Apparatus and Equipment

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(Manuscript received March 6, 1969)

The No. 2 ESS achieves a standardized modular design that is easy to engineer, manufacture, install, operate, maintain, and administer. The use of much existing standard ESS hardware combined with thin film integrated circuits, plug-in growth units, and judicious interframe connectors, has contributed to the development of an economically attractive system for the small central office market.

I. INTRODUCTION

A small electronic switching system, even with the installation of 100 to 200 offices per year, would require production of a modest number of frames. Similarly, a new small electronic switching system cannot by itself support a large number of new apparatus codes that are normally incorporated in new system developments. Therefore, the No. 2 ESS has been designed to utilize much of the No. 1 ESS apparatus and thereby take advantage of the high volume, low-cost items associated with that system.[1,2] No. 1 ESS type peripheral equipment is also utilized: ferreed networks, ferrod scanners, and similar trunk and service circuits. Except for the smaller number of frames, a No. 2 ESS office appears strikingly similar to a No. 1 ESS office.

Utilizing existing standard apparatus provides a further dividend within the Western Electric Company. Start-up costs and development of machinery to fabricate new apparatus items are minimized, and existing standards and frame assembly techniques can be used. For these reasons, the first No. 2 ESS model at Bell Telephone Laboratories, Indian Hill, Naperville, Illinois, more nearly represents a production system than other early models for previous developments. This contributed significantly to minimizing development intervals.

Economies are realized in the system by controlling the size of growable units so that incremental growth unit costs, which are important in a small office, will not be prohibitive.

One example (others are discussed later) is the No. 2 ESS program store, which can grow in pluggable units of 16,384 words of 22 bits per word, contrasted with the No. 1 ESS growth unit of 131,072 words of 44 bits per word.

To further reduce costs, simplified installation is emphasized. The control complex frames are interconnected with connectorized cables. This allows a complete factory test of the entire control complex thus contributing to simplification and reduction in the installation effort in a central office. Other portions of the system, such as the network and communication bus, are also connectorized.

A low cost, small, easily installed system with a highly standardized modular design has been successfully achieved with the No. 2 ESS hardware design.

II. NEW APPARATUS AND EQUIPMENT—BASIC PACKAGES

The major new apparatus items in No. 2 ESS are: (*i*) thin film transistor-resistor logic gates; (*ii*) the network shift register; (*iii*) a peripheral decoder; (*iv*) an ac bus connector; and (*v*) a single-card memory card writer. Sections V and VI discuss these items in detail.

Because of system organization, and to meet economic considerations associated with the small office objectives, No. 2 ESS uses new codes of program store and call store memories. However, these memories are fabricated with the same parts and techniques as in No. 1 ESS to save money and to minimize development effort.

III. FRAMES

The system uses the No. 1 ESS framework; the frames are single sided, seven feet high with modular widths of one foot, one inch. Sheet metal uprights of one and one-fourth by five inches are placed on a one foot deep base to provide an 8½ inch depth for apparatus on the front and 3½ inch depth for wiring on the rear.

3.1 *Frame Equipment*

No. 2 ESS uses No. 1 ESS type apparatus for most of its functions. This apparatus includes ferreed switches for network switching, ferrod sensors for scanning, wire spring relays for trunk circuits, twistor and ferrite sheet memories, and plug-in circuit packs. Newly coded apparatus is described in Section V. These components are arranged on 22 frames listed in Table I in a manner which makes each frame, as nearly as practicable, a completely functional building block free of options.

The master scanner, recorded announcement, power distributing, miscellaneous power, protector, miscellaneous, and the combined distributing frames are the same as in No. 1 ESS. The remaining 15

TABLE I—FRAMES, ABBREVIATIONS, AND LENGTHS

Frame	Abbreviation	Length		Number Required
		Feet	Inches	
Automatic message accounting	AMA	2	2	0 or 1 per office
Combined distributing	CDF*	6	6	1 to 8 per office
Central processor	CP	4	4	2 per office, includes 8192 words of call store and 512 CPD points
Junctor grouping	JG	2	2	1 to 3 per office
Line-trunk switching	LTS	3	3	1 to 4 per line-trunk network
Miscellaneous	M*	2	2	As required
Maintenance center	MC	4	4	1 per control complex may include single card writer
Miscellaneous power	MP*	2	2	1 per office
Master scanner	MS*	2	2	1 minimum per office
Miscellaneous trunk	MT	2	2	As required
Network control junctor switching	NCJS	6	6	1 per line-trunk network
Power distributing	PD*	2	2	2 or 4 per office
Protector	PROT*	6	6	1 to 5 per office
Program store	PS	4	4	2 to 8 per office
6.7 V, 200 A power plant	PWR	2	2	2 per control complex
Recorded announcement	RA*	2	2	1 per office
Ringing and tone power plant	RT	4	4	1 or 2 per office
Supplementary central pulse distributor	SCPD	2	2	0 to 8 per office, supplements CPD in CP
Supplementary call store	SCS	2	2	0 or 2 per control complex supplements call store in CP
Supplementary ringing & tone	SRT	2	2	As required
Trunk test	TT	2	2	1 per office
Universal trunk and junctor	UTJ	6	6	As required

* Identical No. 1 ESS equipment.

frames are designed to reflect the system objective of providing a low cost small electronic central office.

3.2 *Control Panel*

Control panels are provided on most of the No. 2 ESS equipment frames. A typical control panel contains a group of pushbuttons, indicator lamps, and test jacks. Power can be disconnected from or restored to various sections of the frame by operation of the keys. The keys are mechanically interlocked to prevent concurrent removal of power from duplicated units. The control panel also has a remote execute switch which will permit a maintenance man to start a maintenance program previously enabled at the maintenance center. Telephone jacks on the control panel permit convenient voice connections to other locations within the central office.

IV. OFFICE ARRANGEMENTS

4.1 *Floor Plans*

Standard frame arrangements in an office minimize engineering and installation costs. A universal floor plan has been developed which grows naturally from the smallest to the largest installation. The pattern applied to a typical office is shown in Fig. 1. Some important features of this pattern are:

(*i*) The control complex frames, that is, maintenance frame, central processors, stores, 6-volt power frames, and trunk test frame have a fixed relationship in every office.

(*ii*) The frame lineups are so arranged that the office will grow approximately one lineup for every network added.

(*iii*) The protector and combined distributing frames grow perpendicularly to the frame lineups. These frames are aligned with the associated network frames for orderly growth together in a way that automatically minimizes cable and combined distributing frame jumper lengths.

(*iv*) The floor plan fits standard building bays of new buildings and can be readily adapted to existing buildings.

4.2 *Cable Rack, End Guards, and Office Lighting*

The cable rack, end guards, and office lighting equipment are the same as in No. 1 ESS. The cable racks conceal and shield interframe cabling and are supported by the frames (see Fig. 2). Because the frames are low and the aisles are relatively free from overhead racks,

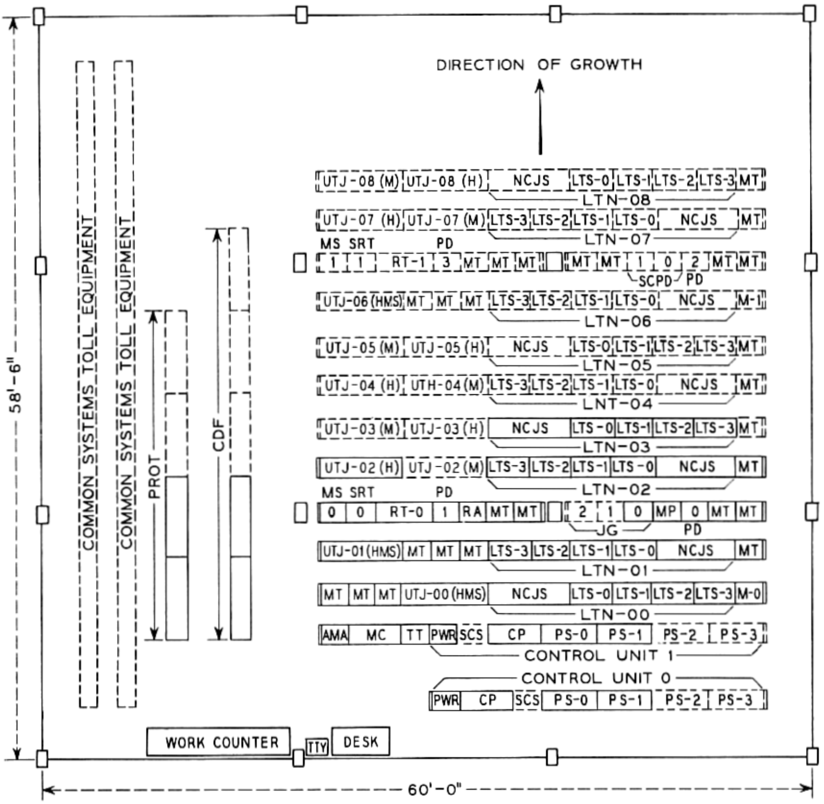

Fig. 1.—Typical No. 2 ESS office floor plan. Solid lines are four line-trunk networks with 4:1 concentration ratio for approximately 6500 lines and 850 trunks and service circuits. Dashed lines show how pattern continues with growth. See Table I for key to abbreviations.

excellent illumination is obtained with either the frame supported lighting or ceiling lighting fixtures. There are guards at ends of frame lineups, and at each exposed frame within a lineup. Aisle alarm lamps, aisle directories designating the frames in each lineup, and frame lighting control switches are in the end guards.

V. APPARATUS

5.1 *Logic*

The No. 2 ESS control complex uses approximately 6,600 logic substrates (14,300 gates) and 300 binary counter substrates. Up to

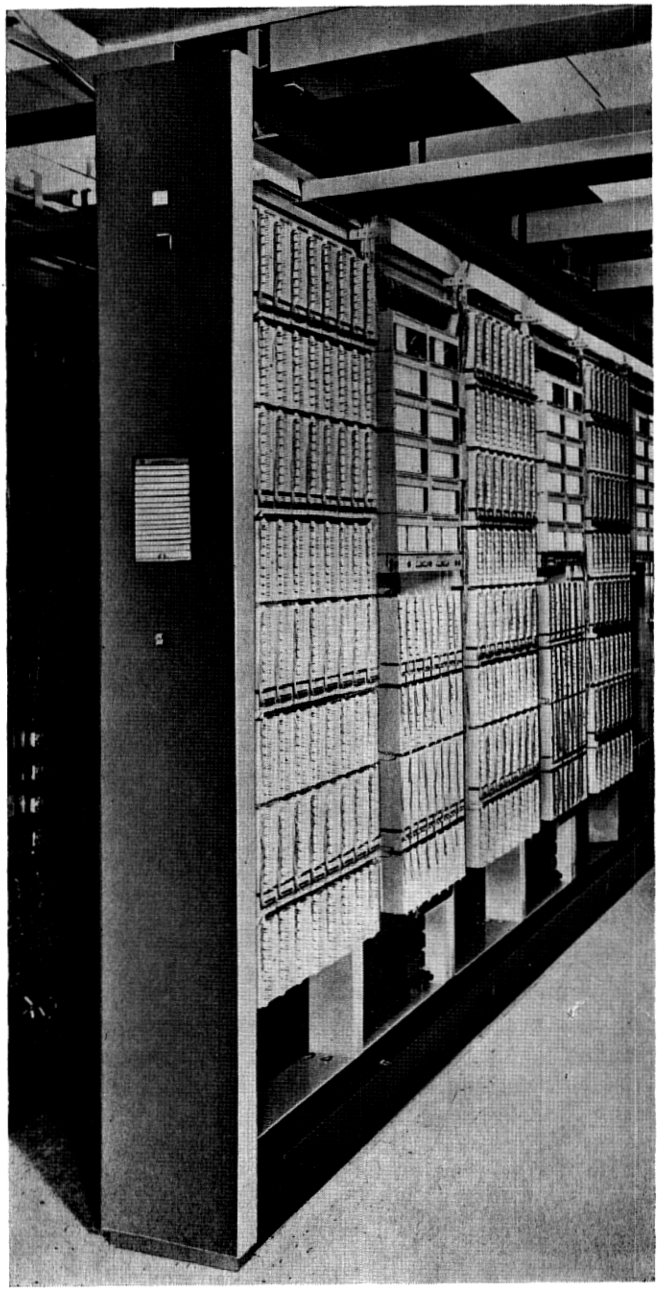

Fig. 2 — Typical equipment aisle.

five logic substrates or four binary counter substrates mount on a circuit pack.

The No. 2 ESS logic circuits are composed of high speed transistor resistor logic gates which are physically constructed from thin film resistors and beam lead transistors on an alumina substrate. Eighteen different codes make up the family of gate configurations consisting of two and four input NOR gates with fanout capabilities of three, ten, and forty-four. The number of circuits per substrate range from one to four depending upon complexity.

Three silicon npn devices are used in the gate circuits: a low current single transistor, a high current single transistor, and a double transistor. The alumina substrate is 0.025 inch thick by 0.55 inch wide by 1.825 inches long with seven terminals on each of the two long sides (Fig. 3). Tantalum nitride resistor films and titanium-gold conductor films are deposited on the underside of the alumina with the beam lead devices appliqued. The nickel and gold plated copper terminals are connected "inboard" from the edge of the substrate with sufficient space remaining for conductor paths to encircle the terminals. This design minimizes the number of crossovers to achieve the desired topology. Only three of the 18 codes require physical crossovers which are made with copper backstraps. Thermocompression bonding is used for all connections on the gate.

