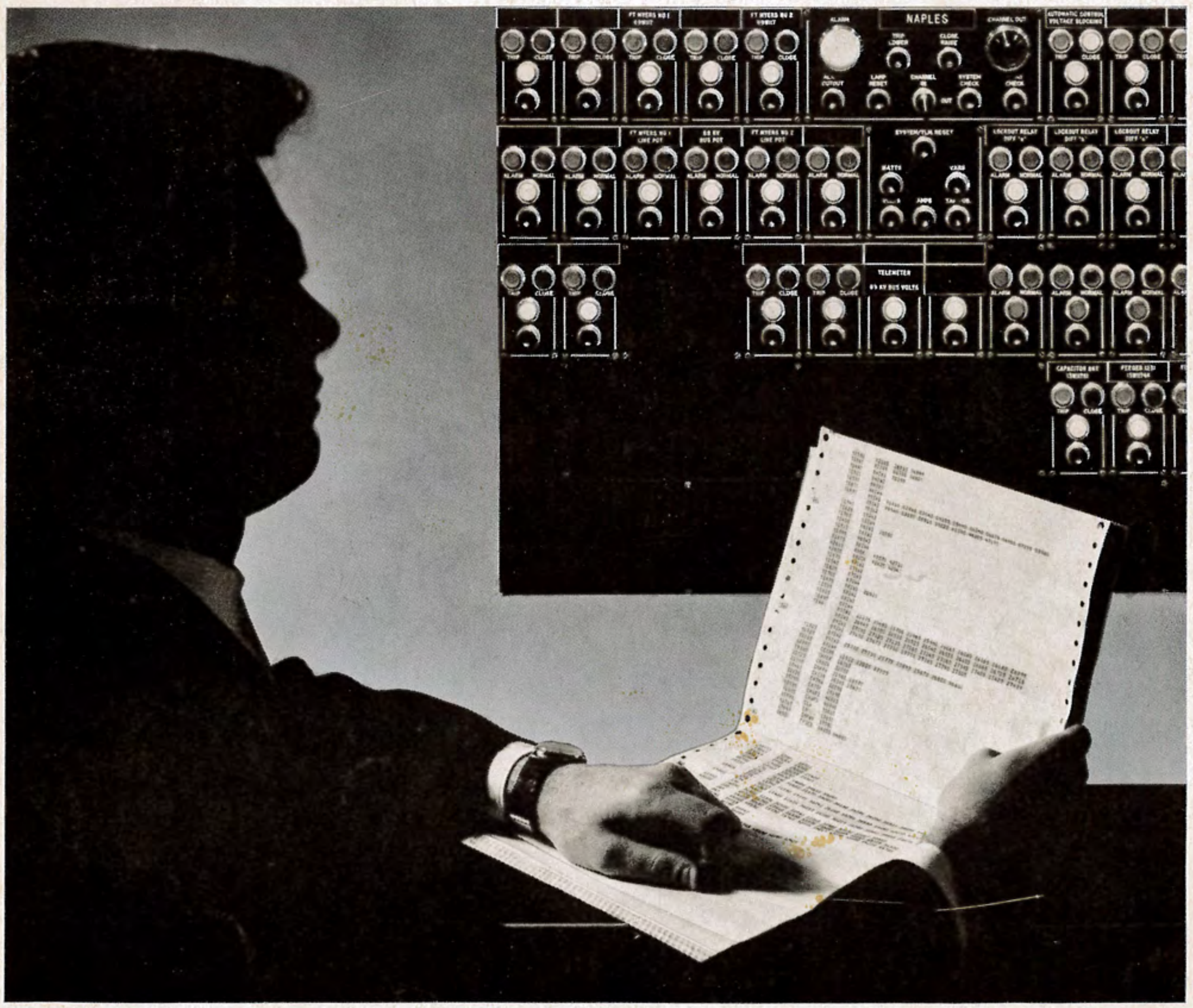
AUTOMATIC ELECTRIC
TECHNICAL JOURNAL



GENERAL SYSTEM

JULY, 1966 VOL. 10, NO. 3

AUTOMATIC ELECTRIC

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COVER ILLUSTRATION—Operator at the master station of an electric power distribution network reviews a log of the status of devices in the field. The data was collected, telemetered, and processed by a new silicon logic industrial system, the Conitel 2000 (see page 82). Three other articles in this issue deal with the subject of data handling: Definitions, page 94; Industrial Data Sets, page 98; and Touch Calling Applications, page 106.

The Automatic Electric Technical Journal
is published by
AUTOMATIC ELECTRIC LABORATORIES, INC.,
a subsidiary of Automatic Electric Company,
Northlake, Illinois, U.S.A.
and the laboratories of its
affiliated manufacturing companies.

OVERSEAS AUTOVON

By Walter Axelsen
Automatic Electric Company

Figure 1. Touch Calling telephone for Overseas AUTOVON provides four pushbuttons (FO, F, I, P) for precedence service, and one button (A) for Abbreviated Dialing.

A high-speed four-wire non-blocking switching system, which is end-to-end circuit switched, has been developed for use in a world-wide military communication network. Initially transmitting voice only, it is designed to handle ultimately all forms of data transmission, at up to 108 kc. Unique services provided include "off-hook" service which completes connections between pre-arranged telephones on a "hot-line" basis, and a number of "precedence" services that permit important calls to override calls of less importance. Conference services of various types are also provided. To meet military needs the system provides automatic "survivability" routing—up to six alternate routes per destination.

For the use of the U.S. military services, a world-wide communication network is now being created that will be capable of automatically switching voice and other communication circuits at very high speeds (4-10 seconds), on a four-wire basis. This new AUTOVON (for "AUTOmatic VOice Network") will be made up of "CONUS" (for "CONtinental U.S.") AUTOVON, and "Overseas" AUTOVON, which will provide service outside the continental limits of the U.S. The latter system is now in production at the Automatic Electric plant. It provides a number of unique services that are not now available through commercial telephone systems.

Communication channels for the AUTOVON system will, in various places, be provided by means of wire lines, carrier, microwave links, and HF, VHF, UHF, and troposcatter radio. Preprogrammed facilities will provide a variety of "dedicated" networks within the complete system. For example, instead of providing a permanent transmission channel between two points, "off-hook" service may be provided, to complete a connection between those two points, and signal the called station in about four seconds, when

This article is based on six papers presented at the IEEE International Communications Conference, Philadelphia, Pa., June 15-17, 1966:

IEEE No. 19TP66—1109
"System Design Parameters of Overseas AUTOVON Switching System", E. J. Glenner, W. C. Miller, and R. J. Murphy

IEEE No. 19TP66—1110
"Application of Common Control to Overseas AUTOVON Switching System", D. K. Lee and H. L. Wirsing.

IEEE No. 19TP66—1111
"Marker and Matrix Configurations for Overseas AUTOVON Switching Systems", R. M. Schildgen, A. S. Cochran, and J. R. VandeWege.

