CHAPTER 2

THEORY OF OPERATIONS

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BOOK 86
VOLUME 10
CHAPTER 2

THEORY OF OPERATION

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THEORY OF OPERATION

2-1

DOOR OPEN CIRCUIT

During normal operation, the left or right car side doors open in each car when the open signal relay left (OSR-L) or right (OSR-R) are energized—that is, when an open signal is applied to trainlines TL16 and TL18 (left side) and TL17 and TLI9 (right side).

Note: Use Table 2-1-1 as a guide to references in this section to system schematic diagram indexes. The index numbers in the text are a combination of the section letter in the table's first column and the position designation on the relevant drawing. For example, to find index D70, find D in the first column of the table; drawing 1C42445, in chapter 9 is indicated. On that drawing, find index mark 70, referenced point on the drawing.

Table 2-1-1. Guide to System Schematics

Section	Drawing Title	Drawing No.	No. of Sheets
A	Annunciators and FIMS	1C42442	10
B	Battery	1C42443	3
C	Control	1C42444	6
D	Door Operator and Indication	1C42445	13
F	Brake	1C42446	5
H	HVAC	1C42447	7
L	Interior Lighting	1C42448	5
M	Communications	1C42449	5
P	Primary Power and Propulsion	1C42450	22
T	Automatic Train Control	1C42451	3
U	Auxiliary Power	1C42452	13
X	Miscellaneous	1C42453	11

As shown at system schematic diagram index D70 through D79, the B+ opening signal trainlines are TL18 (left side doors) and TL19 (right side doors). The B- opening signal is applied to trainlines TL16 (left side doors) and TL17 (right side doors).

Both open signal relays (OSR-L for opening the left side doors and OSR-R for opening the right side doors) are on the door control relay and diagnostic unit panel. These are safety relays. When energized, the first set of normally-open (NO) contacts of OSR-L or OSR-R close, latching B+ from TL38 onto TL18 or TL19 external signal lights circuits. The second set of normally-closed (NC) contacts of OSR-L or OSR-R open, de-energizing the local control relay (LCR). See section 2-3.

The third set of NO contacts of OSR-L or OSR-R open, energizing the motor control relay's (MCR) coil circuit for the door operation—number 2, 4, 6, and 8 door operators on the left car side and door operators number 1, 3, 5, and 7 on the right car side. This can be seen in

system schematic diagram index D20 through D29, showing the control of doors 1-3. With the B+ feed circuit to the MCR coils completed, the relays are energized and the door operator motor armatures are connected for operation in the opening direction. The third set of contacts in opposite position (NC) will open, de-energizing B- from the motor control relays (MCR) by safety monitoring.

The above functions occur simultaneously. The remaining relay functions are described below. The operation of each door operator is identical. Use system schematic diagram index D20 through D29 to follow the description.

A. Door Operator Motor Circuit Activated

The motor control relay (MCR) controls the opening or closing rotation of the door operator motor. When energized, the MCR contacts transfer, and the motor armature is connected for rotation in the opening direction. Near the fully open position, the NC contacts of LS2 open to de-energize the motor. When de-energized, the MCR contacts connect the motor armature for the rotation in the closing direction. At the end of the closing cycle, the NC contacts of limit switch LS1 open and power is removed from the motor. In the opening mode, current is fed from the car 36.5 Vdc (nominal) B+ supply through the NO contacts of the energized motor power relay left (MPR), cutout switch (CO1) NC contacts, service switch (SS), emergency switch (EMS) NC contacts, and motor thermal cutout contacts to the motor field. Continuing through the motor field circuit, the flow of current passes through NC LS2 limit switch contacts, the closed NO MCR contacts, then through the motor armature to the B- line.

The motor circuit is completed and the door operator opens the door panel. At the completion of the opening cycle, NC LS2 limit switch contacts open and power is interrupted in the motor circuit.

This door opening procedure occurs at each of the left or right car side door operators when the OSR-L or OSR-R relay is activated, and all door panels on that car side are open.

B. Opening Cushion Resistor

Near the end of the opening cycle, the NO contacts of limit switch LS3 close. Closing the LS3 contacts inserts the opening cushion resistor across the door operator motor armature. This adjustable resistor causes motor braking to prevent the door panel from slamming open against the door stop.

C. Closing Speed Resistor

With the MCR de-energized, the adjustable closing speed resistor is shunted across the door operator motor armature. Adding more resistance increases door operator motor closing speed. Decreasing the resistance causes the door operator motor to run slower in the closing direction.

D. Torque Limiting Resistor

The NC contacts of limit switch LS4 open near the end of the door closing travel. Opening the LS4 contact inserts an adjustable torque limiting resistor in series with the door operator motor circuit. The torque limiting resistor is inserted in the door operator motor circuit only in the closing direction.

E. Hold Open Resistor

The hold-open resistor is a fixed-value resistor that causes the door to be electrically held open after it has been fully opened during normal operation. In the opening cycle, NC LS2 contacts open to connect the resistor in series with the door operator motor circuit, preventing the door panel from closing when the car is sitting on an incline.

F. Motor Control Relay Circuit

The motor control relay (MCR) changes the door operator motor armature connections, thus causing the door operator to open or close the door panel as described below. When the relay coil energizes, its NO contacts close and the flow of current is through the NC LS2 limit switch contacts, energizing the motor armature for rotation in the door-opening direction.

With the coil of MCR relay de-energized, its NC contacts close, and the flow of armature current is through the NC LS1 limit switch contacts. Now the motor armature is connected for rotation in the door-closing direction, and the door panel closes.

The flow of current to the MCR coils in each instance—whether for door panels 2 and 4, 6 and 8, or for door panels 1 and 3, 5 and 7—is obtained through the specific NC local control relay(s) (LCR) contacts for the left or right car side respectively (LCR2 and 4, LCR6 and 8 or LCR1 and 3 and LCR5 and 7). Current leaving the NC contacts flows through a closed signal-pole of the door operator service switch (SS) contacts to energize the MCR coil. The opposite side of all MCR coils in a specific car are connected to the B-line.

G. Motor Power Relay Circuit

The motor power relay (MPR) supplies the door operator motor circuit with the current necessary for the door operators to function. When the run relay (RR) coil de-energizes, the NC contacts energize the motor power relay. When the doors do not close within 3 seconds after the MCR de-energizes, the TDR relay energizes, and the NC contacts of the TDR open, de-energizing the MRR, which inhibits the doors from closing for 3 or 3.5 seconds. This sequence recurs until the doors are fully closed.

H. Limit Switch Functions

With a door panel fully closed and locked, the door operator limit switch contacts are positioned as follows:

- LS1 NC open,
- LS2 NC closed,
- LS3 NC open,
- LS4 NC closed, and
- PSS (PSR) NO closed.

Figure 2-1-1 illustrates the door operator's cam sequence. The door operator limit switches function as follows.

1. Limit Switch LS1 NC, Door Closing Cutout

   LS1 is a switch actuated into its open mode just before the fully closed position of the door panel. The door panel is powered closed through this switch. Power is interrupted just before the door panel fully closes. This prevents the door panel from slamming closed. The closed door panel and the door operator's circuitry are set up for the next opening cycle.

2. Limit Switch LS2 NC, Door Opening Cutout

   As the door panel nears its fully opened position, limit switch LS2 NC contacts open, and a hold-open resistor is electrically inserted between the motor field and the armature. This holds the door panel open at a reduced current rate to the door operator motor and prevents the door panel from closing when the car is sitting on an incline.

3. Limit Switch LS3 NO, Door Open Cushion

   In the door opening mode, the NO contacts of limit switch LS3 close just before the door panel is fully opened. This switch inserts the opening cushion resistor across the door operator motor armature. This causes a braking action and prevents the door panel from slamming open against the door stop.

4. Limit Switch LS4 NC, Door Edge Force Control

   Limit switch LS4 NC contacts are used in the door operator motor circuitry only in the door-closing mode. Their function is to open and to cause a torque limiting resistor to be inserted in series with the motor circuit when the door operator closing inertia is strongest. The resistor is shunted in the door opening mode and also during most of the closing cycle. Its contact is opened, as described, only during a short segment of the closing cycle.

