No. 1 ESS Apparatus and Equipment

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No. 1 ESS provides a greater variety of services than any prior complex switching system, in central offices of greater capacity, but with more highly standardized equipment of much smaller volume. Much of the credit for this achievement is due to the use of fast electronic circuits under control of a generic program. Apparatus and equipment development was aimed at accenting the benefits in this system, disciplining options to concentrate demands on a few standard frame building blocks, minimizing the varieties and codes of apparatus to take advantage of economies inherent in large volume production, and combining these with flexibility and versatility in a dependable, maintainable, compatible system that will provide all services wanted now and in the future.

I. INTRODUCTION

The goal throughout the No. 1 electronic switching system (ESS) development[1] was to achieve the highly standardized modular design which will be most economical to engineer, manufacture, install, operate, maintain, and administer. As a result, No. 1 ESS uses a limited variety of frames as building blocks and relies on a generic stored program to provide most office-to-office variations. The system represents a giant step forward in combining versatility and flexibility with standardization in switching systems.

This advance in the switching art comes at a most appropriate time. Many of the earliest dial offices are nearing retirement age, and most of them are in buildings too full of equipment to accommodate replacing units of crossbar equipment. No. 1 ESS will avoid the cost of establishing new wire centers in new buildings in these cases. The installation of a first No. 1 ESS which is to serve as a replacement for existing equipment can be made in a toe-hold of as little as 2000 square feet of floor space. This can ordinarily be made available. This first installation will replace two or three times its volume of panel or step-by-step equipment and clear space for large future additions. In this way, existing buildings may ultimately house several times as much switching equipment as they were originally designed for.

There is possibility of a further large dividend. In the past, the Western Electric Company has found it generally uneconomical to manufacture large central office equipments in anticipation of demand. There were too many equipment variables as well as too many new features which continually require design changes. As a result, large central offices have been built to customer order. Now, with the elimination of most equipment variables in No. 1 ESS, and with the facility to add new features by program change alone, line assembly in advance of orders promises large savings in production and investment costs. Consolidation of demands will increase lot sizes in the shop and permit a more uniform flow of production. The present interval between placing an order for a switching system and cutting it into service will be shortened. The unproductive investment period will be correspondingly reduced. Savings will be further enhanced by the concentration of demands for those frames used in common by local, tandem, and toll switching systems.

The outstanding attributes of No. 1 ESS equipment include:

(a) provision in the ultimate for the widest variety of services ever offered in one switching system: all of those now available in the several local, toll, and tandem switching systems for large Bell System installations as well as many new services

(b) flexibility for economical growth and the provision of new features not practical in existing systems, plus the ability to work with all systems

(c) use of just one pair of central processors[2] to serve offices varying in size up to 65,000 lines. This permits the replacement of several existing offices with one No. 1 ESS office

(d) highly automated and sophisticated accounting, maintenance,[3] traffic, and traffic-measuring facilities

(e) relatively few small standardized frames of equipment (with most of the usual variables eliminated)

(f) highly standardized floor plans arranged on a modular basis

(g) small building volume for switching equipment ($\frac{1}{3}$ of previous areas, $\frac{1}{4}$ of previous volumes)

(h) wide battery voltage tolerances.

The more important factors in the equipment design are:

(a) Semiconductor devices and new temporary and semipermanent memories in electronic circuits appreciably increase the operating speed of the system.

(b) Programs in memory replace most of the wired logic required in earlier systems; this simplifies circuits and avoids innumerable apparatus and wiring options.

(c) Communication between equipments by high-speed digital pulses over a relatively few pairs further simplifies the equipment and cabling.

(d) Ferreed switches and ferrod sensors and the simplification of their controls and communicating links compress networks.

(e) Shared trunk controls simplify trunks and service circuits.

(f) New techniques are exploited to reduce operating effort as well as to eliminate much apparatus and wiring in equipment for AMA, maintenance, traffic-measuring, and auxiliary services.

(g) New concepts in protector and distributing frames take advantage of electronic memories and other No. 1 ESS innovations to minimize cross-connection changes, jumper lengths, and frame volumes.

(h) The design of all equipment, framework, wiring, and cabling eliminates options wherever possible.

II. NEW EQUIPMENT MODULES ARE STANDARDIZED

Electromechanical switching systems have come along one after another in orderly evolution. New equipment practices have been introduced one or two at a time, and field experience following each innovation has proved its value. No. 1 ESS (see Fig. 1) is so different in so many ways that it represents a switching revolution. This posed a challenge to develop new forms of apparatus and equipment modules that exploit to the full the capabilities of these new system concepts.

Questions which were considered in the combining of components into frames of one consistent design were: (a) How should semiconductor circuits be packaged in a uniform manner with the fewest variables for their many uses throughout the system? (b) How should ferrite sheet and twistor memories be designed for the stores? (c) How should ferreed switches and ferrod sensors be designed to become network crosspoints and scan points? (d) How should simplified trunks and common trunk control equipment be designed? (e) How should AMA recorders and teletypewriters fit the new maintenance and traffic record concepts? (f) How should power, alarm, and auxiliary services be provided?

The design of a frame could not be frozen until all combinations of units which were to be mounted on it were known. Other factors also had to be kept in mind: frames would have to be interconnected in standardized floor patterns in office buildings; the basic package designs would greatly influence frame associations and interframe cabling. In the foreground of all design decisions was the goal of standardization without optional equipment variables.

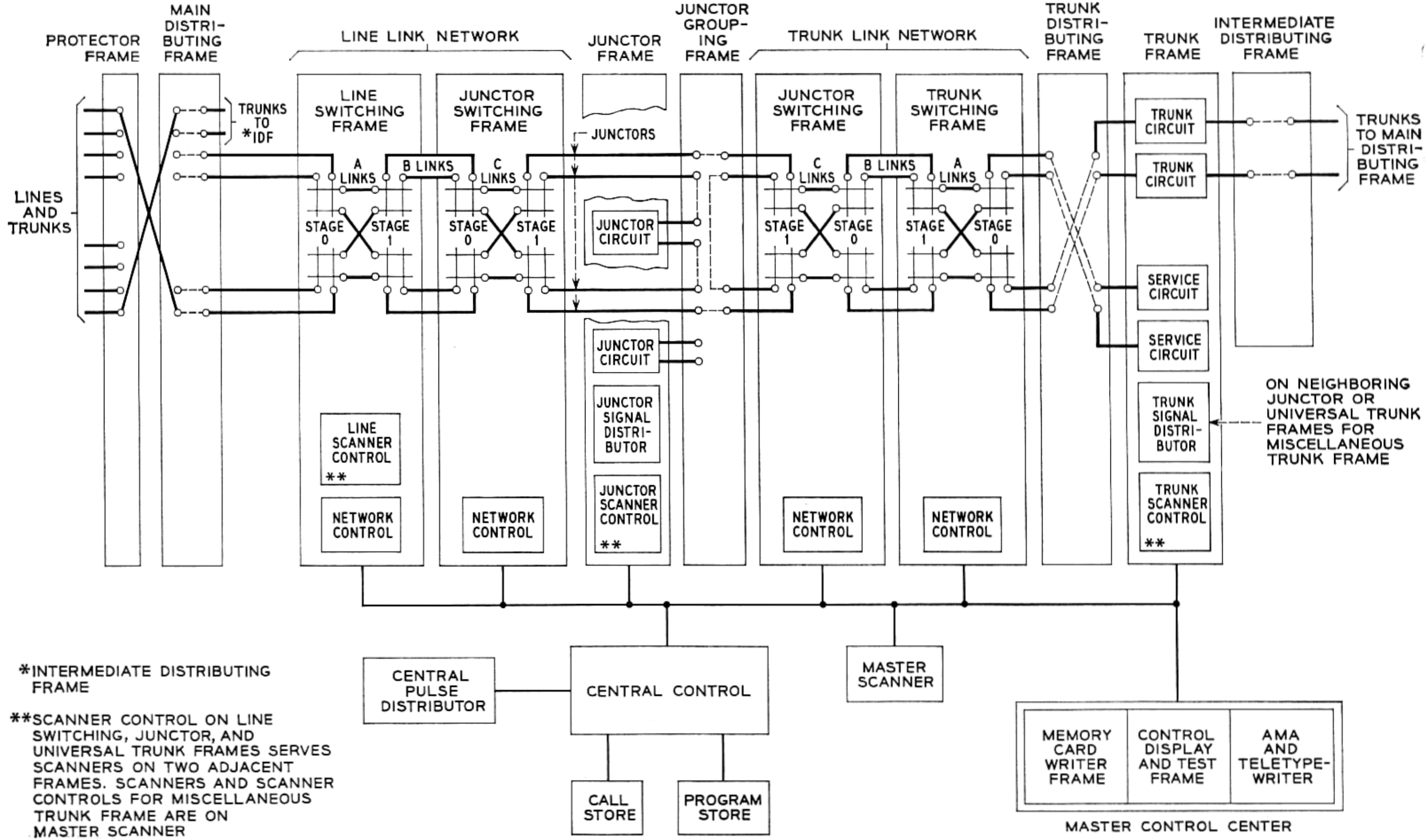


Fig. 1 — Equipment schematic.

2.1 *Basic Packages*

Some of the basic packages developed are: (a) semiconductor circuit packs, (b) ferreed switches, (c) ferrod sensors, (d) trunk and junctor plug-in units, (e) twistor memory, and (f) ferrite sheet memory.

In each of these designs, two basic decisions had to be arrived at simultaneously. First, all possible circuit configurations for functions everywhere had to be considered and reduced to the fewest possible. Second, the innumerable ways for packaging had to be studied and the basic design selected. Then the variables in each case had to be adapted to the standard package with the very minimum of codes. This brought production economies as well as maintenance economies in both equipped and spare packages.

2.2 *Frames*

Concurrently with the basic package developments, frame designs were explored. The frame structure had to be as nearly universal as possible to accommodate all varieties of equipment combinations in the best manner for shop and field. Frames for earlier large dial systems were of a variety of constructions but generally were single-sided and 11 feet, 6 inches high. Many equipment and building standards had been developed over the years around these designs. For the Morris, Illinois, ESS trial installation,[4] double-sided cabinets 7 feet high with doors front and rear were decided upon to minimize lead lengths and to facilitate air conditioning. Requirements for this new system had to be carefully studied to arrive at the ideal frame. Should it be single-sided or double-sided? Should it follow the 11-foot, 6-inch standard, or were there compelling reasons for a new height? Should it be an enclosed cabinet?

2.2.1 *Double-Sided versus Single-Sided Frames*

A study of double-sided versus single-sided frames proved that the very minor floor space advantage in favor of double-sided frames was offset by production and maintenance advantages favoring the single-sided frame. Air conditioning of individual frames, which dictated enclosed double-sided cabinets for Morris, was no longer a requirement. In addition, frame covers were eliminated to reduce cost and to ease system maintenance.

2.2.2 *Frame Studies*

A series of studies determined that the single-sided frame should be 7 feet high with modular widths of 1 foot, 1 inch. Reasons for adopting this design fell into three classes.

(*i*) *Equipment Arrangements:*

(a) It fits the circuit functions into more orderly, symmetrical equipment modules.

(b) It provides short, direct pulse leads for intra- and interframe communication.

(c) It gives floor loads compatible with existing buildings.

(d) It permits economical use of office volume with attractive equipment and building designs.

(*ii*) *Maintenance:*

(a) Access from the floor is preferable to that from rolling ladders.

(b) Accident hazards are less with no rolling ladders.

(*iii*) *Building Costs:*

(a) Considering existing buildings with high ceilings, a possible small floor space loss is offset by savings from the omission of auxiliary framing and rolling ladders.

(b) Considering buildings with low ceilings, there are important additional savings in new building costs and in the ability to install 7-foot frames in commercial buildings.

2.2.3 *The Frame Adopted*

The frame finally adopted is shown in Fig. 2. Sheet metal uprights of 1-inch by 5-inch cross section are centered on the base to provide an $8\frac{1}{2}$-inch depth for apparatus on the front and a $3\frac{1}{2}$-inch depth for wiring on the rear. Frames having five widths on 1-foot, 1-inch modules provide for all equipment.

III. FRAME EQUIPMENTS ARE STANDARDIZED

No. 1 ESS employs new types of apparatus for most of its functions: ferreed switches for network switching; ferrod sensors for scanning; magnetic latching wire spring relays in trunks; twistor and ferrite sheet memories; semiconductor devices in plug-in circuit packs for almost all logic and controls; and others as described in detail in Section V. These components, as needed, are arranged on the 24 frames listed in Table I in ways which make each frame, as nearly as practicable, a completely functional building block free of options. No. 5 crossbar at the same stage of development had approximately 3 times as many frame equipments, 10 times as many trunk equipments, and 100 times as many coded variables for apparatus and wiring options.

The equipment arrangements developed for the different frames follow a standard pattern. Terminal strips, bus transformers, and other apparatus

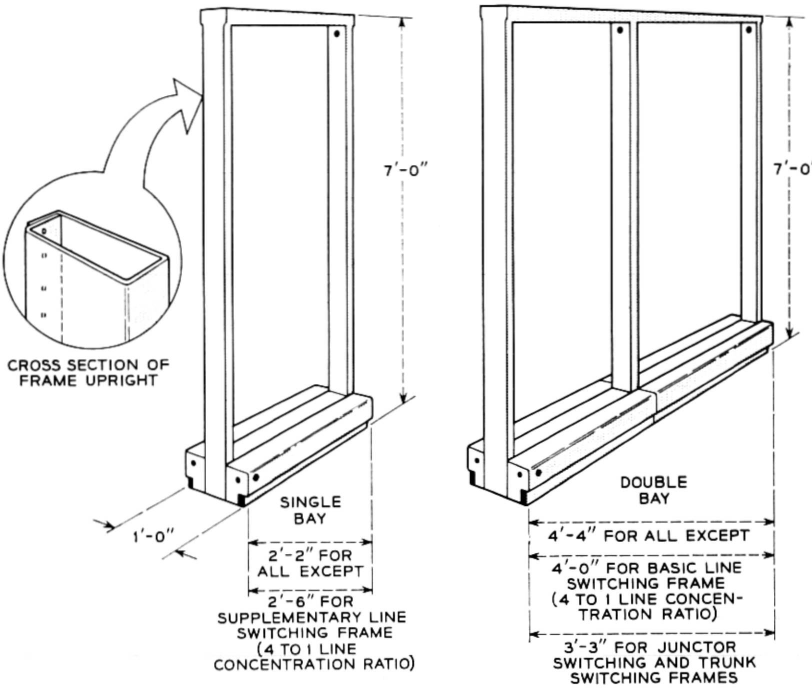


Fig. 2 — Frame.

requiring little maintenance are at the top of each frame, so that practically all maintenance work can be done without the use of stepladders. Frame filters, fuses, and power cutoff relays, as required, are located at the bottom of each frame. Appliance outlets are in the front and rear of each frame base. Every frame has a control panel with telephone and spare jacks and pin jacks for −48 volts, +24 volts, ground, and high-resistance ground. Most frames, in addition, require alarm, off-normal and out-of-service lamps, power cutoff keys, and some keys for special purposes; these are also mounted on the frame control panel located at a convenient height above the floor.

3.1 *The Control Panel*

The typical control panel shown in Fig. 3 carries a group of push-button keys, indicator lamps, and test jacks in a perforated steel housing. The housing acts as a shield to protect adjacent electronic equipment, while the perforations permit vertical passage of air if needed to cool

TABLE I — FRAMES, ABBREVIATIONS, AND LENGTHS

Frame	Abbreviation	Length Feet	Length Inches	Remarks
Central control	CC	8	8	2 per office
Program store	PS	10	10	
Call store	CS	2	2	
Master scanner	MS	2	2	
Central pulse distributor	CPD	2	2	Operate in pairs
Master control center	MCC			1 per office
memory card writer	MCW	2	2	
control display & test	CDT	4	4	
AMA-teletypewriter	AMA-TTY	4	4	
Line switching	LS			4 to 8 per LLN
2 to 1 line concentration (home or mate)		4	4	
4 to 1 line concentration				
basic (home)		4	0	
supplementary (mate)		2	6	
Trunk switching	TS	3	3	4 to 8 per TLN
Junctor switching	JS	3	3	4 per fully equipped LLN and TLN
Junctor	J			
home or mate — basic		4	4	
home or mate — supplementary		2	2	
Universal trunk	UT			
home or mate — basic		4	4	
home or mate — supplementary		2	2	
Miscellaneous trunk	MT	2	2	
Miscellaneous	M	2	2	
Recorded announcement	RA	2	2	
Power distributing	PD	2	2	
Miscellaneous power	MP	2	2	
Ringing and tone	RT			
½-amp capacity		4	4	
6-amp capacity		6	6	
Protector	PROT	6	6	Modules of these lengths are ordered as required
Main distributing (or IDF 8′ high)	MDF	6	6	
Intermediate distributing	IDF → (6 ft 6 in or 4 ft 4 in)			
Trunk distributing (or IDF 7′ high)	TDF	4	4	
Junctor grouping	JGF	2	2	Ordered in pairs

that equipment. The keys are used primarily to disconnect or restore power to various sections of the frame for maintenance purposes, although test functions are also sometimes provided. The keys are mechanically interlocked to guarantee that if one duplicated frame or bus control section has power off, it must be restored to "power on" before the mate control section is turned off. Red lamps indicate trouble conditions, including "power off" in any section, while white lamps indicate an "off normal" condition and whether either frame control is "out-of-service" for any reason. The telephone jacks at the left end of the panel permit convenient telephone connections to maintenance or test personnel at other locations in the office, and the pin-type jacks provide voltage sources for frame maintenance or for portable test sets.

3.2 *Filter and Fuse Panels*

Each frame is equipped with a filter panel designed to restrict the rate of current change on the frame supply feeders. This filter limits the noise transmitted to other frames via the centralized power distributing frame. These filter panels are located in the frame base immediately below the frame fuse panels. Thus the power feeders, terminating on the filter panel after entering via the frame upright, have a minimum exposure to stray noise sources. Power cutoff relay panels, when required, are located in this same area of the frame.

3.3 *The Circuit Packs*

The plug-in circuit packs engage connectors on an apparatus mounting which occupies 4 inches of vertical space. The 36A apparatus mounting is used for the great majority of circuit packs. Three adjacent mountings fit across a 2-foot, 2-inch bay, and each mounts as many as 16 circuit packs on 0.4-inch centers, or correspondingly fewer of those packs that require 0.8-inch or 1.2-inch centers. The 38A apparatus mounting mounts a single circuit pack and is used in locations requiring too few circuit packs to justify the larger mounting.

3.4 *Relay Equipment*

Many trunks have their relays and other components for one or two circuits on small plug-in units which mount interchangeably in supports and sockets on a trunk frame which is universally wired for all of them.

Fig. 3 — Typical frame control panel.

3.5 *Ferreed Switches and Ferrod Scanners*

The ferreed switch affords much greater flexibility than the crossbar switch in possible arrangements of crosspoints and controls. Advantage has been taken of this flexibility to provide the best switch array for each stage of line and trunk switching in the networks. Line, trunk, junctor, and master scanners all have 1024 (64×16) point matrices equipped with ferrod sensors having the proper operating characteristics.

3.6 *Terminal Strips and Bus Transformers*

A universal design of terminal strip and transformer using molded wire techniques is used for all interframe wiring which connects at the top of any frame (see Fig. 4). The conductors of bus systems, which address the frames, are terminated on ferrite core pickoff transformers. These transformers are molded directly into the molded ladder terminal arrays of the terminal strips. Several codes of these bus transformers, terminal strips, and combination units have been made available.

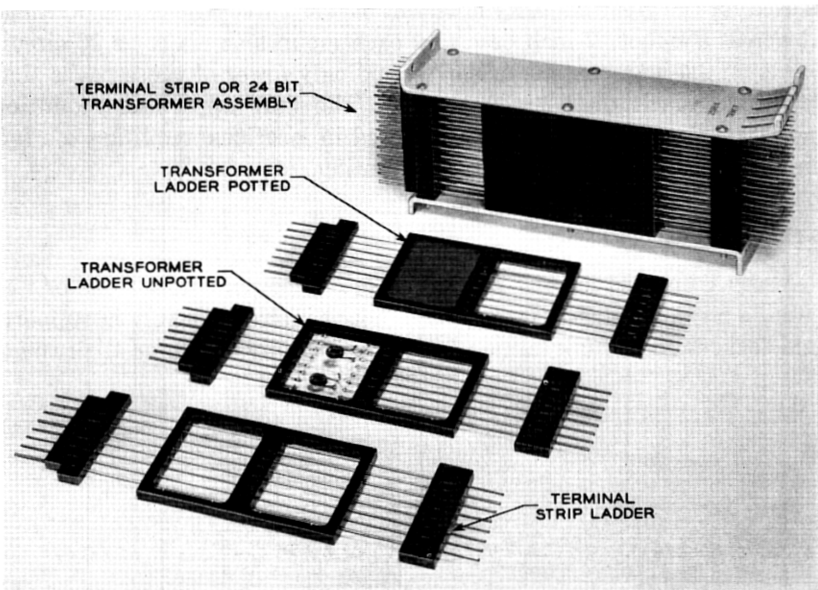


Fig. 4 — Terminal strip and transformer for interframe bus system.

3.7 *Frame Wiring*

In general, all shop wiring is to terminals on the rear, and installer wiring is to terminals on the front of frames; and, in general, both use 26-gauge conductors. Shop wiring includes surface wiring, loose wiring, and local cable of conventional kinds, as well as some new wiring techniques. Where high densities of circuit packs and wired interconnections exist, as in central control, special wiring procedures prescribe specific routings for surface wiring, loose wiring, and local cable.

3.8 *Designations*

Designations on equipment give frame name, frame and bay numbers, and specific functions in accordance with nomenclature and abbreviations standardized for the system.

IV. FRAME ARRANGEMENTS IN AN OFFICE ARE STANDARDIZED

Engineering, installing, operating, and maintenance costs are reduced when frame arrangements in an office are standardized. Important considerations here involve: (a) arrangements of frames on floors, (b) office and frame capacities, (c) cable rack and office lighting, (d) end guards for end of frame line-ups, and (e) interframe cabling and wiring.

Much attention has been given to each of these items as well as to appearance, with results as shown in the figures. Missing from these illustrations, however, is an important feature — the attractive color scheme. Cable rack enclosures, end guards, and frame bases are a dark shade of blue, which makes an attractive contrasting border around the light blue-gray of the frames within each line-up.

4.1 *Floor Plans*

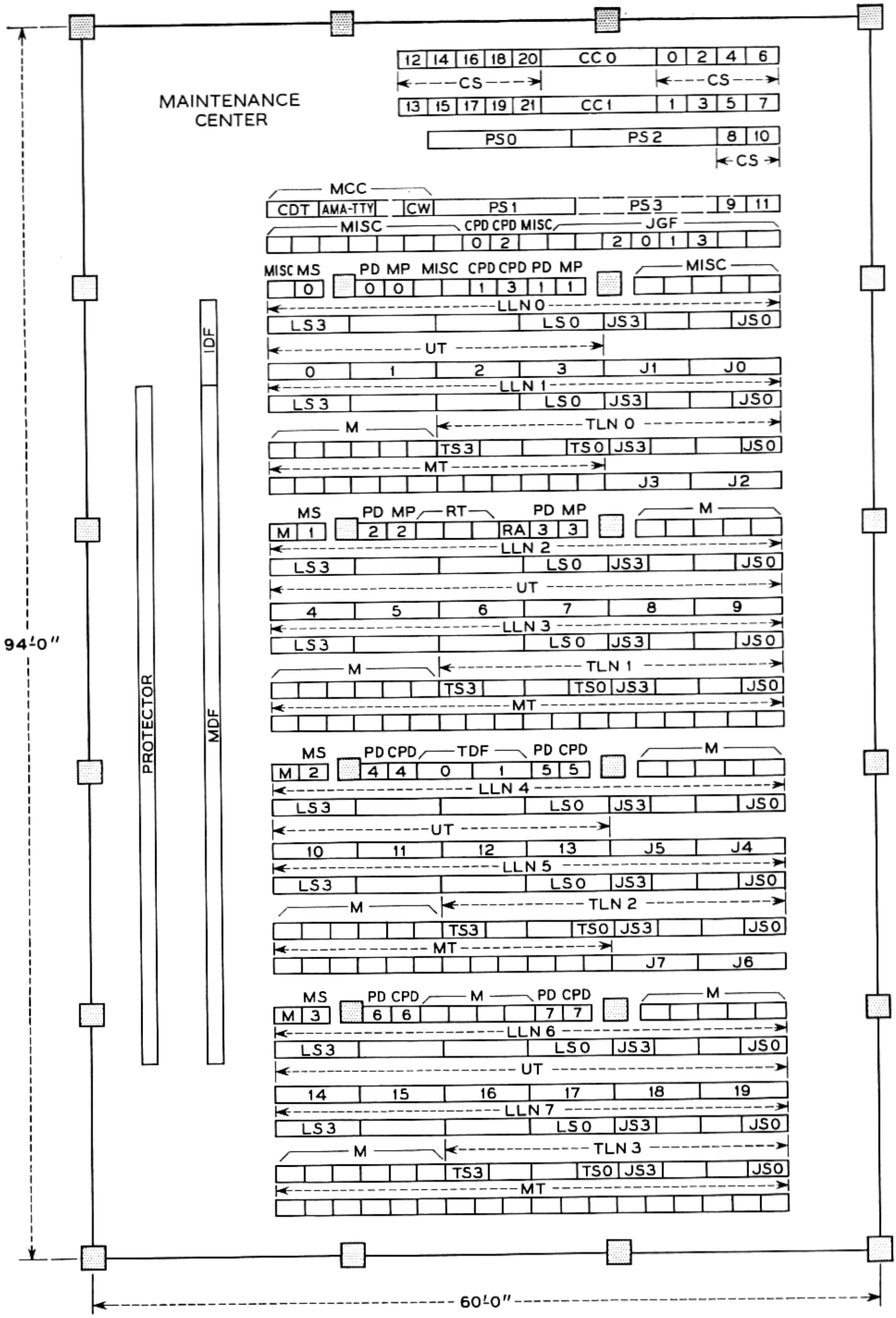
A universal floor plan pattern has been developed which:

(a) Grows naturally from the smallest to the largest installation. With a few minor variations, it makes efficient use of floor space at every size and for all traffic concentrations.

