniques and methods are adopted. It is expected that the trend will be toward:

(1) Reduction in manual effort due to the use of optimum circuit and equipment design, selection of trouble-free components, and the provision of automatic test devices and self-alarming arrangements which will automatically indicate troubles in the switching and transmission network; and

(2) Rapid and efficient trouble reporting and analysis procedures. Maximum use of operator verbal trouble reporting and holding procedures expedites prompt location and correction of trouble conditions. Maintenance arrangements to permit quick answers to operators' reports, together with means for rapid trunk identification should be provided. These methods are successful in the detection of near or distant trouble conditions, insuring that customers will experience fewer direct distance dialing difficulties.

Continuing improvement is expected in dial switching service standards. A reasonable service objective would seem to be about one failure per 100 calls. In the future, it may be practicable to improve this objective.

1.05 The remaining parts of this section discuss test and maintenance facilities and contain applications for their use in various types of offices. Since, with a few exceptions, the sectional centers and regional centers are Bell operated, discussion in this section is confined to the other classes of offices, namely:

Class 3 (Primary Center).

Class 4 (Toll Center or Toll Point).

Class 5 (End Office).

Classification, rank, and homing arrangements for the various offices are discussed in Section 3.

2. MAINTENANCE FACILITIES

2.01 Maintenance and testing facilities provided in any office depend upon the type of switching system and the types of trunk circuits and terminal equipment in that office. The major facilities which should be considered for maintenance and testing are listed as Items 1 to 15 below. Chart 1 indicates probable requirements for these items by class of office. Actual conditions in any location are, of course, the final criteria for selecting maintenance facilities.

(1) *Primary Testboard or Test Unit:* Usually of the 4-jack per circuit type for terminating, testing, and patching *physical* lines. Testing equipment consisting of test and talking cords, test battery, voltmeter, and Wheatstone bridge can be provided either in an associated unit, or on a portable basis.

(2) *Secondary Testboard:* Usually consists of test multiple with or without patching jack bay facilities and test positions equipped for monitoring, talking, transmission measuring, signaling, and miscellaneous trunk tests. The test multiple is usually a single appearance of two jacks per trunk. One jack is a multiple of the switch appearance, (and/or a multiple of the switchboard) which permits making overall tests, including monitoring, and tests toward the line or carrier facilities. The other jack is provided to make the trunk test busy and remove it from service.

(3) *Patching Jack Bays:* May have a 4, 5, 6, or 7 jack circuit. These jacks provide means to:

(a) Test and patch the transmission path between the four-wire terminating set and the other terminal equipment (repeater, signaling equipment, carrier, etc.). Also, transmission path troubles can be sectionalized; the drop circuit can be patched to the transmission path of any other trunk.

(b) Test and patch the signaling and dialing path (E and M leads) between the signaling equipment and the trunk relay equipment. By means of these jacks, signaling troubles can be sectionalized.

(c) Patch DC supervisory signaling leads between trunk relay equipment and signaling equipment (usually designated as A and B or A and D leads) when required. Generally, direct cabling is used and patching facilities for these leads are not required.

For those switching systems in which the test multiple is cut off on an inward or through call, a single monitoring jack, a multiple of the drop patching jack, is desirable because it is always available for monitoring tests. This jack should be installed in the same general location as the multiple test jacks.

(4) *VF Patch Bays:* Provide a patching junction and test point between carrier terminals and voice-frequency terminal equipment. (If the carrier system includes "E" and "M" lead signaling, it is advantageous to provide jacks for these signaling leads.) Also, line facilities can be patched through to any other line using proper pads.

(5) *Testing Jacks:* Associated with CX or SF signaling paths.

(a) *Composite Line Jacks:* Used to obtain testing access between the signaling and dialing equipment and the CX set. This permits a test of circuit continuity and "line" current in the signaling path.

(b) *Test Jacks or Test Points:* For testing SF and CX equipment units – associated with individual equipments.

(6) *Pulse Repeating Test Set:* For pulsing over CX signaling paths and measuring pulsing speed and percent break.

(7) *Pulse Generating and Measuring Test Set:* For pulsing over SF signaling paths and N, O, ON, and similar type carrier signaling paths and measuring pulsing speed and percent break characteristics.

(8) *Switchboard Cord and Position Maintenance Test Facilities* and related test lines from the terminal and switching rooms as required.

(9) *Centralized Test and Make-Busy Jacks:* For trunk maintenance as required.

(10) *Switching Equipment Maintenance Test Sets:* In accordance with the type of switching system employed.

Note: Bell System common control type offices utilize various means for ensuring a satisfactory level of performance of the switching system. These include self-checking features in common control units, and trouble recorders, trouble indicators, registers, alarms, flow lamps, and testing equipment (automatic and manual) for applying operational and marginal tests to the various components of the switching system. The switching system also provides testing access to outgoing trunks for automatic trunk test frames.

Direct-control type offices are not currently equipped with self-checking features and extensive automatic testing equipments. In these cases, it is, therefore, essential that more emphasis be placed on operator reporting of troubles. Furthermore, it is recognized that with the increase in customer dialing and diminished operator contact, greater reliance must be placed on obtaining automatic checking or testing features and more efficient direction of maintenance efforts.

(11) *Sender Test Facilities:* Used where senders are involved.

(12) *Transmission Test Equipment:* (Refer to Section 6.)

(13) *Carrier Testing Facilities:* To test the various types of carrier units that may be involved. Carrier Group Alarms (CGA) are provided as an indirect aid to carrier system maintenance, which releases all connections on a faulty system, makes the carrier channels busy at the offices that select the channels, and provides associated alarm signals in the maintenance area.

(14) *Test Lines:* Details of test lines are discussed in Appendix A to this section. Test Lines (or test terminations) are part of the basic maintenance pattern in the distance dialing plan for the maintenance of trunks. These test lines provide assistance in connection with maintenance tests at testboards and automatic testing equipment.

(a) *Balance (100-Type)* – Provides a dialable termination for balance and noise testing.

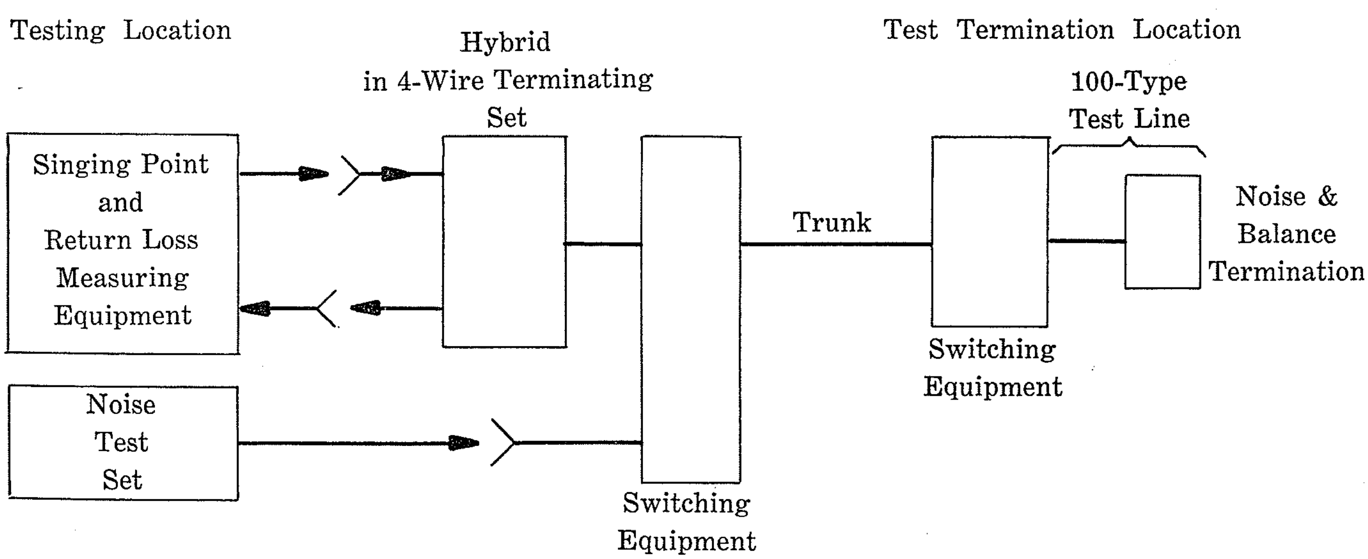


Figure 1
Arrangement for 100-Type Test Line

(b) *Communications (101-Type)*—Provides a communication and test line into a testboard or test position which can be reached over any trunk incoming to the switching system served by that test position. It is used for reporting trouble, making transmission tests, etc.

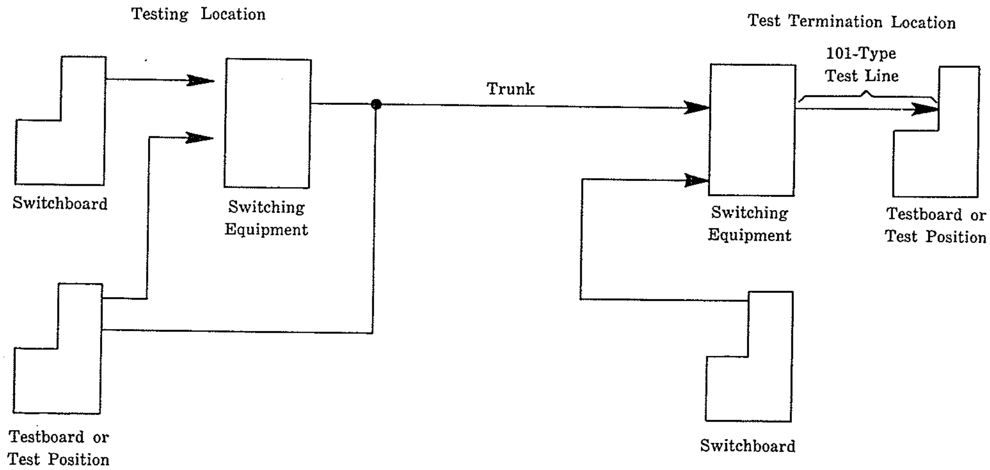


Figure 2
Arrangement for 101-Type Test Line

(c) *Milliwatt (102-Type)*—Provides connection to a 1000 Hertz testing power source for *one-way* transmission measurements. In two-train No. 4 type crossbar offices, Code 102 has been assigned to the toll-completing train, while all other 10X test lines are assigned to the intertoll train. This was done to guarantee that an incoming trunk will satisfactorily complete calls over both the intertoll and toll-completing trains. Previously, Code 959 was used for this purpose.

