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SOAC

STATE-OF-THE-ART CAR DEVELOPMENT PROGRAM FINAL TEST REPORT

VOLUME 4: SIMULATED DEMONSTRATION TEST

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(A division of The Boeing Company)
Surface Transportation Systems Branch
Philadelphia, Pa. 19142

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The Simulated Demonstration Test of the State-of-the-Art (SOAC) two-car train was conducted at the Department of Transportation High Speed Ground Test Center (HSGTC), Pueblo, Colorado. The purpose of this test was to enhance the probability of trouble-free operation of the SOAC in the demonstrations to be held in five U.S. cities which have rail rapid transit systems.

An operating profile that was a composite of the five demonstration cities routes was set up on the UMTA Rail Transit Test Track. The maintenance plans and procedures for SOAC operation in the demonstration cities were exercised. This test revealed the need for modification of several components to achieve the desired level of trouble-free operation. The test was near completion when an accident not caused by any deficiency of the SOAC, occurred on August 11, 1973.

This document, Volume IV plus the following additional volumes comprise Boeing Vertol Report D174-10024, State-of-the-Art Car Final Test Report as specified in Section 17.1.4.2 of the SOAC Detail Specification.

Volume I - Component Testing
Volume II - Subsystem Functional Testing
Volume III - Acceptance Testing
Volume V - Post Repair Testing

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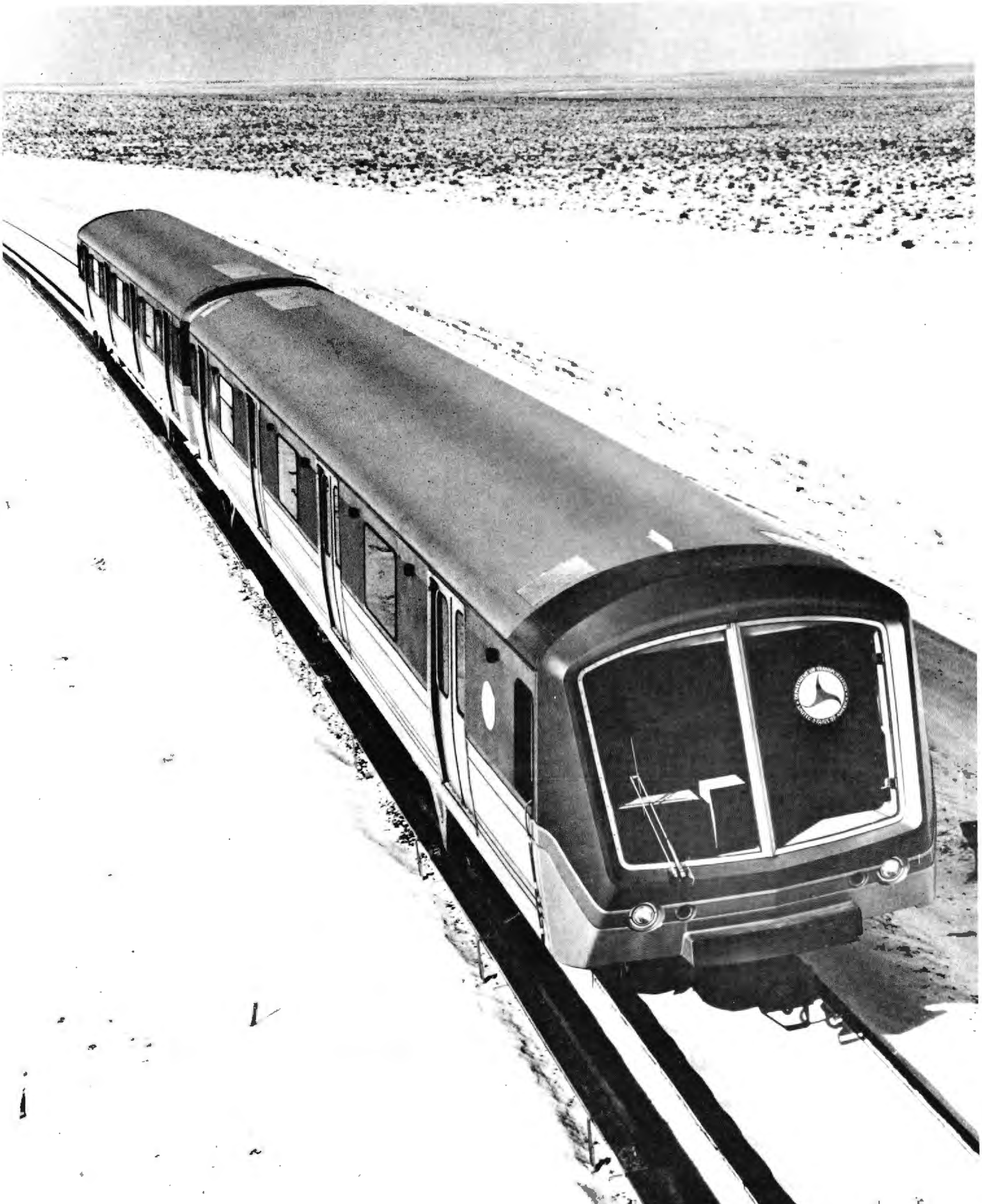


1. INTRODUCTION

Under its Urban Rapid Rail Vehicle and Systems Programs, DOT-UT-10007, the Urban Mass Transportation Administration of the U. S. Department of Transportation is developing and evaluating a series of transit cars designed to advance the technology of urban rail car. The State-of-the-Art Cars (SOAC) are part of this program.

The SOAC will be demonstrated to the riding public on transit properties in five major U.S. cities (New York, Boston, Chicago, Cleveland and Philadelphia).

In preparation for the five cities demonstration, under DOT Contract DOT-UT-10007, a Simulated Demonstration was conducted, at the HSGTC, Pueblo, Colorado during the period of July 23, 1973 through August 11, 1973.

The demonstration profile was set up as a composite of the five demonstration city routes. The objectives of this Simulated Demonstration were: (1) to seek out any remaining equipment problems,and (2) to validate the maintenance plans and procedures to be used during operation of the SOAC in the demonstration cities. In accomplishing these objectives, a goal of 3,000 miles was set for each car, a total of 6,000 car miles in a two- week period. Deficiencies found during this Simulated Demonstration are to be corrected thus enhancing the probability of trouble-free operation of the SOAC in the demonstration cities.

This document, Volume IV - Simulated Demonstration Test, plus the following additional volumes comprise Boeing Vertol Report D174-10024, State-of-the-Art Car Final Test Report as specified in Section 17.1.4.2 of the SOAC Detail Specification.

- Volume I - Component Testing
- Volume II - Subsystem Functional Testing
- Volume III - Acceptance Testing
- Volume V - Post Repair Testing

2. CONFIGURATION

2.1 SOAC

The SOAC was operated as a two-car train unless one car was down for maintenance, in which case single car operation was conducted until two-car operation could be resumed. Each car was operated at normal car weight (AW1 = 105,000 lb.) which represents a load of 100 passengers each weighing 150 lb. This load of 15,000 lb. was achieved by ballasting the car with lead blocks uniformly distributed on the car floor to simulate passengers.

2.2 UMTA Rail Transit Test Track Third Rail Power

The third rail electrical power at the UMTA Rail Transit Test Track presently consists of three sources connected in parallel. The main power source is the electrical output of a General Electric Company Model #U-3DC Diesel-electric locomotive, modified to yield 3,400 amperes at 600 VDC. This is augmented by two trailer-mounted Caterpillar diesel-electric generators each rated at 500 KW at 600 VDC. The voltage regulation of this third rail power supply cannot maintain the voltage limits (450-650 VDC) required in the SOAC Detail Specification No. IT-06-0026-73-20 under all phases of two-car train operation.