   Inserting a torque resistor prevents the two door panels at that location from closing or locking if blocked by a minimum of 3/4 inch rod or a 3/8 inch thick by 2 inch wide flat block.

5. Panel Sensor Switch Relay (PSR) NO Contact

   This contact is open when a door panel is in the fully closed position. Switches LS1 and PSR are series-connected for all door panels on a car side to energize the door close summary relay left (DCSR-L) or the door close summary relay right (DCSR-R). NO contacts of DCSR-L and DCSR-R are series connected in trainline TL20 to provide traction interlocking. Additional sets of DCSR-L and DCSR-R contacts provide door status signals.

[1C42445 SH1(7)]

A: DOOR5013(3)

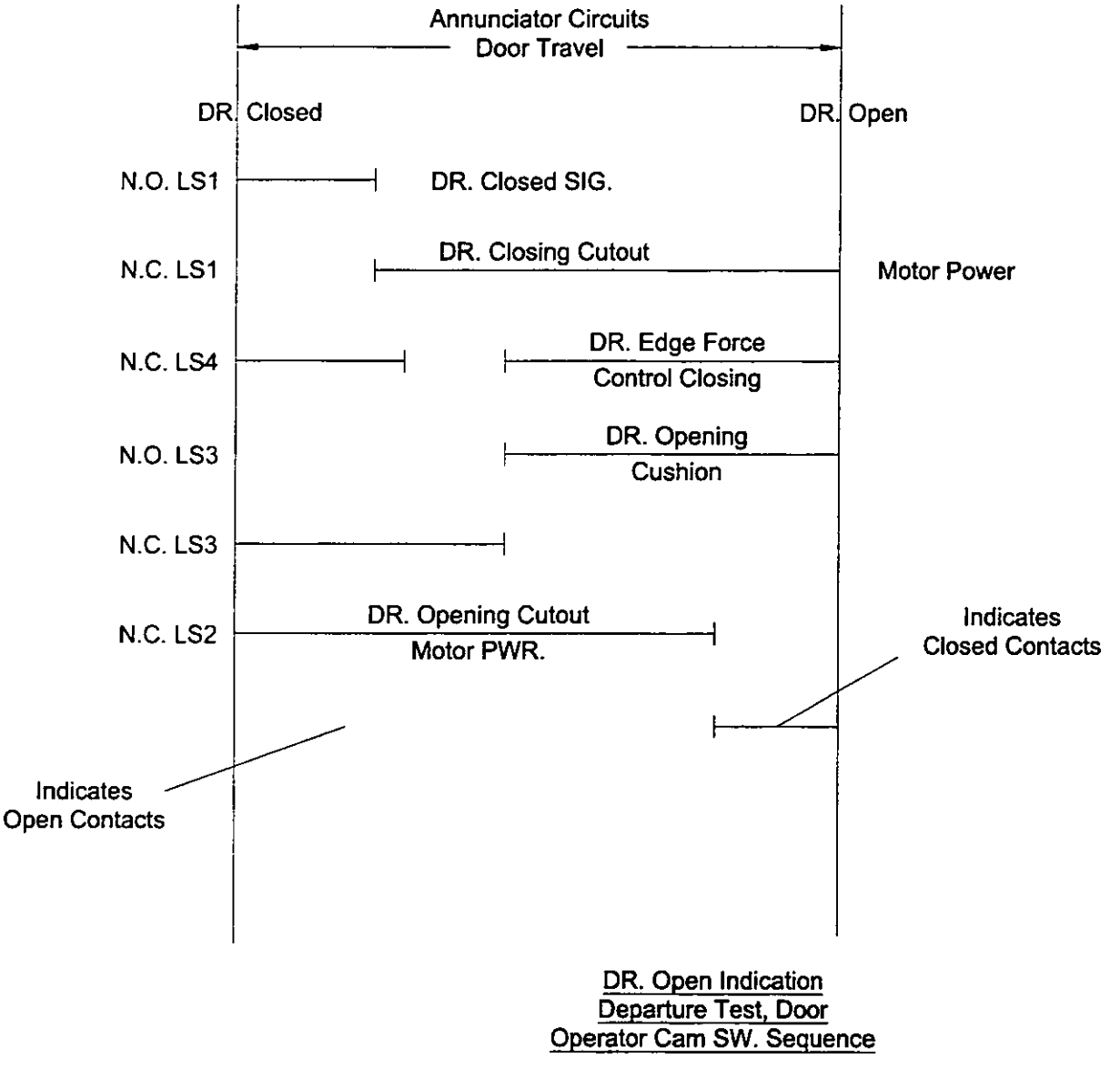

Figure 2-1-1. Door Operator Switch Sequence

EMERGENCY DOOR OPENING CIRCUITS

There is an emergency lever at each door opening on door operators 3, 4, 5 and 6. See Figure 1-1-1. For an emergency opening, the operator moves the red emergency lever (Figure 1-1-3) in the direction of the arrow to mechanically move the door operator from the over-center locked position. This simultaneously opens the emergency switch (EMS) NC contacts, interrupting power to the door operator motor.

In reading the following descriptions, use system schematic diagram index D20 through D29 for doors 1-3. During normal operation, power is continuously supplied to the fields of each door operator motor through series-connected contacts of the cutout switch (CO1), service switch (SS), MPR NO, and emergency switch (EMS) NC contacts. Activating the emergency lever disables the emergency switch (EMS), and the NC contacts open, interrupting the B+ to the motor field. With electrical power now removed from the door operator motor (closing) circuit, the door panel may be manually pushed open the remainder of its travel. Failure to open the emergency switch causes the door operator to attempt to close electrically against the manual opening force. The emergency lever only allows the door panel to be opened when the consist is stopped. If the consist is in motion, the door panel is powered closed through the emergency (EMS) NO contacts, the run relay (RR) NO contacts, and the MPR NO contacts.

In addition, each car has two outside emergency T-handle and cable assemblies. On the right side of the car, the emergency T-handle and cable are attached to door operator 5. On the left side, they are attached to door operator 4. The operation of the outside emergency T-handle and cable is identical to the inside.

Note: If power is available, the emergency lever is reset by moving the emergency lever on the door operator to the right (on left-hand operators) or to the left (on right-hand door operators) until it snaps into its normal position. As soon as the emergency switch (EMS) NC contacts close, the door operator motor activates in the closing direction and the door panel closes. If no power is available, manually close the door panel and lock it with the mechanical lock. In either case, return the emergency lever to its normal position.

DOOR OBSTRUCTION TIMING CIRCUIT

The circuit that controls the door time delay relay is shown on system schematic diagram index D90 through D99. Two parallel paths can control TDR. One path is series-connected NC contacts of open signal relay right (OSR-R), local control relay (LCRI-3), local control relay (LCR2-4), local control relay (LCR5-7), and local control relay (LCR6-8).

The second path is NO contacts of the door close summary relay right (DCSR-R) and the door close summary relay left (DCSR-L), which are connected in series. The time delay relay (TDR) energizes within 3 seconds when the doors are not fully closed. When the doors are closed and locked, DCSR-L or DCSR-R energizes and the NC contacts open, ending the 3 second timing. If the doors do not close within 3 seconds, the NO contacts of TDR close, de-energizing the motor power relay (MPR) on each door operator. The NO contacts of MPR open, interrupting power to the door operator motor circuits. After 3 or 3.5 seconds, the TDR contacts open, energizing the MPR. The doors attempt to close again. This cycle repeats until the doors are closed and locked.

Note: TDR is a repeat cycle timer. When energized, its contacts remain open for 3 or 3.5 seconds, then close for 3 seconds. This cycle repeats until the DCSR relays energize.

Note: Early production panels were designed with a 3 second timer, later panels utilize a 3.5 second timer; they are considered interchangeable.

