TSPS No. 1:

Peripheral Circuits

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The TSPS No. 1 peripheral circuits permit the data processing ability of the Stored Program Control No. 1A to be applied to TSPS functions. These circuits include scanners, signal distributors, networks, trunk and service circuits, operator positions and the position subsystem. A description of each circuit is given, followed by a description of the features provided by the associated maintenance program.

I. INTRODUCTION

Some of the TSPS peripheral circuits are new or have novel features worthy of description while others are very similar to their No. 1 ESS counterparts and need no further description. Thus scanners, signal distributors, the AMA frame, and TTY buffers which have been described previously[1] will not be treated in detail here. The communication bus, networks, trunk and service circuits, local and remote position subsystems, and novel features of various maintenance programs are the essential subjects of this article.

The communication bus joining all units to the Stored Program Control (SPC) is described in Section II.

A network consisting of trunk link network (TLN) and position link network (PLN) frames is used to establish connections between the trunk circuits and the operator positions. The network fabric is new and described later in Section III, although the implementation and control circuitry is similar to that used in the No. 1 ESS network.

In addition to operator positions and trunks, numerous service circuits such as MF receivers and outpulsers also appear on the network. These circuits and their associated maintenance programs are described in Section IV.

Displays for all TSPS equipment and test facilities for all trunks appearing on the network are provided in the Control Display and Test (CDT) frame as described in Section V.

The group of circuits which links the communication bus (data) and position link network (voice) with the operator's console is called the "position subsystem." This subsystem is arranged to work with operators in the same building as the SPC (local) or many miles distant (remote). These circuits, which do not have ESS counterparts, are arranged in a series chain which leads to a maintenance program strategy different than that for other peripheral units. The position subsystem and the associated maintenance programs are described in Sections VI and VII.

The maintenance programs for the TSPS peripheral units operate in the same interrupt structure and under the same executive and maintenance control program as do the SPC generic maintenance programs, which are described in the article, "Stored Program Control No. 1A" of this issue.[2] Thus much of the material of that article is prerequisite to an understanding of the organization, strategy and methods used by the TSPS maintenance programs.

II. TSPS COMMUNICATION BUSES

Communications with units in the TSPS No. 1 is accomplished through groups of paired wires called buses (Fig. 1).

Some of the translation necessary to decode orders from the SPC is implemented on a common basis for a number of peripheral units in the Communications Bus Translator (CBT). The CBT receives 20 bits of data, plus parity and various control signals from the SPC. The CBT translates the information to a code consisting of several groups of one out of N and broadcasts the translated data and the original binary data to the TSPS peripheral units. The use of a one out of N bus and a common translator eliminates the need for a translator in each peripheral unit and allows the peripheral unit to make a simple error check of the data received.

Answer information is transmitted from the peripheral circuits to the SPC via the scanner answer bus (SAB). Enable information transmitted from the SPC is decoded by the Central Pulse Distributor and results in a pulse over a private pair which selects the particular unit which should receive a particular order from the common address bus, and reply over the common answer bus.

The maximum cable length for the CBT address bus is 450 feet. The maximum number of series connected cable pick-off transformers is 50. The bus circuitry and apparatus are similar to that of ESS No. 1[3]; however, both a one out of N and a binary bus are provided, and fanout circuitry is not used as these buses may run in two directions.

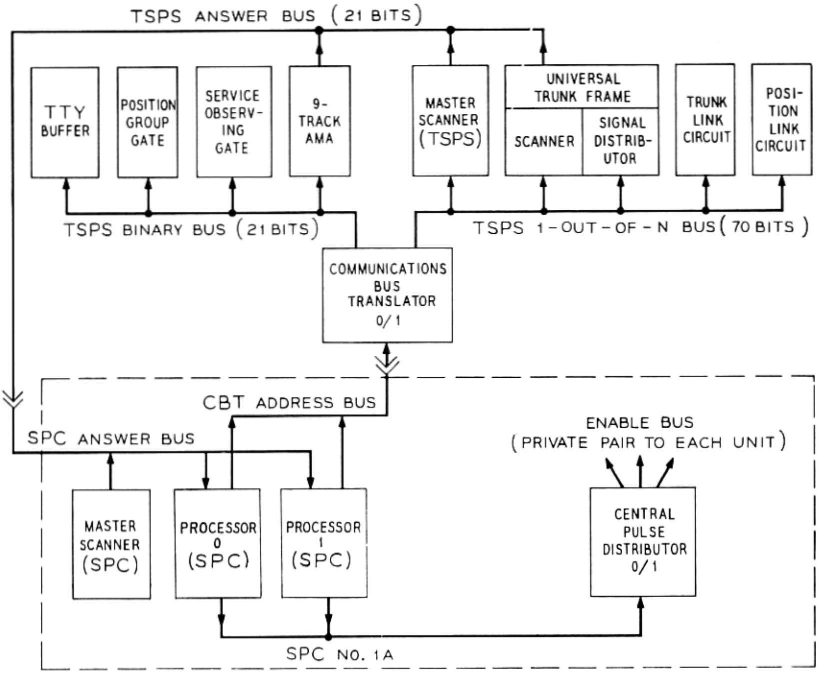

Fig. 1—TSPS No. 1 communications buses.

2.1 *Connecting Units*

The TSPS Master Scanners (MS), Universal Trunk Frame Scanners (UTSC), Universal Trunk Frame Signal Distributors (UTSD) and Networks receive 1 out of N information from the CBT. The AMAs, Position Group Gates, TTY Buffers and Service Observing Gate (SOG) receive binary information. The CBT 1/N translation lead assignments and functions for the connecting units are shown in Figs. 2 and 3.

2.1.2 *Use of SPC Maintenance Programs*

The SPC generic maintenance programs are extended by means of TSPS application programs to serve some of these TSPS peripheral units. For example, the network controllers function in a manner practically identical to signal distributors, from the viewpoint of the SPC. Therefore the SPC peripheral unit fault recognition program, PUFR, which serves the SPC signal distributor, also serves the TSPS signal distributors and the TSPS network controllers. The SPC scanner

BINARY DATA INPUT BIT POSITION 19 18 17 16 15	14 13 12 11 10	9 8 7 6 5	4 3 2 1 0	TRANSLATED DATA OUTPUT I/N DATA: LEAD	I/N	CONNECTING UNIT: TLN	PLN	MSC OR UTFSC	UTFSD
			0 0 0 0 0 1 0 1 0 0 1 1 1 0 0 1 0 1 1 1 0 1 1 1	00 01 02 03 04 05 06 07	1/8	LEVEL		LS	
			0 0 0 1 1 0 1 1	08 09 10 11	1/4	TSBO	LEVEL		
		0 0 0 1 1 0 1 1		12 13 14 15	1/4	SWITCH	SWITCH		
		0 1		16 17	1/2			MT	O/R
		0 0 0 1 1 0 1 1		18 19 20 21	1/4	GRID	GRID		RELAY POINT
	0 0 0 0 0 1 0 1 0 0 1 1 1 0 0 1 0 1 1 1 0 1 1 1			22 23 24 25 26 27 28 29	1/8	JUNCTOR	JUNCTOR		
	0 0 0 1 1 0 1 1			30 31 32 33	1/4	CHANNEL	CHANNEL		
0 1				34 35	1/2				
0 1				36 37	1/2	JSBO	JSBO		
0 0 0 1 1 0 1 1				38 39 40 41	1/4	ORDER	ORDER	BAY	
0 1				42 43	1/2	MATE	MATE		TEST
	0 0 0 0 0 0 1 0 0 1 0 0 0 1 1 0 1 0 0 0 1 0 1 0 1 1 0 0 1 1 1 0			48 49 50 51 52 53 54 55	1/8				CIRCUIT 0 Y
0 0 0 0 0 1 0 1 1 0 1 0 1 1 1 1	0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0			56 57 58 59 60 61 62 63	1/8				CIRCUIT 0 X
	0 0 0 1 0 0 1 1 0 1 0 1 0 1 1 1 1 0 0 1 1 0 1 1 1 1 0 1 1 1 1 1			56 57 58 59 60 61 62 63	1/8				CIRCUIT 1 X
0 0 0 0 0 1 0 1 1 0 1 0 1 1 1 1	0 1 1 1 0 1 1 1 0 1 1 1 0 1 1 1			48 49 50 51 52 53 54 55	1/8				CIRCUIT 1 Y
	0 1			70 71	1/2				CIRCUIT
		0 0 0 0 1 1 1 1	0 0 0 1 1 0 1 1 0 0 0 1 1 0 1 1	72 73 74 75 44 45 46 47	1/8			MS	

Fig. 2—CBT translation, lead assignments and functions for connecting units.

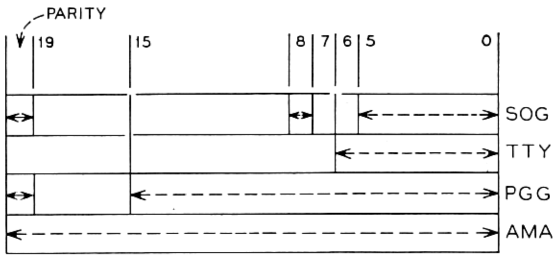

Fig. 3—CBT binary bus lead assignments.

fault recognition program, SCFR, also serves the TSPS scanners. The SPC scanner and signal distributor diagnostics are extended by means of short TSPS application programs to also serve the TSPS units. Thus a description for some of the maintenance program for the TSPS peripheral units is covered in the article "SPC No. 1A" of this issue.

2.2 *False Code Facility*

Invalid 1 out of N or bad parity may be broadcast to the TSPS peripheral units by maintenance programs. To achieve this, a false code register within the CBT is addressed by the program and loaded with a code indicating the modifications desired in the output data from the CBT. The first order distributed through the CBT subsequent to this will be modified accordingly. The false code register then automatically resets and the CBT reverts to normal operation. A We Really Mean It (WRMI) pulse is required to set the false code register to insure that a false code is not inadvertently set up by noise conditions.

2.3 *Interrupts Caused by the CBT*

When data is distributed through the CBT, a parity check is performed by the CBT circuit. A successful parity check in conjunction with proper receipt of timing signals from the SPC causes an All Seems Well (ASW) pulse to be returned to the SPC. Failure to receive an ASW from the CBT will result in an F-level interrupt, and a CBT diagnostic request by the F-level program.

2.4 *CBT Diagnostic Program*

The CBT diagnostic checks the ability of the CBT to receive data from the SPC by using two test ferrods, which report an all ones condition in the buffer register and false code register respectively.

Diagnostics of the connecting units have been structured in such a way that the tests which check the ability of these units to receive data from the CBT are run as subroutines by the CBT diagnostic. A connecting unit which is indicated as being good is selected by the CBT diagnostic and the subroutine for that unit is called to test the ability of the CBT to transmit data on the leads which connect to that unit. This process is repeated with successive unit types until all output leads have been tested. Referring to Figs. 2 and 3, it will be seen that the AMA serves to check all leads of the binary bus, and the PLN, UTSC, and UTSD serve to check all leads of the 1/N bus.

2.5 *CBT Faults Detected by Connecting Units*

The performance of the CBT translation and output circuitry is monitored through responses of the connecting units. If the fault recognition program for a connecting unit detects possible address data problems, a diagnostic is requested both on the particular unit involved and on the CBT. Both the peripheral unit and the CBT are marked in trouble.

As the CBT is assigned a lower unit type number than all connecting units, the CBT diagnostic is run first and updates the CBT trouble flag according to the result. The connecting unit diagnostic then runs avoiding the use of the CBT marked in trouble. Thus of the two diagnostic requests one will pass and one will fail, resolving the trouble either to the CBT or to the peripheral unit.

This process takes some time, however, and in the case of a CBT trouble, a number of peripheral units may be affected by the fault. This condition is guarded against by the fault recognition programs for the connecting units. The typical strategy is to retry the order over the original bus. If this retry also fails, the order is sent to the same unit over the other bus. If that order succeeds, bus trouble is assumed and the enables of all units are updated to change the bus choice. The assumption of bus trouble is not necessarily correct as the fault may not lie in the bus, but in the connecting circuitry of the peripheral unit. However, the bus switch (enable update) is requested to avoid propagation of possible bus troubles.

In the case of scanners, failing orders may be tried with a second scanner unit to positively isolate bus trouble. This strategy cannot be used with other unit types as it would result in an unwanted relay or network operation. A short CBT fault recognition routine is provided by the TSPS application program and is run immediately prior to the generic scanner fault recognition program to isolate bus troubles affecting scanners.

The TTY is not monitored by a fault recognition program but by the craftsman who observes improper printing and manually requests a diagnostic. The TTYs are routinely checked by an exercise which requests a daily diagnostic on each TTY.

The authors acknowledge the contributions of W. R. Serence, and P. J. Cuffaro to the AMA maintenance programming, P. J. Brendel to the AMA data transfer and bus fault recognition programs, and R. J. Greylock and R. Riley whose efforts permitted the extension of SPC programs to TSPS.

III. NETWORK

3.1 *Network Fabric*

The basic function of the network is to connect trunk circuits to position circuits, receivers, outpulsers and other service circuits. Ferreed switches are used as network elements in a fabric designed to meet the particular needs of TSPS, namely: ability to handle large or small installations, serve trunks carrying light or heavy traffic, and permit addition of equipment to grow with a minimum of installer effort.

The network uses 4 stages of switching to provide a 3 link connection from input (trunks) to output (positions and service circuits). Eight by eight ferreed switches are used in the first three stages; 8×4 switches are used in the final stage to provide a 2:1 concentration. The switches are arranged in grids, the first two stages being mounted on the trunk link frame, the last two on the position link frame. The ferreed switches and wiring for one grid are shown in Fig. 5 which,

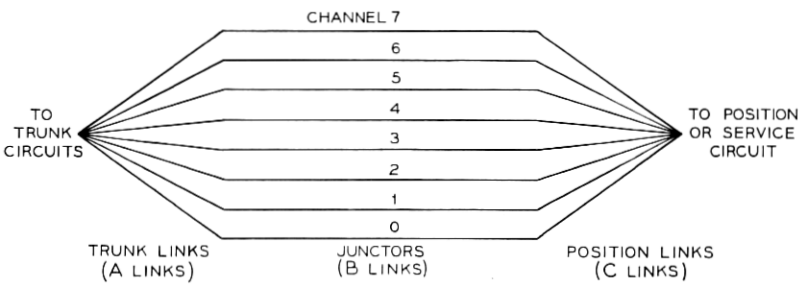

Fig. 4—Eight-channel pattern.

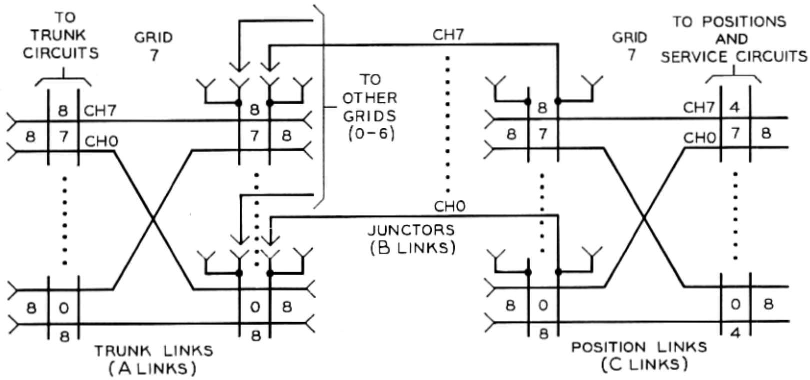

Fig. 5—One grid (7) illustrating the eight-channel pattern.

along with Fig. 4, illustrates the eight possible channels which could be used to connect a given input to a given output. A connection is made up of an A link which interconnects the switches of a grid on the trunk link frame, a B link or junctor which connects a trunk link grid to a position link grid, and a C link which interconnects the switches of a grid on the position link frame. Eight grids are mounted on a frame and are wired as shown in Fig. 6. Thus, one network provides 512 input appearances with full access to 256 outputs.