3. INSTRUMENTATION

The SOAC propulsion and braking system performance was monitored through the use of a plug-in Monitor Panel that presented data on such important parameters as: traction motor armature and field currents, contactor (main, drive, and brake) position, shutdown, etc. (see Appendix A, Operating Instructions, SOAC Propulsion System Monitor). This data was utilized as required.

4. PROCEDURE

The Simulated Demonstration of the SOAC at the HSGTC consisted of two activities: SOAC Operation and SOAC Maintenance.

4.1 SOAC Operation Activity

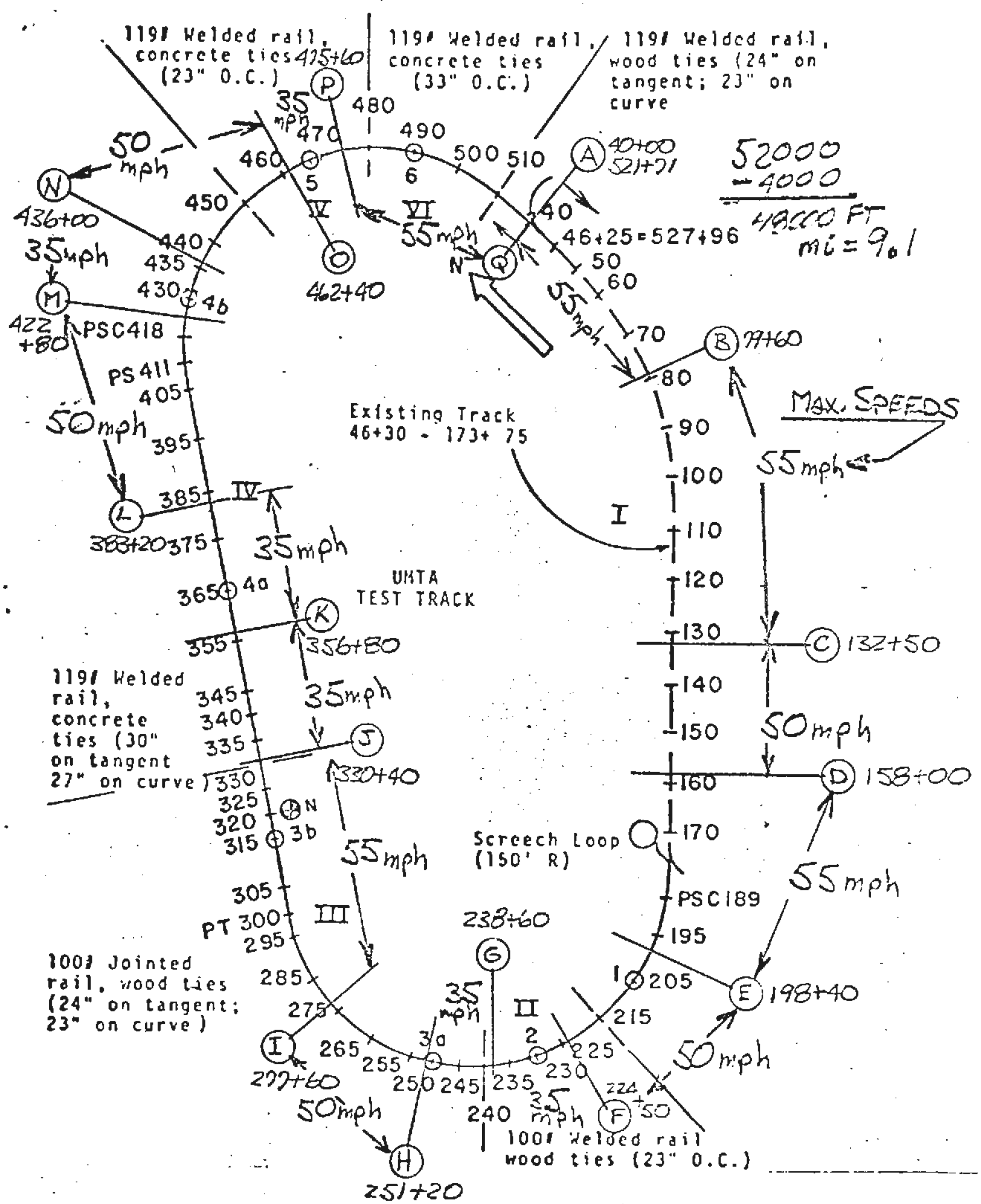
The SOAC Operation Activity consisted of eight hours of train running per day, six days per week, on a simulated transit route "laid out" on the UMTA Rail Transit Test Track at the HSGTC. (See Figure #1, "Simulated Demonstration Route using UMTA Rail Transit Test Track at HSGTC".) This simulated transit route **is** a composite of routes in the five demonstration cities and consists of sixteen stations averaging approximately 1/2 mile apart (ranging from 1/4 mile to 1 1/4 miles) with various run speeds between stations. In order to simulate actual operation on the transit properties, the SOAC was operated on simulated trips consisting of:

(1) Two laps of the UMTA Rail Transit Test Track stopping at each station for door opening and closing on each side of the cars sequentially. The prescribed run speeds between stations were achieved with the SOAC Speed Limiting System using maximum acceleration and full-service braking rates.

(2) Followed by two non-stop laps of the UMTA Rail Transit Test Track made at 80 mph.

After a five minute layover, the same run profile (two station-stop laps and two non-stop laps at 80 MPH.) was made in the opposite direction.

An operational log sheet giving particulars of start and stop times, direction of travel, crew names, car mileage, number of stops and door cycles, monitor data and comments was prepared for each run. (The "Simulated Demonstration Data Sheets" from which this report is written are filed in the SOAC Engineering Data File at the Surface Transportation Systems Branch of Boeing Vertol.) An inspection of the train was made by the motorman prior to the start of each day's operation.



SIMULATED DEMONSTRATION ROUTE USING UMTA RAIL TRANSIT TEST TRACK AT HSGTC

FIGURE 1

Every equipment malfunction that occurred during each day's operation was recorded for corrective action. (The "Discrepancies Reports" from which this report is written are filed in the SOAC Engineering Data File at the Surface Transportation Systems Branch of Boeing Vertol.)

All equipment malfunctions that occurred during operations were categorized and corrective action taken as follows:

FAILURE CATEGORY	EFFECT OF FAILURE	CORRECTIVE ACTION PROCEDURE
A	Unable to move train	Car taken out of service during trip
B	Schedule impaired	Car taken out of service at end of trip
C	Passenger discomfort	Car taken out of service at end of trip
D	No deterioration of schedule or comfort	At next scheduled maintenance periods

Minor troubleshooting to categorize the malfunction was performed by the operational crew. The major troubleshooting and repair work was performed by the maintenance crew

4.2 SOAC Maintenance Activity

The maintenance program for the simulated demonstration was based on the SOAC Maintenance Inspection Plan (Appendix C) that was developed to support the SOAC during the public demonstration program. The SOAC Maintenance Inspection Plan identified the various inspection tasks that should be performed; the frequency of doing these tasks was modified to fit the simulated demonstration schedule and the expected mileage accumulation. In addition to the tasks in the inspection plan, additional inspection tasks were performed to verify the adequacy of the inspection plan and to determine whether these additional tasks might be of value in predicting a failure or condition needing correction.