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DOOR CLOSE CIRCUITS

The door close circuits are shown on system schematic diagram index D70 through D79. The left car side doors close when the opening signal is removed from trainline TL16 (B-). The open signal relay left (OSR-L) relay coils de-energize, causing the closed OSR-L contacts to open and removing power from the coils of the motor control relays for the left car side (MCR-2, MCR-4, MCR-6, and MCR-8). The MCR contacts transfer, reconnecting the door operator motor armatures for rotation in the closing direction. The door panels on the left car side close.

After the door panels reach their fully closed positions, the NC LS1 limit switch contacts open and power is interrupted in each door operator motor circuit. All operators' circuitry on the left car side set up for the next opening cycle.

In closing the right side car doors, the same functions occur for that car side—that is, the opening signal is removed from trainline TL17 (B-). Open signal relay right (OSR-R) de-energizes. The right side car door operators close their door panels as the motor control relays (MCR-I, MCR-3, MCR-5, and MCR-7) also de-energize.

The panel detection sensors form a series loop with summary circuits to activate (drop out) when the door panel moves in front of the sensor.

LOCAL CONTROL KEY SWITCH CIRCUITS

There is a local control key switch located inside of the car at each door opening, and outside of the car at door panels 2 and 4, 5, and 7. The switch is operated by the standard car key. This circuit can be seen at system schematic diagram index D20 through D29 (for doors 1-3). Inserting the key and momentarily actuating the switch to the OPEN position energizes the local control relay (LCR) for that opening. A NO LCR contact maintains power to the LCR coil. The appropriate motor control relays (MCR) are energized by another NO contact of the LCR.

To close the doors, insert a key in the local control switch and momentarily actuate it to the CLOSE position. In the CLOSE position, the NC contacts of the key switch open, de-energizing the LCR. The doors may also be closed by a trainline signal from central control. Energizing the open signal relay (OSR) by trainline causes the NC contact of the OSR in series with the LCR coils to open. The LCR de-energizes, and the doors may be closed by trainline.

CUTOUT AND MECHANICAL LOCK ASSEMBLY

See Figure 2-6-1. The cutout and mechanical lock assembly provides a means to mechanically lock and electrically bypass a failed door panel. This assembly locks that door panel in the closed position and bypasses its control and signal circuitry if a malfunction occurs at the operator or door panel location. When actuated to the LOCKED position, a mechanical locking bar is positioned adjacent to the back edge of the door panel with the door panel in the closed position, thus blocking any door opening movement. This prevents the door panel from being manually pushed open.

CAUTION: IF AN EMERGENCY OPENING IS REQUIRED AT A LOCKED DOOR PANEL, THE LOCKING KNOB MUST FIRST BE MOVED TO THE NORMAL POSITION BEFORE MANUALLY OPEN THE DOOR PANEL.

The mechanical lock feature has three positions and three cutout switches (CO1, CO2, and CO3) which perform certain functions when the locking knob is moved and set to any one of the three positions. This circuit is shown at system schematic diagram index D20 through D29 (for doors 1-3).

A. NORMAL Position

During normal operation, cutout switches CO1 and CO2 are positioned as follows:

- CO1 (NC) contacts are closed.
- CO2 (NO) contacts are open.

1. Cutout switch CO1 is wired in series with B+ feed-circuit to the door operator motor circuit.

2. The NO contacts of CO switch, series-connected on each car side, are open during normal operation. Each set of CO2 contacts is parallel-connected with its adjacent operator's PSS and LS1 NO contacts. When all the door panels on that side of the car close, all the PSS and LS1 switches contacts close and the door closed summery relay coil energizes for that car side. A set of series-connected NO contacts from each relay (DCSR-L and DCSR-R) closes to complete the TL20 trainline circuitry.

B. MOTOR CUTOUT Position

In this position, both cutout switches are open. Power is removed from the door operator motor circuit, and with the cutout switch (CO1) NC contacts open, manual closing of the door panel is possible. The cutout switch (C02) NO contacts remain open to retain the PSS and LS1 switches NO contacts in the door closed summery relay circuit.

C. LOCKED Position

In this position the door operator becomes inoperative, and the door panel is locked in the closed position. Cutout switch CO1 NC contacts are open, and cutout switch C02 NO contacts are closed. Power is removed from the door operator motor circuit with the CO1 NC contacts open, and the PSS and LS1 NO contacts are shunted by the closed C02 NO contacts to keep the door closed summery relay circuit operative for the remaining door operators. This retains the door closed summary relay function when the remaining three door panels on the car side open.

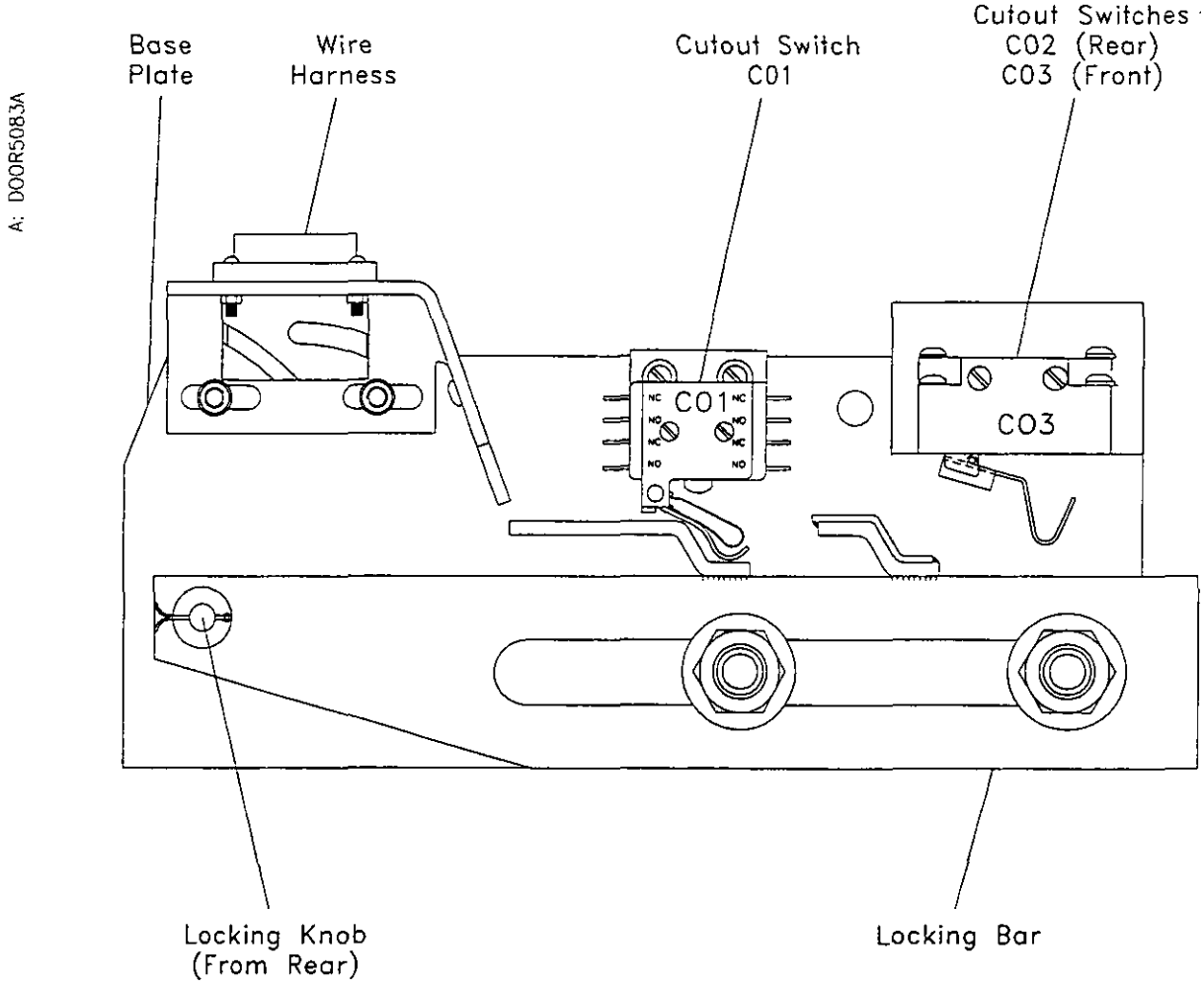

Figure 2-6-1. Cutout and Mechanical Lock Assembly

DOOR CLOSE SUMMARY CIRCUITS

The door close summary circuit is shown at system schematic diagram index D90 through D99. The DCSR-R and DCSR-L relays for each car side energize when all eight series-connected switch contacts (four PSS NO and four LS1 NO) of the door operators on that car side close. As a result, the door panels close.