Positions are engineered for a maximum occupancy of 91.5 percent as determined by requirements on operator work load, and service circuits for 70 percent as determined by the group size. Positions have two appearances on the network; service circuits have a single appearance. If an 8 × 4 switch has two positions and two service circuits on the outputs, the above occupancies result in a link occupancy of 29 percent;

$$\frac{91.5 + 2(70)}{8} = 29\%$$

or a traffic intensity of 148 erlangs (0.29 × 512) at the input of a network. At this link occupancy in order to meet the network blocking objective of 0.001 it is necessary to provide at least two retrials on connections to positions (both appearances are examined on each trial) and at least 3 retrials on connections to service circuits. The call processing program provides the necessary retrials and queuing. Retrials are accomplished by choosing another idle service circuit or position. If the call is blocked after the above retrials, it is queued

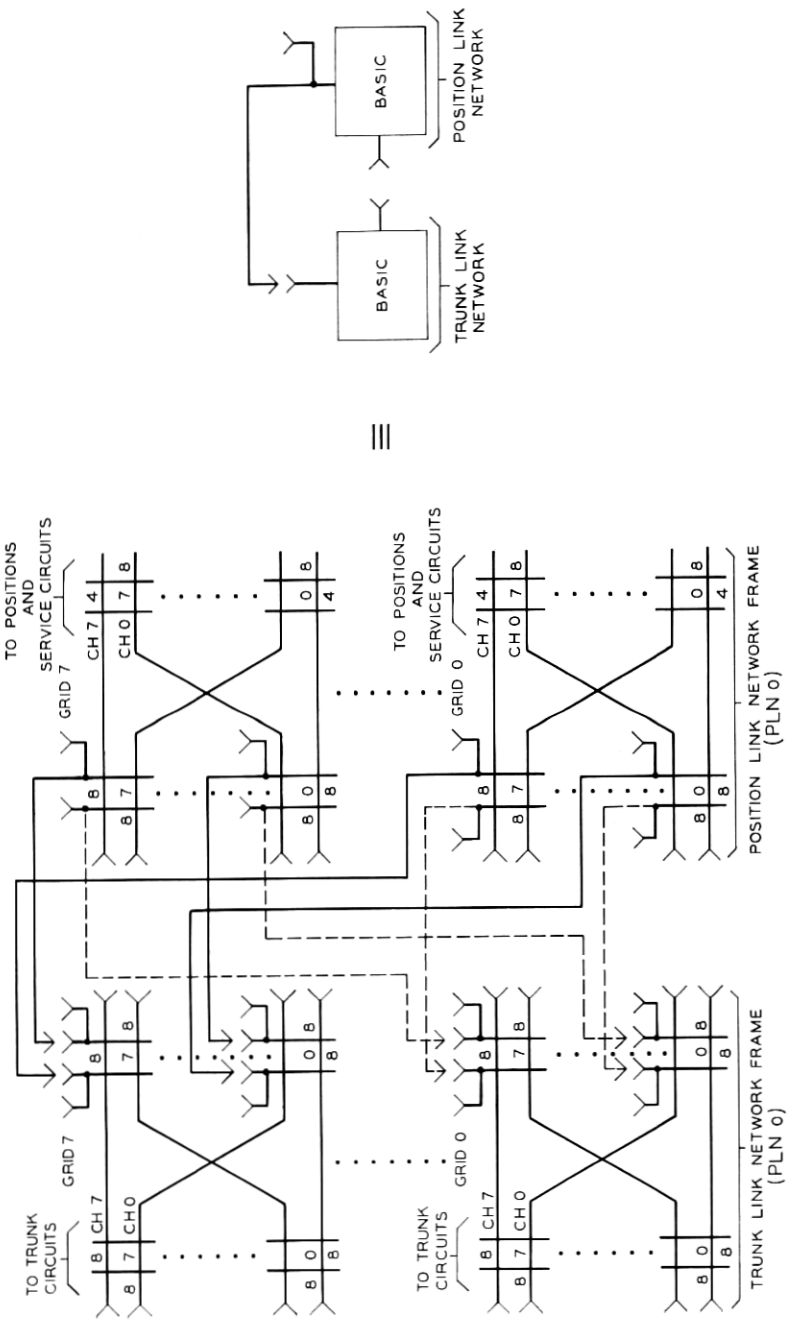

Fig. 6—One network, comprised of eight grids, illustrating junctor wiring pattern and symbolic representation.

and a new attempt is made every half second. On each attempt retrials are made as described above.

If a traffic intensity of 148 erlangs is not reached with 512 inputs to a network, trunk switch buildouts may be connected into the trunk side of the network to increase the linkage load by increasing the number of trunks which have access to 8 A links, as shown in Fig. 7. Thus, additional trunk groups carrying lighter densities of traffic may be accommodated. Concentration at the input to the network may be varied from 1:1 to 4:1 in unit steps by appropriate usage of trunk switch buildouts.

Connectors are provided to minimize installer effort and provide for future growth as shown in Fig. 6. The B links or junctors are hard wired to the position link at the factory, and are distributed across

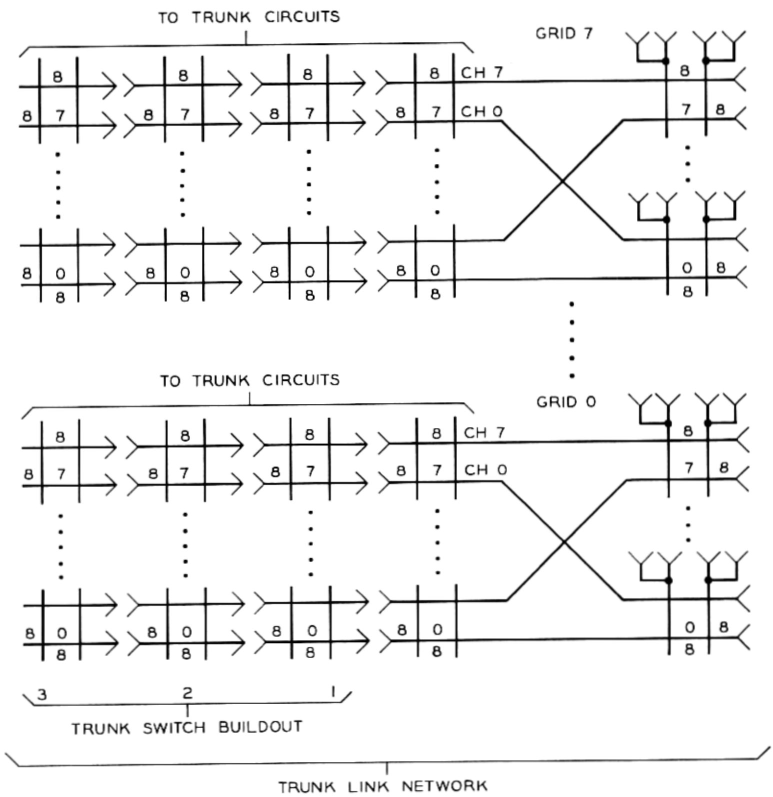

Fig. 7—Addition of trunk switch build-outs to trunk link network.

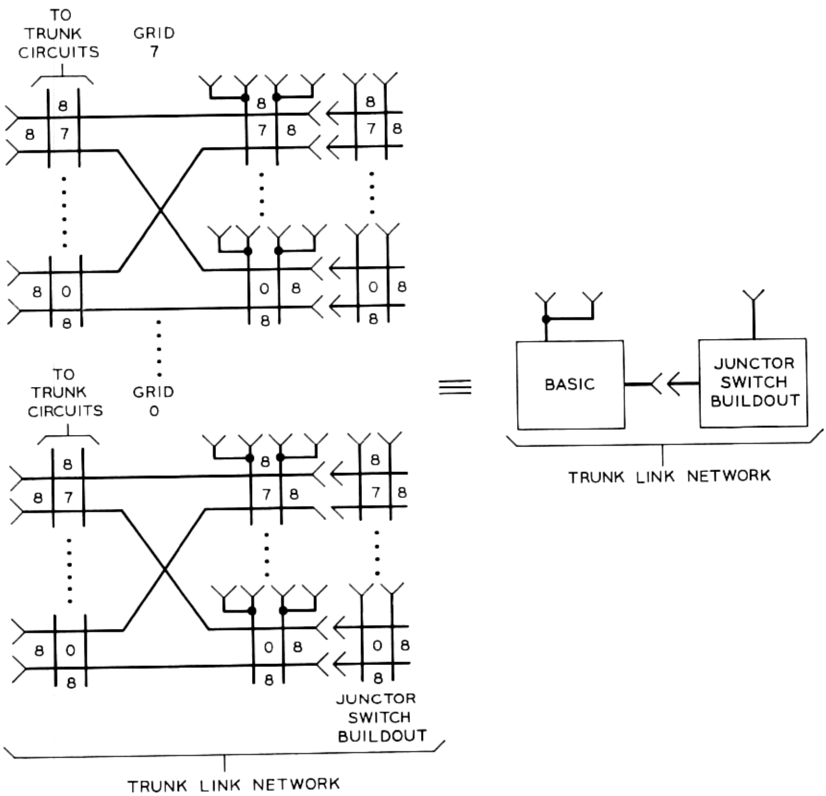

Fig. 8—Addition of junctor switch build-out to trunk link network and symbolic representation.

all grids in the position link to provide full access. At the job site the connector ended cables are simply plugged into the appropriate trunk link grids. Connectors are provided for plugging additional junctor cables as the network grows.

A junctor switch buildout is connected into the basic trunk link frame to provide access to additional position link networks as indicated in Fig. 8. The two network configuration is shown in Fig. 9, and is the smallest size recommended. It uses the junctor switch buildout on the trunk link frame, as previously described, and multiplying of junctors via connectors at the trunk link to provide full access.

A three network configuration requires a junctor switch buildout on the position link frame as does the four network configuration illustrated in Fig. 10. As the network configuration grows, existing

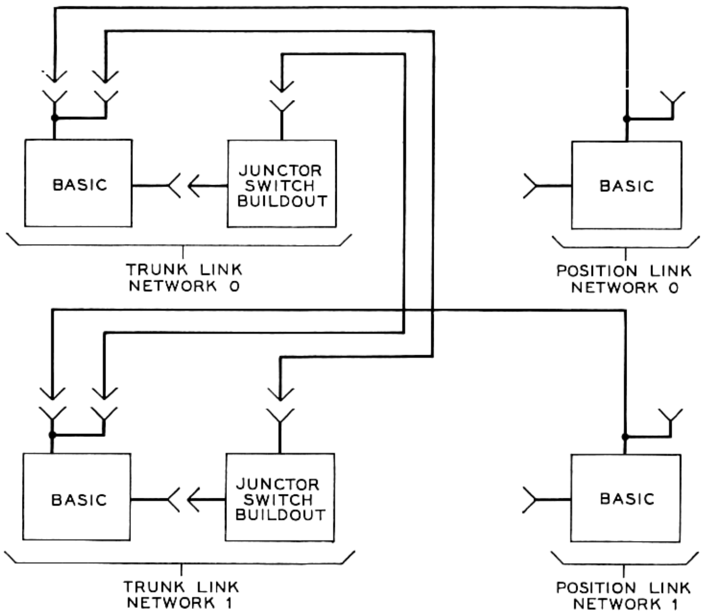

Fig. 9—Two-network configuration.

junctors need not be rearranged. The added buildouts and junctor cables are connectorized for ease of installation.

3.1.1 *Path Hunt Program*

This network organization facilitates a simple path hunt program. As networks are added to the system, an area of memory known as a link map is also added. As shown in Fig. 11, this table is organized in such a manner that when it is desired to connect a trunk to a position, portions of the trunk terminal number (TTN) and position terminal number (PTN) are used by the path hunt program as indices into the link map table to obtain the addresses of three words containing busy-idle bits. These busy-idle bits correspond to the eight sets of A, B, and C links which may be used to connect a given trunk to a given position. The first word contains eight bits corresponding to the eight A links, channel 0 to channel 7. The bits are set to 1 to indicate an idle condition on the corresponding link, and to 0 to indicate a busy condition. Thus, to determine an available path it is merely necessary to form the logical product of these three words. Idle channels will be indicated by 1's in the result. In the example

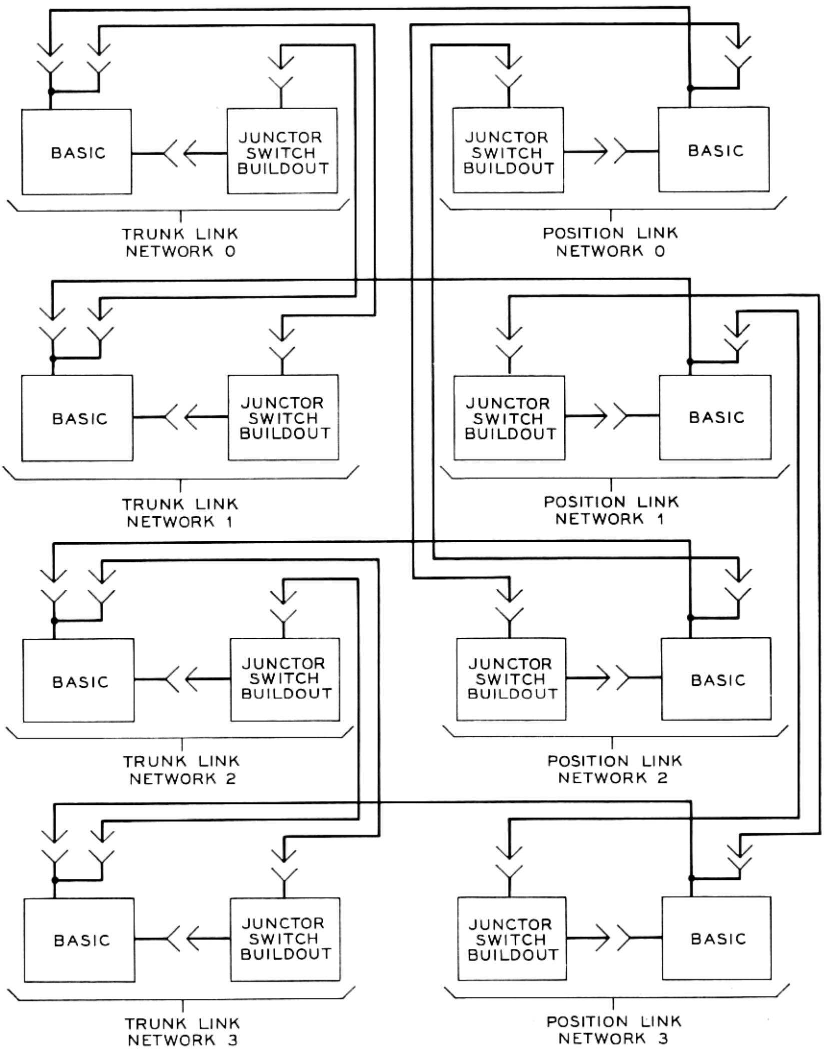

Fig. 10—Four-network configuration illustrating junctor switch build-outs (JSBO) on both trunk and position link networks.

below this procedure indicates that channels 1 and 5 are idle.

Channel:	7	6	5	4	3	2	1	0
A links	1	0	1	1	0	0	1	0
B links	0	1	1	1	0	1	1	1
C links	1	0	1	0	0	1	1	0
Product	0	0	1	0	0	0	1	0

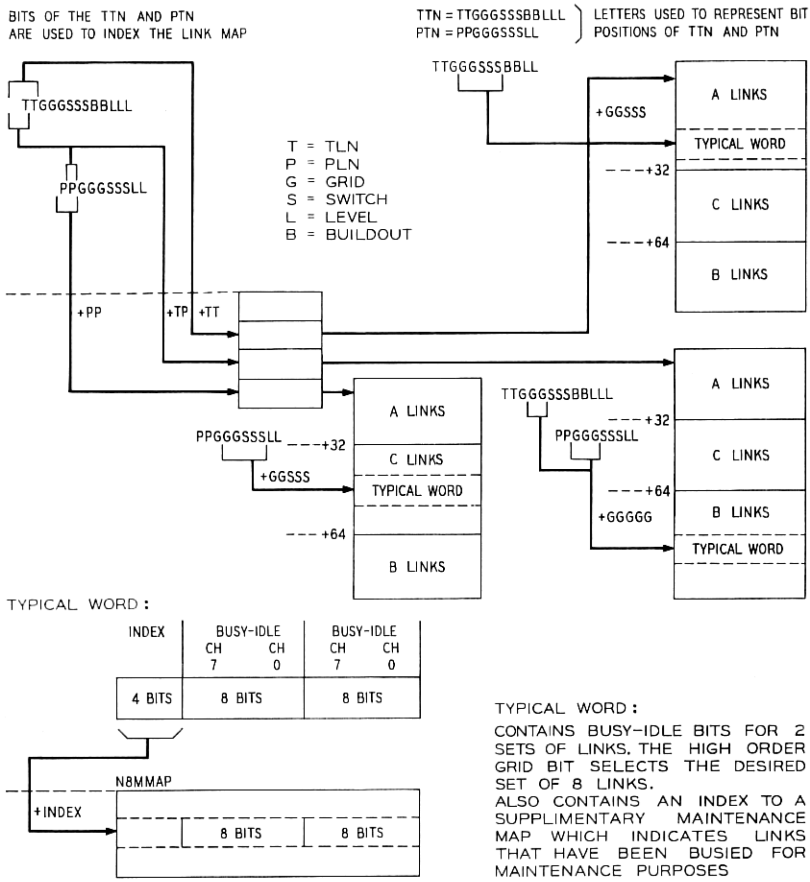

Fig. 11—Link map.

