An Automatic Direct Distance Dialing System

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Abstract—An automatic toll ticketing system was cut into service in Las Vegas, Nev., on November 22, 1964, providing some services never before available. The general purpose relay used in this system embodies imaginative new concepts in device design and application. The ESK relay was supported by several other highly reliable devices produced by Siemens & Halske, including EMD motorswitches and impulse repeaters. A new cordless operator position was developed to reduce both operator work time and possibility for error. Several auxiliary consoles were used for traffic administration, observation, and operator training.

INTRODUCTION

The Automatic Direct Distance Dialing System discussed in this paper was cut into service November 22, 1964. This cutterover concluded a development that had begun about 24 months earlier at Siemens & Halske in Germany and at the United States Instrument Company in Virginia to provide toll ticketing facilities for one of the leading independent telephone companies in the United States.

The system was designed to provide the latest services in automatic ticketing of telephone traffic including coin traffic, immediate time and charges read-out to major hotels, automatic charge computation, cordless type toll board, 3-, 5-, and 6-digit translation, and alternate routing. A block diagram of the equipment is shown in Fig. 1.

SYSTEM NETWORK

The system serves the city of Las Vegas and the Clark County resort area which is served by ten exchanges, four of which are multioffice units. Figure 2 shows the plan of the network. In addition, six tributaries, including the Mercury Test Site of the Atomic Energy Commission, work through the toll center. Figure 3 shows the trunking diagram of a typical tributary office. EAS (Extended Area Service) is provided for local traffic. This network is connected to nationwide facilities over approximately 750 intertoll trunks which terminate in the main exchange. The ticketing system is also housed in the main exchange and is fed over approximately 600 direct distance dialing recording trunks for distribution to the toll network. Special services are also handled over these trunks, as the information and repair services are located in the main exchange.

DESIGN CONSIDERATIONS

Storage and Switching

Inasmuch as the majority of central offices in the telephone network use motorswitch gear for switching, it was decided to take advantage of the buffer storage of the impulse repeater which is part of every impulse controller or first selector in the motorswitch CDO. The penalty of this decision was that an impulse repeater would have to be added to the offices using nonmotorswitch types of gear to maintain a uniform type of interoffice signaling.

Using buffer storage meant that a digit could be memorized in the outgoing trunk of the satellite and the same or a different digit regenerated by the trunk as required. For instance, on I level traffic the digit I is used up in local switching. However, when a trunk records the digits 2 to 9 as the first digit stored in the first selector, it recognizes this as a DDD call and programs the trunk for automatic identification. On calls with the first digit I stored in the impulse repeater of the first selector, the outgoing trunk recognizes a special service call and prepares to program itself accordingly.

Impulse repeaters are also used as buffer stores in the regular ticketer. The large quantity of ticketers made it desirable to have them occupy the least space and be as economical as possible. Each ticketer has two impulse repeaters which are operated in parallel. They store the indication whether the called number contains 7 or 10 digits, the 7-digit calling number, the 7- or 10-digit called number, the register sender number, and the class of call. Care was taken where electromechanical devices were used that all such devices were plug-in units and could be easily removed for routining.

Although the 110-point motorswitch had previously been used in the United States in central office design, the 220-point switch had not been employed. To achieve the required number of paths between the different units in the system and still retain high availability, the 220-point motorswitch was chosen to provide most of the linkage within the system.

Loop Cable Multiples

There are many units in the ticketing system which are connected together for only a few milliseconds—long enough to operate ESK relays. Because of these very short holding times, it was decided to use loop cable multiples for connecting these units. The loop cable multiple permits the use of a large number of leads from one unit to another with a minimum of wire. An electronic test unit insures that only one circuit is connected to the multiple at a time. The test multiple is seized by ground through a 3-kΩ resistance. If the circuit is seized, the test multiple returns current to the requesting circuit. The demand ground is repeatedly applied for approximately 25 ms, released, and reconnected until the multiple becomes seized.

The loop cable multiple, usually furnished in duplicate (one serving odd, the other even equipments), is installed
Fig. 1. Schematic trunking diagram, ADDDS system.

Fig. 2. Plan of the Las Vegas network.
in a loop-around manner so that removal of a unit will not interrupt continuity. It is used between register senders and the translator, data registers and the read-out and Teletype registers, outgoing DDD trunks and the identifier, and the receiving register and the steering circuit.