IEEE No. 19TP66—1112
"Physical Aspects of Overseas AUTOVON Switching System", P. K. Gerlach, E. B. Lopatka, and J. W. Taugner.

IEEE No. 19TP66—1113
"Line and Trunk Design for Overseas AUTOVON Switching System", W. A. Lindbloom, R. C. Clark, and L. L. Smith

IEEE No. 19TP66—1114
"Maintainability Aspects of the Overseas AUTOVON Switching System", J. P. Jallits, W. D. Stejskal, and W. R. Wedmore.

the handset is lifted at the other station to make a call. Several "precedence" services will be available, with means for pre-empting, when necessary, facilities that are engaged on calls of lower precedence. Conference services, either one-way or two-way and of various types, will permit quick communication with and among groups of stations. Services requiring an attendant will be provided through a Dial Service Assistance (DSA) board at each of the major switching centers. The system is designed to provide data as well as voice transmission; the switching matrix will handle up to 108 kc.

An unusual requirement of Overseas AUTOVON is that no call may ever be blocked by busy links between stages in the switch matrix. Every call entering a "Switch" (office) will be completed (provided, of course, that the desired line or trunk is idle—and that it is not "pre-empted" by a call of higher precedence).

The high-speed switching provided by Overseas AUTOVON is made possible by electronic controls (including an electrically alterable memory) and the use of Touch Calling telephones (Figure 1), which cut "dialing" time to one-half or less. Pusbuttons are also provided on these telephones for Abbreviated Dialing Service, and for four levels of precedence above the normal. The actual switching is performed by crosspoint switching matrices (CSM's), using correeds (magnetic reed switches) as crosspoints. These matrices resemble generally those used in the Automatic Electric No. 1 E-A-X (Electronic Automatic Exchange)*; the correeds provide the switching necessary between the electronic controls and the outside lines and trunks.

**Automatic Electric Introduces New E-A-X (Electronic Automatic Exchange)—K. K. Spellnes, Automatic Electric Technical Journal, Vol. 8, No. 4, October, 1962—pp. 122-131.*

Routing and Signaling Plan

Overseas AUTOVON will comprise 22 Switches installed in 14 countries. Calls will be switched end-to-end, on a tandem basis; it is anticipated that, at many of the Switches, tandem calls will represent the bulk of the traffic. The individual Switches will have capacities of up to 2000 terminations, including such tandem-switched trunks. The routing plan is based on originating-office control ("end-to-end" register signaling) and is extremely flexible, since it can accommodate routing or trunking changes made by the memory to provide not only normal alternate-routing but also military "survivability" routing, with up to *six* alternate routes per destination. However, certain offices are "spill-forward" offices only—that is, they must pass all routing information to an office having routing capability.

Originating-office control requires many signals, and military service demands *reliable* signals. To meet these requirements, over the variety of transmission facilities encountered on a world-wide system, "confirmation signaling" is used in Overseas AUTOVON; each signal must be acknowledged before the next can be sent. Information is generally exchanged by means of Touch Calling Multi-Frequency (TCMF) or two-out-of-six MF (2/6 MF) signaling; dial pulsing (DP) is used only on four-wire attendant lines and two-wire user lines at connecting PBX's.

Supervisory signals, such as off-hook, on-hook, ringing, etc., are based on the use of standard E&M control leads.

Most of the facilities for inter-Switch trunks and for access lines are carrier-derived, and single-frequency (SF) signaling is used; on cable circuits, however, duplex (DX), simplex (SX), or composite (CX) signaling may be used.

Transmission Plan

Transmission within the network demands high-quality message channels, with reliable means for establishing connections up to 12000 nautical miles and handling data transmission at up to 2400 bits per second. To achieve this objective, intertoll trunks, PBX and subscriber-access lines, and user loops were designed to provide the following losses:

Circuit	*Design Loss, 1000 Cycles*
Intertoll trunk	0db
PBX access line	
4-wire main PBX to AUTOVON	0db
2-wire main PBX to AUTOVON	4db
PBX tie trunk	
4-wire to 4-wire	0db
4-wire to 2-wire	4db
2-wire to 2-wire	3db
User Loop	
to 2-wire telephone	3db average, to 7db max., contingent on trunk arrangement
to 4-wire telephone	6db
Subscriber access lines to 2-wire and 4-wire telephone set	6db

Through the use of echo suppressors, a 4db receive pad for telephone sets, a data regenerator, and other transmission components, the following losses will be achieved on overall connections through voice channels of nominal 4 kc bandwidths:

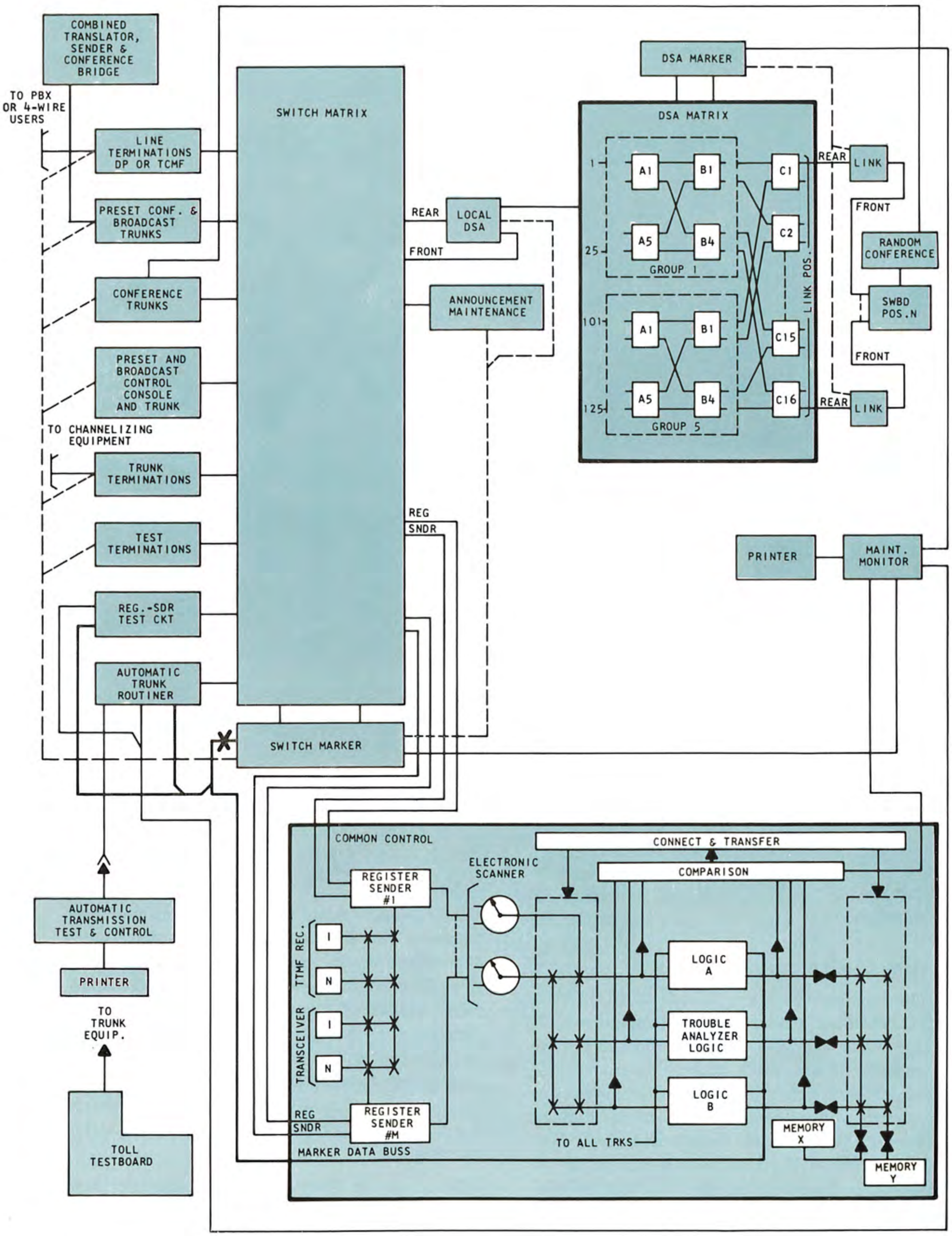
Connection	*Loss (db)* Average	*Loss (db)* Maximum
4-wire/4-wire Voice	12 (16*)	-
Data/Secure Voice	12	-
4-wire/2-wire	13	17
2-wire/4-wire	13 (17*)	17 (21*)
2-wire/2-wire	14	22