(b) Permits an office to start with one line concentration ratio and convert later to another if traffic density changes make it desirable.

(c) Provides short, direct cable runs that minimize cable costs and electrical interference.

(d) Locates the master control center, central controls, and stores



1. SHOWN ARE 8 LLN's FOR 32,768 LINES WITH 4 TO 1 LINE CONCENTRATION RATIO AND 4 TLN's FOR 4,096 TRUNKS WITH 1 TO 1 TRUNK CONCENTRATION RATIO
2. JGF IS CENTRALLY LOCATED FOR ULTIMATE GROWTH TO DOUBLE THE OFFICE SIZE WHETHER GROWTH IS TO REAR, TO ONE SIDE OR, TO ANOTHER FLOOR
3. SEE TABLE I FOR KEY TO ABBREVIATIONS

Fig. 5 — Typical floor plan.

together in preferred locations in one area. Space for about half of the stores is in the initial building, and the remainder is in an addition.

(e) Employs standard building bays and provides for building growth to the rear, to one side, or to a floor above.

(f) Aligns the protector frame and the main distributing frame (MDF) with associated network frames for orderly growth together, in a way that automatically shortens cables and MDF jumpers.

(g) Permits the same pattern to be followed in all new buildings and adapted to existing buildings.

The pattern, as applied to a typical office, is shown in Fig. 5.

The new MDF is parallel to the long building wall, with all frame line-ups perpendicular to it. Central control, store, and maintenance frames are in preferred locations in one area. Network, trunk, and other frames are in building bay modules which grow with the MDF.

Buildings will require a minimum ceiling height of 10 feet under beams. Floor loads are the standard 150 pounds per square foot: 100 pounds for equipment and 50 pounds for cable rack, interframe cable, and maintenance personnel.

4.2 *Office and Frame Capacities*

The more important capacities are shown in Table II.

4.3 *Cable Rack and Office Lighting*

The cable rack, which conceals and shields all interframe cabling, is frame-supported over each line of frames and across aisles (see Fig. 6). A cable rack stanchion ($3\frac{1}{2}$ inches in diameter) is used to support cable rack where frames are omitted for spans of 10 feet or so. The cross-aisle racks are placed at each end of a line-up and at intermediate points as needed. This system of frame and cross-aisle cable racks not only provides for routing and segregating of cables but rigidly interconnects the frames and line-ups, giving great stability to the overall structure.

Also, since the frames are low and the aisles are largely free from overhead racks, excellent illumination is obtained either from ceiling lights or from frame-supported lighting, both of which are standardized.

4.4 *End Guards*

End guards are used at main aisle ends of frame line-ups. Each has a swinging door to give access to cables and equipment inside. Wherever one or more frames are omitted in a line-up, each exposed frame end is dressed with an end guard.

Table II — Office Capacities

Capacity		Number per Office
Total busy hour calls (100 seconds each), intra-office plus incoming plus outgoing		100,000 approx.
Directory numbers		
number groups		128
numbers per group		1,000
office codes		32
Networks		
Line link network with 2 to 1 line switching		
Conc. Ratio	Lines	
2 to 1	32,768	16
$2\frac{1}{2}$ to 1	40,960	16
3 to 1	49,152	16
$3\frac{1}{2}$ to 1	57,344	16
Line link network with 4 to 1 line switching		
Conc. Ratio	Lines	
4 to 1	65,536	16
5 to 1	65,536	$12\frac{4}{5}$
6 to 1	65,536	$10\frac{2}{3}$
7 to 1	65,536	$9\frac{1}{7}$
8 to 1	65,536	8
Trunk link network		
Conc. Ratio	Trunks	
1 to 1	16,384	16
$1\frac{1}{4}$ to 1	20,480	16
$1\frac{1}{2}$ to 1	24,576	16
$1\frac{3}{4}$ to 1	28,672	16
2 to 1	32,768	16
Frames		
Central control		1 pair
Program store		6
Call store		37
Master control center		1
Master scanner		As required
Central pulse distributor		8 pairs
Power distribution		1 per 400-amp peak load for each of −48 volt and +24 volt
Ringing and tone ($\frac{1}{2}$-amp capacity on 2 bays or 6-amp capacity on 3 bays)		1
Junctor grouping frame modules		4 pairs

Equipment in the main aisle end guards (see Fig. 7) includes plates of bus terminating resistors.

On the outside of the end guards are the aisle alarm lamps, the aisle directory for designating the frames in each line-up, and light control switches. A spare fuse holder is provided on the door.

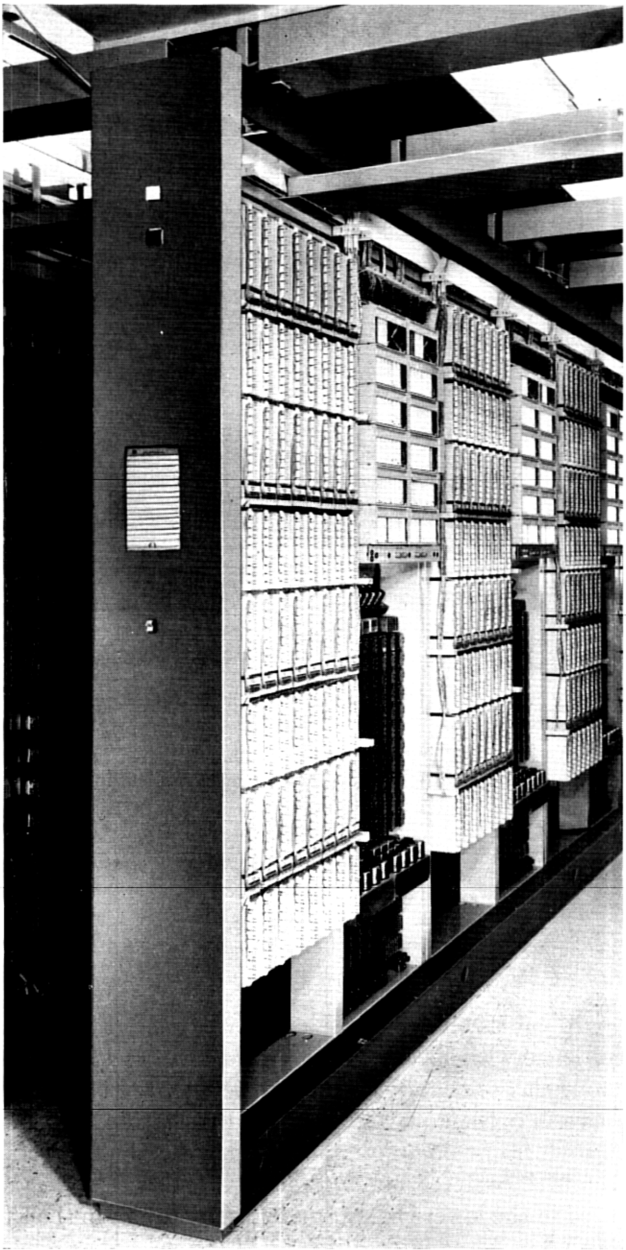


Fig. 6 — Typical maintenance aisle showing cable rack and lighting.

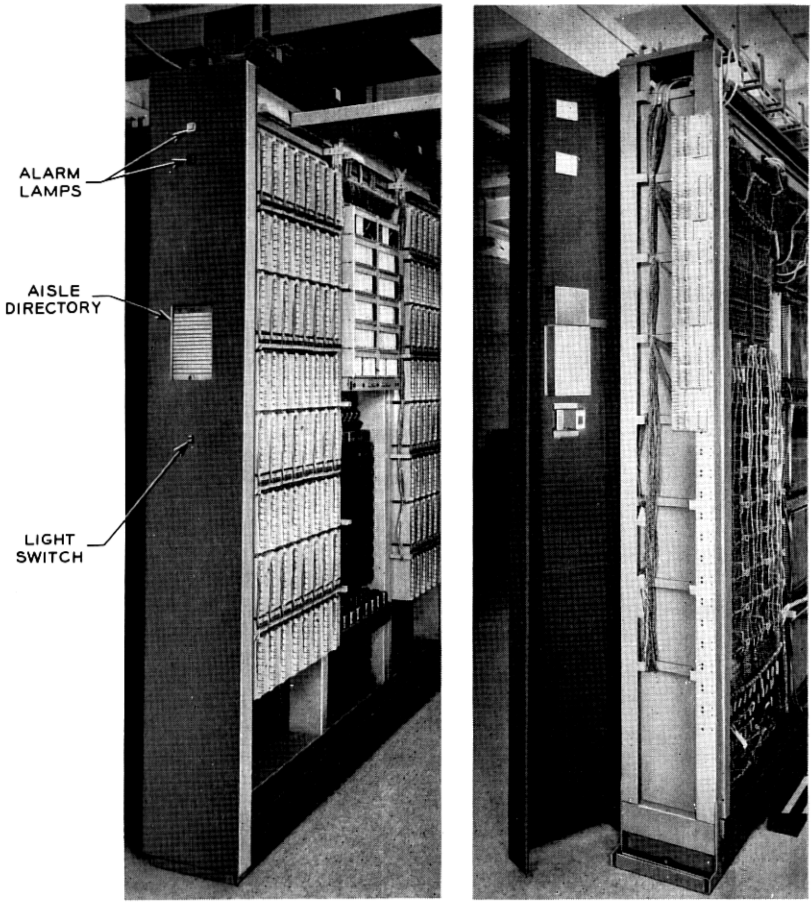


Fig. 7 — End guard and equipment.

4.5 *Interframe Cabling and Wiring*

Switchboard cables and dc and ac power cables for system loads are run in accordance with specific rules to minimize electrical interference. There are four classes of cables which are segregated in their own cable rack sections and broken out and connected in specified ways. The cable rack above each frame line-up has three separate channels on an upper level and a fourth centered below them. Address and answer bus cables are segregated in the lower channel and scanner cables in the front upper channel; both are terminated directly on transformers and terminal strips at the top of the frames. The dc power cables are segregated in the rear upper channel and run down the frame uprights to filters and fuse panels. Tip and ring and relay control cables are in the larger central upper channel, and these run to frame or unit terminal strips or to ferreed switch terminals.

Power wiring for the appliance outlet on each frame is run in the shop. The installer then connects the wire ends at a frame junction by inserting them into the connectors in the appliance outlet on the adjacent frame.

Busways deliver power to the end frame in each line-up. Power wiring for lighting is run in busways to the fixtures over each maintenance aisle. The lamps have switches in the end guards of line-ups connected by low-voltage wiring to relays on the fixtures.

Special frame insulating practices are followed, and frames are connected to ground at only one point to avoid electrical interference from stray ground potentials and currents.

V. APPARATUS TYPES AND QUANTITIES

No. 1 ESS equipment consists to a large degree of new types of switching apparatus. To achieve system economies, a concentrated effort has been made to restrict the varieties and codes of apparatus used to an adequate but limited catalog of each apparatus type. This code concentration permits shop and field economies both in equipped frames and in spare parts.

5.1 *Number of Apparatus Codes and Their Quantities*

The number of codes (or types) of each of the more usual apparatus elements in No. 1 ESS is given in Table III, together with the quantity of each in a typical 10,000-line office.

Approximately 13 per cent of all circuit packs will be of one code and 65 per cent will be of 17 codes.

Since the typical office uses 5.5 transistors, 16 diodes, and 20 resistors per line, the unit costs for these components have a marked influence on the office cost.

5.2 *Semiconductor Devices*

Three transistor codes are used: one general-purpose type for amplifiers and switches, one power transistor type, and one pnpn switch.

Eight diode codes are used: three high-speed types to perform the bulk of the logic functions, three voltage regulator types, one level shifter, and one click reducer.

TABLE III — APPARATUS CODES AND QUANTITIES

Apparatus Elements	No. of Codes	Quantity in Typical 10,000-Line Office
Transistor	3	55,000
Diode	8	160,000
Resistor	23 types	200,000
Transformer or inductor	21 types	26,300
Capacitor	30 types	23,400
Ferreed switch (8 × 8 Type)	4	3,400
Ferreed switch (1 × 8 Type)	2	2,000
Ferrod sensor	4	8,000
Relay	78	14,000
Ferrite sheet memory	1	16
Twistor memory	1	32
Circuit pack	150	12,600

5.3 *Passive Components*

All passive components (resistors, transformers, inductors, and capacitors) for the system were selected from a master list for each class which was catalogued specifically for No. 1 ESS to limit varieties and to assure universal use of high-quality components having reasonable costs. Types were selected with the preferred construction for each desired range of electrical characteristics, and with particular attention to tolerance, physical size, life, aging stability, and failure mode (principal cause of failure at normal end of life).

5.4 *Circuit Packs*

In order to minimize the number of semiconductor circuit pack codes, it was necessary to develop several standard circuit pack arrangements of logic gates. Tests were made of a variety of wired gate packages to determine best circuit and semiconductor arrangements. Following this development work, pilot production of printed wire board designs was tested in brassboard circuits.

A family of packages evolved from this program. The semiconductors and many other small components are mounted on printed circuit packs which engage plug-in connectors in die-cast aluminum apparatus mountings. These mountings accommodate as many as 16 packs on 0.4-inch centers or correspondingly fewer on wider centers. The two packs removed from the mounting in Fig. 8 are typical for low-level logic circuits. They are made from $\frac{3}{32}$-inch thick phenol fiber of a fire-retardant grade and have components mounted on one side with printed wire interconnections on the other. The printed wire paths are gold plated at one end of the board to form 28 connector terminals. The packs are $3\frac{3}{4}$ inches wide and $6\frac{7}{8}$ inches long, providing space for approximately 70 typical ESS components. The number of components per circuit pack varies from as few as 6 relatively large transformers to as many as 84 smaller components, including resistors, diodes, and transistors. This size of pack and number of terminals reflect experience with the Morris trial and represent a compromise among such factors as total contacts required for the system, lead lengths, cost, and number of codes. As shown in the figure, each circuit pack carries a colored label with a code number on the protective aluminum strip at the front. For proper selection, this color and number must match a similar label on the hinged strip at the top of the mounting.

Each apparatus mounting for circuit packs has this hinged designation strip across the top with designation cards, front and rear, to show for each circuit pack its position in the mounting, its apparatus code, and its color code. Circuit packs are physically, although not electrically, interchangeable.

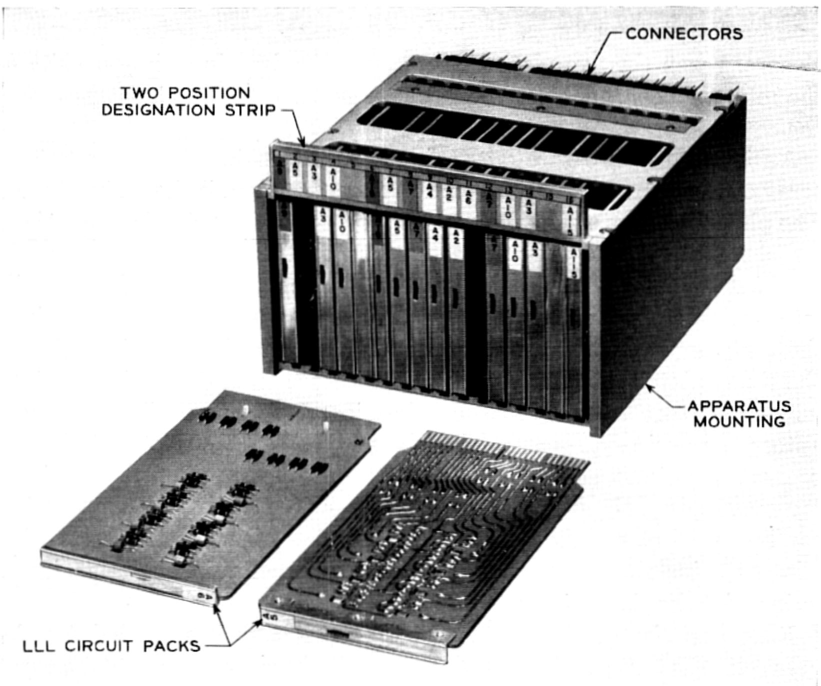


Fig. 8 — Circuit packs and apparatus mounting.

Each circuit pack bears one of three color codes: red, yellow or blue. No damage will be done if the wrong circuit pack is plugged into a connector designated with the same yellow or blue color code, although the circuit will not function properly if the codes do not match. The red packs must be plugged into connectors having the same code and color designation.

5.5 *Ferreed Switches*

The ferreed switch was designed to serve as the crosspoint element for No. 1 ESS networks. It is a two-wire, magnetically latched, pulse-operated device. It consists of two small sealed reed switches which are operated and released by controlling the magnetization of two adjacent rectangular Remendur plates. Remendur, an alloy of iron, cobalt and vanadium, is a magnetic material with a square hysteresis loop. Each plate is magnetically divided into two independent halves by a low carbon steel shunt plate, which also provides the mechanical structure for assembling the crosspoints into various arrays of 8 × 8 switches. When the two halves of each plate are magnetized series-aiding, the flux from both plates returns through the sealed reeds, causing contact closure. When the two plate halves are magnetized in series-opposition, the return flux through the reeds' gap is reduced to practically zero and the contacts open.

An individual two-wire crosspoint is shown in Fig. 9 and an 8 × 8 array of these crosspoints, known as a ferreed switch, is shown in Fig. 10. The phenolic forms on which the coils are wound are molded directly into the shunt plate. The windings are wound on these forms by automatic machines which provide a checkerboard pattern; that is, adjacent coils are wound in opposite directions to reduce magnetic interference. Since the contact gap in the sealed reeds must be accurately located relative to the shunt plate, both reeds of a crosspoint are carefully positioned in a molded contact assembly which, when inserted in the coil form, guarantees the desired tolerances. This contact assembly also provides for properly positioning the Remendur plates within the coil form. Terminals are provided on the front and rear of the switch so that all shop wiring can be on the rear of the frame and all installer wiring on the front. This allows the installer to work in the wider equipment aisles without interfering with the shop wiring.

Four varieties of these two-wire switches have been coded for the network. The first provides one 8 × 8 array, the second two 8 × 4 arrays, the third 16 × 4 of 8 array (which gives 16 lines access to 8 links but each line access to only 4 of these 8), and the fourth four 4 × 4 arrays.

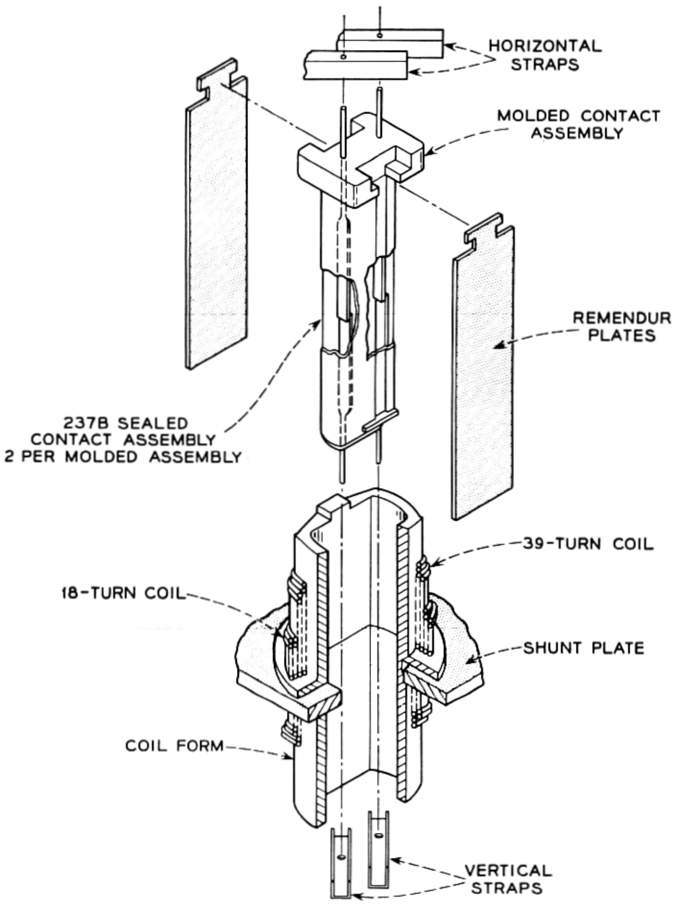


Fig. 9 — Two-wire ferreed assembly.

Another version of the ferreed, used for cutoff and test access, has two sealed reed switches mounted between two rods. One of these is permanently magnetized, and the other, a Remendur rod, has its polarity controlled by a winding, as shown in Fig. 11. Eight of these bipolar crosspoints are assembled into one coded switch, shown in Fig. 12. Two varieties of these switches are used The first has both ends of all crosspoints brought out to terminals, thus providing eight individual crosspoints in one package. The second has one side of all crosspoints strapped together to provide a 1×8 switch.

A summary of the characteristics of these ferreed switches is shown in Table IV.

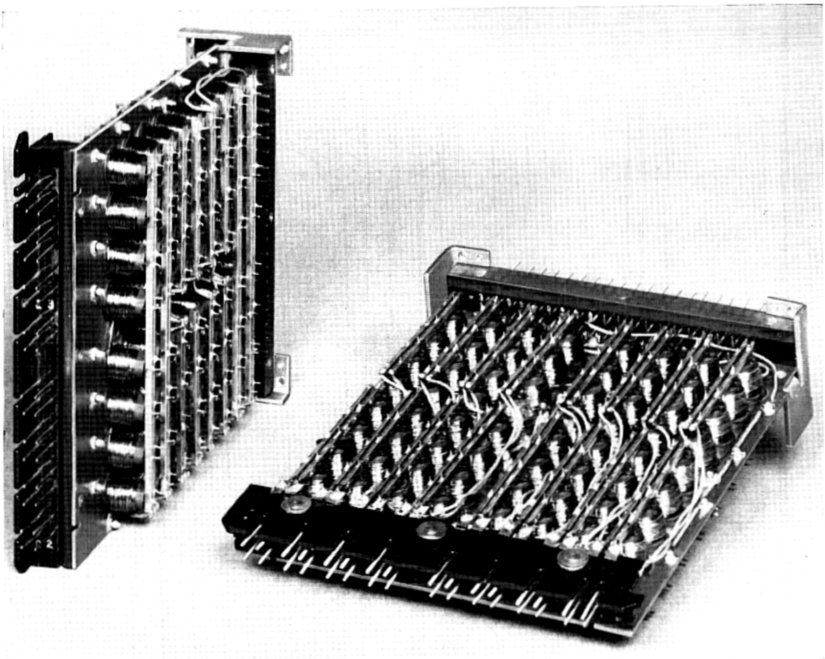


Fig. 10 — 8 × 8 ferreed switch.

5.6 *Ferrod Sensors*

The ferrod sensor, a current-sensing device, has been developed as the building block for all No. 1 ESS scanners. It consists of a ferrite stick located on the centerline of a pair of identically wound solenoidal coils. In the ferrite stick are two holes through which are threaded two single-turn loops of wire, one carrying the interrogate pulse and the other the readout pulse. Coupling between the two loops depends on the magnetic state of the material around the holes, which in turn depends on the amount of dc flowing in the solenoidal coils. Thus, with no current in the control winding (on-hook or open circuit) an interrogate pulse produces a large pulse in the readout loop, whereas presence of dc in the control winding suppresses this pulse.