**Coding Methods**

Within the system, four methods of transferring information are used:

1) 2 out of 5 dc code pulsing, providing up to ten different signals
2) 2 out of 6 multifrequency coding, permitting up to 16 signals
3) 2 out of 4 dc codes using positive and negative potentials, providing up to 16 different signals
4) Ground-and-absence-of-ground pulsing, providing 14 signals.

The code sending is done at a variety of speeds. In order to maintain uniform rates of sending, an electronic time tapper and distribution frame were designed.

**System Features**

The types of calls, their access codes, and types of identification used in the system are shown in Table I.

**Cordless Switchboard**

The ATS operator position is a cordless type switchboard consisting of a top panel and a sloping panel, the latter containing lamps, keys, and combination lamp-keys. A writing panel is provided below. The ease of operation of this board is stressed. All keys are of the push-to-lock, push-to-release, or nonlocking type pushbutton; and all keys are of the illuminated type. This provides immeasurable assistance to the operator by indicating the particular key which must be depressed or the status of the call.

On the top panel are located a ticket box and a visual numerical display. The display uses the same optical principle as a slide projector. Each unit has ten lamps and when one lamp is lit, its light projects through a condenser lens, a figure on a pattern plate, and an objective lens and is displayed on a ground glass panel. The display consists of two groups of three units and one group of four units and is used for displaying either the called area and/or called number, the calling number, or the charge, minutes, and rate on coin traffic. The display is under control of the

<table>
<thead>
<tr>
<th>Type of Call: Coin and Non-Coin</th>
<th>Access</th>
<th>Type of Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Station-to-Station</td>
<td>1 plus 7 or 10 digits</td>
<td>Automatic for 1 and 2-Party; Operator for 4-Party on all calls</td>
</tr>
<tr>
<td>Sent Paid</td>
<td></td>
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<tr>
<td>Collect</td>
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<tr>
<td>Person-to-Person</td>
<td>0 plus 7 or 10 digits</td>
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<td>Sent Paid</td>
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<tr>
<td>Collect</td>
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<tr>
<td>Person-to-Person</td>
<td>0 plus 3 seconds</td>
<td></td>
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<tr>
<td>Collect</td>
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<td>Nondialable Points</td>
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**Fig. 3. Schematic trunking diagram, tributary office.**
operator, except on coin traffic when the charge and minutes are displayed automatically.

Mounted on the sloping panel are 79 keys and lamps, six timer switches, and a keyset consisting of ten digit keys plus a start and an error key. Each position has six connecting links, each link having an ACS (access) key and lamp, HLD (hold) key and lamp, a CLD (called) supervisor lamp, a CLG (calling) supervisor lamp, and TMR (timer) lamp and switch. The timer switch is arranged for 3-, 4-, and 5-minute settings. The face layout is shown in Fig. 4.

The ATS positions are double units constructed of sheet metal. The only other equipment mounted in the positions are a caligraph for timing manually-ticketed calls and terminal blocks for terminating cables from the switchroom. All cables are led from the floor through hollow legs of the positions. The relays and associated equipment for the position and link circuits are mounted in racks in the switchroom.

One supervisory position is provided for every 24 ATS positions, its construction being identical with that of the ATS position except for lamp and key arrangement. This position does not have a number display. At the top of the key and lamp panel are two rows of 24 lamps for indicating whether or not the associated ATS positions are staffed and idle, or busy on a call. Should an ATS operator make her position manually busy to incoming traffic, the associated staffed lamp will flash. Directly below these two rows of lamps is one row of 24 combination keys and lamps for connecting the supervisor to any of the 24 positions in her division, thus providing visual monitoring. This position also has six link lamps representing the ATS links. A 24-position wafer switch, plus a monitor key, provide the supervisor with audible monitoring. The supervisor can be reached from any position including that of the chief operator.

**Master Control Console**

The master control console is a single position provided for the chief operator. On the top panel are seven meters of three different types, and thirty lamps for indicating all trunks busy condition for thirty trunk groups. One set of meters is graduated in fifteen steps representing fifteen call points of a call park. One meter is provided for each call park, ONI, DDD, and TOLL. The second set of three meters is graduated in thirty steps, representing the average waiting time in seconds of the calls in the call parks. Another meter is provided to give the chief operator the percent efficiency at which her positions are working. The efficiency represents the ratio of the number of positions handling calls to the number of positions staffed. The meter is graduated in 100 divisions.