As shown in system schematic diagram index D80 through D89, one set of NO door close summary relay left DCSR-L contacts connect in series with one set of NO door close summary relay right DCSR-R contacts. The contacts close to complete the TL20 trainline circuit when all the doors in a car are closed and relays DCSR-L and DCSR-R are energized.

Another set of NO door close summary relay contacts—right (DCSR-R) and left (DCSR-L), labeled NO—are used for the door open annunciator located on the operator's console annunciator panel. This circuit is shown on system schematic diagram index A77.

Note: Each set of series-connected door operator (PSS NO and LS1 NO) contacts is shunted with a set of C02 NO contacts from its related cutout and mechanical lock. The annunciator circuit remains operative if a certain door operator or door panel becomes defective and is mechanically locked and electrically cutout. In the LOCKED position, the closed C02 NO contacts bypass the series-connected PSS NO and LS1 NO contacts for that operator.

For doors that are not cut out, the annunciator light stays on from the time any door begins to open until all doors are fully closed. The DCSR-L and DCSR-R additional contacts are used for door status signal lights on the annunciator panel. (See section 2-8.)

2-8-1 SIDE DOOR

Each side-door assembly comprises two door leaves contoured to match the outline of the car body. In the open position, they are housed in door pockets in the sidewall. Each door leaf consists of a framing structure, comprising two side extrusions, a mounting bar, a lower extrusion, and a horizontal extrusion. These aluminum alloy framing members are assembled by welding. Foam panels are inserted in the spaces between the framing members. The assembly is covered by interior and exterior glued Araldite and riveted skins with a brushed finish for a uniform matte appearance.

A window frame, located in the upper half and attached to the framing members by brackets, retains the window and window seal. A locking strip locks the window in its seal and the assembly in the window frame. For safety, the window glass consists of three layers - an inner layer of clear, tempered glass; an outer layer of clear annealed glass; and a tinted PVB bonding sheet. The interior glass is also coated by a vandal proof film.

A guide strip, attached to the foot of each door leaf by screws and a guard plate, enables the door leaves to slide along the threshold. At the top of each leaf, there are two housings for the two hangers which link the leaf to the hanger tracks. These parts are hidden by two cover plates on the door leaf.

The forward edge of each door leaf has a rubber seal, male or female depending on the leaf. This seal provides weatherproofing when the leaves are closed. A seal bolted to the outer surface of each leaf provides weatherproofing on the outer surface of the leaves.

Each door leaf has an opening stop with adjustment shims. The stops are bolted to the upper part of the framing structure (the outside edge) that enters the sidewall door pockets when the door opens. Two other stops are bolted to the inner face of framing structure.

A. Door Hanger Assembly

See Figure 4-1-2 and Figure 4-1-4.

1. Door Suspension

Each door leaf is suspended from two hangers that slide along hanger tracks. From the inside, mounting plates are attached with screws and washers into the car body then into the shims which are glued to the car body. Four of the screws have lubricators. The assembly is then secured to the tracks. Each hanger track houses a ball cage and a slide. To secure the leaf, two door hangers are attached to the slide by two screws and to the door leaf.

At the center of the door opening an end-stop screw limits hanger travel. An adjustment device made up of an adjustment bracket and two screws is mounted at the door centerline between the two hanger tracks to adjust the height and perpendicularity of the mechanism. There are two more adjustment devices at the ends of the hanger track.

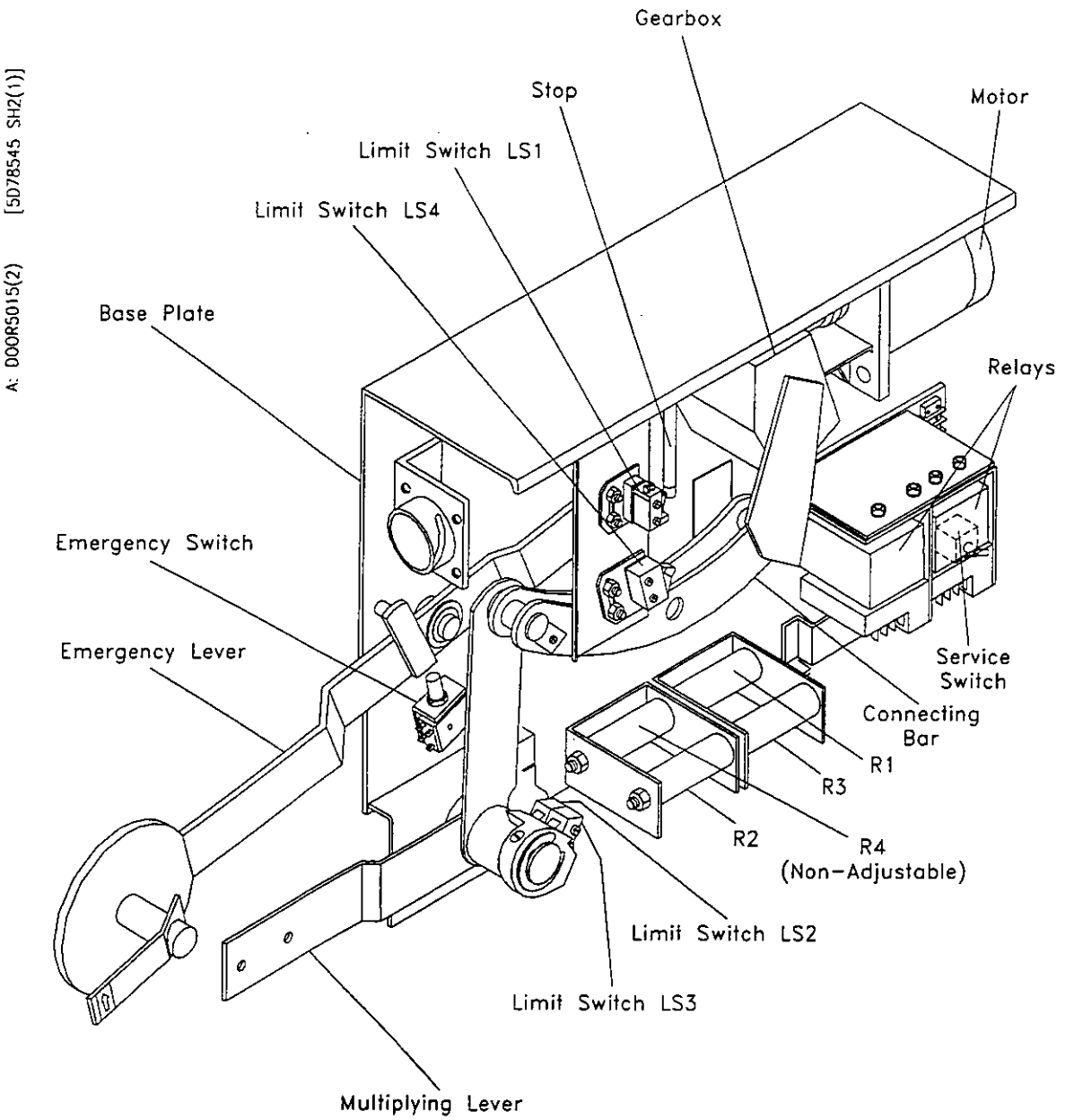

Figure 2-8-1. Side Door Operator LH with Emergency Lever

2. Threshold

The door-threshold assembly has two parts bolted to the car body at the foot of the door frame—the outer threshold and the inner threshold. The outer threshold has a groove which receives a guide strip bolted to the inside of the lower extrusion of each door leaf.