The actual inspection program used during the simulated demonstration consisted of (1) monthly inspections at the beginning and end of the simulated demonstration (the monthly inspection at the end of the program was not done because of the program being cut short by an accident), (2) weekly inspections at the end of each week's running, (3) a nightly inspection at the end of each day. The weekly inspection consisted of the nightly inspection plus checks of the air conditioning system, the air compressor, and the trucks. The nightly inspection checked the following: handbrake operation (this check was performed because of the recurrent problem of the handbrake not releasing properly), third rail shoes for cracks and tightness, and the oil level in the gear units.

Several of the nightly inspection tasks that were originally planned were discontinued after the second night. Weekly rather than nightly inspection was found to be more meaningful for the following items: (1) traction motor brushes, (2) traction motor commutators, (3) M/A brushes, and (4) M/A commutators. The logic system drift test was discontinued as the necessary special test equipment had been removed from the HSGTC.

5. OPERATIONS SUMMARY

The initial plan for the SOAC Simulated Demonstration at the HSGTC specified two-car operation, six days a week for a two week period with the expectation of accumulating approximately 3,000 miles of operation per car. In order to achieve the mileage objective the test period was extended. The first test run was conducted on July 23, 1973 and the last on August 11, 1973 when testing was discontinued as the result of an accident. Thirty-five runs were made and 4,197 car-miles accumulated. (See Appendix C, "Test Log" and Figure No. 2, "SOAC Mileage Accumulation during Simulated Demonstration".)

Of the 4,197 car-miles accumulated, 1,573 were obtained in single car operation. There were five occasions when the test objective of operating the SOAC as a two-car train could not be met due to malfunctions forcing a car out of service. At each of these occasions the SOAC simulated demonstration was conducted using a single car train. (See Figure No. 3, "Daily Mileage per car during Simulated Demonstration".)

5.1 Non-Representative Testing

During the Test Program special test runs were made for the purpose of troubleshooting an identified problem. In one case, Car #2 was unintentionally operated out of test configuration. These tests have been classified as nonrepresentative testing.

As a result of the low oil levels noted during the nightly maintenance inspections, a special test program was initiated to determine the location, rate and cause of leakage. The test profile used for one phase of the oil leakage testing consisted of running the test oval at the normally specified speeds between stations but slowing to 3 mph. instead of stopping at the stations. After 8 such laps the Motor/Alternator (M/A) tripped off. Actuating the M/A Reset push-button could not restore M/A operations. On the spot troubleshooting revealed case ruptures of capacitors in the chopper as indicated by dielectric fluid leakage. Representatives of the propulsion system manufacturer (AiResearch Co.) determined that the capacitor failures were due to the service duty cycle imposed by the test profile. This duty cycle exceeded the design rating of the chopper. The failed capacitors were replaced and use of the non-standard duty cycle was discontinued.

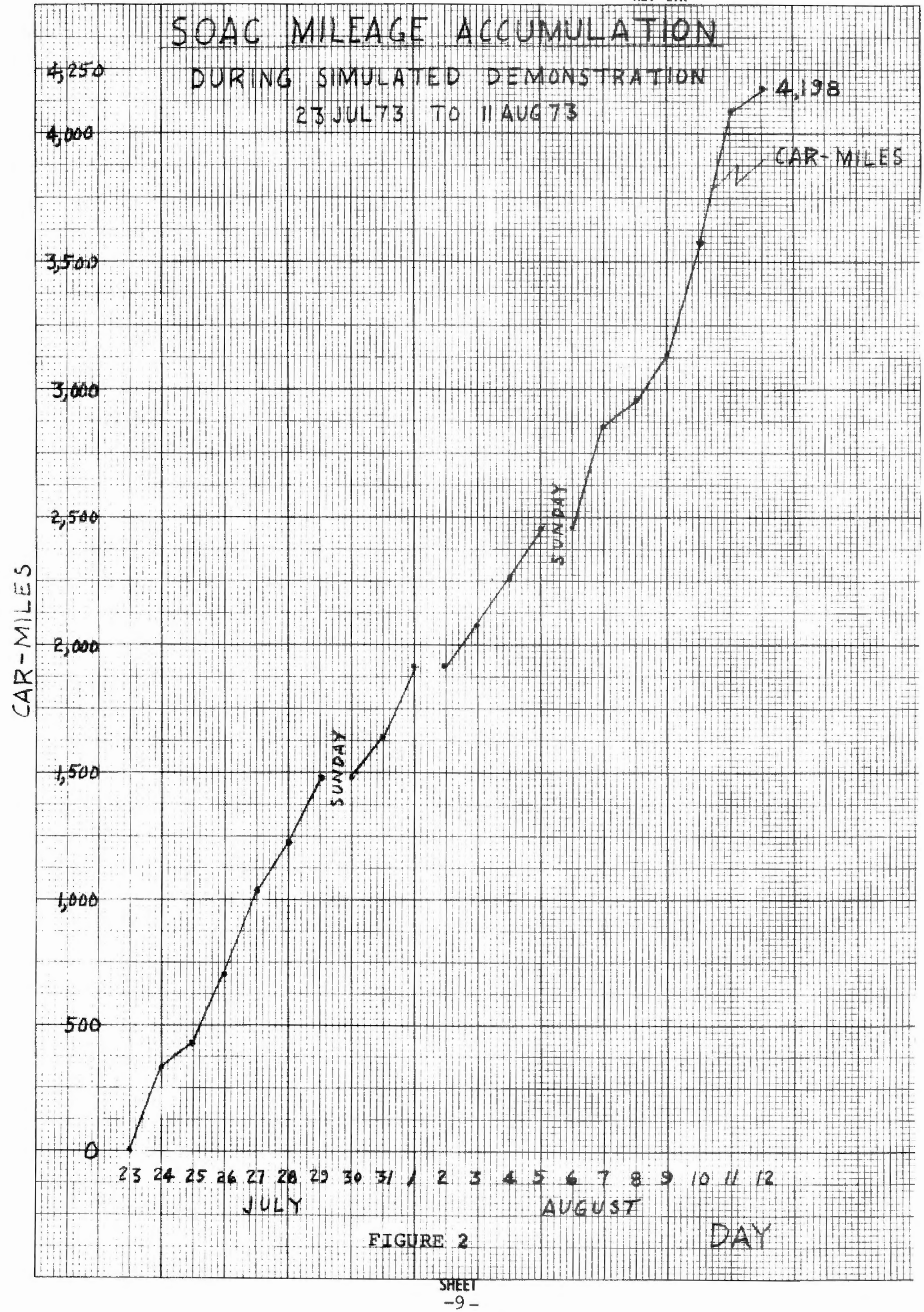

SOAC MILEAGE ACCUMULATION
DURING SIMULATED DEMONSTRATION
23 JUL 73 TO 11 AUG 73
4,198
CAR-MILES
CAR-MILES
4,250
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
SUNDAY
SUNDAY
23 24 25 26 27 28 29 30 31 1 2 3 4 5 6 7 8 9 10 11 12
JULY
AUGUST
DAY