On the sloping panel of the master control console is a lamp field representing all positions; a lamp is lit if an ATS position is staffed. Also on the panel are four wafer switches, three being associated with the call parks and one is a ratio switch. The call park switch allows the chief operator to reduce the call points available from the 15 maximum to any lower number. The ratio switch will change the sequence in which the call parks are served; i.e., step 1 allows one each DDD, ONI, TOLL; step 2, one each DDD, ONI, DDD, TOLL. A total of seven sequences is provided. The chief operator can call or answer any of her supervisors.

A single position, identical to the ATS position, is provided for service observation. It has the same keys and number displays as the ATS positions and, in addition, three wafer switches and a connect key for visual monitor and one for display monitor. A lamp indicates whether a position selected is staffed. The three wafer switches are for selecting the ATS position that is to be monitored, one switch each for hundreds, tens, and unit digits of the position number.

**Control of Calls**

All types of calls are distributed over the staffed positions in sequential order. Control of this process resides in the receiving register, two steering circuits, and the toll translator. One steering circuit is used for normal incoming traffic; it memorizes 1) all positions staffed, 2) the last position served, 3) the position currently being served, and 4) selects the next position to be served. The other steering circuit is used exclusively for ONI overlap. The ATS position which requests an ONI overlap call signals the steering circuit and provides the position number to the toll translator for routing the call to the position. The receiving register receives the type of call indicator from the incoming connecting trunk, determines if a position is idle from the call park status, and then calls for the steering circuit and the toll translator. The design of the receiving register includes an arrangement for routing WH type traffic to a particular position. It also permits one ATS position to transfer a call to another particular position by keying back into the receiving register the number of the position. The steering equipment is arranged for 200 ATS positions. In Las Vegas 120 positions were initially equipped.

**Automatic Station Identification**

The automatic station identification process in this system is accomplished through a ring core number array and an automatic station detector for 2-party lines. The ring core array is designed to handle up to 40 000 stations; at the present time, the largest unit has approximately 18 000 stations. The identifier, using multifrequency 2 out of 6 pulsing, sends to the recorder office 11 characters of information: two class-of-call digits, seven calling number digits, plus the KP and ST signals. A total of 28 steps are included in the identification process of a calling number; the identification time varies depending on whether a party detector is called in or not. The individual lines are identified in approximately 2.5 seconds. The incoming sleeve lead terminals and associated ring core array are arranged in racks of 2500 terminals each. A cross-connecting field permits any terminal to be cross-connected to any class of call. In multunit offices a standby identifier is provided which alternates automati-
Fig. 4. Keyshelf arrangement of operator position.
cally every 12 hours with the main identifier. In this type of office intermediate storage units are provided to prevent the common equipment from being held during the sending of multifrequency digits.

Station detecting requires the insertion of a 0.1 mf capacitor and two silicon diodes connected in parallel with opposing polarity in series with the telephone of the second party on the line. The station detector applies a 0.3-volt potential, via a measuring resistor, to the line and determines if the station is a high- or low-resistance station, i.e., either more or less than 4 kΩ. For example, the current flowing in a station loop without diodes will be of a relatively high magnitude, the voltage across the measuring resistor will also test high, and the detector will indicate the first party station.

Automatic Ticketing

Calls originating at hotels assigned QZ numbers are processed through the ticketing gear as normal calls until reaching the data register. Here the register detects the QZ number and, in addition to calling in a read-out equipment, it will call for a Teletype register and will transfer all call data, including charges, into the Teletype register. The Teletype register will set its associated selector to the QZ terminal, connect itself to the hotel Teletype receiver, and convert the call data to Teletype codes with the aid of a series-parallel translator, transmitting the information to the hotel machine. A common Teletype receiver located in the operator room produces a local copy of the transmitted ticket. The Teletype selector is capable of connecting to 200 QZ numbers.

