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No. 4 ESS:

Data/Trunk Administration and Maintenance

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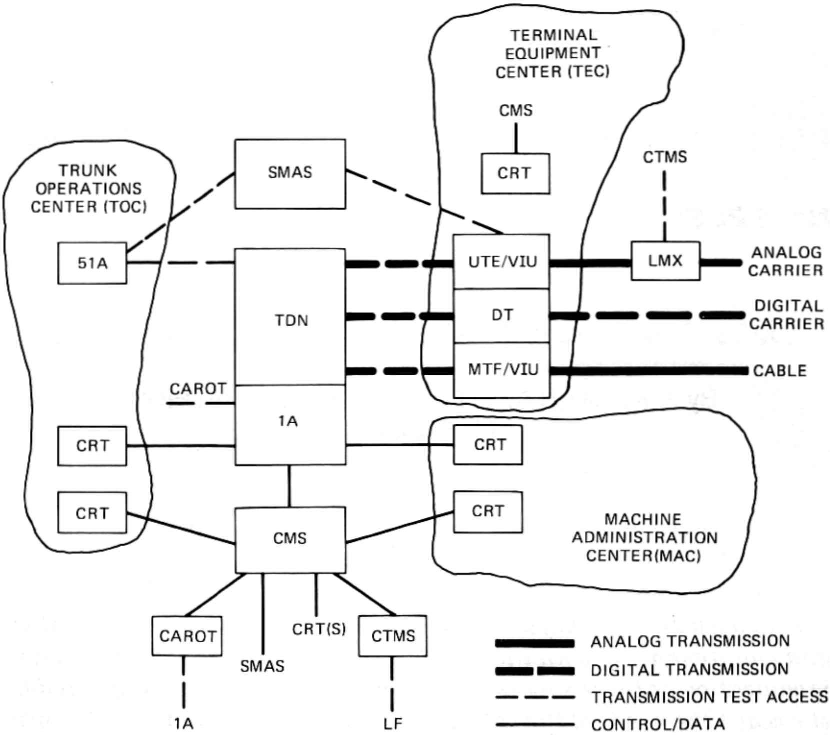
A large data base supports both switching and maintenance functions in No. 4 ESS, a system which has the capability to switch a half million calls per hour on over 100,000 trunks. The data base is described here along with the subsystems that are used to support the installation and maintenance of both the data base and the trunks. The design and organization of these subsystems have been significantly impacted by the real-time needs of the call-processing system and the need to provide accurate, cost-effective ways to install and maintain the large number of trunks and their associated data bases.

I. INTRODUCTION

Two key elements in a No. 4 ESS are the trunks over which customer calls are placed and the data base which supports the call-handling function. Both the trunks and the data base require initial installation followed by ongoing maintenance and change processes. The data bases provided in No. 4 ESS and the subsystems that were developed to support the initial installation and maintenance of both the data bases and the trunks will be described.

The No. 4 ESS data/trunk administration and maintenance subsystems are depicted in Fig. 1. They are structured about the work centers, data bases, and operating features of the 1A Processor and two minicomputer systems, the Circuit Maintenance System 1A (CMS 1A) and the Centralized Automatic Reporting on Trunks (CAROT) system.

The 1A Processor contains the data base to perform the No. 4 ESS call-processing function and to access and control the trunks to perform maintenance functions. The CMS data base contains equipment-related, trunk-layout, and administrative information needed to perform the



1A – 1A PROCESSOR
TDM – TIME DIVISION NETWORK
CMS – CIRCUIT MAINTENANCE SYSTEM
SMAS – SWITCHED MAINTENANCE ACCESS SYSTEM
CAROT – CENTRALIZED AUTOMATIC REPORTING ON TRUNKS
CTMS – CARRIER TRANSMISSION MAINTENANCE SYSTEM
UTE – UNITIZED TERMINAL EQUIPMENT
LMX – L–MULTIPLEX EQUIPMENT
DT – DIGROUP TERMINAL
VIU – VOICEBAND INTERFACE UNIT
MTF – METALLIC TERMINAL FRAME
CRT – CATHODE–RAY TUBE/KEYBOARD

Fig. 1—Data/trunk administration and maintenance system.

circuit order and maintenance functions associated with trunks. CMS also contains a transient data base used to administer the work force involved in these activities. The CAROT system directs routine transmission testing of trunks and has a data base which identifies the trunks and associated test parameters.

Testing and test-access systems include the 51A test position, the Switched Maintenance Access System (SMAS), and the Carrier Terminal Maintenance System (CTMS). The 51A test position provides the ability to manually test trunks; access is via the time-division network, and/or via SMAS to an intermediate point on metallic or analog-carrier derived circuits. The CTMS system provides per-circuit measurements at various points in the multiplex equipment on broadband analog carrier systems.

Processes have been developed to support the initial installation, growth, changes, and maintenance of the trunks and the associated call-processing and maintenance data bases. These processes are carried out in three work centers known as the Machine Administration Center (MAC), the Trunk Operations Center (TOC), and the Terminal Equipment Center (TEC). The MAC is responsible for the data base initialization and update functions as well as for the coordination of circuit order activity. The TOC is responsible for both the circuit order and maintenance testing of trunks and must ensure that both operational and transmission objectives are met. It also detects and then removes faulty trunks from service. TEC responsibilities include initial installation and repair of terminal equipment.

1.1 Objectives

The primary objective is cost-effective administration and maintenance through the application of up-to-date but proven technology, capitalizing on the characteristics of the switching system. This is achieved through a uniform but flexible arrangement for maintenance and administration which was designed into the system and through increased productivity gained by expanding the use of automation. Particular examples are a reduction in paper records for both translation data and work administration, enhanced personnel interfaces, and automated trunk testing and data verification.

1.2 Switching system characteristics

The degree to which the objectives for data/trunk administration and maintenance have been achieved is due in part to the characteristics of the switching system architecture. Since the network is nearly nonblocking, the need for load-balancing trunk assignments is eliminated. Conventional distribution frames and trunk circuits are eliminated by integrating switching, signaling, and transmission functions. This integration is in the form of Unitized Terminal Equipment (UTE) connectorized in its interface with the Signal Processor (SP) and the Voiceband Interface Frame (VIF), and the Digroup Terminal/Signal Processor 2 (DT/SP 2). Automated maintenance functions are incorporated into the common control equipment. Integration also encourages modularization of trunk assignments, which makes the storing and changing of data base information on a group rather than an individual circuit basis practical.

II. DATA BASES

2.1 Overview

The No. 4 ESS has, in addition to resident programs, a large resident data base that is used for switching calls and administering the circuit

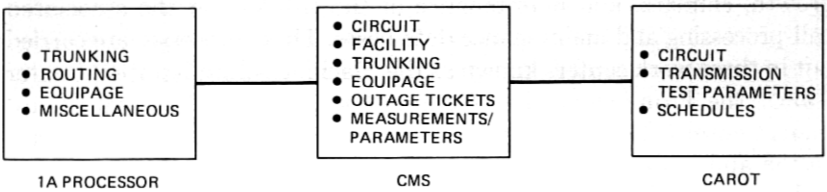


Fig. 2—No. 4 ESS data bases.

order and trunk maintenance processes. The data base used for switching calls is stored exclusively in the 1A Processor and consists of hundreds of thousands of words. The data base for administering the office is mainly stored in two minicomputer systems, CMS and CAROT. Figure 2 shows the major categories of data and their host processors. The following sections explain these data bases in more detail.

2.2 1A Processor resident data base

2.2.1 Data base structure

1A Processor memory primarily contains programs and data used for switching calls. This data includes such information as how calls are to be routed, what interoffice signaling format should be used, and on what equipment the interoffice trunk is terminated. The following presents where the data is stored, what are the capabilities of the data, how the data is stored, how the data is initialized, and what paper records are needed.

The data is stored in one of two ways. It can be stored in core store for fast access with a copy on file store for backup, or it can be stored only on file store. Both ways use electronically alterable memories. The actual choice between core and file store for the location of a particular type of data is engineered for each office depending upon its real-time needs. This flexibility could save up to one-third of the core requirements for office-dependent data in a 20k to 30k trunk office where the real time exists to access data on file store. The routing data provides for:

(*i*) 3 through 9 digit translations
(*ii*) 0 through 14 digit deletions
(*iii*) 0 through 6 digit prefixing
(*iv*) 1 through 14 direct and alternate routes plus up to seven automatic out-of-chain routes
(*v*) 64 non-POTS domains in addition to subdivisions of the POTS domain
(*vi*) 1 through 8 NPAs served on a 7-digit basis
(*vii*) Screening based on a trunk subgroup characteristic that provides up to 16 different routing treatments per called number

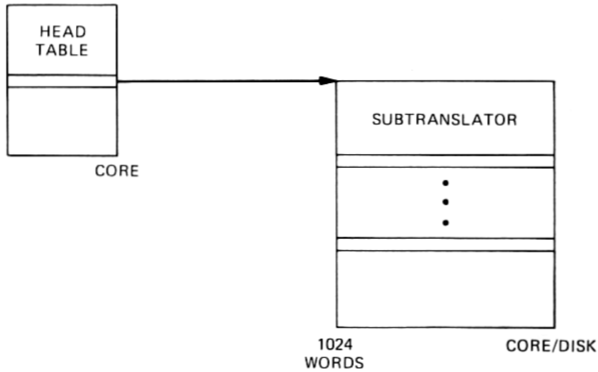


Fig. 3—1A Processor data structure.

(*viii*) Screening based on a trunk subgroup characteristic that provides either normal routing or a tone or announcement per called number.

The trunking data identify:

(*i*) Network location, scan point, and distributor point identification for non-CCIS trunks, band and label information for CCIS trunks, and a trunk name (in alphanumeric format) for up to 107,000 trunks
(*ii*) Circuit identification name (CIN) and trunk hunting data for up to 4000 trunk subgroups, each of which can have up to 1000 trunks and 38 class marks of data such as type of signaling (MF, DP, CCIS), echo suppressor requirements, etc.

The miscellaneous data contains:

(*i*) Floor location, equipage, vintage, and miscellaneous scan and distributor points for all hardware in an office
(*ii*) Parameters to allocate core store and disk to functions like call registers and input/output buffers
(*iii*) Space administration translators used to facilitate the changing assignments.

For most translators, a standard structure is used which is a connected, downward linked, multibranched list with two levels (Fig. 3). This structure provides efficient memory utilization, minimal real time for access (13 percent of per-call time), improved system integrity, ease in changing and growing structures, ease in initial generation, and direct generation of office records from the data using the verify system.

