Translations in the No. 1 Electronic Switching System

By W. ULRICH and MRS. H. M. VELLENZER

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Translations are the means of storing and retrieving office and customer information in a No. 1 electronic switching system installation. The translation scheme must be sufficiently general to handle special telephone services in addition to the items stored as cross connections in present telephone systems. The categories of translation information, the techniques of storage, the means for specifying translation data, and means for making changes therein, are described in this article.

I. INTRODUCTION

The information recorded in the storage or memory units of a No. 1 ESS office consists of four parts:

(1) the transient information about telephone calls in progress and the present state of all lines and trunks in the office,

(2) a program for controlling all system operations that is basically identical in all offices,

(3) a parameter table in the program store (semipermanent storage unit) containing certain information which varies from office to office and which changes only when major additions are made to an office, and

(4) translation information, which includes the bulk of the information that varies from office to office, some of which changes from day to day.

This article is concerned with the translation information and the portion of the program that is used to fetch and administer this information.

The following are the basic categories of translation information, described for the moment in simple form.

(1) Originating line translation: this translation indicates any special treatment of an originating subscriber, and specifies the directory number to be charged for his calls.

(2) Terminating translation: this translation specifies which terminating line should be connected to a calling customer or trunk when a directory number is dialed by the customer or received from an incoming trunk.

(3) Trunk translations: in the No. 1 ESS, a trunk distributing frame allows a trunk circuit in any frame to be connected to any position on the No. 1 ESS switching network. This requires a flexible trunk equipment location to trunk network position translation, as well as the inverse. In addition, the nature and complexity of miscellaneous trunk circuits and the fact that these trunk circuits are served by general-purpose (master) scanners (to detect conditions within the circuit), and central pulse distributors and signal distributors (to change relay states within the circuit) require a translation to let the ESS program know which of these are connected to a particular trunk circuit.

In addition, it is necessary to know which trunks belong to which trunk groups, since a trunk is usually seized because it is an available member of a desired trunk group.

(4) Office code translations: The first three digits of a dialed number must be interpreted to check for validity, detect intraoffice calls, and to select a route for interoffice calls. For some 10-digit calls, a 6-digit translation is necessary.

(5) Routing and charging translations: a route, as derived by the office code translation, is only a route pattern; this must be interpreted to find out which trunk group to use for an interoffice call, and how many digits to pulse forward to the distant office. In case all the trunks in this group are busy, an alternate route must be provided. If a coin zone call is made from a coin telephone, an indication must be sent to the operator so that she may quote the charge; for other charge calls, a "billing index" is recorded on an automatic message accounting (AMA) record along with other details of the call so that the customer will be charged the correct amount for the call. In addition, routing provides information as to the proper disposal of calls to vacant office codes, misdialed calls, incompletely dialed calls, and other similar situations whose treatment differs in different applications of the system.

In summary, translations make it possible for a general-purpose telephone call control program[1] to function in any central office, by providing in a standard form information specific to this office concerning directory numbers, office codes, line and trunk equipments, and routing and charging procedures.

The nature of the information provided by the translations requires that translation data be changeable. Translation data are stored on twistor magnet cards[2] in the program store. Current changes are received as messages from a teletypewriter (used as a major input to the system) and are then stored in the variable memory or call store; thereafter, they are periodically transcribed into the program store, using the program store card writer available as part of the master control center of every office.

The translation problem may be broken up into five parts.

(1) What translations must be performed? This problem will be discussed in terms of the input-output requirements of the ESS translation programs.

(2) In what format are translation data stored in the ESS? The method of storing translation data dictates the translation program, which interprets the translation data derived from the input quantity in such a way as to give the full required output to the telephone operational program.

(3) How are the original translation data specified by a telephone operating company? In this article we will describe some of the forms which have been developed to simplify the problem of specifying translation data. It is important that even the most complex translation items be easily specified.

(4) How are changes in translation data introduced into the system? The ESS program which accepts change data from a teletypewriter, converts these data into a form usable in the system and stores it in the variable memory or call store will be described.

(5) How do we transcribe revised and/or additional translation data into the semipermanent memory or program store from the call store? The process of adding, revising, and deleting translation information in the program store will be described.

II. THE CHARACTERISTICS OF THE TRANSLATION PROGRAM

The translation program (see Fig. 1) is a collection of related subroutines. It is requested by a call control program whenever the latter requires information about a specific item, called the "input parameter" to the translation program. These input parameters are stored in a central control register at the time the translation program is entered. Within one category, such as line translations, there exist a number of input situations, usually specified by entering the translation program at a different entrance point. Whenever the translation program has finished its work, it transfers back to the requesting program. In accomplishing its task, the translation program records its output information

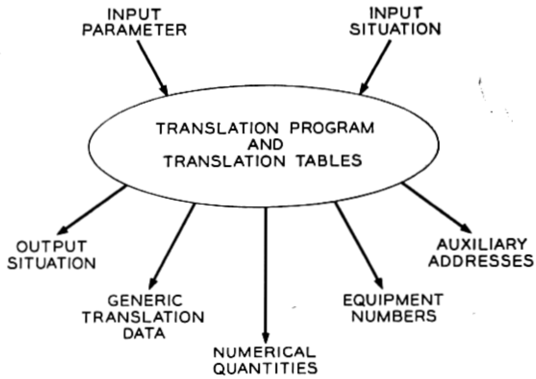

Fig. 1 — Input-output description of translations.

in central control registers and in fixed locations of the call store. If it recognizes an unusual situation, it modifies its return point in the program that requested the translation. The outputs are of five kinds:

(1) Special output situations are the result of finding a special condition as a result of making the translation. For example, if we are making a directory number translation and we find the directory number is unassigned, we wish to indicate that the call should be routed to an intercept operator; we indicate this and other special output situations by modifying the program address to which we return after completing the translation program.

(2) Equipment numbers are the binary addresses required to select a line or trunk network appearance, to operate a relay using a central pulse distributor or signal distributor, or to read a line or trunk scan point.

(3) Numerical quantities such as directory numbers, trunk group numbers, billing indices, and route pattern numbers have the same number of bits and format in all offices; the same quantity may eventually lead to different actions in different offices.

(4) Generic data are nonnumeric output information having the property that a particular binary configuration has the same meaning in all offices. For example, part of the output data from a line equipment translation made in response to a service request is the information concerning whether this is a two-party line and whether it has a TOUCH-TONE subset; to provide this information, a particular group of output bits exists which can be interpreted in the same manner by the call control program in any office.

(5) Auxiliary addresses are program store or call store addresses at which translation information may be found. Sometimes it is more convenient to give as an output the address at which information may be found than it is to give the information. For example, if part of the translation is a list, such as an abbreviated dialing list, it would be impractical to copy the entire list at the time an originating translation is made. Instead, the auxiliary address provides the means for finding the right item in this list at the proper time in the call. The information stored in the block specified by an auxiliary address may consist of generic data, equipment numbers, numerical quantities and auxiliary addresses.

The above is a summary of the characteristics of the translation program in terms of inputs and outputs. The program itself is mainly a series of table look-ups, simple data conversions, and checks for special auxiliary data. Because translations are made so frequently, it is important that the translation program consume minimum time. Because of the volume of translation data, it is important that it be densely and efficiently packed. Because of the large number of required variations in operation and because of the unknown requirements of the future, it is important that the translation scheme be flexible and have ample room for growth of features and services.

The translation program must work with a mixture of data in the call and program stores. The call store contains translation changes representing items of data, such as the class of new customers recently connected to the system, which must be up-to-date but which have not yet been transcribed into the program store. The program store contains the bulk of translation data, including, unfortunately, whatever information has been rendered obsolete by the new information in the call store. The translation program must provide the up-to-date data to the telephone program.

Numerical quantities as defined previously exist in the system; these pose a problem for the program. We must ensure that numerical quantities are never directly examined but are either recorded without examination or are merely stored to act as inputs for a subsequent translation. This makes it possible for all translation outputs to be handled in a standard way in all offices. For example, one part of the line class of service is a numerical quantity representing specialized call routing for this class of service. This quantity may be different for the same general class of service — e.g., PBX toll diversion beyond two message units — in different offices. (The types of classes of service required are too diverse to make the number of a particular class standard in all offices without incurring a heavy economic penalty in all offices.) However, this presents no problem to the office program because it never examines this part of the class of service; it merely stores it, later uses it as an input parameter for the routing translation, and then receives modified routing data. The translation *program* is insensitive to the value of numerical quantities.

III. INPUT-OUTPUT DESCRIPTION OF TRANSLATIONS

3.1 *Line Translations*

The input parameter for line translations is the line equipment number, which is the network appearance of the line in question. The chief outputs are the directory number (a numerical quantity) and the class of service, a combination of a numerical quantity and generic data.

The generic class data consist of a 6-bit major class word, plus a group of bits representing the presence or absence of some particular service or feature, such as a TOUCH-TONE subset, abbreviated dialing, call transfer, dial add-on, etc. (Space exists for many more bits than have yet been assigned to features or services.) The major class represents mutually exclusive aspects of the class of service, such as denied, unassigned, two-party, manual originating, multiline hunting group, or coin. The code for a major class is standard in all offices.

The numerical part of the class of service is a 10-bit number representing the specialized charging and routing or CHART (CHArge and RouTe) class. As previously mentioned, this number is used as an input parameter for routing translations.

Because two-party lines require more complex translation data (two originating classes, two directory numbers per line), an auxiliary address is part of the translation output of a two-party line translation. This auxiliary address is later used along with the party indication as an input parameter to a special translation program for obtaining the originating class of service of the particular party, as contrasted with the particular line.

In the discussion on multiline hunting groups (MHG)* in the directory

* We use the term MHG to refer to a method of selecting an idle line from a group in the central office, as distinguished from the term PBX, which refers to a type of equipment on the customer's premises. In general, an MHG is connected to a PBX on the customer's premises, but some of the smaller PBX's are treated at the central office as a series completion group. Series completion is handled at the central office by attempting sequentially to connect to a series of directory numbers. The main attribute of an MHG is that one directory number may be associated with many lines.

number translation below, it will be seen that each line in the MHG has a special busy-idle bit in the call store, grouped within a series of such bits associated with the MHG. If an MHG line originates, the translation program automatically busies the special busy-idle bit. (The service request detection program[1] has already marked the regular busy-idle bit busy, but that program has no way of knowing that the requesting line was in an MHG or, if so, which line within which MHG.) Thus, an MHG line can be treated very much like a regular line by the service request processing program.