To conserve frame mounting space, the ferrod sensor unit contains two ferrods, one behind the other. These units are mounted on equipment frames in egg-crate apparatus mountings (see Fig. 13), each of which accommodates 128 of these dual units or 256 ferrod sensors. The mounting serves not only as a physical support but also as an array of magnetic shields to prevent interference between adjacent sensors.

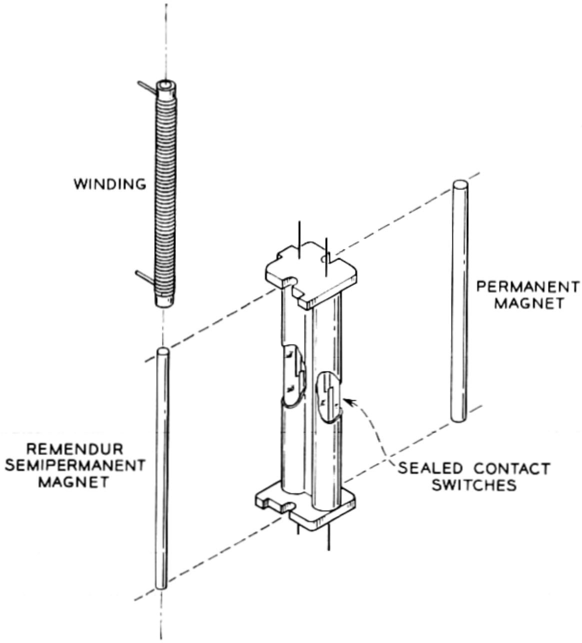


Fig. 11 — Bipolar ferreed assembly.

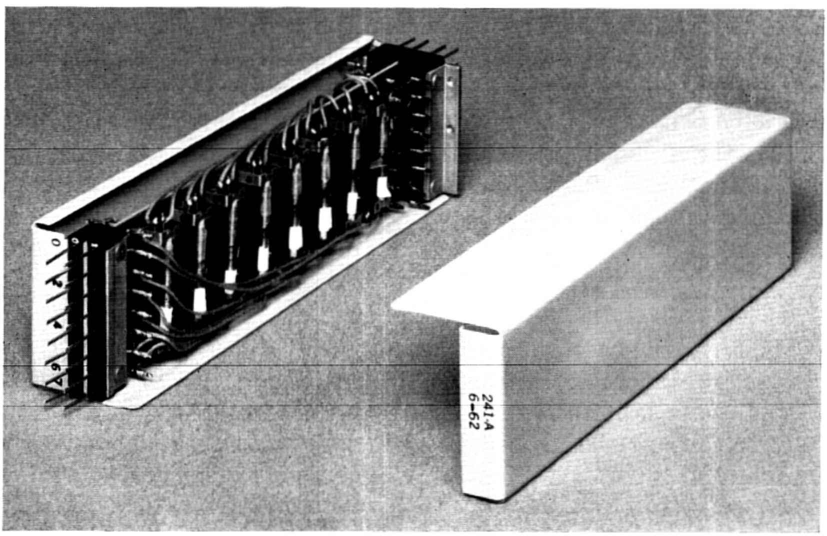


Fig. 12 — Bipolar 1 × 8 ferreed switch.

TABLE IV — SUMMARY OF FERREED SWITCH CHARACTERISTICS

	Over-All Dimensions			No. 1 ESS Network Circuit Requirements										
				Operate and Release Pulse			Characteristics							
	Height (inches)	Width (inches)	Length (inches)	Peak Amperes	25% width (microseconds)	Energy (joules)	Resistance (milliohms)	Operate chatter (milliseconds)	Breakdown (volts)	Dry operate (milliamperes)	Wet operate (milliamperes)	Expected life (operations)	Tolerable surge (amperes)
2-wire (8 × 8 type)	$6\frac{3}{4}$	$2\frac{1}{8}$	$9\frac{1}{4}$	9	200 to 500	0.2	<200	<3	>800	125	0	10^6	3.6
2-wire bipolar (1 × 8 type)	$1\frac{5}{8}$	$2\frac{1}{8}$	$9\frac{1}{4}$	6	200 to 500	0.01	<200	<3	>800	125	40	10^6	3.6

The ferrod sensor units take full advantage of the economies of molding. Both control windings are wound directly on a molded spool which supports the ferrite stick and, in the case of the more sensitive 1D and 1E sensors, the metallic magnetic return path. Two of these spool assemblies are located between two similar molded wire arrays which hold the spools in place and establish contact between the spool terminals and the molded wires, the ends of which serve as the apparatus terminals. In the 1B code, two contact protection networks are also supported between these molded wire arrays. These networks provide protection for the cutoff contacts, which are in series with the control windings and reduce interference in the connecting circuits as the cutoff contacts operate. Both of the sensors in the 1B unit are shop wired for loop start lines, but one of them can readily be converted for ground start operation by changing strapped connections on the front terminals of the unit.

5.7 *Ferrite Sheet Memory*

The 6A ferrite sheet memory is used in the call store for temporary, electrically-changeable information.[5] The memory module, shown in Fig. 14, contains 192 active ferrite sheets, plus 12 spare sheets, arranged in three columns and divided into four sections or submodules. An individual sheet, shown in the inset, is 1.04 inches square and 0.030 inch thick, with 256 holes of 0.025-inch diameter arranged in a 16 × 16 array. The material surrounding each hole acts as a small, two-state magnetic core to store one information bit. Thus the module has a capacity of

49,152 bits, which are organized by the wiring pattern into 2048 words of 24 bits each.

Four one-turn "windings" pass through each hole for X-address, Y-address, inhibit, and readout functions. The Y-address windings are formed by the conductors "printed" on the two sides of the sheets and through the holes by evaporation and plating techniques. Interconnections between adjacent sheets, and between sheets and the connectors at the sides, are by short wire jumpers soldered to the two large land areas on each sheet. The X-address, inhibit, and readout windings are made by threading fine 36-gauge wire through each column of holes. The readout windings are applied on a submodule basis so that each threaded length is the height of the submodule. Connections are made to the terminals printed on the sides of the epoxy-paper printed wire board at the top of each submodule. The X-address and inhibit windings are threaded through the entire height of the module, with X windings terminated on the connectors in the upper right corner and inhibit windings on terminals of the printed wire board at the bottom of the module.

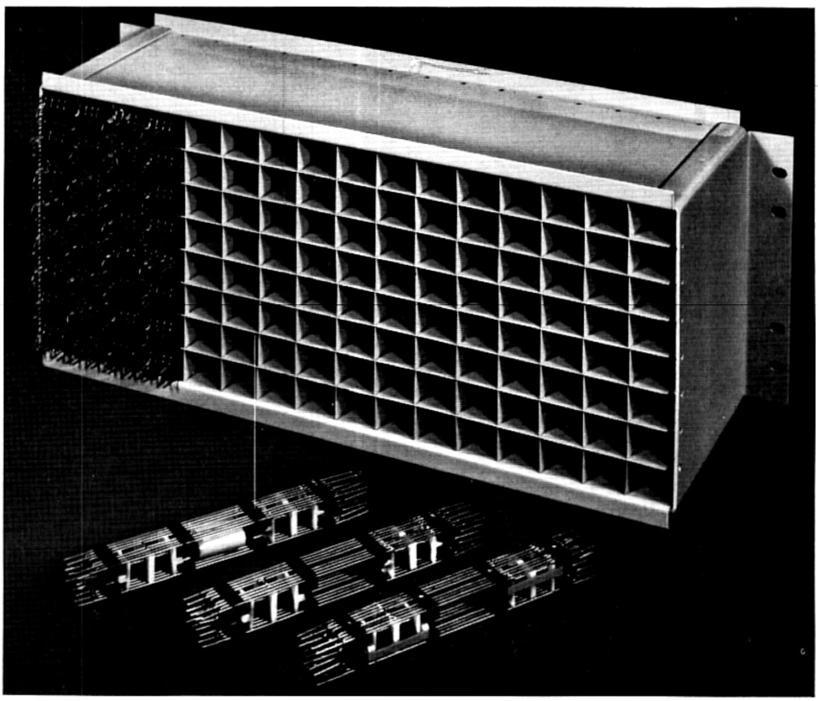


Fig. 13 — Ferrod sensors and mounting.

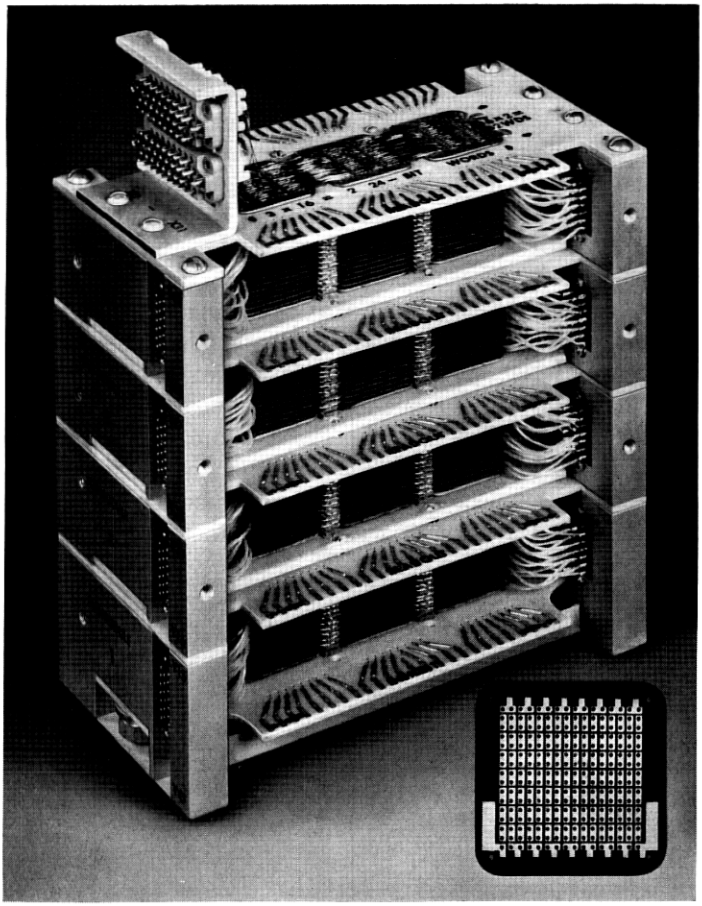


Fig. 14 — Ferrite sheet memory and sheet.

The use of pluggable connectors for all winding terminations facilitates testing and permits a compact assembly of the four modules needed for each call store by plugging the modules together with special, double-ended printed wire board connectors between. This minimizes noise pickup in the readout windings and eases field replacement.

5.8 *Twistor Memory*

The 1A twistor memory is used in the No. 1 ESS program store for bulk storage of the semipermanent program and translation information.[6,7] The memory module, shown in Fig. 15, is composed of 64 twistor planes mounted vertically in an aluminum and steel framework. Each plane is made of stable glass-bonded mica, with solenoid tapes and twistor tapes cemented to each side. Each solenoid tape carries 64 strands of flattened wire, corresponding to 64 memory words, and each wire links a magnetic access core along the rear edge of the plane. The twistor tapes contain separate twistor wires, together with return paths, for simultaneous readout of each of the 44 bits per memory word. Two such tapes, designated A and B, are used for the entire module, and each is cemented to its side of each twistor plane. The two ends of tape A are terminated on the front side of the module, on the lower halves of the terminal fields, while tape B is terminated on the upper halves. The 64×64 field of access cores at the rear is linked by X- and Y-select windings and a bias winding, which are terminated on the rear side on terminal fields at both ends and along the top and bottom edges of the module.

Resilient flat springs between the twistor planes maintain intimate contact between 128 twistor memory cards and the twistor tapes. The memory card (see Fig. 16) is an aluminum sheet 0.016 inch thick with 64 rows of tiny permanent magnets, each representing a bit of information

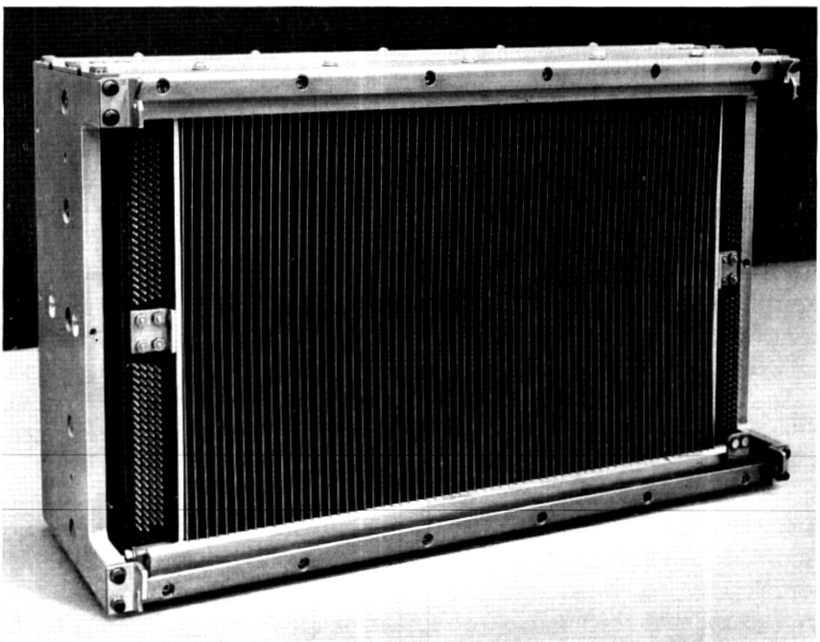


Fig. 15 — Twistor memory module.

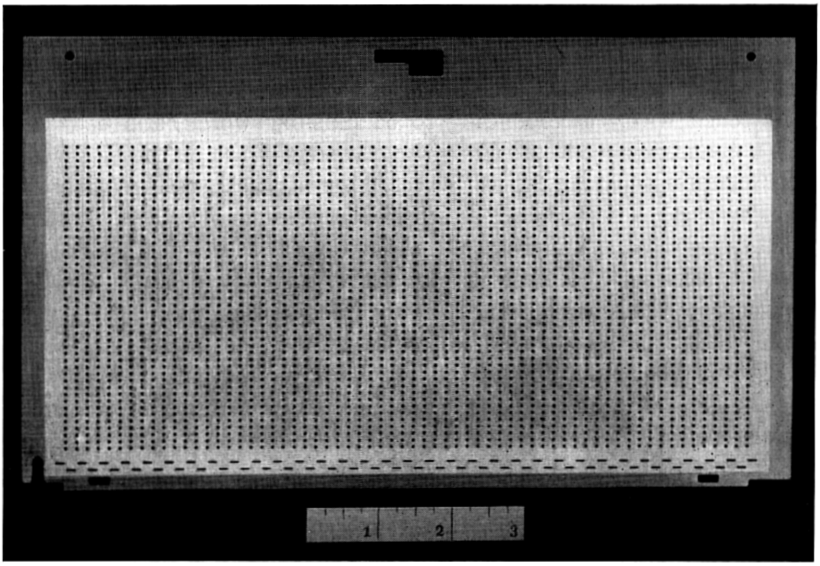


Fig. 16 — Memory card.

to be remembered. Thus the module has a capacity of 8192 words of 44 bits each, or 360,448 bits in all. A magnetized state is read as a binary "zero," while demagnetization corresponds to a "one." Two other rows of magnets along one edge are used for initializing, or controlling, the magnetic state of the twistor wires between word locations, and for sensing the word locations during the card writing process. The card is positioned vertically by a locating notch near one corner, which engages a preadjusted pin in the module. The depth of insertion is individually controlled for each card by two factory-adjusted screws. This maintains accurate registration for the bit magnets with respect to the intersections between the solenoid and twistor wires.

The memory cards are inserted into or withdrawn from the module simultaneously by the card loader. The keyhole-shaped opening near one edge of the card permits the loader to grip the card during insertion and withdrawal, while the rectangular punchings near the other edge are engaged by fingers of the card writing unit to draw the cards individually from the loader during the writing process. Other features to facilitate card loading and writing include: (a) special locating ears at the four front corners of the module for support and accurate positioning of the loader with respect to the twistor planes, (b) a connector in the lower right corner to supply 48-volt dc power to the loader, (c) tapered guiding surfaces to facilitate entry of the cards into the module, (d) accurate dimensional requirements for the alignment and spacing of the twistor planes, and (e) special requirements for card flatness and the force needed to seat the cards in the memory module.

5.9 *Relays*

For operations of relays, such as those performing supervisory functions in the trunk circuits where electronic speeds are not essential, a family of magnetically latching wire spring relays (types AL and AM) was developed. Through the use of a new magnetic structure, each of these relays operates when driven with a −48-volt pulse and remains operated. The relay is released by a controlled +24-volt pulse (sufficient to release the relay while avoiding reverse polarization and resultant reoperation).

Some semiconductor circuits have loads requiring metallic paths. The signal distributor uses a mercury relay driven by a flip-flop to operate the multicontact relays forming the trunk relay selection trees. The program store uses a circuit pack containing eight dry reed relays operated by low-level logic (LLL) circuits. The line switching frame uses two types of circuit packs containing six dry reed relays operated by a four-bit register flip-flop. In both cases these relay contacts operate wire spring relays.

5.10 *Transformers and Terminal Strips*

The 0.5-microsecond interframe bus system[8] has semiconductor drivers in the central control, with receivers in as many as 60 peripheral frames distributed along a pair extending 450 feet. The two transformer single-turn input windings have a ground shield to minimize noise coupling.

The ferrite cores are supported in a dual molded wire comb array as shown (see Fig. 4) with a wire braid shield over the input windings. An array of twelve ladders is assembled to provide for a 24-bit bus. The depth of the transformer matches the size of the semiconductor driver and receiver circuit packs with which it is used. A similar terminal strip provides for those leads which do not pass through a transformer.

5.11 *Connectors*

5.11.1 *Circuit Pack Connector*

The circuit pack connector[9] (see Fig. 17) is essentially a two-piece unit. Twenty-eight 0.036-inch diameter phosphor bronze springs are molded

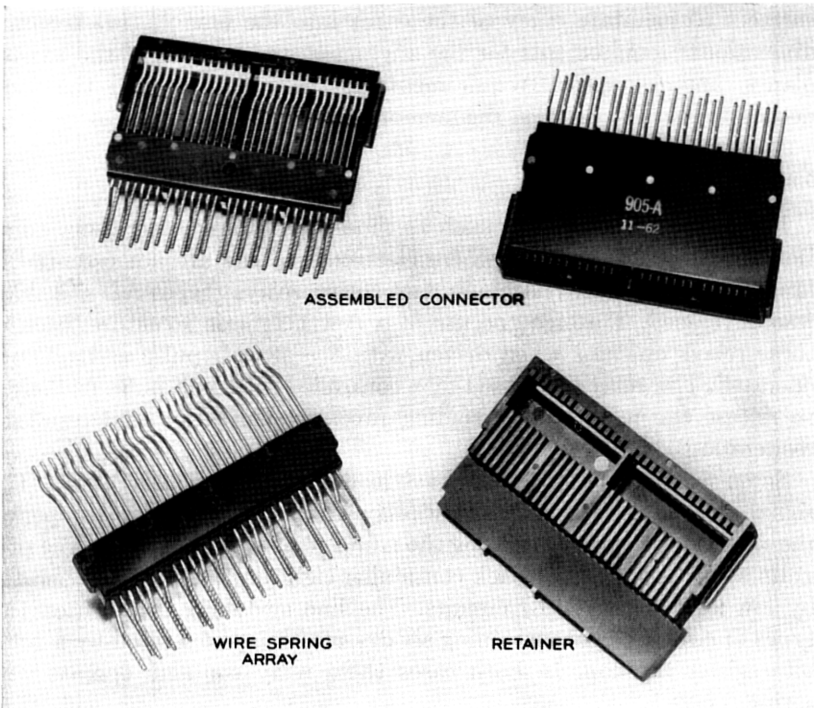


Fig. 17 — Circuit pack connector.

into a phenolic block in much the same manner as the wire spring relay. This pretensioned spring assembly is riveted to a phenolic molded retainer.

A gold overlay contact button is welded to the spring to assure a low-resistance contact. The other end of the spring is serrated for wire wrapping. The contact is designed for 500 insertions and withdrawals of circuit packs.

With the circuit pack in place, the minimum contact force will be 155 grams.

5.11.2 *Junctor Grouping Frame Connector*

The connector and mating plug of the junctor grouping frame are used to interconnect cables with 16 pairs. The contacts are formed from 0.036-inch diameter phosphor bronze wire. Two sets of sixteen contacts, each formed as spring members, are used in the connector, and two sets of flattened contacts are used in the plug. Each contact spring has a nominal force of 250 grams on the mating plug contact. All contacts are gold plated to insure a minimum life of fifty insertions.

5.12 *Distributing Frame Connecting Blocks*

Two new connecting blocks, similar to that shown in Fig. 18, have been developed for No. 1 ESS distributing frames. Both employ terminals of a new design adapted from that in 66-type connecting blocks, which are finding wide use in station systems.[10] The "quick-connect" feature speeds up the making of cross connections, because all that is necessary is to hold a plastic-insulated wire in the slot opening of the terminal clip (with about $\frac{1}{8}$ inch extending beyond) and force it into place with a hand tool. Thus, without prior preparation, a thrust of the hand causes the terminal to cut through the insulation and com-

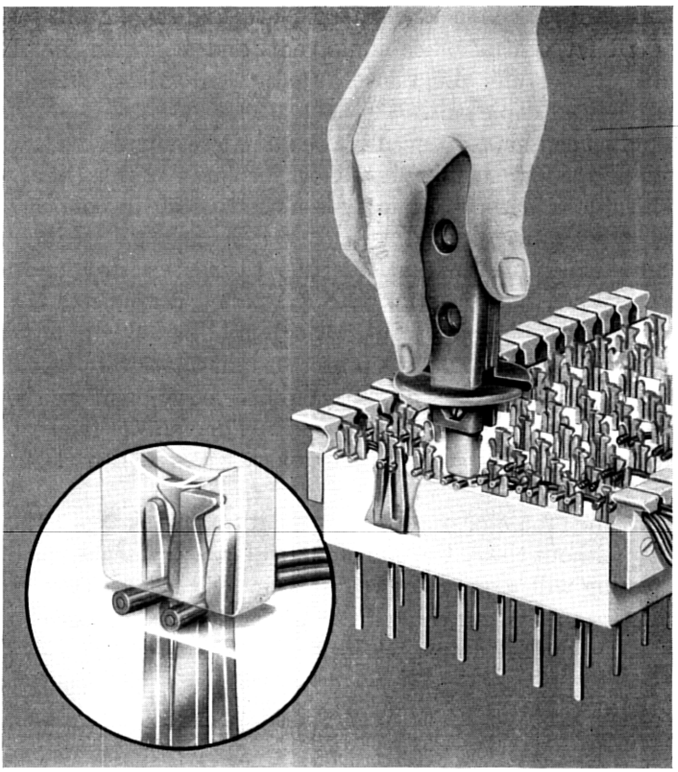


Fig. 18 — Distributing frame connecting blocks and insertion tool.

plete a good connection. A simple forked tool is used to remove a lead without disturbing wires on adjacent terminals.

Each connecting block has 64 pairs of terminals, but one has two slots per terminal to accommodate two jumper wires, while the other has only one slot. Both terminals accept two solderless wrapped connections on the rear. Both blocks are molded from white plastic. The terminals are made from 0.045 by 0.045 inch phosphor bronze.

5.13 *Protector Apparatus*

A new connector, coded 302, terminates 100 outside plant pairs on the protector frame. This new unit is responsible for a 3.3:1 reduction in frame length while providing all of the usual features for protection, isolation, and testing of lines.

The connector panel is a molded, flame-retardant, plastic unit 16.2 inches long and 4.3 inches wide with 100 jacks arranged in four rows of 25 each (see Fig. 19). Each jack has five pins: tip and ring (T&R) for outside plant, T&R for central office equipment, and a ground pin. Each individual protector unit plugs into a jack to provide standard 500-volt protection for one cable pair.

Gold-plated contacts arranged in two 50-pair groups at top and bottom give front access for attaching test-shoes for various cable tests.

A stub cable is factory-terminated on the rear of the connector, using either 24- or 22-gauge conductors.

An individual protector unit (see Fig. 19 inset) is provided for each cable pair. When fully inserted into the panel, it connects the central office equipment to outside plant through gold-plated contacts. A cable pair is disconnected by pulling a protector unit forward to a detent position, which disconnects the central office equipment without disconnecting protection on the outside pair. This feature facilitates office installation, cutover, cable testing, temporary service denials, and other services.

The 3A-type protector units have no heat coils, since No. 1 ESS is self-protecting without them. Certain circuits of other systems which are not self-protecting will require heat coils. They will use 4A-type units. No protection is required for cable systems that are not exposed to foreign potentials. Here, the dummy 5A type will be used.