The channel which is finally used is selected from the available idle channels. The low order bits of the system clock are used to change the first choice channel for each selection to spread usage over the equipment.

3.1.2 *Fabric Maintenance*

The integrity of the fabric is monitored by continuity checks made via ferrods in most service circuits and by operator trouble reports. Continuity check failures or operator trouble reports keyed at the positions result in TTY printouts of the links used on the failing connections. The TTY information may be analyzed to isolate possible network troubles, or troubles external to the TSPS office, either in the trunks or in connecting offices. In the case of continuity check failures involving service circuits, the service circuit is automatically diagnosed to check one possible cause of the failure.

Portions of the network fabric may be made busy for maintenance purposes by a teletype request which initiates a program that sets zeroes in the busy-idle bits for the desired links. As two 8-bit link groups are packed within one 20-bit word of the link map table, the remaining 4 bits may be used to set an index to a supplementary table which indicates to the audit programs exactly which of the links are maintenance busy as shown in Fig. 11.

After calls have been blocked from the links by making them maintenance busy, test connections may be established on these links by means of a TTY request. Suspected hardware faults may then be verified and cleared. A TTY request is available to repeatedly connect and disconnect a test path at 200-millisecond intervals for dynamic testing. If an active switch must be replaced, it may be made busy for the replacement interval by a similar method. It is also possible to busy out a single faulty link for a longer period of time to prevent call failures if the repair cannot be made immediately.

3.2 *Network Controllers*

The ferreed switches are operated by controllers which are similar to those used in No. 1 ESS* described in the September, 1964, B.S.T.J.; therefore, only a general description and new features unique to the TSPS controller will be given here.

The TSPS controller differs from the ESS controller in the maintenance features provided, and in that a separate disconnect order rather than the destructive mark of a subsequent connect order is used to release the ferreed switches.

3.2.1 *General Description*

The controllers, shown in Fig. 12, receive orders in 1/N form from the CBT and operate appropriate path selection relays to set up a pulsing path in the ferreed switches. When the pulse path is complete, as indicated by continuity over that path, a high current pulser fires to effect a connect or disconnect of the ferreed switches, and causes

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* B.S.T.J., September 1964, *43*, p. 2221, No. 1 ESS Switching Network Frames and Circuits, D. Danielson, K. S. Dunlap and H. R. Hofmann.

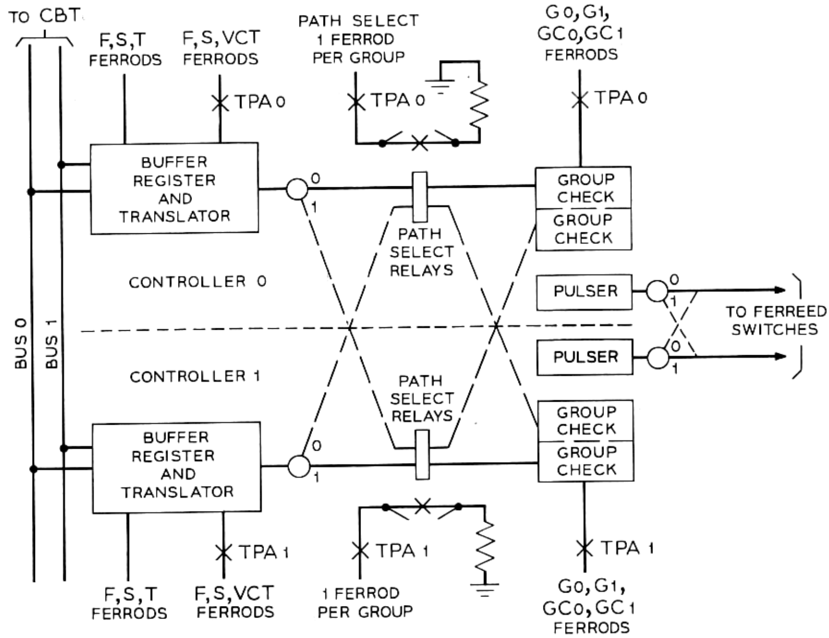

Fig. 12—Network controllers.

a successful completion of these operations to be indicated to the SPC via ferrods designated F, S, and T. Two controllers are used per frame. Controller 0 normally controls wire spring relays which set up pulse paths in grids 0–3; controller 1 normally serves similar relays in grids 4–7. These wire spring relays are a double wound type with one coil connected to each controller. Thus, it is possible for either controller to operate in any of the eight grids should its mate fail.

The path select relays are arranged in various groups. To effect a network connection, one and only one relay in each group is operated. A group check circuit senses the initial current drain within each of these groups to determine if the 1/N condition is met and, if it is not, causes battery to be removed from the path selection relays preventing their operation. It is necessary to prevent the relays from operating under this condition to avoid firing the pulser over an improper path, as the pulser is triggered when continuity is presented to its output leads.

Additional controller points may be cut through via the TPA relay

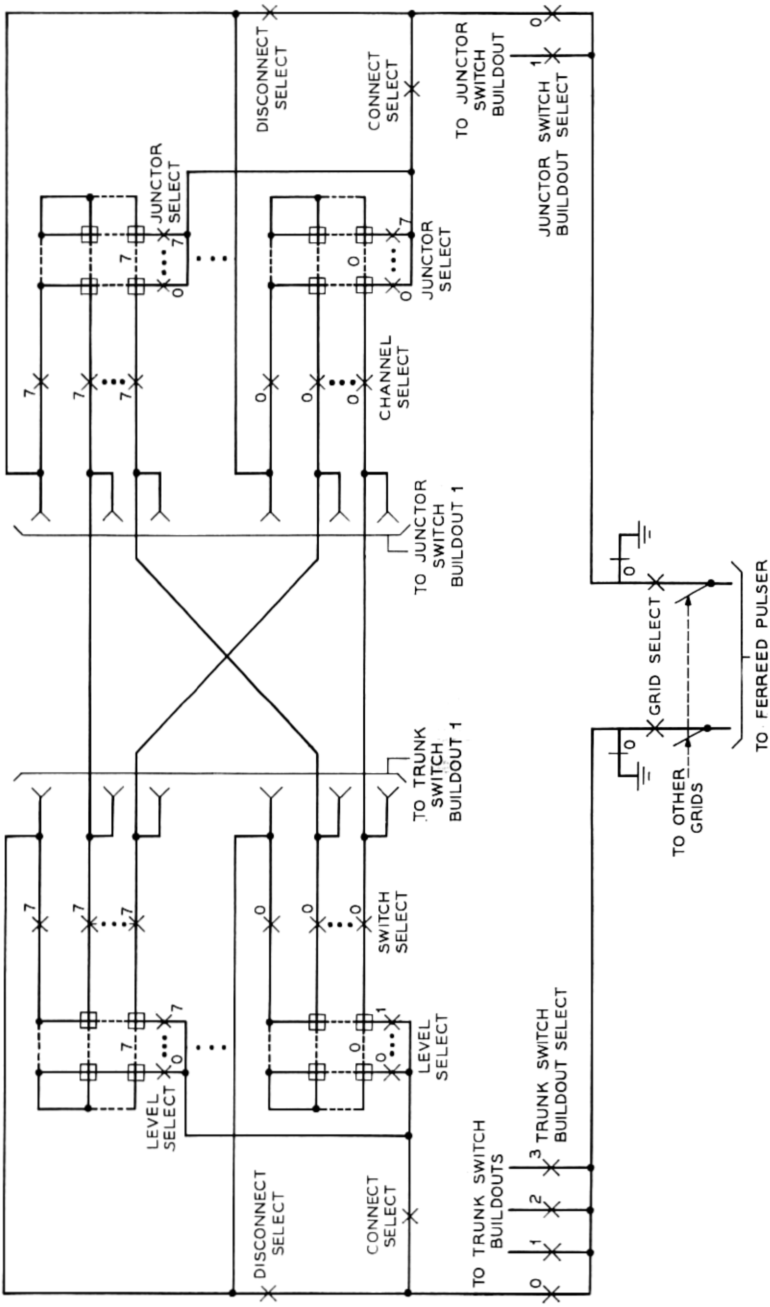

Fig. 13—Pulse path for one grid of trunk link network.

to a diagnostic bus consisting of a group of ferrods shared by all controllers of the same type within the office.

The pulse path selection for one grid is shown in Fig. 13. Path selection relays are operated to select the grid, trunk switch buildout, connect/disconnect, level, switch, channel, junctor and junctor switch buildout. Connectors are provided to plug in buildouts. The additional pulse path selection circuitry for one grid of a trunk switch buildout which would be plugged is as shown in Fig. 14.

As it is necessary to insure disconnection in one buildout before establishing a connection in a second to avoid bridging the talking paths, separate orders for connect and disconnect are required. Thus, the advantages of buildout frames introduces the penalty of a separate disconnect order.

3.2.2 *New Maintenance Features*

The integrity of the pulse path is monitored by the ferreed pulser which detects opens or short-to-ground conditions. An innovation

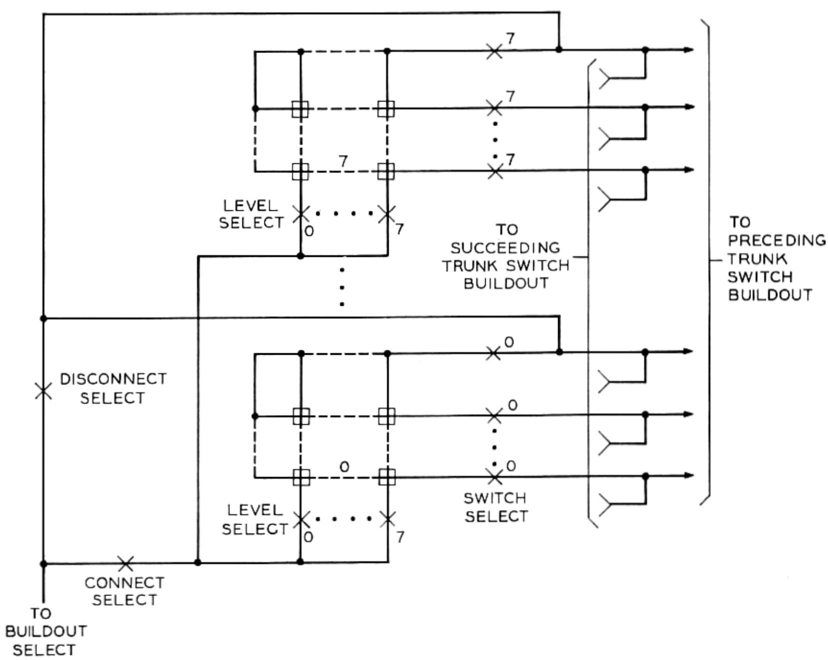

Fig. 14—Trunk switch build-out for one grid.

found in the TSPS controller is the use of transfer contacts on the grid select relays to hold ground on pulse paths in grids other than that grid in which a connection is being established. With this feature, shorts between pulsing paths can be picked up by the short-to-ground detector.

Also new is the indication of short-to-ground conditions via a ferrod to notify the fault recognition program of the short condition while the network order is still available. Network orders resulting in short-to-ground or open pulse path indications are printed on the TTY and may be analyzed to determine the probable location of the fault.

The TSPS network controllers also provide additional outputs from the group check circuits to increase diagnostic resolution.

One path selection ferrod is provided per group and is wired to a make contact from each relay within the group to provide an indication that at least one relay has operated. The steering circuit at the output of the high current pulser allows the use of test orders which operate path selection relays but do not fire the high current pulser. The path selection relays lock up and may be checked via the path selection ferrods for a positive indication of armature movement.

A TTY request may be used to input a test order to be repeated to the frame at 200-ms intervals. This feature may be used to check relay operation and controller functions without pulsing into the fabric which might cause cutoffs or possibly harm the ferreed switches if certain faults are present.

As previously mentioned, under normal operation battery is removed from the path selection relays before they have operated in case of a group check failure. The TSPS controller overrides this check on diagnostic test orders, allowing the path selection relays to operate and lock up, providing specific information on relays which fail to operate.

The authors acknowledge the contributions of the late E. L. Erwin who conceived the network fabric arrangement, L. J. Murphy, who implemented the circuit, and S. Lederman who designed the software control.

IV. CIRCUITS WHICH APPEAR ON THE NETWORK

4.1 *Trunk Group Number*

Every position, service circuit, and trunk appearing on the TSPS network is a member of a group of similar circuits. Each group is assigned a trunk group number (TGN), and each member of the group is assigned a member number (MEMN) sequentially. Table I lists the trunk group numbers and their functional assignment. The TGN and MEMN of a position is identical with the chief operator group number and member number. Hence, TGNs 0–8 are for the 9 groups of positions. TGNs 9–30 are assigned to the various service circuits by their function, with 24–30 unassigned. Thus, each network appearance on the position link corresponds to a member of a group with a TGN between zero and thirty.

TGNs 31–511 are assigned to groups of trunks with network appearances on the trunk link. TGNs 31–39 are unassigned; 40–55 identify groups of service trunks, CAMA trunks, delay call trunks, and test trunks. A TGN of 57 or more identifies a universal trunk group which carries TSPS traffic from the local office to the toll office. Universal trunks are grouped by their origination and function in

TABLE I—TGN ASSIGNMENTS

TGN	Group Function	CRI	Register Type	Link Appear.
0–8	Chief operator groups	0	Sr	PLN
9	Service observing	6	Jr	
10	Coin control and ringback	5	Sr	
11	Audible tone	4	Jr	
12	MF receiver	1	Jr	
13	DP receiver	2	Jr	
14	MF outpulser	3	Jr	
15	Idle line termination	13	Jr	
16–21	Reorder tone and announcement	7–12	Jr	
22	Master test line (TMTL)	23	Sr	
23	Access line zero	24	Sr	
24–30	Unassigned			
31–39	Unassigned			
40	Service trunk (information)	14	Jr	TLN
41	Service trunk (rate & route)	15	Jr	
42–43	Service trunk (unassigned)	16–17	Jr	
44	MFR test	25	Sr	
45	DPR test	26	Sr	
46	OP test	27	Sr	
47	Master test line (PMTL)	28	Sr	
48	Access line one	29	Sr	
49–53	CAMA trunks	30	Sr	
54–55	Delayed call trunks	18	Sr	
56	System monitor circuit	31	Sr	
57–511	Universal trunks	31	Sr	

Note: The Circuit Register Identifier (CRI) is used by many programs in a manner similar to the use of the TGN. The administrative registers of each circuit are of two kinds: senior and junior.

the usual manner (e.g., Dover, N.J., to Morristown, N.J., coin) and each of these groups is then assigned a TGN.

4.2 *Trunks and Service Circuits*

The local-toll TSPS trunks can be placed in six categories since two types of pulsing (dial pulse [DP] and multifrequency [MF]), two types of signaling (loop and E&M) and two types of transmission (2-wire and 4-wire) are provided. The six types, rather than eight, obtain because all 4-wire trunks use only E&M signaling to the local office. At present all TSPS trunks use loop signaling toward the toll office and must be located near enough to the toll office to insure not exceeding a 2-dB loss. It is expected that use of carrier facilities between TSPS and the toll facility will be provided in the near future. A typical trunk is shown schematically in Fig. 15.

4.2.1 *Dial Pulse Trunks*

Handling Dial Pulse Signaling posed the classic problem of how to cope with fast dialing which occurs before a DP receiver is attached. A stored program system aggravates this problem since not only must time be taken to obtain a link connection to an idle receiver, but also the scanning interval time must be considered.

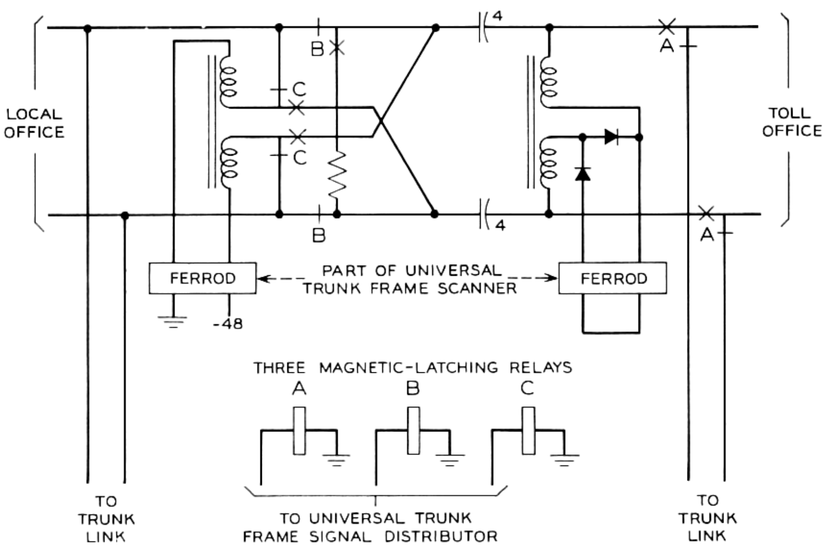

Fig. 15—Simplified schematic—TSPS MF trunk.