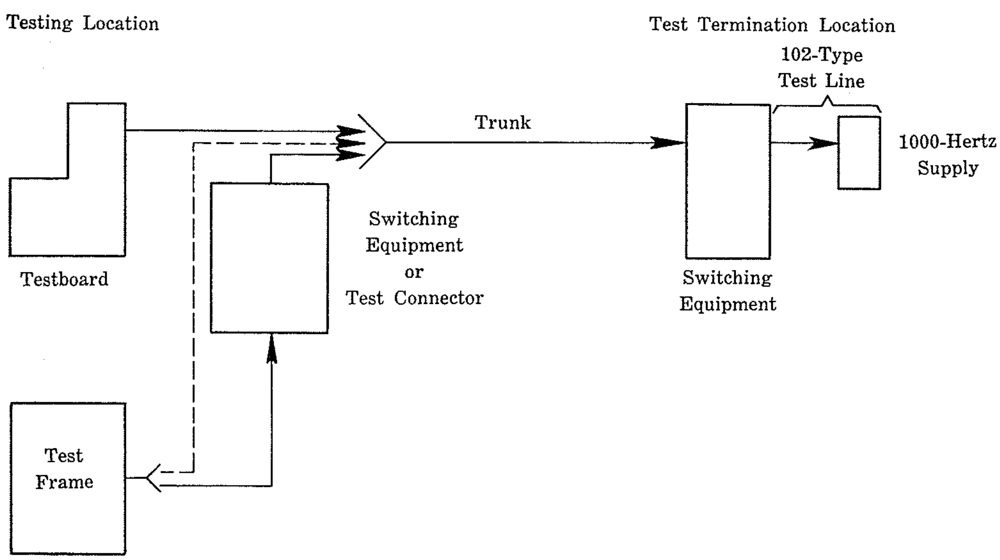


Figure 3
Arrangement for 102-Type Test Line

(d) *Signal-Supervisory (103-Type)* – Provides a connection to a supervisory and signaling test circuit for overall testing of these features on *intertoll* trunks, equipped with rering features, which can be reached by an automatic trunk test frame, or by dialing manually.

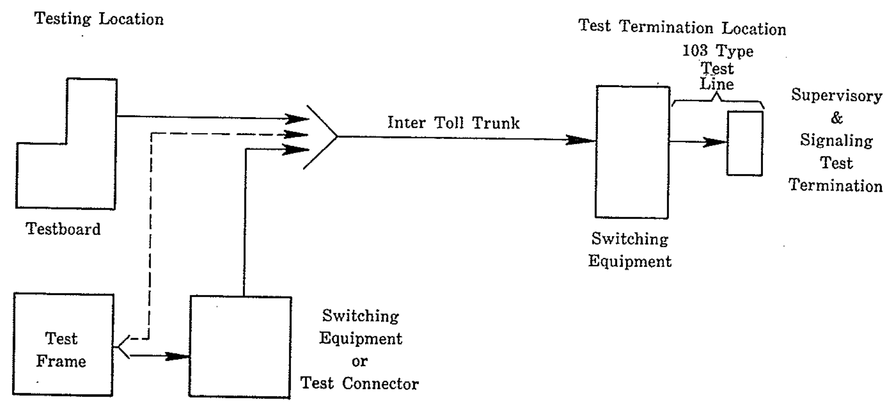


Figure 4
Arrangement for 103-Type Test Line

(e) *Transmission Measuring and Noise Checking (104-Type)* – Provides a connection to a transmission measuring and noise checking circuit at the far end of trunks. The measuring circuit is designed to transmit to the near end of the trunk (the end originating the test) test power, information on transmission measurement, and a rough check of noise measured at the far end of the trunk. Such two-way measurements may be made automatically by the near-end automatic transmission test and control equipment associated with automatic trunk test frames such as those provided in No. 4 type crossbar tandem offices, and for Automatic Transmission Measuring Systems being made available for most types of offices. These tests may also be made on a manually-dialed basis at a testboard or test location capable of seizing, dialing, holding, and measuring on the trunks.

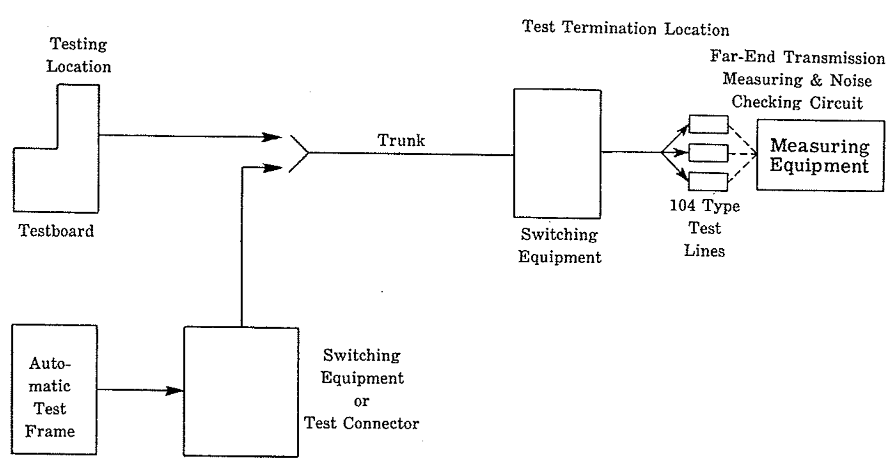


Figure 5
Arrangement for 104-Type Test Line

(f) *Automatic Transmission Measuring System (105-Type)* – Provides a connection to an Automatic Transmission Measuring System responder. This permits two-way transmission loss and noise measurements to be made on trunks when an ATMS director and a suitable test frame are available at the near end of the trunk.

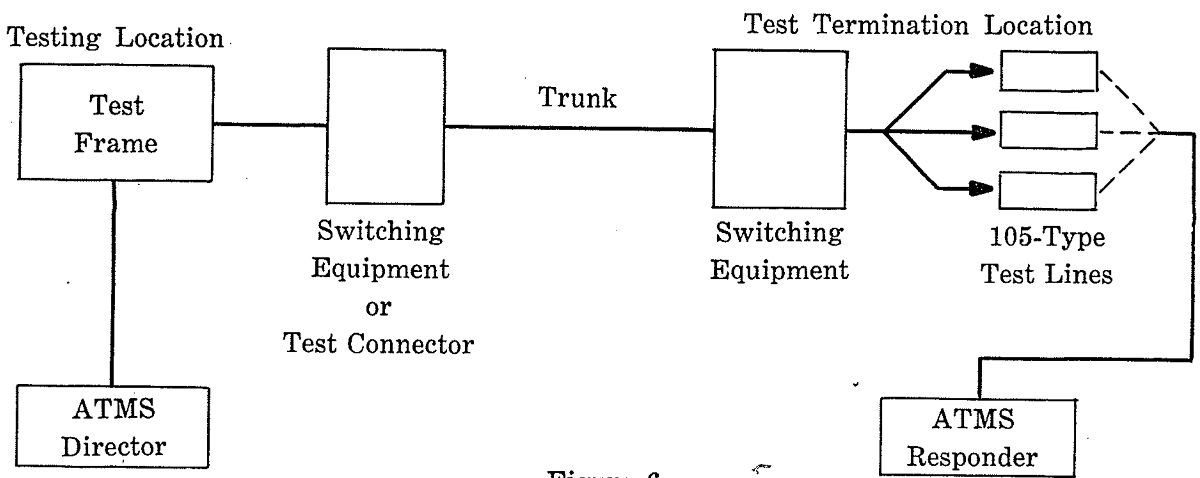


Figure 6
Arrangement for 105-Type Test Line

(g) *Remote Office Test Line (ROTL)* – Provided in remote (attended or unattended) Class 5 offices for making operational and transmission tests of trunks outgoing from the remote office under control of a test frame in another office which is equipped with an ATMS Director, or a manual test frame without an ATMS.

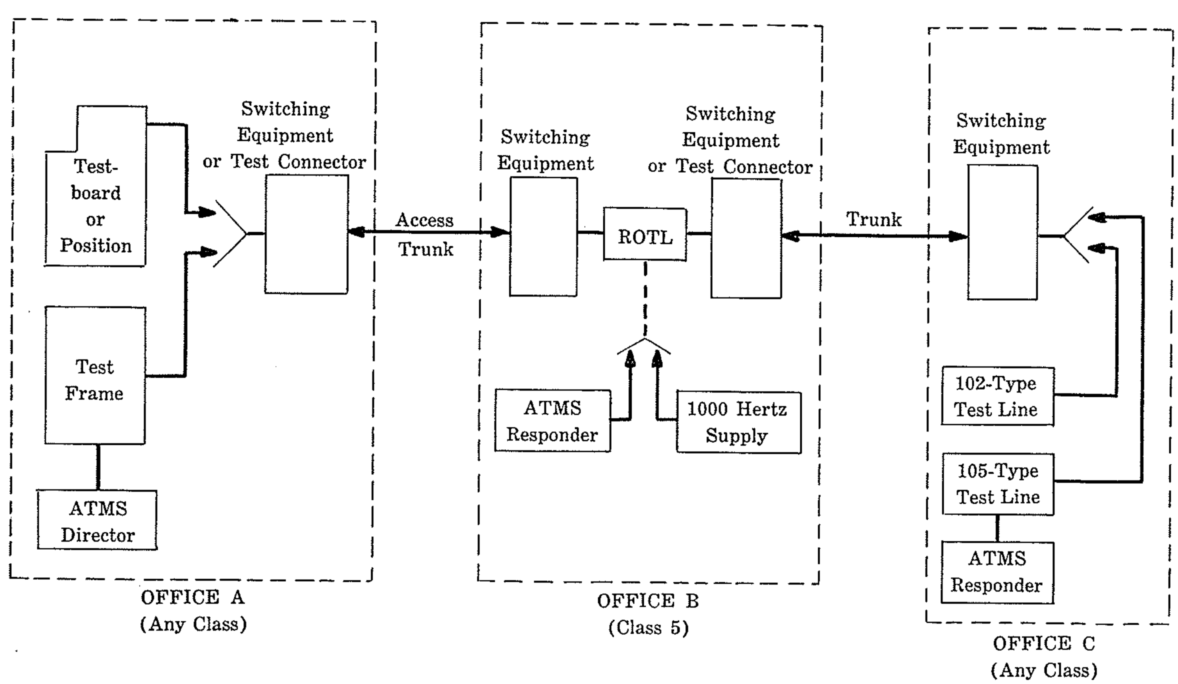


Figure 7
Typical Arrangement for ROTL Operation

(h) *Code 161* – Code used to reach a communication line for operator reporting of trouble to a maintenance center.