3. Extension Arm Assembly

Each door operator connects to the associated door leaf by an extension arm. This linkage comprises a clevis bolted to the door bracket, a connecting rod with a spherical bearing at each end, and a lever. This lever is bolted to the door operator multiplying lever. Shims are added, if required, between the extension arm and the multiplying lever to center the extension arm in the cutout of the vertical sidewall beam.

4. Weatherproofing

Two separate systems provided interior and exterior weatherproofing.

a. A weatherproofing system at the top of the door is mounted to the car body. A sealing brush is bolted to the car body so that the brush remains in contact with the door leaf outer skin.

b. The forward edge of each door leaf has a rubber seal, male or female, depending on the leaf. This seal provides weatherproofing when the leaves are closed. Weatherproofing on the outer surface of the leaves is provided by a folded plate bolted to the outer surface of each leaf. When the door leaf is closed, this seal stop mates with a vertical seal located in an extrusion and mounted to the car body.

Two interior flat seals are held in place by two retainers bolted to the car body. These seals provide weatherproofing between the car interior and the door pockets with the door leaves in open or closed position and the top of the door frame.

5. Mechanical Lock

There is a locking mechanism on each side of the door frame. These mechanisms lock the door leaves closed if the normal closing mechanism fails.

B. Door Operators (Figure 2-8-1).

Each door operator is a set of components bolted to a welded base plate. A motor drives a gearbox, which in turn drives a connecting bar through the action of a cam. The connecting bar transmits the movement to a multiplying lever. The extension arm, which opens and closes the door leaf, is bolted to the multiplying lever. This linkage operates a set of limit switches (LS1, LS2, LS3, and LS4) that receive or transmit electrical signals. A service switch turns off the door operator for maintenance. Both types of door operators—with emergency lever and without emergency lever—are bolted to a mounting bracket welded to the car. Door operators with emergency levers have an emergency switch operated by the emergency lever. See Figure 1-1-1 and refer to drawing 5D78545.

1. Doors with an emergency handle are LH door 3, RH door 5, RH door 4, and LH door 6.

2. Doors without an emergency handle are RH door 1, LH door 7, LH door 2, and RH door 8.

C. Electrical Description (See Figure 1-1-4 and Figure 1-1-5)

1. Controls and Annunciators

a. Annunciator Panel (Operator Console A2 car)

The DOOR OPEN annunciator light is red when a door is open on the consist, regardless of operating mode. It turns off when the door is closed or cut out.

b. Control Panel (Operator Console)

The HOLD DOOR CLOSED control button overrides the signal which commands automatic door opening. This button *must* be held down. If released during the automatic opening sequence, the doors open.

c. External Trouble Light (ETL) (A2/B2 cars)

ETL illuminates when any door in the car is open or when the door-closed summary relay fails to pick.

d. Car Control Panel (A2/B2 cars)

FIMS displays the status of all side doors (open or cutout) on the door status screen. The DOOR SYSTEM button lights red when a door is open.

e. Door Control Panel (left or right)

1) The DOOR RELEASE button lights amber to indicate that the consist has been released from the station. Doors may now be manually closed.

2) The OPEN button opens the doors in yard manual mode.

3) The CLOSE button closes the doors (all modes).

4) The HORN button operates the electric horn.

5) The STOP button emergency stop switch inhibits propulsion.

f. Circuit Breaker Panel (on car control panel)

The doors' circuit breaker supplies power to entire door system.

g. Auxiliary Control Panel Bypass Switches

There are two bypass switches - a zero-speed bypass and a door-closed bypass.

The door-closed bypass switch is mounted on the bypass switch panel on the A2 car.

2. Side Door Control and Annunciator Circuits (Figures 4-1-2 and 4-1-4)

The door opening circuit consists of the following components.

a. The four door operators adjacent to door leaves 3, 4, 5 and 6 each have an emergency lever.

b. The four door operators adjacent to door leaves 1, 2, 7, and 8 do not an emergency lever.

c. There are two door control panels in the A2 car cab.

d. Four emergency manual switches (EMS), associated with the emergency door levers, are integral to operators 3, 4, 5, and 6. These switches cut power to the motor, allowing doors to be opened manually.

Note: The EMS does not function when the car is in motion.

e. There are four key switches (KSI) inside the car, adjacent to door leaves 1, 4, 5, and 8. These three-position switches operate as follows:

1) center position (normal operation),

2) CLOSE position (counter clockwise), and

3) OPEN position (clockwise).

f. There are two outside key switches (KSO) on the exterior of the car, adjacent to door leaves 4 and 5. These three-position switches operate as follows:

1) center position (normal operation),

2) CLOSE position (counter clockwise), and

3) OPEN position (clockwise).

g. The eight 2-position cutout switches and mechanical lock operate as follows.

1) The position closest to the aisle is for normal operation.

2) The position toward the car body is a locking function.

h. Eight 2-position service switches (NC) disconnect power to the door operator for maintenance.

3. Door Control Relay Panel (DCRP) and Door Diagnostic Unit (DDU) Assembly

The passenger compartment has an equipment rack to the left of the X-end door. This rack supports the door control relay and door diagnostic unit panel and associated wiring.

4. Side Door Circuit

The side door circuit is disabled unless the operator inserts the master key in the key switch on the right side panel of the console. When the operator inserts the master key into the key switch to operate the consist, key switch relay KSR picks up and allows trainlines TL18 or TL19 (open left-open right) to be energized.

a. Door Open Circuits

As soon as the consist stops, the zero speed relay (ZSSR) picks up and the run relay (RR) drops out. All door key switches, inside or outside, are in center position for normal operation.

When the lead car's ATC commands platform side doors to open, the trailing car's ATC gives power to LPR or RPR relay, which energizes trainline TL18 or TL19. The leading car energizes trainline TL16 or TL17 from LDR or RDR relay contact. Then OSR-L or OSR-R relay energizes the MPR relay, and the contacts of these relays supply the door operator motor armatures with 36.5 Vdc in the opening direction through the MCR relays.

Before the door leaf is fully open, the NO contacts of LS3 close and connect a high-powered damper resistor that reduces door opening speed to prevent slamming. As soon as a door leaf reaches the end of its travel, the contact of NC of LS2 opens to cut power to the door operator motor.

b. Door Close Circuits

When the operator presses the side door closing button (right side or left side), the contact of LDR opens and OSR-R or OSR-L is deactivated, cutting power to the MCRs. This action opens its contact and cuts off power to the MCR. The MCR contacts then supply the door operator motor armature with 36.5 Vdc in the closing direction. Initially a high torque is applied, then the NC contact of LS4 opens and a torque-reducing resistor is inserted. As soon as a door leaf reaches the end of its travel, the NC contact of LS1 opens, and power is cut to the motor. Activation of LS1 also closes the NO contact to complete the door close summary circuit. When the doors are locked closed, all circuit components are armed for the next cycle.

c. Door Closing Summary Operation

In normal operation, the closing of door leaf commands the contacts of the PSS and LS1 to pick up the door closed summary relays DCSR and maintain the electrical continuity of the line. This relay is also picked up when the cutout switches are in the locking position, with contact CO2 closed.

d. Time Delay Circuit Operation

Activating the mechanical door cutout switch also electrically bypasses PSS and CS1 to complete the summary circuit.

If it is impossible to close one or more door leaves for more than 3 seconds during a closing cycle, TDR is excited and its contact enables power supply to the motor power relays (MPRs). This causes a 3 second power cut in the motor control circuit through the action of the NO contact of the MPRs. TDR then attempts to close the door at 3 second intervals until it is fully closed.

If an obstruction prevents the door closing at the first attempt, after 3 seconds the door can be opened manually to clear the obstruction (See paragraph D.2 below.) The presence of the contacts of LCR1, LCR2, LCR5, LCR6, or of OSR-L or OSR-R in the time delay circuit inhibits TDR during the door opening cycle on the side in question.