The binary counter circuit is compatible with the highspeed tran-

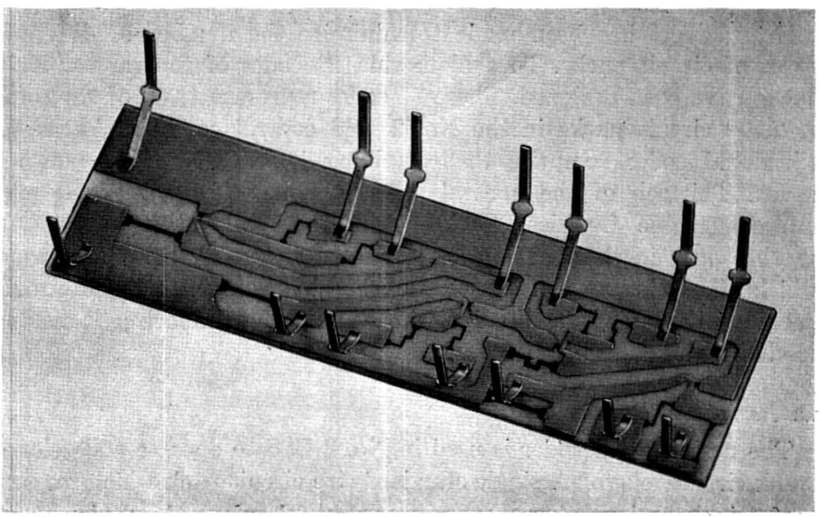

Fig. 3 — Transistor-resistor logic gate.

sistor resistor logic gate and consists of one bistable flip-flop with emitter follower outputs. A pulse steering network at the input enables the binary counter to be used as a toggle flip-flop or shift register stage. A thin film resistor network on a ceramic substrate forms the basic package. Circuit elements other than resistors are conventional leaded components with the leads inserted through holes in the ceramic and connected by soldering to the thin film circuit. Four discrete capacitors, two diodes, four transistors, and 16 thin film resistors are contained on a 0.025 inch by 1.0 inch by 2.0 inch substrate (Fig. 4).

5.2 *Circuit Packs*

The circuit pack is a plug-in subassembly consisting of a 3/32 inch phenolic laminate board with two-ounce copper paths formed through an etching process. These paths interconnect circuit components mounted on the board to form circuit configurations of various types. A plastic faceplate is riveted to the front edge of the circuit pack as a convenient place for code identification and to provide a slot for the tool used to remove circuit packs from the equipment. Twenty-eight terminals at the rear of the board mate with a connector mounted in the wiring field of the frame to provide an interface between the system and the circuit pack. The nominal size of the circuit pack is 3.75 inches high, 6.94 inches deep, with horizontal mounting centers in 0.20 inch multiples from 0.40 inch up through 2.00 inches (Fig. 5).

Every effort has been made to minimize the number of different codes of circuit packs. To achieve this, 21 codes of general use logic packs have been designed. These 21 codes represent 1,900 of the total of 2,700 circuit packs in the No. 2 ESS control complex. About 80 additional codes comprise the remaining logic and special purpose packs. Thirteen of the general use packs have been grouped into interchangeable families. Packs within a family differ from one another only in their output drive capacity. Thus, a circuit change which affects fanout can be accomplished by changing plug-in circuit packs without rewiring that position. Table II summarizes these interchangeable groupings.

5.3 *Peripheral Decoder*

The peripheral decoder is used in No. 2 ESS to operate and release trunk circuit relays.[3] A single standard size circuit pack which mounts on 0.4 inch horizontal centers will control 12 relays. A maximum of 64 of these circuit packs is required for one universal trunk frame.

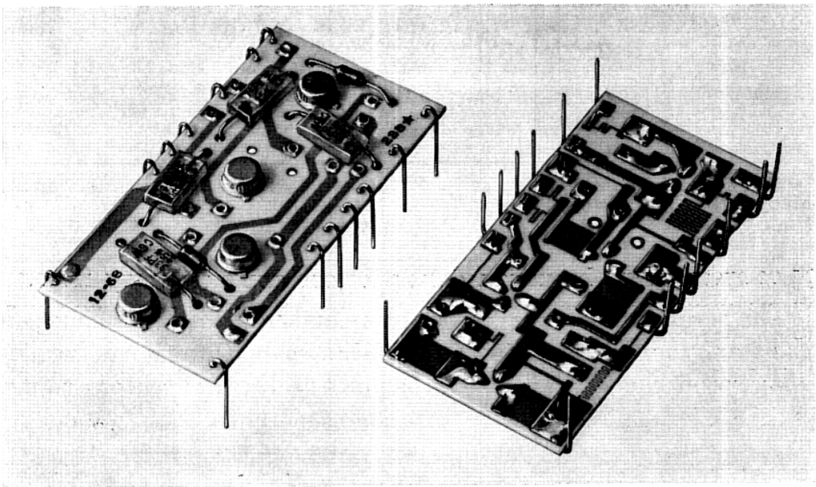

Fig. 4 — Binary counter.

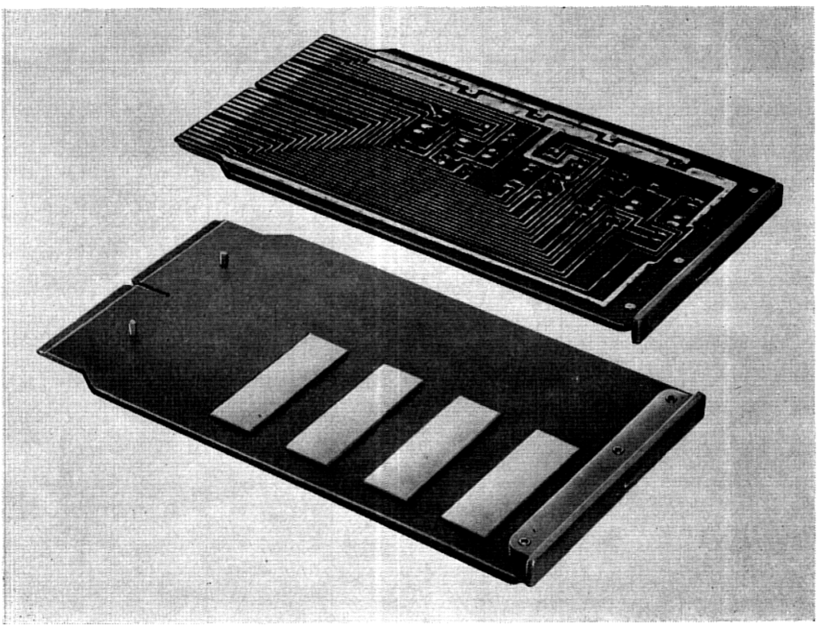

Fig. 5 — Logic circuit pack.

TABLE II—INTERCHANGEABLE CIRCUIT PACKS

Fanout	8 two input gates	2 binary to 1/4 translators	5 four input gates	3 high-fan-in gates	4 gates plus 4 bit register	4 gates plus 2 bit register
Low	x	x	x			
Medium	x	x	x	x	x	x
High			x	x	x	x

The peripheral decoder consists of a number of discrete components and two hybrid integrated circuits which together form a shift register and relay driver unit (Fig. 6). A number of discrete resistors, capaci-

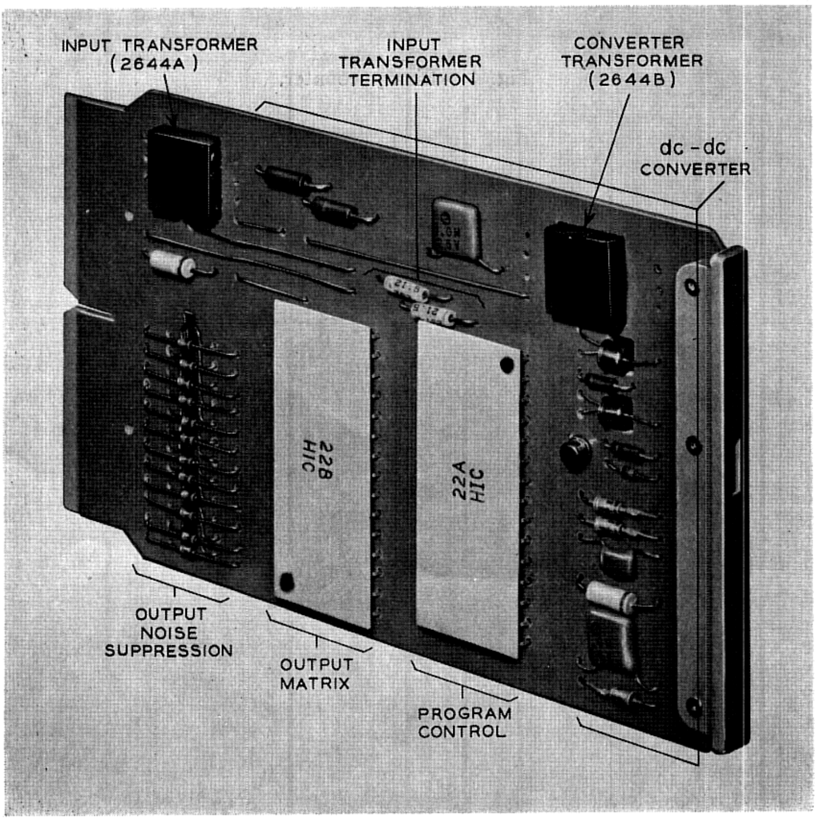

Fig. 6 — Peripheral decoder.

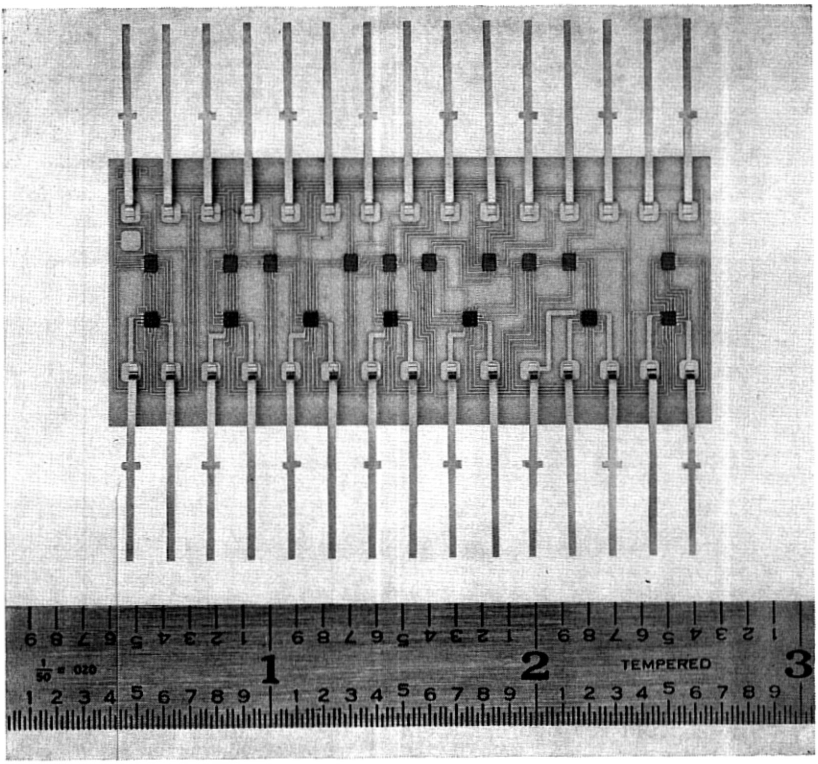

Fig. 7 — Hybrid integrated circuit.

tors, transistors, and a toroid transformer are used to convert 24 volts dc to 4 volts dc. A second transformer receives information from the central pulse distributor. This information is translated by the peripheral decoder and is used to control the trunk relays.

The substrates used for the two hybrid integrated circuits are 0.025 by 1.00 by 2.28 inches, high-alumina ceramics. Gold conductor paths five mils wide are deposited on the ceramic to provide circuit patterns. Thirty of these paths terminate at 75 mil square pads to provide bonding areas for external leads; 15 leads are thermocompression bonded on 0.150-inch centers on each long side of the substrate. The hybrid integrated circuits are mounted across the width of the board and 0.150 inch above it. This minimizes the possibility of broken ceramics from board warpage and rough handling. The separation of

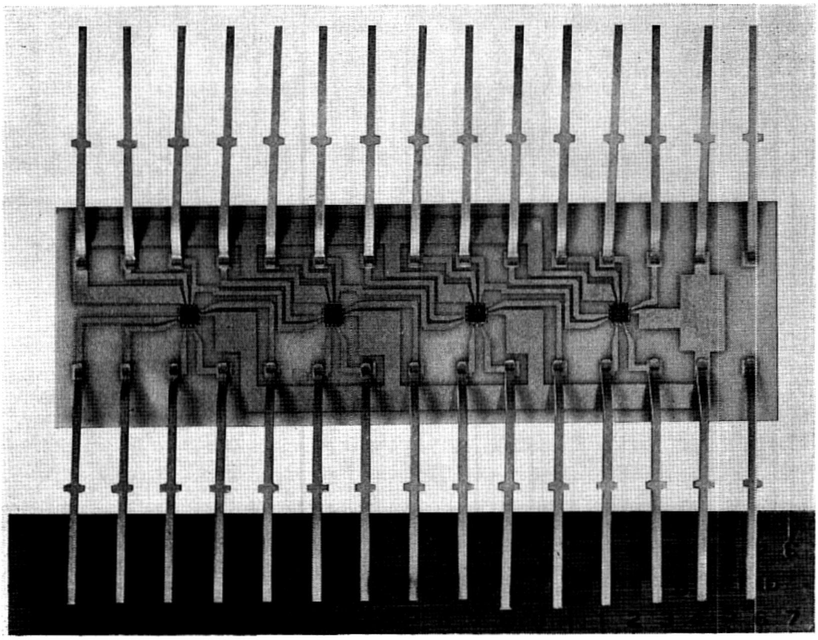

Fig. 8 — Four-bit register.

the ceramic from the board aids in cooling the units since at maximum load they dissipate as much as 0.5 watt each.

As shown in Fig. 7, seven devices on the lower edge of the ceramic form an 8-bit shift register with its associated gating circuitry. The remaining ten units are crossover chips which provide up to 25 "one-over-one" crossovers each. These chips will be replaced by air insulated crossovers in the future. All devices and crossover chips are thermocompression bonded to gold pads on the ceramic surface. A protective coating is applied to the device surface of the substrate. The complete hybrid integrated circuit is then mounted on the peripheral decoder circuit board in the same manner as other discrete components.

5.4 *Network Integrated Circuits*

The device shown in Fig. 8 contains four J-K flip-flops arranged to form a 4-bit register and is used on circuit packs in the network control junctor switch frame. The ceramic circuit, which is 0.025 by 0.68 by 2.28 inches, is fabricated in the same manner as similar devices used in the peripheral decoder.