2.2.2 Data base initialization

The 1A Processor resident data is initially generated by an off-line system running on a general-purpose computer. This system, called the

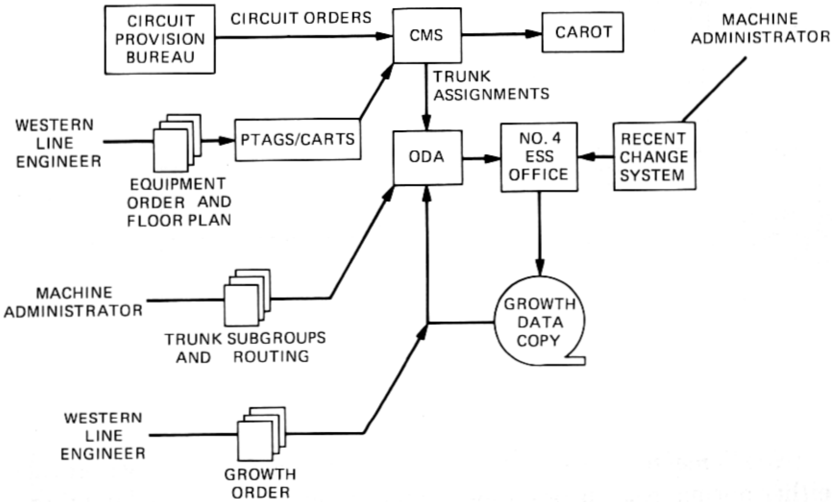


Fig. 4—Off-line generation of data base.

Office Data Assembler (ODA), was designed and implemented by Western Electric in PL1 and assembly language. The same system is used to reallocate storage for each growth interval (typically 1 or 2 years). The inputs to the system (Fig. 4) are the Western Electric specification of floor plan layouts and the telephone company specification of routing and trunking data. The floor plan information is combined with the equipment order for the office and processed by the Western Electric wiring assignment system [Provisional Trunk Assignment Generation System/Circuit Assignments Record Transfer System (PTAGS/CARTS)]. The output of this process is interframe wiring information for the office and a data base for CMS that describes the terminal equipment. This data base is loaded into the CMS and is updated with trunk assignment information as the assignments are made during the precut installation and testing interval. Prior to cutover, the data base from CMS is output on magnetic tape and input to the Western Electric ODA program. Further assignment information, as well as routing information, is added. The output from ODA is the complete data base for the 1A Processor at the time the office is placed in service.

The input records were designed to eliminate unnecessary parameters by algorithmically generating related parameters and functionally grouping the input data. Less than 25 parameters need to be specified for No. 4 ESS. All the office-dependent data is generated by the ODA system. Actual trunk assignments are made manually and input to CMS on-site prior to cutover. This data is input to the ODA system via magnetic tape for conversion into the translator structures.

The routing data comes from two sources:

(*i*) Manually completed records which are made by using the translation guide and traffic routing guide

(*ii*) A mechanized vacant code file.

The output of the ODA is a magnetic tape containing the entire 1A Processor data base. This tape is loaded on-site into the 1A Processor. The ODA system also outputs wiring assignments. Once the data is stored in the 1A Processor, call-processing programs will access the data through a set of special-purpose routines which minimize the effect on per-call real time. Whenever possible, these routines self-detect data errors. The data base is modified, augmented, and verified through the recent change system.

2.3 Circuit Maintenance System data base

The primary storage medium for the CMS system is disk. For a fully equipped No. 4 ESS office, over 300 million bytes of disk storage are provided in CMS. This data includes infrequently changed information such as office equipment layouts, circuit layout records, test records, and trunk group and per-trunk translation data which allows for communication with other systems. Dynamic data such as trouble tickets, circuit orders, and work lists are also maintained by the system. To build this large data base, CMS supports manual input, magnetic tape input, and data link interfaces. Whenever possible the data input is via data link. Most trouble reports are automatically input from the 1A Processor or CAROT when they detect circuit abnormalities. Circuit orders and circuit layout information is generally input through a data link interface to the telephone company circuit layout system.

The office equipment file, which describes the physical equipment in the No. 4 ESS office, is loaded from a magnetic tape generated by the Western Electric Circuit Assignments and Record Transfer System (CARTS), which is a part of the ODA system discussed previously. This tape is loaded in a new office and at the beginning of each growth interval (typically every 1 or 2 years).

Because the CMS data base is so large and overlaps data stored in other systems, CMS provides a data coordination function. It updates the CAROT per-circuit test file, stores test parameters associated with CTMS measurements, and provides precutover trunk assignments to the ODA, which uses this information for initializing the 1A Processor data base. The CMS returns in-effect reports on new circuit orders to the originating circuit layout system. The system also provides trouble ticket analysis data to the telephone company trunk service results plan which generates trouble index reports.

The CMS filing system is responsible for maintaining and securing the system data base. The filing system performs the allocation, accessing, and deletion of files on the disks. Both fixed-length and variable-length files are supported. An integral part of the file system is data base protection software. This software provides for logging data base transactions, backing out updates which must be aborted, and provides various image copy and restore routines for both spare disks and magnetic tape. The filing system also provides absolute write features, directory and compaction routines, and file integrity and audit functions.

III. ADMINISTRATIVE AND MAINTENANCE SUBSYSTEMS

The data/trunk administration and maintenance functions are accomplished through the interaction of several subsystems. Some reside in software in the 1A Processor, some are composed of a minicomputer and its software, while others are totally hardware entities. Each of the major subsystems will be described here.

3.1 No. 4 ESS Recent Change subsystem

The Recent Change (RC) system is a set of programs that interface between the craft at a *TELETYPE®* model 40 terminal and the data base in the 1A Processor. It allows office-dependent data which resides in the 1A Processor to be changed and verified on-site. Because of the volume of changes and the sensitivity of office performance to changes, the process could become time-consuming and error-prone if an efficient recent change capability with built-in consistency checks were not provided. In addition to reducing the administration costs, this system was designed to improve the data base integrity and the personnel interfaces relative to previous electronic switching systems. Major improvements in integrity were achieved by enhancing defensive software and by providing recovery strategies. All changes are interactively checked for range, format, and logical consistency. Only after a change passes these checks is the recent change message allowed to be buffered in the 1A Processor memory. This change procedure does not require knowledge of the translator structures; modification requires only the knowledge of the telephone function to be changed. All memory manipulation and space administration is done automatically.

Personnel interfaces were improved over previous systems by developing functionally oriented forms instead of translator-oriented forms, by eliminating the need for most of the paper records required in previous systems, and by developing an improved language which uses part of the common language identity [Circuit Identification Name (CIN)] of the trunk subgroup and alphanumeric abbreviations for data instead of arbitrary number encoding. The forms for the recent change system and the ODA system are similar in design. The user essentially needs to learn how to use only one type of form for specifying the original ODA data, retrieving existing data, or changing the existing data. These forms

RC: TRK; NEW: OPT (MANUAL) BUF: BTFN TOWN ST BL FBS NBS

ORNU ______1, TSG ____1 CHGO IL CL 57T 57T

	TEC	TESC	ONR	SEC	
TOC	2,	1,	4,	1,	ES ___,

QTRK	FTFN	TSIF	SPC	TAN LVL	FTS
12	1	0	1	0	19
___,	____,	__,	_,	_,	___,
___,	____,	__,	_,	_,	___,
___,	____,	__,	_,	_,	___,
___,	____,	__,	_,	_,	___,
___,	____,	__,	_,	_,	___,
___,	____,	__,	_,	_,	___,

REMARKS "ADD 12 TRUNKS" !

Fig. 5—Recent change message used to add 12 trunks.

are designed to be functionally self-sufficient. For example, only one form needs to be completed to add a trunk, a trunk subgroup, or an NXX code. Some of the forms allow multiple assignments on the same form (e.g., adding multiple trunks or NXX codes). Furthermore, the forms are designed to require a minimum of input. For example, on the add-trunk form (Fig. 5), only the network appearance needs to be specified and the RC system automatically assigns the universal scan points, distributor points, and miscellaneous points. This is possible because the ODA system captures and stores the connectorized cabling information for the office in the data base. The forms were also designed to be "English-language-like," using a subset of the common language name of the trunk subgroup that identifies the city, state, and building to which the trunk subgroup is connected. The forms use standard alphanumeric abbreviations, for example, MF, DP, and CCIS. Since these forms are functionally oriented and are instantaneously available to personnel via the CRT and hard copy, the large volume of paper records necessary for previous systems is no longer required. The need to manually update paper records, a process which is error-prone, is eliminated. Now the records reflect exactly what is stored in the 1A Processor. Furthermore, specialized retrieval routines for use of the administrator are provided to search the data base for information such as all the NXX codes that are routed to a particular routing pattern or all the trunk subgroups that have a particular screening class.

When the recent change messages are put into the recent change system, they actually go through three states, first a buffer state, then a test state, and finally an active state.

The recent change process is started when administrative personnel request via the CRT terminal a particular form needed to change some of the data. The RC system displays the form and the blanks are filled in by personnel using tab controls to advance from blank to blank. The form is then transmitted back to the system. The system performs extensive format, range, and logical consistency checks on the data. If an error is found on the form, it is redisplayed with an indication of where the error occurred. If the form passes all checks, it is stored in the buffer state on disk for later processing. This step serves as a "mail box" storage system and appropriate tools are provided to administer the messages in the buffer state.

Next, the messages can be put into the test state. This step changes the data so that the retrieval routines can display what the changes will be like when activated, but the normal call-processing routines cannot access the data. The output from the retrieval routines resembles the original change request. In this mode, personnel can see what the data presently look like and what the data will look like after the change. Further logical consistency checks are performed at this time by comparing the input data to the actual data in the system (e.g., is there a trunk subgroup in existence to which these trunks are being added). In addition, the trunking data which was changed can actually be used to make test calls and verify working circuits before the data is made available to normal call processing.

When the recent change message is to be activated, the changed data is released to normal call-processing routines. This is called the activate state.

In the event that a software trouble is introduced into the data base, No. 4 ESS has two recovery procedures. The first reinitializes the system from a tape that contains a snapshot of the data base at some previously known "safe point" in time. The second procedure, called rollback, automatically reinitializes the new data from a disk copy of the old data. The action is manually requested from the master control console along with an accompanying phase of software initialization. This procedure can selectively and quickly return the system to various points in time since the last snapshot tape.