D. Electrical Operation

1. Side Door Control Circuit

The side door control circuit can operate in one of three modes that correspond to the operating modes selected by the operator at the operator's console. The modes are automatic, road manual, and yard manual.

a. In the automatic mode, the consist receives a side-door opening signal from ATO as soon as it comes to a complete stop at the station. The side doors must be manually closed after a delay determined by wayside equipment.

b. In the road manual mode, a command from ATO also triggers side door opening. In road manual mode, however, the operator initiates the command to open and close the side doors by using the right-door or left-door control panel.

c. In the yard manual mode, the operator is solely responsible for opening and closing the side door. The operator controls the doors from the left-door or right-door control panel, depending on the consist alignment with the platform.

2. Emergency Opening Circuit Operation

When the consist stops, the emergency lever, accessible by opening its access door, can be used to open the EMS switch which cuts off power supply to the door operator motor. Continued action on the emergency lever

after this point opens the door. When the consist is running, the run relay and MPR are closed even if EMS is actuated. Manual operation is prohibited. The operator disables manual opening through continuity of power to the motor which keeps the doors closed.

3. Auxiliary Control Circuit Operation

   a. Exterior Control

      As soon as the outside key switch is turned clockwise, the corresponding LCR is picked up and sets up a latching circuit.

      The contacts of this relay pick up the MCR to supply the door operator motor with power in the opening direction through the MPR relay. If the key switch is set to CENTER, the door leaves remain open. If the switch is set counterclockwise, the LCR latching circuit opens. The LCR drops out and cuts off the power to the MCR. The door operator motors then close the doors.

   b. Interior Control

      To perform this function, use the inside key switch next to door leaves 1, 4, 5, and 8. The control logic is the same as for the outside key switch (paragraph a, above).

4. Mechanical Locking Feature

Each door leaf has an electro-mechanical locking feature controlled by a two-position cutout actuator that activates two switches. Table 2-8-1 lists the contacts of those switches. The switch positions are NORMAL and LOCK.

   a. The NORMAL position maintains continuity of power supply to the door operator motors.

   b. The LOCK position functions if a failure occurs in the normal locking system. When the switch is in this position, the locking bar is placed across the back edge of the door leaf, preventing manually opening the door.

Table 2-8-1. Switch Contact Activation of Cutout Switch

Cutout Switch Modes	Cutout Switch Positions	
	CO1	CO2
NORMAL	X	O
LOCK	O	X
X = contact made O = contact open		

2-8-2 END DOORS

The end door assembly comprises two planar leaves, each with a window mounted in its upper half (see Figure 2-8-2). Each leaf retracts into a door pocket on each side of the door frame. The door pockets are located between the end sheathing and the end equipment structure. There are sliding end doors on both ends of the B2 car and the X-end of the A2 car.

A window frame welded to the framing structure houses the window seal into which the window is inserted with a locking strip. For safety reasons, the window consists of three layers. These are an inner and an outer layer of clear glass and a tinted PVB bonding sheet. A vandal proof film is also used.

A guide strip is bolted to the foot of each door leaf by four screws and two guard plates and enables the leaves to slide along the threshold. The forward edge of each door leaf has a rubber center seal, male or female, depending on the leaf. Two handgrips are attached by an insert nut with a screw at the front of each leaf, one on the outside and one on the inside. One hand grip is slightly higher than the other.

A. Installation

1. Door Hanger Assembly

   Each door leaf is suspended from two hangers (end hanger and center hanger) that slide along a hanger track. The track is bolted to a folded section welded to the car body. The assembly is identical on both door leaves, except that on the right leaf the center hanger has a drive link. The cable is attached to this link by two turnbuckles.

   A pulley is located at each end of the hanger track. These pulleys are attached to the track by a bolted-on support and a retaining ring, and they guide cable travel.

2. Weatherproofing

   The end doors have three separate weatherproofing systems.

   a. Each door leaf has a center seal, male on the left leaf, female on the right. In addition to providing weatherproofing when the leaves are closed, these seals act as stops during the closing operation.

A: DOOR5000(2) [5D78477 SH2(16)]

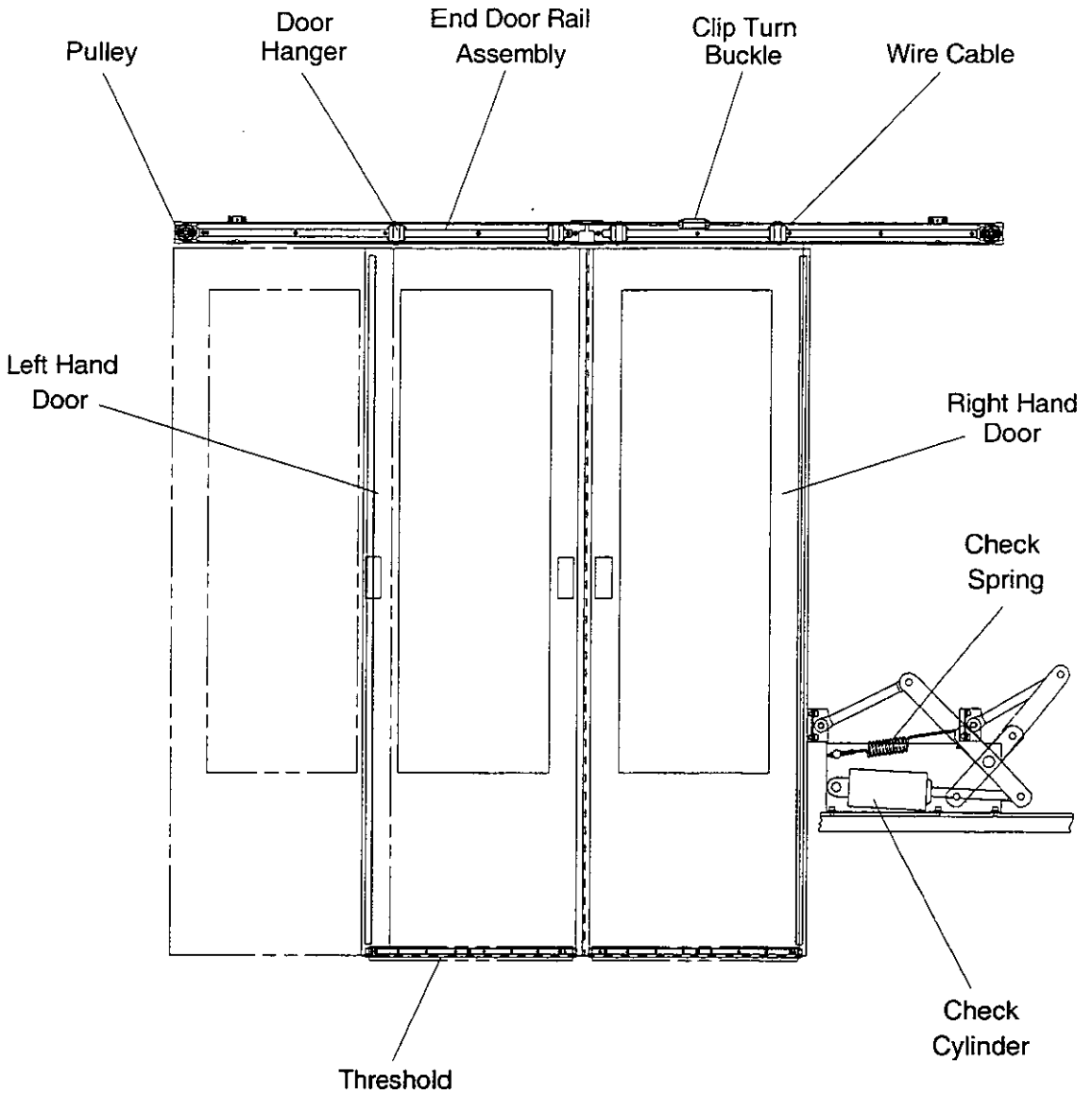

Figure 2-8-2. End Doors

b. A further weatherproofing system at the top of the door includes a sealing brush bolted to the car body, and an inner top seal held in place by a retainer bolted to the car body interior over the full width of the door.

c. Each door pocket is weatherproofed by two vertical seals. These seals are mounted to the car body interior and exterior respectively at the back edge of the door leaves (1 and 2), and they have retainers. These seals cover the full height of the door frame. Each door leaf also has a seal stop of the inner side. This seal also covers the full height of the door frame, and it reinforces the weatherproofing provided by the vertical seals.