If a customer has abbreviated dialing and dials an abbreviated code, the translation must provide the directory number corresponding to that code.

If a customer is connected to certain auxiliary equipment, such as an answering service, a special sleeve lead* condition must be created in an auxiliary line circuit to control this equipment. The sleeve lead represents the busy-idle state of the line. When the customer goes off-hook, this sleeve lead must be grounded by operating a relay. Since the conventional No. 1 ESS line circuit does not provide such a relay, nor the means for controlling one, a special relay in the auxiliary line circuit controlled by a general-purpose output of a signal distributor is used for applying the ground to the sleeve lead. The translation must provide the indication that such an auxiliary line circuit must be controlled (this is one of the bits of generic class data) and must provide the equipment number of the signal distributor point used for controlling this circuit.

A 3-bit disconnect guide is retained throughout the call. Two of the bits refer to specific situations, coin and add-on privilege. The latter requires timing to distinguish between a flash and a disconnect, since a flash is a signal to request a dialing receiver so that another telephone may be dialed and added to the present connection. The third bit is general-purpose and indicates that some special action is required at disconnect time, the special action to be indicated by the translation. Included in this category are lines with sleeve lead circuits (idle must be restored by releasing the relay) and multiline hunting group lines (MHG busy-idle bit must be restored).

A number of special output situations also exist in line translations. The output situation problem is handled as follows:

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* In electromechanical systems, the sleeve lead is a third wire of the connection within the office. The auxiliary equipment can be connected to this point. Every effort was made to make the No. 1 ESS compatible with present customer station equipment.

Suppose there are four special output situations in addition to the normal output situation. The program requesting the translation then places four transfer instructions to the programs corresponding to the four special situations, immediately followed by the program for handling the normal case. Special output situations are discovered in the course of making the translations; the requesting program must be prepared to encounter these situations. The translation program will transfer back to the return address (J)* for the first special situation, to (J) + 1 for the second situation, (J) + 2 for the third situation, (J) + 3 for the fourth situation and (J) + 4 for the normal case. (This avoids the execution time of an extra transfer in the normal case.) This scheme permits several programs to request a particular translation and to have a standard method of handling special output situations that are signaled by the translation program.

The special output situations are as follows:

(1) Unassigned line originates.

(2) Line from master control center originates. Dialing from this line has completely different meaning than dialing from a customer's line.

(3) Line marked in trouble originates. This may well be the signal that the trouble has been cleared and that the line is now also available for terminating calls. The temporary translation routing calls for this number to an operator or announcement will have to be cleared if the subscriber actually dials.

3.2 *Directory Number Translations*

The input parameter for directory number translations is a directory number. A directory number translation is made only when it is already known that the call terminates in the local central office. The directory number is in one of three versions:

(1) Normalized office code plus four binary-coded decimal digits. A *normalized office code* is a 5-bit number representing a particular 3-digit office code of the many that may be handled by one ESS; each of these 3-digit codes corresponds to a different normalized office code. The normalized office code is obtained from the office code translation made when a local subscriber dials a full 7-digit number, or when an incoming trunk sends a full 7-digit number.

(2) Four or five binary coded decimal digits plus the class of an incoming trunk. These must be interpreted to derive the implied normalized office code for this trunk. (Communication of directory numbers

* The J register[3] is used to store the return address. It is set up via the J option at the time of the transfer to the translation program.

among central offices is frequently accomplished by sending only the last four or five digits.)

(3) Standard ESS format, consisting of a 10-bit quantity representing the binary version of the hundreds, tens and units digits, and a 7-bit quantity representing the *number group number*, the identification of the group of 1000 directory numbers to which this directory number belongs. This format might have been derived from an abbreviated dialing translation or from a call transfer translation.

The object of the directory number translation is to find the equipment location of a line associated with the called number and to provide any special information necessary to complete a call to such a line. The directory number translation program checks the busy-idle bit associated with the called line and, if it is idle, marks it busy. If the line associated with the called directory number is busy and has the series completion feature, the translation program will try the directory number to which the called line series completes. If the called directory number has the call transfer service in effect, calls will be transferred to a different directory number; if the latter is not in the local office, the translator output is simply the directory number to which the call is to be transferred.

For any call that can be completed in the local office, the directory number translator returns the line equipment number and the terminating class of either the called subscriber or the line to which his call has been switched because of series completion or transfer. The terminating class information consists entirely of generic data. It consists of a 6-bit major class word having the same meaning and coding as the originating major class word, an indication of the type of ringing signal to be applied, and an additional group of bits representing the presence or absence of particular terminating features and equipment, such as ground start, series completion, and call tracing.

If the directory number is that of a multiline hunting group, the directory number translation hunts for an idle line in the group. The equipment number is then that of the idle line, while the class is that of all the lines in the group. The translation program marks the idle line busy. Subsequent terminating call actions are similar to those for calls terminating to individual lines.

If the called line has an auxiliary line circuit, then the address of the signal distributor point for operating a relay to apply ground to the sleeve lead is provided by the translation.

In addition to the normal case of a line found and available, four special output situations exist:

(1) called line busy

(2) called directory number unassigned; route to intercept

(3) called directory number is associated with a trunk group. This will happen for official numbers that are associated with operator trunk functions.

(4) called directory number has transferred its calls to a number outside this central office. The new directory number is provided as the output of the translation.

3.3 *Office Code, Routing, and Charging Translations*

The office code, routing, and charging translations are probably the most complicated of the translations which occur in the ESS. From an input-output point of view, an office code is given and full routing and charging information is supplied. Internally, a number of translations take place before these final results are given.

A special attribute of office code translations is that the translation depends not only on which number was dialed, but on who dialed it. The chart class of the originating customer will have an effect on the routing and charging. For example, a customer whose toll calls are denied will clearly have a different route when he tries to dial a toll call than a regular individual service customer. Similarly, a customer on a four-party line, who, when making a toll call, must be routed via a centralized automatic message accounting office in order to have his directory number requested by an operator, may well be routed differently than an individual or two-party customer making the same toll call. While these unusual routings are fortunately the exceptions, it does mean that fundamentally the translation consists of finding the appropriate data entry in a two-dimensional, rather than one-dimensional, matrix.

The situations described above could, of course, be handled by program means alone. For example, it would be possible to check if the customer has toll denial, and if so, to see whether this is a toll call, or to check whether the customer is on a four-party line, and if he is, check to see if this is a toll call. But such a scheme would lack flexibility. It would not be prepared for unexpected situations. The more generalized approach uses less real time and is able to handle unexpected situations provided the latter do not exceed the limitations of the over-all plan.

As mentioned previously, that aspect of a customer's class of service which affects the routing of his calls is the chart class. A chart class is a 10-bit number; thus the number of chart classes is limited to 1024.

The office code, routing and charging translations are shown diagrammatically in Fig. 2. The memory layouts of office code translators are

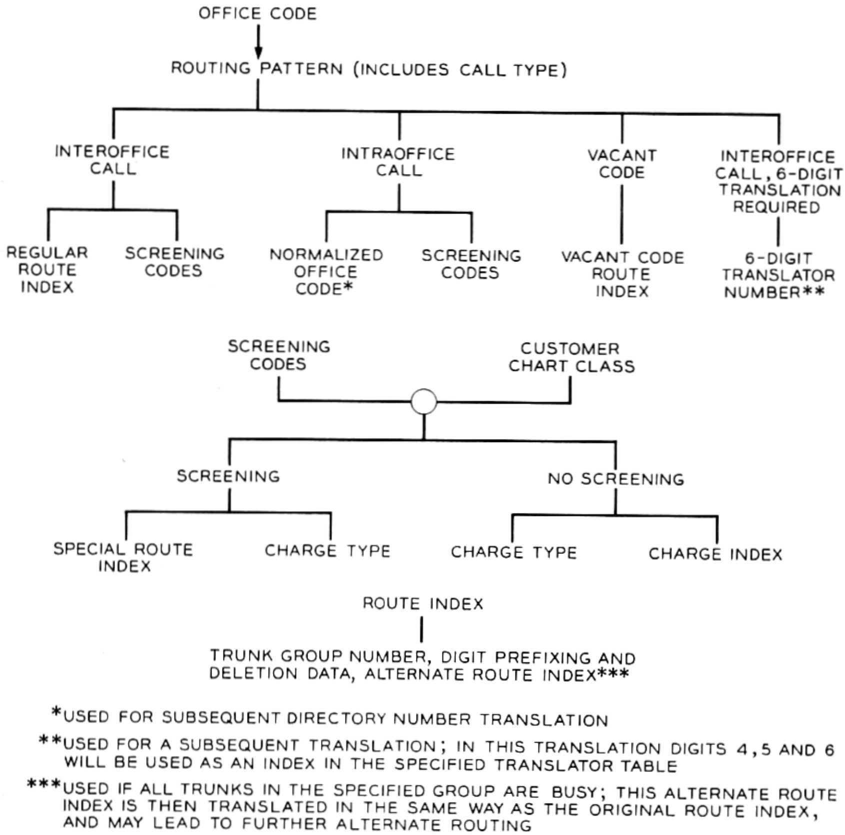

Fig. 2 — Office code, routing and charging translations.

discussed more fully in Section IV, and are shown in Fig. 7. Associated with each office code is a routing pattern. The route pattern first identifies the category of the call, i.e., vacant code, intraoffice, 7-digit interoffice, 10-digit interoffice, 3-digit call, etc. For interoffice codes, this routing pattern gives a regular route index and a series of 15 screening codes corresponding to 15* divisions of the chart classes, or charts. A route index is a number which implies a trunk group plus appropriate digit deletion and digit prefixing information, plus another route index for alternate routing in case the first trunk group is busy. By proper linkage of route indexes, it is possible to create any desired pattern of

* The number 15 is an engineering compromise between a larger number, which would cost extra memory per route pattern, and a smaller number which might excessively limit the screening flexibility.

alternate routing among different trunk groups used for different destinations. A regular route index is used for this call provided no screening takes place. If screening takes place, a special route index will be found and substituted for the regular route index.