If either procedure is used, another procedure, called rollforward, allows the system to reinsert selected recent change messages. This can be done because each message is automatically stored on a cassette tape when it is accepted into the test state. After reinitialization or rollback, this rollforward cassette tape is used to reinsert the recent change messages.

Circuit order work is the responsibility of the dial administrator. However, the initiation of a routing change is the responsibility of the routing supervisor who typically is responsible for all the routing changes in a region. When the routing supervisor determines that a change is needed, a remote terminal can be used to verify the existing data in a particular No. 4 ESS and to enter a recent change message into the buffer state; the activate date and coordinating data must also be entered so that the dial administrator can eventually activate the message.

The routing supervisor must administer groups of routes called routing data blocks. The CINs for all routes, digit deletes, digits to be prefixed, out-of-chain routing information, and INWATS data must be specified. Code routing treatment must also be specified as to: routing data blocks, announcement, tones, and screening. The code translations also resolve the numbering plan conflicts where the NPA and the office code NXX are identical. They are capable of handling toll connecting trunks which originate in any of eight NPAs. The eight NPAs include the home NPA and seven served NPAs. The No. 4 ESS allows a customer in the home NPA and each served NPA to dial seven digits for intra-NPA calls. The routing translators are also capable of handling 64 CCSA domains.

3.2 No. 4 ESS trunk maintenance subsystem

The 1A Processor resident trunk-maintenance software subsystem supports all of the activities that actually involve control, configuration, or data collection associated with circuits that terminate on the No. 4 ESS switch. As described elsewhere in this paper, other subsystems such as the CMS, CAROT, and the 51A test position provide administrative and testing capabilities as a part of the total system plan. However, actual access to the trunks and test circuits that terminate on the No. 4 ESS switch (that is, the ability to set up network connections and read and write the transient data structures used to administer the circuits in conjunction with the call-processing function) is only possible with 1A Processor resident software.

Trunk maintenance software accesses trunks through network connections and through the scan and distribute function in the universal matrix of the signal processor. This is the same interface which is used by the call-processing programs. It accesses the test position and other test circuits as it does trunks except that in some cases there are additional scan and distribute functions via the miscellaneous matrix in the signal processor.

Three communication interfaces exist into the 1A Processor resident trunk maintenance software. The first is a pair of data links (one for each direction) between the 1A Processor and the CMS. This link is similar to the input/output channels used to interface the 1A Processor with *TELETYPE* model 40 terminals. Major differences are: all messages require a positive response, retransmission is provided, and backup via protection-switched spare channels is provided.

The second communication interface is via the Remote Office Test Line (ROTL). This is a software-controlled hardware interface through which the CAROT system can, via analog signals, control trunk transmission testing in No. 4 ESS.

The third and most comprehensive interface is to conventional CRT and teletypewriter devices in the office that are supported by the 1A Processor input/output subsystem. The functions that are supported through this interface are a superset of those supported on the CMS data link.

Trunk maintenance software is a multiprocessing system that uses an engineered number of memory registers similar to the call registers used by call processing. This makes it possible to process concurrent requests and to use the system facilities designed into the system for call processing. A scheduler is provided as one task under the system executive program. This scheduler provides a single control point for the initiation of most tasks. Hence, it is possible to limit deferrable work when the system is operating in real-time overload.

3.3 Circuit Maintenance System

CMS functions as the hub of trunk maintenance activities by interconnecting personnel and other automated systems. It consists primarily of dual processors and their associated peripheral equipment. As shown in Fig. 6, the system interfaces with:

(*i*) Personnel in various administrative work centers of the No. 4 ESS office

(*ii*) The wide variety of test and measurement systems that personnel use

(*iii*) An extensive data base of equipment, test and trouble data, and information on circuit orders

(*iv*) Data processing and operational systems.

Through CMS, work center personnel have access to the operational systems which perform various testing and control functions. Both people and automatic systems can access the CMS data base, either to update it or to obtain information. This arrangement allows craft personnel to perform many maintenance functions through a common interface so that they need not learn individual command languages and functions for many machines.

Features provided by the CMS to the various work centers utilize the *TELETYPE* model 40 CRT. The interface has been designed so that it may be used by inexperienced craft personnel with a minimum of

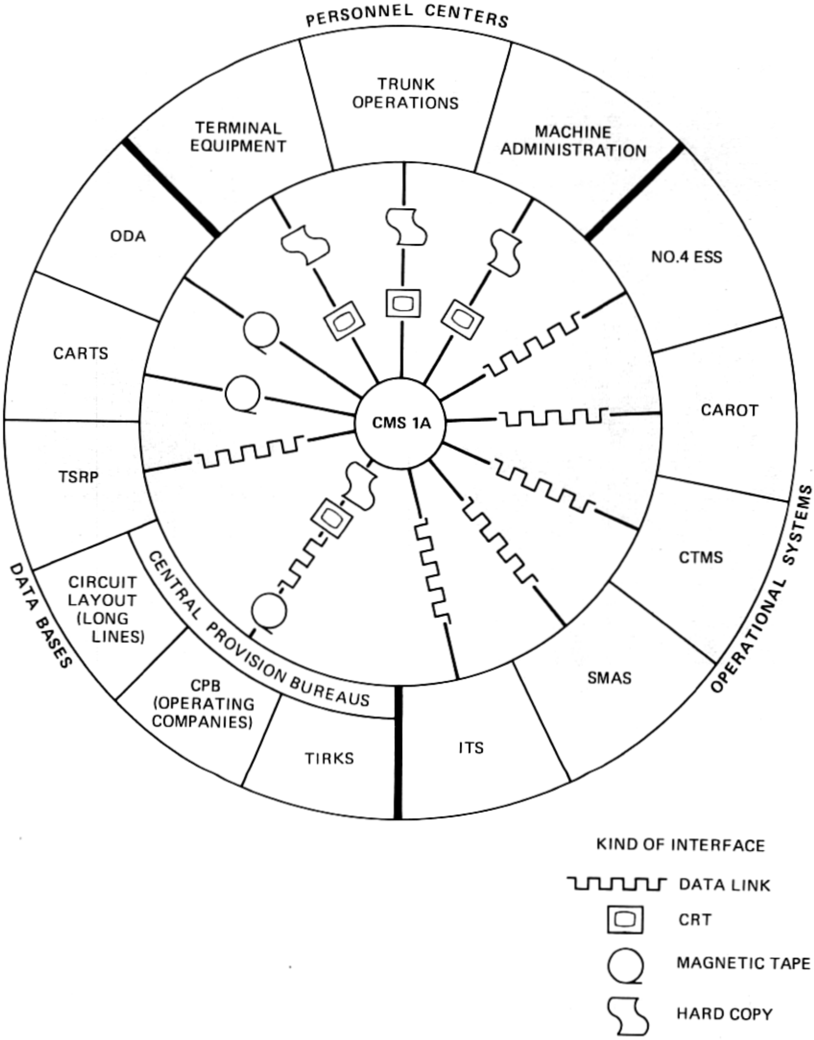


Fig. 6—CMS 1A interfaces.

training and yet it is not restrictive to more knowledgable personnel. Illustrations demonstrating this interface will be given later.

Personnel interconnected by CMS work in three major administrative areas in a No. 4 ESS office: the Trunk Operations Center (TOC), the Terminal Equipment Center (TEC), and the Machine Administration Center (MAC). Personnel in the TOC (Fig. 7) interact with the CMS via a CRT on the 51A test position.

Ordinarily, the TEC has a stationary position with a CRT screen and a printer, as well as a number of mobile CRT units (Fig. 8) that furnish

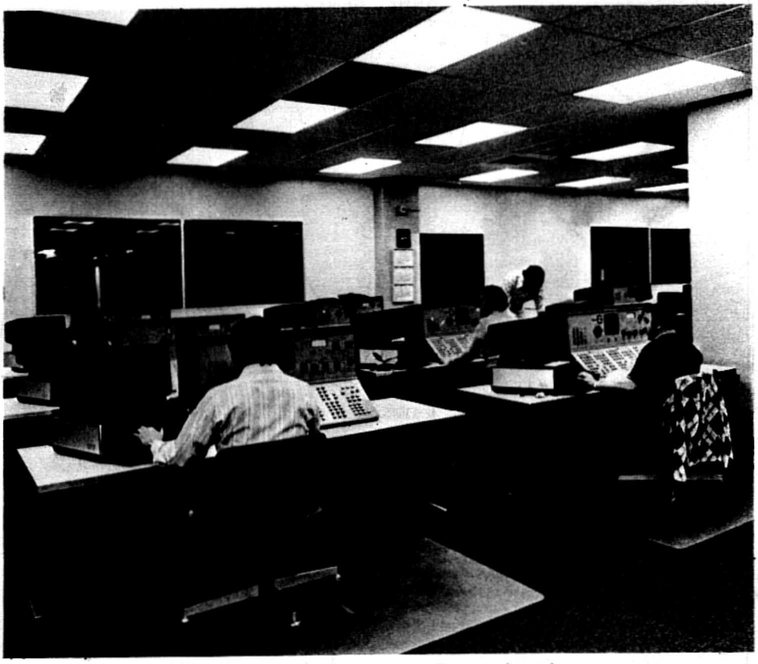


Fig. 7—Trunk Operations Center (TOC).

the same basic features as the 51A test position CRT, only at the frame location.

The MAC administers the circuit order process. Through CMS, personnel in this center obtain new circuit orders which are automatically correlated with existing orders and placed on work lists in the CMS data base. Personnel in the MAC (Fig. 9) can administer and control the completion of the orders via CMS.

Outage tickets and circuit orders are automatically distributed to craft personnel by the system. The algorithm used is based on the premise that maintenance responsibility for each trunk subgroup is assigned to a specific craftsperson. If a trouble occurs on any trunk in the subgroup, a trouble or outage ticket is made out and automatically assigned to the worklist of the responsible craftsperson.