**An additional 4db loss is inserted in the four-wire telephone receiving circuit, but the subscriber is not aware of this because the receiver in the four-wire set is removed from the station hybrid.*

Numbering Plan

The numbering plan of Overseas AUTOVON provides for a three-digit "Switch" (office) code, a four-digit terminal number, and a three-digit area code, on calls made outside the caller's area.

Figure 2. Block-diagram of Overseas AUTOVON Switch. All connections through the switch are completed by the Switch matrix. The DSA matrix distributes service requests among the positions of the Dial Service Assistance switchboard.


COMBINED TRANSLATOR, SENDER & CONFERENCE BRIDGE
TO PBX OR 4-WIRE USERS
LINE TERMINATIONS DP OR TCMF
PRESET CONF. & BROADCAST TRUNKS
CONFERENCE TRUNKS
PRESET AND BROADCAST CONTROL CONSOLE AND TRUNK
TO CHANNELIZING EQUIPMENT
TRUNK TERMINATIONS
TEST TERMINATIONS
REG.-SDR TEST CKT
AUTOMATIC TRUNK ROUTINER
SWITCH MATRIX
SWITCH MARKER
REAR
FRONT
LOCAL DSA
ANNOUNCEMENT MAINTENANCE
REG
SNDR
DSA MARKER
DSA MATRIX
A1
B1
A5
B4
C1
C2
C15
C16
GROUP 1
GROUP 5
1
25
101
125
LINK POS.
LINK
RANDOM CONFERENCE
SWBD POS.N
PRINTER
MAINT. MONITOR
AUTOMATIC TRANSMISSION TEST & CONTROL
TO TRUNK EQUIP.
TOLL TESTBOARD
COMMON CONTROL
CONNECT & TRANSFER
COMPARISON
ELECTRONIC SCANNER
REGISTER SENDER #1
TTMF REC.
TRANSCEIVER
I
N
REGISTER SENDER #M
LOGIC A
TROUBLE ANALYZER LOGIC
LOGIC B
MEMORY X
MEMORY Y
TO ALL TRKS
MARKER DATA BUSS

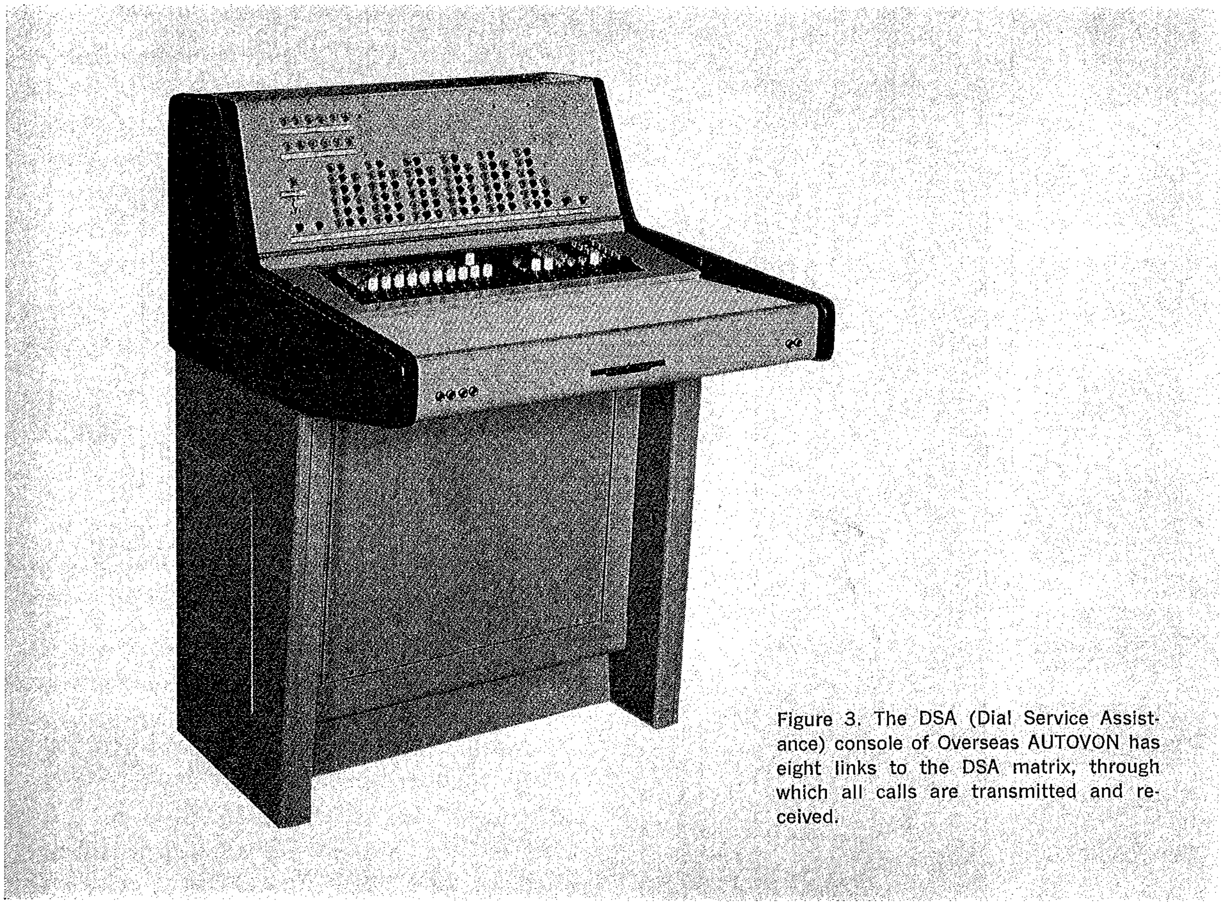


Figure 3. The DSA (Dial Service Assistance) console of Overseas AUTOVON has eight links to the DSA matrix, through which all calls are transmitted and received.