Associated with each chart class is a list of 32 or 64 special route indexes or charge indexes.* The route pattern will contain a screening code for each chart. The translation program will then take the screening code associated with the particular chart of which this subscriber's chart class is a member, and if that screening code is n, will read the nth word of the chart class table. This nth word will either provide a substitute or special route index, or it will provide a charge index to be transcribed on the AMA tape. In either case, a charge type is also found. A charge type indicates such items as whether the call is free, whether a detailed AMA entry (including both the calling and called subscriber's directory number) or bulk AMA entry (including only the calling subscriber's number) will be made, whether the entry must include the length of time of the call or whether an entry may be made as soon as the called subscriber answers.

The office code translation must also provide information as to whether overlap outpulsing is used on the route associated with this call. If overlap outpulsing is to be used, it means that pulsing to the distant office must start after the subscriber dials his hundreds digit, i.e., before he has finished dialing. This means that the connection for outpulsing must be set up before the normal time.

The office code translation program must also take into account the question of whether a subscriber dialed a prefix that he was not supposed to dial, or failed to dial a necessary prefix. The standard prefixes of the future in the Bell System are a 1 for station-paid toll calls and a 0 for person-to-person and special calls. However, not all customers will have the same rules for dialing a prefix 1; for example, dial TWX customers may not have to dial a 1 for toll calls, whereas regular customers will have to dial this 1. We must route the call to an appropriate announcement if the 1 is omitted in dialing by a regular customer.

For an intraoffice call, the office code translation must provide the normalized office code of this call. This is a necessary input for subsequent directory number translations (see above). For interoffice calls, if a 6-digit translation is required, the office code translation must provide the number of the table containing this particular 6-digit translation. Subsequently, a translation will be performed using this table, with digits 4, 5 and 6 as the index within the table, since digits 1, 2 and 3 have

* The following description is further clarified in Section IV and Fig. 9.

already been used in the first translation to select the table. (Prefix 1 or 0 is not counted as a digit in the above discussion.)

3.4 *Trunk Translations*

Fig. 3 gives a diagram of the required trunk circuit translations. There is a significant difference in the required translations between universal trunks and miscellaneous trunk and service circuits. With a universal trunk circuit, a trunk scanner number implies a trunk signal distributor number; universal trunk circuits do not have any associated

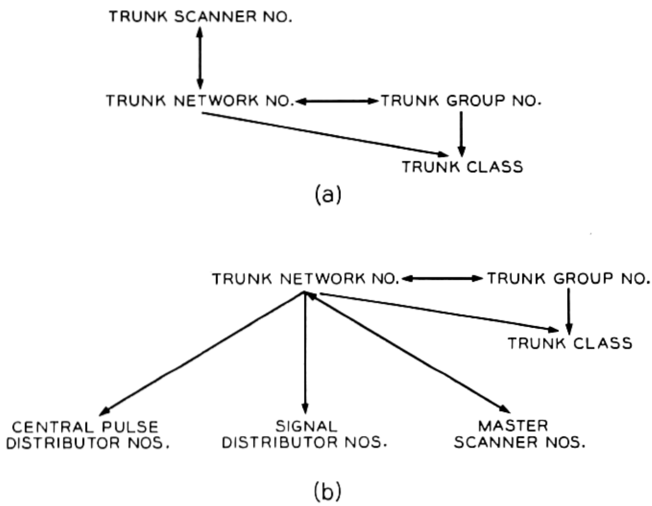

Fig. 3 — Trunk translations.

central pulse distributor points, since one of the requirements of a universal trunk is that it contain only signal distributor controlled relays. Translations must be made from trunk scanner number to trunk network number and vice versa.* The trunk scanner number is the source of information concerning a seizure or disconnect. The trunk network number must be obtained in order to set up a connection to this trunk circuit. A translation from trunk network number to the trunk scanner and signal distributor numbers is required in order to operate the trunk circuit relays when we have seized a particular trunk on the basis of a

* A trunk distributing frame is interposed between the trunk switching frames and the trunk frames, so that any trunk equipment may be connected to any trunk network appearance.

hunt based on network numbers. A translation from trunk network number to trunk group number is required, since the administration of available trunks within a group is made on the basis of the trunk group number. We must be able to find the class of any trunk, and this is done most conveniently by having a translation from the trunk group number to class and from the trunk network number to class.

For miscellaneous trunk circuits the same basic translations are necessary with the following additions: since the master scanner is used for miscellaneous trunk circuits, it is necessary to substitute a master scanner to trunk network number and reverse translation for the original trunk scanner to trunk network number translation. Because the miscellaneous trunks and service circuits are controlled from signal distributor and central pulse distributor points which have no relation to the master scanner number, a translation is required to find the signal distributor and central pulse distributor numbers necessary for controlling a particular trunk circuit.

The trunk class is in a standard 4-word array. The trunk class words are:

(1) common and outgoing information
(2) incoming information
(3) special operator options
(4) trunk circuit program index.

The fourth word contains the trunk circuit program index. This is an indication to the program of the type of trunk circuit; each type of trunk has a different index. The third translation word contains special operator options indicating such items as the type of coin control action to be taken with this trunk. The second word contains incoming information, including the number of digits to be received, the type of incoming pulsing, and whether a start dial signal is expected; for the case of trunks with 4-digit incoming pulsing, a normalized office code is required to steer the call to the proper office code if the particular ESS installation handles more than one office code. The first translation word contains common and outgoing options such as the type of supervision on the trunk, the type of pulsing, the type of trunk circuit (incoming, outgoing or two-way) and details on the form of the outpulsing (for example, start dial signals on dial pulse outpulsing).

Presumably, the trunk class information for any particular trunk takes much less than four words. However, since the number of different trunk classes in any office is relatively small, the gain in having a standard program which will always know what information to expect in a particular bit is greater than the loss of having an unnecessarily large area of memory devoted to the trunk class detailed information. For a particular trunk group, a code is stored which is expanded into the 4-word array; the 4-word block is stored in memory only once if two trunk groups have the same class.

Other translations associated with trunks include the hunt for an idle trunk. In the case of the directory number translation, it is convenient for the translation program to make the busy check because the translation program has all necessary equipment numbers already generated. It is equally convenient for translations to make the hunt for an idle trunk and to make such a trunk busy, to hunt for an outgoing transmitter associated with a particular trunk, to hunt for an idle terminal in a conference trunk, and to restore trunks in memory to the idle state after a disconnect or after the discovery of a blockage in the network.

Table I summarizes the universal trunk translations required for an incoming call. The call is detected by means of a seizure signal recognized by a trunk scanner. The trunk scanner address must be translated to find the trunk network number, so that a receiver may be connected to the incoming trunk. In addition, the class of the trunk must be derived, so that the proper receiver may be connected. The trunk class is derived by translation from the trunk network number. The trunk class also indicates how many digits are expected over this trunk. Finally, the trunk class is also needed to give the call processing program which controls the trunk circuit relays the necessary information as to the type of trunk involved. This information is given in the form of a circuit program index, an identifying number unique to each particular type of trunk circuit configuration. Finally, the trunk network number is used to permit the call processing programs to mark the appropriate path memory for all paths to be associated with this trunk during this call.

Incoming calls are not normally screened, because screening is per-

Table I — Incoming Call Trunk Translations

Quantity	Function
Trunk scanner no. ↓	seizure or disconnect signal discovered at this scan point
Trunk network no. ↓	used for network path hunt and network memory changes
Trunk class code ↓	compact version of trunk class, used to find detailed trunk class information
Trunk class	used to determine the type of incoming receiver needed, incoming pulsing details, type of trunk circuit

formed at the originating office. The translation corresponding to an office code translation is merely one to find out which intraoffice code has been called so that the proper directory number translation may be made.

Disconnect is recognized by the scanner at the trunk circuit. It is again necessary to make a translation from the trunk scanner number to the trunk network number so that the disconnect signal may be associated with the proper path information; the trunk class must be found so that the trunk release operations may be controlled.

Table II summarizes the universal trunk translations necessary for an outgoing call. The trunk was initially seized because it was a member of the trunk group indicated by the route index which was found by the office code translation. For outgoing calls, the route index indicates the number of digits to be pulsed plus any digit prefixing information. The class of the trunk is necessary in this case primarily to select the type of transmitter to be used in connection with this outgoing trunk and to provide the circuit program index necessary to control this trunk.

In order to control a trunk circuit and in order to mark the trunk busy it is necessary to know the scanner number associated with the trunk; for this purpose, a trunk network number to trunk scanner number translation is necessary.

Table II — Outgoing Call Trunk Translations

Quantity	Function
Office code	Dialed by customer
↓	
Route index	
↓	
Trunk group	
↓	
Trunk class	Used for selecting outpulsing transmitter, and indicating type of trunk circuit
Network number of idle trunk	Used for network path hunt and network memory changes
↓	
Trunk scanner number	Used for making scan point memory busy
⋮	
At disconnect time:	
Trunk scanner number	Disconnect detected at this scan point
↓	
Trunk network number	Used for making network memory changes at disconnect time
↓	
Trunk group number	Used for updating list of idle trunks in group
↓	
Trunk class code	Compact version of trunk class, used to find detailed trunk class information
↓	
Trunk class	Used to determine the type of trunk circuit

A disconnect may be initiated by either subscriber at the trunk circuit. A translation from trunk scanner number to trunk network number is necessary at this time to find the proper network path information, plus class.

3.5 *Miscellaneous Translations*

A number of other translations exist, not associated with the basic telephone operation. Some of these are for maintenance purposes. Alarm indications are connected to the master scanner; when such a scan point becomes active, a translation must be made to discover the meaning of this particular alarm indication. If a particular unit is being diagnosed for faulty operation, a list of the scan points for examining the maintenance outputs of the unit and a list of signal distributor and central pulse distributor points for applying test signals to that unit must be provided.

Translations must also be provided for the details of traffic counts peculiar to a specific office, including indications of which traffic counters are to be printed out on a teletypewriter.

In general, translations must provide information on any item that a telephone company may change on a day-to-day or long-term basis.