VI. EQUIPMENT FRAME DESIGNS

6.1 *Network*

The No. 1 ESS network is a space-division network in which two-wire metallic connections are switched through eight stages of ferreed switches.

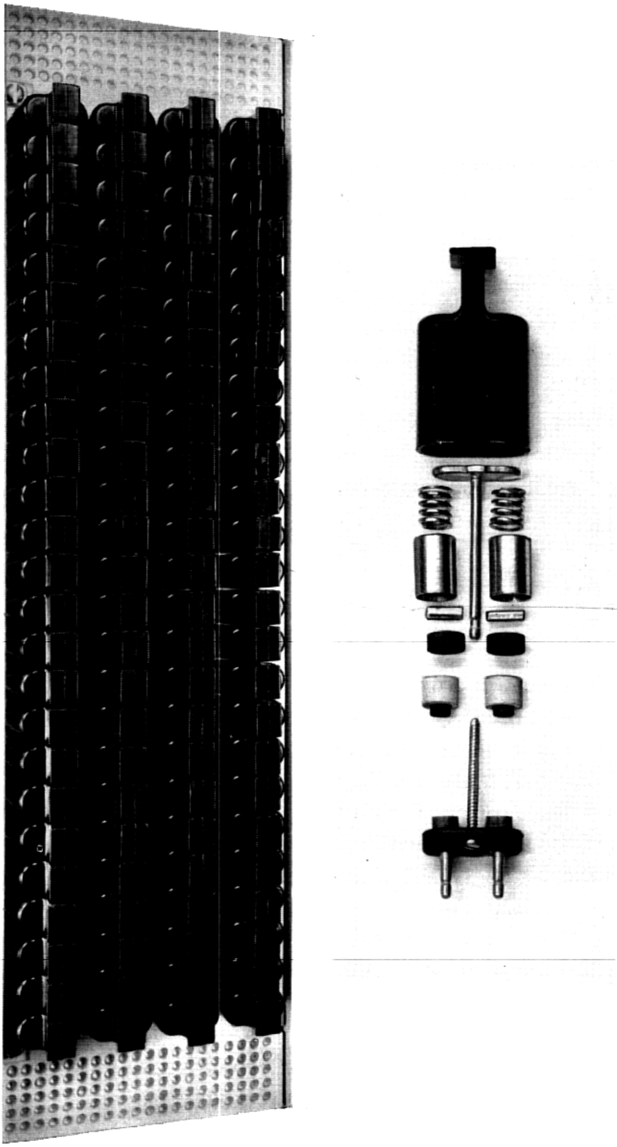


Fig. 19 — Protector and connector.

In addition to the normal interconnections of lines to lines, lines to trunks, and trunks to trunks, the network is used to interconnect lines and trunks to service circuits, such as: tone trunks, signal transmitters and receivers, coin supervisory circuits, ringing circuits, party test circuits, and maintenance circuits. To establish these interconnections, central control selects the desired network paths and, via the central pulse distributor and peripheral bus, addresses the network frames. The network in turn translates and executes these orders to establish the specified paths.

No. 1 ESS offices are arranged to work with a maximum of 16 line link and 16 trunk link networks. With 4:1 concentration, this provides network terminations for 65,536 lines and 16,384 trunks.

The line link network consists of line switching and junctor switching frames, while the trunk link network is comprised of trunk switching and junctor switching frames. Each of these frames provides for two stages of switching. The interconnection of these frames is shown in Fig. 1.

6.1.1 *Line Link Network*

There are two general types of line switching frames in this network; one provides 2:1 concentration and the other 4:1. Two frames are coded for each: one a home frame and the other its mate, which contains considerably less control equipment for line scanner and network.

In both the 2:1 and 4:1 frames, duplicated line scanner controllers are provided in the home frame. These two controllers alternate in serving a pair of home and mate frames, each one in turn controlling the scanner matrices on both frames for a fixed period of time under control of the program. If the active controller fails, the standby assumes control.

The duplicated network controllers in the 4:1 home frame serve a pair of home and mate frames. One controller normally serves the switches on the home frame and the other those on the mate frame, with either one taking over control of both frames if a failure occurs in the other. Duplicated network controllers are required on both home and mate frames, in the 2:1 frames due to the high calling rate there. Each controller normally sets up connections to only one half the switches on its frame, but either will control both halves of a frame under trouble conditions.

In addition to these control equipments, each home and mate 2:1-type line switching frame contains its half of a 1024-line ferrod sensor matrix for detecting service requests, and sixteen line concentrators with 32 lines each. Each concentrator is made up of two first-stage switches, each having four 4×4 crosspoint arrays, and two second-stage switches, each

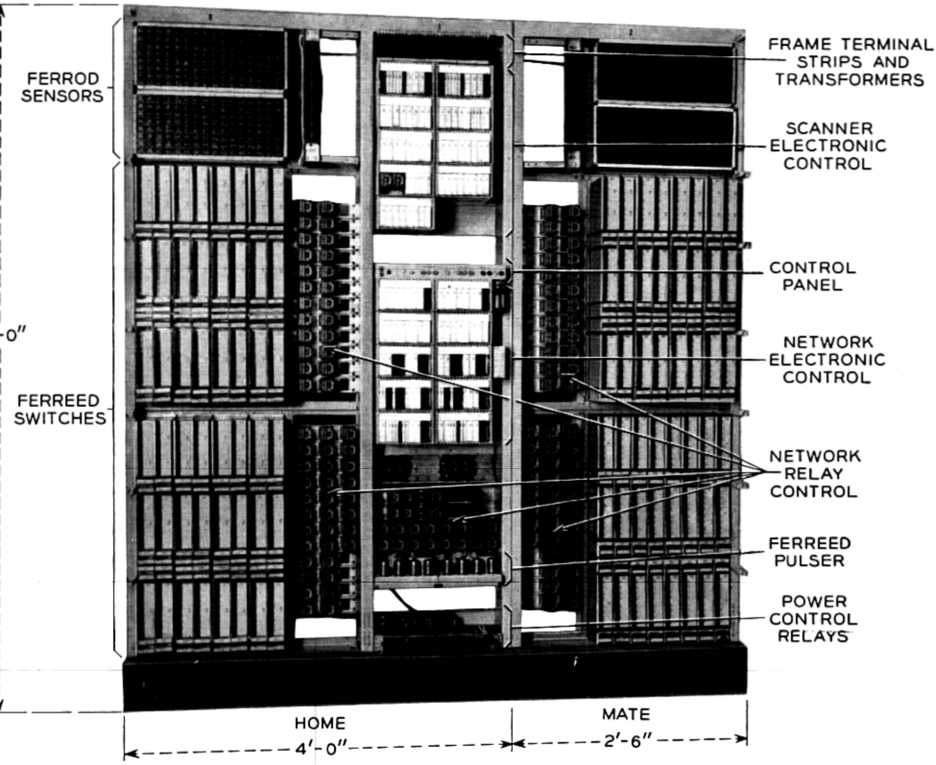


Fig. 20 — Line switching frames for 4-to-1 concentration ratio.

having two 8 × 4 arrays, which provide the 2:1 concentration. Each concentrator also has four bipolar ferreed switches, each with eight two-wire crosspoints for cutting off the ferrod sensors.

Each of the 4:1 home and mate frames contains its half of a 1024-line ferrod sensor matrix and eight line concentrators with 64 lines each, in addition to the above control equipments. Each concentrator has four first-stage 16 × 4 of 8 switches which provide 2:1 concentration and two second-stage switches, each with two 8 × 4 arrays, which provide an additional 2:1 concentration for a combined concentration of 4:1. Each concentrator also contains eight of the above bipolar switches. The four line switching frames are shown in Figs. 20 and 21.

The line junctor switching frame shown in Fig. 22 contains duplicated network control equipment and four grids, each with eight third-stage and eight fourth-stage 8 × 8 switches and eight 1 × 8 bipolar switches

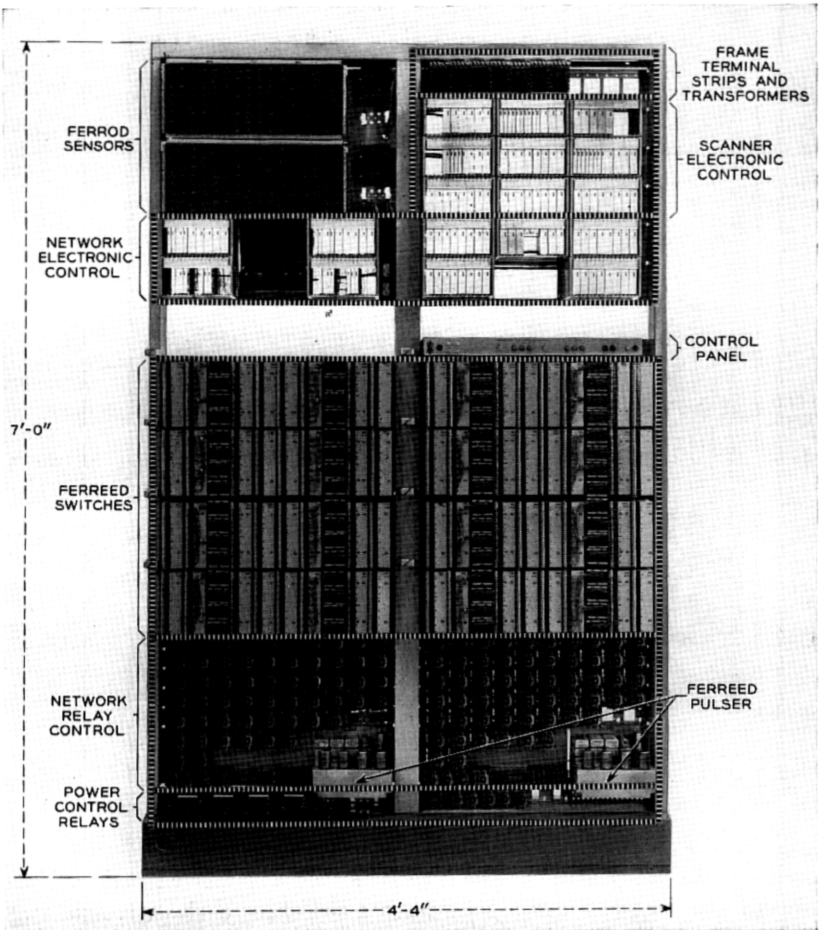


Fig. 21 — Line switching frames for 2-to-1 concentration ratio.

for test access into established connections. This frame has 256 "B" links on its third-stage and 256 junctors on its fourth-stage switches.

Each fully equipped line link network has four junctor switching frames and from four to sixteen line switching frames, counting home and mate frames as separate frames. This provides for concentrating lines ranging in number from 2048 to 8192 (in increments of 512 lines) on 1024 junctors. The 2:1 type of frame is used for concentration ratios of 2:1, $2\frac{1}{2}$:1, 3:1 and $3\frac{1}{2}$:1 and the 4:1 type for ratios of 4:1, 5:1, 6:1, 7:1, and 8:1.

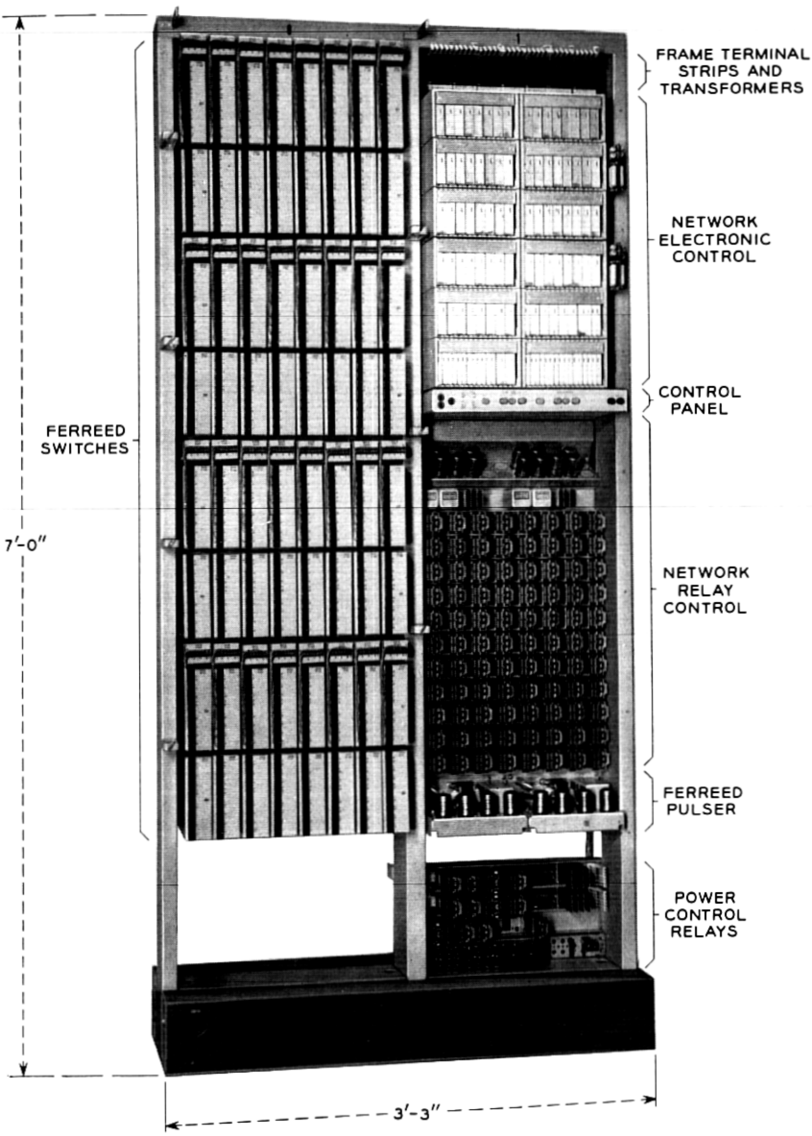


Fig. 22 — Line or trunk junctor switching frame.

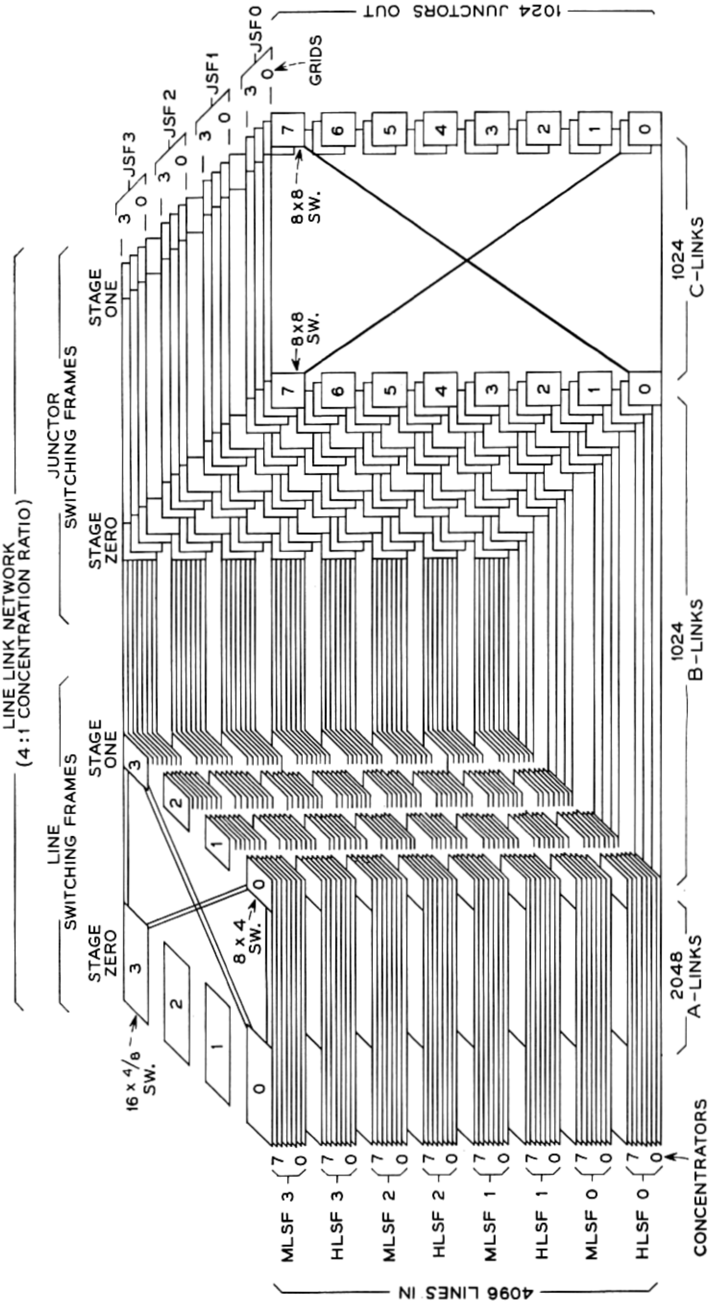


Fig. 23 — Link wiring pattern for 4-to-1 concentration ratio.

All lines on a line link network have access to all junctors via the A, B, and C links, which are spread between the first and second, second and third, and third and fourth stage switches, respectively. The wiring pattern for these links for the 4:1 concentration ratio is shown in Fig. 23.

Since all networks have a maximum of 1024 B links, regardless of their size, all networks other than the 2048-line 2:1 type and the 4096-line 4:1 type require the multipling of B links. Patterns have been established for these multiples to minimize blocking.

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 had to be exercised in the location of apparatus to minimize lead length and in the separation of leads into several local forms to minimize interference.

6.1.2 *Trunk Link Network*

The trunk link network has four junctor switching frames (the same as those in the line link network) and from four to eight trunk switching frames, which are the same as the junctor switching frames except for the omission of the bipolar ferreed switches. (See Fig. 24.)

The trunk switching frame has a capacity of 256 trunks on its first-stage and 256 B links on its second-stage switches.

Trunks ranging in number from 1024 to 2048 in 256 trunk increments are concentrated on 1024 junctors to give trunk concentrations of 1:1, $1\frac{1}{4}$:1, $1\frac{1}{2}$:1, $1\frac{3}{4}$:1, or 2:1. All trunks have access to all junctors, so B links must be multipled for all networks other than the 1024-trunk, 1:1 ratio size in accordance with patterns which minimize blocking.

6.2 *Trunk and Junctor Frames*

6.2.1 *Trunk Frames*

There are two types of trunk frames, the universal trunk frame (see Fig. 25) and the miscellaneous trunk frame. The universal trunk frame consists of a basic 4-foot, 4-inch double-bay frame and a supplementary 2-foot, 2-inch single-bay frame, each of which accommodates 64 plug-in trunk units. The miscellaneous trunk frame is a single-bay 2-foot, 2-inch frame used for mounting the conventional type of wired-in trunk circuits that come on 2-inch and 4-inch mounting plates.

The universal trunk frames, as their name implies, are universally wired so that any plug-in trunk unit may be plugged into any trunk position; each unit may have one circuit or two circuits. The supple-

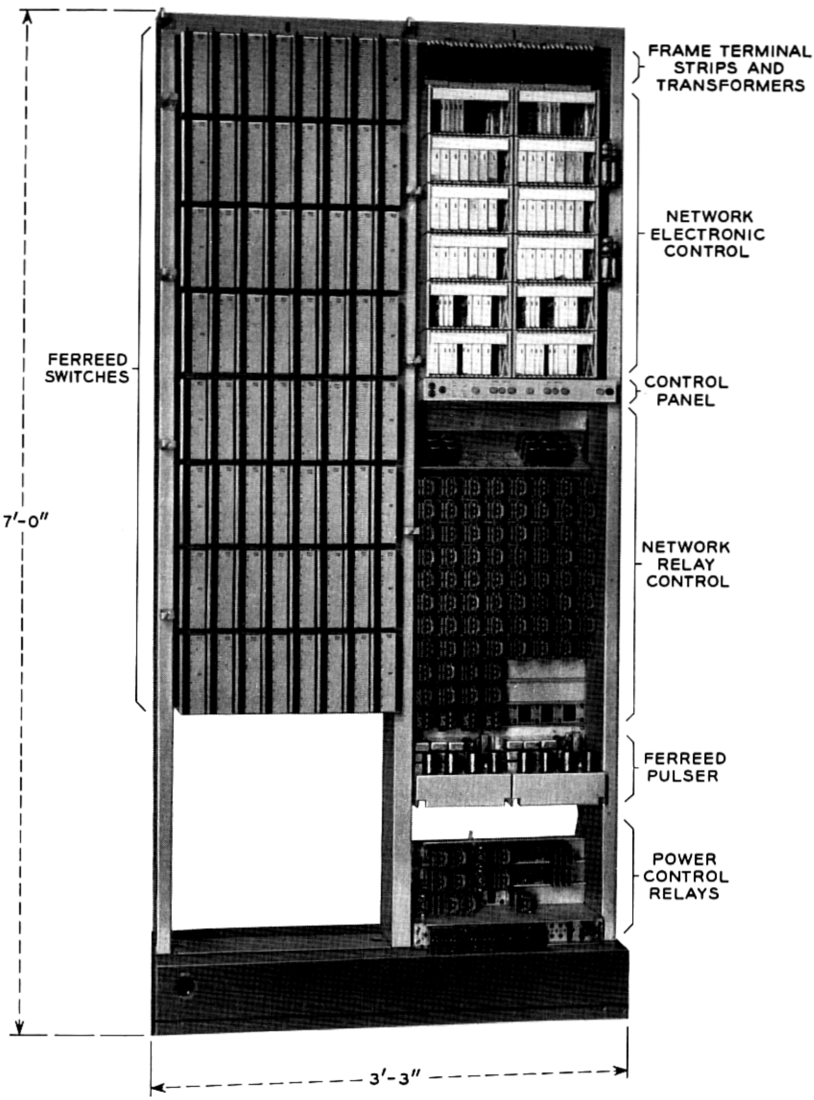


Fig. 24 — Trunk switching frame.

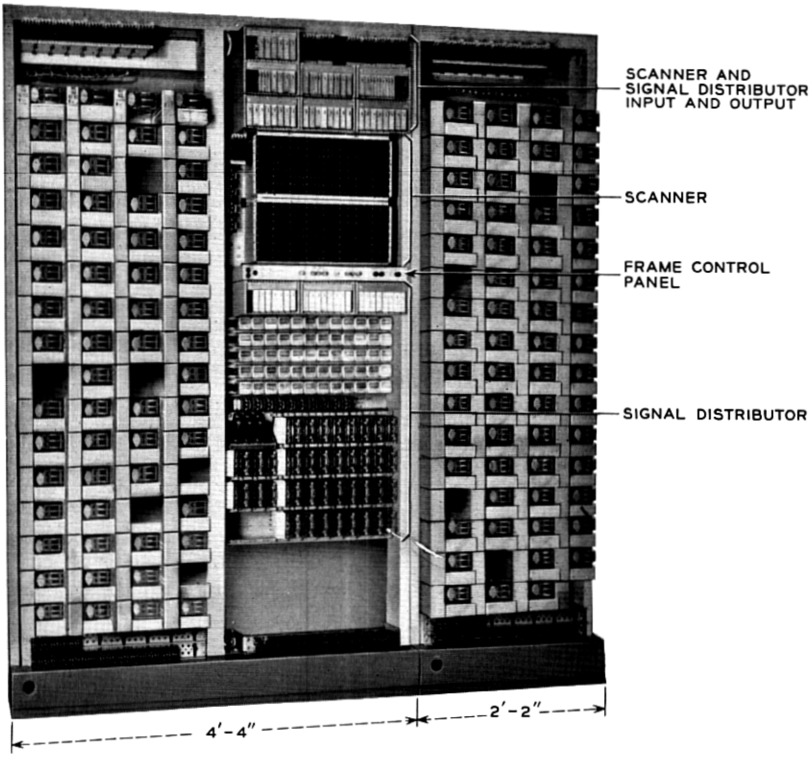


Fig. 25 — Universal trunk frame (or junctor frame).

mentary frame is located to the right of the basic frame so that the control bay, containing the signal distributor and scanner control, falls between the two trunk bays it serves. To save on control equipment, the universal trunk frames work on a home and mate frame basis. The home frame has a 1024-point scanner control unit which operates one half of a 1024-point scanner matrix on each of the home and mate frames. The scanner and signal distributor control equipments are duplicated for reliability.

The miscellaneous trunk frames contain such a variety of trunk and service circuits that it is uneconomical to provide them with universal scanners and signal distributors to satisfy all conditions. Instead, the scanning function for these trunks is performed by the master scanner, and the signal-distributing function is performed by the signal distributors on nearby universal trunk and junctor frames, each of which has 256 of its signal distributor points wired to frame terminal strips for this purpose.

6.2.2 *Junctor Frame*

The junctor frame is similar to the universal trunk frame except that it is wired for plug-in junctors instead of trunks.