The system takes care of the trouble ticket function which includes creation of the ticket, time-stamping pertinent events (such as turndown and turnup times, referral times), and times when automatic tests were run. The ticket also stores a log of comments made by the craftsperson, test results, trouble reported, and trouble-found data. All of these data

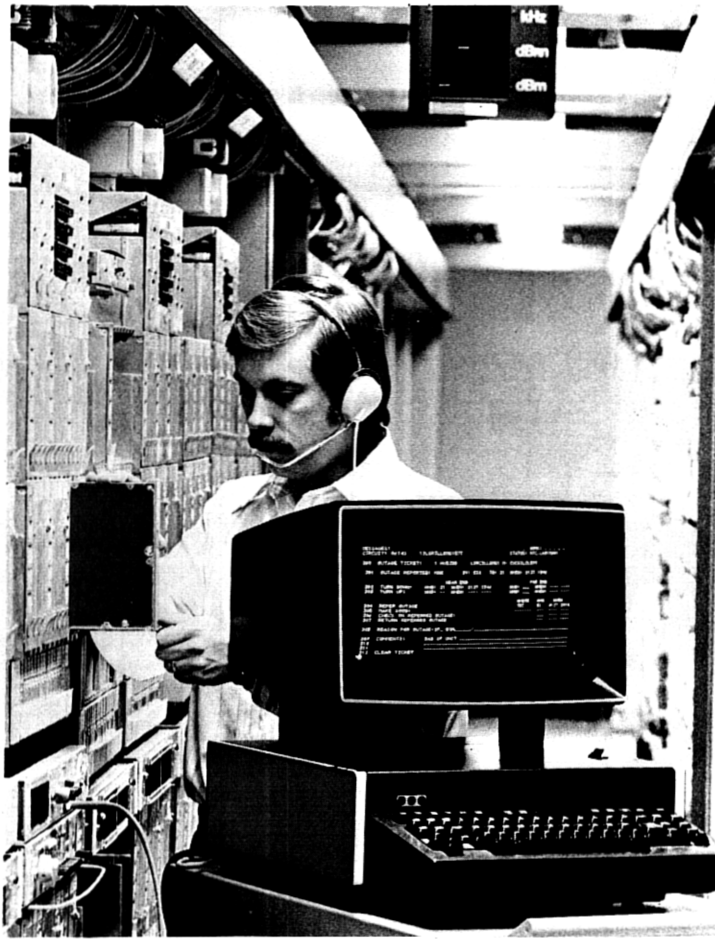


Fig. 8—Terminal Equipment Center (TEC).

are stored and used for the administrative analysis work that the system performs each evening.

CMS has personnel-machine interfaces in the various work centers in the office. When a tester has sectionalized a trouble and wants to refer it to the repair work center, the tester enters a command to the system which will automatically send the trouble ticket to the work center and put it on the responsible craftsperson's work list.

The CMS system provides personnel with access to its data base. This

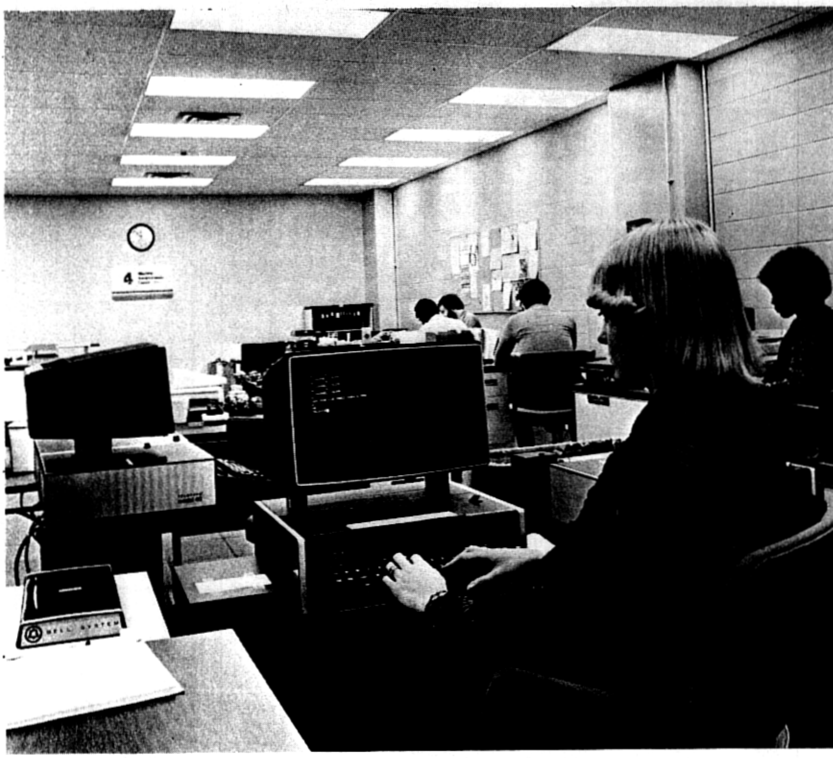


Fig. 9—Machine Administration Center (MAC).

data base includes trunk, equipment, test and trouble data, and circuit order information.

Administrative features of the CMS system support the "control area" organization, which allows a local assignment of craft personnel to control areas. The control areas consist of a designated control position and up to nine other positions. These positions make up a unit whose activity can be managed by the control position and upon which administrative reports are grouped and distributed. Typical TOC control areas might be set up in an office with one control area responsible for all intertoll trunks and another responsible for all of the toll connecting trunks.

The system generates administrative reports for each control area.

These reports include: the morning report of all trunks that are out of service as of 8 o'clock that morning; a daily outage ticket analysis listing by trunk subgroup, type of trouble, and outage time for all of the troubles cleared the previous day; also various circuit order activity reports.

Another administrative feature is the display of the activity log of each position assigned to the control position. This display indicates the work load of a given craftsperson and how many troubles have already been cleared. If the work load is too large, the control position can redistribute some or all of the work to other positions. This feature can be used to set up a dispatcher mode of operation, to facilitate night transfers of work, and to redistribute work when a craftsperson is ill or on vacation.

The CMS is designed to continue operating with varying degrees of degradation after any single hardware failure and even after certain multiple failures. For this reason each CMS system has two processors which allow for a switchover to single-processor operation. Some data are stored in duplicate on disks so that a craftsperson can restore full capacity within a short time of a single disk failure. Reconfiguration capability in the event of multiplex equipment failure is built into the software. Input/output channels are automatically reassigned to keep all essential communication links active in the event of limited failures.

3.4 Test position 51A

The 51A test position (Fig. 10) provides the capability to manually test trunks. It is a console at which the craftsperson can sit and conduct manual trunk testing and maintenance of toll and intertoll trunks terminating on the No. 4 ESS. The 51A has a sloping key panel and a number of built-in test equipment items. A CMS CRT sits on the left-hand side of the test position and is used as the major input/output device during trunk testing.

The key shelf is divided into three major parts; two are identical and known as Test Access Trunks (TATs), and the third provides communications functions. Each of the three parts of the key shelf is equipped to handle communications between the test position and test positions or test boards in other central offices. The TATs provide a set of keys and lamps to access and control any trunk appearance on the No. 4 ESS and/or a trunk accessed via the Switch Maintenance Access System (SMAS) 3B. The TAT trunk is similar to a standard E&M-lead trunk. Control of access to any trunk on the No. 4 ESS switch is via CMS to the 1A Processor. The SMAS access (SMAS is optional) is to the voice-frequency level point of trunks as they appear at the analog carrier system or the metallic facilities.

Test access is primarily requested through CMS. Test calls to specific trunks are established via the 1A Processor or through the CMS-SMAS

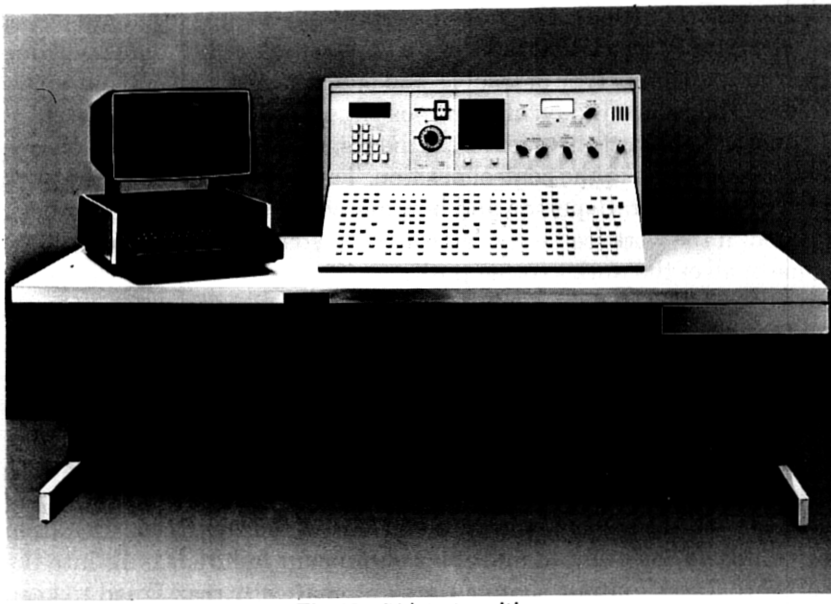


Fig. 10—51A test position.

register bank. Alternate methods are via the No. 4 ESS TTY channels or via the test position keyset to SMAS. The function of each kind of access can be further understood by a review of the functional block diagram (Fig. 11).

The keys and lamps are divided into six areas. These are TAT and circuit status, transmit and receive functions, and signaling and transmission test and control. These keys and lamps accomplish specific functions or access specific test equipment. The major test equipment measures signal level and frequency or noise. Impulse noise can also be measured. For intertoll trunks, direct connections can be made for measuring the performance of the echo suppressors. For toll connecting trunks, the four-wire return loss can be measured. Via SMAS 3B metallic trunk access, digital multimeter functions can be accomplished. For other measurement functions beyond those capabilities built into the test position, jacks are provided on the right side of the test position with work space and ac power outlets.

Via the No. 4 ESS network, any trunk in the office can be accessed, and then via the SMAS access direct cross-office measurements of the terminal equipment can be made. With the CMS CRT, demand tests can be made via CAROT and CTMS.

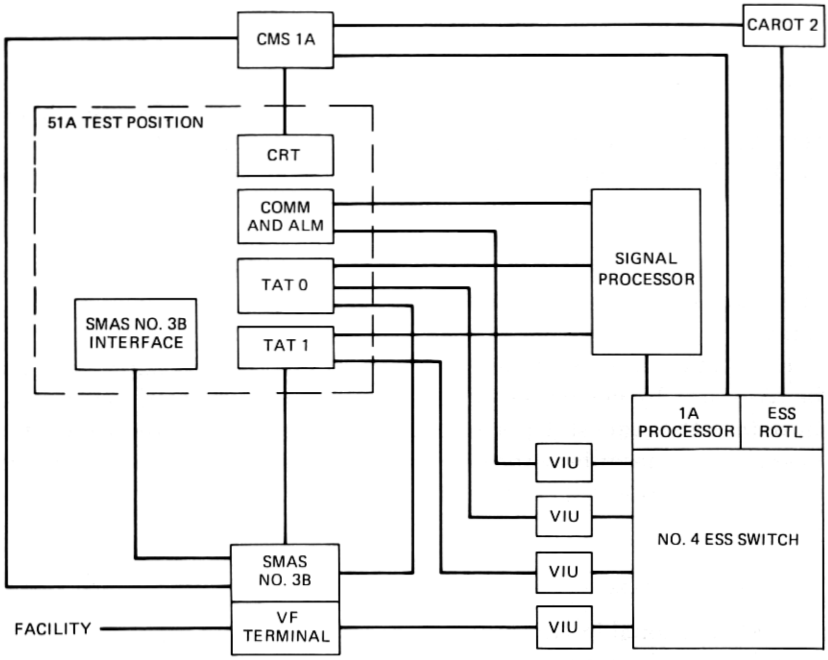


Fig. 11—Trunk accessing diagram.