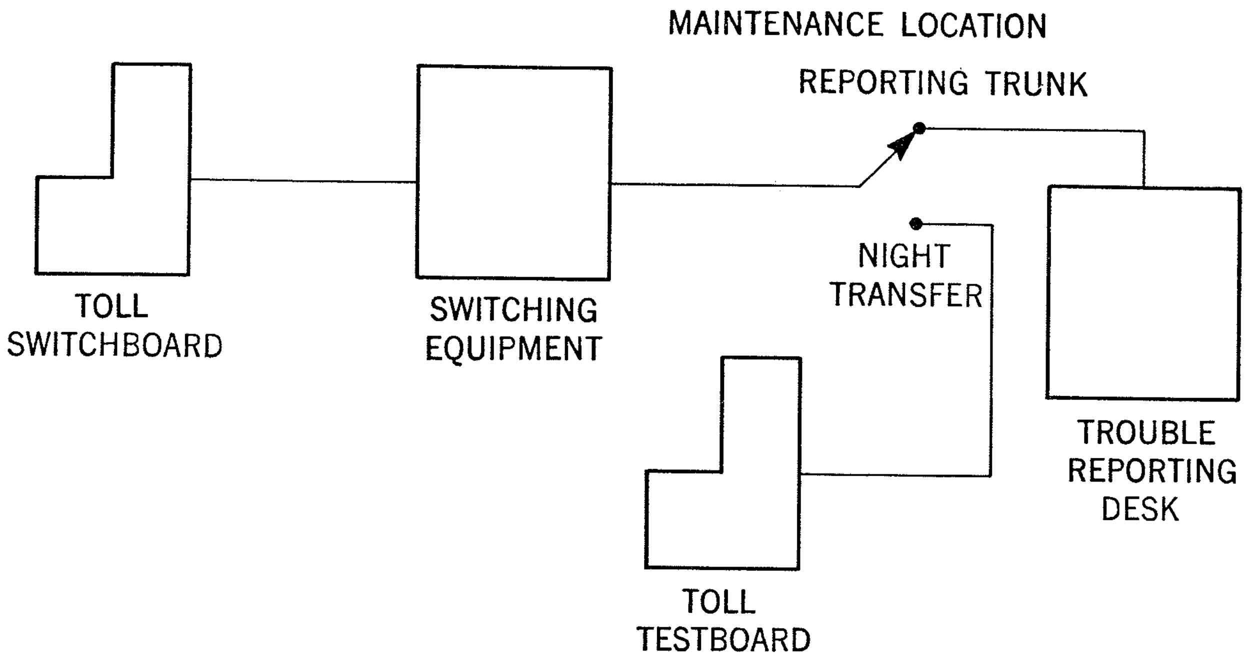


Figure 8
Arrangement for Operator Trouble Reporting Using Code 161

(i) *Code 958* – Provided to reach a communication trunk to the switching system maintenance center to aid in clearing intersystem troubles. (It is planned to change to another series of codes in the future.)

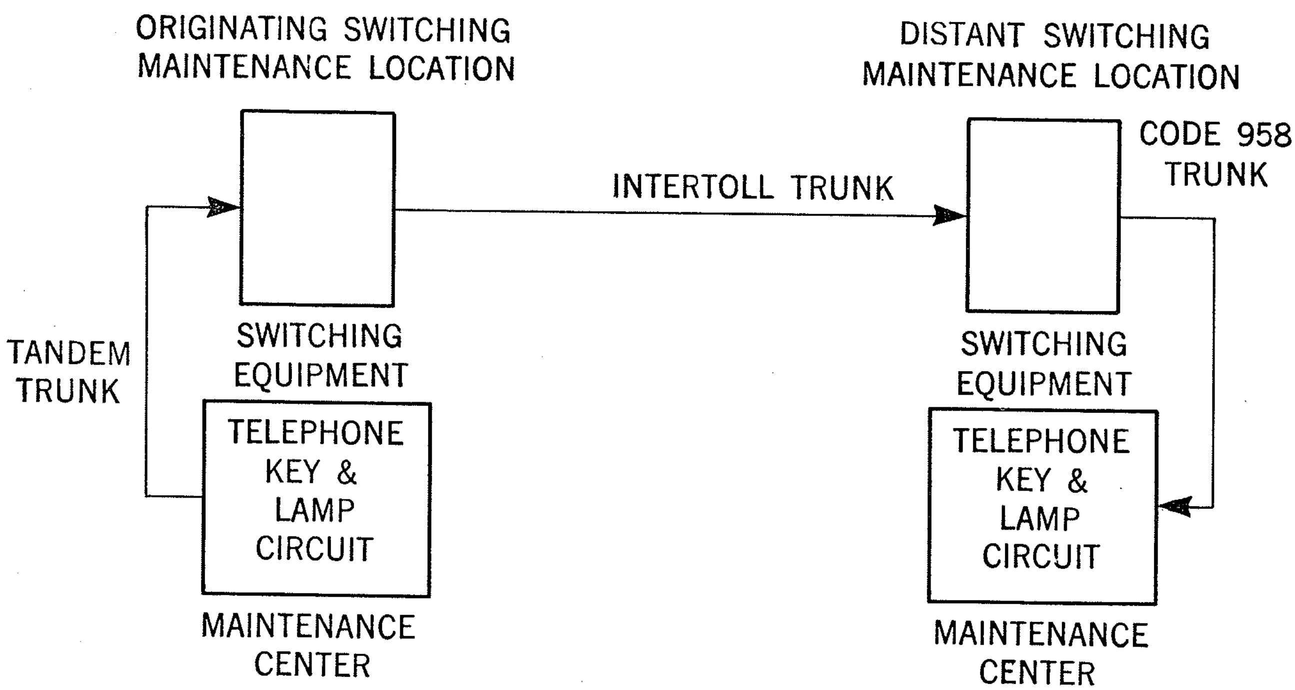


Figure 9
Arrangement for Code 958 Communicating Trunk

(15) *Additional Test Lines for Toll-Connecting Trunks:* Details of additional test lines required in Class 5 offices for testing toll-connecting trunks are discussed in Appendix A to this section. Test lines in Class 5 offices are reached by dialing a customer-type telephone number. The maintenance facilities for toll-connecting trunks are determined on the basis of the components and transmission requirements for the trunks in question. For example, a trunk between a Class 5 office and its home office may employ the same type facilities as an intertoll trunk and, therefore, requires the same treatment as an intertoll trunk.

(a) A "synchronous" test line for testing the ringing, tripping, and supervisory features of incoming trunk relay equipment – usually provided in Bell System-type panel and Crossbar offices. It is "synchronized" with automatic progression test equipment in the originating office, i.e., once connected, it sends forward an ordered sequence of signals to the test frame without need for additional signals from the test frame in the distant office.

(b) A "nonsynchronous" test line for operational tests (not synchronized with automatic progression test equipment).

(c) Loop-around test line for one-man, two-way, transmission testing of four-wire or equivalent trunks.

(d) An open circuit termination for testing negative impedance-type repeaters.

(e) A short-circuit termination for testing negative impedance type repeaters.

TEST AND MAINTENANCE FACILITIES BY CLASS OF OFFICE

(Subject to modification depending on type of trunk or circuit facility, type of switching system, and economic considerations.)

Item No.		Test and Maintenance Facility	Class of Office Class 3	 Class 4	 Class 5
1		Primary Testboard (Note 1)	x	x	
2		Secondary Testboard	x	x	
3		Automatic and/or Manual Test Facilities	x	x	x
4		Patching Jack Bays	x	x	
5		VF Patch Bays	x	x	x
6		CX or SF Signaling Path Test Jacks:			
	(a)	CX Line Jacks	x	x	
	(b)	Equipment Units with Jacks	x	x	x
7		Pulse Repeating Test Set for CX	x	x	
8		Pulse Generating and Measuring Test Set for SF or N, O, ON, and Similar Carrier Systems	x	x	x
9		Switchboard Cord and Position Test Facilities	x	x	x
10		Centralized Trunk Test and Make-Busy Jacks for Maintenance Use Including Operating Room Trunk Make-Busy Facilities	x	x	x
11		Switching Equipment Maintenance Test Sets	x	x	x
12		Sender Test Facilities	x	x	x
13		Transmission Test Facilities	x	x	x
14		Carrier Test Facilities	x	x	x

Item No.		Test and Maintenance Facility	Class of Office Class 3	 Class 4	 Class 5
15		Test Lines:			
	(a)	Balance (100-Type)	x	x	x
	(b)	Communications (101-Type)	x	x	x
	(c)	Milliwatt (102-Type)	x	x	x
	(d)	Signal-Supervisory (103-Type)	x	x	
	(e)	Transmission Measuring and Noise Checking (104-Type)	x	x	x
	(f)	Automatic Transmission Measuring System (105-Type)	x	x	x
	(g)	ROTL – Remote Office Test Line			x
	(h)	161 Trouble-Reporting Trunk	x	x	
	(i)	958 Switching System Maintenance Center Communication Trunk	x	x	
16		Test Lines for Toll-Connecting Trunks			
	(a)	"Synchronous" Test Line (Note 2)	x	x	x
	(b)	"Nonsynchronous" Test Line			x
	(c)	Loop-around Transmission Test Line			x
	(d)	Open-Circuit Test Termination	x	x	x
	(e)	Short-Circuit Test Termination	x	x	x

NOTES 1. Provide only if justified for primary testing of physical facilities. Primary toll test units may be applicable in some cases.

2. Provide for testing the ringing, tripping, and supervisory features of incoming toll-connecting trunks.

DESCRIPTION OF TEST LINES

1. GENERAL

1.01 Test line and test termination are terms sometimes used interchangeably to name a testing equipment, facility, circuit, or testing communication channel. These include simple passive terminations and relatively complex testing circuits capable of applying marginal signaling tests, transmission tests, and recognizing and replying to specific signals received.

1.02 In general, test lines will return a steady–state "off-hook" signal which removes the single–frequency signaling tone to permit measurements to be made under normal "in service" conditions.

1.03 Test lines are always adjusted to provide the correct level as measured at their actual switch appearance. (See Section 6, Paragraph 8.16)

2. SPECIFIC PURPOSE TEST LINES

Test Lines for Testing Trunks

2.01 *Balance (100-Type)* – Is recommended for industrywide use to facilitate connection to a termination for balance and noise testing. The requirements for this termination are as follows:

(1) Provides off-hook supervision to calling end as long as trunk is held by calling end. Some Class 5 offices furnish continuously repeated 10-second supervisory cycles consisting of a 9-second off-hook interval followed by a 1-second on-hook supervisory interval.