5.5 *Bus Connector*

Transformer-coupled bus signaling is used between the central processor frame and the program store frames, and between the central processor frame and the network frames (see Section 7.2). As shown in Fig. 9, these connections plug in by means of newly coded connector assemblies.[4]

The balanced transformer-coupled bus loops through each frame and passes through a pick-off transformer for each required bit. Good noise and crosstalk characteristics are achieved by balanced grounding through center-tapped inductors in a physical package similar to the transformer. The inductor or transformer assembly mounts in the frame on a plate. The mating connector is arranged for attachment to the end of an interframe cable. The inductor or transformer assembly has a structure resembling a chest of drawers with a maximum of 12 trays assembled into a stamped metal housing. Eight male connecting terminals are provided on the front surface of each tray. Four of these connecting terminals mate with one connector while the four remaining terminals mate with the second connector. Thus, two cables plug in to each assembly.

VI. EQUIPMENT FRAME DESIGNS

6.1 *Control Complex*

6.1.1 *Central Processor Frame*

The central processor frame, Fig. 10, is part of the control complex which provides the primary control for operating a No. 2 ESS central

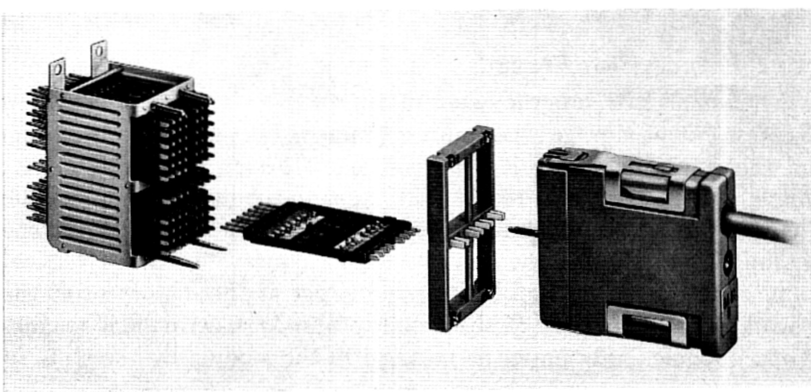

Fig. 9 — Bus connector.

office. The central processor uses instructions coded in adjacent memory frames to direct calls through the central office and to aid in detecting and analyzing improper performance of the equipment involved in this task. The processor is capable of addressing and reading a maximum of 262,144 words of semipermanent memory. This memory is located in program store frames providing up to 65,536 words of memory per frame.

Each central processor provides the logic to read and write into 32,768 words of temporary memory. This memory is provided by a complement of four call store units. The first two call store units mount in the processor frame while the remaining two optional units mount in a supplementary call store frame.

A local central pulse distributor matrix located in each processor frame provides for up to 512 enabling central pulse distributor points which may be equipped as required. One circuit pack provides a maximum of eight central pulse distributor points. Points on this matrix are also used to enable supplementary central pulse distributor frames. Each supplementary frame provides an additional 512 duplicated central pulse distributor points used for signaling purposes.

Communications with the peripheral equipment is by means of ac signals. These signals are carried over dedicated interframe address and answer buses which originate and terminate on the central processor frame. This plug-in access, provided by the bus connectors as well as the other control complex connectorization discussed in Section 7.2, allows the control complex to be thoroughly shop tested, disconnected, the frames shipped to the central office, and easily reconnected. This results in improved shop testing and a reduced installation interval.

6.1.2 *Program Store Frame*

The No. 2 ESS program store frame shown in Fig. 11 provides 65,536 words of storage when fully equipped. The word size is 22 bits and the store cycle time is 6 microseconds. Four pluggable memory units allow for growth in 16,384 word steps to the maximum of 65,536. The pluggable memory unit (Fig. 12) installs from the front in one of the four dedicated frame locations and occupies 26 inches of vertical frame space. This unit can be installed either at the factory or at the central office. The heart of the memory unit is a permanent magnet twistor module. Information is retained in the module by the state of

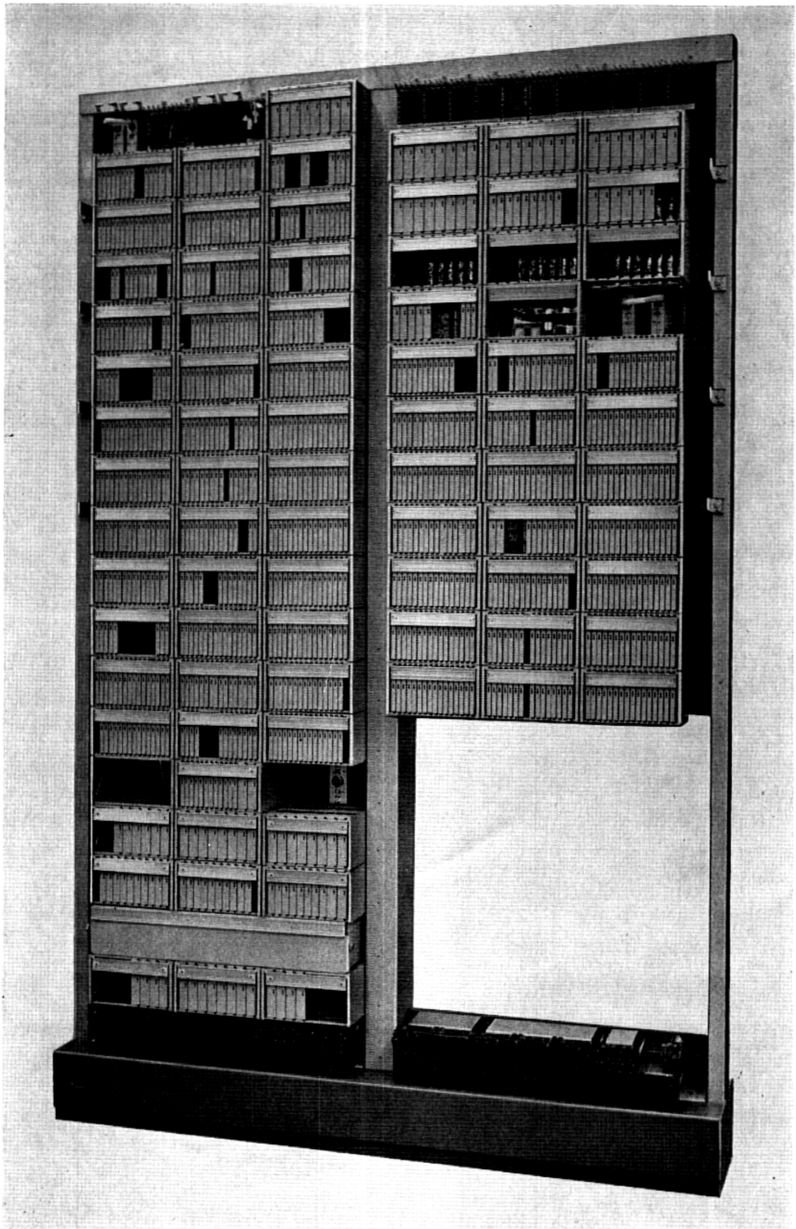

Fig. 10 — Central processor.

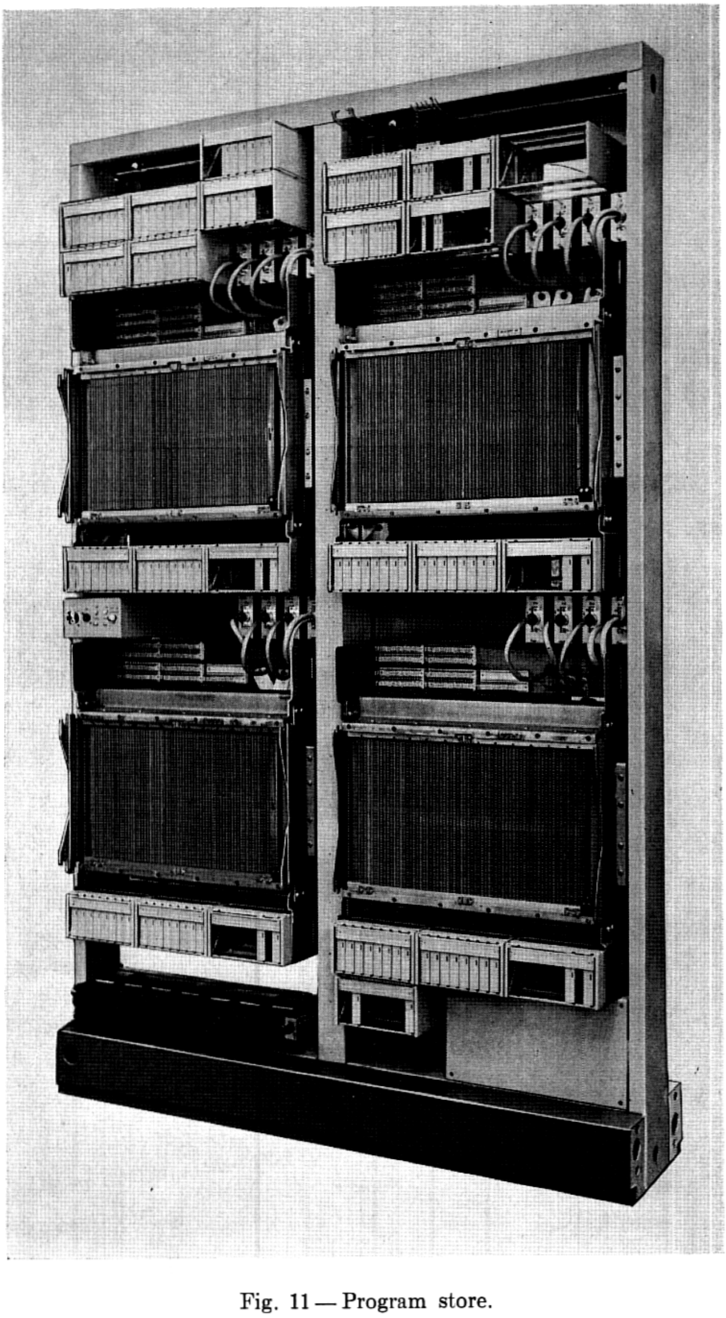

Fig. 11 — Program store.

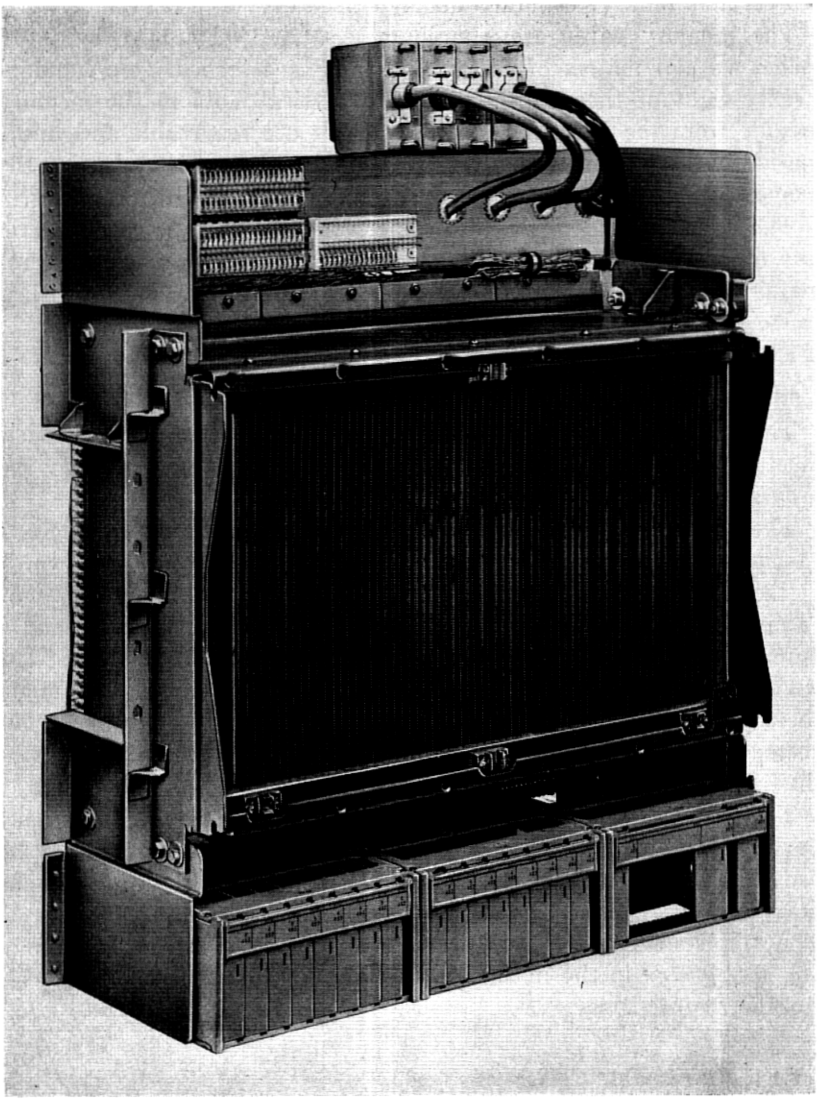

Fig. 12 — Program store unit.

magnetization of small permanent magnets. A magnetized magnet represents a binary "0" and a demagnetized magnet a binary "1".

The memory cards are aluminum sheets 6½ by 11¼ by 0.016 inches with a matrix of 64 by 44 magnets attached. One hundred twenty-eight of these cards slide into vertical slots in the memory module from the front. The memory cards are removable and information on them can be changed by removing the cards and using the memory card writer to change the magnetization of their magnets.

The common control for the memory module units is contained in two units each occupying 12 inches of vertical frame space. The remaining frame space contains miscellaneous units such as the fusing, connectors, and a test jack panel.

6.1.3 *Call store*

The call store is used to hold rapidly changing information that must be available for interrogation and modification by both the program control and the input-output circuits.[5]

The call store is arranged in modular units each providing 8,192 16-bit words of storage in the fully equipped form and 4,096 words in the half equipped form. A 4,096 word call store unit consists of 74 circuit packs, a ferrite sheet plug-in module of 4,096 words, and a dummy module containing terminating resistors. To grow to 8,192 words, the dummy module is replaced by a second 4,096 word ferrite sheet module and several circuit packs are inserted in prewired connector positions. The 8,192 word call store unit as a whole connects to the frame through three patch cables.

The first 16,384 words are provided in two call store units equipped in the central processor frame. Two additional call store units may be provided in the supplementary call store frames to increase the temporary storage from 16,384 words to the maximum of 32,768 words. The supplementary call store frame is a growth unit and may or may not be required in the initial installation, depending on the office call storage requirements.