For automatic prepay coin traffic, a computer is necessary. The paystation ticketer is seized in the same manner as regular traffic seizes regular ticketers via 1 and 0 levels; immediately upon completion of subscriber dialing the ticketer generates a coin return signal to cause the paystation to return the coin to the subscriber. After receiving the digits from the register sender, the paystation ticketer connects itself to the computer via a multiple and gets the initial 3-minute charge. It sends this to the position storage from whence it is displayed to the operator with a CN (coin) or CNP (coin-person) lamp indication. In case the called number is not rated in the computer, the rate display will flash and the ATS operator must secure the rate code and key it into the paystation ticketer. After the operator monitors the initial deposit, she releases the ATS position and the ticketer continues with the call.

Just prior to the end of three minutes, the ticketer automatically collects the initial deposit and initiates a request for an ATS position. This time only the NFY (notify) lamp is lit. Should the subscriber wish to continue to talk, the operator will again release the ATS position and the paystation will resume timing of the call. Timing is interrupted as long as the operator remains on the circuit.

An on-hook condition received from either the calling or called subscriber signals the ticketer to connect to an ATS position and to request the computer to provide the changes. The ticketer transmits the charge due and the minutes for display to the operator and lights the CHD (charge due) lamp. The rate is also part of the information sent to the position but its display is controlled by the operator. Upon collection of the charge due the ATS position is released.

The computer contains an electronic scanner which is continuously looking for a data register or a paystation ticketer requesting service. Upon detecting a unit requesting service, it connects to the circuit and receives the called office, calling office, type of call, conversation time, and in case of paystation ticketer, the rate code if present.

The computer also receives the information that it is connected with either a paystation ticketer or a data register and if a ticketer, whether it is the initial or the overtime period. The computer receives this information in 2 out of 5 dc code and stores it on cores. The principle of the computer is simply that if a wire is threaded through the cores of the called and calling office code points, the corresponding rate cores are activated.

The rate code is then passed to a repeater and to a core field to be expanded into a 1 out of 200 output. Combined in the data field with the fixed class of call (station day rate or person night rate, etc.), the charge is sent out from this field in 2 out of 5 code when initial period charge is required. For overtime charge calls and calls from the data registers, further processing in the computer calculating section is required before the charge information is delivered to the requesting circuit.

The computer is arranged for 10 originating rate points. It is presently rating approximately 95 percent of the outgoing traffic from Las Vegas.

Major Components

ESK Relay (High Speed Noble Metal Relay)

The ESK relay was originally conceived primarily for use in switching arrays; however, later application research developed it as an excellent general purpose relay. The relay unit consists of a strip of five relays. There are four basic types: 1) four make contacts, 2) two make and two make-before-break contacts, 3) six make contacts, and 4) four make and two-make-before-break contacts. The four-make combination has an operate time ranging from 0.8 to 3 ms and the 6-spring combination operates in 1.5 to 4 ms. This is largely due to the light-weight contact armatures which weigh only 0.3 gram each.

These ESK 5-relay units, called strips, have a plastic mounting frame containing five bobbin channels and six holding channels for the flux plates, polar strips, and armature springs. The channels have grooves into which the parts are inserted from either side. The parts snap into position and interlock with each other within the channels. The comb-shaped flux plates and polar strips are inserted into the frame from different sides and at two levels, spaced apart the width of the airgap. These units overlap in the holding channels. At the same time, the channel separates the contact armatures physically from the polar strips, and thus from the mating contacts. At the point where a folded German silver spring projects from the coil, a high-grade...
ferronickel contact armature is welded. The vertical portion of the spring acts as a torsion member while the horizontal portion holds the spring in place in the holding channel of the plastic frame. Resting against the outer sides of the polar strips are German silver contact spring strips, each of which has five twin-contact springs which operate completely independently of each other. Contacts are welded to the ends of the springs at right angles to the mating contacts on the armatures. A slight offset in the spring forms produces the bias with which they rest against the polar strips and determines the contact pressure.

Each relay of the strip has an operate and a hold coil. The coils are self-supporting due to the adhering nature of the coil wire and are slipped onto the frame from both sides. The relay strips are made in two types; one where the relay contacts of the strip are connected in a multiple, the contact multiple and pole piece each formed as a single punching. The other type provides five independent relays, each having its own pole piece and contact springs. No screws or rivets are used in assembling the relay strip; assembly consists of inserting the individual parts into the frame. No adjustments of any sort are necessary.