(2) Provides a termination (600 or 900 ohms, plus a capacitance) which simulates the nominal office impedance.

2.02 *Communications (101-Type)* – This is a communication and test trunk to the testboard or maintenance center for purposes of obtaining assistance in trunk testing and as a termination for making two-man, overall transmission tests.

2.03 *Milliwatt (102-Type)* – Provides connection to a 1000-Hz power source required for one-way transmission testing. The features of this termination are as follows:

(1)

(a) Some early types provide continuous tone through a sequence consisting of a 9-second off-hook signal, during which 1000-Hz test power is applied, followed by a 1-second on-hook interval with no test power.

(b) Other types provide a 9-second off-hook signal with test power, followed by a steady on-hook signal without test power until released.

(2) Provides an idle circuit termination during the on-hook condition.

(3) Furnishes the necessary pad switching signals and test power level for intertoll trunks terminated on No. 4-type systems. In offices using fixed 2 dB pads (TP-2), the test pads are included in the test line to reduce the testing power to the proper level at the switches.

2.04 *Signal-Supervisory (103-Type)* – Provides a test termination required for overall tests of trunk signaling and supervisory features. Test calls directed to this test trunk may be originated manually, or by automatic test equipment. The features of this termination are as follows:

(1) On seizure, the test trunk returns an off-hook signal.

(2) On receipt of a ring forward (rering) signal, the test trunk returns an on-hook signal.

(3) On receipt of a second ring forward (rering) signal, the test trunk returns a 120 IPM tone signal.

2.05 *Transmission Measuring and Noise Checking (104-Type)* – Provides a test termination for two-way transmission testing and one-way noise checking. This termination can be used to test trunks from offices equipped with either the Automatic Transmission Test and Control Circuit, or the Automatic Transmission Measuring System associated with automatic trunk test frames. It may also be used for manual, "one-man," two-way, transmission measurements from a testboard or a maintenance center. The features of the 104-type test terminations are:

(1) Provides the test pad as required by the office in which it is located.

(2) Provides off-hook supervision.

(3) Measures the 1000-Hz loss of the trunk from originating end to far end.

(4) Adjusts a transmitting pad to equal the trunk loss measured in (3). If this loss exceeds 10 dB, the transmitting pad value is reduced by 10 dB and a subsequent "wink" signal indicates this fact to the originating end.

(5) Makes a recheck of the trunk loss. Then, by means of a local loop, checks that the pads have been properly adjusted. In case of failure in either of these checks, a repetition of the measurement is requested.

(6) Sends 1000-Hz test power directly on the trunk to permit a receiving measurement at the orginating end.

(7) After a timed interval, sends 1000-Hz test power through the transmitting pad adjusted in (4), preceded by a "wink" signal if it has been reduced by 10 dB. This provides information on the loss in this pad to the orginating end.

(8) Checks whether the noise received is greater than a preset value.

2.06 *Automatic Transmission Measuring System (105-Type)* – Provides access to an Automatic Transmission Measuring System responder at the far end and permits automatic, two-way, transmission loss and noise measurements to be made on trunks from the near-end office when it is equipped with a suitable test frame and an ATMS director. The responder is not readily adaptable to manual tests unless the near-end office is equipped with a compatible test unit such as the ATMS director.

2.07 *ROTL* – Remote Office Test Lines installed in remote Class 5 offices make possible operational and transmission tests of trunks outgoing from the remote office by means of a control test frame located in another office.

2.08 *Code 161* – Code 161 has been assigned in most Bell System toll switching offices to reach a communication line terminated at a trouble-reporting location. This code is used by operators to report troubles encountered on trunks.

2.09 *Code 958* – Code 958 has been assigned throughout the Bell System, for the present, as a communication trunk for receiving incoming calls to the switching system maintenance center for purposes of obtaining assistance in clearing intersystem troubles. Equipment troubles in a remote office may be responsible for the reactions being experienced on calls between two offices. When there are indications of an intersystem trouble, tracing and clearing may be expedited by the use of this line for communication between the two maintenance centers involved.

Additional Test Lines for Testing Toll-Connecting Trunks

2.10 Test lines similar to those described above are reached by dialing a customer–type telephone number when testing toward a Class 5 office, or by dialing an arbitrary 3-, 4-, or 7-digit number when testing toward a toll office. In addition to the features described above, test lines in Class 5 offices are arranged to trip machine ringing.

2.11 The loop-around test line in a Class 5 office enables one man in a toll office to make two-way transmission tests. Test calls directed to this test line are manually originated. It is used to measure the near-to-far loss of four-wire or equivalent trunks. This test line has two terminations, each reached by means of separate subscriber–type telephone numbers. After having measured the far-to-near end loss of all trunks in the group (using 102-type test line), one trunk is selected as a reference trunk. Using the reference trunk, one termination of this test line is dialed. Then taking each of the remaining trunks in turn, the other termination of this test line is dialed and test power is sent out over the trunk under test and received on the reference trunk. By knowing the far-to-near loss of the reference trunk and the overall measurement of the two trunks, the near-to-far loss is calculated by subtraction. The features of this test line are as follows:

(1) Trips machine ringing.

(2) Provides idle circuit termination on each test number.

(3) When the second connection is made, both idle circuit terminations are removed.

(4) Provides direct connection between two test numbers.

(5) Provides a holding circuit through the sleeve to prevent switch-train release during supervision changes.

(6) Provides off-hook supervision after both test numbers have been selected.

2.12 A short-circuit termination and an open-circuit termination are provided to test the stability of trunks having negative impedance-type repeaters.

(1) Trips machine ringing.

(2) Returns an off-hook to the calling end as long as the connection is held at the calling end.

(3) Provides essentially an AC short circuit, or open circuit across the tip and ring.

2.13 "Synchronous" type test lines are required for offices (usually in connection with Bell System panel and crossbar-type offices) where ringing, tripping, and supervisory features are in the incoming trunk relay equipment. Marginal tests of the supervisory and tripping functions are provided. Tests may be originated on either a manual or automatic basis. In No. 1 ESS offices an equivalent program-controlled test line operation is provided to satisfy the requirements of the originating office test frames. The test line is required to perform the functions as described below:

(1) Test for application of the ringing signal.

(2) Test for pretripping of machine ringing during the silent interval.

(3) Provide interrupted audible ringing tone during one 2-second ringing interval.

(4) Test for tripping machine ringing during a 3-second silent interval.

(5) Provide the following supervisory tests:

(a) An off-hook signai of approximately 1.3-second duration for synchronizing with automatic progression test equipment in originating offices. During the off-hook period, soak current is applied to supervisory relays.

(b) The synchronizing signal is followed by two separate off-hook signals of 0.3-second duration, during which the soak current is applied to the supervisory relays.

(c) Following one synchronizing signal and each of the two successive short off-hook signals, an on-hook signal of approximately 0.2-second duration is returned, during which time the release current is applied to the supervisory relays.

(d) A second series of off-hook signals, consisting of a synchronizing signal and two flashes is returned. During each off-hook interval of this series, operate current is applied to the supervisory relays. During each on-hook interval, an open-circuit condition is presented to the supervisory relays.

(6) Send tone signals to the originating office as follows:

(a) Audible ringing tone for 0.3-second intervals interrupted for 0.2-second as an indication that the trunk circuit tripping features operated on the pretripping test.

(b) A "tick-tock" tone at the rate of 120 IPM without flash as an indication that the test termination has completed all tests and is awaiting disconnection.

Note: The incoming trunk circuit should return the regular audible ring to indicate tripping failure.

2.14 A "non-synchronous" test line is required for all dial-type Class 5 offices, including those having the synchronous-type test line. This line provides an operation test which is not as complete as the synchronous test, but can be made more rapidly. The nonsynchronous-type is the only one required for those offices where marginal-type tests cannot be applied directly to the incoming trunk circuit, as is frequently the case with step-by-step type systems. However, test terminations provided for application of marginal-type tests to circuits, such as connectors in step-by-step offices, generally meet the minimum requirements for nonsynchronous-type incoming trunk test lines, and are frequently used for this purpose. In some instances, connector test terminations can be used to apply marginal tests to such circuits as toll transmission selectors. The minimum requirements for a nonsynchronous test line where the synchronous test line is not provided are as follows:

(1) Starts to function under control of ringing signal.

(2) Permits audible ringing signal to be returned for a minimum 0.5 second to originating office.

(3) Causes ringing to trip.

(4) After ringing is tripped, returns the 60 IPM line busy signal which consists of alternate 0.5-second off- and on-hook signals with low tone applied during each off-hook period until disconnection. Where the synchronous test line is provided, only the 60 IPM line busy signal is required. The nonsynchronous-test line used in many Bell System step-by-step offices for the application of marginal tests to connector circuits, provides the following:

(a) Starts to function under control of the ringing signal.

(b) Permits audible ringing signal to be returned for 1.0- to 1.5-seconds.

(c) Returns an initial off-hook signal of 1.0 to 1.5-seconds duration during which time ringing is tripped.

(d) Provides the following supervisory signals sequentially after the initial off-hook tests are applied:

1. 0.5-second on-hook.
2. 1.0- to 1.5-seconds off-hook.
3. 0.2-second on-hook.
4. 0.3-second off-hook.
5. 0.2-second on-hook.
6. 0.3-second off-hook.
7. 0.2-second on-hook.
8. 0.3-second off-hook.
9. 2.0-seconds on-hook period to permit disconnection from the test line.
10. Alternate 5.5-seconds off-hook and 2.0-seconds on-hook intervals are repeated until disconnection takes place. The first two 5.5-second intervals are provided to facilitate testing of the ringing forward (rering) and control features provided on some operator selected trunks to end offices and are desirable where these features are provided.

Assignment of Test Numbers at Class 5 Offices

2.15 To permit maximum use of automatic trunk test facilities provided for terminating trunks, a uniform assignment of four-digit test numbers is desirable. This is particularly important for all Class 5 offices homing on the same Class 4 office. Uniform test number assignment is also an asset to a well-organized maintenance plan.

2.16 The number of directing digits preceding the four-digit test number should be kept to a minimum.

Trunk Transmission Test at a Manual Switchboard Position

2.17 A test line which furnishes 1000-Hz test power may be given a switchboard jack appearance to which incoming trunks may be connected manually by the operator. This procedure is similar, therefore, to reaching the test power by dialing the 102-type test line where it is available. The requirements for this termination are as follows:

(1) Furnishes "off-hook" supervision and sends test power at 1000 Hertz on the trunk to which it is connected for a test interval of about 9 seconds.

(2) Furnishes "on-hook" supervision and disconnects the test power for one second out of every ten seconds continually during the test.