6.1.4 *Maintenance Center*

The maintenance center frame (Fig. 13) provides the equipment which allows manual control of the system. Interrogations are made through a teletypewriter or the display panel controls. The answers are returned on a printout from the teletypewriter and visually on the display panel.

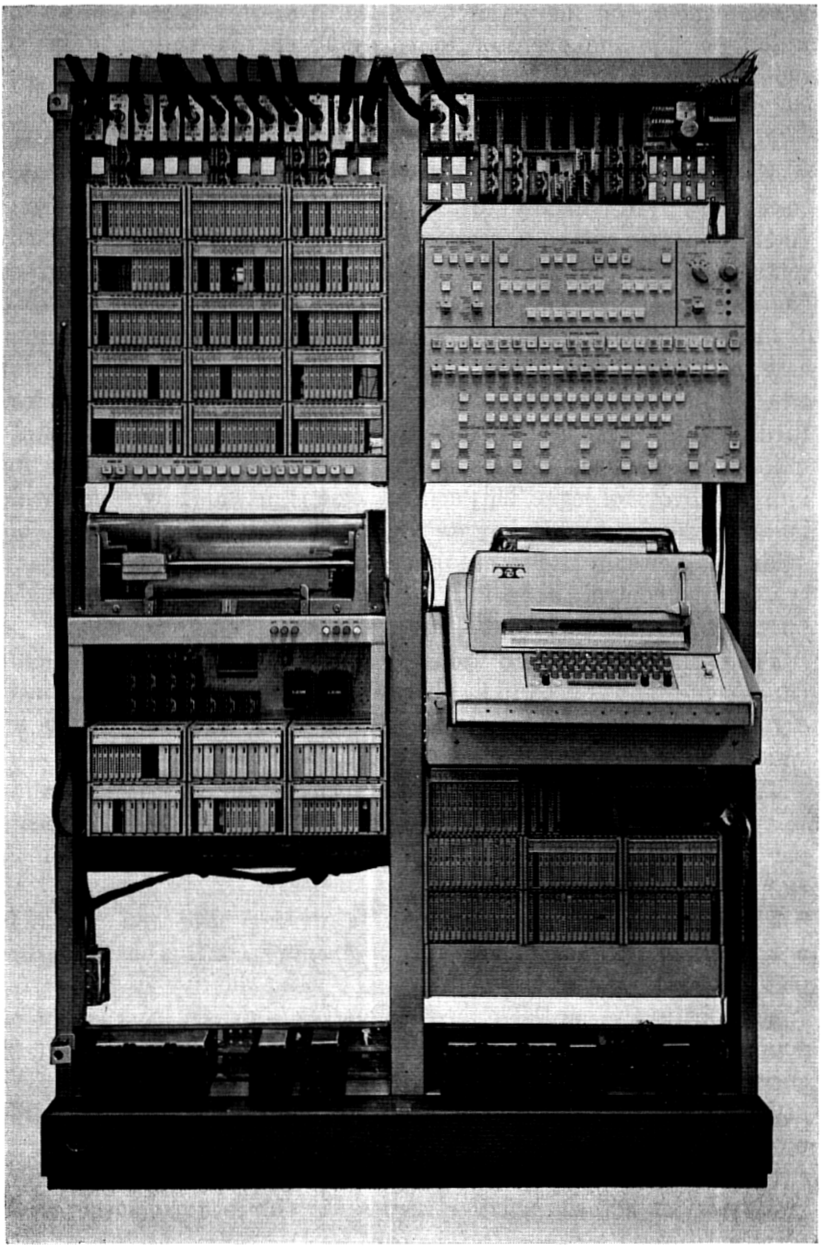

Fig. 13 — Maintenance center.

The controls on the maintenance frame are arranged in a manner which permits the operator to easily reach the various keys and switches which must be operated. Units not containing keys and switches are relegated to less convenient areas on the frame.

The maintenance center circuit provides the means for interrogation of the control complex. The maintenance center gathers information to be displayed visually to the operator. The control unit signals enter the frame via connectors and through buffer circuits their contents are shown on the display panel. The logic, which gathers the control unit information, is mounted on general purpose circuit packs.

The teletypewriter control circuit provides the logic to communicate with a maximum of eight teletypewriters directly or through data sets. The control equipment consists of a panel which contains keys to disconnect signals from the teletypewriters and data sets, and a unit which directs signals shared by all teletypewriters to their individual control logic. This control logic is provided by a unit which is arranged for two teletypewriters but equipped to control one. Additional circuit packs are added separately for the second teletypewriter control, when it is required. The control logic is able to operate either 33- or 35-type teletypewriters.

The optional single card writer (Fig. 14) is mounted in the maintenance center and is used to magnetize permanent magnet twistor memory cards. The card writer consists of two basic units: the control and logic circuit, and the mechanical card writing unit.

The control and logic unit contains circuit packs, controls, and a relay panel. Two connectors for the writing head are centrally located on the rear of the relay panel together with a connector cable for coupling to the card writing unit.

The card writing unit consists of a writing head and means for accurately moving the head over a memory card. The head drive uses two rods to precisely position the head relative to the surface which locates the card. The head mounting is driven by a lead screw coupled to a dc motor with a gear belt. A base casting provides a flat surface for the card and a rigid mounting for the head drive. The casting is fastened to the subframe at three points to minimize strains or distortions.

Once a magnet card is placed in the writer, the magnetizing information, after a teletypewriter request, is obtained from the system via a teletypewriter request. The card writing unit, driven at a speed of 10.3 inches a second, is used to write 11 bits simultaneously. Since

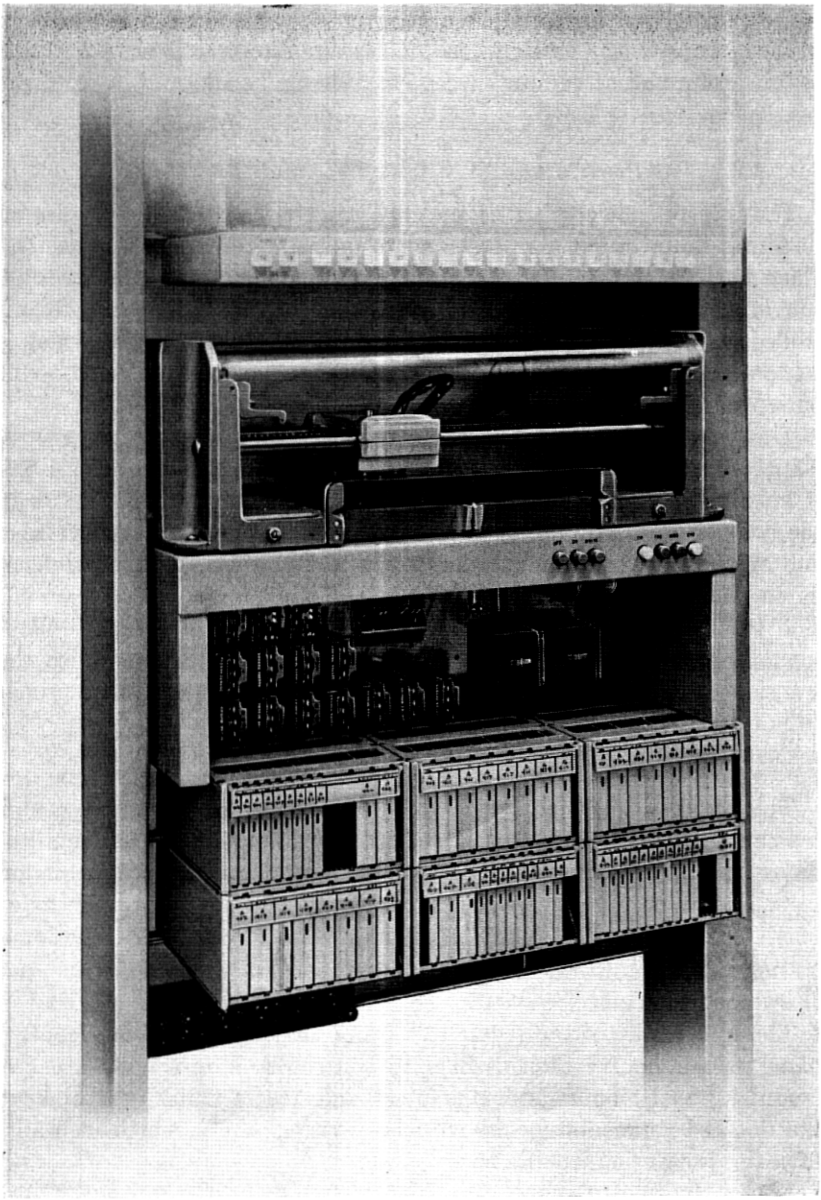

Fig. 14 — Single card writer.

the system can furnish 22 bits every 25 milliseconds, the information to be magnetized is stored in a register and on demand is gated in 11-bit groups to the writing head. The same circuitry is used for each 11-bit group and after four successive passes all 44 bits of every magnet row are written.

6.1.5 6.7 *Volt Power Plant*

The 6.7 volt power plant is designed to provide +6.7 ±0.2 volts up to a maximum of 200 amperes and to operate from −48 volt central office battery. Each plant consists of two major parts: the dc-to-dc converter and plant control circuitry. The converter uses silicon controlled rectifiers to invert the −48 volt dc to high frequency ac which is stepped down, rectified, filtered, and appears as regulated 6.7-volt power on output buses in the plant.

The control circuitry, consisting of contactors, wire spring relays, distribution fuses, and timing circuits, connects and removes the +6.7, +24, and −48 volt loads located in the various equipment frames in the control unit. The power is removed in descending order of voltage and restored in ascending order to protect the semiconductors from damage caused by higher voltages being on while lower voltages are off. The total 6.7-volt load is split into approximately 25 ampere time-sequence steps for removal and restoration in order to minimize the transient effects and ground noise which could interfere with proper circuit operation.

6.1.6 *Trunk Test Frame*

The trunk test frame is located between the maintenance center frame and the 6.7 volt power frame. This equipment permits maintenance personnel to make a variety of operational and transmission tests on trunks and service circuits. Leakage and continuity checks of both trunks and lines can be made although complete functional testing of customer lines is directed from a No. 3 local test cabinet elsewhere in the office.

The upper half of the trunk test frame, Fig. 15, contains a control panel which houses alarm, display, control, and test apparatus. A modular panel-mounted telephone set and access trunk control keys are located immediately above the writing shelf which contains facilities for storing trouble record cards.

Above the control panel provision is made for the voltmeter test panel and five optional test units: (*i*) transmission measuring set, (*ii*) noise measuring set, (*iii*) impulse counter, (*iv*) peak-to-average

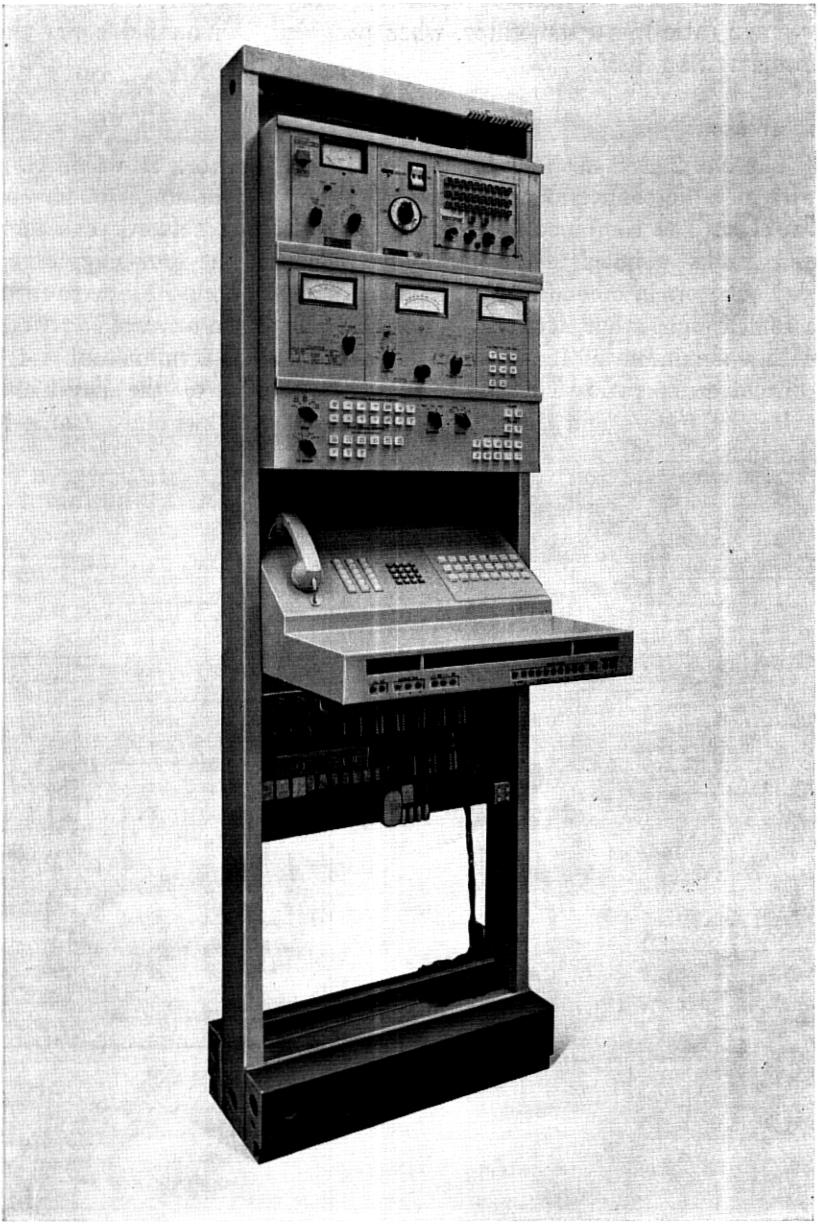

Fig. 15 — Trunk test frame.

ratio meter receiver, and (v) voice frequency oscillator. The peak-to-average ratio meter generator, when provided, is mounted below the frame writing shelf.