6.2.3 *Trunk and Junctor Units*

6.2.3.1 *Plug-in Trunks and Junctors.* Since most trunk and junctor functions are performed by common control equipment such as central control scanners and signal distributors, the size and complexity of these trunk and junctor circuits is greatly reduced. Most high-runner incoming and outgoing trunks are simple circuits containing two or three relays.

This reduction permitted the development of the family of small plug-in trunk and junctor units. The simple angle-type sheet metal chassis shown in Fig. 26 mounts the transmission components, magnetic

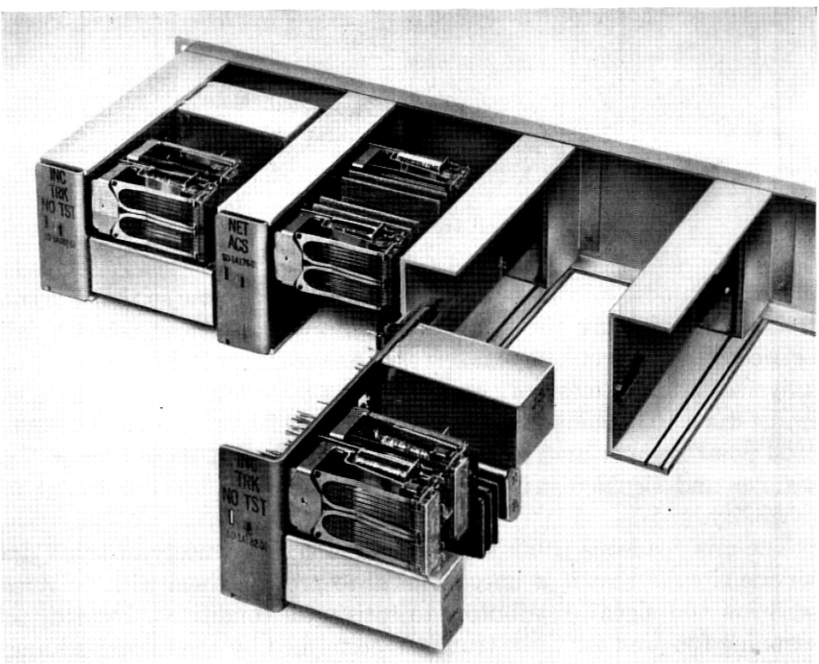


Fig. 26 — Plug-in trunk units.

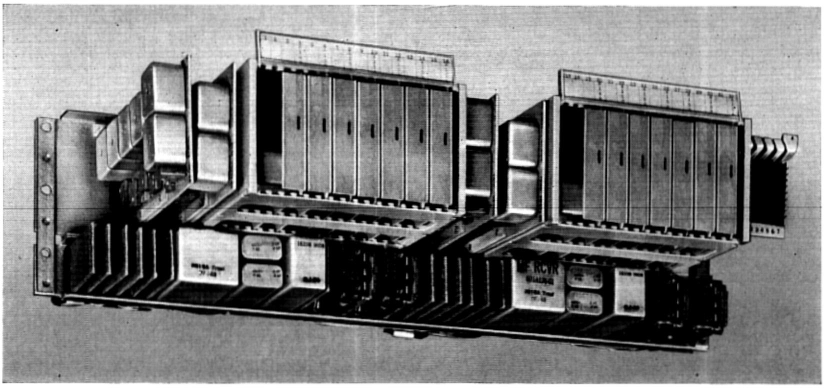


Fig. 27 — MF receiver unit.

latching relays, and a printed board connector. All units are surface wired using wire wrapped connections. Each plug-in chassis can be used for one or two (identical) trunk circuits, and all have a preassigned terminal pattern to insure compatibility with the universal frame wiring. In a typical office, all junctor circuits and 78 per cent of all trunk circuits will be of this type.

6.2.3.2 *Wired-in Trunk and Service Units.* The transmitters, receivers, trunks, 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. Typical is the MF receiver shown in Fig. 27. These surface wired units will be located on the miscellaneous trunk frame and cabled via unit terminal strips to their associated master scanner, trunk signal distributor control points and distributing frame terminations.

6.3 *Central Control*

The central control,[11] shown in Fig. 28, comprises the logic portion of the system central processor. It contains approximately 2300 circuit packs, the majority of which are LLL (low-level logic). This basic logic circuit, a diode-transistor AND-NOT gate, is used to generate all logic functions and memory cells or flip-flops.

The advent of nanosecond logic circuits has necessitated much closer design cooperation between the circuit and equipment designers than was the case in relay switching systems. Wiring patterns and rules had to be developed to insure satisfactory switching speeds, circuit crosstalk

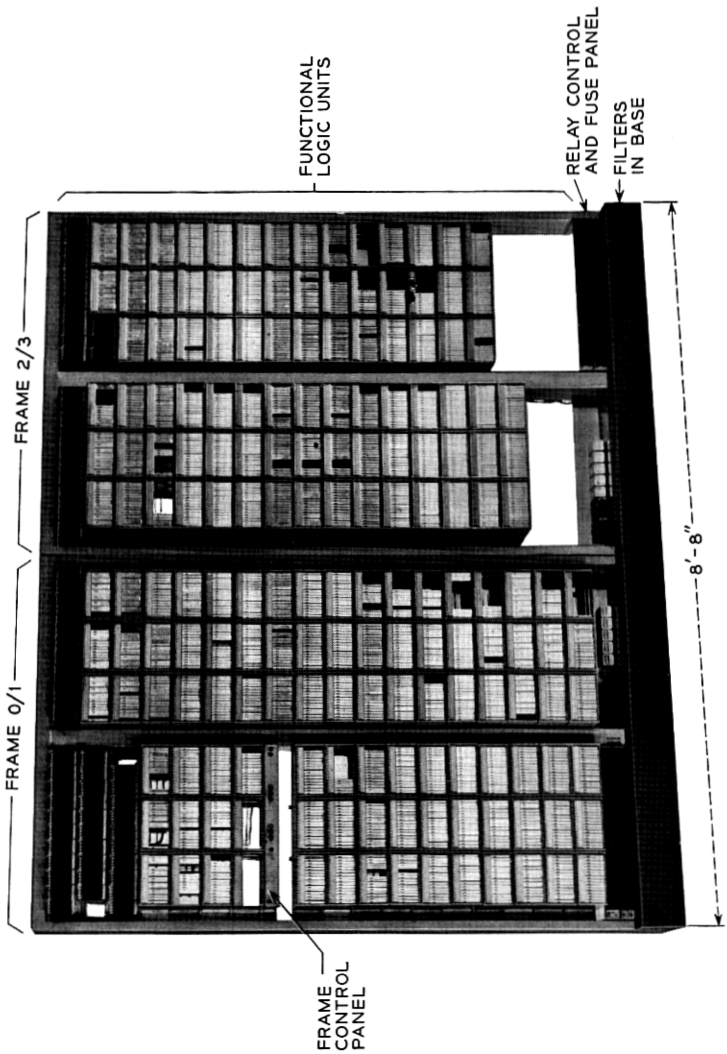


Fig. 28 — Central control.

protection, and a consistent manufactured product. Such requirements have dictated the dense packing of components shown.

The functions of the four bays of equipment can be subdivided under three major headings: input-output, data processing, and control and system maintenance facilities.

The input-output equipment comprises approximately 26 percent of the equipped volume of central control. The transformers, inductors, terminal strips, cable receivers, drivers, and logic are located near the top of each of the four bays: those for the program store and call store address and answer bus in bays 0 and 1, peripheral unit scanner answer and verify bus in bay 1, central control match bus in bay 2, and bus selection for peripheral unit addressing and central control matching in bay 3.

The data-processing function represents 47 percent of the central control volume and is distributed over all four bays. The 23-bit masked and unmasked bus systems used for data handling within the central control required an unconventional circuit pack organization. To provide uniform operation for all bits of a word and to meet timing requirements, no bus bit lead could exceed 6 feet in length. Apparatus for the various registers is distributed over several mounting plates. A particular register function is distributed over several mounting plates, each bit occupying only a few circuit packs on each plate. This permits the output gates of eight different registers associated with the same bus bit to be assigned to the same circuit pack, thus minimizing bus lead length and simplifying flip-flop control leads and maintenance diagnosis.

Aside from power filters, fuse panels, power control, and manual control panel, the remainder of the central control (approximately 20 per cent) is for maintenance facilities. The match bus and buffer register bus are organized in the same manner as the masked and unmasked bus systems. The emergency alarm and maintenance decoder are centralized functions providing a means for detecting, isolating, and performing maintenance checks of a malfunctioning central control. This equipment is located in bays 2 and 3 with portions extending into other functional units of the frame.

6.4 *Program Store*

The program store is the large, semipermanent memory for program and translation storage. It has a capacity of 131,072 words of 44 bits each, or 5.8×10^6 bits in all. The store, shown in Fig. 29, consists of three frames. Two double-bay frames contain the twistor memory modules, access circuits, and other related circuits, while the single-bay frame at

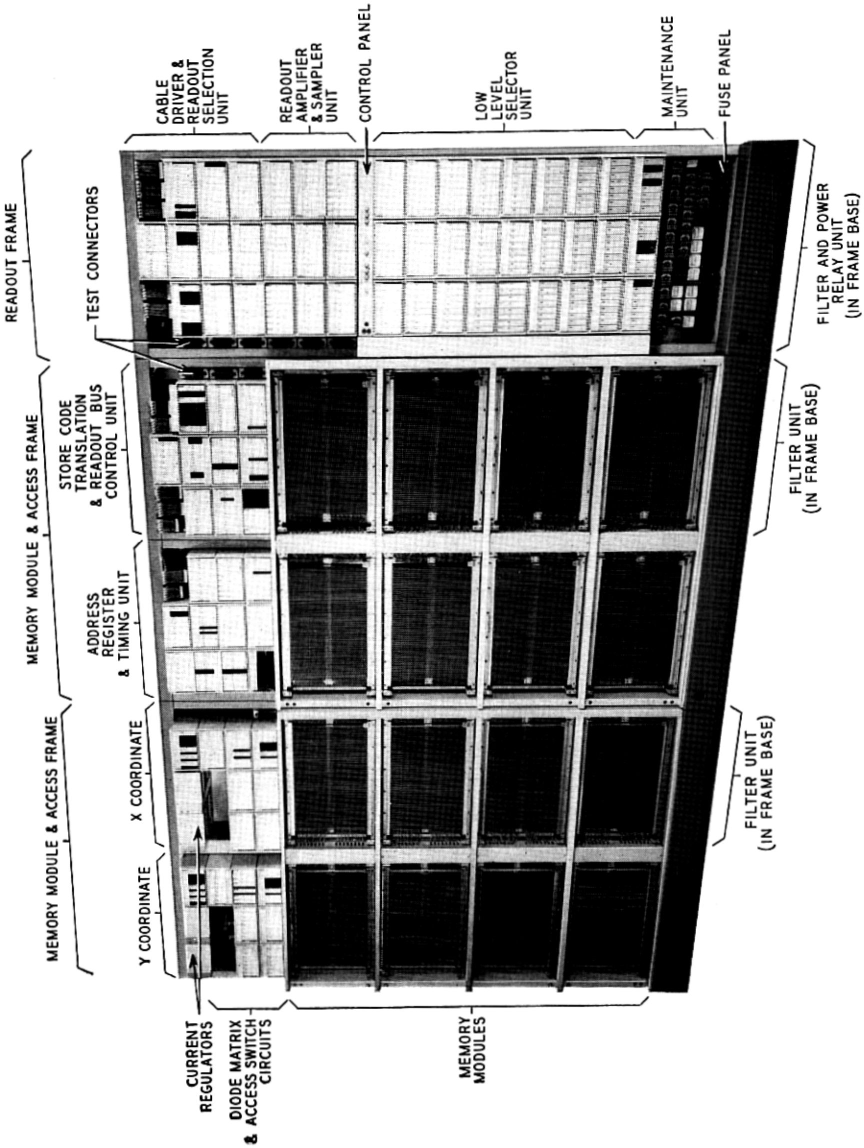


Fig. 29 — Program store.

the right contains circuits associated primarily with readout. Due to the high density of the memory modules, their frames are the heaviest in No. 1 ESS, with a weight of approximately 1900 pounds each.

The memory modules are arranged in a square 4 × 4 array to permit the 256 × 256 coordinate access wiring to be made on the rear with simple, short jumpers between modules.[6] Readout connections between modules, though not quite as simple, are also relatively short with this arrangement.

The input address is received by centrally located transformers at the top of the middle frame. Here it is efficiently channeled to register and access circuits to the left, and also to selectors in the readout circuits to the right, where selection is made as to which readout group and tape (A or B) should be read. Similarly, the timing unit is centrally located to synchronize operation of the access circuits to the left with strobe pulses for the readout circuits to the right. The diode matrix and access switch circuits are above the memory modules where they connect conveniently with the modules by means of a Y-access cable which runs vertically down the left side of the store and an X-access cable which runs horizontally just above the module array.

Readout connections are made on the front side of the store with cable running vertically in shielded ducts between the columns of modules and horizontally in ducts between the first and second and between the third and fourth rows of modules. These cables are further protected from noise pickups by use of close-twisted pairs and by limiting to two inches the unshielded length of leads which connect to the twistor tapes.

The X and Y readout multiples continue in shielded enclosures to terminals of the low-level selector circuit packs at the right. The selected outputs are then channeled to the samplers, amplifiers, and cable drivers above, and to the readout terminals at the top of the frame. This arrangement achieves shortest wiring runs and maximum separation between the sensitive readout circuits and the high-energy drive pulses of the access circuits.

Current regulators for both access and bias are located at the top of the first frame with the diode matrix and access switch circuits. This is important because tracking circuits on these units must maintain a fixed 2:1 relationship between currents for bias and for access drive. Also, this position at the top of the frame, with clearance above and below, provides for adequate heat dissipation.

Most circuit components for the program store are mounted on circuit packs, but the current regulators are packaged in a manner similar to the No. 1 ESS universal trunk circuits, as shown in Fig. 30. The unit contains

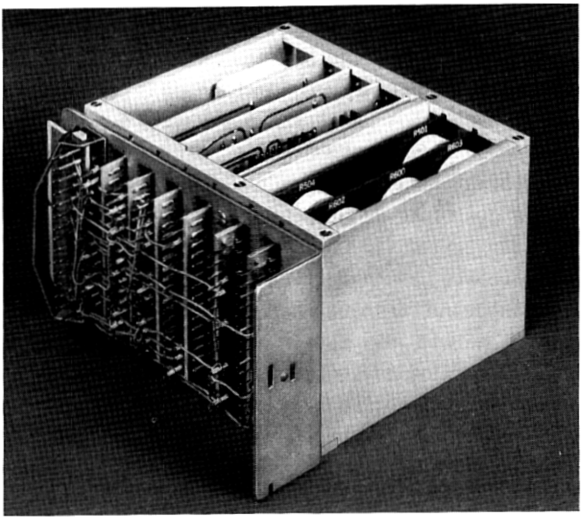


Fig. 30 — Current regulator for program store.

preadjusted potentiometers which compensate for variations in two reference resistors, zener voltage level, and the characteristics of the difference amplifier. Hence, replacement must be as a combination and not as separate packs.

Memory modules are mounted on the frame with three-point suspension to avoid distortion as a result of warping or twisting of the frame during shipping and installation.

Sliding covers are provided in front of the memory modules to protect memory cards from accidental damage. Each cover over a module containing program information is locked in place with a screw as a guard against accidentally disturbing the office program during translation changes.

6.5 *Call Store*

The call store, shown in Fig. 31, is the temporary, electrically changeable memory for telephone calls in process and for storing recent translation changes. It has a capacity of 8192 words of 24 bits each, or 196,608 bits in all.

Special emphasis was placed on short, direct connections between the ferrite sheet memory modules and their associated access and readout circuits.[5] The memory unit, containing four memory modules, is located behind the vertical panel below the center of the store, with Y-access circuits located immediately on the right and X-access circuits on the left.

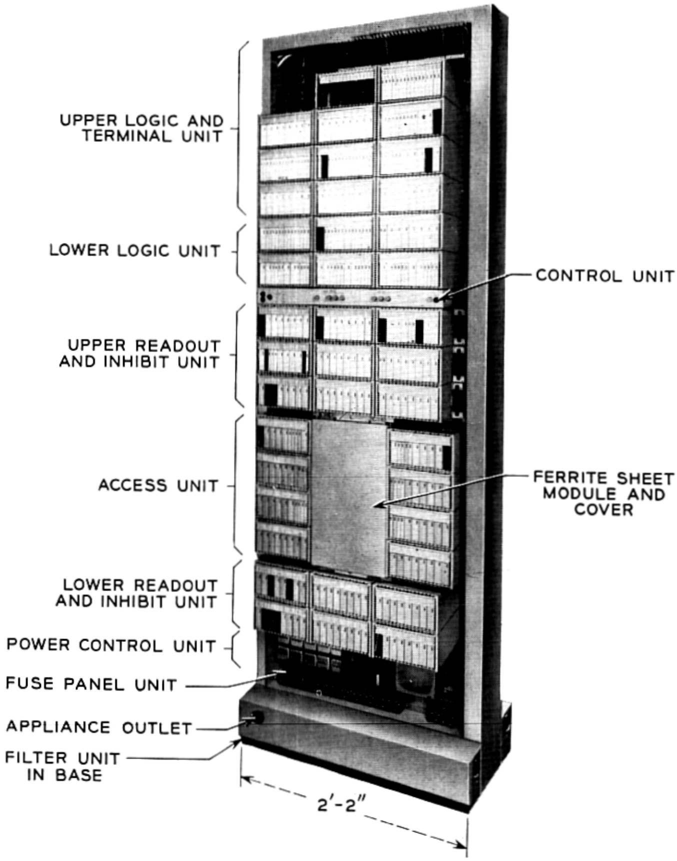


Fig. 31 — Call store frame.

Readout and inhibit circuits are divided, with some circuits above and some below the memory unit.

How direct the connections are is shown in a rear view, Fig. 32. At the right, each of four modules is connected with two cables only a few inches long to carry the X addresses from the diode matrix circuit packs to X connectors on the modules. Similar cables carry the Y addresses from circuit packs at the left to Y connectors on the various submodules of two memory modules, while other cables carry the Y addresses between modules in a slip pattern. To avoid congestion, yet facilitate handling, the access 18-conductor cables use stranded 28-gauge Teflon-insulated wire. A single shield over each cable minimizes interference with the sensitive readout circuits and also provides a common ground.

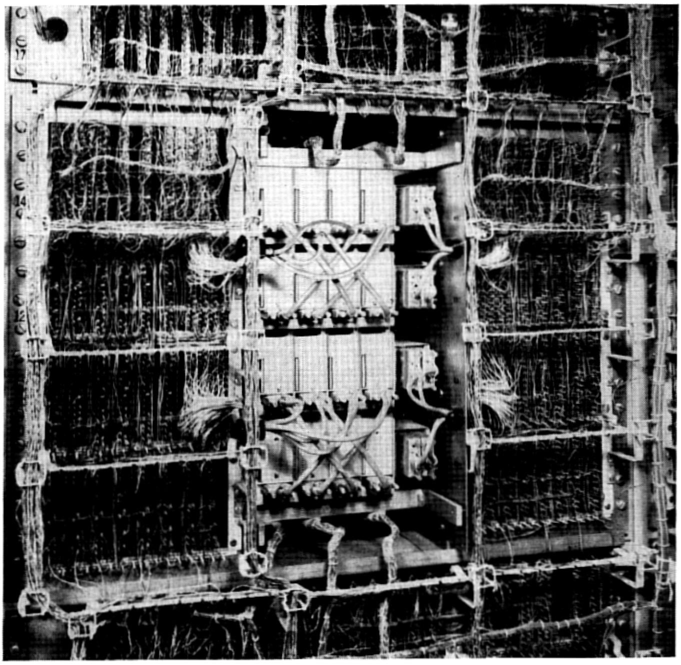


Fig. 32 — Call store — closeup of rear showing cabling of memory modules.

The readout and inhibit connections are carried from the memory unit to circuit packs above and below by two groups of three cables each. The left cable in each group carries inhibit signals, while the remaining cables are for readout. As shown, interconnections between circuit packs are made with a combination of surface wiring and loose wiring similar to that used in central control. Power distribution is by frame local cable.

The four memory modules are plugged together by double-sided connectors, which connect terminals on the edges of five printed circuit boards in each module with corresponding terminals on the edges of five boards in each adjacent module. Four of these boards carry readout connections with 50 connector terminals at each edge, while the fifth board carries a similar number of inhibit connections. Other connectors at the top of the upper module and bottom of the lower module connect with the readout and inhibit cables visible in the figure.

After plugging together, the modules are mounted in a framework which supports four apparatus mountings for circuit packs on each side. The five connectors at top and bottom which mate with this assembly are mounted in a floating manner on hinged brackets which may be

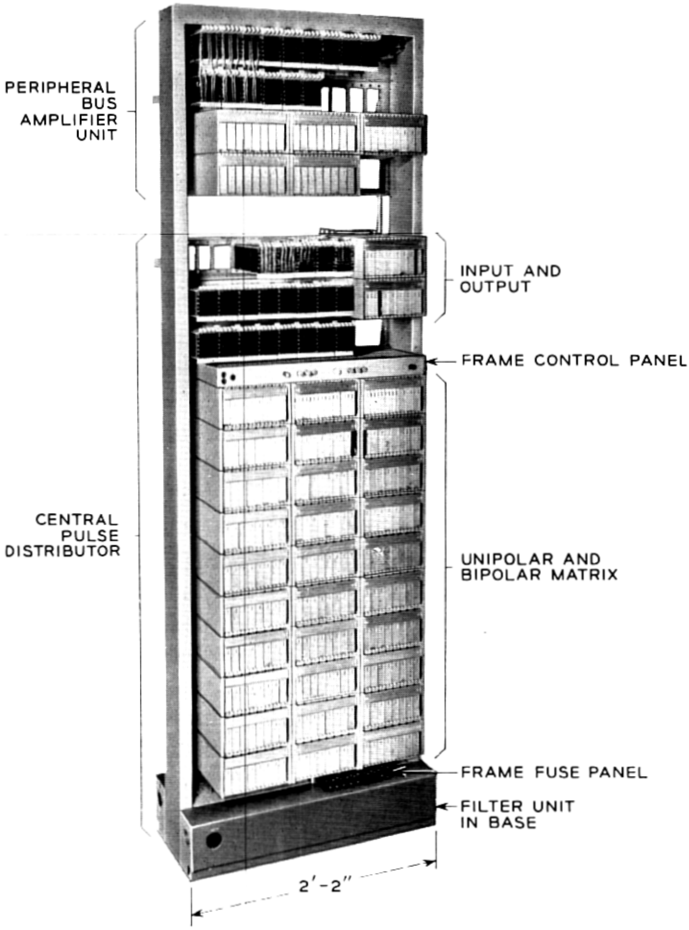


Fig. 33 — Central pulse distributor.

opened or closed from the front. This not only eases assembly and avoids alignment problems but also provides some mechanical advantage to assemble simultaneously five connectors of 50 contacts each.

6.6 *Central Pulse Distributor*

The central pulse distributor (CPD), shown in Fig. 33, is an electronic coincident-voltage transformer output selection matrix designed primarily to enable one of various peripheral units served by a common peripheral bus to accept information transmitted over this bus.

Five hundred and twelve outputs of the matrix are designed to produce pulses of single polarity for the enable function. An additional 512 addressable points of the matrix are combined into 256 bipolar outputs capable of generating pulses of either polarity. These are used to operate remotely located flip-flops associated with maintenance and diagnostic functions as well as certain trunk and service circuits with high repetition rates.

In some offices the CPD loads require a proportion of outputs differing from the 512 unipolar and 256 bipolar outputs. The frame has been wired to permit a limited amount of trading of 64 unipolar points for 32 bipolar points or vice versa in the central portion of the frame. This permits the CPD, through insertion of the appropriate complement of circuit packs, to have a range of capacities from 512 unipolar and 256 bipolar pulse outputs to 0 unipolar and 512 bipolar pulse outputs.

In the application of these frames to a variety of office sizes, it became apparent that an amplifying and load-distributing point would be required for peripheral bus systems having a large number of peripheral units. Since, for electrical reasons, the peripheral bus enable leads which originate in the CPD must be approximately the same length as their associated peripheral bus leads, the peripheral bus fan-out equipment was also mounted in the CPD frame. With this arrangement the bus and enable leads originate on the same frame. By running these leads along the same cable rack, they will be kept approximately equal in length. The amplifier circuit packs are provided in this universally wired frame unit whenever the office has from two to four bus systems, each with a maximum of 50 loads or 450 feet of bus cable between the central control and its most remote peripheral load.

6.7 *Master Scanner*

The master scanner is used to monitor various administrative and diagnostic points throughout the system. This scanner, like others on the line switching, junctor, and universal trunk frames, consists of a 1024-point ferrod sensor matrix and duplicated control equipments. These alternate on a periodic basis in controlling the interrogate and readout pulses of the matrix.