IV. MEMORY LAYOUT

A major aspect of the translation problem is that of storing the large volume of the translation data in memory. The design of the memory layout was influenced by three requirements:

(a) The data can be stored in either program store (PS) or call store (CS).

(b) The data must be densely packed in order to conserve memory space.

(c) The output of a translation must consist of generic data, equipment numbers, and numerical quantities.

Because of requirement (a), a 23-bit word was chosen as the basic translation word (TW). Its physical location is either a 23-bit CS word, the right part (23 bits) of a 37-bit* PS word, or the left parts (14 bits each) of two consecutive PS words. In the latter case, the first of the two words contains the 14 least significant, the second one the 9 most significant bits of the translation word.

An exception from the rule of the 23-bit translation word is found in abbreviated dial and transfer lists. It was found that 23 bits were inadequate, but 28 bits were adequate, for most entries in such a list. A

* Of the 44 bits in each program store word, 7 are check bits; hence only 37 useful bits of data are available in each word.

list word therefore consists of 14 bits; two such words form a list entry. Such lists are preferably stored in the upper or left bits of program store words. In the call store, such list words are stored in two 23-bit words.

Translation data exist in the PS as a collection of tables. The set of tables devoted to each type of input parameter is called a "translator." Corresponding to the various input parameter types, there are line equipment number translators, directory number translators, 3-digit code translators, trunk network number translators, etc.

Translators are composed of subtranslators, each subtranslator corresponding to a growth unit of the central office. For instance, there is a subtranslator per line switch frame, per trunk switch frame, per number group (i.e., block of 1000 directory numbers), etc.

Subtranslators are joined together to form a translator in the following way:

The binary representation of the input parameter is divided into two parts, the *subtranslator selector* identifying the unit and the *index* identifying the item within the unit. A head table contains the addresses of all subtranslators. The head table exists for the ultimate size expected for the particular central office, but only as many subtranslators are provided as have corresponding units, and new ones are added as the number of units increases (see Fig. 4).

A subtranslator is a table which consists of one translation word (TW) per index. This word, the primary translation word, contains either the complete data connected with the input parameter, or if one word is not sufficient, a reference address to an auxiliary block where the data are stored in auxiliary translation words. To make the recognition of auxiliary addresses possible, the complete data cannot start with three leading zeros; a word whose three leading bits are zeros is then interpreted as an auxiliary address.

The requirement for conserving memory space suggests the technique of using abbreviated codes for generic data. The call control programs which use translation need directly usable information. Therefore, generic data consist of separate groups of bits for each item described. The number of bits must be large enough to allow for all possible values of the data, whether they occur in a particular office or not. For instance, the type of outpulsing used on outgoing trunks is described in 3 bits to allow for all possible types of transmitters, although there might be only one type, multifrequency transmitters, in actual use. By listing the values of the generic data which occur frequently in a particular office and assigning consecutive numbers to them, one arrives at an abbreviated code for the actually occurring data combinations in a particular office. The detailed version of this data is therefore stored

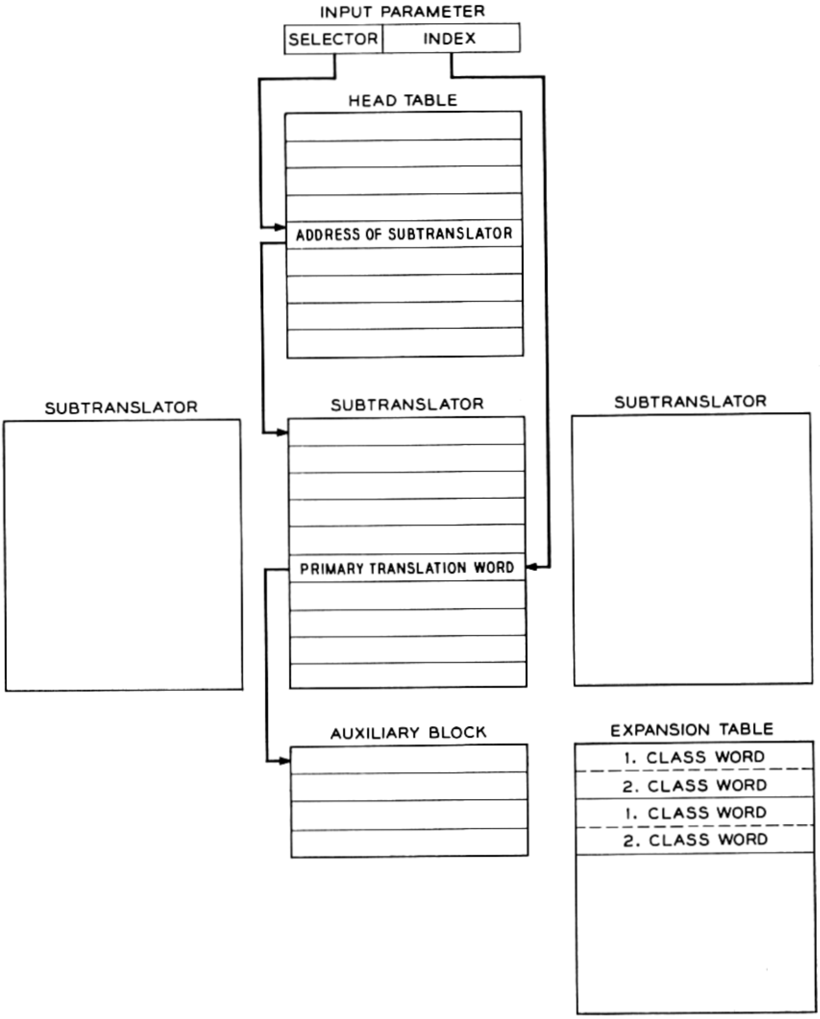

Fig. 4 — Pictorial description of a translator.

once in an expansion table; everywhere else the abbreviated code is stored. Since the call control programs are interested in generic data, the translation program expands the abbreviated code (which is not generic) before delivering it to the call control program.

Examples for the use of abbreviated codes are the line class of service, the trunk class, and the route index:

(a) Class of service includes equipment information, special service information, and routing and charging information. In the detailed form, it occupies two translation words. For a reason which will soon become apparent, the size of the abbreviated codes is limited to 6 bits, which makes it possible to use them for the 56* classes of service most frequently occurring in a particular office. Consequently, for many lines the primary translation word is sufficient to hold the originating information, i.e., the directory number (17 bits) and the abbreviated code (6 bits). Lines for whose originating class of service no abbreviated code exists need at least four words of storage, one for the auxiliary address, one for the directory number, and two for the class of service.

(b) The trunk class describes equipment and use of a trunk or service circuit. When spelled out in detail in the trunk class expansion table, the data occupy four translation words. However, the abbreviated trunk class code appearing in the trunk network number translator and the trunk group number translator is only 8 bits long, allowing for 256 different classes of trunks in a particular office.

(c) A route index is an 11-bit abbreviated code for a particular routing describing the first-choice trunk group, the alternate route and special treatment. The detailed route information, taking up two translation words each, is stored in the route index expansion table.

To summarize: a translator consists of a head table, one or more subtranslators, auxiliary blocks, and possibly expansion tables (see Fig. 4).

A detailed description of the line equipment number translator is given here as an example (see Fig. 5). It has four types of primary TW's:

(a) The TW contains an auxiliary address (complex class of service).

(b) The TW contains an abbreviated class code and a directory number (simple class of service).

(c) The TW contains the abbreviated code for MHG lines, the MHG number and the terminal number (i.e., the position in the multiline hunting list).

(d) The TW is zero (unassigned line).

The class expansion table contains two class words for each abbreviated code. They provide for the following categories:

(a) major class: a code for the mutually exclusive aspects of the class of service, as individual line, coin line, multiline hunting group, etc.

(b) feature class: a group of bits representing the presence or absence of some equipment and service features as TOUCH-TONE dialing, ground start, abbreviated dialing, variable or preset transfer, etc.

* 56 instead of 64 since codes 0 to 7 are not usable. Their binary representation, starting with 000, conflicts with the code for an auxiliary address.

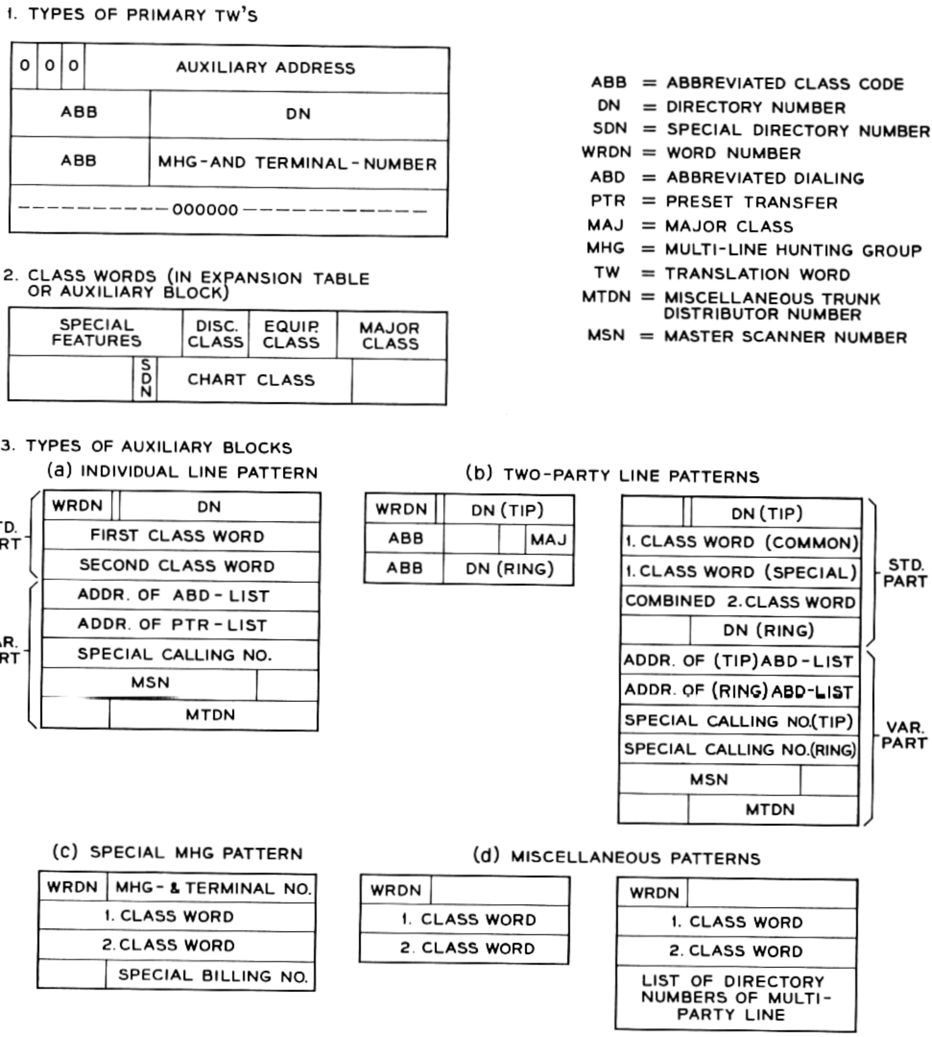

Fig. 5 — Data stored in line equipment number translator.