The unique solution employed in TSPS provides a two-pulse detector in each DP trunk circuit. That is, the first two pulses of any dialed digit can be recognized and stored by the trunk whether or not a DP receiver is attached. Thus, if a customer dialing from a step-by-step local office manages to start the next digit (after the initial 0 or 1) before a link connection is established to an idle receiver, the call is not necessarily lost. When the receiver is attached, it notes the state of the two-pulse detector (0, 1, or 2 pulses) by a voltage state sent over the ring lead and follows subsequent pulsing over the tip lead. If 0 or 1 pulse is found, then the receiver connection is considered to have been made in time and the call is handled normally. If a count of two is noted, then a ferrod output of the receiver is energized to alert the SPC that receiver connection occurred too late. The call is then aborted and connected to reorder tone. Laboratory testing, simulation, and some limited field experience indicate that the probability of 2 (or more) pulses before a receiver connection is very low, and there should be no need to expand the feature to a three or four pulse counter.

The two-pulse detector is realized by use of three dry reed relays which are part of a six-relay pack intended for two TSPS trunks. The remainder of the trunks consists of a transmission path, three magnetic latching relays, two ferrod scan points and a pulsing relay. The magnetic latching relays define the different talking and signaling states of the trunk under SPC control, while the pulsing relay follows dial pulsing from the local office and repeats the pulses for use by the DP receiver. The two scan points are in a supervisory scan field and provide supervision toward the local office and toward the toll office.

4.2.2 *MF Trunks*

The MF trunks resemble the DP trunks in appearance and are simpler, since a pulsing relay and two-pulse counter are not required. The three magnetic latching relays provide eight possible states, six of which (including the idle state) are used at present.

The delayed call trunk is essentially an MF trunk which has both its ends connected to the toll office. This allows an operator to originate calls from her console and reach both the calling and called parties.

Operation of the magnetic latching relays and scanning of the supervisory ferrods is handled the same as in No. 1 ESS which has previously been described.

4.2.3 *Service Circuits*

The circuits terminated on the position link frame which can be connected to trunks as needed are called service circuits. These include digit receivers, digit outpulsers, coin control circuits and announcement trunks. Maintenance of these circuits is aided by use of service circuit test circuits connected to the trunk link frame and discussed in Section 4.4.

4.2.3.1 *Dial Pulse Receivers.* The dial pulse receiver receives dial pulses over the tip lead and counts complete digits using conventional relay circuitry. Upon seizure the receiver notes the state of the two-pulse counter in the trunk via a voltage on the ring lead. Its counting circuitry is advanced by one if a "1" is noted on the ring lead. A "reorder" ferrod is energized if a "2" is noted on the ring lead since this could mean two or more pulses were received by the trunk before the receiver was connected. Output from the DP receiver is in BCD code on four ferrods and a "signal present" ferrod is energized each time an interdigital interval is recognized. Thus, scanning of all but the "signal present" ferrod can be a directed scan and the SPC need only deal with whole digits, not the individual pulses of a digit.

4.2.3.2 *MF Receiver.* The major portion of the MF receiver is similar to conventional MF receivers and delivers only whole digits to the SPC. However, in addition to the 10 decimal digits, several "start" signals can be received. Both start pulses and digits are received as frequency pairs in 2 out of 6 combinations. This 2-out-of-6 (2/6) reception is passed to the SPC ferrod scan points. The variety of "start" pulses (pairs of tones) are used as a means for the local office to describe the type of call (coin, noncoin, dial "0" or 0+) to TSPS, thus permitting several types of calls to be handled by a single group of trunks. The SPC translates the 2/6 code to BCD (in the case of a digit) for temporary storage in the software trunk register.

While the MF receiver is primarily used to receive digits from a local office, it can also be connected to the toll office side of the TSPS trunk. This is done when a call which could not be handled by TSPS (mobile radio, marine, etc.) has been passed forward through a toll office connection to a cord switchboard operator. In this case when the cord switchboard operator must signal back to the calling customer (possibly to collect or return a coin) inband tones are generated at the operator location and sent to TSPS. An alerting pulse (reversal) permits

TSPS time to attach an MF receiver which then receives the inband tones. TSPS then sends appropriate signals to the local office.

In the reverse direction there is the further problem of passing a disconnect or flash by the calling customer forward to the cord board location without actually disconnecting. The MF receiver has the ability, when connected to the toll office side of the TSPS trunk, to generate a +130 volt simplex "ring-forward" signal which is recognized by the toll office trunk and passed to the cord board operator. One or two spurts of this ring-forward signal can be used to indicate flash or disconnect while still maintaining the connection in case the switchboard operator must take some additional action.

4.2.3.3 *MF Outpulser*. The MF outpulser transmits standard 2/6 frequency combinations to the toll office under SPC control. Since several signals must be sent to it by the SPC in fairly rapid sequence, it is controlled by CPD outputs rather than signal distributor points. A pair of CPD enables will cause the outpulser, once connected to the toll office side of the TSPS trunk, to outpulse the correct digit, time the length of the pulse, and time the appropriate interdigital interval. The present timing is that specified for Bell System use and can easily be changed to a lower value if projected higher outpulsing speeds are standardized.

4.2.3.4 *Coin Control and Ringback Circuit*. The coin control circuit can generate three signals, used for coin collect, coin return, or ringback to the calling customer. When E&M signaling between the local office and TSPS is used or when the local office is an ESS office, these three signals are sent as inband tones. In this case the timing of the "quiet period" before tones are sent as well as timing of the tone interval itself are done by the coin control and ringback (CC&R) circuit. Signal distributor point input (from SPC) is used to select the particular signal to be sent.

When the local office trunk uses loop signaling (except for ESS local offices) the three signals are sent by use of "high-low" dc signaling. This requires +130 and −48 volt potentials on the T&R leads which are recognized by marginal and polar relays in the local office. The CC&R circuit applies the correct potentials to the line, again under signal distributor point control, and provides the required timing.

4.2.3.5 *Audible Tone Trunk*. Audible tone is returned to the customer whenever the connection to an operator is expected to take longer than four seconds. The customer would then hear standard 2 second on—4 second off tone, simulating an operator being rung. This informs him that his call is recognized and that an operator connection is being accepted.

4.2.3.6 *Recorded Announcement and Tone Circuit (RATC)*. A recorded announcement is used to inform the customer of unusual delays or catastrophic conditions (fire, flood, etc.), which have caused traffic to back up. Standard procedure is to allow two repetitions of the announcement and then switch to reorder tone. The RATC circuit is arranged to connect to a continuous recorded announcement so as to start at the beginning of the announcement, count two cycles of the message, and automatically switch to a source of reorder tone. The initial connection is, of course, under SPC control and provision is made to have the announcement bypassed and immediate application of reorder tone if appropriate SD point signals are received from the SPC.

Announcements may be provided for a variety of reasons such as local call intercept (LCI) or delay messages. These different announcements require separate groups of announcement trunks. However, in event of a catastrophic condition, special announcements can be recorded on two spare tracks of the announcement machine and these messages would be routed to the two groups of RATC circuits connected to those tracks. As these two groups become overloaded all other RATC circuits can be switched (at the announcement frame circuit) to these two disaster channels. Thus, all RATC circuits in the office can be used for disaster purposes, if needed, without requiring a large, separate, and mostly unused, group of RAT circuits for that eventuality.

4.3 *Maintenance of Trunks*

Automatic maintenance facilities are not provided in TSPS for universal trunks, as responsibility for maintenance of these trunks rests on the local office. The local office performs routine testing to the toll office in the usual manner, with TSPS merely forwarding the test codes which have been pulsed from the local office. If trouble is detected by testing from the local office, a craftsman at the TSPS control display and test frame may be contacted to aid in isolation of the trouble by testing back toward the local and forward to the toll office.

Routine checks made in the TSPS office during the processing of calls may result in indications of trunk trouble. When connecting service circuits to trunks, continuity checks are made via ferrods in the service circuit. Continuity failures may indicate possible trunk trouble and result in a TTY printout identifying the trunk involved. For outpulsers, continuity and polarity are checked before outpulsing; and continuity is again checked after outpulsing to verify proper response from the toll office. If relays within the trunk fail to operate, a TTY report is also made. When a pattern of printouts indicates a particular trunk, the craftsman may remove the trunk from service and check for possible faults.

4.4 *Maintenance of Service Circuits*

Trunk group numbers 44, 45 and 46 are test circuits which may be connected to a service circuit in order to diagnose them; (see Fig. 16). The circuits are set in their various states and their reactions are checked via ferrods.

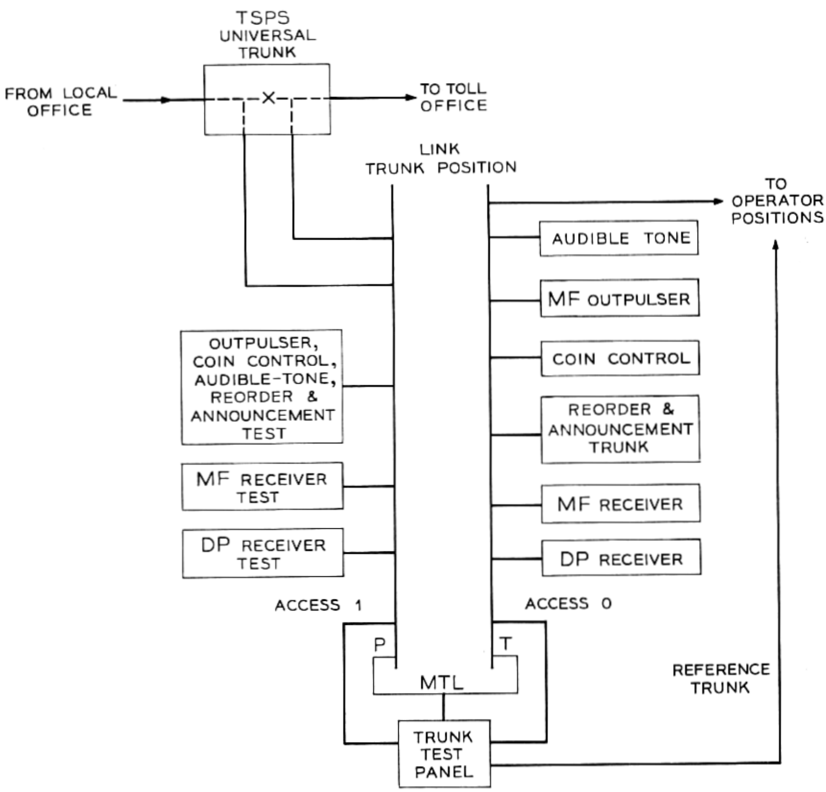

Fig. 16—Test circuits for trunk and service circuits.

Service circuit diagnostics may be initiated by manual requests from the TTY or the control display and test (CDT) frame, by the automatic progression test program, or by requests from other programs which encounter difficulties in using a particular service circuit during call processing.

Service circuits to be diagnosed are processed one at a time by a control program which prepares the circuit for diagnosis and transfers it to the appropriate diagnostic program. The diagnostic programs are broken down into a number of different phases so that a particular test may be requested from the TTY or CDT frame. The tests for each service circuit are summarized in Table II.

Diagnostic results are processed by the dictionary output control program (DOCP) using a pseudo unit type number to produce a trouble locating number in the usual manner. Thus standard dictionary lookup techniques have been extended to the service circuits.

Automatic progression testing of service circuits is initiated twice a day. All circuits are diagnosed with a TTY report only on those circuits which fail diagnosis. The circuit is diagnosed a second time before removing it from service to prevent out-of-service conditions resulting from transient errors.

The test circuits are also monitored for failures. If a test circuit is used on two consecutive failing diagnostics it is considered suspect, and a service circuit which is assumed to be good is selected at random to check the test circuit. The diagnostic for this service circuit is run in the usual manner but the results are used to produce a trouble number for the test circuit rather than the service circuit. In this manner the service circuit diagnostics perform double duty, and diagnostics for the test circuits are obtained for free.

The Circuit Maintenance List Auxiliary (CMLA) is also processed by the trunk maintenance programs. Circuits are placed on the CMLA by audit programs to return them from an unknown hardware state to the idle condition. Circuits are removed from this list, all relays are initialized and the circuits are then returned to the appropriate idle link list. Universal trunks are placed on the high and wet list where they are held in a busy condition until a seizure is no longer indicated. The trunk is then idled.

The authors acknowledge the contributions of W. Fisher who designed the trunks and R. F. Pina who wrote the trunk and service circuit maintenance programs.

V. CONTROL DISPLAY AND TEST FRAME

The Control Display and Test (CDT) frame, shown in Fig. 17,

TABLE II—TESTS FOR SERVICE CIRCUITS

Test Code	Coin-Control and Ringback	Audible Tone	MF Receiver	DP Receiver	MF Outpulser	Reorder Tone & Announcement
1	*Inband Coin Signaling* Check quiet period, level and duration of tones	*Frequency Content and Interval*	*Loss* Check reception for all frequencies under loss and tone duration variations	*Digit 1 and 2* Check proper interrelation of signals from trunk 2 pulse counter	*KP & ST* Frequency and duration of KP and ST	*Announcement Sequences*
2	*High-Low Signaling* Check voltage and duration of collect, return, and ringback signals		*Twist* Check reception of digits when one frequency is appreciably lower than the other	*Pulsing* Check proper reception of various pulse rate, percent break and digits	*Tone Duration* Proper duration of pulsing	*Frequency Content of Reorder Tone*
3			*Simplex Rering* Check voltage and duration of signal		*Loss* Check levels of all frequencies	
4			*Saturation* Check ferrods			

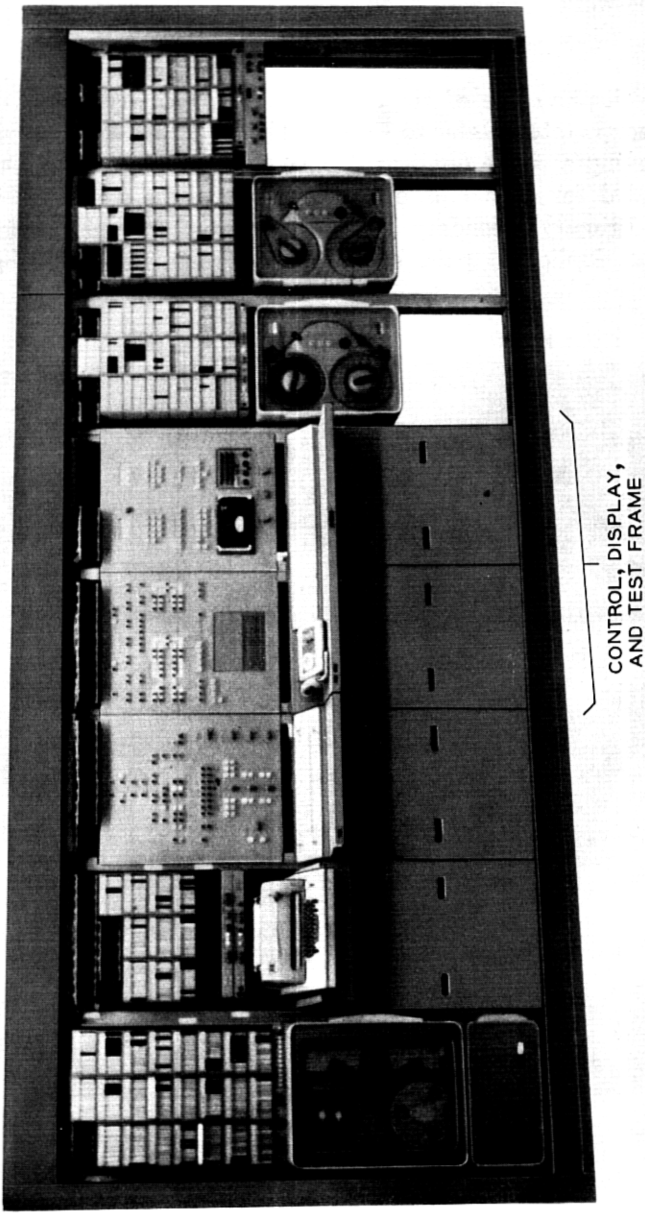

Fig. 17—Control, display, and test frame.

provides display facilities for all TSPS equipment and a Trunk Test Panel (TKTP) which may be used to test all equipment appearing on the network.