The magnetic circuit of the relay is similar to that of a shell-type transformer. The coil is mounted on the center leg of the core. The flux branches off symmetrically at the ends of the core and closes via the two yokes (polar strips) at the front side of the relay strip. The center core is designed as a flux plate. When not excited, two contact armatures rest against the two sides of the flux plate with a slight bias. The two air gaps lie between the upper end of the flux plate and the opposite polar strips. The flux plates are coated with plastic so as to insulate them from the contact armature when the relay is operated. When excited, the contact armatures move toward the polar strips. The contacts close before the armatures touch the polar strips and when the armature completes its travel the contact forces are at their maximum value of 20 to 25 grams.

**EMD Motorswitch**

The necessity for rapid switching from one circuit to another and providing high-quality voice transmission made the motorswitch ideal as a linkage device. The motorswitches employed in this system are controlled by a marker.

The motorswitch's known advantages are: precious metal contacts in the transmission path; shock-free operation at setting speeds up to 180 steps per second; individual drive, and solderless multiple bank, all of which provide a relatively inexpensive but superior linkage. The speed is attained by an impactless motor which employs no ratchets, pawls, or stops. The motor consists of two motor magnets and two motor interrupter contacts, the motors being displaced at right angles to each other. The rotary armature is made of laminated soft sheet iron and possesses, in addition to the two main poles, two auxiliary poles to prevent dead centers. An interrupter disk is mounted on the armature spindle which operates the motor interrupter springs alternately, but in overlapping sequence as the motor rotates, thus connecting and disconnecting the motor magnets and providing continuous drive. The motor's rotary force is transmitted by a gear train, with a quarter revolution being equivalent to one step of the contact arm. To stop the switch, both motor magnets are energized simultaneously. The switch brakes with a slight oscillation which creates a wiping action on the bank contacts of those wipers which continually ride on the bank.

To achieve high-transmission quality and permit the use of precious metal in the talking circuits, a column with slip rings sits in the middle of the wipers. During idle as well as motion periods of the switch, the two middle wipers of the 4-wiper set are neither in contact with the slip rings nor the bank contacts. Only after the switch has been set are the press-on magnets operated to connect the wiper arms both to the slip rings of the column and to the bank contacts.

The entire motorswitch mechanism, setting member and drive motor, is assembled on a diecast aluminum frame. When a switch is inserted in the rack, the switch frame is precisely positioned by tapered guide pins located on the contact bank frame. The wiper arms are thereby automatically aligned with the contact bank so that adjustment in the contact bank assembly is never required.

The contact bank comprises the contact field, common to all the switches of a rack. The contact field is made of multiple strips formed into a bank assembly which is termed the solderless multiple. The multiple strip is provided with either 2 by 4 or 4 by 4 narrow, flat conductors, depending on whether a 4-arm or 8-arm motorswitch is used. The flat conductor is stamped out of brass and folded to fit around and riveted to a bakelite support. Welded to the contact points of the flat conductors facing the switch arms carrying the speech path are silver-palladium laminations. The strips of the contact field are not rigidly mounted and are vertically oriented to shed dust and make bank cleaning unnecessary.

**Impulse Repeater**

The impulse repeater is an electromechanical numerical storage device which incorporates a leaf storage principle. As used in the ticketer it can store 32 bits (2 steps per bit) of information. The 69 stainless steel radial metallic leaves are part of a rotating contact disk that is insulated from the spindle on which it is mounted. The leaves of the contact disk can ride on either the front or rear surface of an insulated guide ring fixed to the chassis. The leaves are deflected according to the condition of the marking magnet which carries a split control spring on the outer end of its armature at a point where there is a recess in the guide ring. The contact disk rotates clockwise incrementally under control of the storage magnet. A locking pawl working in conjunction with the storage magnet meshes with a gear wheel associated with the contact disk, advancing the disk one step at each release of the storage magnet. Upon energization of both the storage and the marking magnets, the leaf is depressed so as to ride on the rear side of the guide ring. Upon release of the storage magnet the leaf is
moved into the guide ring for retention of the digit bit.