(c) chart class: a code representing the charging and routing directions

(d) disconnect class: a group of bits indicating the action to be taken at disconnect time.

The auxiliary blocks appear in several patterns:

(a) Individual line pattern: this pattern contains as the standard part the directory number and the two class words (which provide the same categories as those in the expansion table). The following variable part may be entirely or partially missing depending on the class of service. It contains successively the address of an abbreviated dial list, the address of a transfer list, a calling number which differs from the billing number, and sleeve lead auxiliary line circuit data.

(b) Two-party line pattern: this comes in an abbreviated and in an expanded form. In the abbreviated form, the pattern contains abbreviated class codes and directory numbers for both parties and, for reasons of expediency, the common major class and equipment features. In the expanded form, it contains the detailed data for both parties. The common equipment features and disconnect class are stored only once. The variable part of the pattern contains, if they exist, the addresses of the abbreviated dial lists both for tip and for ring party, special calling numbers for both parties, and the common sleeve lead data.

(c) MHG pattern: If a line from a multiline hunting group is not billed to the main directory number, or if its ground start feature differs from that of the majority of lines in the group, an auxiliary block is required which contains the MHG number, terminal number, two class words, and billing number (either special or common).

(d) Miscellaneous patterns exist for multiparty lines and the line from the master control center.

(e) Multiline hunting groups have their own miscellaneous translator. Its head table contains for each group, identified by its PBX number, the address of a common block. The common block contains the main directory number, two originating and one terminating class words, and the hunting list as a standard part. A variable part may contain the address of an abbreviated dial list, and/or sleeve lead data for an electromechanical overflow counter.

The office code translations require a number of special techniques in order to include the screening facility previously described. The translation memory layouts are shown in Fig. 6. The first step in making an office code translation is to find a route pattern number associated with each office code. This is done by looking in a table of a thousand office codes to find a route pattern number. Assume that the route pattern for a given office code is 41. Via the route pattern address table, this route pattern number is expanded into the address of the corresponding route pattern information. The route pattern information is a 5-word block. The first word contains a route index (the standard route index) and the call type information. The next 4 words contain 15 screening codes corresponding to the 15 charts or divisions of chart classes.

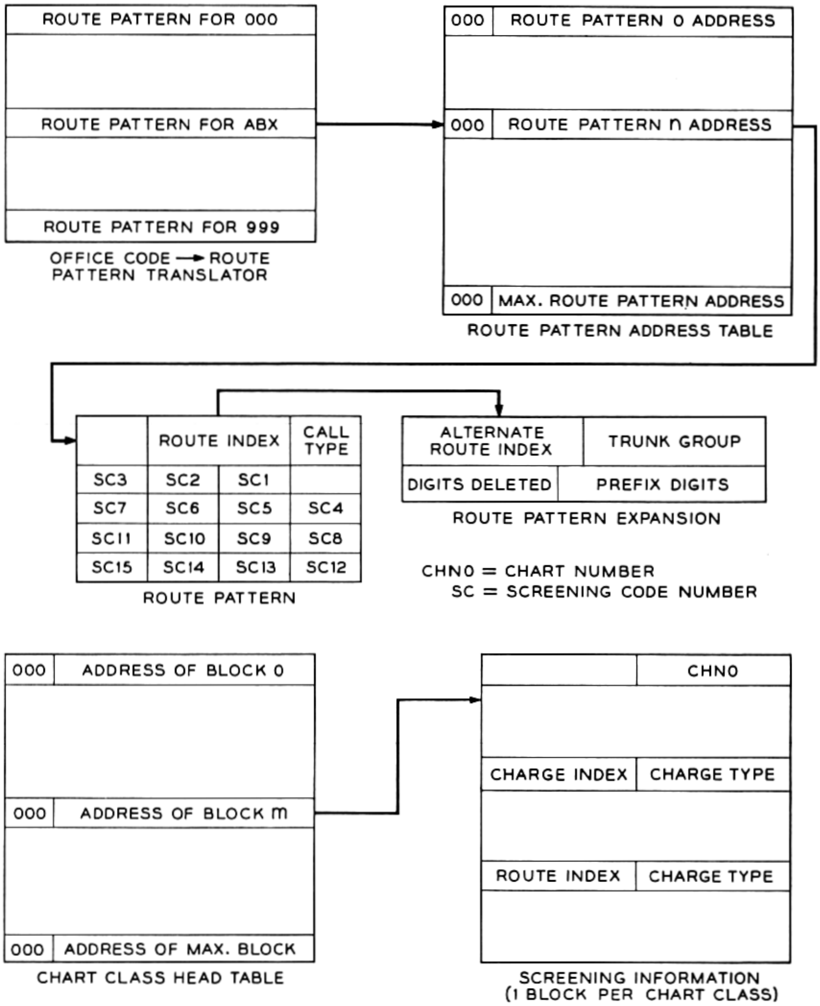

Fig. 6 — Memory layouts for office code translations.

Next, the originating customer's chart class must be used to find screening and charging information. If this chart class is M, the *m*th word of the chart class head table indicates the address of the block of screening information. A preliminary word in this block gives the chart number (1–15) corresponding to the block. If the chart number is, for example, 11, then SC11 in the route pattern would indicate the word in the screening information block which is applicable to this call.

If SC11 = 23, word number 23 of the screening information block is the desired screening word. The contents of this screening word are the charge type and either the billing index (if no screening is invoked) or a special route index (if screening is invoked).

The route index is separately expanded into 2 words of data giving the first-choice trunk group, an alternate route index in case this trunk group is busy, and an indication of how many digits are to be deleted and/or which digits are to be prefixed for outpulsing over the trunk group indicated by this route index.

Other cases, such as vacant codes, intraoffice codes, and codes requiring six-digit translations, are handled by variations of this basic technique. For example, if six-digit translation is required, the expansion on the route pattern indicates that an auxiliary three-digit translation is required and that this translation is stored at a table starting with a given address.

Translation data which have recently been changed are stored in the call store until they have been transcribed into the program store. While in the call store, such entries are referred to as recent changes (RC's).

RC's are stored in the same form as the data will later have in the program store, i.e., as primary and auxiliary TW's. However, since they do not appear in the context of a subtranslator, their association with a particular input parameter must be established. This is done by storing with them their primary translation address or TAG, i.e., the address of the subtranslator location associated with the primary TW.

An RC entry therefore consists of a primary part and possibly an auxiliary block. The primary part occupies two call store words, an RC register. The first word contains the TAG and the status bits, and the second word contains the primary TW.

The four states of the status bits correspond to the four possible states of an RC:

11 — temporary, i.e., do not incorporate RC into PS;
10 — permanent, i.e., incorporate RC into PS;
01 — delayed, i.e., RC is not yet active; and
00 — deleted, i.e., inactive or no RC.

A temporary recent change is used in connection with certain services which require a change of translation information that is not meant to be permanent. For example, the record that a subscriber wants calls to his telephone number to be transferred temporarily to another telephone number is not meant to be entered in the permanent translation record of the system. The record should be used in making the terminating translation whenever the subscriber is called; it must temporarily override the permanent translation information. However, the permanent translation information must not be lost, because it contains all aspects of his normal service which are reinstated when the temporary change of translation is deleted. Temporary translation changes are used in connection with temporary transfers, or with an indication that a line is temporarily out of service because of trouble.

The primary RC's are stored in the primary RC area in ascending order of their TAG's. RC's with the same TAG but with different status (and data) may exist simultaneously. If they do, they are arranged in the order: temporary, permanent, delayed, and deleted.

If an RC requires auxiliary data, it is stored temporarily in the auxiliary RC area and the primary TW is referenced to this temporary auxiliary block.

RC's must be available for translation. Therefore, before translation data are read from the program store, a search is made through the RC area for possible superseding information. For some translations, such as trunk and 3-digit code translations, the search may be bypassed if an RC indicator, a call store bit dedicated to this function, indicates that no RC exists at this time for the translator.

The search through the primary RC area is performed as a so-called "binary hunt."

Let us assume that the RC area contains exactly $2^n - 1$ entries, as shown in Fig. 7. Therefore, there is a central register which divides the area into a lower and an upper half. Since the RC's in the area are ordered according to their TAG's, comparing the primary translation address of the item for which the translation is about to be made with the TAG in the central register renders a three-way decision: an RC for the item is found in the central register, an RC may exist in the lower half, or an RC may exist in the upper half. If no RC is found in the central register, the search is continued in either the lower or the upper half, which is again an interval of the size $2^m - 1$. The process is continued either until an RC is found in a central register or until the interval is reduced to size $2^1 - 1 = 1$. If no RC is found within n steps, then it has been proven that no RC for the item to be translated exists.

The restriction that the size of the RC area be exactly $2^n - 1$ registers is unnecessary. If the size is m, the area is considered to consist of two overlapping sections of size $2^n - 1$. After an initial decision as to which section applies, the hunt can proceed exactly as described above. Again, after $n + 1$ steps, it is proven that no RC for the item to be translated exists.