6.2 *Network*

The No. 2 ESS network is a space division network in which two-wire metallic connections are switched through eight stages of ferreed switches. The combined line and trunk switching network has lines and trunks assigned to terminals at one side of the four-stage array with junctors interconnecting the switches on the opposite side to form a folded eight-stage network. No. 2 ESS offices are arranged to work with a maximum of 15 networks providing 30,720 terminals at a 4:1 concentration ratio. The interconnection pattern of the line-trunk switching frames and the network control-junctor switching frame is shown in Fig. 16.

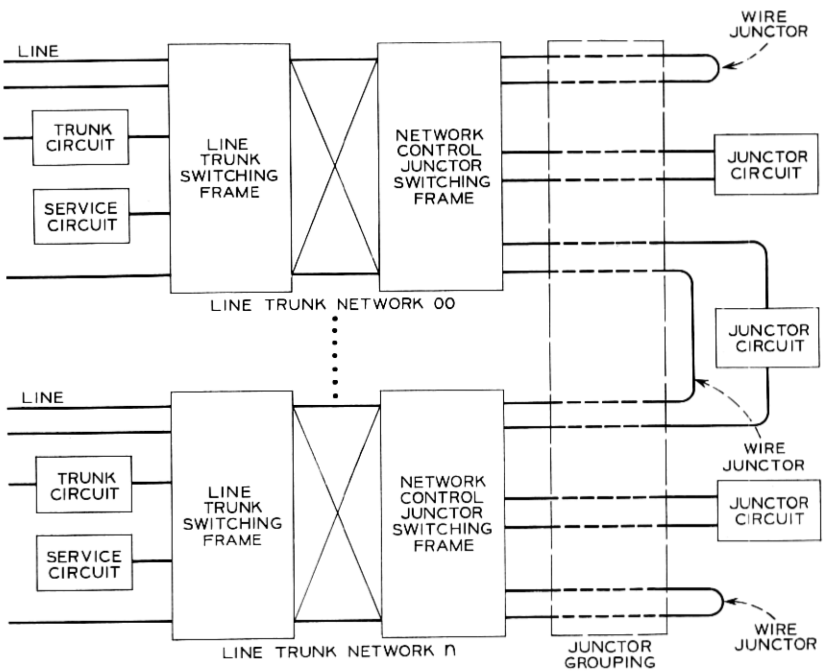

Fig. 16 — Network block diagram.

6.2.1 *Line-Trunk Switching Frame*

The basic line-trunk switching frame, Fig. 17, provides two 256 terminal concentrator groups with two stages of switching. Two of these frames, together with a network control junctor switching frame, provide a four-stage 1,024 terminal network having a 2:1 concentration ratio. Each concentrator contains its own scanner module, two stages of ferreed switches plus the cutoff switches, switch control relays, and connectors for B links and network control paths. The first stage switches have 4 by 4 crosspoint arrays and the second stage switches have 8 by 4 arrays to provide the 2:1 concentration.

Line-trunk switching frames 2 and 3 of a network are equipped with B link umbilical cords which permit these frames to be multipled to the B link connectors of frames 0 and 1. Thus, a network is provided having 2,048 terminals with a 4:1 concentration ratio.

Connectors in each concentrator group receive mating plugs for scanner control and readout, network control, ferreed switch pulsing paths, and diagnostic circuits. Scanner readout is via two series paths, each through one to four concentrator groups in a network.

The minimum growth increment for a line-trunk switching network is a frame containing 512 terminals. Testing and installation intervals are minimized through the umbilical cord and connector system incorporated in this design.

6.2.2 *Network Control Junctor Switching Frame*

Duplicated network and scanner controllers contained in the network control junctor switching frame, Fig. 18, serve from one to four line-trunk switching frames. One network controller normally serves the switches on any one of the eight concentrator groups and any one of the eight grids. At the same time, the other controller may be carrying out an order in one of the other equipped concentrator groups and in one of the seven remaining grids. Under no condition is it permissible to address a controller in such a manner that it will try to carry out an order in a concentrator group or grid being used by the other controller. However, each controller is capable of taking over complete control of the network if a failure occurs in its mate.

The scanner controllers detect service requests via the 512 ferrod sensors located on each line-trunk switching fame. One scanner readout cable plugs into a connector on concentrator group 0 and the other into concentrator group 4. Patch cords are used to extend these

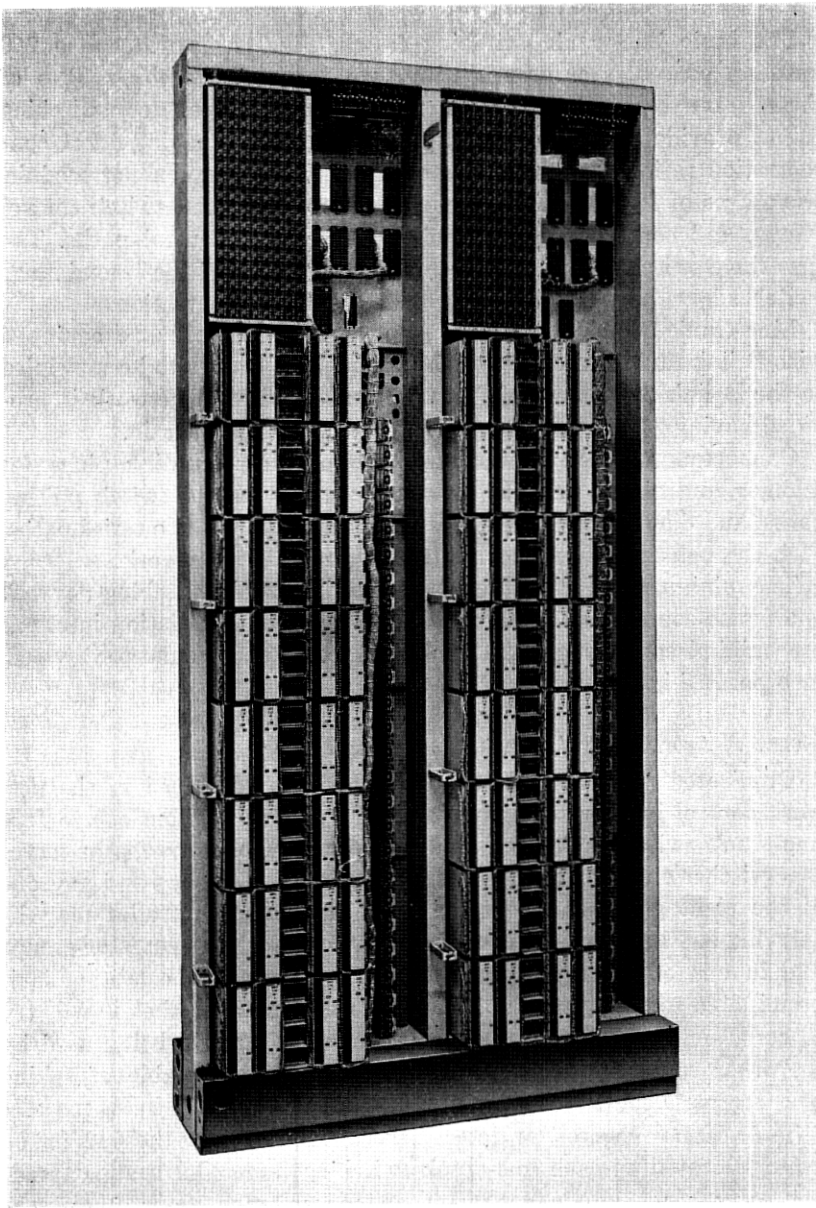

Fig. 17 — Line-trunk switching frame.

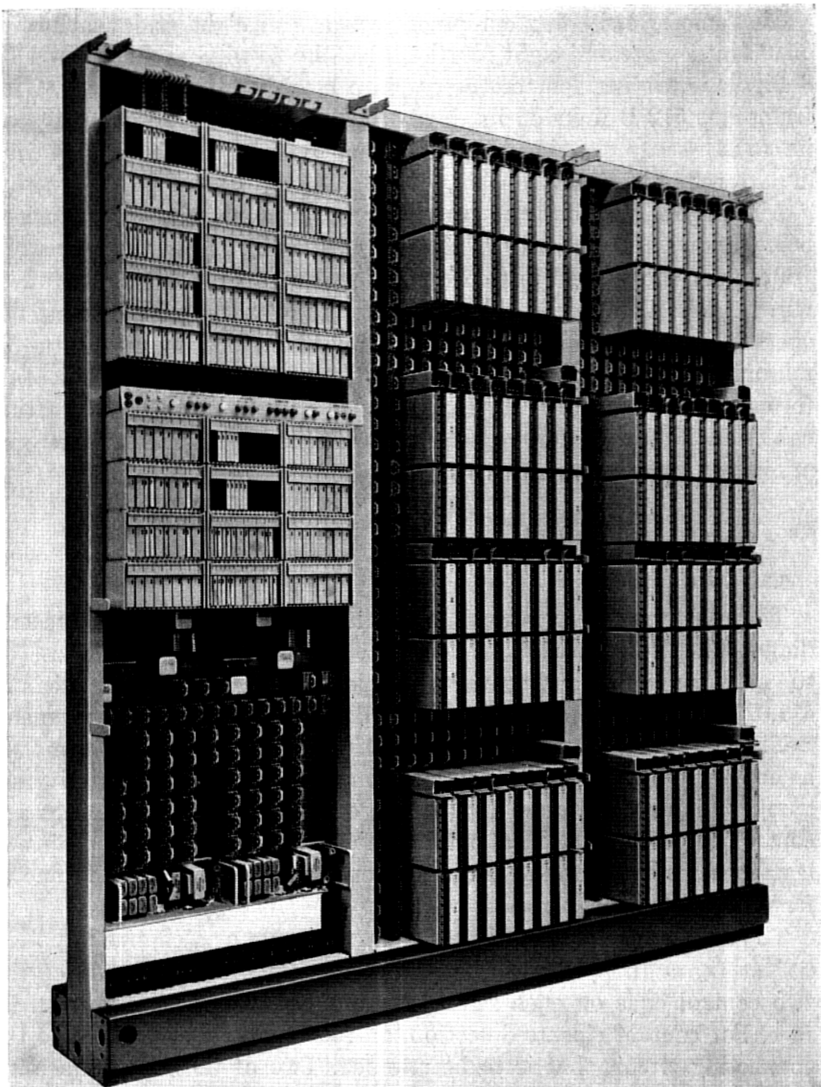

Fig. 18 — Network control junctor switching frame.

series loops for ferrod sensor state detection from concentrator groups 0 and 4 to groups 1, 2, 3, and 5, 6, 7, respectively.

The junctor switching equipment consists of eight grids, each with eight third-stage and eight fourth-stage 8 by 8 switches and eight 1 by 8 bipolar switches for test access into established connections. This frame has 512 B links on its third-stage switches and 512 junctors on its fourth-stage switches. Multipling of B links has been organized in patterns to minimize blocking.

All network access to the peripheral bus system is by connectorized bus transformers located in the network control bay. All network frames are shop-wired in the conventional manner, using unit surface wiring and frame local cables. However, since these frames are pulse operated, extreme care has to be exercised in locating apparatus to minimize lead length and in separating leads into several local cable forms to minimize interference. The use of intranetwork connecting cables facilitates factory testing of a complete network complex and minimizes installation intervals.

6.3 *Peripheral Equipment*

6.3.1 *Master Scanner*

The master scanner is used to monitor various administrative and diagnostic points throughout the system. This scanner, like those on the network frames and universal trunk and junctor frame, consists of a 1,024 point ferrod sensor matrix and duplicated control equipment.

The master scanner, shown in Fig. 19, provides a 1,024 point matrix as contrasted with the 512 point optional matrix unit in the universal trunk and junctor frame, Fig. 22. In order to provide the necessary control point duplication at minimum expense, each office contains at least one master scanner frame and one universal trunk and junctor frame equipped with a master scanner.

To provide for detecting either contact closure or a change in potential at the scan points of the connecting circuits, both ends of the two control coils on each sensor are brought out to terminals on its face. For contact closure detection, all four contacts are cabled to the connecting circuit that is to be scanned. Two of the four connecting leads furnish battery power and ground to the ferrod sensor control windings so that a contact closure over the second pair may be observed. For potential change detection, these coils are strapped together, series aiding, and are connected to the circuit under surveillance with a single pair of wires.

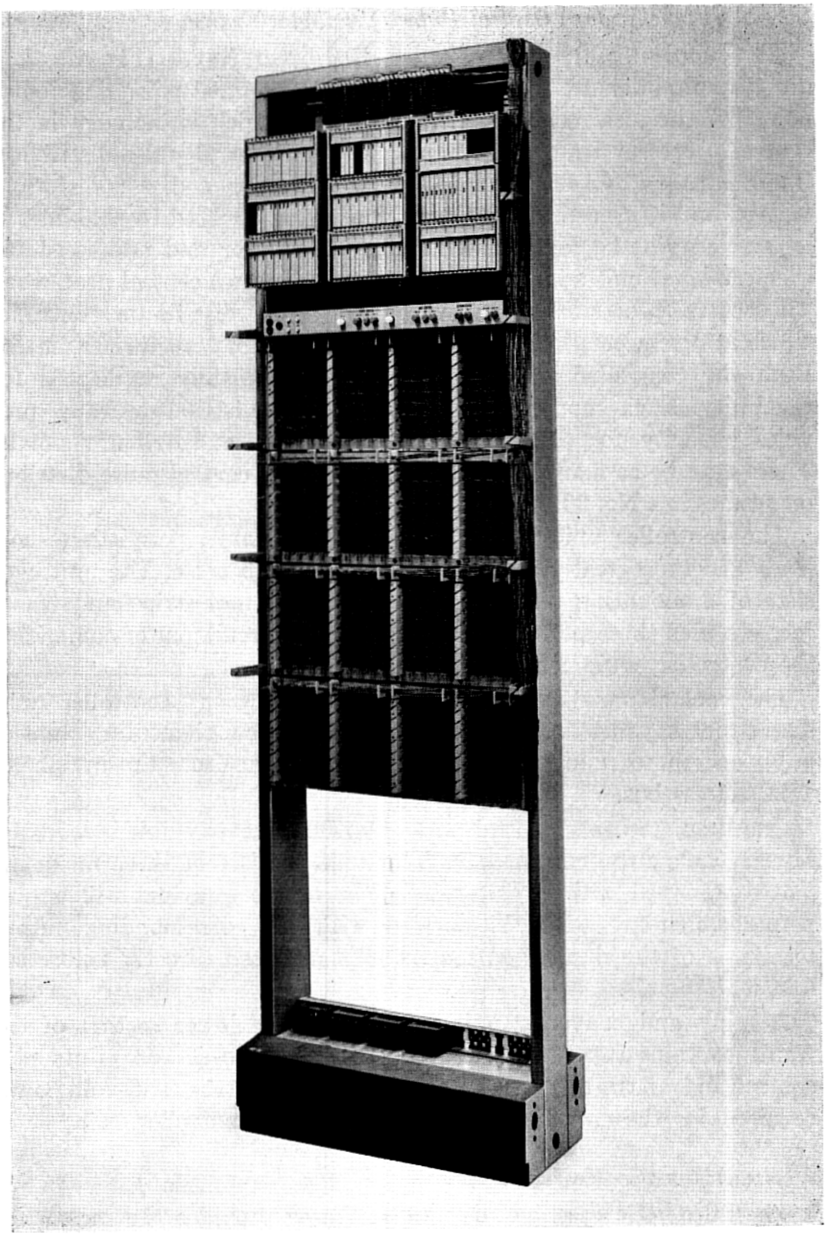

Fig. 19 — Master scanner frame.