In addition to the contact disk, the guide ring, and the marking and storage magnets, there is a scanning arm and a retransmission magnet. The scanning arm is mounted on the same spindle as the contact disk, rotating with the contact disk in the clockwise input direction. The scanning arm is insulated from the contact disk, and it scans in a counter-clockwise direction. Under the control of the retransmission magnet, which in turn is controlled from another relay, the scanning arm scans over the storage leaves. Operation of the retransmission magnet permits a torsion spring on the spindle of the contact disk to drive the scanning arm back over the storage leaves one-half step. The other half step is controlled by the retransmission ratchet level upon release of the retransmission magnet. The rotation of the contact disk tensions the torsion spring and operation of the retransmission magnet lifts the pressure spring off the torsion spring.

The storage and retransmission operations of the impulse repeater can be simultaneous, but as the unit is only used as a buffer store in the ticketer this feature is not used.

The components of the impulse repeater are mounted in a diecast chassis which is shock mounted on the frame to reduce noise. A 16-terminal plug is provided for electrically connecting the unit to other components of the ticketer giving ease of maintenance.

Illuminated Lamps and Keys (Switchboard Keyshelves)

The combination lamp and key device has the indication lamp enclosed in the key. The key, besides containing the indication lamp, can have up to 24 contact springs. The contacts are actuated by the guiding sleeve when the key is depressed or turned. The illuminated keys can be classified into three groups, each of which contains a number of variations:

1) Nonlocking illuminated keys
   a) push keys
   b) turn keys
   c) push and turn keys.
2) Locking illuminated keys
   a) release upon reoperation of the key
   b) release upon operation of another interlocked key
   c) release controlled from a remote point.
3) Illuminated magnet locking keys
   a) operation and release controlled electrically.

In order to assure that the lamp is visible under all conditions, even in direct sunlight, the head of the key is provided with a floodlight structure which deflects the light of the lamp from below so that it emerges focused through the top rim of the key. The illuminated rim of the otherwise colored key stands out, especially when viewed at an angle to the key. Various colored caps are used which accommodate the engraving of a designation on the top of the cap. The cap diameter is smaller than that of the head of the key so the illumination is also clearly visible from above.

The different types of keys have the same mounting dimensions and are held to a metal frame by two screws. The mounting holes for the keys in the keyshelf housing are fitted with rings which serve as dust-tight seals, while providing lateral clearance sufficient to permit easy operation of the key. Where no action is required, a lamp indicating sufficient, illuminated buttons of the same appearance and size of the keys are supplied.

The lamp used in these keys and buttons is of the bayonet-type and is easily replaceable from the top of the keyshelf.

Type 70 Relay

The type 70 relay is of a flat design which consists of a coil wound directly on a flat cross-section, 7-piece core. Each core may have as many as five inductive or non-inductive windings. The armature is also flat and has a nonmagnetic metal residual strip to prevent the relay from remaining operated from the force of residual flux.

Up to 18 springs may be equipped on each relay. The springs are made of nickel silver and are bifurcated to enable each of the twin contacts to act independently. Each spring is positioned independently of adjacent springs. The adjustment and support of each spring do not affect the adjustment of other springs in the same pile-up. The springs are mounted in a vertical plane and are so designed as to have a wiping action in their operation. Contacts are riveted to the springs which permits easy replacement in the field. Contacts normally are made of silver; however, other alloys such as platinum, gold, palladium, and tungsten are used where required. The extra length of the contact springs extends their fatigue life and reduces the chance of changes in contact pressure.

A ball-type rolling action permits the armature to move through an arc of less than one degree, ten minutes. The relay operates in a range of 8 to 60 ms and releases in a range of 8 to 250 ms.

Conclusion

This large toll ticketing installation was designed, installed, tested, and cutover on schedule in a period of less than 24 months. No major problems developed either at the time of cutover or later as the system assumed the full load of this heavily-used toll office. During almost two years of service, this system has demonstrated its ability to deliver continual high-reliability performance without requiring high maintenance effort.

This is due not only to good design but to the following inherent features of the system:

1) Solderless bank multiples of the motorswitch stages.
2) Nontrailing wipers and noble metal contacting surfaces in the voice path switched circuits.
3) High reliability of the impactless and ruggedly built motorswitch.
4) Extremely high reliability and negligible maintenance of the ESK relay.
5) Regeneration of impulses on all incoming trunks.
6) Excellent performance of the magnetic core computer.