FIGURE 2

THE BOEING COMPANY

NUMBER
REV LTR

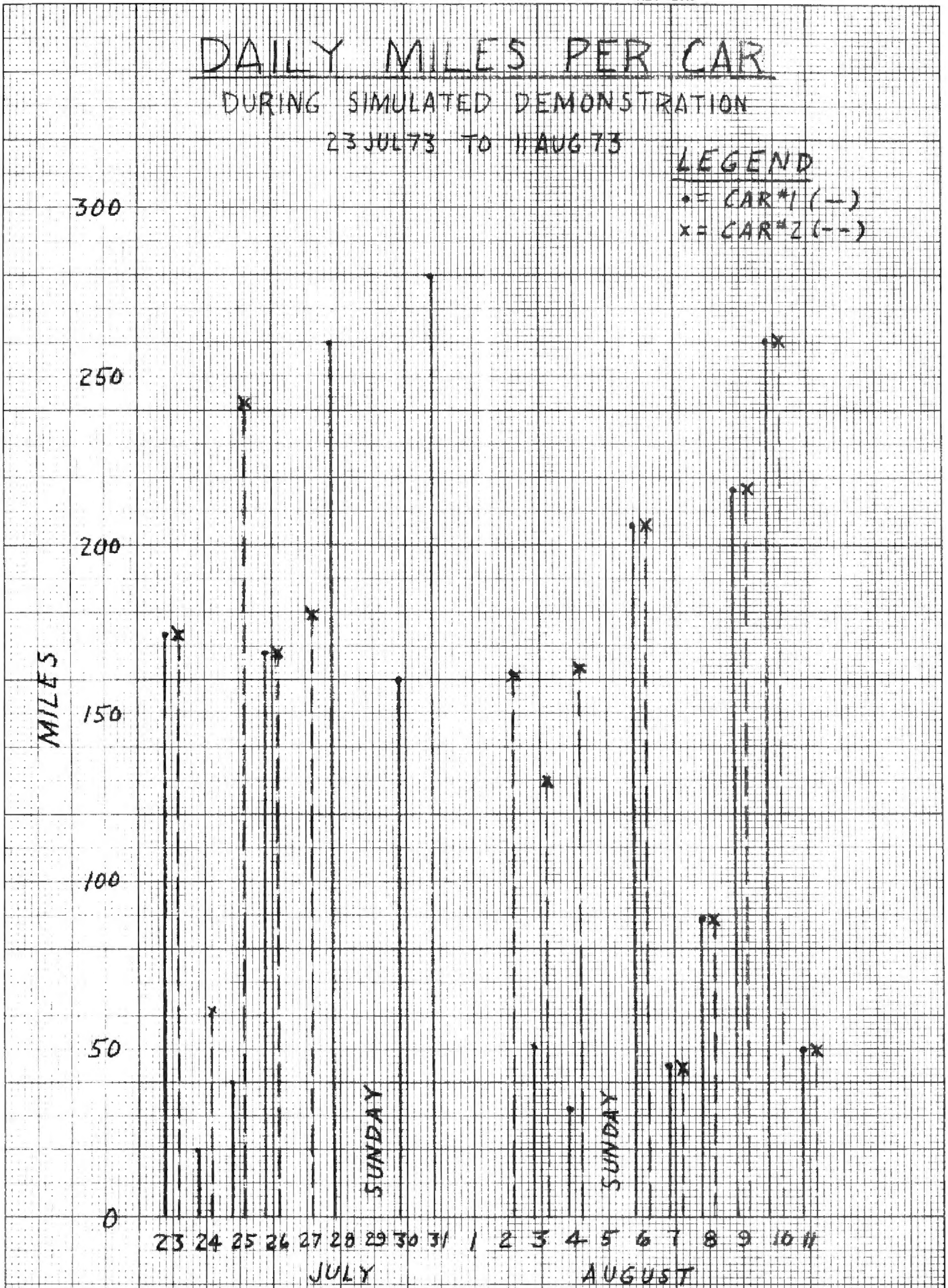


FIGURE 3

Another non-representative failure occurred when the blower-propulsion interlock was disconnected from Car #2, and not reconnected after special instrumentation was removed. During the start-up procedure the motor blowers were inadvertently not turned on, and after the car was operated for 82 minutes, travelling 60 miles, the propulsion system shutdown. The blowers were turned on and the propulsion system was reset and testing was resumed. After 120 additional miles of car operation another propulsion shutdown occurred. Resetting the propulsion system would not restore proper operation. On the spot troubleshooting indicated in open armature circuit in one traction motor. Detailed inspection of this motor revealed that excessive heating of the motor had occurred. The brush springs had failed, the brushes were stuck in the holders, arcing had occurred between the brushes and the commutator, and a portion of the brush-holders had melted. The brushes and brush-holders were replaced and the commutator was resurfaced without removing the motor from the car.

5.2 Results

5.2.1 Component Failure/Replacement

The significant component failures during the Simulated Demonstration are listed in Table No. 1 in accordance with the failure categories outlined in Section 4.1.

5.2.2 Gearbox Oil Leakage

During the simulated demonstration it was noted that excessive oil leakage was occurring. Although this problem did not prevent operation it was considered undesirable and in need of correction.

The gearboxes were frequently measured for oil level during the runs to establish the amount of leakage. (The "Oil Leakage Data Sheets" from which this report is written are filed in the SOAC Engineering Data File at the Surface Transportation Systems Branch of Boeing Vertol.) It was discovered that the oil-level dipsticks were improperly calibrated which had resulted in overfilling of the gearboxes. After the oil-level dipsticks were properly calibrated and the gearboxes were filled to the recommended level, the oil leakage was substantially reduced. Review of the oil level data indicated that the prime factor affecting leakage was the number of starts and stops.

TABLE #1

COMPONENT FAILURE/REPLACZMENT

ITEM #	CAR #	COMPONENT	FAILURE CATEGORY	DESCRIPTION OF FAILURE	CAUSE OF FAILURE	CORRECTIVE ACTION TAKEN
1	1	MA Logic Relay #K-9	B	Contacts #6 and #7 welded	Not definitely identified	Replaced relay.
2	1	P-Signal Generator Card and Relay	B	Relay contacts welded and resistor burned "open".	Not definitely identified	Replaced card and relay.
3	1	Air Conditioning Compressor Starter Relay	C	Replacement coil in relay had burned out.	Not definitely identified; suspect either environment effect or manufacturing defect.	Replaced starter relay and returned failed unit to supplier
4	2	Third Rail Shoe	C	Crack in shoe, evidence of high temperature on top of shoe. (Car #2 had been towing Car #1).	Pueblo peculiar problem of corrosion on contact surface of third rail causes high contact resistance.	Replaced third rail shoe. Problem not anticipated on transit properties.
5	2	Third Rail Shoe Shunt	C	Approximately 1/4 of shunt had been chafted away.	Shunt had been rubbing on unused lugs of third rail shoe mounts.	Modified design of lugs by cutting away unused portion of lugs.
6	1	PCU Printed-Circuit Cards	B	Piece-part failures on cards	Defective Integrated Circuits on cards.	Replace cards.
7	1	Motor Alternator PDR	B	PDR had developed an internal short circuit.	Repeated stress caused by high in-rush currents at third rail gaps.	Modified design to incorporate current limiting resistance.
8	2	Air Compressor Circuit Breaker	C	One terminal had broken off this 3-phase breaker.	Manufacturing defect	Replace circuit breaker.
9	2	Air Compressor Motor	C	Motor (three-phase) had burned out.	Broken terminal on the the 3-phase circuit breaker deprived this 3-phase motor of one phase causing it to stall and draw excessive current.	Replaced motor. Motors are being rewound from 230 v 208 v thus permitting higher currents. Cirucit is being modified to incorporate a motor-start function.

TABLE #1

COMPONENT FAILURE/REPLACEMENT (CONT'D.)