6.3.2 *Supplementary Central Pulse Distributor Frame*

The supplementary central pulse distributor frame (Fig. 20) is a growth unit intended to supplement the 512 central pulse distributor points of the local central pulse distributor which is included in the central processor frame. The supplementary central pulse distributor frame consists of two major parts, a controller and a transformer matrix, and is used primarily for signaling as opposed to enabling. It is enabled via the local central pulse distributor and addressed via the peripheral unit address bus by either of the two central processors. The central processors signal the central pulse distributor controller which in turn accesses the central pulse distributor transformer matrix. Both the controller and the matrix are completely duplicated for reliability. Each supplementary central pulse distributor frame provides capacity for 512 duplicated central pulse distributor points. There may be as many as eight supplementary central pulse distributor frames in a No. 2 ESS office.

The controller unit is at the top of the frame, permitting short leads and thus greatly reduces their exposure to noise. The unit consists of a mounting plate equipped with terminal strips and transformers plus three plates equipped with the circuit packs comprising the controller equipment.

The control panel is mounted directly below the controller unit. The panel keys control frame power for the supplementary central pulse distributor and permit isolating the frame from the peripheral unit address bus.

One supplementary central pulse distributor matrix unit is mounted directly below the control unit. This unit consists of three mounting plates equipped with circuit packs. The matrix provides 512 output points which are wired in parallel with the corresponding output terminals of the duplicated matrix unit mounted directly below the first matrix unit.

A relay and converter unit mounted in the lower section of the frame contains two + 24-volt to + 6-volt dc-to-dc converters plus control and alarm relays. The converters furnish the + 6-volt power required for the circuit packs mounted in the controller unit.

6.3.3 *Automatic Message Accounting Frame*

The automatic message accounting frame provides the means for recording customer billing data on a nine-track magnetic tape. The tape is written as data are collected by the system. This tape is sub-

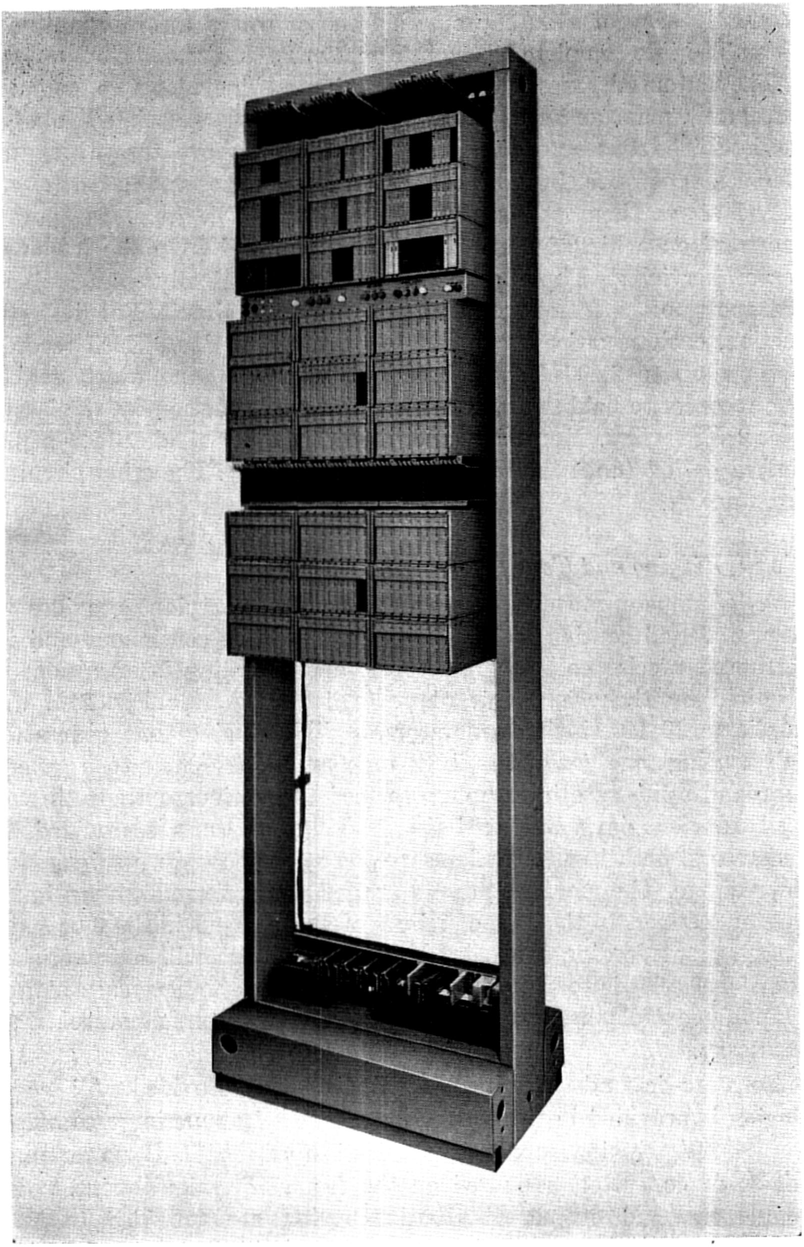

Fig. 20 — Supplementary central pulse distributor frame.

sequently sent to a data processing center where the information is assembled into complete billing information.

The automatic message accounting frame includes two complete automatic message accounting circuits and their associated tape recorders. The two recorders are mounted one above the other, near the center of the frame with the control logic and other circuit packs above them at the top of the frame. The tape transport is mounted on a hinged plate and can be removed from the frame for major servicing. Three connector cables electrically connect each transport to the frame-mounted portion of the circuit. For dust protection, each recorder has a hinged transparent door. Each recorder accepts up to 2,400 feet of half inch magnetic tape which enables one recorder to hold several days of billing information for the largest No. 2 ESS office. Normally, one circuit handles all data for a prolonged period (until the tape reel is full of data). The other circuit is for standby.

6.3.4 *Ringing and Tone Frame*

A ½ ampere capacity ringing and tone power plant provides interrupted and continuous 20 Hz ringing current, continuous and interrupted precise call progress tones, and signaling interruptions as required by the office. This plant (called 841A, see Fig. 21), uses duplicate 20 Hz ringing generators, audible ringing tone generators, call waiting tone generators, high tone generators, busy tone generators, and solid-state interrupters to feed the various outputs through load transfer relays. Balanced distribution of all tones is provided. All generators, both regular and reserve, are continuously monitored for low voltage. The monitor outputs are fed to the ferrod sensors in the master scanner. In the case of failure of any element in the 0 or 1 side of the plant feeding the office loads, the system will automatically transfer the loads to the other side and provide the necessary alarms. Manual controls are provided to override automatic control when necessary.

Both ac-dc and superimposed ringing are provided. All coded ringing is provided in the connecting circuits. In superimposed offices, the + 48V tripping supply is obtained from the 610D power plant (dc-to-dc converter) mounted on the frame. Terminal strips, power connectors, and output distribution fusing are provided in these plants for connection to associated office equipment.

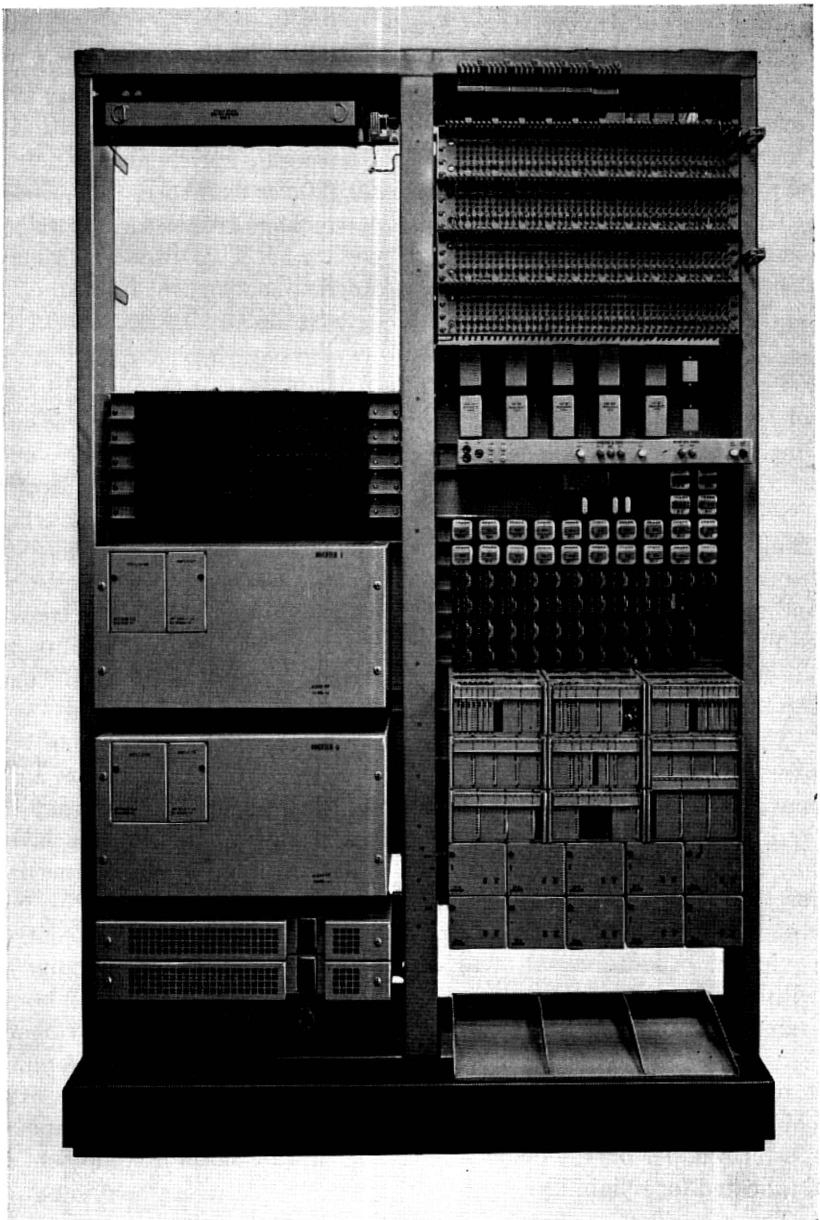

Fig. 21 — Ringing and tone frame.

6.3.5 *Recorded Announcement Frame*

The recorded announcement frame provides for a maximum of six announcements on a small magnetic drum recorder. Each announcement channel has a record-reproduce amplifier associated with it. Distributing resistors are provided for each announcement channel to isolate the outputs, which may total 120 (20 per channel).

The supervisory control unit, a 624 telephone set, is used to select the desired channel for recording or monitoring. This unit, which may be remotely located, can serve two recorded announcement frames.

6.3.6 *Trunk Frames*

There are two types of trunk frames, the universal trunk and junctor frame, and the miscellaneous trunk frame. The universal trunk and junctor frame accommodates a maximum of 256 trunk circuits and their associated trunk control scanners and peripheral decoders. It also provides space for an optional 512 point scanner for miscellaneous trunk circuits. The miscellaneous trunk frames contain a variety of trunk and service circuits which do not fit the universal trunk size and control point requirements. The scanner function for these trunks is performed by a master scanner. The peripheral decoder points on the miscellaneous trunk frame are assigned as needed for trunk and service units located on each specific frame.

The universal trunk and junctor frame (Fig. 22), as its name implies, is universally wired so that any universal trunk or junctor unit consisting of four circuits arranged on a 2-inch mounting plate may be equipped in each of the 64 unit positions in bays 0 and 2 of the three-bay frame. These bays also contain the scanner ferrod sensors needed for trunk circuit supervision. The center bay contains the trunk peripheral decoder and scanner control equipment. To save on control equipment, the universal trunk and junctor frames may be equipped with a 1024 point scanner control. If so equipped, it is called a home frame, or if not equipped with a scanner control, it is called a mate frame. The home frame operates either one-half of a 1,024-point scanner matrix on each of the home and mate frames or a 512-point scanner matrix on the home frame and the optional 512-point master scanner on the home frame. The scanner control equipment is duplicated for reliability.