5.1 *Displays*

Lamp displays are of three types: A/B, primary/secondary, and trunk group status. Refer to Fig. 18. The A/B display is provided for units having a single duplicated pair, for example AMAs. One lamp is provided for each half of the pair and is lit steady to indicate trouble. Primary/secondary lamps are provided for units having more than one duplicated pair, such as the Trunk Link Network. The

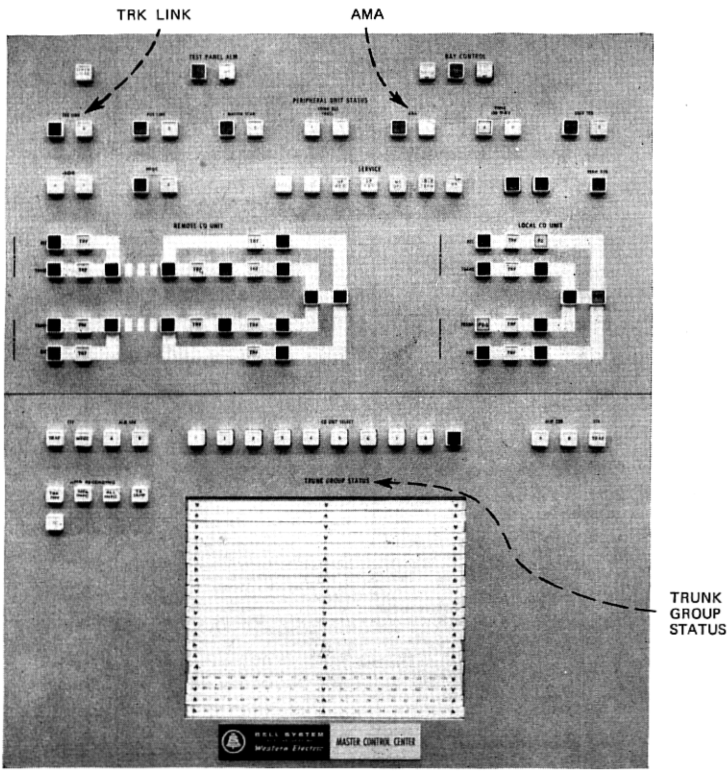

Fig. 18—Display panel.

secondary lamp is lit steady to indicate trouble in one half of a pair, and flashed to indicate such a condition in more than one pair. The primary lamp is used in a similar manner to indicate trouble in both duplicated halves of a pair. Trunk group status lamps are provided for all units which have been assigned to trunk groups; (refer to Table I). The lamp is lit steady to indicate one or more members of a trunk group out-of-service and flashed to indicate when the number placed out-of-service exceeds a service affecting threshold.

The position subsystem is comprised of a serial chain of units and is pictured on the display panel in block diagram form. An A/B lamp display is provided for these units. As the equipment configuration is different for local and remote groups, separate diagrams are provided for each. In the normal case the lamp states from all chief operator groups are ORed together. If it is desired to view the status of a single group, a key may be depressed to select a status display of that group alone.

A test of the more than 500 lamps of the CDT frame may be initiated from the TTY.

5.2 *Trunk Test Panel*

The Trunk Test Panel shown in Fig. 19, has four (4) network appearances (Access 1, Access 0, PMTL, TMTL) as previously shown in Fig. 16. The access circuits 0 and 1 are to connect to voltmeter or transmission test terminations.

The voltmeter termination may be used as a voltmeter or milliammeter, keys being used to select the function and meter scale to be used. By means of graphs contained in the circuit drawing, readings may be converted to resistance readings if desired.

The transmission test termination provides facilities to send tone to, or measure tone levels from the circuit under test. Quiet terminations or noise measurement facilities may also be connected under key control.

A reference trunk to each chief operator group (see Fig. 16) is used for transmission testing with positions, allowing one man tests to be made with any position on a loop around basis. Two man tests may also be performed with a craftsman at the position if desired.

A key telephone set provides for 4 to 15 lines which may be utilized for central office lines, tie lines or intercom lines within the building.

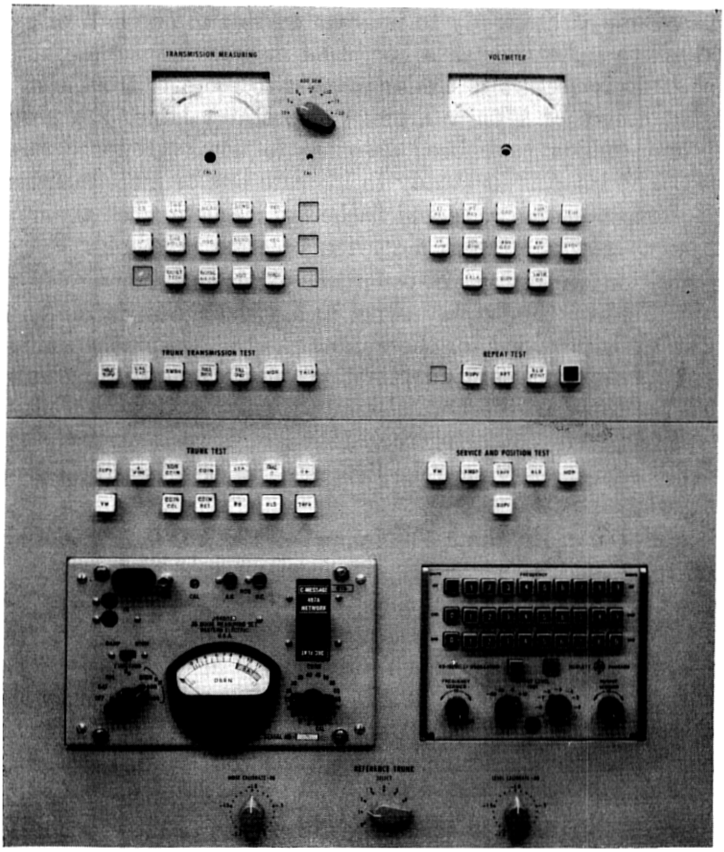

Fig. 19—Trunk test panel.

A telephone headset may be associated either by the key telephone set, or the Master Test Line. If desired, the frame belt line may also be added on a call.

5.2.1 *Test Connections*

Facilities are provided which enable the craftsman to connect any circuit with a network appearance to the test lines at the Trunk Test Panel. The craftsman establishes a connection to a MF receiver by operating the Test key and, using the MF keyset at the test panel, keys in the Trunk Group Number (TGN) and Member Number (MEMN) of the circuit to be tested. The circuit under test is then connected to the Master Test Line at the TKTP. If a voltmeter or transmission test is to be made, the circuit must be connected to the appropriate access circuit. Under key control, trunks are connected to Access Line Zero; positions or service circuits are connected to Access Line One.

If a trunk, service circuit, or position is traffic busy when testing is requested, it will be automatically camped on. When the circuit becomes idle, it will be removed from service and a TTY message will inform the craftsman that the circuit is available for testing.

Programmed tests may be requested on circuits connected to the test panel by keying in test digits.

5.2.2 *Service Circuit Testing*

Service circuit diagnostics can be requested by keying in test information after the TGN and MEMN which selects the tests to be performed as shown in Table II.

5.2.3 *CPD and SD Operations*

The craftsman is given the capability to easily operate or release any relay in any circuit on the network including the Trunk Test Panel itself. He can also pulse any unipolar or bipolar CPD point in any circuit on the network. Once set up from the TKTP these tests can be controlled remotely at the circuit location by plugging a pushbutton control (32A Test Set) into a frame belt line.

5.2.4 *Scan Display*

When the Scan Display key is operated a program displays the states of the ferrods associated with the circuit that is under test by the TKTP. The ferrod states will be displayed on the Program Display lamps on the SPC Control and Display Panel and will be extinguished when the key is released.

5.2.5 *Maintenance Busy, Out-of-Service, and High and Wet*

Trunks, service circuits, or positions are unavailable for service (indolent) because they are "maintenance busy," "out-of-service," or "high and wet." Maintenance busy implies that the circuit is under control of a maintenance program; that is, the circuit is about to be tested from the Trunk Test Panel or by a diagnostic, or is currently under test, or has just been tested and has not yet been restored. Out-of-service implies that the circuit, after being tested, has been found faulty and is being kept from service until it can be repaired or replaced. Incoming trunks that are maintenance busy or out-of-service appear busy at the originating office. All circuits that are out-of-service are kept on a list which can be printed out on the TTY by operating the Busy Status key or by TTY request. High and Wet implies that the circuit (trunks only) is in the state of permanent seizure.

The Trunk Test Panel program makes a circuit maintenance busy before testing and restores it to idle or out-of-service after testing. A circuit can be taken out-of-service after failing a test, or restored to service after being repaired by operating the Make-Busy key or Remove Busy key.

5.2.6 *Thru Test and Incoming Call*

Trunks incoming to TSPS from local central offices are routinely tested at the local office by sending codes over the trunks which request connections to test equipment in the toll office. The TSPS receives these codes, identifies them as test codes, and checks their validity. If found valid, they are pulsed forward to the toll office, and the trunk is placed in a state appropriate for the test. This eliminates contacting the TSPS maintenance center for most tests.

If a trouble is found, it may become necessary to sectionalize the trunk to locate the trouble. A feature is provided to permit the local office to contact the TSPS maintenance man over the suspected trunk. The craftsman at the local office dials another test code which the TSPS recognizes as an incoming call to the TKTP. The audible signal at the TKTP is rung and the MTL lamp flashed, indicating an incoming call; audible ringing is returned on the trunk. When the craftsman operates the Test key, the calling trunk is connected to the Master Test Line.

5.2.7 *Trunk Class Lamps*

Universal Trunks connected to Access Line Zero will have their class of service identified by the Trunk Class Lamps. Lamps light to indicate that the trunk carries noncoin, coin, 1+, 00, and/or 0+ traffic. If any trunk (not restricted to universal trunks) is a 4-wire trunk, a lamp indicating 4-wire lights and several relays within the trunk test panel operate to configure the test circuit for the 4-wire trunk.

When testing universal incoming trunks, it is necessary to test the trunk toward the originating office, toward the toll office, and in the "cut-thru" state. The desired state is established automatically by the program in response to the Toll Only and Toll Bridged keys making it unnecessary for the craftsman to obtain the trunk type, study the SD and CD, and decide which relay must be operated.

Outpulsing is necessary to complete a test toward the Toll Office. This is done by requesting a connection to Access Line Zero and keying in the outpulsing information after the TGN and MEMN. Then by operating one of the "TOLL" keys and the OP key on the TKTP, the proper code will be outpulsed.

5.2.8 *Equipment Location*

Once a trunk or circuit has been found faulty, it must be repaired or replaced. This requires knowledge of its physical location in the building. In past systems, a translation would be provided by a book. Operation of the TCN key will cause a machine translation and TTY printout of the equipment location and network appearance of the circuit last connected to the Master Test Line.

5.2.9 *Position Testing*

The transmission path to positions may be tested from the trunk test panel by means of reference trunks extending from the test panel to each chief operator group. Located at the position end of the reference trunk are a milliwatt supply and terminations which are used in conjunction with the test meters at the panel to calibrate the reference trunk for transmission testing. The Access 1 circuit is connected to the other end of the transmission path through the network. Two modes of testing are provided; one-man tests, and two-man tests.

The one-man position test consists of four separate parts; near-end to far-end loss and noise, and far-end to near-end loss and noise measurements. Before making these tests the reference trunk is calibrated. The calibration of the reference trunk consists of three separate parts; loss and noise calibration and a noise level check.

A two-man test may be made with one man at the trunk test panel and one man at the position, using the following portable test equipment which is plugged in at the position:

21A Transmission Measuring Set
3B Noise Measuring Set
132A Test Set.

In this case the position is connected to Access line 1 but no reference trunk is used.

5.2.10 *Operator Keyed Trouble Reports*

Instead of filling out trouble tickets, operators key trouble codes into the TSPS when they encounter trouble or receive reports of trouble. These reports, and as much pertinent call data as is still in the system, are printed on the service bureau TTY and/or on the toll office TTY. Certain of the reports, which may be TSPS affecting, will be printed at the maintenance TTY. The craftsman is expected to monitor these reports and act accordingly if he detects a pattern indicating a common piece of equipment.

The authors acknowledge the work of W. A. O'Connell who designed the CDT frame and J. W. Seazholtz, P. J. Brendel, A. W. Robinson and R. A. Thompson for their many contributions to the program.

VI. THE TSPS POSITION SUBSYSTEM

The TSPS position subsystem links the peripheral address bus, master scanner, and link cut-through circuits with the eyes, ears, hands, and voice of the operators. Specifically, voice circuits are provided to connect an operator to the trunk; and data is sent to light incandescent lamps and multidigit *Nixie** displays. At the same time data is returned from operator key actions or alarm outputs. Provision is included to reach operators at remote locations as well as operators in the same building. Thus, small groups of operators can be employed in suburban "traffic offices" while the full access link and single common control provide the efficiencies inherent in a single large group of operators. A single position subsystem provides circuitry for up to 62 operators, 2 supervisors, and one chief operator. A maximum of 9 such subsystems can be provided although the total number of positions cannot exceed the original design intent of 310 and, moreover is dependent on the traffic mix at a particular location.

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* Trademark of the Burroughs Corporation, Electronic Components Division, Plainfield, New Jersey.

6.1 *Local Subsystem-Sending*

In the local case, shown in Fig. 20, the path from the address bus to the operators is comprised of a group gate, position signal distributor, position buffer for each operator, and a console for each operator. The group gate acts as a time buffer and also converts binary information from the high-speed bus to a set of 1-out-of-8 (1/8) codes applied to the position signal distributor (PSD). Transfer relays are included between the group gate and position signal distributor for use in fault recognition and to permit operation with two bad units. The PSD acts upon the 1/8 coded instructions to select the desired position buffer and operate or release a miniature wire spring (MWS) relay within that position buffer. Outputs from the buffer connect to incandescent lamps within the operator's console. The MWS relays of the buffer are predominantly magnetic-latching and are arranged on printed circuit boards of the A-pack type.

The "local" case actually provides for the operator group to be

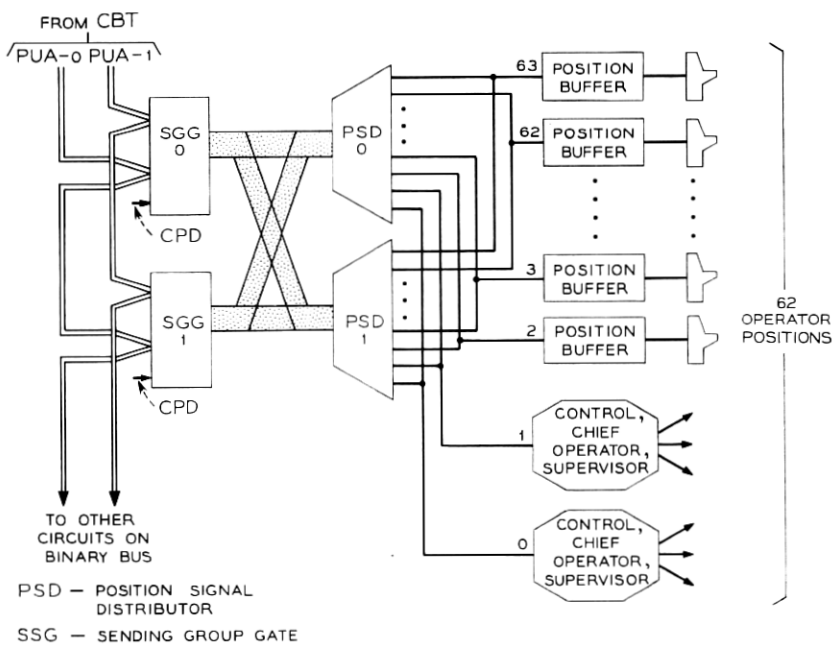

Fig. 20—Local subsystem—sending.

located up to about 4 miles from the group gate at the base location. The sets of 1/8 leads between group gate and PSD can be run as twisted pairs in cable facilities for that distance. Longer distances (the remote case) require additional circuitry interposed between the group gate at the base end and the PSD at the remote end. This remote operation is discussed in more detail later.

6.1.2 *Position Group Gate (Local)*

The group gate connects to the peripheral address bus and central pulse distributor in the same manner as other bus-connected circuits such as scanners, signal distributors, etc., as shown in Figure 1. It is actually made up of two independent halves with the usual 4 enables. Normally both halves are used simultaneously to send data to a chief operator group, providing two separate information paths. Should one half develop a fault, the remaining half is used to send all the information previously sent via the two independent paths. Input information is in the form of a 17-bit word arranged as shown below:

16	15	14 13 12 11 10 9	8	7	6 5 4 3 2 1 0
PAR	NIXIE	ADDRESS	N/M	O/R	INFO

As used here "address" means the operator position number and "info" refers to a particular relay in the associated position buffer. Bit 7 designates operate or release, bit 8 designates normal or maintenance order, and bit 15 is used when sending multidigit Nixie displays. The Nixie displays, which may be up to 12 digits in length, are used to give time, coin charge and initial period information, calling or called numbers, and other numerical information to the operators. A special part of the PSD is dedicated to Nixie displays as described later.