ITEM #	CAR #	COMPONENT	FAILURE CATEGORY	DESCRIPTION OF FAILURE	CAUSE OF FAILURE	CORRECTIVE ACTION TAKEN
10	1	Traction Motor Thermal Protection Switch	B	Switch imbedded in motor field structure had failed "open and interrupted the field circuit.	Switch or wire leads to switch failed open.	Changed traction motor.
11	1	Chopper Commutating Capacitor B		Caapacitor failed.	"Infant mortality" of newly installed capacitor.	Replaced capacitor.
12	1	Main Overcurrent Relay Contacts	B	Contacts would not release.	Insufficient tension in contact springs.	Modified design - installed stronger springs.
13	2	Cable Connector-Traction Motor Armature	B	Both halves of the connector had been destroyed and the cable burned open	Connector inadequately tightened causing a high resistance contact resulting in severe overheating, melting, and arcing.	Replace table, connectors, a[illegible] traction motor.

Several special runs were made to determine data on gearbox oil leakage. Some of these runs were non-stop at constant speed, some were non-stop at varying speeds, and others were the standard simulated profile with sixteen stops. At the completion of each of these special runs the gearbox oil level was measured and the underside of the gearboxes was checked for leakage. The oil leakage rate in transit service which has various speeds in addition to station stops and starts would be similar to that experienced in the Operational Profile used in this Simulated Demonstration Test. The leakage rate for 500 miles of such operation varied widely among the eight gearboxes in the two-car SOAC. The lowest was 0.1 quart and the highest was 1.2 quarts. (See Figures 4 and 5, "Oil Measurements, SOAC #1 and #2".) Based on the data obtained, it was decided that the #1 gearbox of Car #1 would be removed after the Simulated Demonstration and returned to Garrett-AiResearch for incorporation of design changes to reduce oil leakage and laboratory test for confirmation.

Laboratory tests conducted by Garrett-Airesearch traced the oil leakage problem to the omission of oil drain holes between the labyrinth seal and the tapered roller bearing adjacent to it. The effectiveness of the labyrinth seal decreases with decreasing shaft speed. When the gearbox was operated under repetitive stop-start conditions oil leaked out through the labyrinth seal. The gearbox was modified by adding two 3/4 inch drain holes, at the labyrinth seal and also to the seal cavity on the cover side of the gearbox. These holes permit oil that accumulates in the seal cavity during operation to drain back into the sump when the car stops. The modified gearbox, when tested, had an oil leakage rate of 0.88 ounce per 600 stops. This is considered an acceptable oil leakage rate.

5.2.3 Motor-Alternator and Propulsion System Performance

Many Motor-Alternator (MA) shutdowns and Propulsion System shutdowns occurred during the runs. As an assist in determining the cause of these incidents, the AiResearch Division of the Garrett Corporation augmented their support of the SOAC Simulated Demonstration by supplying an Auxiliary Power System (Motor-Alternator) Monitoring Box and another SOAC Monitor Panel (See Section 3) thus permitting simultaneous monitoring of both cars.

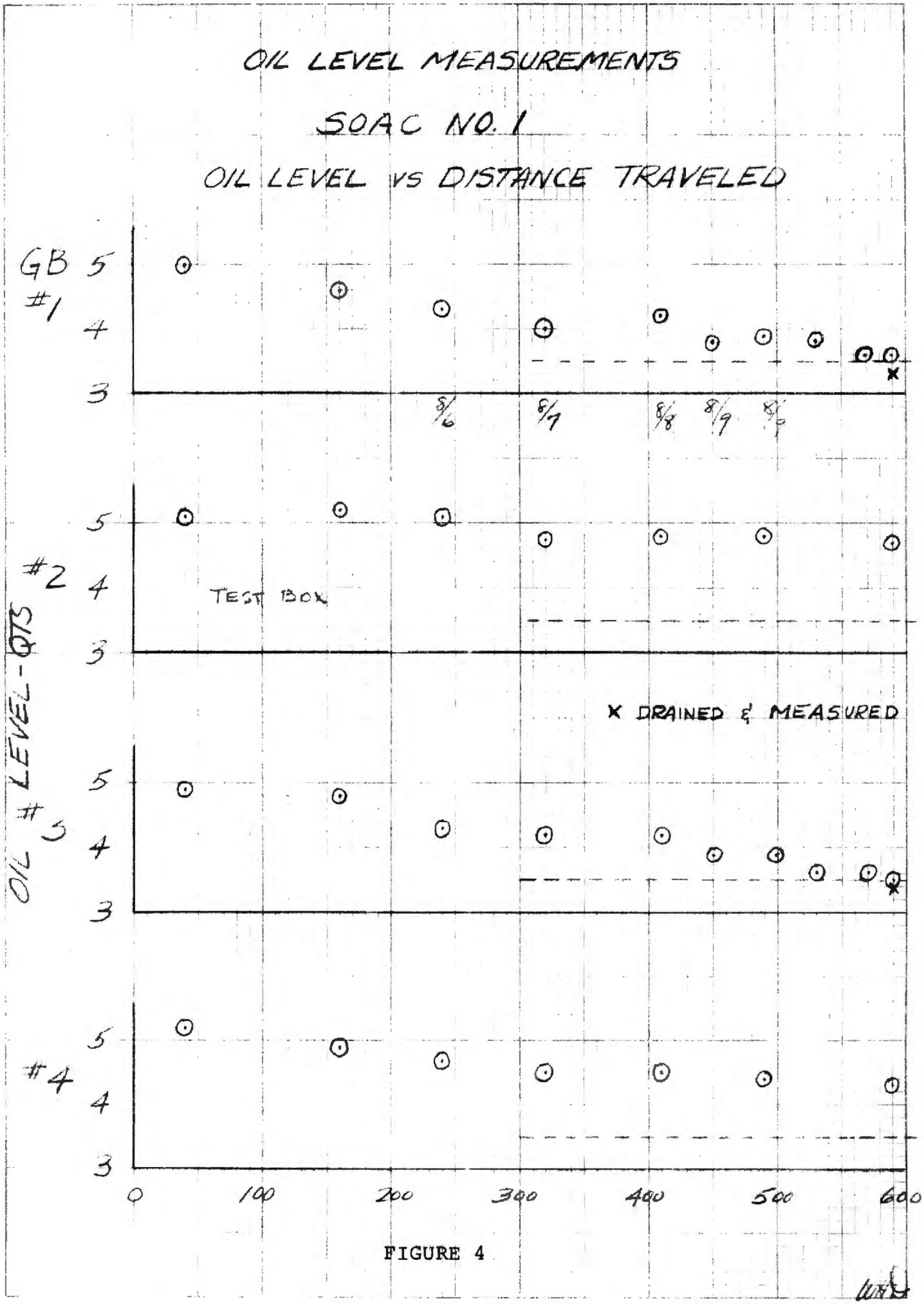

OIL LEVEL MEASUREMENTS
SOAC NO. 1
OIL LEVEL VS DISTANCE TRAVELED
OIL LEVEL - QTS
GB #1
#2
#3
#4
TEST BOX
X DRAINED & MEASURED
8/6
8/7
8/8
8/9
0
100
200
300
400
500
600
5
4
3