2.18 Jack appearances in switchboards may be provided for the loop-around, short circuit, open circuit and balance termination test lines with operating features as covered in this Appendix under *Test Lines for Testing Toll Connecting Trunks.*

Section 8

Internat'l Dialing

INTERNATIONAL DIALING

CONTENTS PAGE

1. GENERAL

1.01 Worldwide customer direct distance dialing (DDD) will have a major impact on the communications industry in many areas, such as numbering, signaling, switching, equipment, transmission, etc. The following is a description of the preliminary plans for International Dialing.

1.02 Within the North American integrated network there is customer international dialing. However, for a telephone call to a location outside North America, the call request is transmitted to the international gateway office involved where an operator sets up the connection on a manual basis or by operator distance dialing (ODD).

1.03 The increased intercontinental traffic which occurred since the transatlantic telephone cables were placed in service led to plans for modernization of overseas service. As a first step, negotiations with some of the European telephone administrations were initiated in 1958 to explore the possibility of dialing overseas calls. These discussions led to the introduction of operator distance dialing (ODD) early in 1963 on circuits from the United States to England and Germany. Currently, ODD is used on circuits to additional European countries and to Australia, Japan, and other points.

1.04 The international organization working to further the improvement of international communications is the International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunication Union (ITU). It has been studying a wide range of technical matters related to the implementation of worldwide ODD and, ultimately, DDD. The U. S. government and some of the common carriers, including the Bell System, are members.

1.05 The CCITT is an assembly of engineers and specialists representing the telecommunication administrations and organizations of the world, both governmental and private, and also the telecommunication industry in general. Its members meet to study questions and prepare recommendations dealing with the international aspects of telephony and telegraphy. Although the recommendations of the CCITT are not regulations, they represent a common basis of agreement between telephone operating organizations around the world for technical and operating uniformity in international services.

1.06 The CCITT recommendations are contained in a series of volumes, published by the International Telecommunication Union in Geneva, Switzerland. The latest series (1964) have blue covers and are, therefore, designated "Blue Books of the CCITT." The contents of the Blue Books are:

Volume	Recommendations
I	General information, list of questions and Study groups
II	Leasing of telecommunication circuits Telephone operation and tariffs Telegraph operation and tariffs
III	Line transmission
IV	Line maintenance and measurement
*V	Telephone transmission performance and apparatus
VI	Telephone signaling and switching
VII	Telegraph technique
VIII	Data transmission
IX	Protection against disturbances Protection of cable sheaths and poles

*Volume V has not been issued as a Blue Book. The present Volume V, Red Book – New Delhi, 1960, is supplemented by a Volume V bis, Red Book – Geneva, 1964.

1.07 The members of the CCITT have reached agreement on the general framework through which worldwide DDD will be achieved. The general plan is based on the national telephone development as forecast by the countries of the world for the year 2000 A.D. It presumes All-Number Calling. Nearly all telephone operating organizations are either on an All-Number Calling basis or are changing to All-Number Calling.

2. WORLD NUMBERING PLAN

2.01 The worldwide numbering plan developed provides each customer with a unique world telephone number. Each world telephone number consists of a country code prefixed to the national number of the station, but with the restriction that the country code plus the national number cannot exceed twelve digits.

2.02 The number of digits can vary up to the limit of twelve depending on the requirements of a particular country. With a few exceptions, a world number can be held to eleven digits. In addition to the world telephone number, the originating customer dials an international access code. The codes for North America are discussed under Paragraph 2.09 in this section.

2.03 For numbering purposes, the world is divided into zones and every country assigned a distinctive country code. Each country within a particular numbering zone has as the first digit of its country code the zone number. The country codes may be one-, two-, or three-digit numbers. For example, USSR has been assigned the 1-digit code 7; Belgium will have the 2-digit code 32; Portugal will have the 3-digit code 351. The European world numbering zone has a very large requirements for 2-digit country codes; therefore, this zone has been assigned both the digits 3 and 4.

2.04 The variable number of digits in the country code permits a variation in the number of digits in the national number, while still limiting to twelve the number of total digits of a customer's world number. The total number of country codes available from this choice of a one-, two-, or three-digit code is adequate for requirements as foreseen to 2000 A.D.

2.05 An exception to the plan, of each country having a distinctive country code is the North America zone. Since North America has an integrated numbering plan the single digit 1 is used as the country code by all the countries in the North American zone.

2.06 The world numbering zones are:

1 – North America (including Hawaii and the Caribbean Islands, except Cuba)

2 – Africa

3 & 4 – Europe

5 – South America, Cuba

6 – South Pacific (Australasia)

7 – USSR

8 – North Pacific (Eastern Asia)

9 – Far East and Middle East

0 – Spare

The assigned world numbering zones are illustrated in Chart 1.

2.07 The world telephone number of a customer in the United States would be the digit 1 plus his present national number, e.g., 1 + 311-555-4982. Other examples are:

North America		Africa	
United States (N. Y. City)	1-212-393-9800	United Arab Republic	20 + 8 digits
Canada (Montreal)	1-514-870-1511	Nigeria	234 + 8 digits
		Liberia	231 + 6 digits

Europe		South America	
United Kingdom	44 + (8 or 9) digits	Brazil	55 + 9 digits
Switzerland	41 + 8 digits	Argentina	54 + 8 digits
France	33 + 8 digits	Peru	596 + 8 digits
Portugal	351 + (7 or 8) digits	Ecuador	593 + 7 digits

2.08 All national telephone systems will need to resolve the following:

a. Introduction of international access codes to overcome the ambiguity when national and foreign numbers employ the same initial digits.

b. Possible expansion of the digit capacity of registers in local and toll offices.

c. Arrangements to route calls from the originating local office to the appropriate international gateway office.

2.09 The Bell System plan for overseas DDD is based on the world numbering plan. The following two international access codes are planned for use within the North American integrated network:

011 + For overseas station-to-station calls.

01 + For overseas calls requiring operator assistance, such as person-to-person, credit card, and collect calls.

The customer will dial the appropriate access code, then the country code (1, 2, or 3 digits), followed by the national number of the called station.

2.10 The fundamental plan is based on the use of electronic equipment to be available in future ESS-type offices; or in the case of existing electromechanical-type offices, as available at a Traffic Service Position System (TSPS). Local common control offices where this offering is to be made must be modified to accept the international access codes plus a maximum of 12 digits.

These offices will forward the recorded numerical information to the TSPS. In the case of non-senderized step-by-step offices, the initial "0" of the access code, will cause a trunk to the TSPS to be seized. The TSPS will record all digits following the initial 0.

2.11 The serving TSPS will bring in a TSP operator on a person-type call. From an analysis of the three digits following the international access code,the switching office will route the call to the appropriate international (overseas gateway) office. Routing under the plan will be accomplished in two steps. In the first step, the TSPS, by means of an arbitrary 3-digit routing code, will route to an overseas sender at the international office. The overseas sender will return a proceed-to-send signal, whereupon in the second step the TSPS will outpulse the country code and national number over the established connection to the overseas sender. The overseas sender will then establish the connection to the called overseas customer and provide the interface between the North American signaling system and the CCITT No. 5 signaling system used on international trunks.

2.12 It is expected that overseas DDD features can be provided economically in future ESS-type offices. It is anticipated that common control-type offices in only a few cities will have sufficient volumes of overseas business to justify the expense of modifying such offices for overseas DDD, of establishing overseas features at TSPS entities, and of training TSP operators in overseas operating practices. In the case of predominantly step-by-step areas, economic justification requires a sufficient volume of overseas business to justify the cost of establishing overseas features at the TSPS system and of training TSP operators in overseas operating practices.

3. INTERNATIONAL ROUTING PLAN

3.01 The CCITT worldwide routing plan closely parallels the plan used in North America. It is an hierarchical arrangement with three levels of international centers designated CT1, CT2, and CT3. High-usage circuit groups between any pair of CT's are authorized whenever economically justified. The overflow traffic not handled on the high- usage routes would be switched over the final route to the next higher ranking office. Chart 2 illustrates the plan.

3.02 The CT1's are connected together two by two by low delay probability circuit groups. However, in exceptional cases where a significant economy may be made and provided that transmission and other quality of service standards are maintained, two CT1's may be interconnected through an intermediate transit center of unspecified order (CTx).

3.03 A CT1 center is important in the world plan. The choices of CT1 locations are made jointly on a world basis, since every country which has a CT1 is concerned with the costs of providing direct circuit groups to all other CT1's. To minimize costs, it was agreed that CT1's will be few in number and will be at strategic locations throughout the world. The CT1 locations are determined by the flow of international transit traffic and are essentially gathering points for the traffic from a very large area. A CT1 will be located in an area where there is a large volume of terminal traffic, but an additional important consideration is its position as a cross-road for transit traffic.

3.04 Seven CT1's have been designated with provisions to add others as required.

CT1	Area Served
New York (White Plains)	North and South America
London	Western Europe and Mediterranean Basin
Moscow	Eastern Europe, North and Central Asia
Sydney	Australia
Tokyo	Eastern Asia
Singapore	Southeast Asia
Unnamed Center in India or Pakistan	South Asia, Near East, and Middle East

3.05 The principal countries in each CT1 zone have been assigned one or more CT2's, depending on their relative size and traffic patterns. Twelve CT2's are in the United States (each Regional Center excluding White Plains which is a CT1, and the present international gateways, i.e., New York, Miami, and Oakland); two are in Canada (Montreal and Vancouver which are international gateways).

3.06 Practically all the CT3's now designated are in North and South America, Europe, and the Mediterranean Basin.

TENTATIVE HOMING OF CT2 & CT3 EXCHANGES

CT1	CT2	CT3
New York (White Plains)	18	19
London	9	16
Moscow	4	
Sydney	4	
Tokyo	1	1
Singapore	1	1

3.07 The maximum number of circuits to be used for an international call is fixed by the CCITT at 12 with up to a maximum of 6 of the circuits being international. In exceptional cases and for a low number of calls, the total number of circuits may be 14; but, even in this case, the maximum number of international circuits is 6. In this instance, the final international route would be:

CT3 ⟶ CT2 ⟶ CT1 ⟶ CTx ⟶ CT1 ⟶ CT2 ⟶ CT3

3.08 The engineering of final routes to handle the busy-hour traffic of the worldwide network poses an interesting traffic engineering and routing problem. The busy hour for calls is concentrated within a few specific hours of the day because of time zone differences. The London-New York busy hour is concentrated in the period 9 A.M. to 12 Noon (New York time) which in London time is 2 P.M. to 5 P.M. The costs involved in engineering sufficient busy hour circuits, which would be idle during most other hours in the day, has prompted the members of the CCITT to initiate a study on ways to solve these problems, such as using flexible routing and some type of network management.