The group gate is reset and prepared for the next order upon receipt of a "check-back" pulse. For maintenance orders this pulse is generated within the group gate itself while for normal orders to a position the pulse originates at the particular MWS relay concerned and is regenerated and passed on by the PSD.

In the maintenance mode the information portion of the group gate order may be intended for the group gate itself or some subsequent circuit. Certain orders that are acted upon by the group gate could also cause some reaction (usually undesired) in subsequent circuits, and these maintenance orders are blocked by the group gate to prevent this. With the exception of transfer and quarantine orders, these various maintenance orders are provided for diagnostic program purposes to allow the programs to temporarily set up checking configurations and comparison circuitry as a diagnostic check is performed.

6.1.3 *Position Signal Distributor*

The position signal distributor (PSD), shown in Fig. 21, and all circuitry following it is arranged the same for both local and remote traffic offices (operator groups). It is made up basically of two relay trees, one of which selects a set of cut-through relays to connect a multi-lead bus to a particular buffer while the other connects an apex pulser to a particular lead of this bus. It differs from a universal trunk frame signal distributor in that it is completely duplicated, including all relays of both trees. Thus, if any portion of one half of the PSD should fail it is still possible to reach every lamp in every position via the remaining half.

6.1.3.1 *Apex Pulser and Check-Back Pulse.* When a path is established to a particular MWS relay in a position buffer, an apex pulser sends operate or release current through the relay winding. As the relay armature moves, a momentary ground is generated from a de-

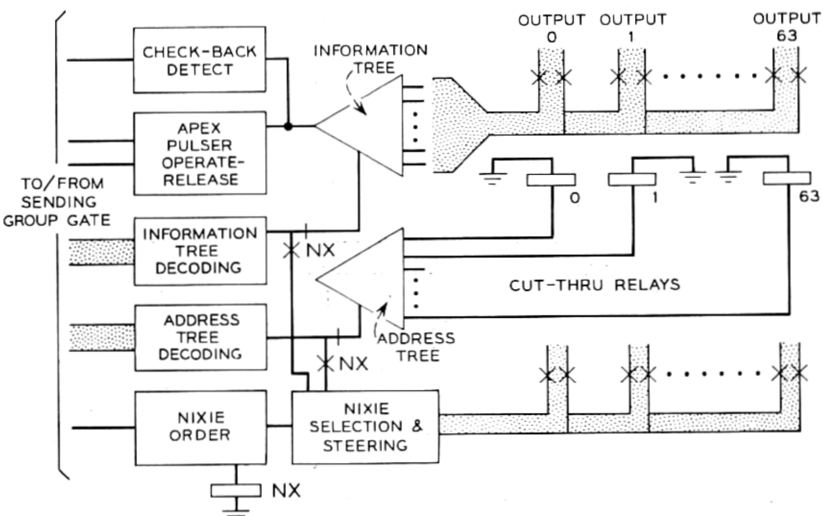

Fig. 21—Simplified schematic of position signal distributor.

liberate "bunching" of one contact set and used as a check that the relay did, indeed, operate or release. Since this check-back path is common to all MWS relays of a position buffer, a check for permanent ground (caused by a poor relay with "floating" armature) is made by the PSD prior to any relay operation. This check-back pulse sets a flip-flop in the PSD which causes pulser current to be cut off and a regenerated pulse to be sent to the group gate. In the event the MWS relay fails to function normally and no check-back pulse is generated, the group gate is not reset, and subsequent scanning of a maintenance ferrod (F point) will alert the SPC to the failure. The SPC then sends a system reset to clear the group gate. This releases the PSD and cuts off the apex pulser current. As a back-up to the above two methods of cutting off pulser current, a timer is started on each PSD order and is designed to cut off pulser current in about 12 milliseconds. Normal operate or release time for the MWS relay is about 5 ms. The timer will cut off the current even if a system reset is not sent. At the same time an alarm is generated and returned by the Alarm Sender (described later) to alert the SPC that a time-out has occurred. While the bulk of the PSD is comprised of relay trees and relay logic, the check-back circuitry is all electronic and provides rapid return of the reset signals.

6.1.3.2 *Nixie Display Orders.* A multidigit display such as a 10-digit number reaches the operator via Nixie tubes positioned near the top of her console. A total of 12 Nixie tubes are provided (to ultimately handle digit displays for overseas dialing). Since each tube contains 10 cathodes (digits), a total of 120 subsystem orders pertain to Nixie tube operation. Actually a few more orders are used since preparing for the display and releasing the display must also be considered.

Nixie displays are characterized by the necessity for sending several orders to one position in a short time. This differs from the incandescent lamp displays where lamps are lighted singly at a position with several seconds between each order as the operator takes various actions on a call. Because of this difference a separate portion of the PSD handles Nixie orders exclusively.

The technique used is to dedicate the PSD to a particular position for the length of time needed to send a complete Nixie display. A "priming" order is first sent to the PSD to establish this dedicated path. This order results in two 10 lead buses and one 6 lead bus being cut through to a particular position. A signal on one lead of the 6-bit bus selects a pair of Nixie tubes. This is immediately followed by a pulse on one lead of each of the 10-bit buses to select a digit in each of the pair of tubes. The advancing to successive pairs of Nixie tubes is accomplished automatically by the PSD, while the selection of a particular digit is dependent upon receipt of orders from the stored program control. After advancing through all 6 pairs of tubes, or at any time the program reaches the end of the display being sent, a "release" order is sent to the PSD. This drops the connections to the position and restores the PSD to its normal undedicated state.

The pulses mentioned above are not applied to the Nixie tube elements directly but instead are used to break down (ionize) a miniature neon lamp provided in series with each Nixie tube cathode as shown in Fig. 22. This neon lamp, which is a very low cost device, has two well defined states and is used as the "memory" element as well as a "switching" element of the Nixie display. Thus a display is "locked-in" through the medium of the ionized neon lamps, and the Nixie display remains ON after the PSD releases from the position. It is later extinguished under either program control or operator actions by momentarily opening the holding battery. The entire display, including Nixie tubes and sockets, all neon lamps, and all biasing resistors, is mounted on one printed wiring board and can be easily removed for maintenance purposes. The complete display board is shown in Fig. 17 in the article "TSPS Physical Design" in this issue.

6.1.3.3 *PSD Maintenance Orders.* The PSD is arranged for several different maintenance checks. The electronic check-back circuitry can be tested for both steady ground conditions and for lack of ability to detect the check-back pulse from MWS relay. The timers can be checked to insure proper timeout and that alarms are generated and returned via the alarm sender. One of the most powerful maintenance checks, however, is the ability to take two output trees, one which normally selects a position, and one which normally selects a particular lamp at a position, and connect them to each other. Orders can then be sent which are expected to result in a match or are expected to mismatch with the resulting actual matches and mismatches used to pinpoint troubles.

If tests such as mentioned above result in trouble being detected in a PSD other maintenance orders can be sent to quarantine the half of the circuit found in trouble. Transfer relays can be operated to link the A half of the PSD with the B half of a previous circuit. Any such orders, upon execution, generate alarm codes which are returned

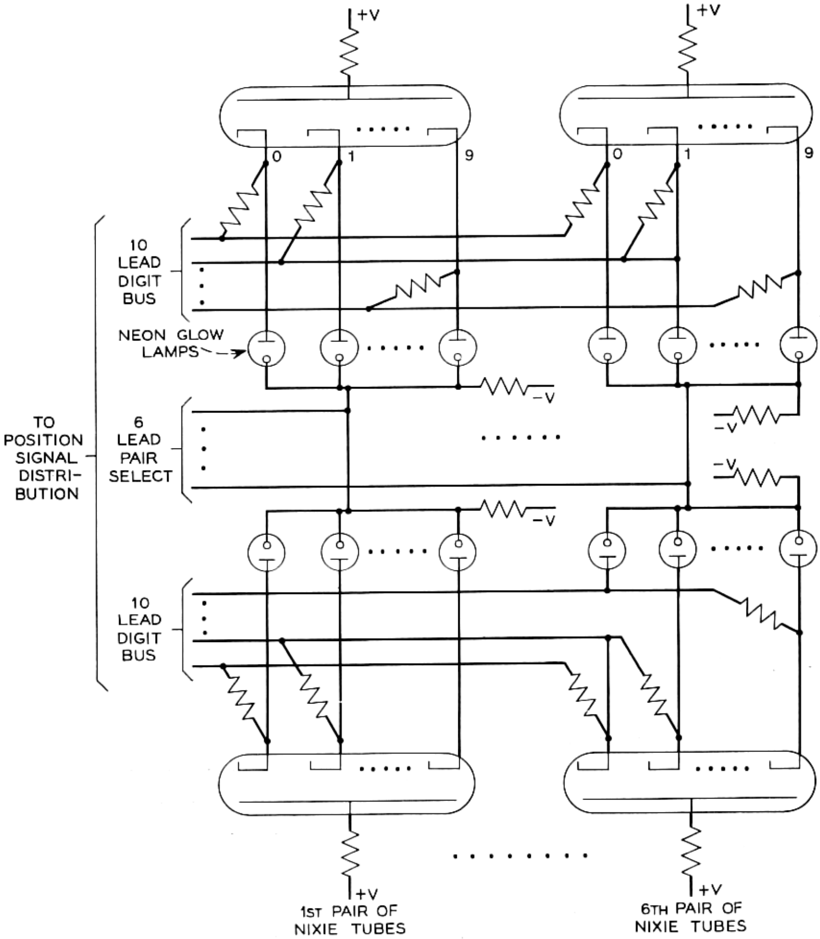

Fig. 22—*Nixie*® display printed circuit board.

to the SPC via the alarm sender and serve to verify that such orders were correctly executed.

6.1.4 *Position Buffer*

The position buffer consists of a number of A-type circuit packs, each of which contains from 3 to 8 miniature wire spring relays. The MWS relays operate incandescent lamps on the operator's 100B console. They are also used to cut through a transmission path and extend the transmission path to a supervisor or monitoring circuit as desired. These miniature relays are predominately magnetic latching and operate or release on a short pulse of current from the PSD with no holding current required. A few are not magnetic-latching and are operated by a pulse from the PSD but lock to contacts of some other relay. This facilitates the release of position lamp displays since one or two key relay operations at the end of the operators work will release several relays. Provision for growth is made by providing for 16 buffers per frame and by permitting frames to be partially equipped. As positions are added, a set of 10 plug-in circuit packs, which constitutes a position buffer, is inserted for each position.

6.2 *The 100B Console*

The physical aspects of the new operator consoles are discussed in the article "TSPS Physical Design" of this issue.[4] The additional features covered here include arrangement of key codes for receipt of information from operators and transmission arrangements.

The information keyed by the operator utilizes a 3-out-of-9 code (3/9). That is, each of the keys has contacts which close ground to 3 leads of a 9 lead bus when the key is depressed. Use of a 3/9 coding scheme has several advantages: each key needs just 3 make contacts (a fourth contact is sometimes used to light a lamp as the key is depressed), 84 combinations are possible (allowing for future growth), only 9 leads need to be cabled to the position itself, and the code is self-checking as is any M/N code. A detector circuit mounted within the position insures that a 3/9 condition is present before any service request is sent to the position scanner. This prevents the system from dealing with false 1/9 or 2/9 codes generated during the downward travel of the key. Since valid information is present only while the key is depressed, the scanner receives a pulse of information and must be fast enough to reach the position while the pulse is present. In the worst case (fastest operators) these pulses will be about 35 ms in length.

The 100B console is arranged for 4-wire transmission. As already noted, the link and service circuits, as well as several trunks, are all 2-wire transmission circuits. A 24V4 repeater physically located near the link frames converts the 2-wire path to 4-wire and also provides sufficient gain to reach remote positions up to about 10 miles distant. Where T-carrier is used to reach remote positions, the 2-wire to 4-wire conversion is provided in the T1 channel banks. A transmission path to 3 separate supervisory trunk circuits connects to each position.

These are used to connect to a supervisor for needed assistance or to permit monitoring from either supervisor console. Another transmission path connects to all positions and permits monitoring from a specially equipped monitoring position.

6.3 *Local Subsystem Receiving*

6.3.1 *Position Scan and Gate*

The position scan and gate (PS&G) circuit, shown in Fig. 23, is arranged as an autonomous scanner continually looking for key signals from the operators. As mentioned in Section 6.2, the keys are arranged to provide a 3/9 code, and a detector circuit is provided in each console to discriminate against 1/9 or 2/9 codes. When a 3/9 code is detected, a "service request" lead to the position scan and gate is

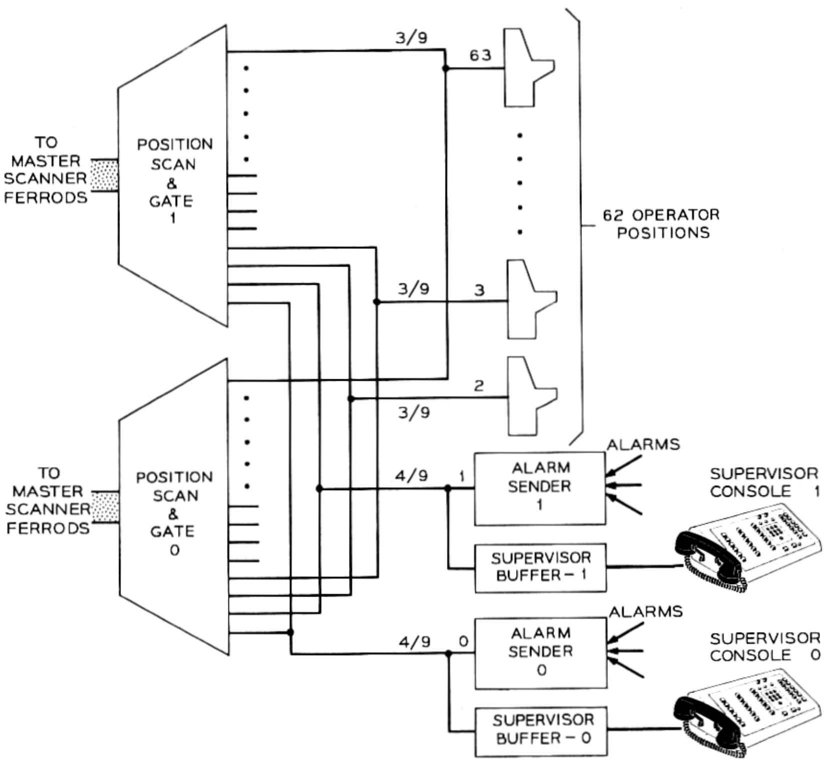

Fig. 23—Local subsystem—receiving.

energized. This service request lead is in addition to the 9 leads of the 3/9 bus. The scanner is continually checking these service request leads, and upon noting a signal, it stops at that point and accepts the 3/9 code information.

The 3/9 information, together with a 6-bit binary number indicating the position involved and a parity bit, is returned over a 16 bit bus to the SPC via a master scanner. Sixty-two of the 64 possible inputs to the PS&G come from positions. The other two inputs are shared between two supervisor consoles, a chief operator administration circuit, and an alarm sender circuit.

The scanner is controlled by a 40 kHz oscillator driving a 6-bit binary counter. The binary counter outputs are arranged in two groups of 3, and each 3-bit segment is expanded to a 1-out-of-8 (1/8) code output. The two 1/8 groups are arranged in a horizontal-vertical grid arrangement with a 2 input gate at each of the 64 intersections. Thus, 64 outputs are obtained with a pulse appearing sequentially on each. This scan pulse is combined with a service request, when present, to stop the oscillator and inhibit further scanning. The state of the 6-bit binary counter is sampled to generate a position number, the 9 leads from the position (or other circuit) are sampled to obtain the keying information, a parity bit is generated, and the resulting 16-bit output is sent to a master scanner ferrod row. When the SPC scans this row and accepts the information, it sends a "scan complete" pulse via the group gate to the position scan and gate. This restarts the oscillator to permit scanning to resume and sets a flip/flop to prevent the scanner from again stopping on the same point. When the operator releases the key, this flip/flop is cleared and any subsequent keying by that operator will cause the scanner to again stop on that position.