The matrix is divided into 64 groups, each consisting of 16 scan points which are scanned simultaneously. These groups are divided into two general categories, one containing supervisory scan points which are scanned every 100 milliseconds and the other containing directed scan points which are scanned as required by direction of a noncyclic program.

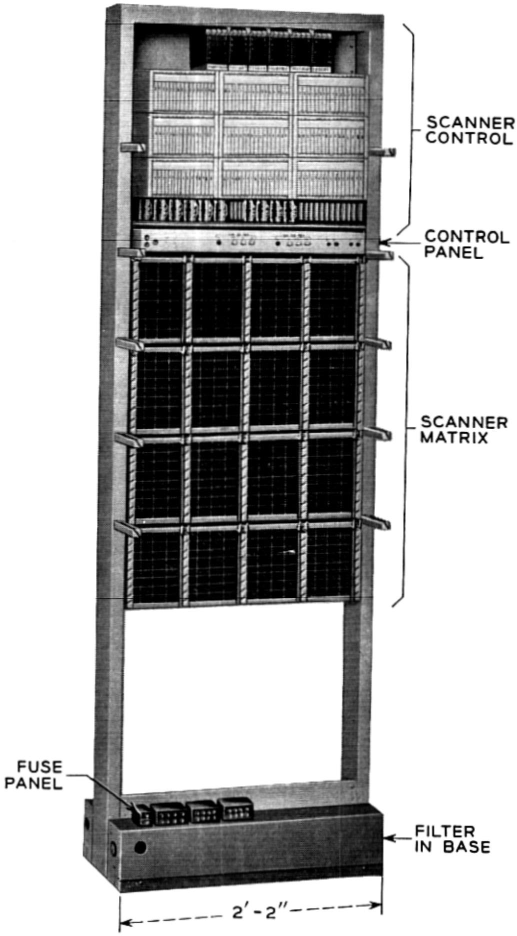


Fig. 34 — Master scanner.

With the exception of certain fixed points, which are the same for all offices and always appear in the same matrix location on the first master scanner, scan points are assigned as required on an office basis. Supervisory scan points are assigned in rows, starting at the bottom of the matrix, and directed points are assigned from the top down.

The master scanner, shown in Fig. 34, is a 2-foot, 2-inch single-bay frame. The electronic control equipment is located in the upper part of the frame to keep the address bus leads as short as possible, and the 1024-point matrix, equipped with 512 type 1E (sensitive) ferrod sensors (two sensors each), is located directly beneath this equipment to minimize the length of the interrogate and readout pulse leads. To provide for detecting either (a) a contact closure or (b) 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 front face. For contact closure, all four terminals are cabled to a connecting circuit that is to be scanned. Two of the four connecting leads furnish battery and ground to the ferrod sensor control windings so they may detect a contact closure over the second pair. For potential change, these coils are strapped together, series-aiding, and are cabled to the circuit under surveillance with a single pair of wires to detect a change across its scanned points.

6.8 *Master Control Center*

Reliable system operation and the rapid diagnosis and repair of system malfunctions rely heavily on maintenance programs. Upon detection of a malfunction, either by circuit or program means, fault-recognition programs are called in to recover the system's call processing ability. These programs control any necessary switching of subsystems and request, via memory, an appropriate diagnostic program to localize the fault to a particular package. The results of the diagnostic programs are printed out via a maintenance teletypewriter. Using the maintenance dictionary, these results can be translated to the location of the fault by the maintenance personnel.

Routine test programs are provided to search for faults which are likely to go undetected in normal call processing. These test programs can be initiated either automatically on a scheduled basis or via a manual teletypewriter request.

The master control center includes the communication facilities between the maintenance personnel and the system. Most of these communications will occur via the maintenance teletypewriter.

The master control center consists of the three frames shown in Fig. 35. The two-bay frame at the left contains the maintenance teletypewriter and two magnetic tape recorders for automatic message accounting. The third and fourth bays from the left contain the system control, display, and trunk and line test facilities. The memory card writer occupies the single-bay frame at the right.

6.8.1 *AMA and TTY Frame*

The magnetic tape recorders shown in Fig. 36, used for AMA (automatic message accounting), are provided on an active and standby basis to insure a continuous capability. In contrast to other systems, these tape

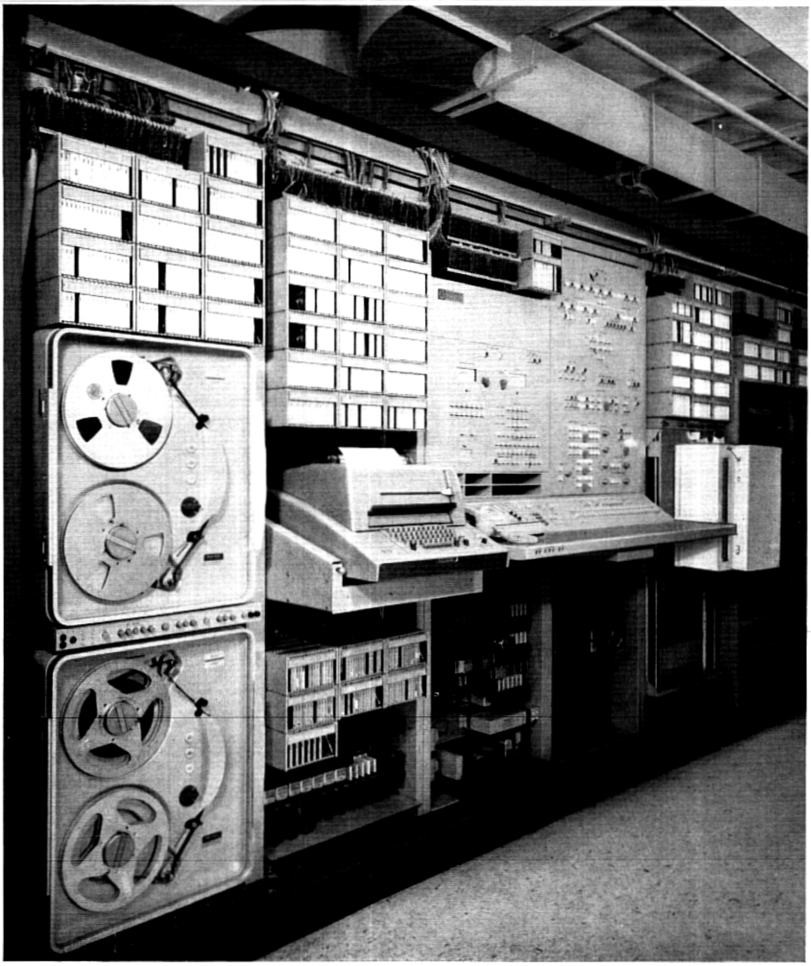


Fig. 35 — Master control center.

records are in the form of completely assembled call data, blocks of which are transferred from the system memory on a start-stop basis. The recorders are driven by three-phase, 208-volt, 60-cps motors supplied from the protected ac power plant to further insure continuity of recording.

The 35-type (keyboard send-receive page printing) teletypewriter is mounted on a retractible shelf to provide improved maintenance access while minimizing its projection into the maintenance aisle. A second

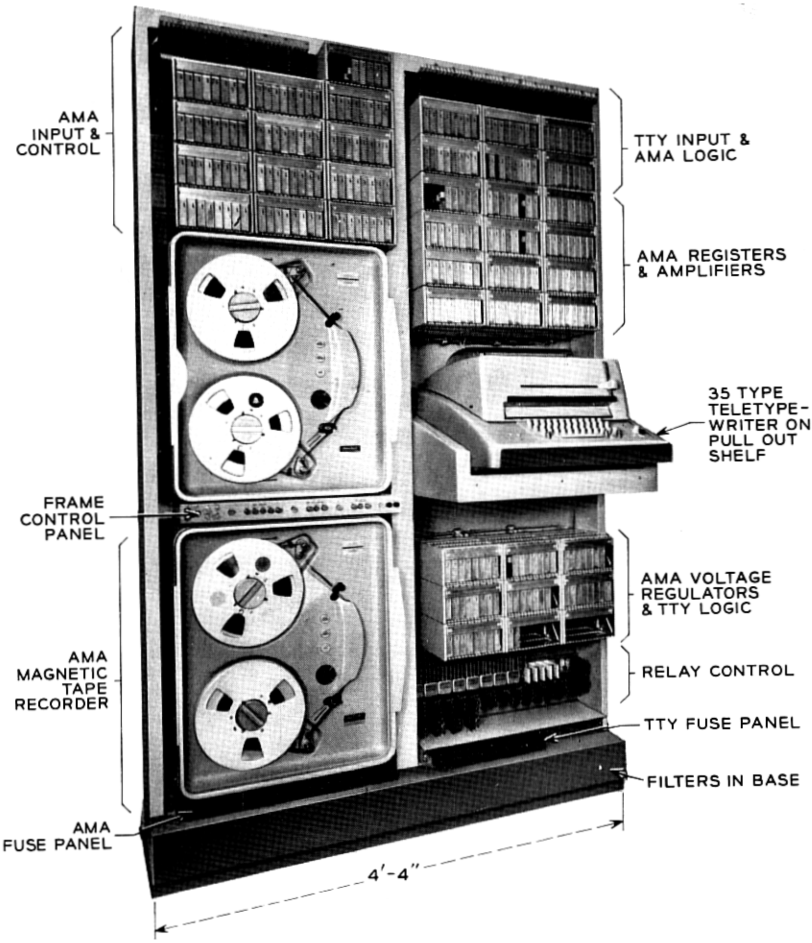


Fig. 36 — Automatic message accounting — teletypewriter frame.

maintenance teletypewriter, pedestal mounted, is installed in the office, when fully attended, or at a remote maintenance center when desired. This machine duplicates the access to the system provided by the unit in the AMA-teletypewriter frame.

6.8.2 *Control, Display and Test Frame*

The control, display, and test frame, located adjacent to the maintenance teletypewriter, provides a system monitoring, manual control, and test center. This equipment permits the maintenance man to observe the current in-and-out-of-service status of various units, to assert manual control over the system, and to make a variety of line and trunk tests.

The left half of the keyshelf and control panel, shown in Fig. 37, contains a 23B transmission measuring set, a voltmeter, a clock, a telephone set (6-button 560-type or an 18-button 623-type), a number of lamps and pushbutton keys and a TOUCH-TONE dial. This equipment provides for trunk and line testing.

The right half contains lamps, pushbutton keys, and rotary switches. The upper one-third of the panel contains the system alarm lamps and a system block diagram lamp display. An individual display is provided for each central control and program store frame. Two lamps are provided for each other class of unit such as call store, line switching frame, etc. The rest of the panel is arranged in three operating areas.

The status lamps monitor the data routing flip-flops in the central control, program stores, and call stores, and indicate certain troubles such as peripheral control failure, system time-outs, etc. Keys are provided for instituting traffic control, retiring system alarms, and removing power from the frame.

The emergency action area provides manual controls for overriding the system when the system is unable to restore itself to normal operation or when maintenance activity or additions to the office require. The program interrupt control and data word controls permit manual interruption of the program, display of a 24-bit data word, and insertion of a data word into the system.

6.8.3 *Memory Card Writer*

The memory card writer is used for writing, or changing, the information stored on the memory cards of the program stores.[6] Normally, only translation information is changed, but special facilities not generally available in a telephone office permit the writer to be used for program changes as well. The memory card writer, shown in Fig. 38, consists of a single-bay frame 2 feet, 2 inches wide. Like the program store, the card writer requires a maintenance aisle at least four feet wide to permit safe handling of the card loader.

The memory card writer contains the 1A card writing unit and associated 1A card writing head as mechanisms which physically handle the cards and magnetize, or demagnetize, as required, each of the bit magnets. These mechanisms occupy 44 inches of frame height and are located in the lower portion of the frame, with bottom 12 inches above

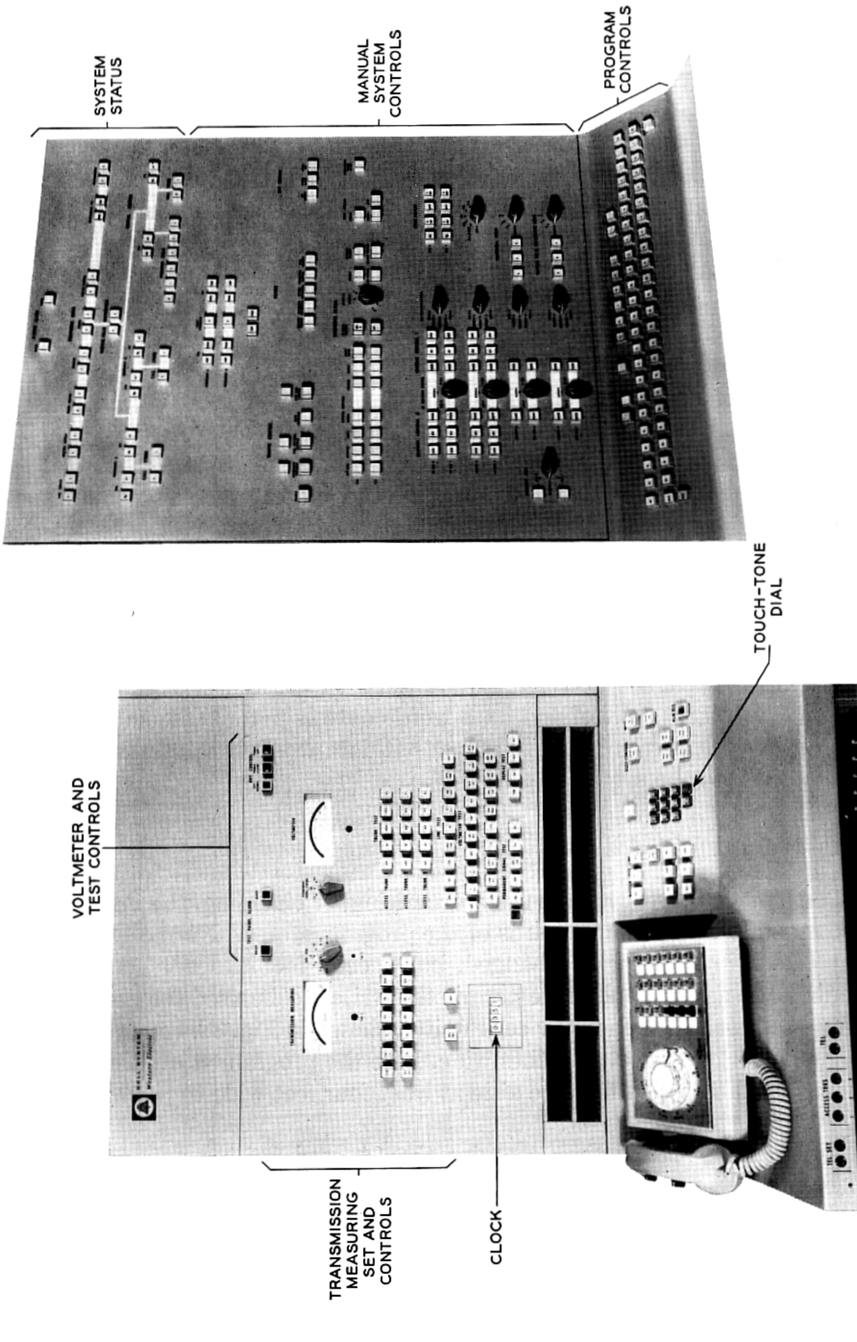


Fig. 37 — Panels of control display and test frame.

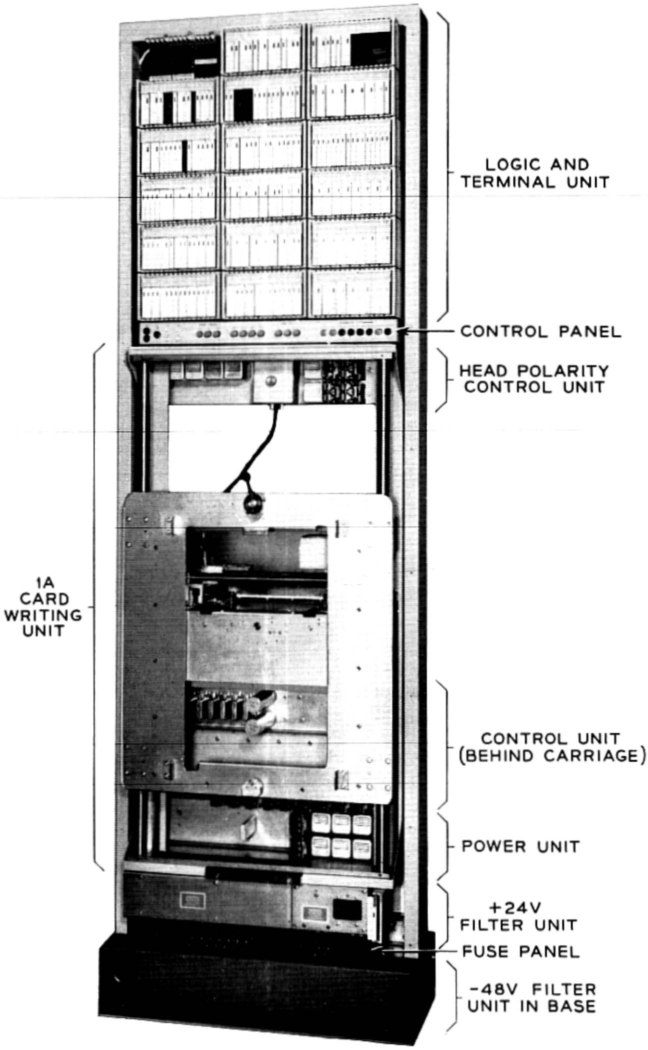


Fig. 38 — Memory card writer.

the floor for convenient attachment and removal of the card loader. The control panel is mounted immediately above the writing unit with the logic circuitry above. The head polarity section is mounted just below the control panel on the rear side of the writing unit, together with the connectors for the writing head.

Other control circuits which are closely associated with operation of the

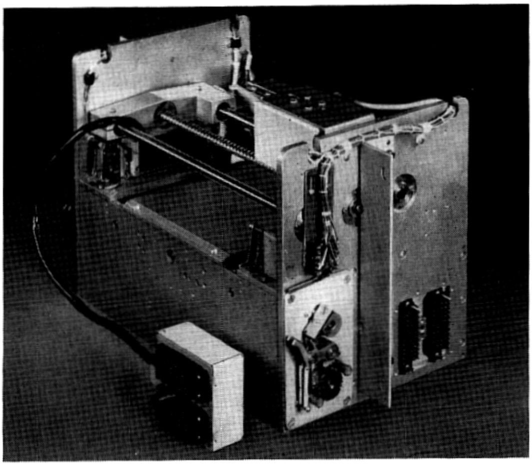


Fig. 39 — Card writing mechanism — end view.

writing unit are mounted near the lower end of this unit, on the rear side, together with a power control unit.

For normal operation, a loader with cards to be written is mounted to a movable carriage on the card writing unit with the left, or "A" end up. At this time the carriage is in its lowest position. The WRITE button on the control panel is then depressed to start the card writing sequence for pass A. When the 64 cards with upward-facing magnets have been written, a buzzer sounds and an INVERT LOADER lamp lights to signal that pass A is complete, and indexing pawls are automatically retracted, allowing the carriage and loader to return to the starting position. The speed of this downward motion is controlled by two hydraulic cylinders. A rubber bumper cushions the shock when the carriage reaches the bottom.

The loader is then removed from the carriage, inverted end-for-end, and reattached with B end up. The WRITE button is again depressed, starting the sequence for pass B. When writing is complete, the buzzer again sounds, an END lamp lights, and the carriage is again returned to its down position.

6.8.3.1 *Card Writing Unit.* The 1A card writing unit, shown in Fig. 39, consists of a framework with a central, easily removed mechanism for handling the cards, a 1A card writing head which is attached to this mechanism, and the rectangular carriage at the front, which is used to mount the card loader. The loader is supported on this carriage by a pin assembly at the bottom and by a lever-operated clamp at the top which engage notches in the ends of the loader. The vertical position of the carriage is determined by racks at the sides and by pawls at the ends of the central mechanism which engage these racks. The carriage is located horizontally by ball bushings in the corners which ride on the two vertical guide rails.

The central mechanism is capable of removing the cards, one at a time, by means of two finger assemblies which can be driven backward and forward in slots of the writing table. These assemblies are shown in the extended position in Fig. 40. The L-shaped details at the sides actuate switches to signal whether the loader is correctly mounted for pass A or pass B, as may be required. The fingers are spring-tensioned downward against a stop surface. The front ends are hooked and tapered so that as the fingers are driven toward the cards, the tapered ends ride up over the edge and surface of the card until the hooks drop into small, rectangular perforations provided in the cards for this purpose. The fingers are then driven backward, drawing the card across the writing table until the card comes to rest against fixed backstops. The fingers are also spring-tensioned in a longitudinal direction to avoid high forces when the card strikes the backstops. The motion of the finger assemblies is stopped by operation of switches which brake the finger drive motor to a stop, and

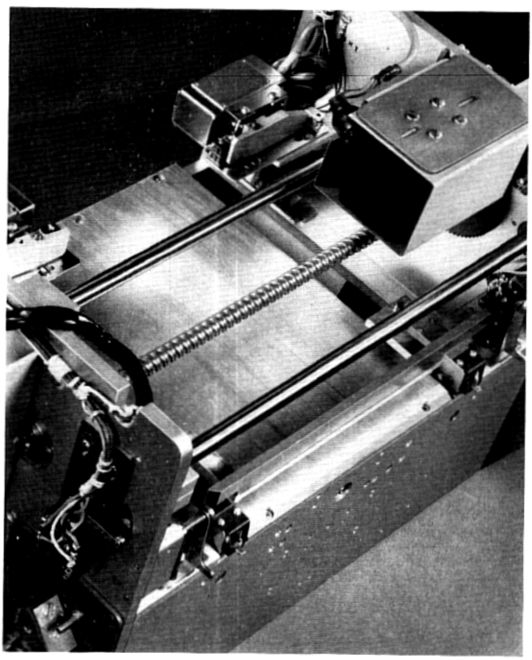


Fig. 40 — Card writing mechanism — top view.

start the drive motor for the writing head. The motors are 208-volt, 3-phase to increase reliability and to deliver a more uniform speed of head travel.

As the writing head passes over the length of the card, it magnetizes the initializing magnets, senses the location of these magnets, and writes each bit of each word as it passes by. Use of the initializing magnets for position-sensing avoids the need for critical mechanical tolerances in longitudinal card and head positions. After the last word on a card is written, switches in the top center of Fig. 40 sequentially disable the sensitive position-sensing circuits and reverse the head drive motor to return the head to its normal position at the left end. Other switches at the left then start a sequence of operations which cause the finger assemblies to insert the card back into the loader, disengage the card by raising the fingers until the hooks clear the top surface, withdraw the fingers to an intermediate position near the center of the table, raise the loader one step by means of the solenoid-operated pawls, drive the fingers forward a fixed distance sufficient to insure engagement of the next card, and repeat the process.

6.8.3.2 *Card Writing Head.* The card writing head, shown in Fig. 41, incorporates a number of design features which have been found necessary to meet its demanding requirements. The head is spring-tensioned against the surface of the card by means of four phosphor-bronze leaf springs. It is supported by two rollers (with ridges which rest on the card in the spaces between the magnets) and a single ball bearing outside the magnet area at the left end. This complex suspension is needed to

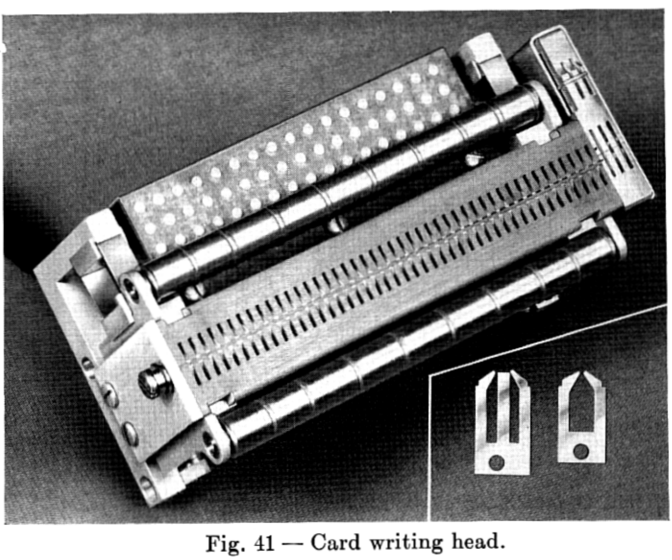


Fig. 41 — Card writing head.

maintain control of the spacing, designed for the range 0.0005 to 0.0015 inch, between the pole pieces and the magnets on the card.