4. SPECIAL FACILITIES (TASI)

4.01 The submarine cables used in the worldwide network will usually be equipped with a concentrator system such as TASI.

4.02 TASI (Time Assignment Speech Interpolation) is a system which increases the capacity of the cables. The system takes advantage of pauses and listening periods in two-way telephone conversation to interpolate or interweave other speech signals. This enables the voice channels to carry more conversations. Each transoceanic call – like most other long-distance calls is carried over a pair of facilities, one used for each direction of speech. With one person talking and the other listening, one direction is idle, and there are moments when neither person speaks. TASI locates this idle time and momentarily disconnects the voice paths from those speakers who are silent and connects the idle voice paths to those beginning to talk.

4.03 To insure that a disconnected talker will be connected to an idle channel whenever he speaks again, the TASI equipment samples each channel 8,000 times a second to select an idle one. Thus, although any single channel may carry one talker after another in rapid succession, TASI sorts out the conversations and sends them to their proper listeners.

5. SIGNALING

5.01 Intercontinental signaling converters are now only furnished at the international gateway offices. The following paragraphs describe the CCITT intercontinental signaling arrangements.

5.02 The initial operation on the transatlantic telephone cables was ringdown. To improve service, plans were formulated to introduce operator dialing at the international gateway offices. However, telephone systems have been developed independently on each side of the Atlantic and as a result, the signaling systems used in Europe for international traffic are not compatible with those used in North America. Neither the North American nor the European signaling systems were compatible with the TASI (Time Assignment Speech Interpolation) equipment used on the submarine cables. Moreover, circuits in Europe are operated on a one-way basis whereas in North America, most long-haul circuits are operated on two-way basis.

5.03 Agreement was reached in 1960 with the British, French, and German administrations on a specification for an intercontinental signaling system which was TASI-compatible and which provided an interface between the North American and the European systems and for two-way operation of the circuits. This system (sometimes called the "Atlantic" system) used a modified version of the North American multifrequency pulsing for the interregister transmission of address information and a new two-frequency signaling system for line (supervisory) signals. The signaling system uses the North American signaling frequencies of 2400 and 2600 Hz. The conversion from North American multifrequency pulsing to Atlantic is accomplished at the international gateway office in the senders of the 4A or 4M crossbar systems. A signal converter was developed, as were overseas trunk circuits, senders, etc., for the 4A or 4M crossbar system.

5.04 To avoid the necessity for making bilateral agreements on a signaling system with each country planning to interconnect with the United States, the CCITT was requested to study the Atlantic system for standardization as a recommended intercontinental signaling system. With some minor changes, it was accepted by the CCITT and designated the CCITT System No. 5. The necessary modifications to convert the Atlantic design equipment to CCITT No. 5 System are being made.

5.05 The members of the CCITT are studying an intercontinental CCITT System No. 6. This system is expected to have the capacity to pass additional signals not available now. For example, it is expected to pass signals which will activate locally generated audible ringing tones. Details of the final design have not been formulated at this time. Some of the features being tentatively considered, however, are mentioned since they may be of general interest. The system will include a common signaling channel carrying a serial information stream, which incorporates part or all of the signals from a number of voice channels. This will be similar to a data transmission system, and will probably operate at 2400 bits per second. This common channel may be coterminal with the voice channels for which it carries signals, in which case it is called "associated," or it may not be coterminal. If it is not coterminal, a variety of configurations are possible, several of which may become part of System No. 6. For these non-associated configurations, logical interpretation and recoding will be required at intermediate points. Important features of the system will be to provide a coding scheme to minimize errors, and arrangements to assure trouble-free common channel operation. This system will fit in well with advanced ideas regarding domestic signaling methods, and with the stored program control arrangements expected to be employed at intercontinental switching offices. The CCITT System No. 6 is expected to be available for use early in the 1970's.

6. TRANSMISSION AND MAINTENANCE

6.01 International dialing, with the possibility of connecting as many as twelve circuits in tandem, poses very stringent problems in transmission design and maintenance. With an increase in circuit length and in the number of links in the circuit as well as the use of TASI, there is a probability of greater overall net loss variation. There will be some increase in noise, distortion, and time of transmission. Achieving performance objectives becomes increasingly important, however, since only a part of the overall customer-to-customer connection would be within an administration's network and subject to its control.

6.02 The circuits in tandem may include circuits on submarine cables and satellites. The limits placed on the maximum permissible transmission time on a call may require control measures to prevent the inclusion of more than one satellite circuit in the overall connection.

The present CCITT recommendation on delay places some restrictions on the use of circuits with round trip delays in excess of 400 ms.

6.03 The large number of circuits in tandem also increases the probability of having several echo suppressors in tandem. Whether or not more than one half echo suppressor in each direction of transmission can be used is not known at this time. Control measures may be needed to inactivate the other echo suppressors.

6.04 The procedures involved in the establishment and maintenance of international circuits have been, and are, on a continuing basis, the subject of study by members of the CCITT. The recommendations cover all aspects of international circuits, from the interexchange of information concerning the type of facilities, switching systems, and signaling arrangements, to detailed responsibilities of control and other points for the establishing, routine testing, trouble-locating, and sectionalizing procedures, etc., for international circuits.

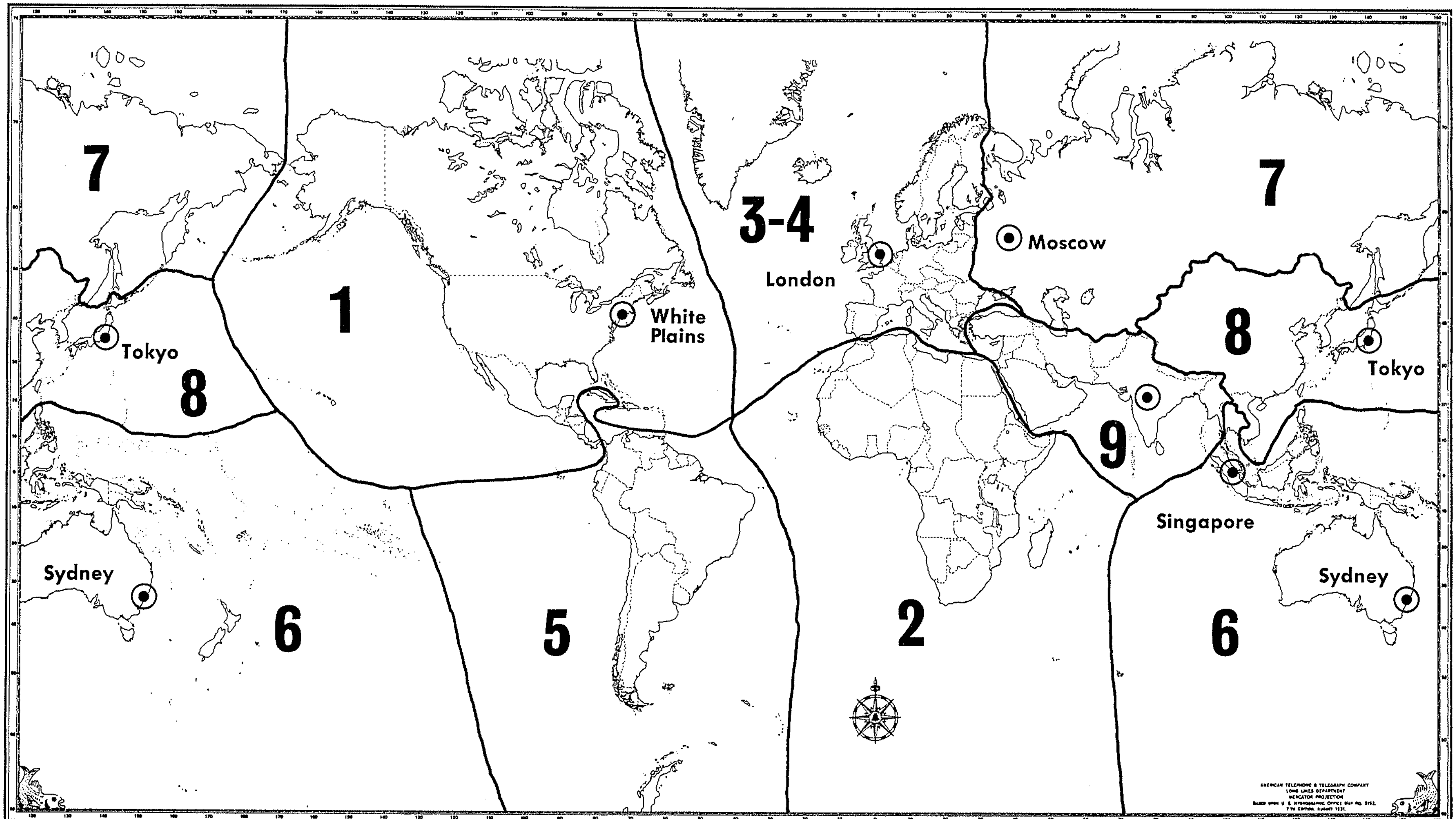
6.05 At the time international circuits between two countries are established, detailed agreements are reached on all of the specific items involved in maintenance. The agreements are largely based on the current recommendations of the CCITT.

7. TRAFFIC OPERATING

7.01 Person-to-person calls in the international service are called "personal calls." At the present time, overseas calls to most countries are charged for at personal rates. However, on calls to Japan and to a number of European countries station-to-station rates also apply. Credit card and collect calls are accepted between some countries. It is planned that these and both station and personal calls will be available eventually between North America and most countries.