The communications portion of the test position contains appearances for specific interoffice and intraoffice communications as well as standard telephone services. The keyset that is used for communications, SMAS access and other TAT functions contains *TOUCH-TONE®*, dial pulse and multifrequency signaling capability. A register is provided to store dialing digits and outpulse them when required.

3.5 Switched Maintenance Access System 3B

The Switched Maintenance Access System (SMAS) 3B is optional in the No. 4 ESS. If provided, it is available on analog trunks as well as other unitized facility terminals. On trunks employing analog carrier systems, SMAS provides monitoring (bridging) and splitting access to the +7, −16 transmission level points on the transmission leads (T, R, T1, R1) and to the E&M signaling leads. For metallic trunks, dc access is provided to the transmission leads and the signaling leads. SMAS is not applicable to the digital carrier trunks that terminate on the digroup terminals.

3.6 Centralized Automatic Reporting on Trunks (CAROT)

CAROT is a minicomputer system that provides a means for automatically scheduling and performing routine transmission tests on outgoing trunks at the proper facility-dependent test intervals. Trunks beyond the turndown limit are reported to CMS after the trunk has been reaccessed and a confirmation test has been performed. Trunks with less severe impairments or trunks which could not be tested in four test attempts are reported at the end of the routine test period.

Data for the computation of the trunk transmission maintenance index is compiled from the results of routine testing. Statistics concerning the number of trunks tested and the number of various maintenance conditions found are provided. An additional report gives the operational health of the CAROT controller, ROTLs, and terminating test lines.

Real-time, on-demand tests of single trunks or trunk subgroups can be requested by personnel via CMS and will be performed as specified by data in the request. Upon completion of circuit order tests, CMS will pass the data describing the new or disconnected trunk to CAROT. The appropriate action will be automatically taken to update the CAROT data base.

3.7 Carrier Terminal Maintenance System

CTMS (optional in No. 4 ESS) provides testing and maintenance for L-multiplex, M-multiplex, and other coaxial and radio facility equipment in the office. CMS and CTMS interact via a data link to provide trunk trouble sectionalization features on those trunks which CTMS accesses. The types of tests provided by CTMS to CMS (hence, at the 51A) are tone and noise level measurements and the detection of the presence or absence of SF tones on a specific trunk in the carrier terminal. This set of tests will provide positive trunk trouble sectionalization data on most of the troubles encountered.

IV. CIRCUIT ORDER PROCESSING

A circuit order is the official request that an office receives to install, change, or remove trunks between itself and some far-end office. The request may include one or many trunks. The procedure used to accomplish the requested changes, additions, or deletions is known as circuit order processing. The following describes the equipment installation, data-base updating, testing, and coordination functions as they are performed in No. 4 ESS.

4.1 Circuit order initiation

Circuit orders are received by the CMS from the telephone company circuit provision bureau via data link, magnetic tape, as as paper requests which are entered locally via CRT. CMS queues these requests until the machine administrator can inspect the list of new circuit orders and schedule them for assignment. Also, a current list of all pending circuit orders is available via CRT. If a group of trunks is a modular engineered group (12 or 24 trunks, which all have the same characteristics), the circuit provision bureau will have submitted one circuit record layout card, and the machine administrator will be requested to make only one network assignment for this modular group. The assignments for the other circuits will be automatically generated. If the trunks are not modular engineered, separate circuit record layout cards exist and separate assignments are made for each.

4.2 Data base changes

The administrator assigns the circuit to the No. 4 ESS time-division network (this automatically assigns terminal equipment because of the connectorized arrangements) and enters this information into the 1A Processor data base by means of the recent change "add trunk" message (Fig. 5). For this message, the craftsperson simply specifies part of the common language name for the TSG (from the circuit order), the type of equipment needed (e.g., A6 without echo suppressor), the quantity of trunks to be added (e.g., 12), and the traffic number of the first trunk.

This network assignment information and other translation data is also entered into CMS via CRT. The machine administrator schedules the two work centers (TEC and TOC) to perform their respective jobs. The circuit order administrator then refers the order to the TEC and TOC work lists. CMS maintains a list of all pending circuit orders which can be displayed on a CRT.

4.3 Testing activity

The TEC has a list of pending work including circuit orders. (See Figs. 12 and 13.) In response to entries on the work list, the TEC makes the cross-connects, installs plug-ins, and runs office tests as required. After this work is completed, the TEC personnel update the TEC status (as it appears on the work list) to "CMP" for completed.

At some later time, determined by the dial administrator, the TOC work list will identify that this trunk on the circuit order is to be tested. The craftsperson can verify that the equipment has indeed been cross-connected and plugged in by checking the status of the circuit order which was set by the TEC. The craftsperson can then perform trunk testing from the 51A test position. When all circuit order tests pass for this trunk, the maintenance status of the trunk will be changed to "active" in the 1A Processor memory (by an input message submitted in the TOC via CMS) and CMS will be notified that the work is completed for this order.

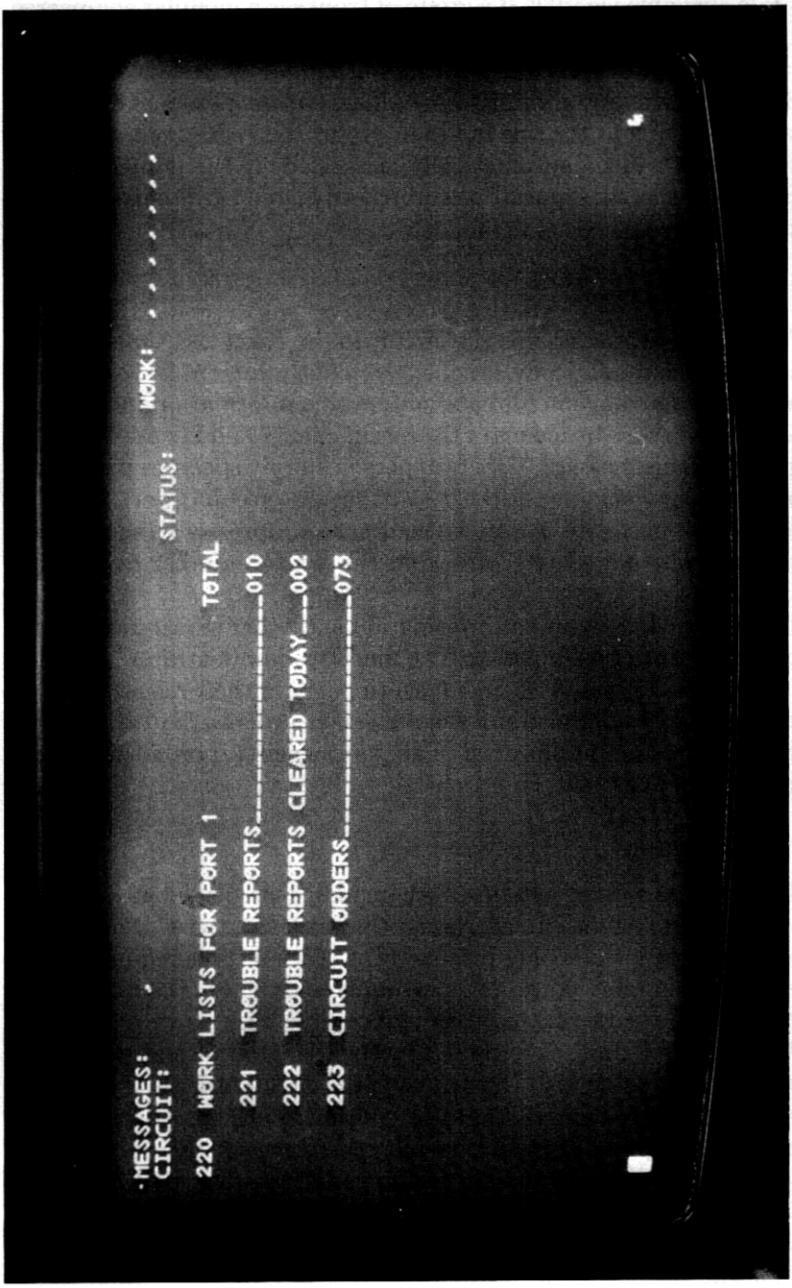


Fig. 12—TEC work lists.