The miscellaneous trunk frames, Fig. 23, contain such a variety of trunk and service circuits that it is uneconomical to provide them with universal scanners to satisfy all conditions. Instead the scanning

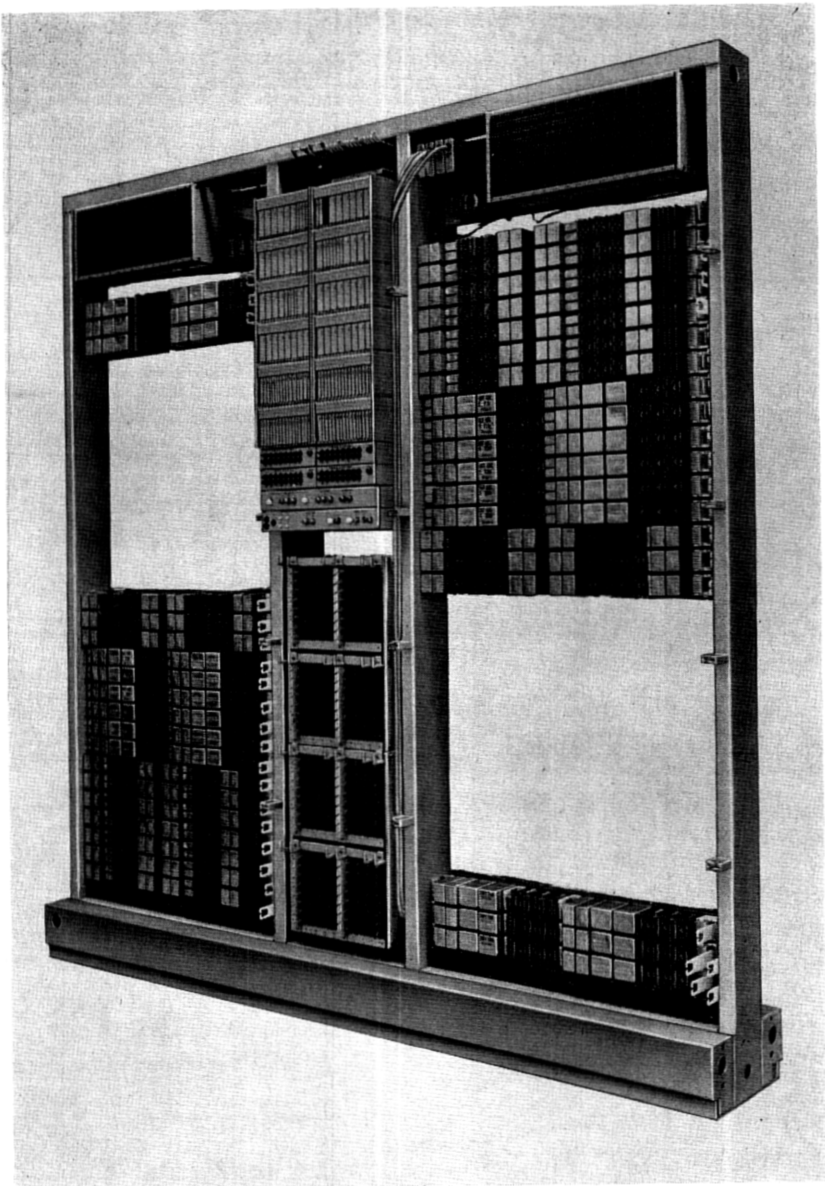

Fig. 22 — Universal trunk and junctor frame.

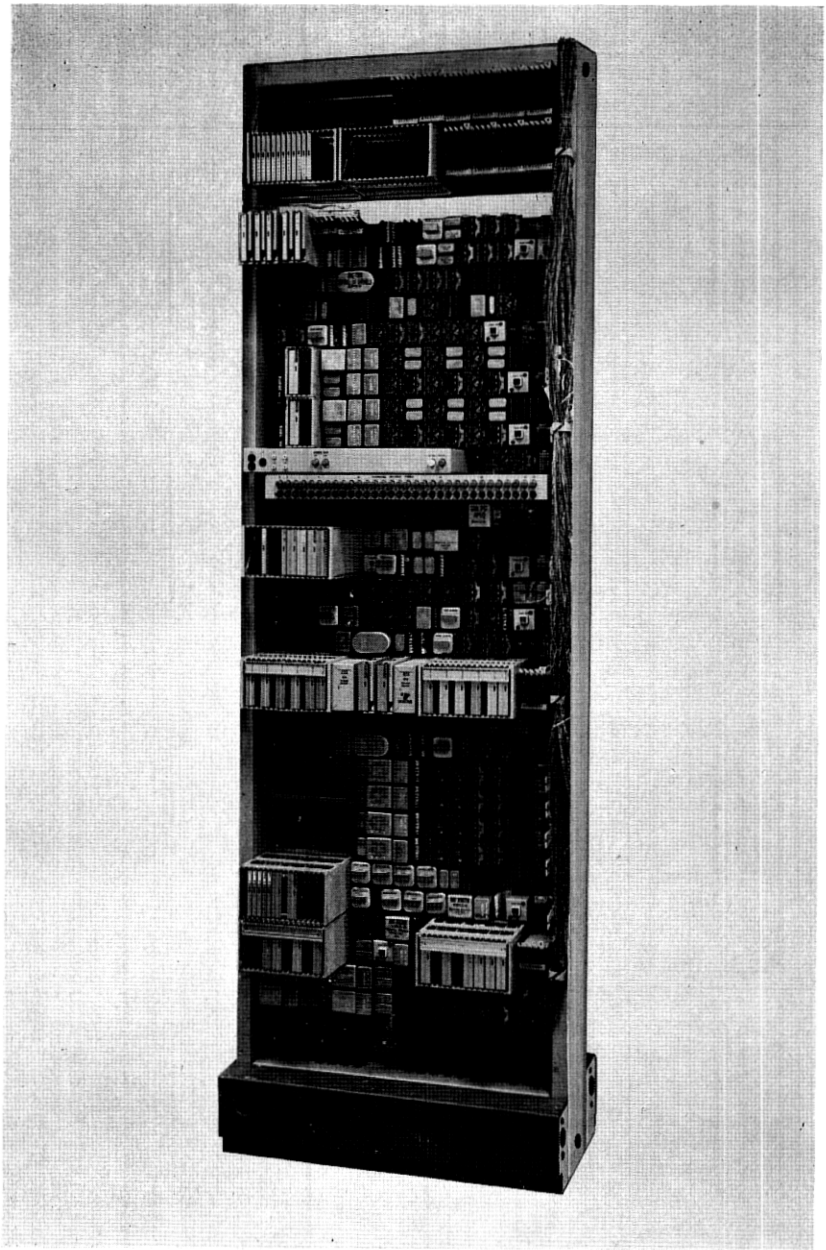

Fig. 23 — Miscellaneous trunk frame.

function for these trunks is performed by the scanner either on a universal trunk and junctor (home) frame or on a separate 1,024-point master scanner frame.

Connectorized bus transformers are provided at the top of the universal trunk and junctor frame for access to the peripheral bus.

6.3.6.1 *Universal Trunk and Junctor Units.* Since many trunk and junctor functions are performed by the common control equipment such as the central processor scanners and peripheral decoders, the size and complexity of these trunk and junctor circuits are greatly reduced. Most high-runner incoming and outgoing trunks are simple circuits containing two or three relays. This simplicity and uniformity of control point requirements permitted the development of a family of single four-circuit units on two-inch mounting plates, as Fig. 24 shows. All units comply with an assigned terminal pattern to insure compatibility with the universal frame wiring. In a typical office, all junctor and 50 percent of all trunk units will be of this type.

6.3.6.2 *Miscellaneous Trunk and Service Units.* Those trunks, transmitters, receivers, and service circuits which do not fit the universal pattern have their combinations of semiconductor circuit packs, networks and relays wired in the conventional manner on mounting plates. A typical unit of this type is the multifrequency receiver shown in Fig. 25. These units are located on the miscellaneous trunk frames and are cabled to their associated master scanner control points.

6.3.7 *Miscellaneous Frame and Miscellaneous Power Frame*

The miscellaneous frame is designed to accommodate a variety of units which require neither peripheral decoder nor scanner control. These units include emergency manual lines, a multiplicity of common systems units, the power for testing battery supply, and so

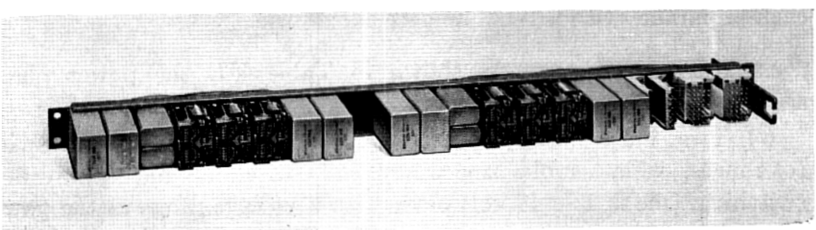

Fig. 24 — Universal trunk unit.

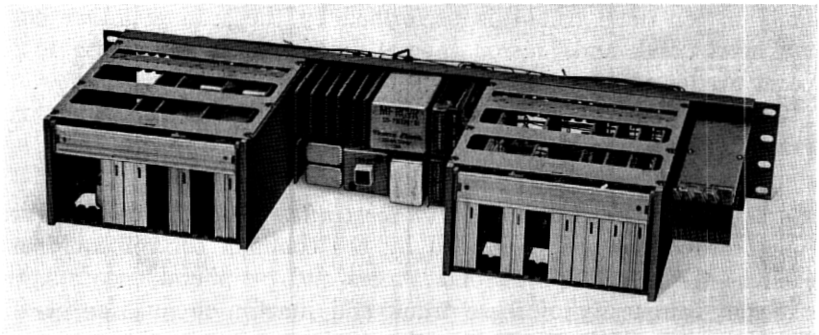

Fig. 25 — Multifrequency receiver.

forth. They are designed to accept a number of standard power filter, fuse panel, and control panel combinations to meet varying office requirements.

The miscellaneous power frame is a miscellaneous frame equipped with an ac distribution panel for 120-volt single phase loads requiring protected or essential 60-Hertz supply, the + 130-volt and − 130-volt fuse panels, and the floor alarm units.

6.3.8 *Power*

6.3.8.1 *Power Distributing Frame.* The power distributing frame is the battery load distributing point of the system. Three power feeders (−48 volts, ground, and +24 volts) from the power plant terminate on bus bars on the frame. These bars in turn supply the fuse blocks for individual frame feeder fuses. Two 35,000 microfarad capacitor banks near the bottom of the frame provide low-impedance shunt filters across the power supply feeders (−48 volts to ground and +24 volts to ground).

The individual load frames are supplied by feeder pairs or triples (as required for frame loads) from 5-, 15-, or 30-ampere cartridge fuses, each in parallel with a 1-1/3 ampere alarm fuse.

6.3.8.2 *Power Plants.* As shown in Table III, the power plants associated with No. 2 ESS include:

(*i*) Two 111A battery plants with large battery voltage swing tolerances, which avoid emergency cell switching and counter-cell switching. One is a − 48 volt plant with a voltage range at the power distributing frames of − 43.75 to − 52.5 volts. The other is a + 24 volt plant with a voltage range at the power distributing frames of

+ 21.75 to + 26.25 volts. Power from these plants in the power room is delivered to two or more power distributing frames in the switchroom.

(*ii*) Two 6.7 volt power plants supply the control complex logic. These are located in the switchroom and are described in Section 6.1.5.

TABLE III—POWER SUPPLIES

Power Supply	Type of Plant or Unit	Capacity (Rated) Amperes	Code
In Power Room			
−48 volt dc (−43.75 to −52.5 V) +24 volts dc (+21.75 to +26.25 V)	storage batteries (without emergency cell or counter cell switching) rectifier charged	10–800	111A
+130 volt dc, −130 volt dc	dc-to-dc solid-state conversion from −48 volts for coin control	$\frac{3}{4}$; 2 and 5	610B; 651A
Reserve ac supply	dc motor-driven alternator for 120–208 volt single-phase power	($1\frac{1}{2}$ kW)	504B
In Switchroom			
Ringing and tones	solid-state generator with a precise tone plant	0.5	841A
6 volt power plant	dc-to-dc converter with sequence controller	200	J86859A
PBX talking battery filter on miscellaneous frame	coil and capacitor panels	15, 25, and 60	
120 volt ac for Frames: maintenance center; RA; RT; Miscellaneous for ac TTY data sets, test battery supply unit	commercial power with or without reliable supply distributed from MP frames		
Appliance outlets frame lighting	distributed from ceiling-supported busway		

(*iii*) The ringing and tone supplies located in the switchroom. These are described in Section 6.3.4.

(*iv*) The + 130 and − 130 volt dc-to-dc converters (610B power plants) which convert the − 48 volts to the potentials needed for coin control. Power from these plants is delivered to fuse panels on a miscellaneous frame and then distributed to all frames in the office which require it.

(*v*) A small emergency 504B alternating current plant (an alternator driven by a dc motor) providing "protected" power. A distribution panel on a miscellaneous frame provides a centralized point in the switchroom for all frames in the office which require ac power even when commercial power fails.

(*vi*) An engine alternator to substitute for commercial ac power to charge batteries and supply essential ac loads after a commercial power failure has persisted for a time.

6.4 *Distributing Frames*

The No. 2 ESS combines all of the functions of the main distributing frame, intermediate distributing frame, and trunk distributing frame in a combined distributing frame. As in No. 1 ESS, junctor grouping and protector frames are also provided.

6.4.1 *Combined Distributing Frame*

The combined distributing frame provides for connection of 6,080 central office pairs (Fig. 26). Reliable quick jumper connections to connecting blocks are made with a special tool and 22 gauge W-type distributing frame wire.

The combined distributing frame faces the protector frame across a four-foot aisle and the two frames grow perpendicular to all other frame lineups. The combined distributing frame provides a means for interconnecting:

(*i*) lines terminated on the protector frame and network terminals,

(*ii*) trunks terminated on the protector frame and trunk circuits,

(*iii*) trunks terminated on signaling and transmission equipment and trunk circuits,

(*iv*) trunk circuits, service circuits, and network terminals, and

(*v*) lines or trunks terminated on the protector frame and miscellaneous circuits.

Service observing jack panels, which provide access for service

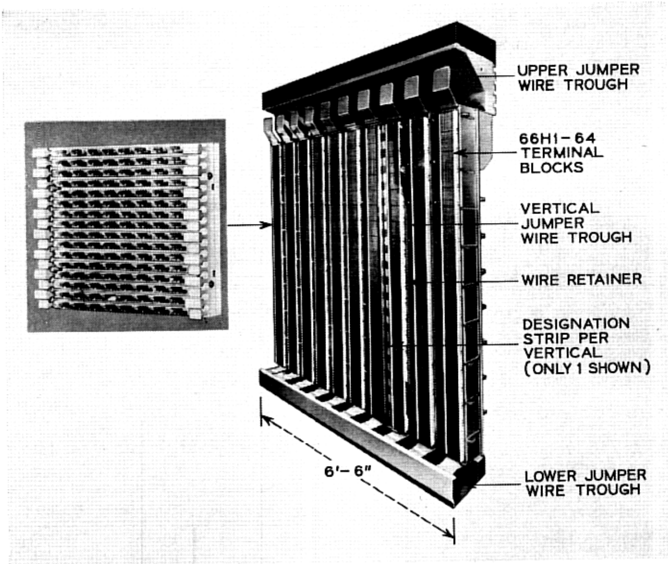

Fig. 26 — Combined distributing frame.

observing circuits for every line within the office, are mounted on the rear of the combined distributing frame as needed.