Considering the fact that in most cases no RC will be found, a modifi-

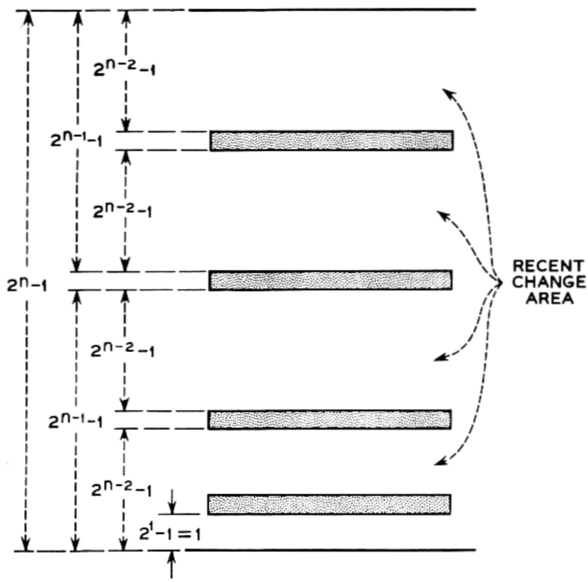

Fig. 7 — Recent change hunt.

cation to accelerate the hunt was designed by substituting a time saving two-way decision for the three-way decision: if an RC exists at all, it may be in the central register or the lower half of the interval, or it may be in the upper half. If an RC exists in some central register, it is considered to be in the lower half; the hunt is then continued, and from then on the result of the decision will always be the upper division, with the final result that the hunt ends in the register just below the one with the found RC. By examining as a final step the register just above the "end" register, either the RC is found or its nonexistence determined.

Auxiliary data are always obtained at the address stored in the primary TW. The translation program does not care whether it is a temporary or a permanent auxiliary address.

V. INITIAL PREPARATION OF TRANSLATION DATA

Fig. 8 shows how translation data enter the system. Originally, the telephone company fills out forms from which punched cards are derived. These punched cards are processed by a general-purpose computer program and are then placed on twistor cards which are inserted into the ESS program store. Subsequent information is inserted by means of

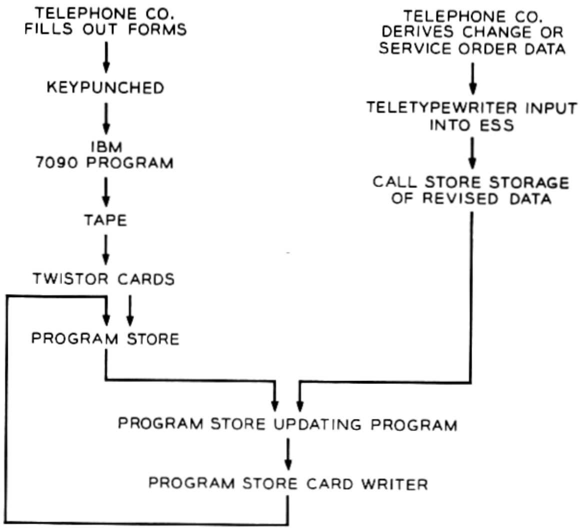

Fig. 8 — Method of placing translation data in program store.

a teletypewriter message typed into the system; the system then stores the translation information corresponding to this information in the RC area of the call store. During the actual running of the system, the call store is always checked for any updating information of the program store translation information, so that the translation program delivers the most current translation information. Periodically, the old records from the program store and the recent changes from the call store are processed, and a new set of program store cards are created using the program store card writer. The change messages are then deleted from the call store, and the associated memory is again made available for new change messages.

A set of forms for deriving the original translation data was created for use by operating telephone companies. In creating these forms, an attempt was made to simplify the task of filling in the high-runner information and to make the complicated data conversions a part of the general-purpose computer program for taking the contents of these forms and creating the information to go on the program store.

Fig. 9 shows the major form used for line information. The form is organized by directory numbers and is headed by an office code and hundreds indication. These forms were designed to simplify keypunching. The small numbers shown on these forms indicate the column of an IBM card into which the appropriate information is to be entered. The

ESS 1100
11-63

DIRECTORY NUMBER RECORD
CONVERSION
NO. 1 ESS

ESS UNIT ______

OFFICE CODE ______
HUNDRED ______

DIRECTORY NUMBER	LINE EQUIPMENT NUMBER: NET	FRAME	BAY	CONC.	SWITCH	LEVEL	RING COMB.: MULT.	CODE	CLASS INFORMATION: CLASS: 1FB					USOC	EQUIPMENT	FEATURES	SUP. INFO. REF.: PAGE	LINE	REMARKS	OLD DIRECTORY NO.	OLD CABLE PAIR	NEW CABLE: CABLE	PAIR
49	00	0	0	0	0	00	–	–	✓						—	—	–	–					
48	15	7	2	7	3	15		1						2FR	0111	0372	—	—	HIGHEST LEVEL IN 4:1 CONC OFFICE				
47	15	7	1	7	7	03		2						2FR	0111	0372	–	—	" " " 2:1 " "				
46	HG			N	ø	00	1	7											ENTRY FOR AN MHG				
45																							
44																							

Fig. 9 — Form used for line information.

office code and hundreds information, being common to an entire page of a form, is placed in the left columns of the card so that it can be simply duplicated in going from card to card. It is followed in the sequence of columns by the last two digits of the directory number and the line equipment number. This line equipment number is written in the standard format of line equipment numbers in the ESS, i.e., a 2-digit network number, a 1-digit frame number, a 1-digit bay number within the frame, a 1-digit concentrator number, a 1-digit switch number and a 2-digit level number. All the digits of the line equipment number must be filled in unless the directory number is associated with more than one line equipment number. This is the case for a multiline hunting group. If a particular directory number is associated with such a group, the person filling in the directory number record fills in the letters MHG in the network and frame columns, and the number of the hunting group in subsequent columns.

Next comes a pair of columns for ringing combinations. For all individual lines nothing is filled in. For two-party lines, the number 1 or 2 is filled in, and for multiparty lines an M is written in the first column and the code is written in the second column.

Next comes a group of columns for the class information of the customer. This class is summarized in a uniform service order code (USOC) and two 4-digit numbers summarizing the special equipment and features associated with this subscriber. The five most common USOC codes in a particular office will be written in as headings for the first five columns, and a check mark will then indicate if a subscriber's class of service is one of these. If not, the 3-digit USOC designation is written in the last column of the class heading. The equipment and features columns consist of two 4-digit octal numbers which specify special equipment and special features associated with this line. Each of the octal numbers summarizes a maximum of three binary conditions. It should therefore be quite easy to remember the significance of each of these octal characters, especially those pertaining to features that are very common. For a subscriber who has no special equipment or features, it is sufficient to have the equipment and features columns blank.

If additional digital information is required, this information is found in a supplementary reference form, and the basic directory number record merely points to the page and line on this form at which this supplementary information is to be found. Supplementary information includes such items as sleeve lead circuit scanner and signal distributor addresses, abbreviated dialing lists, fixed transfer lists and series completion lists.

This directory number record is straightforward, especially for lines with simple features and equipment information. For the lines which have more complicated information, a somewhat higher degree of knowledge of the system is required. For example, it is necessary to know that when a line has a sleeve lead as part of its auxiliary line equipment, it is necessary to fill in supplementary information; this supplementary information should be the master scanner and signal distributor number of the sleeve lead circuit.

For multiline hunting groups, the form shown in Fig. 10 is used. Each terminal in a multiline hunting group is identified by the group number and the group terminal number. It is, of course, necessary to specify the line equipment of each terminal. The main directory number of the MHG must be shown, and if a particular terminal is to be reached on a nonhunting basis using another directory number, this must also be specified. The make-busy arrangements must be specified, and the

ESS 1105
11-63

MULTI-LINE HUNTING GROUP RECORD
NO. 1 ESS

ESS UNIT ________

PAGE ____ OF ____

LINE	GROUP NUMBER	GROUP TERMINAL NUMBER	LINE EQP NO HUNTING ORDER						DIRECTORY NUMBER	NON-HUNTING DIRECTORY NUMBER	MAKE BUSY		CLASS INFO			CHART CLASS		SUP INFO REF	
			NET	FRAME	BAY	CONC	SWITCH	LEVEL			TYPE	KEY NO	USOC	EQP	FEA	CHART	COLUMN	PAGE	LINE
00																			
01																			
02																			
03																			
04																			
05																			

Fig. 10 — Form used for entering multiline hunting group information.

USOC code, equipment, and features may have to be specified separately for different terminals if not every line in the hunting group has identical treatment. In the case of MHG's, a single USOC code may specify a number of different toll diversion treatments, so that it is necessary to indicate the specific chart class. (Normally, a chart class is implied by the USOC code.) Supplementary information may be required for at least some of the terminals in the hunting group if, for example, they have sleeve leads.

The trunk forms are relatively straightforward and will not be described in detail here. They present the information that is necessary for making the translations indicated in Section III.

The specification of the 3-digit translations is considerably more complicated. Five different forms must be filled out. Furthermore, there is considerable interrelationship among these five forms.

The first and simplest of these forms is the basic 3-digit translation form in which, for every 3-digit code, a rate and route pattern, simply a 4-digit number, is specified (see Fig. 11). All office codes having the same rate and route pattern must have the property that all classes of service in the particular office are routed and charged in an identical manner. A similar form is filled out for each 6-digit translator.

Next, a rate and route pattern record must be filled out (see Fig. 12). This pattern gives a regular route index, a call type, an indication of whether overlap outpulsing can be used with the regular route index, and a series of 15 screening codes. If this is an intraoffice call route pattern, the normalized office code is substituted for the regular route index. Each intraoffice office code must have a separate route pattern.

The screening codes that are written in the 15 double columns must have corresponding entries on the form shown in Fig. 13. This form has

ESS 1300-B
11-63

THREE DIGIT TRANSLATIONS
NO. 1 ESS

ESS UNIT ______

BASE RATE AREA ______

PAGE ____ OF ____

___ 1ST DIGIT						___ 1ST DIGIT					
2ND & 3RD DIGITS	RATE & ROUTE PAT.	REMARKS	2ND & 3RD DIGITS	RATE & ROUTE PAT.	REMARKS	2ND & 3RD DIGITS	RATE & ROUTE PAT.	REMARKS	2ND & 3RD DIGITS	RATE & ROUTE PAT.	REMARKS
00			50			00			50		
01	0009		51			01	0006		51		
02	0002		52	0008		02	0007		52		
03	0003		53			03	0000		53		
04	0004		54			04	0001		54		
05	0005		55			05			55		

Fig. 11 — Three-digit translation form.