The digits are of the following values:

"Area" Code	*"Switch" Code*	*Terminal Number*
NYX	NNX	XXXX

in which

N is any of the digits 2 through 9

X is any digit (0 through 9)

Y is either 0 or 1

System Configuration

The subsystems comprising each Overseas AUTOVON Switch are shown in Figure 2. It should be noted that all lines and trunks are terminated on the switch matrix. All connections through the office are completed through this one matrix, and under control of its marker; together with the electronic Common Control, these subsystems may be considered the heart of the AUTOVON Switch. They identify the class of each call, including the precedence (if any) that it is to receive; they provide instructions for its completion, and actuate the proper correeds to close the desired path between the calling and called lines.

Incoming calls on lines or trunks are received in the Line and Trunk Groups. When a user initiates a call, the removal of tone toward the Switch causes the line circuit to call for service from the Switch Marker.

The Marker identifies the calling line, then transmits the line-number identification to the Common Control, which allots one of its registers to the call and sends to the Marker the equipment number of this register. The Marker now "knows" the identity of the calling line, and of the register allotted to the call; it proceeds to find a path through the switch matrix, connecting the calling line to the register. After checking the connection for continuity, the Marker releases.

The Common Control has meanwhile presented the line number to its logic, which provides the "class" of the calling line (e.g., whether it is

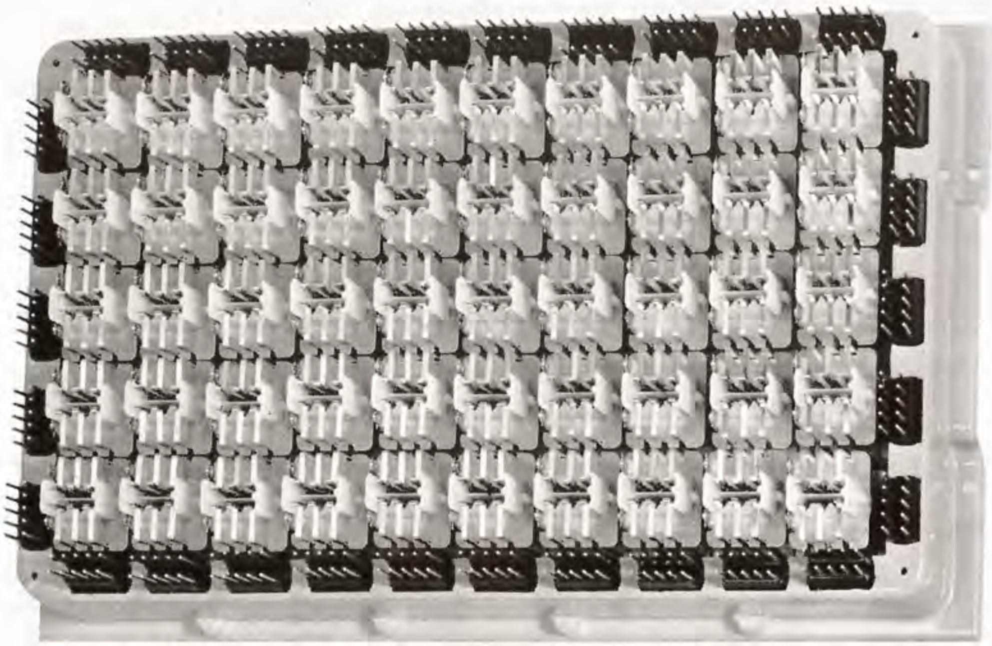


Figure 4. Correed Crosspoint Matrix ("CSM") for Overseas AUTOVON.

a PBX or a direct AUTOVON line, or an inter-Switch trunk). On the basis of this information, the Common Control assigns a DP, or a 2/6 MF, or a TCMF receiver to the call; it then returns dial-tone to the calling line. As the dialed digits are received in its register, the Common Control determines when translation is needed on this specific call, and it provides the translation. It then calls in the Marker (for the second time) and indicates the line circuit being called. The Marker opens the existing path through the matrix to the register, and establishes another connection through the matrix, thus connecting the calling and the called lines (on line-to-line calls).

Calls to an attendant at the Dial Service Assistance (DSA) board (Figure 3) terminate on DSA trunks, which may be interconnected to one of eight links of the DSA switchboard, through a three-stage DSA matrix that has its own, separate, DSA marker.

As previously mentioned, the crosspoint matrices (CSM's) employ, as crosspoints, a correed similar to that used in the Automatic Electric No. 1 E-A-X. To provide the four-wire transmission path required, however, the correeds used in AUTOVON matrices are each equipped with six (instead of four) reedcapsules. The individual matrix modules consist of 50 correeds (10 rows of 5 each) soldered into a two-layer printed wiring board (Figure 4).

Three-stage matrices may be used for Switches of up to 200-250 terminations. In the larger AUTOVON Switches, five-stage matrices are required.

Marker Concepts

The Switch and DSA Markers are composed of groups of circuits that are required to perform specialized operations, and are controlled by wired-program "sequence and supervisory" circuits. These circuits monitor the progress of each call through the other circuits and, after each operation, generate commands to these circuits to effect the next operation. Since each operation has a pre-set time limit, the controls immediately detect any failure to complete an operation,

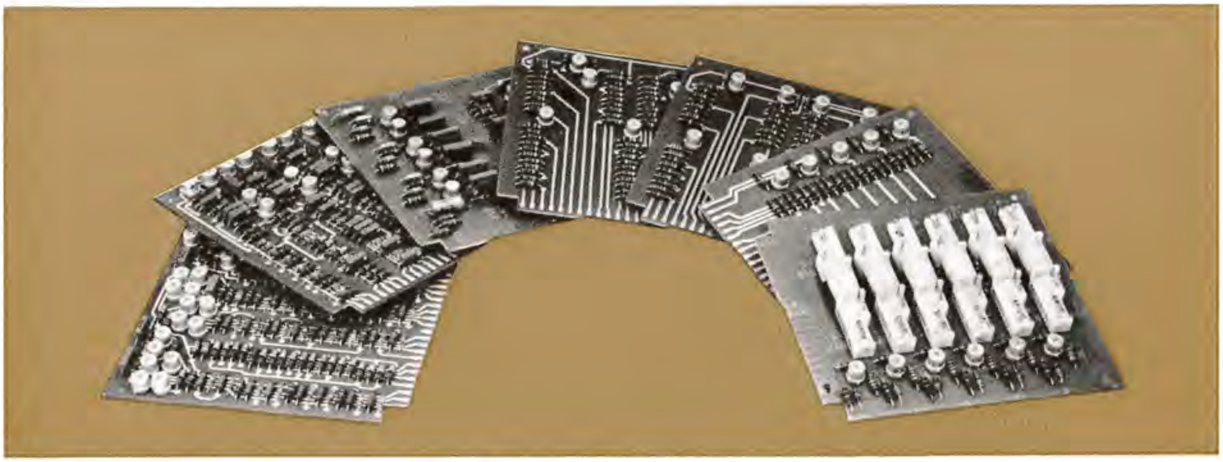


Figure 5. Electronic-logic Printed-Wiring Cards.

and arrange for corrective action. They may call in the maintenance monitor, or may take certain programmed steps to circumvent the problem before signaling the maintenance monitor.