FIGURE 4

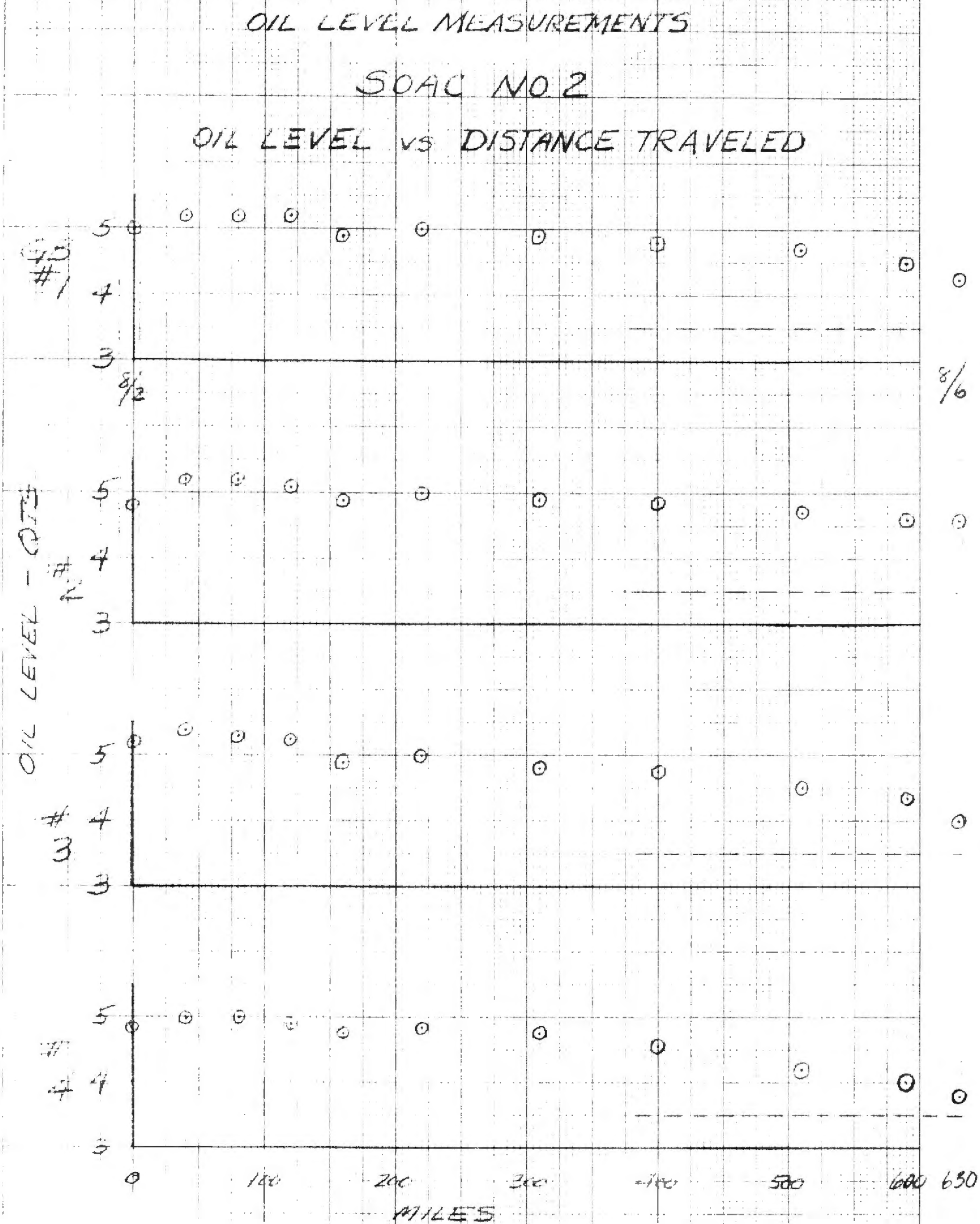


FIGURE 5

W.H.
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One of the parameters monitored was the voltage of the chopper capacitor bank which is a function of the third rail voltage. During two-car train operation the third rail voltage was found to go out of allowable limits (450-650 VDC) for SOAC operation. These occurrences were dependent upon where the two-car train was on the UMTA Test Oval and whether the SOAC was accelerating, braking, or going through a third rail gap. It was during such out-of-limits voltage periods that Motor-Alternator shutdowns could be expected.

Various settings of the third rail power supply (diesel-electric locomotive and trailer-mounted diesel driven generators) were tried in attempts to stabilize the voltage and bring the voltage regulation within the allowable limits. These efforts were not successful and train operation was accomplished by having the motorman operate the master controller in a manner that resulted in the current demand during periods of acceleration, braking, and going through third rail gaps, being within the voltage regulation capability of the third rail power supply. This procedure did eliminate the MA shutdowns caused by inadequate third rail voltage regulation but resulted in the two-car train being gradually, instead of instantaneously, commanded to full acceleration and deceleration rates.

There were instances of abnormally large current demands from the chopper by the traction motors during dynamic brake to friction brake transition. This condition was evidenced by the "chopper over-current" light appearing on the SOAC Propulsion System Monitor Panel and also by a jerk of the car resulting from sudden application of the friction brakes at approximately 3 to 5 mph when braking to a stop. This is caused by improper blending during the transition from dynamic to air braking as car speed approaches zero mph when either the deadman feature or the full-service position of the master controller is used to stop the train. A smooth stop without the jerk of the car could be obtained if the motorman watched both the P-Wire Meter and Brake Cylinder Air Pressure Gauge and moved the master controller to a position that called for less than full service braking when the train had slowed to approximately 8 mph; and returning the master controller to full-service brake position when a speed of less than 3 mph had been reached. The cause of the "chopper over-current" still remained to be determined when the simulated demonstration was suspended.

5.2.4 Other Discrepancies

5.2.4.1 Complete release of the hydraulically actuated parking brake on each car could not be reliably obtained. Troubleshooting this discrepancy revealed that the pressure exerted by the hydraulic actuators upon the brake shoes caused the wheel and axle assemblies to move the chevron springs in the trucks. The amount of movement of the chevron springs was a function of how energetically the hydraulic parking brake was applied by the motorman. Therefore, the movement of the chevron springs was not consistent. Some applications of the parking brake resulted in a movement of the chevron springs that was sufficent to allow the slack adjusters in the wheel brake unit to make an adjustment. When this occurred the brake shoes still pressed against the wheels when the parking brake was released. The slack adjuster pawls were removed from these wheel brake units and several apply-release cycles of the parking brake were made successfully. There were also lock-ups of the parking brake that were traced to malfunctioning of the hydraulic system; these occurrences are believed to be due to an improper setting of the relief valves.

The desired 100 apply-release cycles of the parking brake were not made prior to suspension of testing.

5.2.4.2 Intermittent clunking and squealing noises were noted on Truck #1 of Car #1 when the car stopped or started on a curve. It was found that this condition was caused by inadequate clearance between the metal stop and the rubber bumper on the truck frame and the stop on the truck bolster. This clearance was planned to be increased by grinding down the metal stop on the truck bolster. The test was suspended before the additional clearance was obtained. The effect of the inadequate clearance is aggravated on the UMTA Test Oval as several of the simulated station stops are located on superelevated curves with the superelvation always acting on the same side of the car.

5.2.4.3 The coupler at the No. 1 end of Car #1 could not be centered and locked by its pneumatic controls. Detailed examination of the piping and valving of these controls and the coupler was not completed prior to suspension of testing. The reason for this discrepancy remains to be found.