3. Threshold

The threshold is a single-piece construction. It mates with the door leaf guide strips. It is attached by nine screws to welded-on folded sections.

4. End Door Check Assembly

The end door check assembly provides a push-to-open, spring close arrangement. The assembly consists of a pneumatic check (air) cylinder, lever and connecting rod assembly, base plate, extension spring, and bracket assembly.

B. Mechanical Operation

By opening the end door, passengers can move from car to car. To open the door, use the hand grip to slide one of the leaves into its pocket. The opposite leaf opens simultaneously through the action of the cable drive mechanism. The door check cylinder damps the door leaf to prevent slamming.

2-8-3 CAB DOOR

A. Configuration

The cab door is located at the Y-end of the A2 car passenger compartment and is constructed of a framing structure consisting of two side members with two horizontal members, welded to the side members. Within this outer framing structure is an inner structure consisting of two vertical channels, two horizontal channels, and a center channel. The outer framing structure is covered by outer and inner panels that have a smooth finish. The spaces in the inner structure are filled with foam panels.

The center section of the door contains the window seal in which the window fits. A locking strip holds the seal in place. The window has three layers - clear annealed glass, clear semi-tempered glass, and a bonding sheet of tinted PVB. A vandal proof film is also attached on the outside (faces passengers when closed).

The door has a double latched lock and handle on the cab side. On the passenger compartment side, the door is latched by a tubular handle and a lock. A catch on the door edge prevents the door from moving when closed. An air grille in the lower half of the cab door exhausts stale air from the cab.

There are three catches on which to hang a curtain. The catches are mounted to the upper half of the door above the window on the cab side by two screws and two washers each.

B. Mounting

The cab door is mounted on a piano hinge that is bolted to the cab bulkhead. It can swivel through 90 degrees. The seat stops the door from opening any wider.

C. Operation

Only BART personnel can open or close the cab door. It can be opened by its handle if the latch is unlocked with the standard car key. It locks automatically when pulled closed.

2-9 DOOR DIAGNOSTIC UNIT (DDU)

2-9-1 INTRODUCTION

The door diagnostic unit (DDU) monitors the operation of the door operating system. It does this by monitoring the state of relays and switches within the door control relay panel and on door operators together with the trainline signals concerned with control of the doors. The DDU processes these input signals and logs faults or operating anomalies. Refer to drawing 6D56953 in chapter 9.

The DDU is connected to the door relay panel by an array of Phoenix connectors around the perimeter of the I/O board and an internal harness, from which it draws its operating power supply (P5-1, P5-2). A second supply is routed through the portable test unit (PTU) key plug, when connected to receptacle DJ-3 on the door control relay panel and diagnostic unit. This supply is fed back into the DDU, where it powers the DDU's output circuits when it is used to exercise the door control system.

The DDU can be used on either A2/B2 cars or C2 cars. To enable the DDU to differentiate between the two, a second connection is made to the I/O printed circuit board at P5-16. For A2/B2 cars, this input is low (negative). For C2 cars, it is high (positive).

The DDU circuits use TTL/CMOS devices, operating on logic (low) voltages, whereas the inputs to the DDU are 36.5 Vdc nominal. The DDU therefore reduces these inputs to logic levels of voltage.

The DDU has two logs where it stores data from the door operating system. One contains fault data and the other contains status data. Entries in both these logs are tagged with the four-figure car number, date, and time (PST) of occurrence. The PTU can be used to download, display, and delete (*fault only*) the contents of these logs (500 entries each). Entries to the logs are made on a first in, first out (FIFO) basis. That is, when the log is full, entry 1 is overwritten by entry 501. Fault log entries caused by doors opening while in yard manual mode are logged in the status log, which cannot be reset. The status log is a FIFO log, to prevent overwriting. In this case the next entry is overwritten instead.

In addition to the two logs, the DDU provides other indications by means of external LEDs.

The DDU performs a self-test on power-up. The PTU can be used to check the status of this test. The self-test may also be initiated by the PTU and the result displayed on it. Internal faults in the DDU are recorded in the unit's status data log.

2-9-2 DOOR CONTROL SYSTEM OPERATION OVERVIEW

The OSR-L or OSR-R relays send the door open signal for the left or right side of the vehicle. LCR relays 1 through 4 command door pairs to open. The OSR or LCR relay must be energized to open a door set. De-energizing either of these relays results in loss of the signal and causes the doors to close.

The run relay (RR) activates when the car speed exceeds two miles per hour. When energized, the RR removes the supply to the other relays in the door relay panel. This causes the doors to close due to loss of open command signal. In normal operating mode, propulsion power is inhibited by a door opening. The recording of fault or status data is not affected by the operating mode of the car.

If a door does not close within three seconds of the open signal being removed, the time delay relay (TDR) energizes the left or right slave relay (S.R.) for 3 or 3.5 seconds, which removes the supply to the door operator motor for 3 or 3.5 seconds. When the TDR energizes, a contact closure is made to the PA system to toggle the door obstruction warning messages. This cycle of removal and application repeats until the obstruction is removed and the doors close.

When all the doors on one side of the car are closed, the door close summary relay for that side of the car energizes.

2-9-3 FAULT DATA LOG

The DDU detects and records the following faults in the fault log.

- Door (#) opened without command.
- Door (#) closed without command.
- Door (#) cut out.
- Door (#) did not open when not cut out.
- Relay (identification) changed state without command.
- Relay (identification) did not change state with command.

These faults may result from the failure of a discrete component in the door relay panel which can be identified by the PTU when connected.

When a fault is logged, a snapshot of the inputs to the DDU from the same side of the car on which the fault occurred is included in the log. If a door opens on the wrong side of the car (e.g., left side when right side is commanded), the snapshot includes the inputs from both sides of the car.

Trainline operation of doors in yard manual also includes information from both sides of the car as well as trainline status information.

2-9-4 STATUS DATA LOG

The DDU detects and records the following faults or operating anomalies in the status log.

- Door (#) did not close. (There is an obstruction.)
- Door (#) opened too fast.
- Door (#) closed too fast.
- Door (#) opened too slow.
- Door (#) closed too slow.
- Door (#) open when hostle X is active.
- Door (#) open when hostle Y is active.

Unless the DDU is operating in response to commands issued from the PTU, only five occurrences of the same fault are recorded in the status data log to preserve space.

A door obstruction fault is not recorded until the TDR and SR cycles the door for 300 seconds (five minutes).

The opening and closing times of the doors are based upon the dc voltage being at or close to its nominal 36.5 Vdc. If the voltage falls below 30 Vdc, the door moving times is slower than those specified and door speed faults are ignored.

2-9-5 LED INDICATORS

There are four visible LEDs mounted on the I/O printed circuit board (circuit references CR 2, 4, 5, 7). The following paragraphs explain their functions.

A. The red POWER APPLIED LED lights when the input power supply to the DDU is more than 22 Vdc and goes out when the power supply is below 22 Vdc.

B. The red UNIT ACTIVE LED flashes on and off when the DDU is operating and the input voltage is more than 22 Vdc. It is extinguished at all other times.

C. The green DOORS CLOSED LED lights when both door-closed summary left (DCS-L) and door-closed summary right (DCS-R) relays energize—that is, when all doors are detected closed. This LED is extinguished when either relay de-energizes.

D. The red FAULT REPORTED LED lights when a fault occurs and is recorded in the fault log. It is extinguished when the fault log is cleared via the PTU.

2-9-6 INPUT SIGNALS

Table 2-9-1 lists the inputs the DDU receives from the door relay panel. (This table is currently under revision.)