Markers are provided in pairs, with one always on standby; an allotter periodically transfers the traffic from one Marker to the other, to assure that the Marker on standby is in working condition.

The Switch Marker receives three basic types of requests for its service—first, when a local or tandem call incoming to the switch matrix requires a connection to a register; second, when the Common Control requests that a sender be connected to an outgoing trunk to outpulse to the next office; third, when the Common Control instructs the marker to make the final connection (local, terminating, originating, or tandem).

Automatic control of register occupancy during heavy traffic is provided in AUTOVON by sensing the register occupancy, and prohibiting the origination of traffic from local PBX trunk groups during the overload period. PBX traffic is allowed to re-enter the system when the register availability improves. The effect of this control is to afford a measure of priority to tandem and terminating traffic, thus alleviating network congestion.

Calls Originating on Matrix

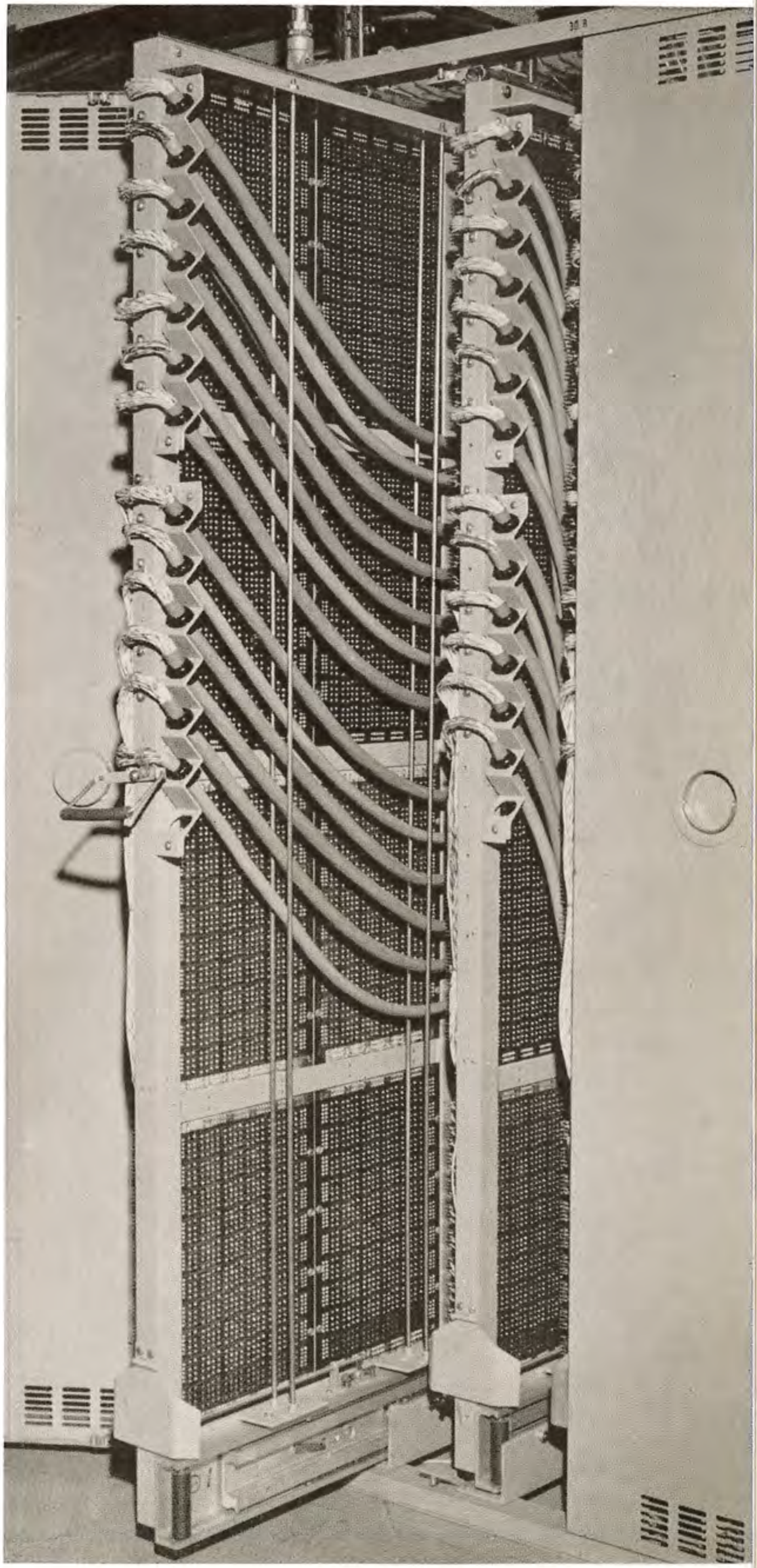
When processing an originating call the Marker randomly identifies, by means of an electronic scanner, the trunk group number (trunk group tens and units digits) of a circuit calling for service; the "call" mark is a negative potential appearing on the TG lead of the trunk. After the trunk group has been identified, the Marker applies a positive "blanking" potential to the call mark (TG) leads of all other trunk groups, so that when the Marker operates its scanner to select the trunk number (trunk tens and units digits), only call marks from circuits in the identified trunk group will be seen by the Marker, on the appropriate TK leads. If it is an "off-hook" line that is requesting service, the Marker immediately recognizes the trunk group number, and forces the scanner to set to this group for identification of that line.

After identification is complete, the Marker sends a call-for-service mark to the Common Control. When an idle register is found by the Common Control, the marker forwards the originating-equipment number to that equipment by means of DC signaling. The sending unit makes a bit-for-bit comparison check on the transmitted data and informs the receiving unit when the correct information has been received.

The Common Control returns the originating equipment number to the Marker, along with the equipment number of the selected register, in order that the Marker may operate to select an idle path between the two circuits, and "pull" the crosspoint correeds to complete the connection through the switch matrix.

Conventional cut-off correeds hold the connection through the hold windings of the matrix, and

Figure 6. The "Drawer Cabinet", which houses the crosspoint switching matrix (CSM) cards.



block further access by the Marker to any link in the path.