5.2.4.4 Side door binding and hangups during opening and closing were experienced at the beginning of the Simulation Test. These discrepancies were corrected by cleaning of the door relay contacts, adjustment of the door actuating mechanisms, and repeated operation of the doors during the test. Prior to the simulated demonstration the door mechanisms had seen little service. Some sluggish door operation was also experienced due to binding caused by thermal expansion when the SOAC was parked for long periods of time exposed to the bright sun at the test track with the car air conditioners turned off. This was considered a problem peculiar to the Pueblo HSGTC as the discrepancies disappeared after the air conditioners operated for a short period of time. Periodic cleaning of the door relay contacts to remove dirt accumulation is recommended.

5.2.4.5 There was occasional tripping of the Main Interior Light circuit-breaker of Car #1. Smoke was noticed coming from the low voltage circuit breaker panel during one such instance. Troubleshooting revealed a loose cable to terminal board connection due to the use of a wrong size terminal screw for the connection. This had resulted in a high resistance connection that had heated to the extent that the cable insulation had been degraded. Tripping of the circuit breaker still occurred after the proper size terminal screw had been installed. The reason for the circuit breaker tripping was not found prior to the suspension of testing.

5.3 Suspension of Testing

The Simulated Demonstration Test was scheduled to conclude on August 15, 1973 and the SOAC was to leave HSGTC on August 17, 1973 for demonstration at the New York City Transit Authority. At 2:30 P.M. on August 11, 1973 the SOAC ran through an open track-switch on the UMTA Test Oval and collided with a modified gondola car. The cab end of SOAC #2, the High Density Car, was severely damaged in the accident and all coupler shear-pins were sheared. SOAC #1 suffered slight damage to the anticlimber on the R-end and loss of shear pins in the R-end coupler. The cars were taken out of service for repair and the Simulated Demonstration Test has been suspended until the State-of-the-Art Cars are returned to service as a two-car train.

6. CONCLUSIONS

The Simulated Demonstration Test of the SOAC two-car train at the HSGTC revealed that a few components require additional attention to achieve trouble free performance.

1. The gearbox oil leakage problem has resulted in a design change that has been confirmed by the Garrett-AiResearch Company in laboratory test. Retrofit of all gearboxes is in process.

2. The numerous MA and Propulsion shutdowns experienced during two-car train operation has been found attributable, in most instances, to the inability of the third rail power supply at the HSGTC to meet the voltage limits required by the SOAC Specification. The chopper over-currents experienced in the braking mode as car speed goes below 5 mph. and the random MA and Propulsion shutdowns are discrepancies that require corrective action.

3. The requisite number (100) of apply-release cycles of the parking brake still must be completed to validate that the modification made achieves reliable brake releasing.

4. The cause of the tripping of the Main Interior Light Circuit-Breaker of Car #1 remains to be determined.

5. The lack of response by the coupler at the #1 end of Car #1 to its pneumatic centering and locking controls must be corrected.

6. Additional clearances must be provided between the stop on the #1 truck frame of Car #1 and its bolster.

The Simulated Demonstration Test was still in process when the accident took the SOAC out of service. Completion of the test is planned after the cars have been repaired. Correction of deficiencies will be accomplished during repair and subsequent retest. Volume V of this series of test reports will document the retest at HSGTC.

APPENDIX A

OPERATING INSTRUCTIONS, SOAC PROPULSION SYSTEM MONITOR

(AN AIRESEARCH MANUFACTURING COMPANY DOCUMENT)

OPERATING INSTRUCTIONS

SOAC PROPULSION SYSTEM MONITOR

1. General Description

The SOAC Propulsion System Monitor consists of the necessary instrumentation to display the important propulsion and braking system parameters. The unit is housed in a metallic case and contains the display console board, the solid state circuitry necessary to drive the display monitors, and the interconnection cable to couple the unit to the Propulsion Power Control Unit (PPCU).

Located on the face of the unit are:

1. A connector for interface with the interconnection cable
2. Two meters with 100-0-100 scales
3. Two channel selector knobs
4. Lamps for data display
5. Jacks for external connections to auxiliary instrumentation
6. A lamp "press to test" button.

The display board is divided into four sections. These sections are:

1. Operation Annunciator Section
2. Parameter Monitor Section

3. Shutdown Monitor Section

4. Power Supply Monitor

2. Installation

A fifty foot cable, located in the cover of the unit, is all that is required to connect the unit to the vehicle. The cable length is ample to provide for location of the unit in the cab of the vehicle during troubleshooting or operational demonstration. The cable is equipped with an MS24266R22B55SN connector which plugs into the mating connector on the monitor display board, and an RH3406KE36-10PX connector which mates with connector PPC8 on the Propulsion Power Control Unit P/N 524060.

After installing the monitor cabling the propulsion system should be energized in the normal manner. Function the "press to test" button and determine that all lamps light.

Note: After functioning the "press to test" button, all lamp in the Shutdown Monitor section will remain lighted. To reset these lamps, function the Propulsion Reset button on the motorman's console

Displays

OPERATION ANNUNCIATE

Located on the left hand side of display board is the

Operation Annunciate Section of the unit. This section displays the digital logic functions of the drive and brake system. Each of the display functions is equipped with the amber lamp, and a plug jack for external instrumentation. (Caution: The impedance of the external instrumentation can load the monitor and produce error in the readings. An impedance of 100K for the external instrumentation will produce approximately 1% error in measurement). Common or ground jacks are provided at the bottom of the unit for use with external instrumentation. The following is a description of the logic presented in this section of the monitor.

Row 1 (left hand)

1. Transition Error - A lighted lamp indicates the presence of a transition error. A transition error indicates that the propulsion or brake systems have conditions which are inconsistent with the commands given. A transaction error will not exist if all of the following conditions exist:
   - (a) Drive command is present
   - (b) Brake contactor is in drive mode
   - (c) Drive contactor is closed
   - (d) Main contactor is closed
   - (e) Direction logic is correct
   - (f) Friction brakes are not applied
   - (g) Hand brake is not applied

or, if all of the following conditions exist:

(a) Brake command is present

(b) Brake contactor is in brake mode

(c) Main contactor is closed

(d) Direction logic is correct

2. Main Contactor - A lighted lamp indicates that the main contactor is closed and that power is applied to the propulsion system. The main contactor is closed if the motor alternator contactor is closed and the main contactor overcurrent memory is not set.

3. Drive Contractor - A lighted lamp indicates that the Drive Contactor is closed and the system is in a condition to apply positive tractive effort to the vehicle. The Drive Contractor is closed if all of the following exist:

   (a) Drive command is present

   (b) Brake contactor is closed in the drive mode, and open in the brake mode

   (c) Main contactor is closed

   (d) Drive contactor overcurrent memory is not set

   (e) Quick shut down memory is not set

   (f) Knife switch is closed

4. Brake Contractor - A lighted lamp indicates that the brake contactor is closed in the brake mode and the system is in a condition to apply negative

tractive effort (dynamic brake) to the vehicle. The brake contactor is closed in the brake mode if all of the following conditions exist:

(a) Brake command is present

(b) Brake contactor is not closed in the drive mode

(c) Drive contactor is not closed

5. Chopper Contactor - A lighted lamp indicates that the chopper contactor (internal to the chopper) is closed. This contactor is closed in the drive mode, and open in the brake mode.

6. Brakes Applied - A lighted lamp indicates that friction or handbrakes are applied.

7. No Motion - A lighted lamp indicates that the No Motion Relay (K22) is activated. The no motion relay should activate only at or near zero velocity of the vehicle.

8. Propulsion Shutdown - A lighted lamp indicates that a Propulsion Shutdown has occurred. This action is caused by Quick Shutdown (QSD) logic, which has memory and reset of the system is required should this function occur. Reset is accomplished by pressing the Propulsion Reset button on the motorman's console.