The interval allowed for a complete scanning operation as described above is 10 milliseconds. This is a compromise between sufficient speed to insure reaching key signals as keys are depressed and moderate scan rates to insure not placing a real-time burden on the SPC (fast scans result in *no* information most of the time). Thus, the scanner would expect a restart of the oscillator within 10 ms. If no restart occurs after about 150 ms, then the scanner is automatically placed in quarantine, alarms are generated, and diagnostics are requested. Checks are also made to insure that the scanner progresses correctly from position to position. If failure is noted, the quarantine state is automatically entered. The scanner is fully duplicated and operates by a "leap-frog" arrangement wherein one scanner skips a position if the mate scanner is momentarily stopped at that position.

6.3.2 *Alarm Sender*

The alarm sender receives alarm information from all subsystem circuits except the group gate and temporarily stores them until such time as the PS&G can accept them and transmit them back to the SPC. The storage and ultimate transmittal to the PS&G, as well as a progression arrangement to allow handling of several alarms at once, is accomplished primarily through relay logic.

Circuits sending alarms to the alarm sender quite often send 2 or 3 alarms in succession. For example, if the PSD sends a timer alarm indicating that an operation took too long, it will also send an indication of the state of the transfer relays and an indication of the operational status (normal, quarantine, power off) of the circuit. These are picked up by successive scans of the alarm sender and sent to the SPC. Alarms are arranged in a 4/9 code to distinguish them from operator key codes. Also, in the case of alarm codes, a maintenance bit is sent by the PS&G as well as the 16 bits of information mentioned in Section 6.3.1. This maintenance bit appears as a separate ferrod indication scanned by the SPC to insure immediate detection of maintenance information. The 6-bit position number becomes a "circuit number" indicating which circuit (PSD, PS&G, 100B console, interrupter, etc.) is generating the alarm.

The alarm sender also provides for input information from the position subsystem frame location by the maintenance man using a combination of thumbwheel switches. The thumbwheel switch allows the maintenance man to set up an order, verify visually that it is correct, and then have it scanned and sent to the SPC. The SPC then acts on the order perhaps causing some requested reconfiguration or some lamp display at a position. This gives a maintenance man concerned with position subsystem maintenance (which might be remote from the rest of the TSPS installation) some of the control normally provided by the MCC maintenance teletypewriter.

6.4 *Remote Subsystem—General*

The remote position subsystem, shown in Fig. 24, was designed for use with T1 carrier to reach operators up to 80 miles from the base location. The group gate, T-carrier, and Data Assembly and Check (DAC) circuit comprise a data link that is unique and worthy of discussion. T1 carrier terminal equipment encodes 24 analog circuits (voice) into a serial pulse stream and reconstructs the 24 analog signals at the distant end. The sampling rate is 8 kHz so that each of

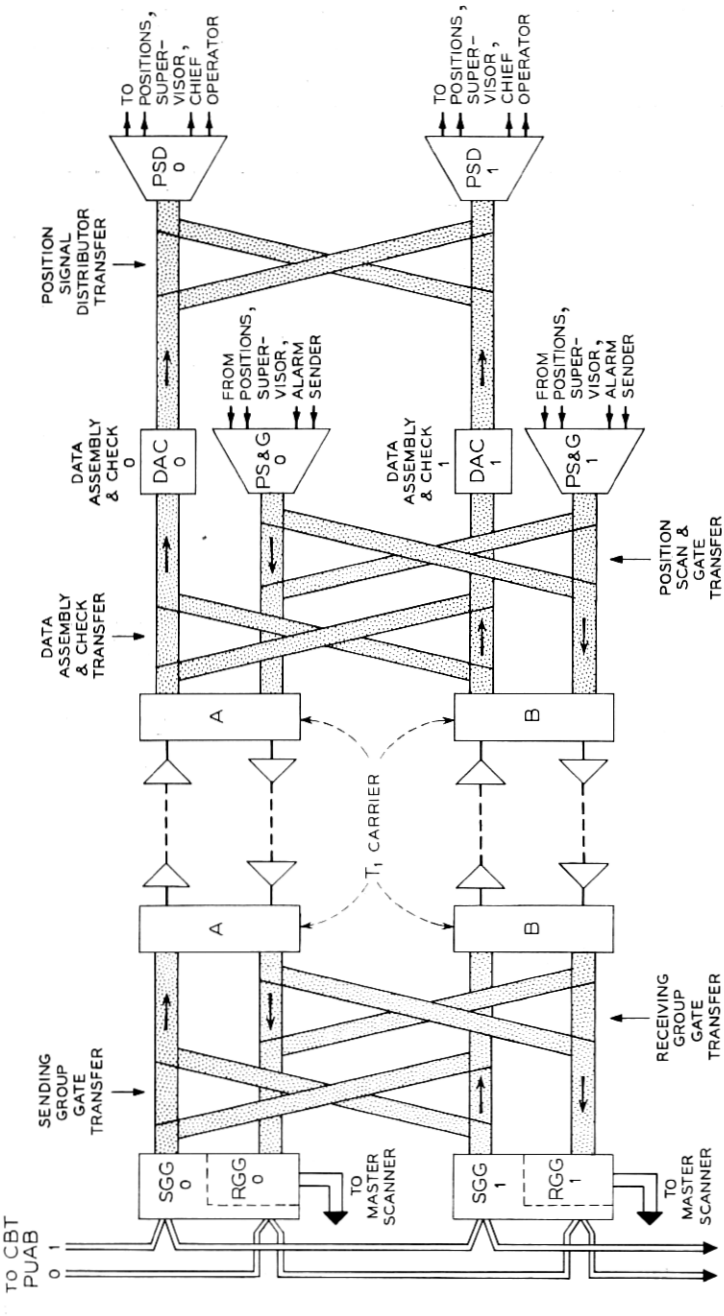

Fig. 24—Remote position subsystem configuration.

the 24 channels is scanned every 125 microseconds. The terminal equipment is designed to encode the amplitude of the analog input into a 7-bit binary number but actually transmits an 8-bit binary number. The eighth bit is normally used as a "signaling" bit to indicate a 0 or 1 supervisory state.

For TSPS the ability to encode 24 voice signals into digital form is used intact to provide voice circuits for 24 remote operators. The 8th bits from each of the 24 channel are combined to give essentially a 24-bit word which can be sent from the group gate at the base location to the DAC circuit at the remote location. It is possible to send a new 24-bit word every 125 μs, and thus considerable data (to control lamp displays and return key signals) can be sent to and from operator positions over the same path that is needed for the voice circuit. This is the rare case where it seems we are obtaining "something for nothing." In practice two T1 banks are used for reliability and either one alone can handle all data to and from a chief operator group (62 operators, 2 supervisors and 1 chief operator). These are designated T1-A and T1-B, with T1-A also carrying the voice circuits to 24 of the 62 operators and T1-B serving as a voice backup for those 24 operators. To serve up to 48 operators a third T1 bank is added and designated T1-C. T1-C handles no data but provides 24 voice circuits and is also backed up by T1-B via a relay transfer arrangement. For full groups of 62 operators, a 4th T1 is added and partially equipped. It, too, can be backed up by T1-B.

6.4.1 *Remote Subsystem—Sending*

The sending portion of the position group gate, when arranged for remote operation, acts only as a time buffer and does not change the format of the instructions received from the SPC. Thus the same 17-bit word received over the binary bus is applied to 17 of the 24 T1 channels. Other channels are used for synchronization, maintenance transfer of paired DAC circuits at the remote end, and a special TTY circuit to the remote site. The 17-bit word is sampled by T1 for 5 ms which results in 40 consecutive transmissions of the same information to the remote end. At the remote end the DAC circuit receives the information from T1 carrier and eventually converts it to the set of 1/8 codes required by the position signal distributor (PSD). The PSD, as mentioned before, is the same for both local and remote operation.

6.4.2 *Data Assembly and Check Circuit (DAC)*

The DAC circuit checks parity on the first T1 transmission and, if good, temporarily stores the 17-bit word. It then checks the second T1 transmission (the second transmission of the *same* information) and, if parity again checks, it compares the two 17-bit words. If the comparison test passes, it then converts the binary information into a set of four 1/8 codes (plus a few other outputs) for use by the PSD. If the comparison fails then the stored information is discarded and two more T1 transmissions are checked and compared. This process continues until a valid comparison is found or until all 40 T1 transmissions have been completed. A "comparison failure" alarm is then generated and returned to SPC via the alarm sender.

The combination of both parity and comparison guards against bad data due to short noise bursts on the T1 line. The probability of a few consecutive pulses being mutilated in a stream of pulses is not too low and the DAC effectively increases the overall reliability of the sending chain. In order to periodically check the operation of the comparison test feature in the DAC the group gate is arranged, under control of a maintenance order to send alternate "ones" and "zeroes" on consecutive T1 transmissions. It is also arranged to send bad parity to check the parity circuits of the DAC. Other diagnostic checks used for DAC maintenance depend upon the succeeding circuit (PSD) diagnostic tests to isolate trouble.

6.4.3 *Remote Subsystem—Receiving*

The use of the 8th bit on each T1 channel is the same for sending or receiving. The output of the Position Scan & Gate (PS&G) is changed slightly to connect to T1 carrier instead of ferrods on a master scanner. The 17-bit output from the PS&G (3/9 code, 6-bit position number, parity, and maintenance bit) is applied to T1 carrier until a "scan complete" pulse is received by the PS&G and scanning resumes.

The 17-bit information is sampled by T1 carrier every 125 μs and transmitted to the receiving portion of the group gate at the base location. This receiving group gate (RGG) accepts the data and checks parity but does not make the comparison test as made in the other transmitting direction by the DAC circuit. This is permitted because the data is intended for the SPC where the correctness of 3/9 codes and parity can be checked. The RGG does, however, require two transmissions of the information in case the T1 sampling at the distant end occurred in the middle of the 17-bit data.

Once two transmissions have been received, the RGG generates an "information present" signal to a ferrod scanned at a fast rate (10 ms) by the SPC. SPC then makes a directed scan of the 16 ferrods containing position number, 3/9 code, and parity. It next sends a "scan complete" (CPD pulse) signal to the group gate which forwards it over T1 carrier to the distant position scan and gate circuit. This restarts the PS&G oscillator and permits scanning to resume as in the local case.

Thus for the remote receiving case the only additional circuit (other than the carrier system) is the receiving group gate. However, the maintenance procedure is more elaborate since two sets of transfer relays are involved; one at the output of the PS&G as it connects to T1 carrier, and another set at the input to the RGG at its connection to T1-carrier. Remote subsystem diagnostics use these transfer points plus portions of diagnostics on succeeding circuits to isolate trouble. The position subsystem maintenance programs are described in succeeding sections.

6.5 *Auxiliary Subsystem Circuits*

There are a number of small circuits used with the position subsystem for control, monitoring, and traffic data purposes. Circuitry is provided for two supervisor positions and one chief operator position as well as a wall-mounted traffic register cabinet. The traffic register cabinet contains registers and a jack field which permit traffic data to be recorded from any 9 traffic service positions. These register counts can be read and reset by the chief operator and supply information to supplement the regular traffic printouts on her TTY machine.

Up to four administration cabinets may be provided, one of which contains lamps and keys used to facilitate training of inexperienced operators plus a few lamps to indicate heavy traffic or system initialization. Five traffic service positions, identical to others in all respects, are designated in the stored program as training positions. By use of the proper keys, the chief operator can exclude certain types of traffic from each of the five positions. As new operators at these positions become more proficient, the chief operator can change the restriction to permit a wider variety of calls at any one or all of the five positions. Alternatively she may use them for all traffic just as the rest of the positions are used.

The supervisor consoles and associated circuits are more sophisticated than the wall-mounted cabinets just described since they permit the two supervisors to perform a variety of functions. The supervisory buffer contains a small switching network so that calls arriving over one of three trunks from operators, or one of three transfer trunks from the toll office can be switched to either console or any one of four jack appearances positioned around the operating area. These jack appearances allow a roving supervisor to plug in her headset and be connected immediately without returning to her console. Flashing, wall-mounted lamps alert her to an incoming call.

The calls to the supervisor may be from the operator directly or may be from a customer who was transferred to the supervisor via a toll office connection. This latter type of call would have been set up by a TSPS operator after hearing the customer specifically request a transfer to her supervisor. The former type call, coming from an operator requesting assistance, appears on one of three trunks common to all operator positions. In addition to the small network, the supervisor buffer contains the relay logic to light lamps at the supervisory consoles, place calls on hold, permit monitoring by a supervisor of any operator talking path, and permit calls to be originated by either supervisor to any operator or to the outside world.

These circuits, together with the alarm sender, share the first two position numbers (0 and 1) in the 6-bit position address. That is, the first two position buffers on the PB frame are not intended for operator positions but instead provide outputs to these other circuits. Similarly, the first two inputs to the position scan and gate do not come from positions but instead arrive from these other circuits. Thus, in a TSPS traffic office the first physical position is designated position number 2 and the 62 positions use up the remainder of the 64 position addresses. This is illustrated in Figs. 20 and 23.

One other subsystem circuit worthy of note is the teletype channel and machine provided for each chief operator. In addition to several other TTYs used by TSPS for other jobs, each chief operator group (traffic office) is provided with a receive-only TTY. Traffic data for the associated operator team is sent to these machines at regular intervals by the SPC. Maintenance information pertaining to that group can also be sent when requested. In the local subsystem case the chief operator's TTY is handled in the same manner as other TSPS TTYs; i.e., a TTY buffer is reached via the PUAB and connects to the TTY machine. However, in the remote case use is again made of the T1 carrier signaling bit (that "free" eighth bit!). In this case the TTY buffer output is applied to a spare T1 channel ("spare" only in the data sense—17 of the 24 channels were used for group gate output—all are used for voice). The 125 μs sampling rate is much faster than the TTY requires and permits simple reconstruction of the TTY signal at the distant end. Thus, no data sets or dedicated outside line are needed for remote chief operator TTYs.

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VII. POSITION SUBSYSTEM MAINTENANCE PROGRAMS

7.1 *General*

The position subsystem maintenance program package is designed to complement reliable, duplicated hardware so that the hardware-software combination accurately passes information from the peripheral unit address bus to the operator and from the operator back to the master scaner without interruption of call processing operation. This package of programs includes a fault recognition program, diagnostic programs, automatic exercise programs, demand exercise programs, and hardware initialization programs.

The fault recognition program detects abnormal circuit responses of two types; errors and faults. An error is a statistical failure usually caused by noise which does not persist from a short term point of view, whereas a fault is a hardware failure. In both cases, it is the responsibility of the fault recognition program to:

(*i*) successfully complete the intended system operation,

(*ii*) remove a faulty unit from service,

(*iii*) identify the fault for maintenance personnel by teletypewriter (TTY) message or request a diagnostic to be run later which will identify the fault, and

(*iv*) return a working system to call processing as quickly as possible.

Diagnostic programs are written to facilitate quick repair by maintenance personnel to minimize the possibility of simultaneous failures in duplicated units taking a chief operator group out of service. These programs, running under control of the Maintenance Control Program (MACR), compare the actual test results with expected results, and pass the comparison results to the dictionary control program (DOCP) for data reduction and generation of a dictionary number which is printed on the TTY. Maintenance personnel look up the dictionary number to determine the location of the fault.

Since dictionaries are generated for single faults only, it is important to discover a single fault before a second fault develops. Some faults, particularly those in circuits which perform maintenance functions, will not be detected during normal call processing. Therefore, automatic exercise programs are run on a regularly scheduled basis to uncover those faults.

In cases where it is not economical to provide fully automated diagnostic capability (e.g., double fault and intermittent fault situations), demand exercise programs may be called by maintenance personnel to provide diagnostic test results (called "raw data") or test order sequences suitable for visual or test equipment checks to aid them in their analysis of the trouble.

Finally, initialization programs are provided which return either an individual operator position or the whole position subsystem to a known initial state. An individual position is initialized to prepare that position to receive calls whenever an operator plugs in her headset or upon request by the audit programs. A position subsystem and all associated operator positions are initialized when some major system failure has allowed the software records of hardware states to become jumbled.

7.2 *Position Access Fault Recognition Program (PAFR)*

As indicated previously, it is the responsibility of the Position Access Fault Recognition Program (PAFR) to respond to any indication of abnormal circuit response (a trouble—either an error or a fault), complete the intended system operation if one was in progress, remove a faulty unit from service, identify a fault for maintenance personnel, and return a working system to call processing quickly. In order to understand the details of the implementation of this philosophy, it is first necessary to examine the mechanisms for detecting troubles.

7.2.1 *Trouble Detection*

Each group of call processing orders (maximum of 17) to be sent to an operator position is loaded in a block of memory called a position information buffer (PIB) which is added to the linked list of PIBs of either half of the group gate for the operator group containing the position. Once every 25 milliseconds the PIB Execution Program (PIBE) gets an entry from PAFR in J level and distributes one order to each group gate half which has a PIB linked.