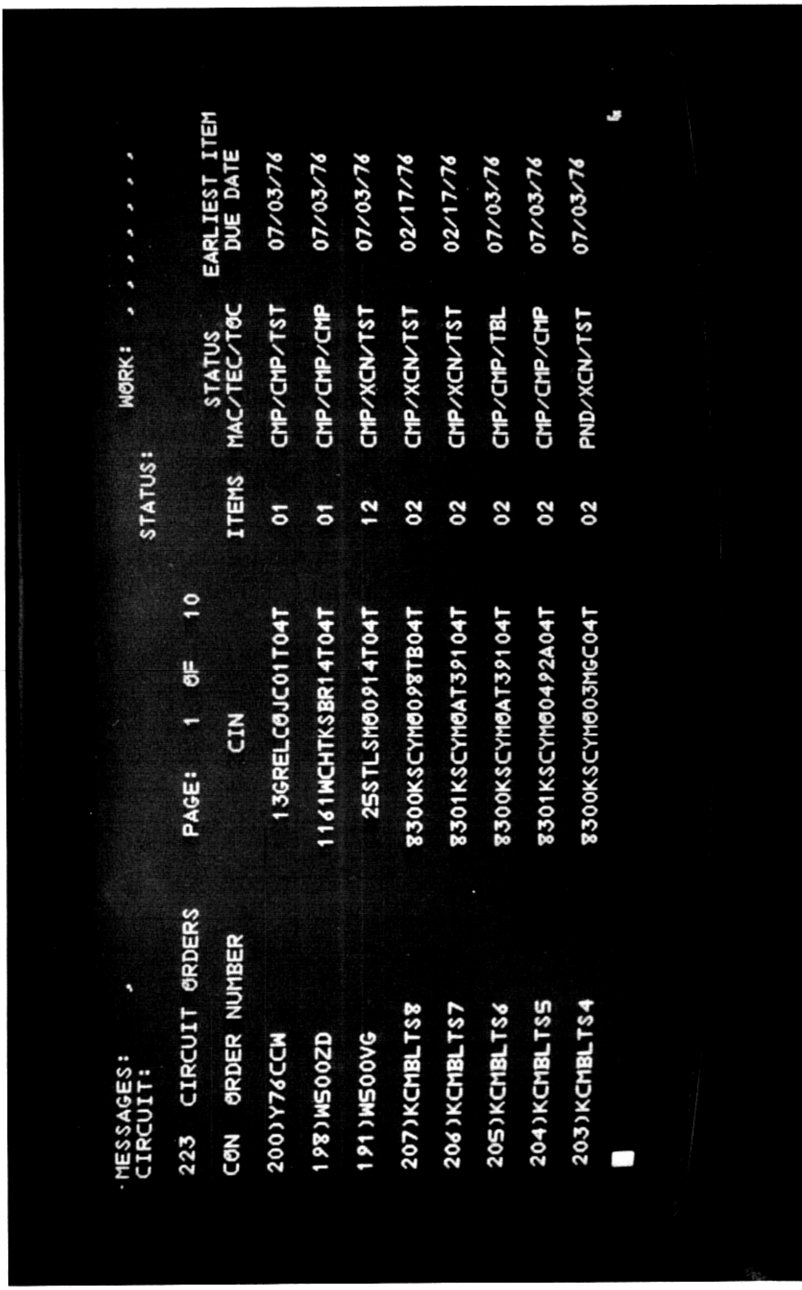


Fig. 13—TEC circuit order list.

4.4 CAROT data base changes

The machine administrator is notified that the work has been completed on this circuit order and can request CMS to issue an "in-effect" report to the circuit provision bureau and to update the CAROT data base for subsequent routine transmission testing. The transmission of an in-effect report and the update of test parameters to CAROT will be automatically effected across the CMS 1A interfaces to CAROT, and to the circuit provision bureau.

V. ONGOING TRUNK MAINTENANCE

Major elements of the ongoing trunk maintenance function are trouble detection, removal from service, and trouble sectionalization and repair. The trouble-detection function is performed by the 1A Processor resident trunk maintenance software and by the CAROT system. When appropriate, the trunk involved is automatically removed from service. Detected troubles are always referred to the CMS for further resolution. The CMS provides automatic and semiautomatic features to notify craft personnel about the trouble and to support the testing and administrative processes that ensue through restoral to service of the then repaired circuit.

5.1 Trouble detection and removal from service

Trouble detection in No. 4 ESS is primarily accomplished through several automatic processes. These include:

(*i*) Trunk tests or analysis stimulated by call failures
(*ii*) Circuit supervision monitoring
(*iii*) Routine trunk tests
(*iv*) Carrier failure processing
(*v*) Equipment monitoring.

In addition, summarized call failures and other data are periodically output to craft personnel for their inspection to ensure that undetected trouble conditions do not exist. Upon request specific, detailed data pertaining to the use of trunks and the disposition of calls is available in real time to the craft personnel. Manual trunk tests can be performed at the 51A test position in the TOC.

5.1.1 Automatic trouble detection

The call-processing software uniquely identifies every trouble condition it encounters to trunk maintenance, along with pertinent data. Each trouble condition is categorized as to whether or not it indicates a potentially faulty trunk and/or service circuit. For each trouble condition that implicates a trunk or service circuit, one of three processes are followed:

(*i*) Run a test on the trunk and/or service circuit.

(*ii*) Return it to service and test it only if it fails again within the next "*n*" calls.

(*iii*) Error analyze by returning to service and counting the number of successful and failed call attempts that occur. Compare the failure rate with that for its peer group (e.g., trunk subgroup) and, using a set of thresholds, determine if the individual trunk or circuit should be removed from service.

If a test is run and it fails, the trunk or service circuit is removed from service. If the test passes, the trunk or service circuit is entered into the error analysis process to protect against trouble conditions that the test does not detect. The results of the error analysis process can be to leave the trunk in service, leave it in service but report it to CMS as being suspect, or remove it from service.

Routine transmission tests and routine operational tests are automatically performed on all one-way outgoing and two-way trunks. The transmission tests are scheduled and performed under the control of CAROT (see Section 3.6). CAROT interfaces to the 1A Processor through a hardware interface known as a Remote Office Test Line (ROTL). The ROTL is controlled by software in the 1A Processor and connects to both the CAROT and the No. 4 ESS Time-Division Network (TDN). By controlling the ROTL hardware, the 1A Processor is able to communicate with CAROT via multifrequency and other tones, to connect transmission test equipment in the ROTL via the TDN to the trunk under test, and to allow CAROT to control that test equipment. The CAROT system, upon finding a faulty trunk, can request that a trunk be removed from service by the 1A Processor. The 1A Processor immediately notifies CMS of the outage, and CMS creates an outage ticket which it assigns to a craftsperson. Subsequently, CAROT will notify CMS of the test results; these results will be included on the outage ticket. When CAROT identifies a trunk as marginal (i.e., not bad enough to remove from service), it notifies CMS and a trouble ticket is created and assigned to a craftsperson.

Routine operational tests include the typical types: 103, synchronous, centrex II, centrex III, and step-by-step types. They are scheduled and run by the 1A Processor. The data base can specify the test types and directory numbers for up to two tests per trunk subgroup. This flexibility is needed when the far-end office utilizes different trunk equipment for through and terminating switched calls. Trunk failures are reported to CMS. Protection is provided against the removal of an excessive number of trunks because of faulty test data or far-end test lines. Up to 24 trunk subgroups can be tested concurrently in the routine mode.

Carrier failure alarms can be reported to the 1A Processor via miscellaneous scan points in a signal processor. Each scan point is related via translation data to either 12 or 24 trunks, all of which are assigned to consecutive appearances on a Voiceband Interface Unit (VIU). This modularity is inherent in the connectorization plan used for the terminal equipment. The trunks will be removed from service and restored to service in response to the alarm. Each transition is reported to CMS.

Trunks terminating on a Digroup Terminal (DT) are not assigned to an alarm scan point. Rather, the digroup terminal has built-in alarm detection capabilities for reporting directly to the 1A Processor over the peripheral unit bus. In the case of a T-carrier failure, the trunks are removed from and restored to service and all transitions are reported to the CMS. Other impairments on T-carrier are also detected by the DT (e.g., slips) and are reported to the CMS by the 1A Processor.

The No. 4 ESS has the ability to continue to process calls even though one or more common control peripheral equipment units have totally failed. The trunks associated with the failed equipment are inoperable and are removed from service to prevent their seizure for use in a call. One or more modules of trunks, each of which contains 120 to 4096 trunks, is processed either in base-level processing or in a phase of software initialization. The trunks are automatically restored when the equipment is restored. For common control equipment failures, the CMS is not notified of the trunk outages. Rather, a message is sent to a teletypewriter located in the TOC to notify personnel of the outage. There is no repair function to be performed on the trunks. However, notification of far-end offices and coordination of the restoral process may be necessary.

5.1.2 Data for manual trouble detection

The plant and traffic measurement systems periodically present data organized by control area, trunk type, and failure type on all call failures in the office. These counts, together with base counts of the traffic volume, can be manually used to monitor trunk performance. This information can be scheduled as it is needed. In addition, once each day, or on demand, a list of the trunk subgroups with the worst performance is output on hard copy to the TOC. The list contains the eight trunk subgroups, in each of eight call-attempt ranges, that had the largest number of call irregularities in any 15-minute period since the list was last periodically output. Two-way trunks are considered separately for input and output. The call irregularity rate of a trunk subgroup on the list is manually determined to be acceptable or unacceptable.

In response to plant/traffic measurement reports, the worst trunk subgroup list, or other trouble detection processes, there can be a need to collect specific or exhaustive data or counts of call irregularities on trunks. The "data trapping" feature provides the capability to collect data for manual analysis. A "trap" is established by inputting a teletypewriter message to the system that identifies:

(*i*) The type of call irregularities (e.g., permanent signal, partial dial or "all")
(*ii*) The trunk(s) or trunk subgroup(s)
(*iii*) The sample rate (can be 100 percent)
(*iv*) The schedule (start time, stop time, repeat daily option).

Each time a call irregularity that is being "trapped" happens, a printout will be generated containing all pertinent data. This would include trunk identity, digits, service circuits, call-processing software state, failure identity, and other data as applicable. An option exists to count the events in addition to or in lieu of the data printouts. Up to 31 such "traps" may exist at any one time. In addition, up to four "office traps" may be established. Additional features of the "office trap" are that they each apply to all trunks in the office and a separate sample rate can be requested for each call irregularity type requested.

5.1.3 Removal from service

Faulty trunks are removed from service to prevent their use for a customer call. Except for removals due to common control equipment failures, all outages are reported to CMS, which creates a trouble or outage ticket for each occurrence. When trunks are removed because of common control equipment outages, messages are printed on a teletypewriter in the TOC. The number of circuits involved may be from 120 to several thousand per occurrence. No repair action by TOC personnel is needed; however, notification of far-end offices may be required. Trunks may also be removed from service because of a manual request via the CMS or by CRT directly to the 1A Processor. As with automatic removals, the CMS is always notified when a trunk is manually removed from service.

Two mechanisms are used to ensure that an excessive number of trunks is not removed from service by the automatic system. The first is that automatic processes, which might be the source of failure while the trunks are good (e.g., a bad far-end test line used for routine tests), cannot remove more than a fixed percentage of a trunk subgroup from service unless manually permitted to do so. The second safeguard is that a continuous audit of all out-of-service trunks is made against redundantly stored information that authorizes the outage. When an automatically detected condition (e.g., carrier failure alarm) is determined to be the only reason for a trunk to be out of service, the trunk will be automatically returned to service (and CMS notified) when the condition comes clear.

5.2 Trouble sectionalization and repair

Troubles can be automatically detected and reported to CMS by the No. 4 ESS or CAROT, or they can be manually reported to CMS via a CRT input. For example, suppose that CAROT detects excessive loss on the incoming path of a trunk between Chicago, Illinois, and Orlando, Florida, during routine testing. After repeating the test to verify the trouble, CAROT notifies the No. 4 ESS to remove the trunk from service and then sends a report to the CMS identifying the trunk and the trouble encountered. CMS creates a trouble ticket, assigns it to a work list, and sends the TOC a work message on the CRT screen (Fig. 14).