ESS 1305
11-63

RATE & ROUTE PATTERN RECORD
NO. 1 ESS

ESS UNIT ______

RATE & ROUTE PATTERN 1ST & 2ND DIGITS ____

R&R PAT. 3RD & 4TH DIG	RATE & ROUTE CHART SCREENING CODE															REG. CALL TYPE	REGULAR ROUTE INDEX	F.A.T. NO.	OVERLAP OP.	REMARKS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15					
00			01													10	0100			
01			01													10	0101			
02			02													10	0102			
03			03													10	0103			
04			04													10	0104			
05			05													10	0105			
06			06													10	0106			
07			06													10	0107			
08			00													07	0108		✓	
09																		01		

Fig. 12 — Rate and route pattern record.

two columns devoted to each chart class. Associated with each screening code is a charge index and sometimes a special route index.

To illustrate the problem of filling out these forms, let us consider only that aspect of the forms dealing with the translation necessary for wide area telephone service (WATS). We will consider here only interstate WATS. This service permits all subscribers to dial calls outside their state within certain zones on bands. Six different bands are provided, and a customer is able to reach all bands up to the farthest band that he is allowed to reach. For example, a customer in New York subscribing to band 6 will be able to call anyone in the continental U. S. outside New York State, whereas a customer having only band 1 service can call only a few of the surrounding states. The office code form has been filled out for a few typical office codes. These office codes include 9 numbering plan area (NPA) codes (codes indicating a 10-digit call to an area outside the subscriber's 7-digit area) and one conventional 7-digit code. Different route patterns have been assigned to each of these codes, and the route patterns are expanded on the rate and route pattern record. Route patterns 0 through 7 are associated with call type 10 (a 10-digit call). Whereas route pattern 8 is associated with a 7-digit code, route pattern 9 is associated with a 6-digit foreign area translator. Since routing will be done on the basis of the 6 digits dialed, no route index is specified. Nine different regular route indexes are shown for the nine route patterns. In addition, a series of screening codes for chart 3 has been assigned. Chart 3 is the chart assumed to be used in the local office for the WATS classes of service.

In Fig. 13, columns are labeled by the appropriate class of service.

ESS 1304-A
11-63

RATE AND ROUTE CHART 03
TITLE
NO. 1 ESS
ESS UNIT

PAGE 1 OF —

SCREENING CODE	SUBSCRIBERS CLASS OF SERVICE																							
	COLUMN 0001						COLUMN 0002						COLUMN 0003						COLUMN 0004					
	WATS 1M						WATS 2M						WATS 3M						WATS 4M					
	SPEC ROUTE INDEX	CHG.	ACC I	ACC O	SP CALL TYPE	REM.	SPEC ROUTE INDEX	CHG	ACC I	ACC O	SP CALL TYPE	REM	SPEC ROUTE INDEX	CHG	ACC I	ACC O	SP CALL TYPE	REM	SPEC ROUTE INDEX	CHG.	ACC I	ACC O	SP CALL TYPE	REM.
00	0081	000					0081	000					0081	000					0081	000				
01		015						015						015						015				
02	0081	000						015						015						015				
03	0081	000					0081	000						015						015				
04	0081	000					0081	000					0081	000						015				
05	0081	000					0081	000					0081	000					0081	000				
06	0081	000					0081	000					0081	000					0081	000				
07																								

(a)

ESS 1304-A
11-63

RATE AND ROUTE CHART 03
TITLE
NO. 1 ESS
ESS UNIT

PAGE 2 OF —

SCREENING CODE	SUBSCRIBERS CLASS OF SERVICE																							
	COLUMN 0005						COLUMN 0006						COLUMN 0007						COLUMN 0008					
	WATS 5M						WATS 6M						WATS 1F											
	SPEC ROUTE INDEX	CHG.	ACC I	ACC O	SP CALL TYPE	REM	SPEC ROUTE INDEX	CHG	ACC I	ACC O	SP CALL TYPE	REM	SPEC ROUTE INDEX	CHG.	ACC I	ACC O	SP CALL TYPE	REM	SPEC ROUTE INDEX	CHG.	ACC I	ACC O	SP CALL TYPE	REM.
00	0081	000					0081	000					0081	000										
01		015						015						015										
02		015						015					0081	000										
03		015						015					0081	000										
04		015						015					0081	000										
05		015						015					0081	000										
06	0081	000						015					0081	000										
07																								

(b)

Fig. 13 — Rate and route chart.

Two types of WATS classes of service exist, measured-time and full-time. Customers who have WATS measured-time service are charged a base rate for a certain number of hours of calling time, and are charged for overtime on a time basis. Customers who have WATS full-time service are allowed to call for an indefinite amount of time for the basic rate. Six of the seven screening codes refer to the six bands of WATS: the seventh refers to intrastate numbers. All interstate WATS customers are denied intrastate calls and are routed to a special announcement indicated by special route index 0081. Customers who are allowed to complete their calls because the calls are within their allotted bands are routed via the regular route. The charge index for measured-time WATS customers is assumed to be 15 and for full-time WATS customers is assumed to be 16. (The charge index numbers are for this particular office.) If, on the other hand, a customer is denied the right to make this call because the call is outside his band, there is no charge, a condition indicated by charge index 0. In examining the rate and route chart it can be seen that customers with WATS 1 service are allowed to call any codes within screening code 1, customers with WATS band 2 service within screening codes 1 and 2, . . . , and WATS band 6 service customers are allowed to dial any office codes with screening codes 1–6. For example, any office code having a route pattern which has a screening code 4 on chart 3 would be denied to the customer with WATS 1M, 2M and 3M, and would be permitted to customers with class of service WATS 4M, 5M and 6M.

The chief difference between the WATS 1F and WATS 1M customer is a different charge index for those calls that are not denied. This charge index then implies what type of charge record will be made of this call. (Presumably, in this case, the operating company is interested in taking data even though no charge will be made on each individual call.)

The translation forms have a dual use. They are used for creating the initial translation information and they become part of the office records. When subsequent changes are made they are made on these forms. A number of other forms, similar to the forms described, have also been created for maintaining office records. However, the above records contain most of the information necessary for generating the original line, trunk, and office code translation information. These forms are then punched on IBM cards and go through an extensive sorting, checking and data conversion program. This program has been written for an IBM 7090 computer and is approximately 15,000 words long. To compile the data for a 5000-line office should require approximately one hour of running time.

VI. PROCESS OF ACCEPTING RECENT CHANGES

The bulk of all RC's are introduced into the No. 1 ESS through service orders sent over the service order teletypewriter. A service order is the form by which the operating company informs everyone concerned of the pertinent facts of pending changes on customers' lines and telephone numbers. The message is expressed in telephone company language and may contain, from the viewpoint of ESS, both significant and superfluous information. (For example, the fact that a pink phone should be installed is not pertinent translation data in ESS.)

Fig. 14 shows a copy of a service order with its various fields. The first three fields on the first line are intended to hold the service order number, the activation code, and the service order type. The activation code indicates whether an RC should become effective immediately or

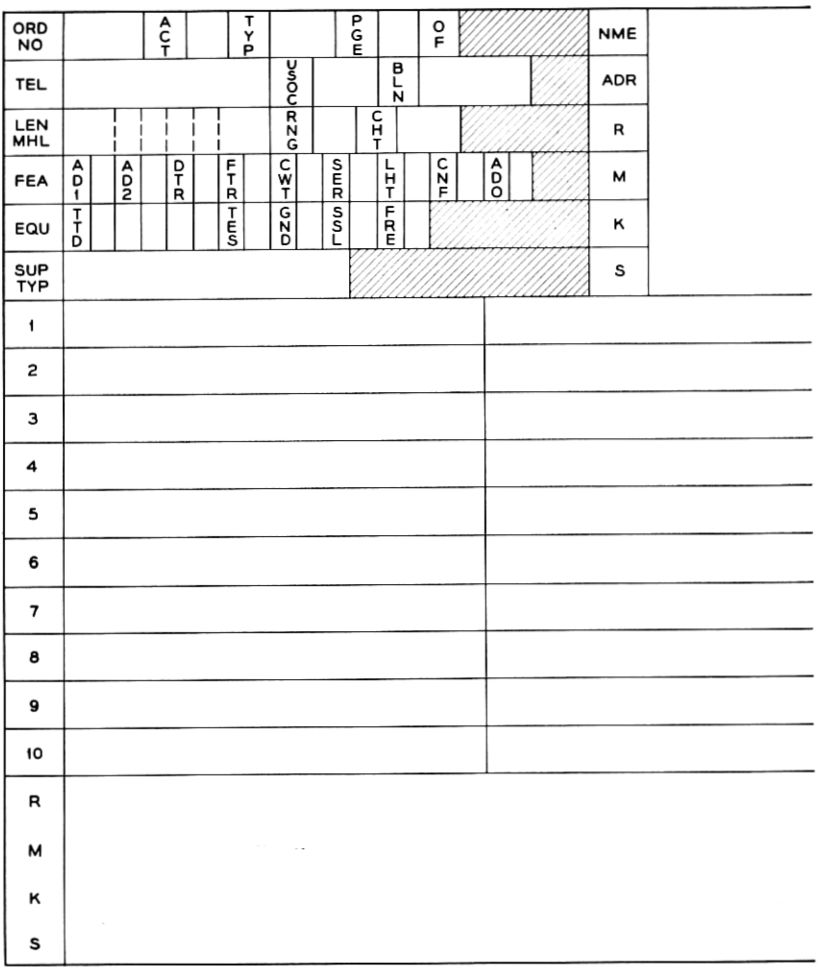

Fig. 14 — Service order format.

be delayed. The service order type (in order, out order, change directory number, change class of service, etc.) indicates how to process the following data.

The fields on the second line are reserved to hold directory number, unified service order code (USOC), and billing number, if it differs from the calling directory number. The third line has the fields for the line equipment number, or the MHG number if the service order refers to a multiline hunting group, the type of ring, and the chart class. The next two lines have the fields for all service and equipment features. A check in one of them indicates the existence of the feature in question. Then follows a field for the type of supplementary data. If this type is not blank, the supplementary data, such as an abbreviated dial or transfer list, or sleeve lead data, or a multiline hunting list, follow on the lines underneath.