Table 2-9-1. DDU Input Signals

P1-18	Door 2 armature input	P5-16	A/B-C2 mode input
P1-19	Door 4 armature input	P5-17	Door closed summary in (trainline signal)
P2-18	Door 6 armature input	P5-18	Door closed summary out (trainline signal)
P2-19	Door 8 armature input	P6-1	Open signal relay - left (OSR-L) status
P3-18	Door 1 armature input	P6-2	Open signal relay - right (OSR-R) status
P3-19	Door 3 armature input	P6-3	Run relay (RR) status
P4-18	Door 5 armature input	P6-4	Local control relay 1 and 3 (LCR1&3) status
P4-19	Door 7 armature input	P6-5	Local control relay 2 and 4 (LCR2&4) status
P5-1	+36.5 Vdc	P6-6	Local control relay 5 and 7 (LCR5&7) status

Table 2-9-1. DDU Input Signals

P5-2	36.5 return	P6-7	Local control relay 6 and 8 (LCR6&8) status
P5-8	Door open left (trainline signal)	P6-8	Time delay relay (TDR) status
P5-9	Door open right (trainline signal)	P6-9	Door close summary relay - left (DCSR-L) status
P5-10	Door open left return (trainline signal)	P6-10	Door close summary relay - right (DCSR-R) status
P5-11	Door open right return (trainline signal)	P6-11	Slave relay left (SR-L) status
P5-12	Yard mode hostle X (trainline signal)	P6-12	Slave relay right (SR-R) status
P5-13	Yard mode hostle Y (trainline signal)	P7-2	RXD232
P5-14	Yard mode hostle X and Y return (trainline signal)	P7-3	TXD232
P5-15	Run mode	P7-5	GND

The P5 connection of the door closed summary ensures connection of the DDU to the car harness. The door closed summary signal does no more than enter pin 17 and exit pin 18.

2-9-7 OUTPUT FUNCTIONS

The DDU can generate command signals to the door relay panel which activate the relays of that panel and thus operate the door controls. This facility is only enabled with the PTU key harness connected to DDU receptacle DJ-3, as the power supply for the output drivers is routed through it. The following paragraphs describe the output signals.

A. The run relay (RR) energize signal removes the power source to all other relays, thus closing the doors due to loss of open command signal.

B. The local control relay 1-3 (doors 1 and 3, LCR1 and LCR3) open signal commands door leaves 1 and 3 to open.

C. The local control relay 2-4 (doors 2 and 4, LCR2 and LCR4) open signal commands door leaves 2 and 4 to open.

D. The local control relay 5-7 (doors 5 and 7, LCR5 and LCR7) open signal commands door leaves 5 and 7 to open.

E. The local control relay 6-8 (doors 6 and 8, LCR6 and LCR8) open signal commands door leaves 6 and 8 to open.

F. The left and right slave relays switch the power to the door operator motors.

When the power supply of the output drivers is removed by disconnecting the PTU key harness, the drivers have no effect on the DDU or door relay panel circuits, thus avoiding the generation of false command signals to door relay panel components.

2-10-1 INTRODUCTION

The PTU for the DDU is a Microsoft® Windows 3.1 compatible application providing a diagnostic and exercising interface to the DDU. The application runs on a laptop computer and is used to test, monitor, and troubleshoot the car's door relay panel. The PTU receives, deciphers, and displays information from the DDU and may also be used to control the door system for testing purposes.

2-10-2 SOFTWARE

The PTU software program communicates with the embedded software in the DDU. The PTU software performs the following functions:

- user identification input and recording,
- downloading and saving recorded information from the DDU,
- displaying and defining the downloaded information,
- deleting information downloaded from the DDU,
- initiating built-in testing of the DDU,
- receiving and displaying results of built-in testing of the DDU and indication of failed LRUs,
- controlling operation of the door system,
- receiving and displaying states of door system devices during test,
- receiving software version from the DDU,
- receiving checksum from flash memory from DDU,
- transferring variable values to the DDU, and
- verifying proper vehicle type for mode of software operation.

A. Functional Description

When connected to the DDU, the PTU initializes and establishes communications. If this is unsuccessful after 15 seconds, an error message appears on the PTU screen.

Note: Even without the DDU interface, the operator can then bypass the communications error message and display the DDU information previously uploaded to the PTU.

When communications is established, information is uploaded from the DDU to the PTU. This includes the DDU software version, value of checksum in memory, and the car number.

The operator is then prompted to enter his or her employee identification number, after which the built-in test of RAM and ROM may be run or bypassed. If the test is run, the DDU shuts down for an automatic setup for the test. This is flagged on the screen for the run test or bypass option. The test results are displayed on the PTU screen.

1. If the **File** option is chosen from the task bar at the top of the screen, the PTU can be used to download the contents of the DDU fault and status data logs. The number of faults in the memory is displayed on the PTU at all times. The data downloaded is stored in a data file in the PTU. This may be on the PTU hard disk or a floppy, the latter being the default medium. The data can be examined later, either on the PTU or on a desktop computer loaded with the PTU software. The data file includes the operator's identification.

   After downloading is complete, use the PTU to clear the DDU data logs, returning them to their original empty state. This cannot be done before the data is downloaded; if it is not done, the logs continue to accept new data as before until they are full.

   The data is also translated into English phrases that define the faults. These phrases, along with the time (PST) and date of occurrence are then displayed on the PTU screen (scroll through the display).

   With the PTU connected to the DDU and communications established, the door operators can operated and monitored. To achieve this, connect the PTU key harness to DDU receptacle DJ3. The harness is a multi-pin connector configured to mate with receptacle DJ3 on the DDU, with a wire link shorting pins A and C in the connector. Without this, the DDU's output drivers do not receive power, and the PTU can only act as a monitoring device.

2. If the **Test** mode is selected from the task bar, the PTU displays test screens which guide the technician through the testing process. Tests may be performed on only one door or on a number of doors together. The PTU screen displays the status of the devices under test. These include trainline signals, car battery voltage level, and components of the door operator(s) and relay panel.

   The command selected from the screen will operate relays on the relay panel, which cause the door or doors to operate. A message is displayed, warning the technician that the door(s) is about to open.

The technician may select all sequential doorways or a single doorway to cycle open and closed under automatic control of the PTU. The range of the number of cycles is from one to continuous. If more than one cycle is selected, a **Stop** button appears so that the exercise may aborted. When one doorway to cycle once is selected, the time taken to open or close are displayed.

To update variables within the DDU, select **System Parameters** from the task bar. The screen displays allow the technician to make changes to the car number, date, and time (PST).

The final selection on the task bar is **Help**. Access this selection from any screen. The **Help** screens provide:

- operating instructions for the PTU program,
- safety and operational warning where appropriate,
- definitions of all variables displayed, and
- diagnostic help aids.

The diagnostic help aids are linked with the fault name and/or the results of control actions. If a fault is displayed or a control error occurs, the reason for that failure is displayed when requested. The diagnostic messages show a clear path which leads to the failed LRU. If necessary, the help message boxes explain how and where to connect measurement tools to aid in troubleshooting to the LRU. Instructions are also included, such as:

> Toggle the door open and closed, then look at relay DCSR and verify that it did not change state when commanded.

Other help screens are available which provide instructions for the adjustment of doors.

B. Fault Identification

The fault and status data in the DDU logs is binary information indicating the presence or absence of faults or activity state in the door system. Setting a fault or status data to TRUE or 1 indicates the presence of the fault or device active. Setting it to FALSE or 0 indicates the absence of the fault or device inactive.

When a fault is detected, a snapshot is taken of the inputs to the DDU from the same side of the vehicle that the fault occurred and is recorded in the fault table. (When a door(s) opening on the wrong side of the vehicle is the fault, the snapshot includes data from both sides of the vehicle.) When the PTU scrolls through the fault table, the status of all inputs relating to the side of the vehicle on which the fault occurred is extracted from the snapshot data and displayed. The data includes the door number, faulty system (such as door operator or door relay panel), time and date of the fault occurrence, and car number.

When a failure has more than one potential cause, messages are displayed which prompt a check of all possible causes. The following entries are two examples of such messages.

> Check and clear door track and/or threshold of debris.
>
> B+ not present at door (#). Check service switch or motor has failed.