The heading of this display shows a "1" in the WORK field; this indicates new work on the first work list. The lack of other entries in the remainder of the heading indicates that there are no other messages pending and no individual trunks currently being worked on.

The "WORK 1" message can be sent to the CRT independent of any display that is on the CRT. In the general case, the CRT will have a display other than that shown in Fig. 14. If the craftsperson responsible for the work list does not know what to do next, the 3-digit input command "100" should be entered via the keyboard. This command generates the display in Fig. 14, which is an index of possible commands.

Entering "201" causes the current list associated with work list "1" to be displayed, with the most recent entry at the bottom of the list (outage number 273 in Fig. 15).

The craftsperson selects it to work on by entering "110/0273" (the "110" activation command and the assigned outage number) and then enters "300" to see the outage ticket (Fig. 16).

Noting the nature of the problem (see comments field in Fig. 16), the craftsperson decides on a strategy for locating the trouble and inputs a command (710/102) to connect the faulty trunk to a test tone in Orlando, Florida (Fig. 17).

CMS communicates the command to the No. 4 ESS, which seizes the trunk, outpulses the directory number for the far-end test line, and connects the trunk to the 51A test position.

The craftsperson then requests sectionalization measurements by inputting the command "631/1/R" (Fig. 18). The CMS sends a message to the Carrier Terminal Maintenance System (CTMS), which makes a series of tone measurements in the carrier equipment and passes the results back to the CMS. The CMS processor compares measured values with expected values and determines whether the trouble is in the near-end equipment, the carrier equipment, or the distant office. In this

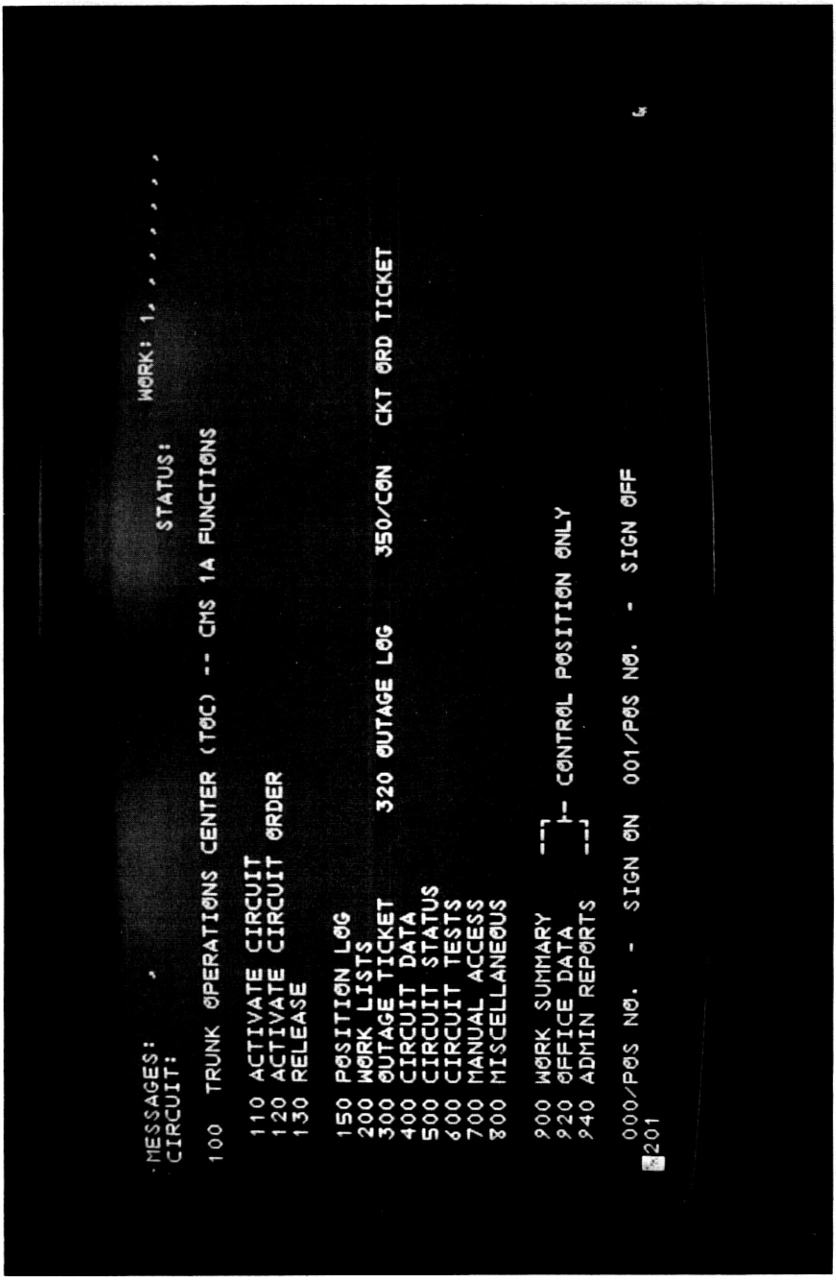


Fig. 14—CMS functions.

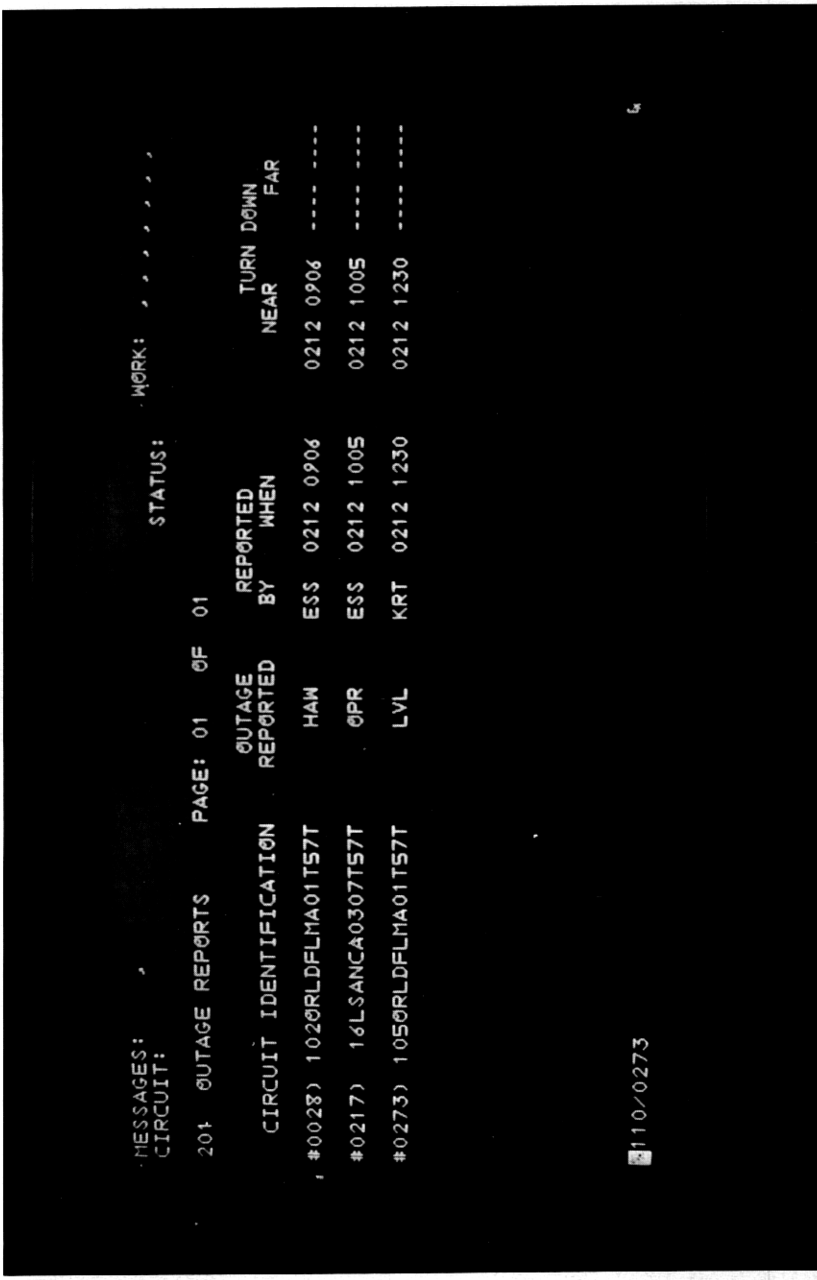


Fig. 15—Outages work list.

Fig. 16—Outage ticket.