6.4.2 *Protector Frame*

The No. 2 ESS uses the No. 1 ESS protector frame (see Fig. 27), which has protectors for 6,000 outside plant pairs. These protector units which serve the tip and ring conductors guard against lightning and other foreign high potentials.

6.4.3 *Junctor Grouping Frame*

The junctor grouping frame, which is used for the distribution of network junctors, provides up to ten vertical files for network or junctor circuit appearances (see Fig. 28). Each vertical file contains 32 plugs and 32 jacks which may be used to interconnect either the junctors from one network (64 eight-pair junctor subgroups) or 32 junctor circuit subgroups.

The junctor grouping frame can grow in two-file increments as central office requirements dictate. One growth module consists of two 37-inch high vertical mounting plates containing two files of 16 plugs and 16 jacks each. Files may be added when necessary and any file may be used for either network junctor or junctor circuit

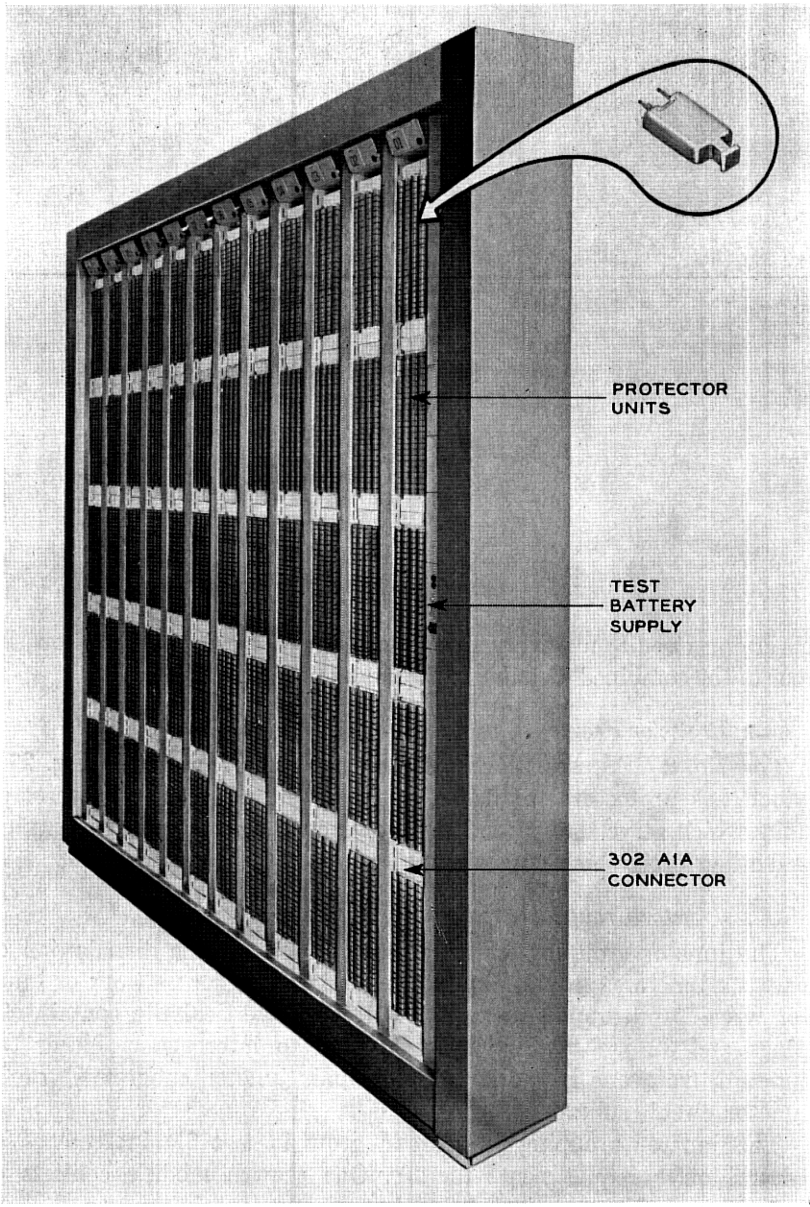

Fig. 27 — Protector frame.

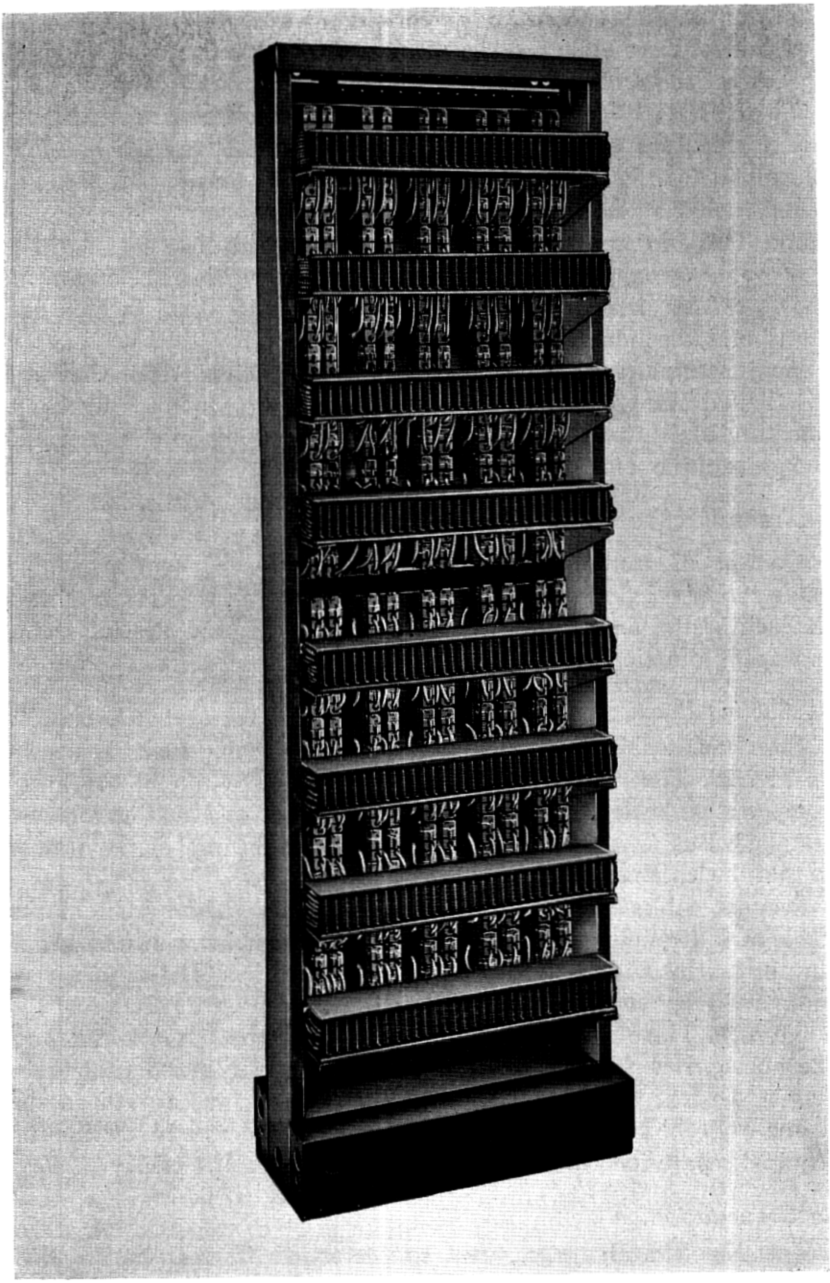

Fig. 28 — Junctor grouping frame.

appearances. Files chosen for junctor circuits are totally filled before a new junctor circuit file is assigned. A typical 4,000 line office with 4:1 concentration requires four files on one junctor grouping frame.

There are eight cable trays on the front of the frame, one for each shelf, which are used to store plug patch cords. Every file has four plugs and four jacks per shelf. Plugs and jacks on network files are wired such that each receives one junctor from every grid of a network. Two slips are wired between the line trunk networks and the junctor grouping frame by an installer on alternating shelf pairs of the file.[3] This permits all plugs to be wired in identical fashion and distributes the junctors to minimize blocking.

As junctor circuits are added to a junctor circuit file, they are distributed evenly over all eight shelves until the file is totally filled. Junctor distribution is achieved by patching the plugs of one shelf into the jacks of the same shelf in a prescribed manner.

VII. INTERCONNECTING METHODS

Control of transient noise requires the use of compartmented cable racks, segregated cables and wiring paths on the frames, filters in each frame on all dc power supply feeders, and special frame grounding practices.

7.1 *Cabling Practices*

Interframe cables are run in compartmented cable racks as shown in Fig. 29. The relatively sensitive bus leads are run in the lower compartment which is shielded when the front and rear covers are installed. Bus transformers are mounted near the top of the frames so that the length of exposed leads will be minimized.

Scanner cables are run in a shielded channel at the front of the cable rack (equipment aisle side) where they can drop down to frame terminal strips with relatively short noise exposures. The tip and ring leads and relay control leads are placed in the center top section of the cable rack. These cables run down the front of the frame uprights to the appropriate frame terminals. The power distribution cables are run in the rear top section of the cable rack. These cables feed the frame from the rear. Separate cross aisle racks are used to provide the required separation between these different classes of leads.

7.2 *Connectorization*

The No. 2 ESS system uses connectorized frames that can be functionally tested in the factory. The connections between the main-

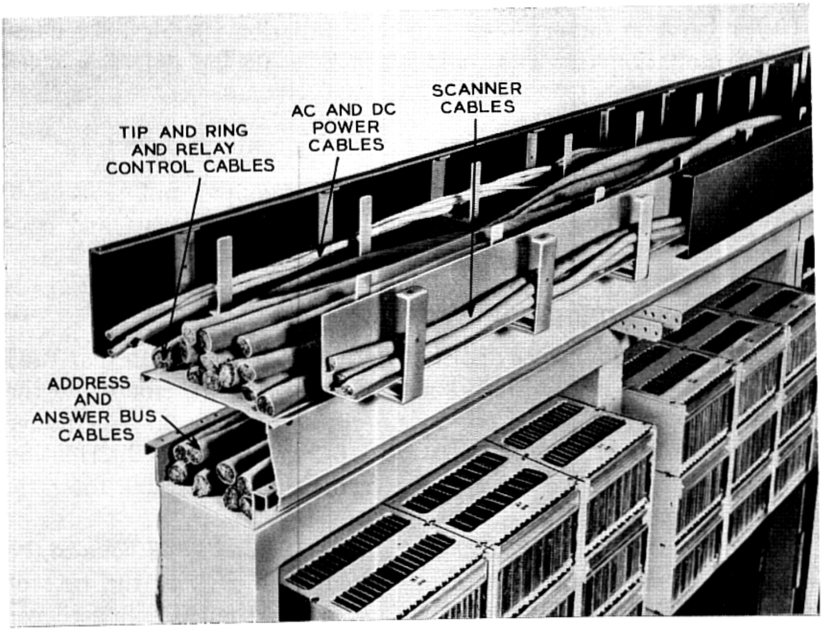

Fig. 29 — Cable rack.

tenance center, central processor, supplementary call store, and program store frames are provided by means of cables equipped with connectors. Similarly, all the leads between each network control junctor switch frame and its four associated line-trunk switch frames have connectors. The buses between the central processor, master scanner, universal trunk and junctor, and network frames also have connectors.

All of these connections represent an important but small percentage of the total number of interframe connections that are provided in a typical office. It is not practical to equip all leads with connectors because of the wiring variability from office to office.

The use of connectorized cables in central office equipment in place of installer-connected wiring has some obvious advantages as well as disadvantages. Some advantages are:

(*i*) installation intervals are shortened and installation costs reduced,
(*ii*) office growth procedures are simplified,
(*iii*) factory frame testing is facilitated, and

(*iv*) subsystem factory tests reduce installation troubles, the number of installation test sets and delays in replacing defective office equipment.

Some disadvantages of equipping cables with connectors are:

(*i*) additional equipment mounting space is required, and
(*ii*) equipment costs are increased by added apparatus and connections.

7.3 *Direct Current Distribution*

The No. 2 ESS dc power distribution system is similar to that used in the No. 1 ESS except that + 6.7 volt power is distributed to the control complex logic. This power is derived from the 6.7 volt power frame which converts − 48 volts to + 6.7 volts. Power distribution feeders are run between these power frames and the frame filters in the control complex.

The power distributing frames distribute + 24 and − 48 volts to the individual frame filters. Filters are designed to restrict the rate of change of current in the power feeders to less than 0.1 ampere per microsecond to insure less than one volt of noise at the power distributing frame bus.

Except for the control complex, all even-numbered frames are fed from an even-numbered power distributing frame and all odd-numbered frames from an odd-numbered power distributing frame. In the control complex, all frames in control unit 0 are fed from even-numbered power distributing frames and 6.7 volt power frames and those in control unit 1 from odd-numbered frames. Equipment frames having duplicated control equipment are supplied by two sets of feeders, one set from each power distributing frame.

In order to minimize noise caused by either stray circulating ground currents or transient noise potentials within the building, the No. 2 ESS equipment is grounded at a single point.

7.4 *Alternating Current Power Distribution*

Only single-phase 120-volt ac power is required in the No. 2 ESS switchroom and the only units requiring protected ac are: (*i*) the recorded announcement machine, (*ii*) maintenance teletypewriters, (*iii*) ac data sets, and (*iv*) key telephone equipment, when provided.

All loads are normally supported by commercial ac power. In the event of a power failure, the emergency power plant supplies the required protected ac within five seconds and the remainder of the load, the essential ac, is furnished by the standby engine alternator. The protected and essential ac is distributed from an ac distribution panel on the miscellaneous power frame.

VIII. SUMMARY

The following equipment design developments and philosophies have been instrumental in achieving the low-cost objectives for No. 2 ESS: (*i*) Use of currently manufactured, high volume production, low-cost apparatus items, (*ii*) plug-in growth units such as the call store, program store, and central pulse distributor, (*iii*) thin film integrated circuits (*iv*) judicious use of connectors on cables between major frames, (*v*) peripheral decoder, and (*vi*) single card writer. The design has provided for extensive factory testing, reduced installation intervals, and ease of growth. Compact designs provide additional savings in floor space.

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