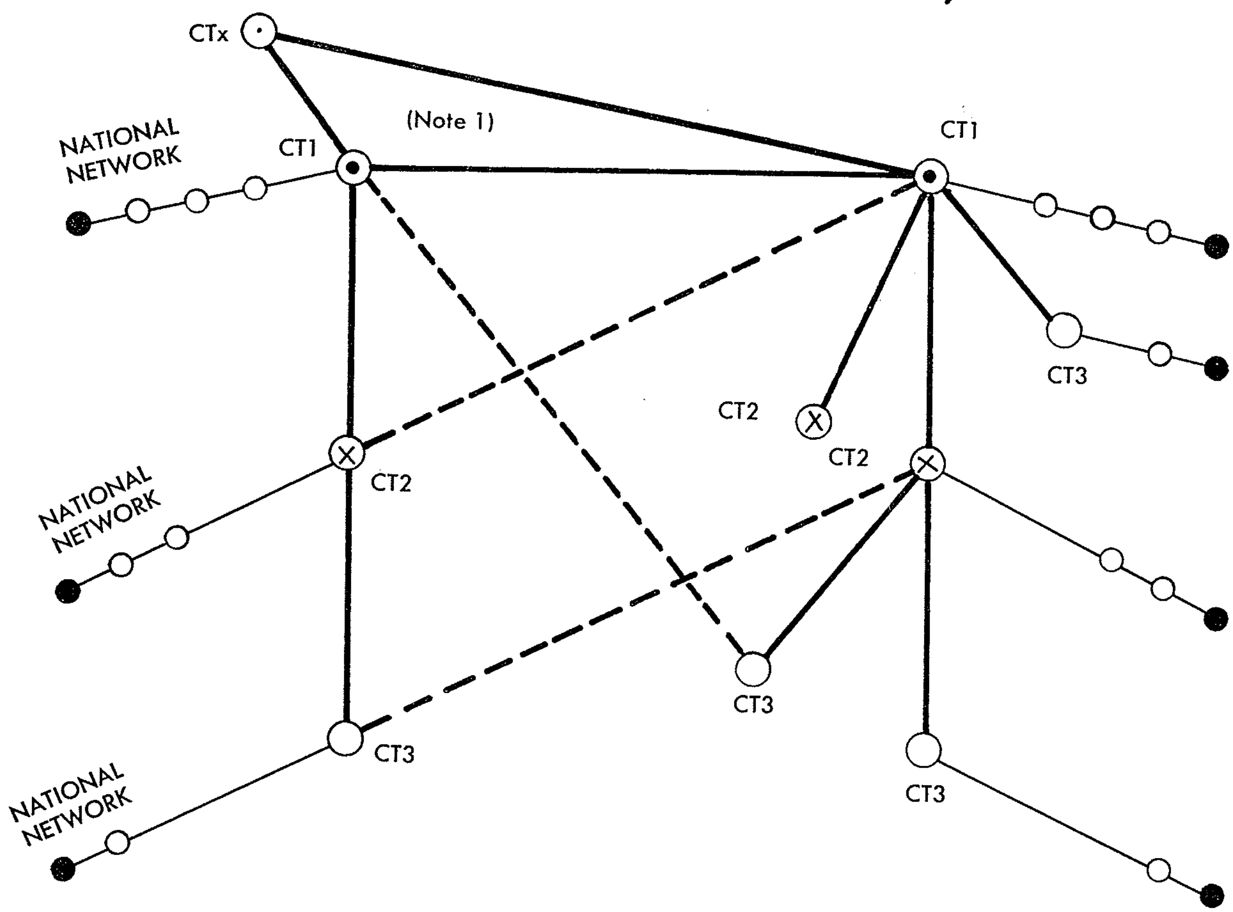
7.02 In the international service, an operator may have language difficulties or be unable to interpret a national tone while establishing a call. To alleviate this on operator-dialed calls, the calling operator is able to ring forward on the circuit. This causes the connection to be connected to an assistance operator in the terminating country. On operator-dialed calls from North America, the language digit required for this service is automatically inserted by the switching equipment and pulsed forward between the country code and the national code of the number dialed. On customer-dialed calls, a discriminating digit rather than a language digit will be used. However, at the outset, it is planned to send the language digit instead of the discriminating digit on both operator- and customer-dialed calls.

World Numbering Zones and World Major Switching Offices



INTERNATIONAL ROUTING PLAN

(Classification and arrangement of centers)



International Network

- CT1 (First Category CT)
- CT2 (Second Category CT)
- CT3 (Third Category CT)
- CTx (Unspecified Category CT)

International Final Route ———

High-usage Circuit Group — — —

Note 1: Final Route if CT1-CT1 direct circuit is not provided.

National Network

- Toll Center (long distance exchange serving a subscriber through a toll connecting trunk and local center).
- Other National centers (i.e. CSP's).

Final circuit group ——— .

Section 9

New Services

NEW SERVICES UTILIZING DDD NETWORK

CONTENTS PAGE

1. GENERAL

1.01 Increasing needs of communications users and the progressing state of the telecommunications art have generated additional services which differ in some respects from ordinary message toll service. Some of the existing new services which employ the Direct Distance Dialing Network are discussed in this section.

2. WIDE AREA TELEPHONE SERVICE (WATS) – GENERAL

2.01 *W*ide *A*rea *T*elephone *S*ervice (WATS) is a service designed to meet the needs of customers having substantial volumes of toll calls over a wide area. Within the continental United States (excluding Alaska), customers may subscribe to any one of six interstate areas on either a full-time flat rate basis or on a measured time basis. In addition, various intrastate band arrangements are available. Similar service with varying rate bands is also available within Canada.

2.02 Within the United States, the WATS service may be subscribed for on an outward basis or on an inward basis. Since the operations are somewhat different, they are described separately in Parts 3 and 4 below. Currently, only outward WATS service is available in Canada.

3. OUTWARD WATS

3.01 WATS customers are furnished "access lines" arranged for dial originating service only connected to a central office suitably arranged to originate a WATS call. From the originating WATS serving office to the destination, the call is handled in the same manner as any other DDD call.

3.02 Equipment should be arranged to block customer-dialed out-of-band calls (calls not included in subscribed-for calling areas). Blocked calls should be diverted to an appropriate recorded announcement or to a special intercept operator.

3.03 For the customer to pass a call to an operator on nondialable calls, it is desirable that the central office code of the calling number carry with it distinctive information. The line number would be the regular 4-digit WATS line number in the central office. The C.O. code, in ANC form, would be the distinctive part as follows:

(1) The initial digit "0" for a full-time line. The initial digit "1" for a measured time line.

(2) The third digit could designate the calling area subscribed for: 1 through 6 designating the interstate bands; 7, 8, and 9 intrastate.

(3) The middle digit, which should not contain 0 or 1, is flexible in its use. Different digits could be assigned to different central offices served by the same Accounting Center. It could also be used in cases where an office serves lines for more than one state (e.g., Kansas City or Cincinnati) to distinguish in which state the customer is located.

4. INWARD WATS

4.01 Inward WATS allows a subscriber, in consideration of a monthly payment, to receive telephone calls which have been placed without charge to the originating party from within specified areas. Similarly to outward WATS, customers may subscribe to various service bands on either a full- or measured-time basis.

4.02 Calls may be made, at no charge to the calling party, to any inward WATS line from the telephones of concurring Telephone Companies located within the rate band for which the called inward WATS customer has subscribed. Calls from telephones not located within such a rate band or in nonconcurring Company areas, are blocked.

4.03 Most calls to inward WATS lines are dialed directly by the originating party. Where DDD is not available, calls to inward WATS lines are placed through the outward Toll Center operator.

4.04 Inward WATS customer lines are assigned to a local dial office equipped for inward DDD. Preferably, this should be in a central office in the customer's wire center.

4.05 AMA records or operator tickets are made on all calls destined for inward WATS subscriber lines. They are not used for billing purposes, but are required for Bell-Independent settlements, Division of Revenue purposes, and other statistical data.

4.06 Inward WATS is handled by means of special code assignments. These consist of a Special Area Code (SAC), specifically "800," followed by a specific NNX code for each telephone NPA. Of the 640 codes available, all "NN2" codes are reserved for intrastate, leaving the others available for interstate usage.

4.07 Dialing the special inward WATS code will route the call to an office within the WATS state which is capable of six-digit (6D) translation. By means of this translation of the SAC and NNX codes, the call will be routed toward the telephone NPA where the inward WATS subscriber is located. The call must be routed to the principal city office for that NPA which, in turn, is capable of 6D translation.

4.08 When the call arrives at the terminating principal city, the SAC plus NNX codes will have been deleted and a 1XX type code substituted which will include the digit which is the key to the rate band (in respect to the inward WATS subscriber) from which the call originated.

4.09 If the inward WATS call is routed via an intermediate office en route to the principal city of the terminating NPA, the SAC (800) will be code compressed to a "Pseudo-SAC" with the third digit being the key numeral to the rate band. When finally routed over a direct trunk group to the terminating principal city, the 6-digit combination of Pseudo-SAC and NNX code will be converted to the appropriate 1XX code for identical treatment as though the call had come directly from the originating WATS state.

4.10 Chart 1 illustrates the inward WATS switching plan discussed in Paragraphs 4.06-4.09.

5. TELETYPEWRITER EXCHANGE (TWX) SERVICE

5.01 TWX Service consists of teletypewriters and associated station equipment located on the customer's premises, through which dialed connections are established to both 60-speed and 100-speed TWX teletypewriters. Messages may be sent by a manual typing operation or automatically by punched tape. They may be received on page copy, forms, or punched tape, or a combination of these items. Teletypewriter punched tape may be used in conjunction with various types of Data Processing Machines.

5.02 The methods used to route and switch TWX traffic are described in the following paragraphs.

5.03 The routing pattern for traffic between 60-speed TWX stations is basically the same as the telephone network. The switching office serving the calling station operates on the dialed address and causes a connection to be established to the called station by the same switching offices and interexchange trunks used if the call were between two telephone stations.

5.04 The major part of the traffic between 100-speed stations is routed according to the TWX Switching Plan. This plan is an arrangement of those offices which serve the majority of 100-speed TWX stations. All of these offices are structured in a switching hierarchy containing three classes of offices, Primary, Secondary, and Tertiary.

5.05 Final groups connect each Primary office to each of the Secondary offices in its region and to all the other Primary offices. Also, final groups connect each secondary office to each of the Tertiary offices in its area. In addition, high-usage groups have been established between any other two offices where economically warranted.

5.06 All of the 100-speed TWX stations served from offices included in the TWX switching plan are assigned a numerical address of 10 digits, the first three digits indicating a Special Code (SAC). (See Chart 2.)

5.07 Some few 100-speed TWX stations are located so that it is not feasible to provide an access line to one of the switching offices included in the TWX Switching Plan. These offices are provided with a unique SAC (510). Calls from these offices to other 100-speed stations are routed over the telephone network to the nearest Primary office in the TWX Switching Plan. From there on, the call is routed according to the TWX Switching Plan.

5.08 Traffic from a 60-speed station to a 100-speed station, included in the TWX Switching Plan, is routed over the telephone network to a 4A office equipped with converter circuits. From there, the routing is in accordance with the TWX Switching Plan. Traffic from a 60-speed station to a 100-speed station not served from an office in the TWX Switching Plan is routed the same as a telephone call to a 4A office equipped with converter circuits and, from there, completed in the same manner as a telephone call.