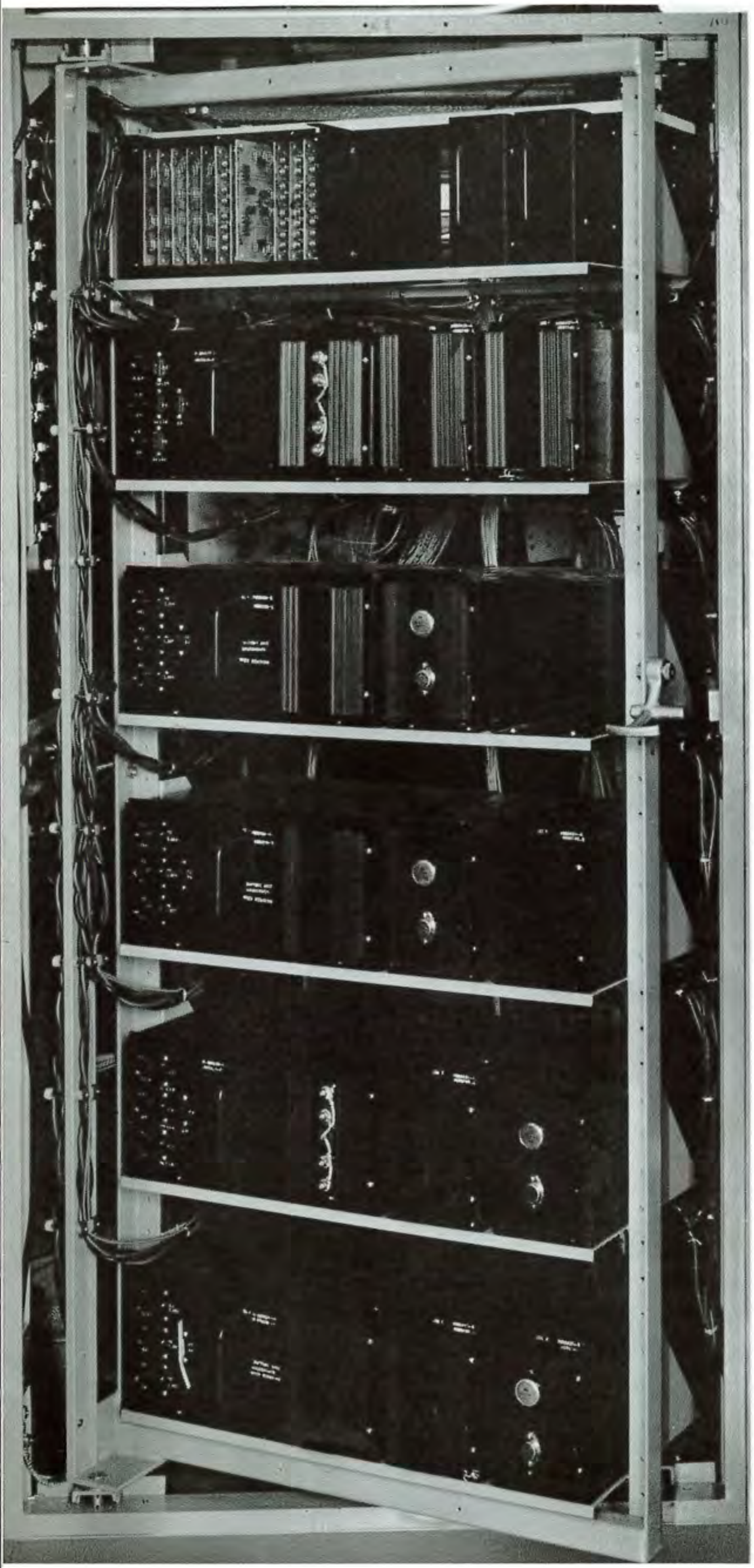
A check for continuity of the five signaling leads (T, R, T1, R1, EC) through the matrix is then performed, and after informing the Common Control that the connection is complete, the Marker enters a "clear-out" phase in order to return to idle and serve other traffic. The Common Control returns dial-tone to the calling line, and operation proceeds as previously described.

Originating Inter-Switch Calls

When a locally originated call is to be extended to another Switch, a second type of request is made of the Switch Marker, involving the connection of sender equipment to an outgoing trunk. This request is initiated by the Common Control when a call has proceeded to this stage of completion. The equipment numbers of the two circuits in question are sent to the Marker, which proceeds, as previously described, to establish a matrix connection. There is a possibility, however, that the outgoing trunk selected, which was idle when last checked by the trunk scanner, may since have been seized from the other end and thus made busy; therefore, the Marker must also test the trunk for busy. Should the trunk be found busy, the Common Control will be informed.

If a new call necessitates pre-emption of an occupied trunk or line circuit, the Marker is so informed by the Common Control; it generates a signal to the circuit involved, causes the original connection to be dropped, and then completes the connection requested by the Common Control. Similarly, an incoming line or trunk can be "locked out" by the Common Control, which so instructs the Marker instead of providing a terminating equipment number.

When a fault is discovered in the on-line Marker, and the allotter determines that a transfer is necessary, the standby Marker is switched in and told to complete the desired connection—which was, of course, recorded in its register as well as in that of the Marker on line.



The Common Control

The Common Control provides capabilities for registering, translating, and sending telephone address information, and has storage facilities for real-time monitoring and "updating" of the line and trunk conditions in the switch. Its time-shared common logic provides the sequential control of all calls in process. Acting upon registered information, this unit also directs the Switch Marker to establish the appropriate cross-matrix connections, as described above.

The Common Control is implemented with electronic as well as electromagnetic circuitry. The electronic circuits are designed on a "building block" basis, using transistor-resistor logic (NOR gates) as the basic logic elements, and transistor flip-flops for temporary storage. The electromagnetic circuitry employs correeds for connect functions, and as an isolation interface between the electronic portion of the Common Control and the outside plant.

Translator Sub-System

The translator subsystem provides the Common Control with the ability to perform translation of up to and including six-digit codes, as well as of directory numbers, and to provide special features, including service treatment ("class mark") on a per-line basis, Abbreviated Dialing, "off-hook" service, service zone restriction, and special network handling.

Dial Service Assistance

Dial assistance, directory information, intercepting, and random conference calls are routed to the DSA switchboard through the DSA matrix, with its separate marker. "Gating" of calls assures that they will normally receive service in approximately the order in which they are received; however, preferential answering of any type of call—such as CLR, assist, etc.—can be applied to any position. Automatic load-control balances the number of positions manned, and provides visual and audible alarms when the degree of unbalance exceeds a predetermined value.

Figure 7. A Typical "Gate Cabinet." Electronic, electromechanical, and power equipment are mounted in separate cabinets of this design.