The 45 writing sections of the head contain 6 laminations each, of the type shown in the inset at the right in Fig. 41. Each lamination is 0.006 inch thick, is made of Allegheny-Ludlum Company No. 4750 (similar to a purified No. 45 permalloy) to achieve higher saturation flux, and is insulated on the surfaces with magnesium methylate. The coils are wound in place on one leg of each group of laminations, using solenoid-winding techniques. Each section is shielded to prevent interference between sections. The sections are assembled in the head with the windings on alternate sides to fit on the required 0.100-inch centers. A phenolic spacer holds the air gaps in alignment.

Pole pieces for the initializing heads are similar to those of the writing sections but are of unlaminated No. 45 permalloy, with the coil on the upper yoke between the legs. Each of the two sensing sections contains 9 laminations of 0.004-inch thick No. 4-79 permalloy, which was chosen for high permeability at low flux densities. As shown in the inset, the sensing laminations have two air gaps with spacing which corresponds to the effective length of the initializing magnets. After all sections are assembled in the head, the surface is lightly ground to bring the tips of the laminations, gap spacers, and body to a common plane.

Early experience showed the need for a nonmetallic body for the writing sections to avoid excessive eddy current losses. Phenol fiber was chosen because of its close match in temperature coefficient of expansion with aluminum used for other structural parts.

The flexible cable which extends between the head and connectors at the top of the writing unit uses 28-gauge wire which is stranded and Teflon-insulated to avoid fatigue failures.

6.8.4 *Card Loader*

The 1A card loader, shown in Fig. 42, is used (a) to insert the twistor memory cards into and to withdraw them from the twistor memories in the program store, (b) to transport the cards between the program store and the memory card writer, and (c) to support the cards on the memory card writer.[6] The loader is a box-shaped structure with one side open and with narrow grooves in the top and bottom surfaces, shown in Fig. 43, to support the cards in the same relative position as in the memory module. The end castings, handles, top and bottom plates, and other structural parts are made of magnesium to minimize weight. Even so, the loader weighs approximately 24 pounds when empty and 40 pounds when filled with cards.

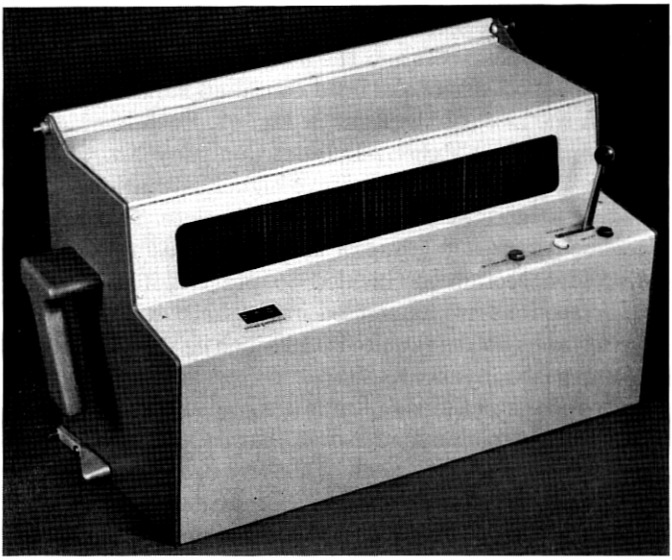


Fig. 42 — Card loader with cards — view of control side.

The cards are engaged by pins on individual finger-like actuators which are arranged in two rows and are attached to a common extruded-aluminum traverse bar. This bar is supported and driven by ball screw shafts at the ends, which are coupled through worm gear speed reducers to a small 115-volt ac-dc motor in the rear center. The screw shafts move the traverse bar through its 7-inch range of motion in about $\frac{1}{2}$ minute

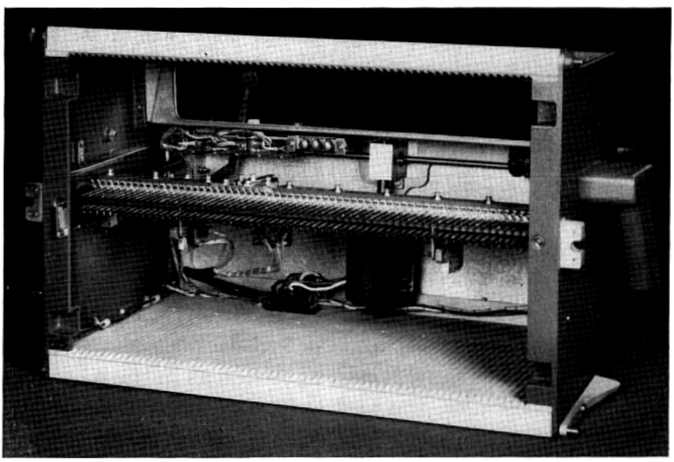


Fig. 43 — Card loader — front side showing card actuators.

with the motor operated on 48 volts dc. The actuators are pointed at the tips and are inserted between pairs of cards in the wider spaces opposite the twistor planes. Movement of an operating lever at the rear causes a gang rotation of the actuators, which causes small transverse pins to enter the openings provided in the cards for this purpose.

The insertion force exerted on each card is controlled within the range 4 to 6 lbs by means of individual, pretensioned springs and an interlock which removes power from the drive motor if the force on any card reaches the upper limit. This assures proper seating of each card in the memory module and protects the memory from damage if a card should jam or stick. Since all cards are inserted simultaneously, the loader must provide total seating forces of 500–700 pounds, sufficient to cause serious damage without the protective interlock.

In use, the loader is precisely positioned on the memory module by means of pins in the four corners, which engage slots in corresponding ears on the module. The cards are engaged or released from the drive mechanism by the operating lever, while the motor drive is controlled by INSERT, NEUTRAL and WITHDRAW buttons on the control shelf. The neutral position is achieved when the actuator pins are centered in the card slots, permitting engagement or release without disturbing the cards or developing high friction forces.

Some features of the loader provided to achieve reliable operation are as follows:

(a) A window above the control shelf permits viewing irregularities that might occur during operation.

(b) The motor receives power through two spring-loaded pin contacts which bear against disk-shaped contacts on the memory module. This construction permits appreciable misalignment in any direction without failure.

(c) A filter in the motor circuit prevents electrical interference from being transmitted to sensitive circuits in nearby frames.

(d) Many points of wear are protected by use of special bearing surfaces.

(e) An adjustable indicator on the control shelf helps the operator keep track of the store and memory module with which he is working.

(f) During card writing, surfaces of the loader engage microswitches on the card writer so that incorrect mounting for a writing pass is detected electrically.

(g) When the cards are fully withdrawn into the loader, the lower ends are held by friction grips which prevent the cards from shifting accidentally when the actuators are disengaged.

(h) A mechanical interlock permits the loader to be attached to the card writer only when the actuators have been disengaged as needed for the writing operation.

6.9 *Power Distributing Frame*

The power distributing frame is the battery load distributing point of the system. The 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-μf capacitor banks are provided near the bottom of the frame to 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 by frame loads) from 5-, 15- or 30-ampere cartridge type fuses having $1\frac{1}{3}$-ampere alarm fuses in parallel with them.

Each power distributing frame has a 400-ampere peak capacity for each voltage and is located in the office area of the frames it serves. Duplicated circuits are fed from different power distributing frames.

6.10 *Ringing and Tone Supply Frames*

In keeping with the application of semiconductor circuitry to perform switching functions, new forms of ringing and tone supply equipment have been designed. Two sizes of plants are available to accommodate the wide range of office requirements — a $\frac{1}{2}$-ampere capacity plant, shown in Fig. 44, and a 6-ampere plant. In both sizes the frames are located in a switchroom frame line.

These plants (806H and 808A) provide ringing current, tones, and signaling interruptions. Twenty-cycle ringing (not audible) is generated by 110A frequency generators which furnish a regulated output. All tones except high tone consist of two signals, generated by transistor oscillators, which are added together and amplified in power transistor amplifiers. Duplicate 20-cycle ringing generators, tone generators, and interrupters are provided. Normally all generators are running, but only the interrupter supplying the load is powered. The outputs of both ringing generators are monitored for high and low voltage by the system; it selects the generators to be used and automatically transfers to the other set of generators in the case of failure. All generators and interrupters are transferred as a unit. Manual controls are provided to supersede automatic control when necessary.

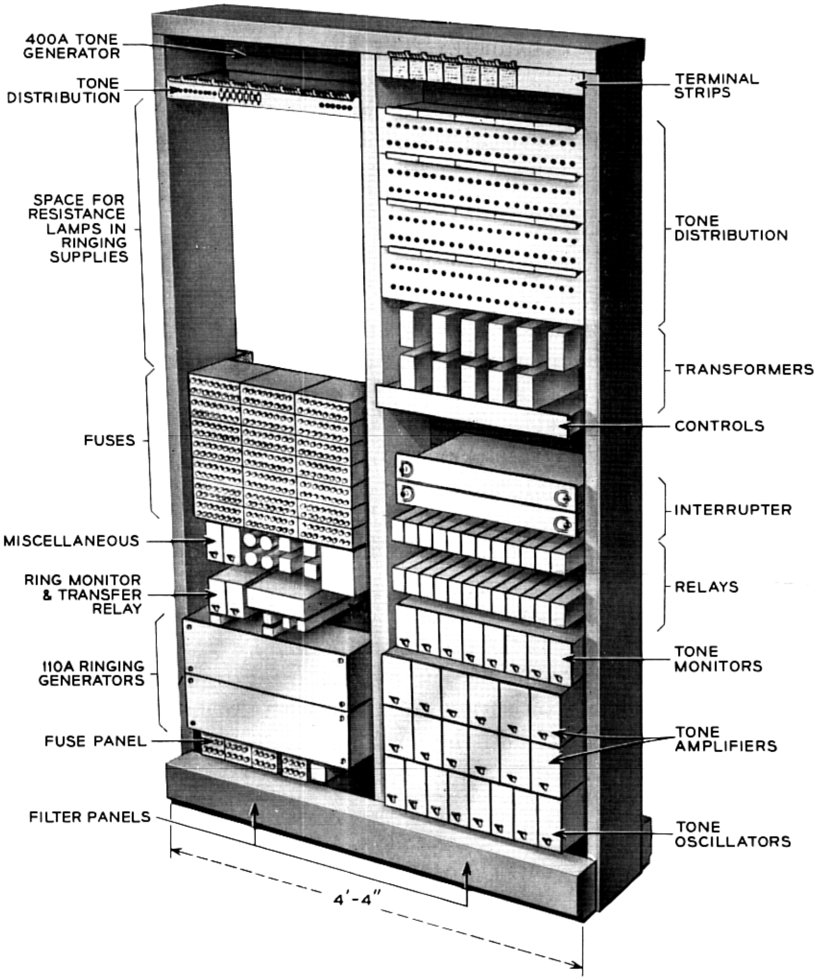


Fig. 44 — Ringing and tone supply frame (806H).

All ringing and tone supply fuses, decoupling resistors, and resistance lamps required by the various load frames are located on this frame.

6.11 *Recorded Announcement Frame*

The recorded announcement frame provides for a maximum of 6 announcements on a magnetic drum recorder (approximately $9\frac{1}{8}$ inches diameter and $1\frac{9}{16}$ inches long). 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.

6.12 *Miscellaneous Frame*

This frame is designed to accommodate a variety of units which require neither signal distributor nor scanner control. These units include emergency manual lines, supplementary AMA tape recorders (for those offices requiring more than the two provided on the AMA-teletypewriter frame), a multiplicity of common systems units, the power for test battery supply, etc. 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 the above frame equipped with (a) the +4.5-volt supplies required by the central controls, (b) the +130-volt and −130-volt fuse panels, (c) the ac distribution panel for 208-volt, 3-phase and 120-volt, single-phase loads requiring protected or essential 60-cycle supply, and (d) the floor alarm units. Two of these frames are located near the first pair of power distributing frames to permit the central control +4.5-volt supply to be run with the ground return cable between central control and the power distributing frame to minimize stray noise pickup.

6.13 *Power Plants*

As shown in Table V, the power plants associated with a No. 1 ESS include:

(a) Two 111A battery plants with very 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.

(b) The ringing and tone supplies are located in the switchroom. These are described in Section 6.10.

(c) +130- and −130-volt dc-to-dc converters (610B power plant). These units convert the −48 volts to the potentials needed for coin control. Power from these plants is delivered to fuse panels on a miscel-

TABLE V — POWER SUPPLIES

Power Supplies	Type of Plant or Unit	Capacity (Rated)	Code
	In power room		
−48 volt dc (−43.75 to −52.5 volts)	storage batteries (without emergency cell or counter cell switching) rectifier charged	10–800 amp	111A
+24 volt dc (+21.75 to +26.25 volts)			
+ 130 volt dc	dc-to-dc electronic conversion from −48 volts for coin control	$\frac{3}{4}$ amp	610B
−130 volt dc		2 amp and 5 amp	651A
Reserve ac supply	dc motor-driven alternator for 120/208 volt, 1- and 3-phase power	$1\frac{1}{2}$ kw	504B
		5 kw	
	In switchroom		
Ringing and tones on RT frame	electronic generator with a precise tone plan	0.5 amp	806H
		6 amp	808A
+4½ volts on MP frame	derived from +24 volts		
PBX talking battery filter on misc. frame	coil and capacitor panels	15, 25, and 50 amp	
±120 volt for Frames {AMA-TTY, CDT, RA, RT, Misc. for TTY data sets, test battery supply unit, 2A sending panel}	commercial power with or without reliable supply distributed from MP frames		
Appliance outlets Frame lighting	distributed from ceiling-supported busway		
±208-volt, 3-phase for AMA-TTY and CW frames AMA recorders on misc. frame	commercial power with or without reliable supply distributed from MP frames		
±208-volt, 1-phase for RT frame			

laneous power frame in the switchroom and distributed to all frames in the office which require it.

(d) A small, emergency 504B alternating current plant (with an alternator driven by a dc motor). Protected power from the 208-volt, 60-cycle, three-phase alternator is delivered to a circuit breaker and fuse panel on a miscellaneous power frame in the switchroom. From this panel single-phase and three-phase power is distributed to all frames in the office which require ac power at any time commercial power fails.

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

VII. INTERCONNECTING METHODS

The use of high-speed electronic circuits in packs assembled in large numbers has introduced a variety of restrictions in the unit, frame, and interframe wiring. Distributed impedances on circuit packs and their interconnecting wiring must be very rigidly controlled in a nanosecond pulse system. The control of transient noise requires (a) the use of compartmented cable racks, (b) segregated cable and wiring paths on the frames, (c) filters on all dc power supply feeders, and (d) special frame grounding practices. Some of the related problems and their solutions are discussed here.

7.1 *DC Power*

Early tests of the dc power distribution system coupled with tests of major functional elements (brass-board variety) showed the need to introduce load filters at the functional frames in addition to a common low impedance filter within the switching equipment area. Three conductors (+24-volt, −48-volt and a common ground feeder) are run from the power discharge fuses to each of the power distributing frames (centralized power distribution points) where low-impedance shunt filters (35,000-μf capacitor banks) are provided for the +24- and −48-volt system.

Individual frame filters (usually choke input L type or capacitor input π section) are designed to restrict the rate of change of current on the frame supply feeders to less than 0.1 ampere per microsecond. This limits the noise produced at the power distributing frame filter to less than one volt. The central filter can adequately attenuate the noise transmitted to other frames to less than 0.5 volt.

Power distribution leads are run as two- or three-conductor cables between the power distributing frame and the individual frame filter panels. The frame feeder sizes have been matched, as have the filters, to the frame load requirements to insure adequate system operation under conditions of commercial power failure (within the engineered battery reserves). A maximum drop of one volt* between the power distribution (PD) frame and the individual frame fuse panel bus is anticipated (within a maximum loop distance of 175 conductor feet).

All even-numbered frames (except the program store and frames having duplicated control equipment such as the network frames) will be fed from an even-numbered PD frame and all odd-numbered frames from an odd-numbered PD frame. Two sets of feeders, one from each PD of a pair, will be run to those frames having duplicated control equipment.

To minimize noise caused by stray ground circulating currents or by transient noise potentials within the building, all frames and cable rack are insulated from the building at the time of installation. The frames (and cable rack) are bolted together and individually bonded to a No. 6 AWG frame aisle ground conductor. This ground network connects to the ground bars of the PD frames to provide personnel protection. The PD frame ground bars are interconnected with 750 MCM cables. This ESS ground network is connected to the central office ground, the protection frame ground and ac power entrance ground at only one point (ac neutral or ground return conductors are not connected to the system ground within the ESS switchroom.)

Cable racks (and conducting cable sheaths) from any uninsulated frames (including the protector frame, power room frames, and any in other switchroom areas) are insulated from the ESS frames by insulating pads, fasteners, or isolating sections. Power plant ground returns are similarly insulated from their power plant frames.

Limited amounts of +130 volt and −130 volt power (voltage limits 125 to 135 volts) are required for coin control but no other No. 1 ESS functions. These are distributed to the coin trunks via the 130-volt distributing fuse panels located on the miscellaneous power frame.

7.2 *AC Power*

Some critical ac loads which can tolerate a service interruption of only a few seconds are: (a) AMA magnetic tape recorders, (b) recorded announcement machines, (c) maintenance teletypewriters and data sets, (d) master time-of-day motor, (e) tone interrupter, and (f) 20-cycle static subharmonic ringing generator in smaller offices.

Normally these loads will be operated from commercial ac service. In the event of ac power failure, the 504B emergency power plant will

* In the case of the junctor frame, this figure is allowed to be 1.7 volts maximum, since this will not result in denied service or a reduction in supervisory range but only a slight transmission impairment on limiting loops.

supply the needed 3-phase, 208-volt and single-phase, 120-volt, 60-cycle power within 5 seconds.

This protected ac supply as well as the essential ac supply furnished by the standby engine alternator is distributed from an ac distribution panel located on a miscellaneous power frame. This panel is equipped with circuit breakers for the 3-phase and single-phase, 280-volt loads, and fuses for 120-volt, single-phase loads. A power factor correction panel is also supplied to compensate for highly inductive loads.

New cables (410A and 411A) were coded to provide 18-gauge triples and pairs for ac distribution. These PVC-insulated cables have a distinctive yellow sheath to permit easy identification.

7.3 *AC and DC Cabling*

The ac and dc distribution cables are run from the miscellaneous power and power distributing frames in the rear (wiring aisle side) of the frame line cable rack. Power cross-aisle racks are provided as required to distribute these cables to their proper frame lines. There, ac cables are dressed down the rear of one frame upright while the dc cables are contained within one or more frame uprights.

7.4 *DC and VF Signaling*

DC signaling leads, relay connections, and tip and ring leads through the networks and trunks are subjected to a wide variety of transient noise pulses. In an all-relay switching system, these transients usually do not cause a system malfunction, because of the inherent insensitivity of the relay network.

7.5 *AC Pulse Signaling*

Master scanner pairs and manual override pairs from the master control center are not very noisy nor very vulnerable to noise. These are relatively long cables which have intimate contact with logic circuitry, so there is some danger that any noise they generate or transmit could disturb more sensitive areas. Their exposure to relay noise could introduce this noise into vulnerable areas of logic. The 0.5-microsecond unipolar pulses carrying data and control information between the central control, central pulse distributor, master control center, stores, and peripheral units are the most vulnerable to the noise of signaling connections. They are run as balanced circuits and brought into each frame through shielded transformers, with the lead length on the unbalanced output to the cable receiver kept less than 18 inches.

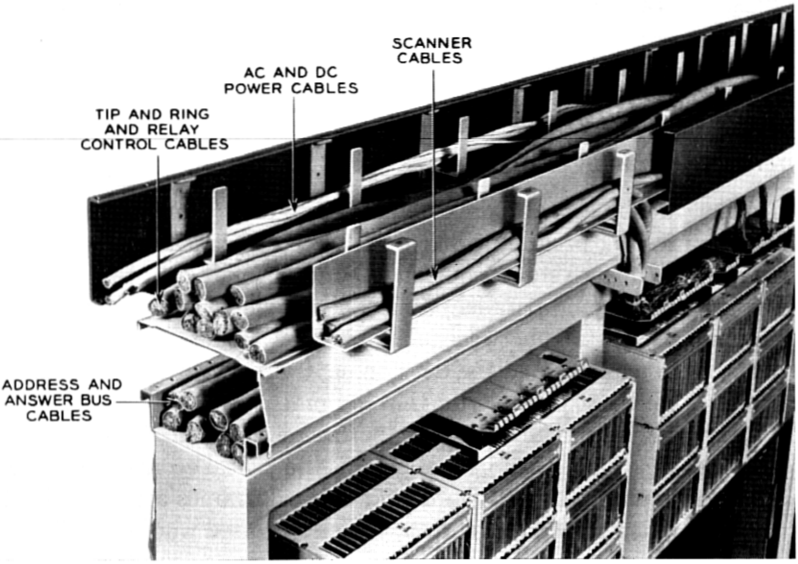


Fig. 45 — Compartmented cable rack.

The 0.5-microsecond signal distributor bipolar pulse leads are not noisy and are less sensitive to noise than the unipolar. However, they are still a problem, since they enter frames without using shielded cable receiver transformers, and these leads cannot be kept as short as those to the cable receivers.

7.6 *Cabling Practices*

Studies and laboratory tests showed that the economical answer to these interframe cabling problems lay, not in the use of shielded wire or coaxial cable, but in a compartmented cable rack as shown in Fig. 45. The 0.5-microsecond unipolar and bipolar pulse leads are run in the lower compartment (having removable front and rear covers) with minimum lead length exposure between the compartment and the transformers mounted at or near the top of each frame.

The scanner cables are run in a shielded channel at the front (maintenance aisle side) of the cable rack where they can drop down to frame terminal strips with relatively short exposures. The tip and ring leads and relay control leads are placed in the center top section of the cable rack. These cables are run over the scanner cables, down the front of the frame upright to the frame or unit terminal strips or ferreed switch terminals. AC and dc power distribution cables are run in the rear top section.

Separate cross-aisle racks are provided to maintain this needed separation between different classes of leads.

7.7 *Frame Wiring Methods*

During the brassboard development stages of central control and stores, the testing program proved that some wiring methods common to relay switching systems could not be used for high-speed pulse circuits. The lengths and parallel paths of signal wires had to be controlled to minimize crosstalk between circuits. This resulted in circuit pack placement restrictions and the development of new wiring practices and associated hardware suitable for this equipment.

Where present practices of unit surface wiring and interunit loose wiring and local cables can be used, this is the logical economical answer. In general, trunk units and trunk and network frames are wired in this way. This wiring method, as shown, can also be used where circuit packs and interconnections are less congested and circuit design permits.

Where high densities of circuit packs and wired interconnections exist, as in central control, special wiring procedures prescribe specific routings for surface wiring, loose wiring, and local cables. The following basic wiring rules are recommended:

(a) Use most direct route via horizontal and vertical runs.

(b) Do not sew signal wires into a cable.

(c) Surface or loose wiring can be used provided a multiple does not exceed 6 feet and other multiples do not follow the same path for more than 3 feet.

(d) Twisted pairs are used (one wire grounded) when multiples are 6 to 10 feet in length.

The wiring rules illustrated in Fig. 46 are the outgrowth of this development. Fig. 47 shows these rules applied in a wired frame. The individual mounting plates are first surface wired in the shop and verified with a dc test. The associated mounting plates of a unit are surface wired together. The loose wiring support details are then mounted on the units, and the units in turn are installed on the bay or frame. A preformed loose wiring harness is mounted on the support details and the leads are terminated.