5.09 Canadian TWX offices are currently served from switching offices not included in the TWX Switching Plan. When the volume justifies, certain Canadian offices will also be included in the TWX Switching Plan. These stations are assigned a unique SAC (610) and traffic from these stations to U.S. stations is routed in the same manner as has been previously described for U. S. SAC (510).

6. DATA SERVICES

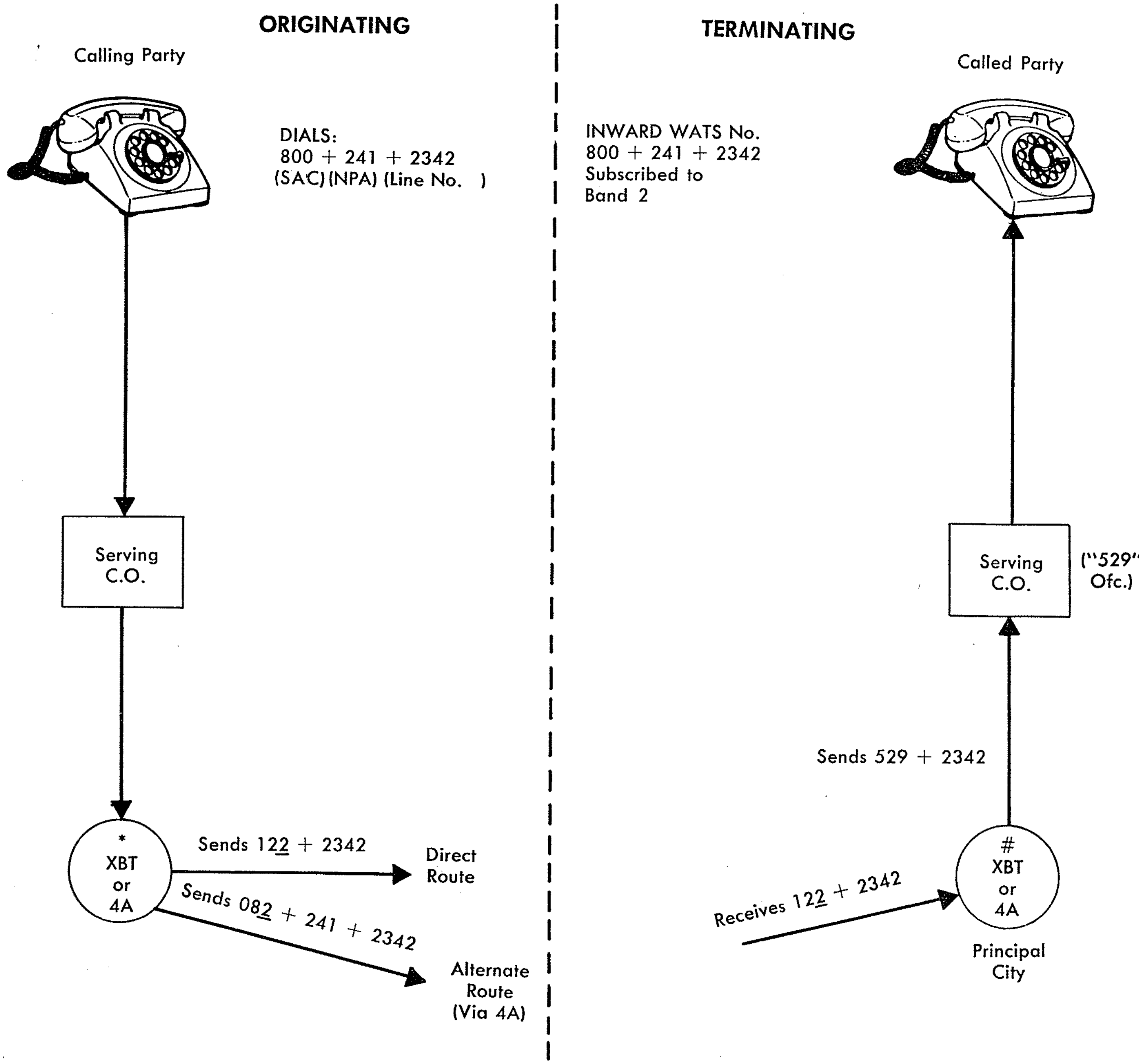
6.01 The increased use of computers and automatic data processing systems in the commercial, industrial, and military areas has substantially increased the demand for greater varieties of data services and data transmission channels. This expansion, with its attendant requirement for a variety of speeds and channel usage time, has encouraged development of service offerings that use the regular switched message telephone network in establishing the communications channels.

6.02 Operationally, data service is quite simple. A regular telephone call is made to establish a connection between two points. Usually, regular voice communication may be carried on, if required. Operation of a pushbutton, associated with the telephone set at each end of the connection, disconnects the telephone instruments and connects data sets to the telephone lines. The data set, depending upon the type, accepts analog or digital (usually binary) information at the transmitting end and, if necessary, modulates the baseband signal to a frequency band suitable for use over telephone circuits. At the receiving end, the data set demodulates the line signal and returns it to baseband. At the end of the transmission, regular voice communication can be resumed, if desired, or the connection can be terminated by hanging up the telephone.

6.03 The Telephone Industry is continuing its effort to achieve higher speeds and greater accuracy, to provide more effective means for handling the variety of data transmission requirements, and to broaden the scope of data processing applications by reducing the cost of transmitting information.

INWARD WATS SWITCHING PLAN

Illustrative



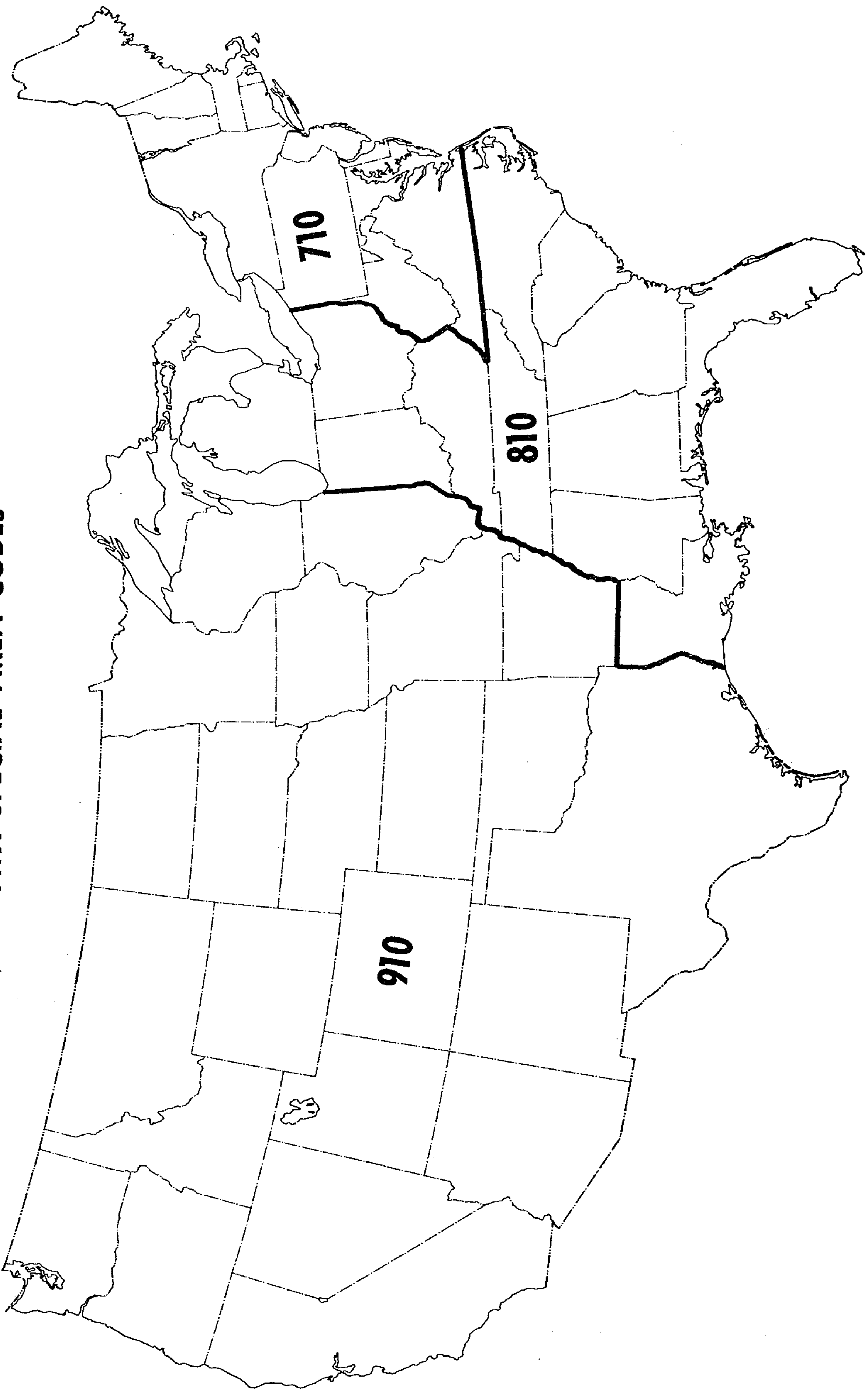
*6D Translates 800 + 241:

1. Determines terminating prin. city (Atlanta).
2. Determines "Band" of Clg. Party in respect to 800 + 241 (in this Case "2").
3. Sends forward over appropriate group the required digits including the "Band indicating" digit "2" underlined.

#6D Translates 122 + 234:

1. Determines if Called Number is eligible to receive Band 2 calls or not.
   a. If not, call is routed to vacant code intercept.
   b. If eligible, routes call to serving C.O., sending forward digits necessary to complete call.

TWX SPECIAL AREA CODES



Section 10
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CONTENTS PAGE

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1.01 A considerable number of articles dealing with distance (nationwide) dialing have been written by Bell System people and published, either in Bell System publications or in trade journals. This bibliography lists a number of these articles which, although treating principally of Bell System problems in distance dialing, may have industrywide applications. In general, this material will be available at most technical reference libraries, and may be of some assistance to those who wish to explore in further detail subjects related to distance dialing.

1.02 In addition, many other valuable papers have been written by people outside the Bell System relating to distance dialing generally, as well as to particular problems that distance dialing poses to independent manufacturers. No attempt has been made to include these, nor has any attempt been made to include textbooks on the subject. The list, though not complete, may nevertheless be helpful.

1.03 In general, reference has been made only to articles published subsequent to 1944, since it has been during this period that the most intensive activity has occurred in distance dialing. This period has been one of evolution and some of the earlier articles have, in certain respects, been superseded by later material. Care should be taken, therefore, to select the latest writings on a particular subject.

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