A distributed order to a group gate half normally results in an enable verify response from the enabled group gate half. Failure of the SPC to receive the enable verify results in an F level interrupt. The Central Pulse Distributor Fault Recognition Program (CPFR) passes to PAFR those failure reports that might be unique to a group gate. These might result from problems in the group gate itself, in the central pulse distributor (CPD), or peripheral unit address bus (PUAB).

Each sending group gate half (SGG) and receiving group gate half (RGG) has three master scanner points (F, S and T) which uniquely describe its state. When an SGG is enabled, its F point becomes a 1. If the order executes properly, the group gate is reset and the F point returns to 0. Failure of an SGG to be reset within 25 milliseconds indicates that the order failed.

All position subsystem circuits other than SGGs and RGGs transmit alarms through the alarm sender (AS) if abnormal circuit conditions are encountered. Every 10 ms the Group Gate Scan (GGSN) program scans, in J level, those RGGs whose information-present ferrods are set. If the RGG F point is a 1, GGSN interprets the data as an alarm and passes it to PAFR.

CPFR gives control in F level to PAFR to allow PAFR to save the data on the F level interrupt in memory dedicated for that purpose. Similarly GGSN enters PAFR in J level with alarms which PAFR saves in an area of memory called an alarm hopper. In both cases PAFR returns control after saving the data, and processing of the data is deferred to the next regularly scheduled entry to PAFR.

7.2.2 *J Level Entry to PAFR*

PAFR is entered from the executive control program in J level once every 25 ms. In general, the following operations are performed:

(*i*) A check is made that all SGGs are reset from orders sent by PIBE the previous cycle. If any failed to be reset, PIB execution is suspended on that group, and the failure is placed in the miscellaneous failure hopper for later fault recognition work.

(*ii*) RGG F points are checked for power off.

(*iii*) A test is made to verify that the SGGs can be reset if it was requested by the SGG diagnostic.

(*iv*) All SGGs are reset so that subsequent failures will be recorded.

(*v*) Control is given to PIBE to send another order to each group gate half which has an active PIB linked.

(*vi*) Continuing fault recognition work from a previous failure is resumed. The failing order is retried using various choices of bus, group gate half, and subsystem configuration. By analyzing the results, the faulty unit will be found. If at all possible, a hardware configuration will be established which will execute the order.

The handling of a failing order by PAFR actually varies according to a failure option specified in the PIB:

(a) option 0—if all efforts to execute the order fail, abandon the PIB and decrement the success address.

(b) option 1—if all efforts to execute the order fail, abandon the PIB, decrement the success address, and put the position in the "maintenance busy" state.

(c) option 2—make a single retry for an operate order only, decrement the success address if the retry fails, but allow PIBE to continue on with the PIB.

(d) option 3—ignore the failure and do no retries.

(*vii*) If fault recognition is not in progress, PAFR looks for new work: enable verify failure, teletypewriter request (Section 7.2.4), miscellaneous failure hopper entry, alarm hopper entry, or maintenance PIB request (Section 7.2.3).

PAFR must have complete control of a group before attempting fault recognition work. PIBE is stopped immediately from doing any more work on the group gate half which experienced the reset failure or enable verify failure. PIBE is also asked to stop work on the other group gate half as soon as the current PIB is executed. PAFR saves information about the PIBs in storage areas called "pseudo PIB," PIB-A for the failure half information and PIB-B for the good half information. After fault recognition is complete, PAFR uses this information to reestablish the PIB link lists as they were at the time of the order failure if the order failure was an error or to link the PIB to the working group gate half if one half contains a fault.

7.2.3 *Maintenance PIB*

PAFR provides special services for position subsystem diagnostic and exercise programs by administering a maintenance PIB. Up to 10 orders can be sent. Most of the time the maintenance PIB is executed concurrently with normal call processing PIBs. The results of each order are returned in the PIB to be interpreted by the program using the PIBs. The normal sequence is:

(*i*) Send the order with true parity.
(*ii*) Look for an enable verify failure.
(*iii*) Look for a change of FST points.
(*iv*) If no change, look for a reset failure.
(*v*) If a reset failure occurred, look for an alarm.
(*vi*) Store the result.
(*vii*) Repeat (*i*) through (*vi*) for each order.

One of 16 different variations of this sequence is selected on each order by specifying four control bits for the order, e.g., send bad parity, scan the diagnostic bus, or abort the PIB on a specific failure.

7.2.4 *Teletypewriter Requests*

Teletypewriter entries allow maintenance personnel to put a chain of position subsystem units (see Fig. 24) in service or out of service or operate transfer relays to switch unit halves between chains.

7.2.5 *Nixie Order Failures*

Because of the interdependence of orders in the order sequence required to establish a Nixie display, PAFR does not attempt to get failing Nixie orders to succeed. The operator will recognize that she does not have a correct display and request the display by depressing the time and charge key. If five Nixie failures have occurred within the hour, the failing chain is removed from service and diagnostics are requested on all units in that chain.

7.2.6 *Order Failures to the Service Observing Gate (SOG)*

The SOG is similar enough to a position group gate to be handled by PAFR in much the same way. If retrying the order over both buses does not successfully execute the order, the SOG half is removed from service and the maintenance personnel are notified via TTY message and the MCC lamp display. Because the loss of service observing does not immediately affect service and because the service observing system has its own established maintenance procedures, no automatic diagnostic is provided. However, a diagnostic procedure has been developed using the repetitive order sending program of the Position Access Exercise Program (Section 7.4).

7.3 *Position Subsystem Diagnostics*

The local and remote position subsystem hardware is designed such that the local subsystem can be considered a degenerate case of the remote from the point of view of the diagnostic program designer. Therefore, the discussion which follows will be concerned with the remote subsystem shown in Fig. 24.

For units in the sending chains (SGG, DAC, PSD) input test access is obtained through the sending chains themselves. Maintenance circuitry is provided to return test results from each sending chain unit as independently as possible of other sending chain units. For units in the receiving chains (RGG, PSG), maintenance circuitry controlled by signal distributor applique relays and PSD applique relays is provided to generate input test sequences to each unit. Test results are returned over the receiving chains themselves. From consideration of paths traveled by test information, several conclusions can be drawn.

(*i*) It will not be unusual for a single fault to cause failures in diagnostic tests for more than one unit.

(*ii*) If several units in a chain fail diagnostics, the failure in the unit nearer the processor is probably more significant and should be repaired first by maintenance personnel.

(*iii*) A failure in a sending chain unit is probably more significant than a receiving chain failure and should be replaced first by maintenance personnel.

(*iv*) In designing tests for a particular unit, tests over shorter or more independent paths should be run first. This leads to diagnostic designs for sending units where input tests are run first, then internal tests and finally output tests. Similarly in the RGG diagnostic, tests using RGG test inputs are run before tests using PSG test inputs.

(*v*) In designing tests for a particular unit, it is frequently desirable to terminate the test sequence after a failure in a given group of tests. To continue with a test sequence dependent on circuitry already found to fail would result in inconsistent failure patterns and a dictionary number of doubtful value.

(*vi*) As a result of (*iv*) and (*v*), the first test failure in a diagnostic is probably the most significant and should be repaired first by maintenance personnel.

In all cases where a unit has two input or output routes, the same set of tests is run over each route. Where transfer relays are involved, a common set of tests is used for the output circuitry of one unit and the input circuitry of the following unit.

The T1 carrier and the PSG present unique problems. The sending and receiving T1 carriers are standard Bell System equipments incorporated into the position subsystem. As such, they already have maintenance practices established for them. A Carrier Alarm Actions (CAAC) program has been written which supplements the existing maintenance procedures in four ways:

(*i*) provides teletypewriter reports of alarm status,
(*ii*) provides means for service removal and restoral of T1 data links as well as transfer of operator talking paths to the spare T1-B,
(*iii*) exercises transfer relays associated with operator talking paths, and
(*iv*) provides mechanization of a manual maintenance practice to isolate trouble to the local terminal, the remote terminal, or the interconnecting transmission line.

Because the PSG is an autonomous, asynchronous scanner on the remote end of the receiving chain, it is difficult to diagnose. Its diagnostic (PSGD) is relatively independent of other diagnostics, having its own control structure but sharing subsystem subroutines.

Diagnostic tests for the four remaining units, SGG, RGG, DAC and PSD are run under one control program which:

(*i*) provides common interface with the maintenance control program (MACR) and the dictionary number generation control program (DOCP),
(*ii*) initializes common scratchpad memory and critical subsystem maintenance circuitry,
(*iii*) assembles subsystem status information,
(*iv*) calls subroutines for the individual sequences of tests (called phases) for the unit being diagnosed,
(*v*) after completing a diagnostic, restores the subsystem to its state prior to the latest diagnostic but modified to reflect the results of that diagnostic, and
(*vi*) updates the master control center (MCC) lamp status.

Each subroutine for a phase initializes the circuitry to be tested prior to test to maximize the probability of obtaining consistent results in the presence of a fault.

7.4 *Position Access Exercise Program* (*PAEX*)

If a fault develops which is not detected by PAFR, the occurrence of a second detectable fault may create a situation in which a diagnostic will develop a dictionary number not appearing in the trouble location manual (TLM). This is because the TLM is generated by the insertion of single faults. Faults in circuitry providing infrequently used call processing functions or maintenance functions could cause this problem.

PAEX provides an automatic exercise which is entered once every 24 hours. All position subsystem diagnostics are run, supplemental tests are made, and the resulting data is analyzed. Any failure results in a TTY message indicating the faulty unit or failing circuit function. If all tests pass, the subsystem is reconfigured according to a predetermined sequence so that, over a period of time, units experience equal stress in different configurations.

PAEX also provides demand exercise functions to aid maintenance personnel in repairing subtle faults for which automatic maintenance is economically impractical.

(*i*) *Diagnostic Demand Program.* Any or all phases of a subsystem diagnostic may be requested once or repetitively with or without raw data printout by TTY request.

(*ii*) *Thumbwheel Switch Demand Program.* The DAC, PSD and PSG diagnostics can be requested with or without raw data printout from the thumbwheel switch located on the alarm sender frame. This allows maintenance personnel at a remote location to obtain data on a remote TTY.

(*iii*) *Remove/Restore Service Program.* This program lets maintenance personel put units in-service or out-of-service from the maintenance TTY.

(*iv*) *Repetitive Order Sending Program.* A request can be made from the TTY to have any order or combination or orders (10 maximum) sent once or repetitively to allow visual or instrument checking of circuit functions. The orders are sent via the maintenance PIB. The results from the most recent maintenance PIB execution are saved in a memory buffer. If the most recent result differs from the result obtained in the previous PIB, the number of the PIB, the number of the order, and the result are saved in a second memory buffer which has capacity for thirty such transient results. The transient buffer can be reinitialized from buffer bus keys on the MCC. The contents of either buffer can be read out on the TTY at any time. These features have been found to be particularly useful in diagnosing troubles resulting from component degradation causing marginal performance and intermittent failures.

7.5 *Position and Position Buffer Maintenance Program (PPBM)*

This program is designed to be a tool of maintenance personnel for maintaining the 100B console, the position buffer, and the position signal distributor applique circuits. In addition it controls the out-of-service state of positions with regard to signaling (not talking), insures that a position is initialized (only software) before being allowed to handle calls, and initializes a position (hardware and software) in response to a keyset request from the operator position.

PPBM will remove a position from service (*i*) if the position fails to initialize properly, (*ii*) if it is requested by a call processing program as a result of an order failure, (*iii*) if it is requested by maintenance personnel from the digiswitch, and (*iv*) if it is requested by an audit program. The out-of-service state is indicated to the operator by a flashing lamp. She then plugs out and moves to another position.

Plugging in to an out-of-service position by maintenance personnel puts that position in the maintenance mode. Any key code received from that position is passed to PPBM which then operates the position buffer relay to light the position lamp associated with that key. The operator keyset is used to input requests to test those relays, lamps and Nixie tubes which are not directly associated with keys.

If trouble with the position buffer relays is suspected, the relay card with the suspect relay is placed on an extender card so that the relays may be observed and the relays are tested by entering requests from the digiswitch. A digiswitch code is sent through the alarm sender and via the Group Gate Scan Program (GGSN) which recognizes it as an alarm to PAFR. PAFR translates the alarm, identifying it as a digiswitch code, and passes it to PPBM. PPBM translates the particular code and sends the requested order or orders. When the trouble has been isolated, the board is replaced, and the position is returned to service either by a digiswitch request or by a keyset sequence from the position.

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VIII. TSPS SERVICE OBSERVING CIRCUITS

Service Observing (SO) is handled differently in TSPS than in other systems in that the information sent to the service observing operator is taken from memory and is a repeat of the original signals. A special data link between the TSPS equipment location and the SO desk location is utilized for all signals except for the talking path. The talking path itself is also handled in a unique manner so as not to require additional trunk or link circuitry for service observing. The SO equipment is installed in the TSPS office and is subject to the same lead length restrictions on various inputs, but the drawings are part of a separate series used for traffic management and are not a part of the TSPS drawing series.

The service observing monitor circuit permits monitoring of the customer-to-customer talking connection. When it is known (by the SPC) that the next call (of a designated type) is to be observed, two link connectors are set up to reach an idle TSPS operator via an idle SO monitor circuit. An SO monitor circuit is furnished for each chief operator group and has appearances on both the trunk link and position link to permit this insertion into the talking path. The connection is shown on Fig. 25. Output from the high impedance connection provided by the monitor circuit is then sent over transmission facilities to a distant SO desk.

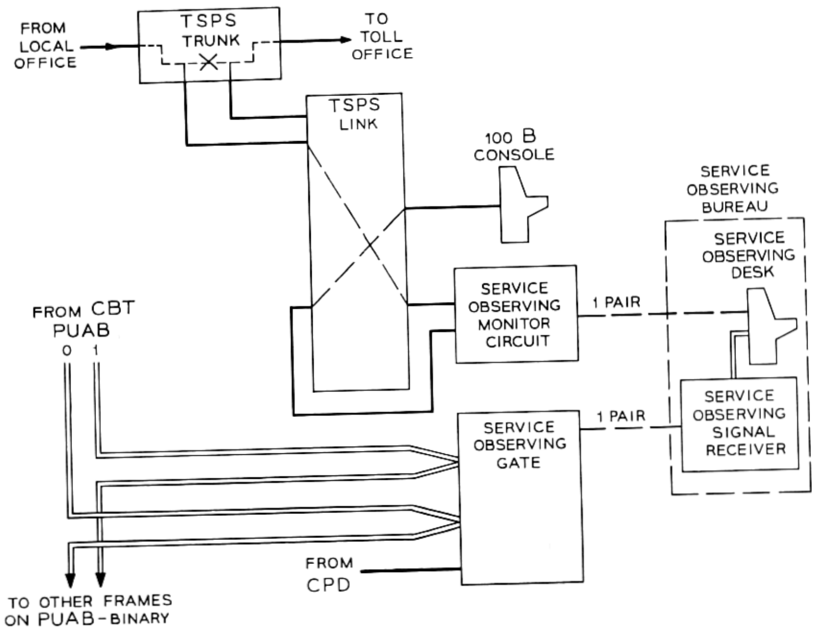

Fig. 25—Service observing data and transmission configuration.

All signaling, including dialed digits, ANI information, coin signals, etc., sent or received by SPC during the processing of the call is obtained from memory and transmitted to the SO desk to which the talking path connection was made. This is accomplished by means of the SO gate which connects to the PUA binary bus in much the same manner as a position group gate (Section 2.1). In fact the service observing gate (SOG) is treated by maintenance programs as another (the tenth) group gate. Only one (duplicated) SOG is provided per TSPS installation although up to eight SO monitor circuits may be provided.

Information received over the binary bus is temporarily stored and converted to 3 groups of 1-out-of-5 (1/5) codes. These 1/5 combinations are then sent as three frequencies over a single cable pair to the SO desk equipment. In practice, two transmissions are sent; and after reserving certain combinations for the idle (or rest) state, there are 1024 combinations available. This provides 128 combinations for each of the 8 possible SO monitor circuits and is sufficient to send all information required for service observing.

A few dc signals can be received over the pairs of wires used for the monitor circuits and these are recognized by the monitor circuits and coupled to ferrod scan points scanned by the SPC. This permits service observing operators at some remote location to indicate how many SO desks are manned and what type of calls are to be observed. Thus, observing can be concentrated on those types of calls felt to require special attention.

IX. CONCLUSION

The TSPS periphery combines the technology of existing developments, where applicable, with new designs unique to TSPS, as in the position subsystem. The necessary functions are provided in the most economical manner consistent with the needs of the Bell System for availability of TSPS and the state of the art at the time of the development.

X. ACKNOWLEDGMENT

Although the names of a few people have been mentioned, the design and development of the peripheral units and associated maintenance program required the efforts of many people in the TSPS laboratory and a number of resident visitors from Operating Companies and Western Electric.

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