When an RC is introduced via the teletypewriter, the data are selected from the appropriate fields as a function of the service order type, and digested. If the format is not correct, the RC is rejected. Otherwise, the code in the field is translated from telephone company language into the cipher used inside ESS. For example, unified service order code (USOC) 1FR (one party flat residential) is translated into the codes for major class = individual line, and chart class = flat rate; line equipment number 02425212 is translated into its binary form 00101001101101100. The translated item is then stored in the proper place of the auxiliary block of memory in the call store which is seized at the start of the assembly of any new RC. The proper position within this block is determined by a pattern decided upon by an examination of early data. If the pattern allows a variable-length block of memory, the largest size is selected initially and revised downward as more information is absorbed.

In this way, the RC is gradually built up in the auxiliary area regardless of whether the block will finally be retained or not. At the end of the assembly, a compressibility check is made. If the class of service allows an abbreviated code, the auxiliary block is abandoned, and only a primary entry with complete data remains. If the data cannot be compressed, the primary entry is made up with the reference to the auxiliary block already prepared. In any case, the primary RC is entered into an RC buffer register.

The RC buffer register is an intermediate storage location in which the primary RC's are stored before being inserted in the ordered RC area. This buffer storage is necessary so that the actual insertion can take place whenever spare time is available in the system.

Supplementary data, such as abbreviated dialing or fixed transfer lists which are not part of an auxiliary block, are also temporarily assembled in the auxiliary area. For each of the items in the lists, a primary RC entry will then be made as room in the RC buffer allows.

Insertion consists of the following steps: first, the point of insertion in the ordered list is determined. Then a search is made for an inactive RC register in the neighborhood of the point of insertion. If such a "hole" is found, all entries between the point of insertion and the hole are moved to create a "hole" at the point of insertion. Finally, the primary RC from the buffer is inserted there.

The RC buffer is administered sequentially, with the top entry following the bottom entry, and emptied on a first-in, first-out basis.

The time spent in the insertion process is unpredictable, because it depends on the number of RC registers between the point of insertion and the first available empty space. Occasionally, this time might exceed the allowable limit permitted by the main program of the system. Therefore, the insertion sequence is temporarily interrupted if the allowable time has expired, and continued later when time is again available.

In order to minimize insertion time, an effort is made to scatter the active RC's over the entire primary area. This effect is achieved by merely changing the status bits of an RC that is to be removed to the "deleted" or inactive code. Eventually, it will be overwritten in the insertion process, since a deleted status is the indication of an available space.

No action is taken to delete auxiliary blocks. As soon as the reference to them becomes inactive in the primary RC, they are "dead," scattered between still-active blocks. A consolidation routine is required which is performed every night. This routine rearranges the scattered active blocks into a contiguous file. It is a very time-consuming routine. It runs through all primary RC's, singling out those which have a reference address to an auxiliary block in the still unarranged area, comparing the reference addresses, and in the end arriving at the RC with an auxiliary block nearest to the end of the consolidated area. This block is then moved to close the gap and its reference address is changed. The process is repeated until all "dead" spaces are squeezed out.

Most service orders request a delayed activation of the change. In this case, the primary RC or RC's for line equipment number and/or directory number are given delayed status until activation is called for by dialing the service order number from a special telephone line termination.

In order to preserve the connection between service order number and resulting RC's, an RC entry with the service order number as TAG is made, whose primary TW contains either a line equipment number, a directory number or an MHG number to identify the primary RC's which have to be activated. If more than one such identifier is needed, a reference address leads to an activation block which contains them. At activation time, the entry which contains the service order number is deleted, while entries identified by the service order number are given "permanent" status.

Changes on trunk circuits or office codes are treated in a way similar to those originated by service orders. They are normally introduced over the maintenance channel of the teletypewriter. They lack a service order number and therefore cannot be accepted on a delayed basis. Although they use telephone company terminology, their format is closer to the needs of ESS.

VII. PROGRAM STORE UPDATING

When recent changes have accumulated in the call store, they are transcribed onto the program store. The future location of primary RC's is predetermined by their TAG. The future location of auxiliary blocks is chosen when the RC is received, and the location stored as the permanent auxiliary address in a control word preceding the auxiliary block. This control word is not part of the auxiliary block and is not carried over to the program store.

It is required that any number of modules be updated at a time and also that the updating of a module may be interrupted at any time without harm.

For each card of a module about to be changed, a card image is prepared in the call store by copying into it the contents of the old PS card. Then a search is made through the RC area to find the RC data modifying the card image. The address of the 64 words in the card corresponds to 64 program store addresses. Whenever a permanent RC with a TAG equaling one of those addresses is found, the corresponding card image location is changed. If the primary TW contains anything but a temporary auxiliary address, it is transcribed as such. If the primary TW contains a temporary auxiliary address, the control word of the auxiliary block containing the future permanent auxiliary address is transcribed instead (see Fig. 15).

If the primary TW contains a temporary auxiliary address, whether

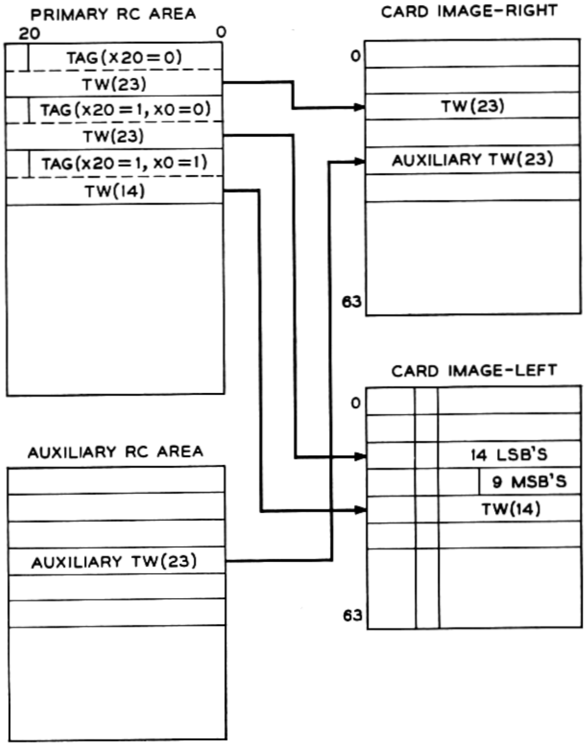

Fig. 15 — Transcription of recent changes from the RC area to the card image.

the TAG belongs to the card or not, the permanent auxiliary address is examined and the following cases are distinguished:

(a) None of the auxiliary TW's belong on the card.

(b) The auxiliary block starts on the card. It may or may not end on it.

(c) The auxiliary block ends, but does not start, on the card.

(d) Sixty-four auxiliary TW's in the middle of the auxiliary block belong on the card.

Whatever portion of the auxiliary block belongs on the card is then transcribed onto the card image.

The card images thus prepared are used to write new memory cards. After a module has been written and inserted into the PS, a limited verification takes place. An error in a changed word does not cause rejection, since the RC is still available.

After an arbitrary number of modules has been written, verified, and duplicated,* the RC area is updated; the RC data which were correctly transcribed to the PS are eliminated as follows:

All primary RC's with permanent status are examined, and the following cases are distinguished:

(a) The primary TW contains anything but a temporary auxiliary address. The primary TW in the RC area is compared with its counterpart in PS. If both are equal the RC is deleted.

(b) The primary TW contains a temporary auxiliary address. Each auxiliary TW in call store is compared with the contents of the program store words at the location of the permanent auxiliary address. If all words match, the block is considered correctly transcribed. If the primary TW in PS already contains the permanent auxiliary address, the primary RC is deleted. If it does not yet have the right reference address, the primary TW in the RC area is changed by replacing the temporary with the permanent auxiliary address. If the block was not correctly transcribed, no action is taken.

This method of updating the RC area explains why the limited verification method is permissible: if a changed word is incorrectly transcribed to the PS, no harm is done, since the RC is not deleted. It will be corrected at a later time.

This method of updating also makes the writing of modules independent of each other. For instance, if an auxiliary block overflows from one module into the next one, and if either module is revised, the RC will stay intact until the other part is done. Or, if the primary RC is in one module, the auxiliary block in another, either module may be written without consideration of the other one. Also, the writing of a module can be interrupted without any damaging effect, since no changes in the RC area are made before the three steps of writing, verifying and duplicating are completed.

Available space in the PS translation area is administered via linked lists of available space. The lists are first created in PS when the original translation data are installed. Lists are maintained for spaces of 2, 3, $\cdots$, 31 words, and one list is maintained for larger spaces, both in the right and the left halves of the PS. Each of the larger spaces contains the address of the next large space and contains its own length. As new space is needed, or as active space is relinquished, the linked lists and their headcells are updated via the recent change mechanism. If space

* The first of the two duplicate modules is written as described above. The second is merely copied from the first one.

is seized from a larger area, the length information for this area is updated.

VIII. CONCLUSION

The translation plan for No. 1 ESS has accomplished a number of goals. It has provided:

(1) compact storage of subscriber, trunk and office code data — data that are currently stored in cross connections in electromechanical systems,

(2) convenient means for handling changes in such information,

(3) facilities for providing much of the information that permits a generic program to handle a specific No. 1 ESS installation,

(4) convenient forms of input and output data for use by a generic office program, and

(5) convenient means for introducing translation information changes in a working office.

Translations have been a major tool in making a generic No. 1 ESS possible and efficient.

IX. ACKNOWLEDGMENTS

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REFERENCES

1. Carbaugh, D. H., Drew, G. G., Ghiron, H., and Hoover, Mrs. E. S., No. 1 ESS Call Processing, B.S.T.J., this issue, p. 2483.
2. Ault, C. F., Gallaher, L. E., Greenwood, T. S., and Koehler, D. C., No. 1 ESS Program Store, B.S.T.J., this issue, p. 2097.
3. Harr, J. A., Taylor, F. F., and Ulrich, W., Organization of No. 1 ESS Central Processor, B.S.T.J., this issue, p. 1845.