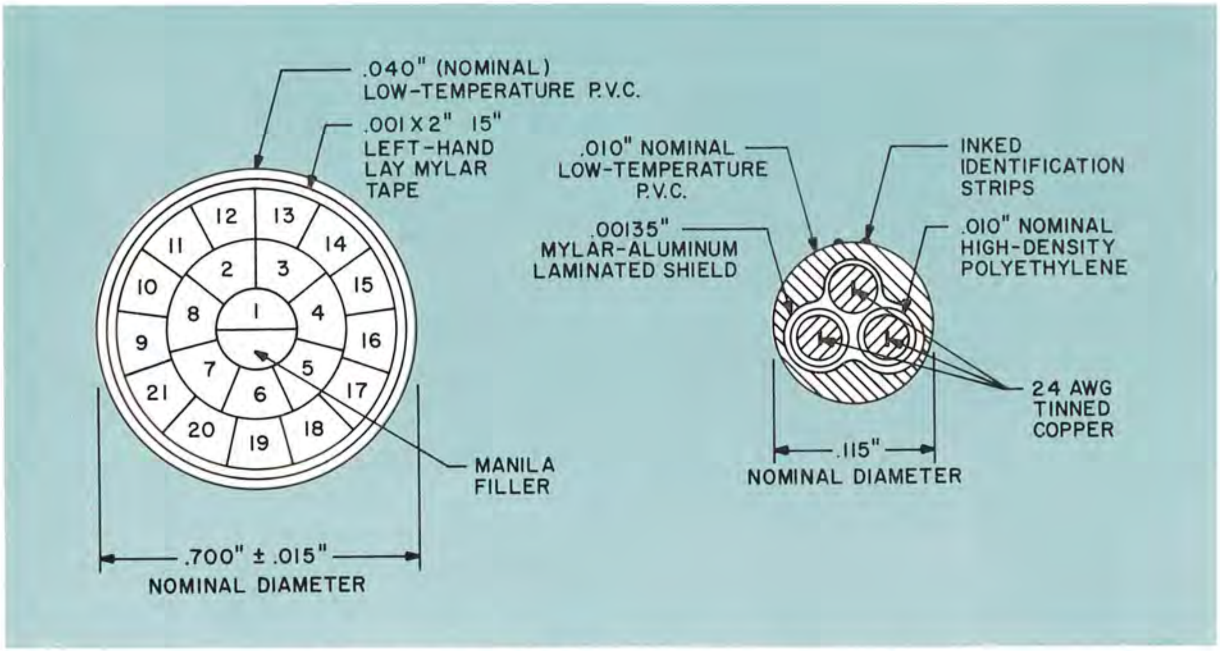


Figure 8. Construction of 21-pair transmission cable of Overseas AUTOVON.

Conference Calls

"Pre-set" conference calls may be made from designated stations, by dial operation. In addition, certain positions of the DSA console may be arranged to set up "random" conference calls of either the "progressive" or the "meet-me" type.

Physical Arrangements

Since Overseas AUTOVON is a military communication system, its equipment is required to withstand extreme operating conditions. It may be subjected to extreme stresses in equipment and storage, and is required to operate at temperatures of 45° to 105°F, with 20 to 90% relative humidity. The specifications also imposed specific qualitative and quantitative requirements as to reliability and maintainability. All of these requirements were considered in the "packaging" of Overseas AUTOVON.

There are basically five kinds of assemblies in the system:

1. Correed switching matrix (CSM) cards. These are assemblies of correeds, wave-soldered to a two-layer printed-wiring card, one layer carrying the "horizontal" conductors of the matrix, the other the "vertical." A die-cast aluminum frame is fastened to the soldered assembly to support it, to protect the correeds, to provide carrying handles, and to brace the solderless-wrap terminals staked to the cards (Figure 4).

2. Electronic-logic printed-wiring cards (Figure 5). These are single- and double-sided cards, 5½" x 6", with 23 contacts on each side.

3. Power-supply modules, used to convert and regulate exchange battery (-48VDC) into supply voltages for the logic cards. There are three packages: a DC-DC converter, a ±16V regulator, and a -8V regulator.

4. Electromechanical equipment. Relays, rotary stepping switches, miscellaneous correeds, resistors, capacitors, and lamps.

5. Hybrid assemblies. These are, as might be guessed, assemblies composed of both electronic and electromechanical components.

To mount these various assemblies, two types of housings were designed:

The "drawer cabinet" (Figure 6) houses the crosspoint switching matrix (CSM) cards in five vertical, slide-mounted "drawers", each carrying a maximum of eight CSM's.