VIII. DISTRIBUTING FRAMES

In many large central offices, the main distributing frame (MDF) now determines the length of the building. No. 1 ESS employs frames one-

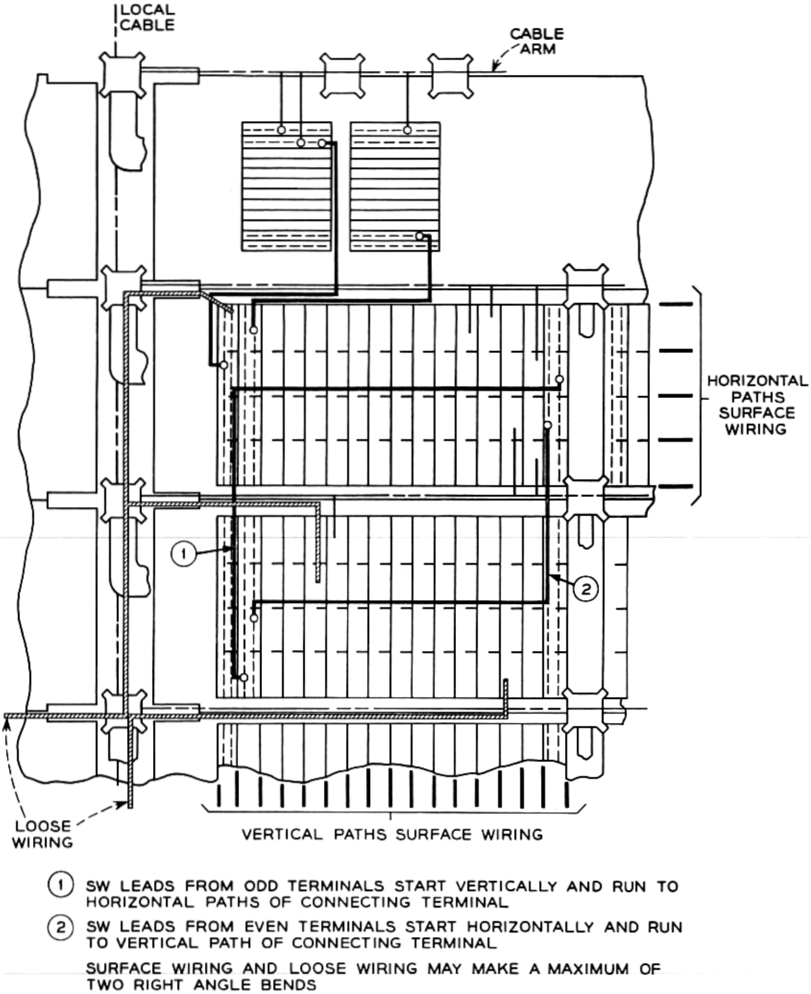


Fig. 46 — Central control wiring rules.

half the height of these large MDF's and requires one-third the floor space of existing offices. Distributing frames of radically new design were needed to match the space economy of the new system. Fortunately, the new programmed logic, the electronic memories, and the nonexistence of sleeve leads eliminated some of the need for cross-connection capacity formerly required. Fewer jumpers are required and fewer changes are needed in the jumpers that remain. In preceding systems, the frequency of jumper changes is increasing and their costs are climbing every year. What was needed for No. 1 ESS, therefore, was a design which would

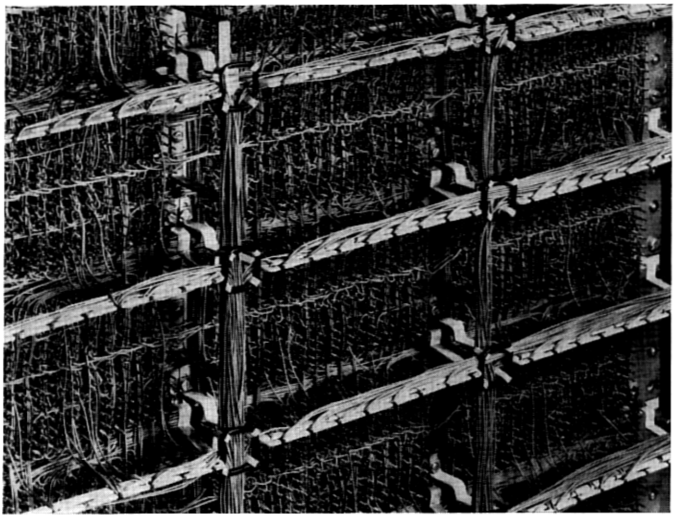


Fig. 47 — Central control wiring methods.

shrink the distributing frames to a compatible size and correspondingly reduce the cost of cross connections. This was accomplished with the new frame designs.

8.1 *Protector Frame*

One module of single-sided protector frame 6 feet, 6 inches long, 8 feet high and 1 foot deep (see Fig. 48) provides the protectors for 6000 outside plant pairs. A protector unit (without heat coils) guards against lightning and other high foreign potentials and serves tip and ring conductors of a pair. The connector for 100 protector units is shipped with a stub cable long enough to reach its termination in a cable vault or on a wall rack. The module has 12 verticals of five connectors each. Provision is made for test desk circuit appearances as well as for every needed maintenance access to any circuit or group of circuits. A compact loudspeaker system incorporates the microphone in a frame upright and the loudspeaker in the upper right-hand corner of the module. No plugging-up panels are required since lines in trouble are automatically routed to trouble intercept by central control. A conductor identification circuit will permit the cable splicer to identify pairs without manual help at the central office.

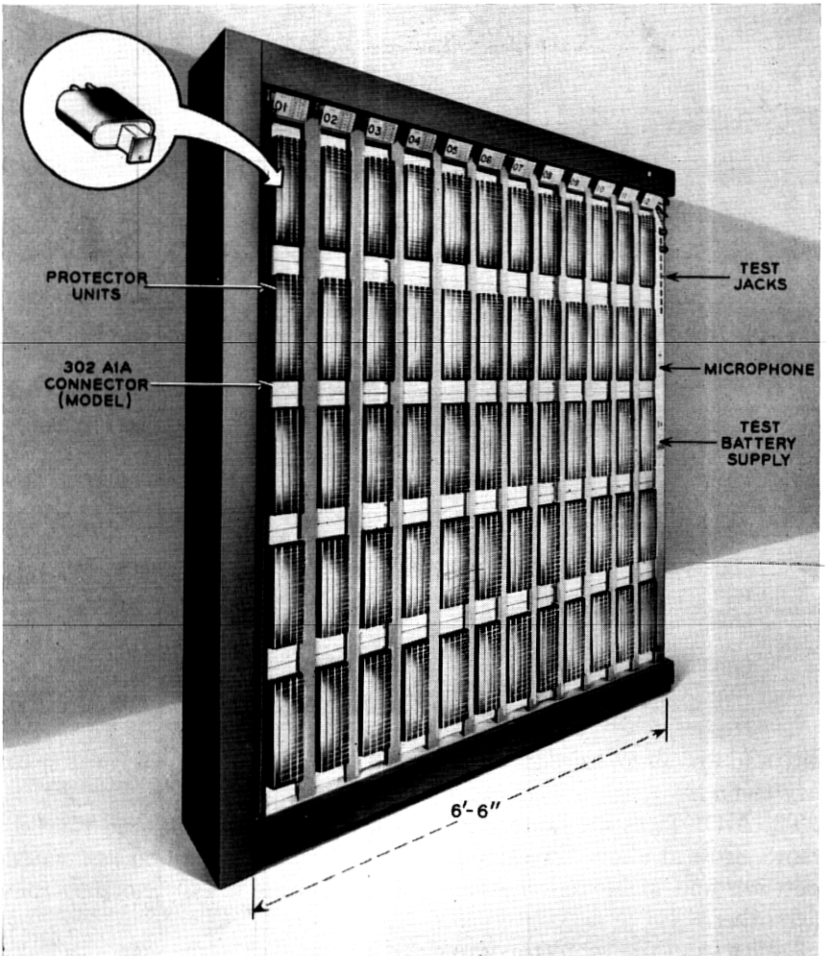


Fig. 48 — Protector frame.

8.2 *Main Distributing Frame (MDF)*

The MDF, shown in Fig. 49, makes a corresponding reduction in size by eliminating most long jumpers. Outside plant pairs and inside equipment pairs are interspersed in a manner which greatly reduces jumper length, the space for storing jumpers, and the space for making cross connections. The cost of making changes is reduced by the elimination of most long jumpers, by the introduction of "quick-connect" terminal strips, by avoiding changes completely where program and circuits per-

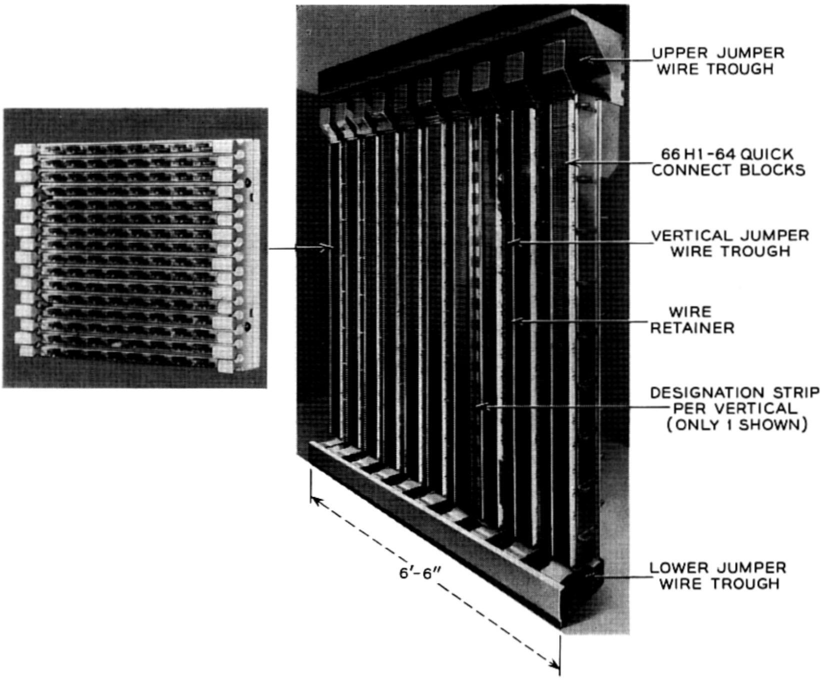


Fig. 49 — Main distributing frame.

mit, and by simple designation procedures which make terminations easy to find.

The MDF faces the protector frame across a 4-foot aisle, and the two frames grow at about the same rate. The frameman will find associated protector and MDF terminations across this aisle usually not far from each other.

Cables from the protector frame are interspersed with system switchboard cables on the single-sided MDF. Line link networks and auxiliary line circuits are cabled there directly; trunk, service, and associated auxiliary circuits appear first at an intermediate distributing frame (IDF) where they are cross connected to tie-cables to the MDF. Thus the trunk circuits have two jumpers each, for multiplied access to outside plant pairs.

A module of single-sided MDF is 6 feet, 6 inches long, 8 feet high and 1 foot deep. This gives 6000 pairs from outside plant access to as many as 6080 central office pairs. Connecting blocks on each of ten verticals have 1216 "quick-connect" terminal pairs in one plane on the front (each terminal arranged for two cross connections) and solderless wrapped terminals in one plane on the rear. The five odd-numbered verticals terminate 1200 protector frame pairs each. The five even-numbered verticals terminate 1216 system pairs each. Cabling patterns distribute protector and system pairs on their interspersed verticals in a manner designed to permit the great majority of all cross connections to be between adjacent verticals. Jumper troughs above and below the connecting blocks provide for the longer jumpers between nonadjacent verticals.

Lines from line link networks are distributed horizontally across the midsection of the system verticals. Line auxiliaries such as long-line circuits and bridge lifters are similarly distributed below them. The cables to the intermediate distributing frame (to cross connect to trunks and trunk auxiliaries there) are distributed horizontally across the upper sections of these verticals.

Each fully equipped vertical with pairs from the protector frame presents 1200 outside plant pairs for direct cross connection to as many as 2432 system pairs on the two adjacent verticals (left and right). The 1200 pairs on an intermediate vertical include 20 pairs from each of 60 different 100-pair cables from outside plant.

This vertical distribution of outside pairs combined with the horizontal distribution of system pairs guarantees a wide exposure of outside to system pairs of different types on adjacent verticals. To provide further homogeneity as an office grows, the protector frame modules are equipped in numerical sequence, as at present, but at each stage of growth, protector pairs are distributed over three MDF modules in a manner such that the last MDF module in a line-up is one-third filled when the second last module is two-thirds filled and preceding modules are completely filled.

Service observing cross connections for lines and PBX trunks are made on the rear of the MDF so that this activity does not interfere with the cross connecting of outside to system pairs on the front of the frame. Circuits from the service observing desk (and from a No. 6 service observing set) are distributed over small jack panels located at the top rear of the five verticals for protector frame pairs. Patch cords cross connect from these jacks to the rear of nearby line terminals as required.

To make all terminations easy to locate, a vertical designation strip is hinged in front of each vertical jumper trough. When rotated to the left or right, it covers the adjacent one-half of the jumper trough on that side. In either position it clearly designates all terminals in the vertical. Designation areas are in colors to assure quick identification of out-

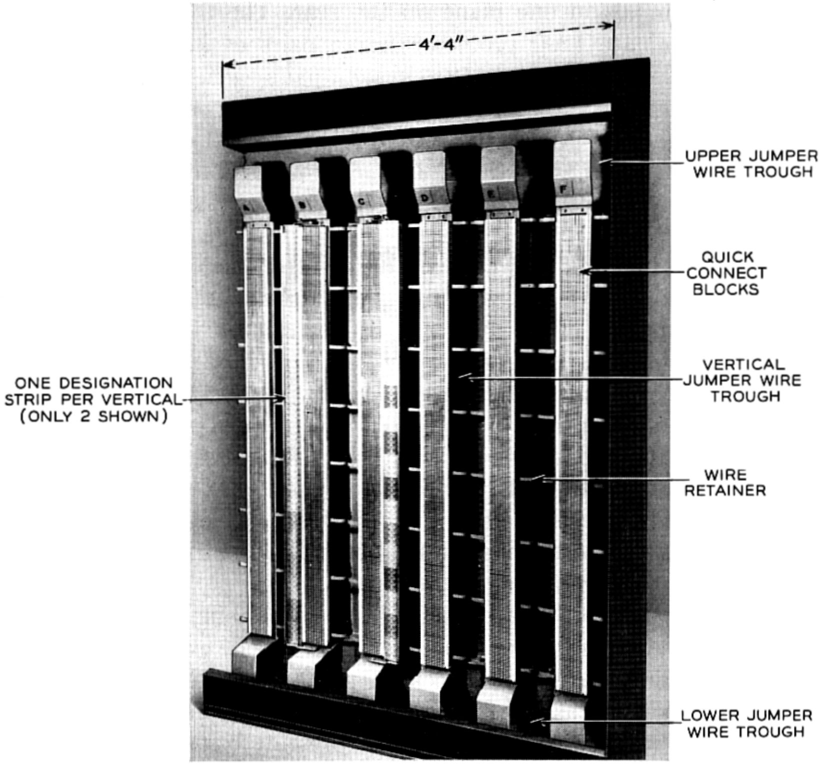


Fig. 50 — Trunk distributing frame.

side and system pairs and of the blocks of associated terminals in each. Blue and gray in alternate horizontal stripes identify the blocks of outside pairs; yellow and gray identify the system pairs.

8.3 *Trunk Distributing Frame*

A trunk distributing frame (TDF), shown in Fig. 50, fits in a frame line-up. It is similar to the MDF except that it has six verticals of 1216 terminal pairs each in a module 7 feet, 0 inch high and 4 feet, 4 inches long, and provides for only one connection on each quick-connect terminal. It terminates all cables from trunk link networks on the odd verticals and all circuits from universal and miscellaneous trunk frames on the even-numbered verticals to give short jumper cross connections between networks and trunks. This permits the traffic to trunk link networks to be balanced from time to time without recabling.

8.4 *Intermediate Distributing Frame*

The intermediate distributing frame (IDF) will normally be located at the head end of the MDF and in line with it, the two frames growing in opposite directions. Here the IDF will employ the same distributing frame module as the MDF. Occasionally, the IDF may be located in a frame line-up when shorter cable runs are needed to meet transmission limits. Here, the IDF employs the same module as the TDF.

In either case, the new IDF terminates all cables from equipment frames for trunk circuits, service circuits, and trunk auxiliaries (for carrier, repeaters, etc.) on connecting blocks of alternate verticals. Tie-cables from the MDF are interspersed on intervening verticals in a manner which permits most cross connections to be between adjacent verticals. Trunk access to protector pairs is thus multiplied by providing two jumpers (both usually short): one from the trunk to an MDF tie-cable appearance and one at the MDF between the protector and tie-cable terminals.

8.5 *Junctor Grouping Frame*

In No. 1 ESS, a new approach was developed for the distribution of junctors. In previous systems, junctors were cabled from the link frames to the junctor grouping frame (JGF), where they were interconnected directly or by jumpers in fixed patterns, depending on the number of line-link and trunk-link frames in the office. No 1 ESS uses plug-ended cords and jacks instead of jumpers. They are particularly attractive for additions, since junctors can be quickly redistributed by merely rearranging patch cords which have 16 pairs in each.

No. 1 ESS derives added benefits from this extremely flexible junctor redistribution. Junctor patterns in this system are a function of traffic type (intraoffice, interoffice, or tandem) as well as of office size, and this increases the number of patterns and the frequency of changes to balance traffic because: (a) Junctor circuits as well as network junctors are terminated on the junctor grouping frame, as shown schematically in Fig. 51. These circuits provide for the completion of intraoffice traffic without going through trunk-link frames. (b) Likewise, provision is also made on the junctor grouping frame for completing trunk-to-trunk traffic without going through the line-link frames.

The JGF shown in Fig. 52 fits in regular frame lineups under standard cable rack and is 2 feet, 2 inches wide. Frames are provided in pairs, one pair being required for each 16,000 lines in the average office.

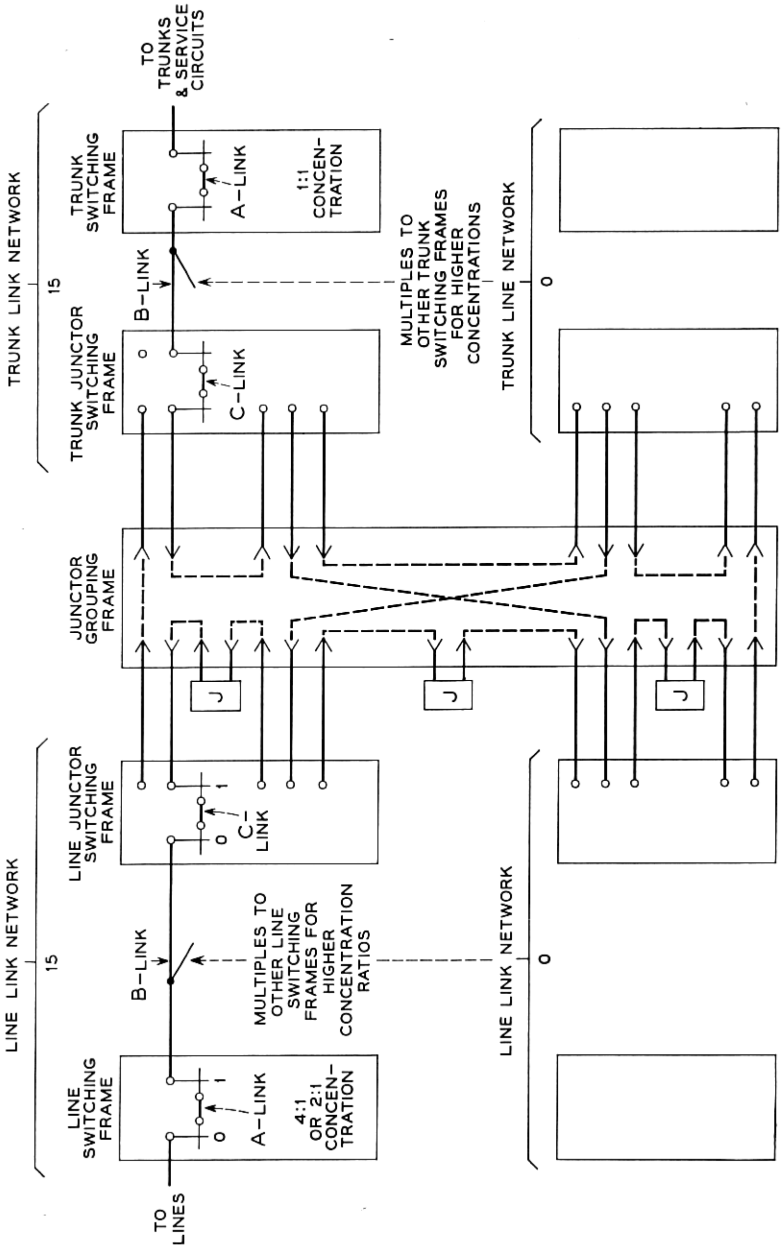


Fig. 51 — Typical connections for line link network and trunk link network.

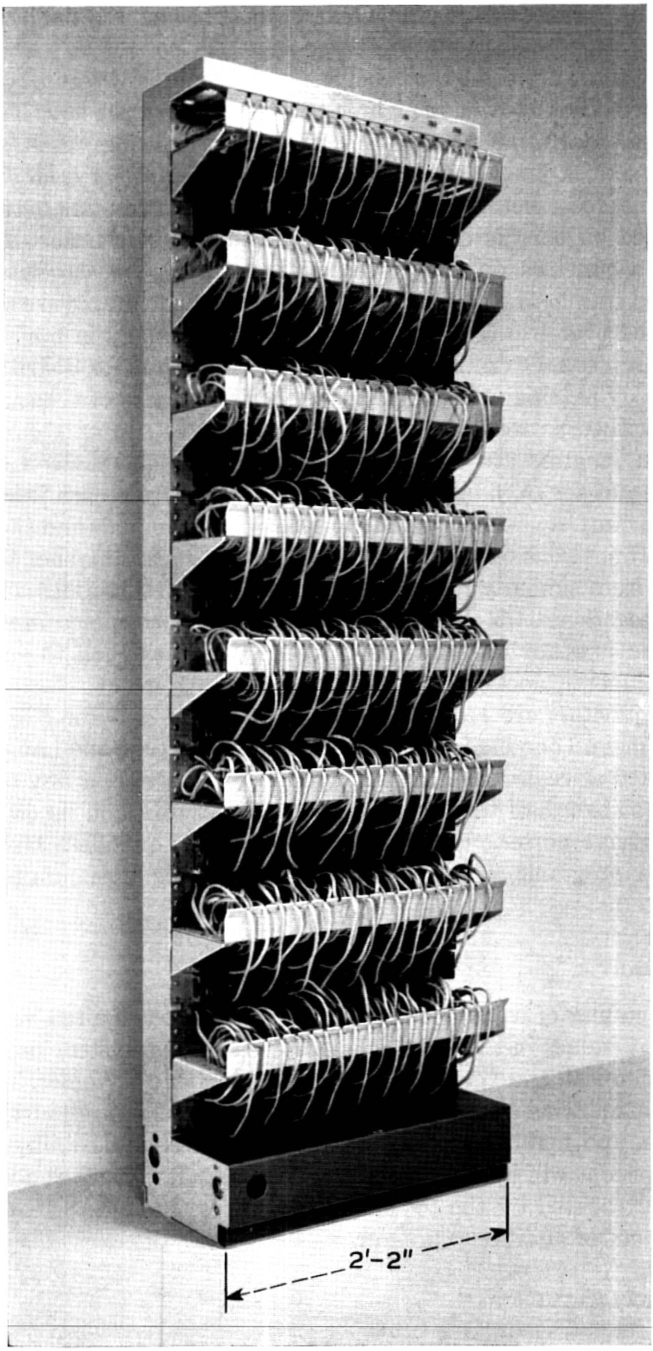


Fig. 52 — Junctor grouping frame.

On the front are eight cord shelves, each having eighteen 32-terminal plug-ended cords above and eighteen 32-terminal jacks below. The plugs and jacks on a frame are arranged in nine vertical files, each of which contains sixteen plugs and sixteen jacks, two of each for each shelf. All even-numbered junctors from one line-link or one trunk-link network are terminated on one file of an even-numbered grouping frame, and odd-numbered junctors on the corresponding file of the associated odd-numbered frame. The junctor circuits from a junctor frame are similarly distributed over two files; but being only half as many in number, two junctor frames are terminated on a pair of files. Junctor distribution is achieved by patching the plugs of one shelf into jacks of the same shelf in a prescribed pattern.

Sixteen junctors are terminated on each plug and sixteen on each jack, one junctor from each grid of a network (or from each junctor circuit subgroup). A slip is wired between the plug terminals and their associated terminations on the rear of the frame in such a manner that two junctors from similarly numbered grids or junctor subgroups are never coupled together. This slip permits all verticals to be cabled in identical fashion but spreads the junctors differently on each shelf to guarantee minimal junctor blocking.

When junctors are redistributed, all plugs of even- (or odd-) numbered frames on one shelf will be disengaged at one time and immediately reconnected as required. This will remove from service at any one time only one-sixteenth of the junctors from each network and junctor frame and thus have no serious effect on traffic if done outside a busy hour. Computer programs are being used to establish the optimum plug and jack patterns.

IX. SUMMARY

The wedding of a generic stored program with a limited variety of equipment frames in the No. 1 electronic switching system provides a new, economical, and versatile tool for the telephone customer. This system is introducing many new patterns in manufacture, installation, operation, and maintenance to the Bell System. The flexibility of this system concept will be demonstrated in the next few years as additional services are offered by the telephone companies through the continuing development of additional programs.

X. ACKNOWLEDGMENTS

As is the case in all complex systems, the apparatus and equipment described here are the result of the efforts of many people in several departments of Bell Telephone Laboratories, particularly Systems Engineering, Systems Development, and Device Development. In addition, our associates in the engineering and production departments of the Western Electric Company have made many contributions.

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