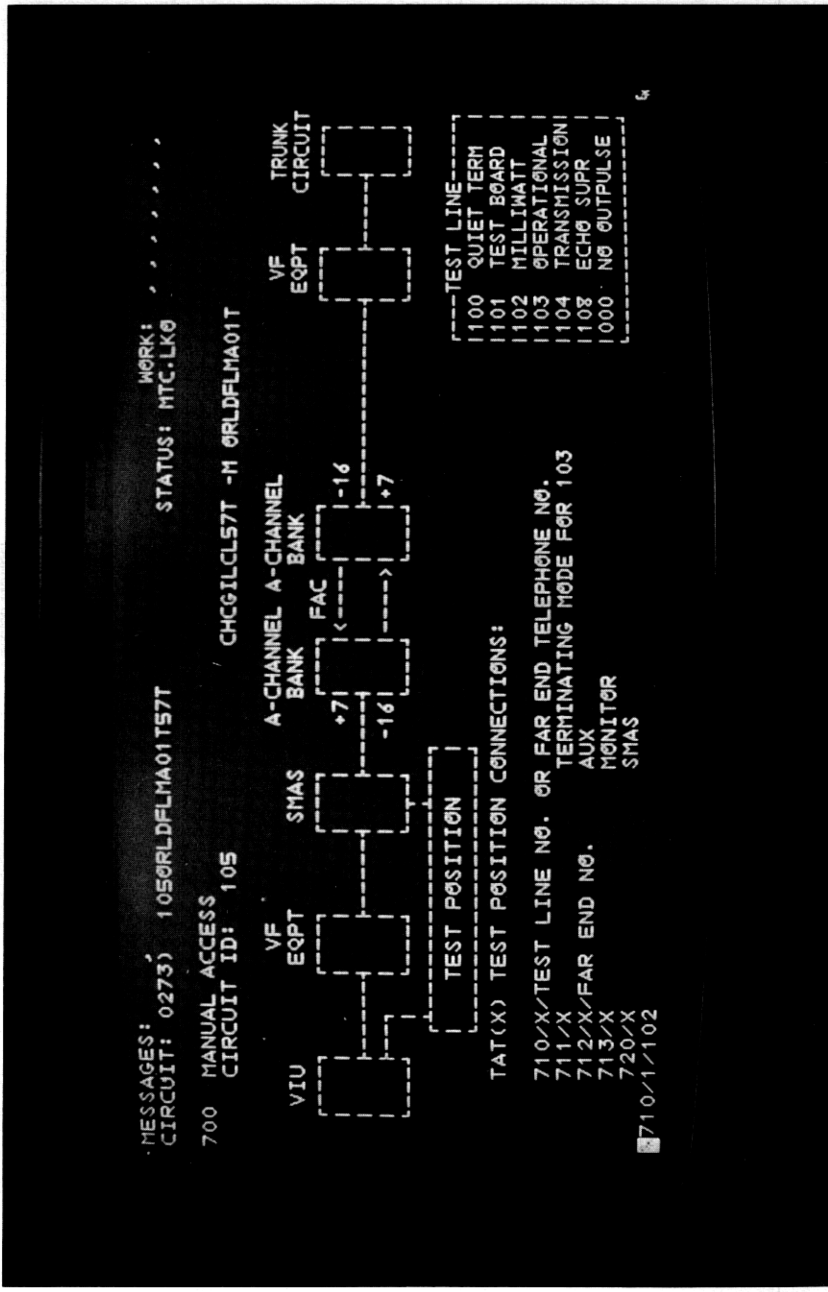


Fig. 17—Manual access commands.

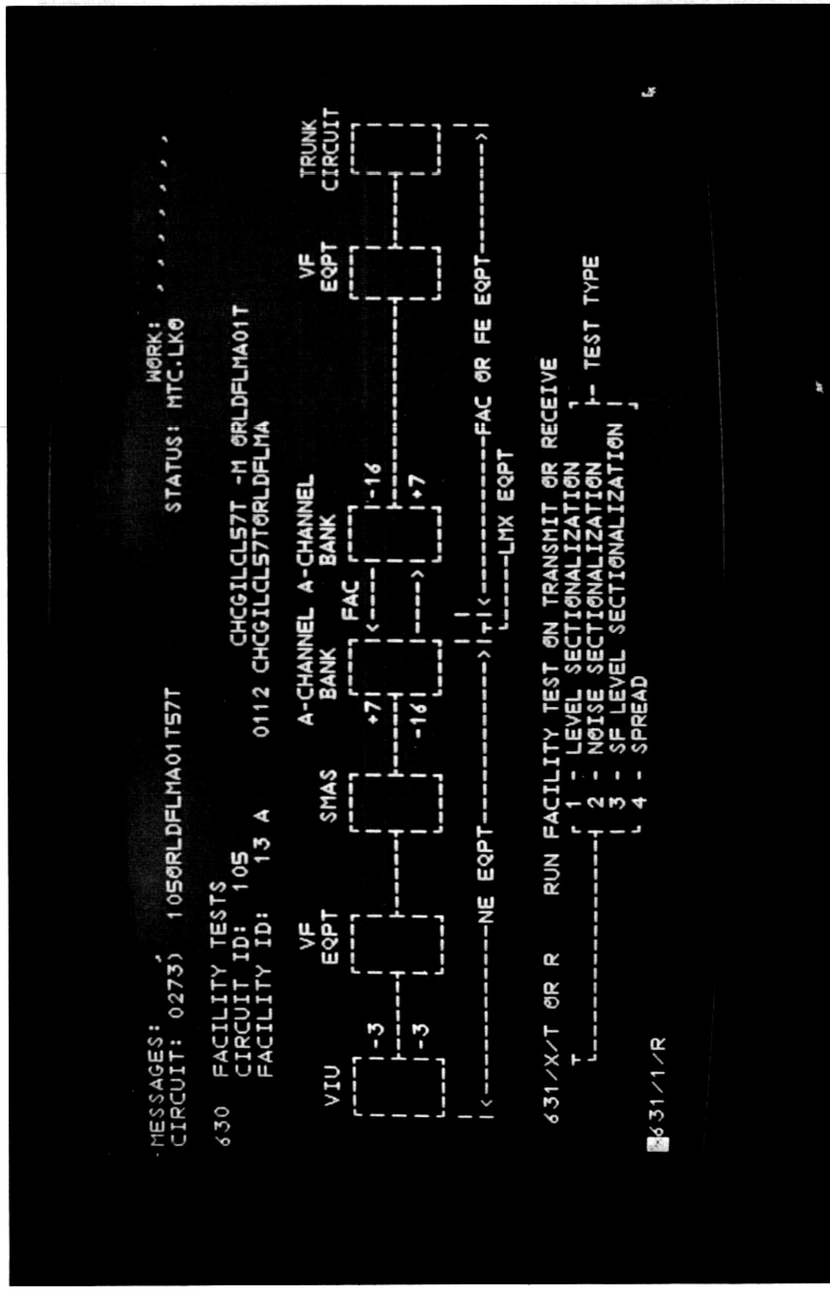


Fig. 18—Sectionalization test.

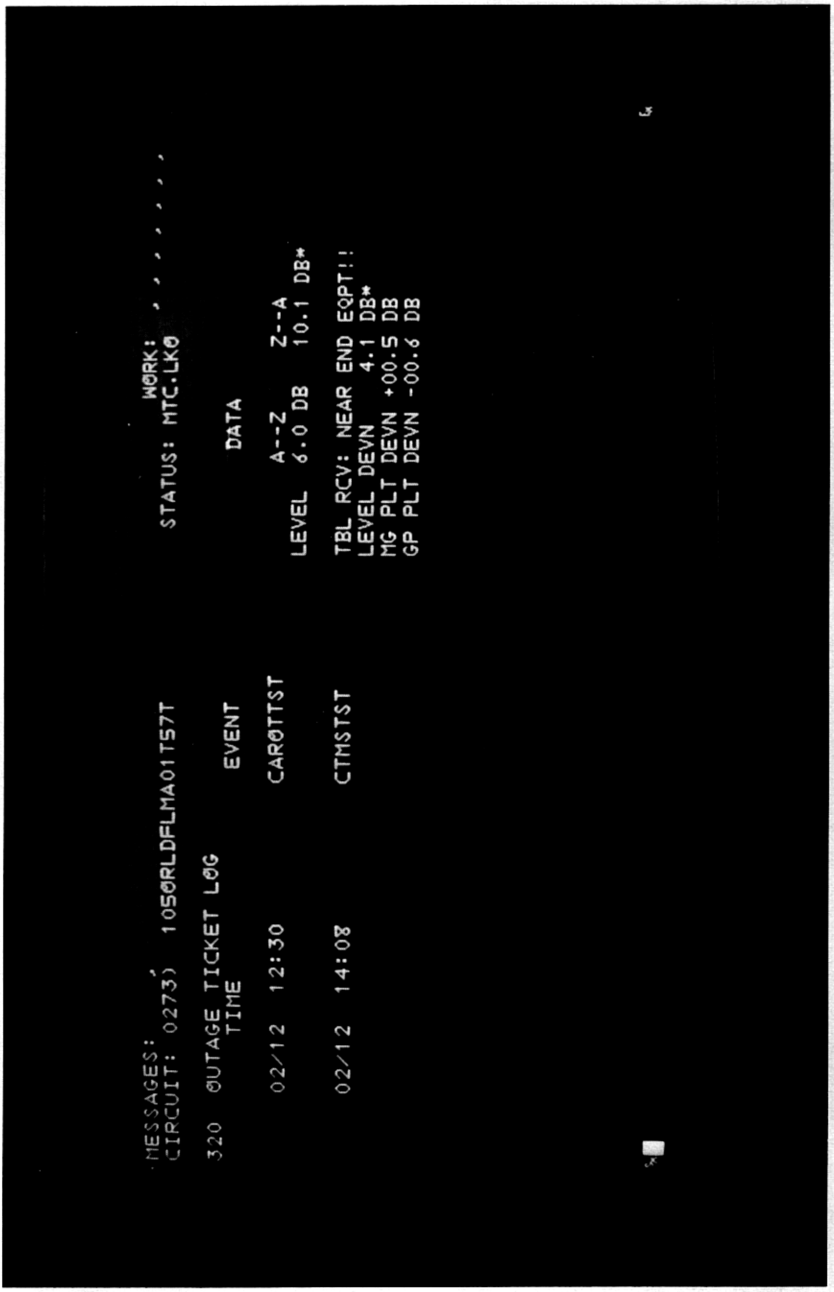


Fig. 19—Sectionalization results on outage log.

case, the trouble was in the No. 4 ESS office as noted on the outage log (Fig. 19).

The craftsperson can then enter the results of the tests on the trouble ticket and refer the trouble to the TEC. The personnel in the TEC can repair the faulty equipment, utilize the CMS to verify the problem has been fixed, put the trunk back in service, and clear the trouble ticket.

The preceding example was based on the assumption that the craftsperson was familiar with the CMS system and knew exactly what commands to enter to perform the desired functions. However, at any step it is possible to recall the "100" display (Fig. 14) to obtain a list of functional areas and then to enter the code (e.g., "700") for a functional area to obtain a list of functions (Fig. 17) within the area.

VI. SUMMARY

A No. 4 ESS can have over 100,000 trunks and the associated data base to support call processing. Both the trunks and the data base require installation, updating, and maintenance to meet initial and changing needs and to resolve and correct trouble conditions. The data base has been described.

The large quantities of data and trunks concentrated in a single switching machine created a concern that the cost of installation, update, and maintenance not grow disproportionately when compared with existing switching systems. Also, there were objectives to improve these processes to make them more efficient and less error-prone. The large concentration of trunks and data in No. 4 ESS that created these concerns also made it economic to develop auxiliary systems and subsystems to deal with them.

The systems developed include a Western Electric software system to generate, on a general-purpose computer, the initial data base from office wiring and trunking information, 1A Processor resident software to administer and maintain both the data base and the trunks, and three minicomputer systems (CMS, CAROT, and CTMS). The CMS provides a common interface to office personnel for all trunk maintenance activities and provides many administrative and coordination functions. CAROT and CTMS automate transmission testing capabilities that rely on an extensive data base.

Throughout the design of these systems, an emphasis has been placed on enhancing the personnel interface with the machine and on minimizing the need of manually produced records. Routine and administrative functions have been automated.