The "gate cabinet" (Figure 7) mounts the

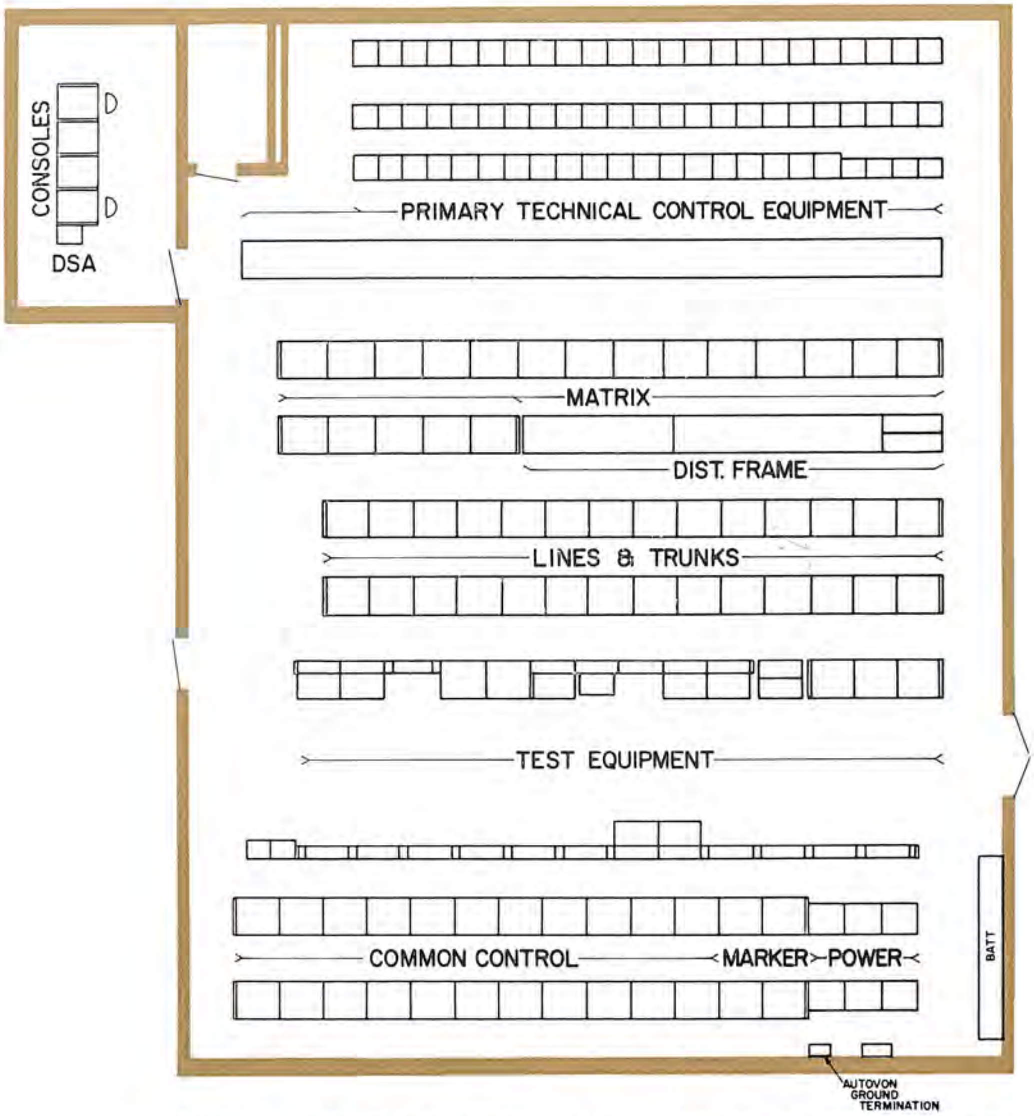


Figure 9. Floor Plan of Typical Overseas AUTOVON Switch. The test equipment separates the electromagnetic and electromechanical apparatus (correed matrices, line and trunk circuits) from the electronic Common Control and Markers.

electronic power modules, logic wiring cards, and electromechanical line and trunk circuit assemblies on hinged gates. The electromechanical assemblies are mounted on either "bases" (panels) or "piggybacks" (small gates hinged inside the main gate).

Cabling

To meet the exacting transmission requirements of Overseas AUTOVON, the length and type of cable used were a prime consideration. Cable lengths were minimized by providing the densest possible packaging consistent with the dimensional, floor loading, and environmental specifications.

The transmission cable (Figure 8) is made up of 21 shielded, twisted pairs, and carries the talking pairs to and from each four-wire "line" on the CSM cards. Each pair, with its related drain wire (24 AWG solid tinned-copper), is wrapped with .001 mylar tape, metalized with a laminate of .00035" aluminum. From 2 to 12 of these transmission cables connect each drawer to the cabinet terminal blocks.

Besides the transmission cables, each drawer is connected to the terminal-block field on the

Figure 10. This card punch and printer in the Maintenance Center provides visual reports of malfunctioning equipment in the AUTOVON Switch.

rear of the cabinet by control cables, which carry the "pull" and "hold" potentials and supervisory signals to and from the crosspoint correeds. Each cable has 20 pairs and 20 singles of 24 AWG solid tinned-copper wire in a layer-type construction. Insulation of individual conductors is .010" thick, while the outer jacketing is .040" thick polyvinyl chloride (PVC).

To minimize the possibility of breaking the conductors from repeated opening and closing of the drawer, two things were done:

1. The cables were clamped at the front of each drawer (rather than the back), thus distributing the necessary bending over a maximum length of the cable.

2. The axes of each cable at its front and rear clamps inclined 45° from the vertical, and 90° from each other. One-piece nylon bushings provide positive strain-relief for each end of every cable.

Site Considerations

As the structures provided for Overseas AUTOVON are now being used to house tropospheric-scatter radio and other communications gear, they are of semi-permanent or permanent type, with reinforced concrete floors designed for loading of 125 pounds per square foot. The floor plan of a typical switch is shown in Figure 9.

Interconnecting the cabinets is a network of cable runway, 2'6" wide through the equipment area to permit separation of transmission, signaling, and supervisory cables. Over the Common Control areas, sheet-metal compartments provide additional separation.

External connections between the various equipment groups are made through a six-foot-high, double-sided distributing frame of the standard type.

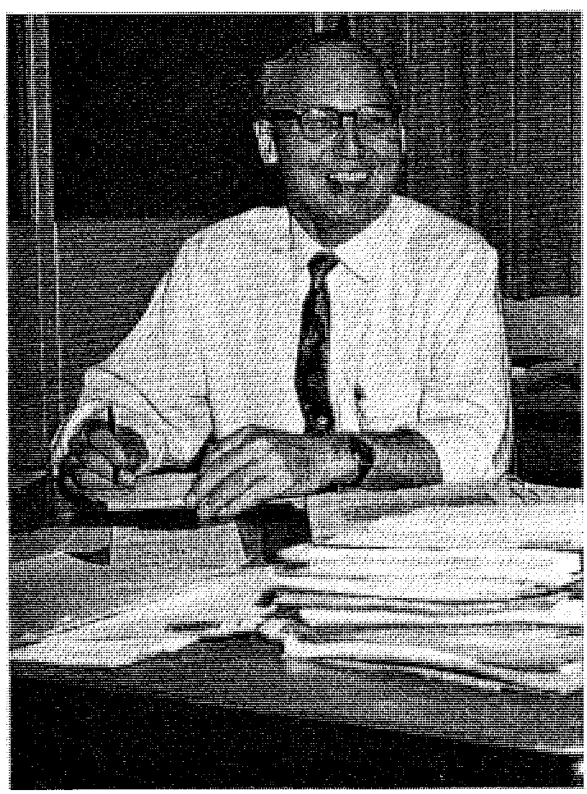
Maintainability

As previously mentioned, the specifications for Overseas AUTOVON include specific qualitative and quantitative requirements as to reliability and maintainability. The quantitative parameters are 800 hours mean time between failures, and 30 minutes mean "down time" for service-affecting failures.

Maintainability features provided included automatic self-analyzing features that report failures to a central Maintenance Center where they are printed-out, and built-in equipment for automatic and manual routining of critical functions at predetermined intervals.

Maintenance functions are concentrated in the Maintenance Center, which includes a monitor and printer (Figure 10) an automatic trunk-routiner, a toll test board, an office routiner for testing specific common-control functions and equipment, and a central display and alarm position. System operation is continually monitored to verify compliance with the requirements.

Overseas AUTOVON demonstrates that an end-to-end circuit-switched system provides capabilities, for military communication, beyond those of existing point-to-point networks. Like the Automatic Electric E-A-X, it proves that it is feasible to combine electromechanical and electromagnetic devices with sophisticated electronic devices, to produce a practical communication system. Commercial communication systems of the future will probably employ features and techniques that were developed for the Overseas AUTOVON.



WALTER AXELSEN entered our Drafting Department in 1923, and in 1927 transferred to the Advertising Department. In 1945 he became Advertising Manager with responsibility for preparation of sales and technical literature and advertising. After serving as assistant to the editor of the Automatic Electric Technical Journal, he was made editor in 1955. In 1960 he moved to the Public Relations Department, where, as Technical Information Manager, he continued as editor of the Technical Journal until the beginning of this year. He has for some years served as editor of technical papers presented before professional societies by staff members of Automatic Electric Company and the Laboratories.