   Quick shutdown set is caused by any one of the following:

(a) Logic power loss

(b) Traction overcurrent

(c) Any motor overtemperature

(d) Chopper overtemperature

(e) Drive contactor overcurrent memory set

(f) More than two capacitor bank fuses blown

(g) Truck current unbalance beyond tolerance

(h) Main contactor overcurrent memory set

Propulsion shutdown causes all of the following actions to occur:

(a) Open drive contactor

(b) Energize Propulsion Trip trainline

(c) Clamp dynamic brake signal

(d) Initiate Tractive Effort Pause

Row 2

1. Field 1 Forward - A lighted lamp indicates that the field relay for the motors on truck No. 1 is in position to provide a so called forward conduction of field current. Since the direction of current from the field supply defines this terminology "forward" should not be confused with the direction of the car.

The following equality exists:

Field 1 Forward = Reverse selection and drive command,
or forward selection and brake command

2. Field 1 Reverse - A lighted lamp indicates that the field relay for the motors on truck No. 1 are in a position to provide a so called "reverse" conduction of current.

   Field 2 Reverse = Forward selection and drive command, or reverse selection and brake command

3. Field 2 Forward - Same as Field 1 Forward except for Truck 2 - Note: Field 1 Forward and Field 2 Forward should always be lighted at the same time.

4. Field 2 Reverse - Same as Field 1 Reverse except for Truck 2 - Note: Field 1 Reverse and Field 2 Reverse should always be lighted at the same time.

5. PCL Power OK - A lighted lamp indicates that the propulsion control logic power supplies is within the specified voltage tolerances. This function is redundant, but opposite in lamp condition, to the Power Supply Monitor section.

6. Chopper ON - A lighted lamp indicates that the chopper is in a condition to conduct current.

7. Third Rail OK - A lighted lamp indicates that the input voltage to the vehicle is within the specified voltage tolerance (400V - 750V).

8. TE Pause - A lighted lamp indicates that the propulsion system is in a tractive effort pause condition and neither positive or negative tractive effort is available. A tractive effort pause causes all of the following to happen:

(a) Chopper is turned off

(b) Motor field currents are turned off

(c) Motor current command logic is clamped

(d) Chopper θ command logic is clamped

(e) Jerk limit logic is clamped

A Tractive effort pause is caused by any one of the following conditions:

(a) Propulsion trip (QSD)

(b) Transition error

(c) Motor air flow loss

(d) Motor alternator not ready signal

(e) Motor alternator quick shutdown

(f) Capacitor bank voltage greater than 900V

(g) Capacitor bank voltage less than 400V

(h) Brake command and a no motion relay signal has existed simultaneously longer than two seconds

PARAMETER MONITOR

Located in the middle section of the display board is the Parameter Monitor. This section functions in conjunction with the channel selection knobs and the meters at the top of the display board. The section is divided in half with the left hand meter, left hand channel selector knob and the left hand row of parameter lamp functioning together, and the right hand meter, right hand channel selector knob and right hand row of parameter lamps functioning together. The parameter lamps are green and indicate the parameter selected by the channel selector knob for display on the appropriate meter. Each parameter is also equipped with a plug jack for external instrumentation. The following parameters are located in the left hand row of the center section and are displayed as selected on the left hand meter:

(1) I arm Truck 1 - Full Scale = 1000 AMPS

Motor armature current on Truck No. 1 (Cab end truck). The meter reads positive current (needle moves to right on increasing current) regardless of drive or brake command.

(2) I Field Truck 1 - Full Scale = 100 AMPS

Motor field current on Truck No. 1. The meter reads positive and negative current depending on the field current direction

(3) Input Capacitor Volts - Full Scale = 1000 VOLTS

Capacitor bank voltage

(4) TE Command - Full Scale = 100%

Indicates commanded tractive effort in percent for both drive and dynamic brake command. The meter reads positive for both commands

(5) 0 Command - Full Scale = 100%

Indicates firing angle of the chopper thyristors in percentages for both drive and dynamic brake commands. The meter reads positive for both commands.

(6) <u>Motor Overtemperature</u> (Motor NOT Overtemperature)

A full scale, positive meter reading indicates the motor tempeatures are within the specified tolerance. A reading of zero (0) on the meter indicates overtemperature.

(7) <u>Air Flow Loss</u> (Air Flow NOT Lost)

A full scale positive meter reading indicates the airflow is within the specified tolerance. A reading of zero (0) on the meter indicates loss of air flow.

(8) <u>MA Ready Loss</u> (MA Ready Signal Present)

A full scale positive meter reading indicates the MA ready signal is present. A reading of zero (0) on the meter indicates a MA Ready Signal Loss.

(9) <u>Calibrate</u> - Full Scale = 10 VOLTS

The meter is connected directly to this jack so that a voltage may be applied to calibrate the meter, or the meter can be utilized for an external voltage measurement of 10 volts DC or less.

The following parameters are located in the right hand row of the center section and are displayed on the right hand meter:

(1) <u>I arm Truck 2</u> - Full Scale = 1000 AMPS

Motor armature current on Truck No. 1 (opposite cab end). The meter reads positive current regardless of drive or brake command

(2) I Field Truck 2 - Full Scale = 100 AMPS

Motor field current on Truck No. 2. The meter reads positive and negative current depending on the field current direction

(3) Motor Volts - Full Scale = 1000 VOLTS

Meter reads representative voltage applied to the traction motor sets. This voltage may also be considered chopper output voltage. The meter reads positive voltage whether drive or braking is commanded.

(4) TE Calculated - Full Scale = 100%

The meter reads the calculated tractive effort that the propulsion system is developing. This is calculated using readings from the motor armature currents and the field current. The meter reads positive, whether the command is drive or brake.

(5) Velocity - Full Scale = 100 MPH

The meter reads vehicle velocity. This is the same signal that is applied to the digital speedometer on the motorman's console.

(6) Air Overtemp (Air NOT Overtemperature)

A full scale positive meter reading indicates that the cooling air leaving the chopper is and has been within specified tolerances. Small thermal fuse switches located in the air stream leaving the chopper will open and remain open should an excessive temperature occur. A zero (0) reading on the meter indicates an overtemperature has occurred and a probable chopper fault in the form of high temperature rise has existed or does exist. These switches are primarily for fire protection and must be replaced if activated. Activation of the switches causes a propulsion trip to occur.

(7) Spare - For future installation of a parameter if desired

(8) Spare - For future installation of a parameter if desired

(9) Calibrate - Full Scale - 10 VOLTS

The meter is connected directly to this jack so that a voltage may be applied to calibrate the meter, or the meter can be utilized for an external voltage measurement of 10 volts DC or less.

SHUTDOWN MONITOR

Located in the left hand row of the section under the right hand meter is the ShutDown Monitor. This section of red lamps indicates the initial event in a series shutdown due to a system fault. A logic monitor card located in the Propulsion Power Control Unit (PPCU) contains first event memory circuitry which latches to the first event and clamps out all of the secondary events preventing their display. (NOTE: Occasionally when two or more events occur in a very short time (a few microseconds) more than one light may light simultaneously).

The digital events registered and displayed on the Shutdown Monitor are as follows:

(1) Quick Shutdown

One of the events causing a QSD has occurred. (See description of Propulsion Shutdown in the Operation Annunciate section)

(2) Emergency Relay

The emergency relay (K21) has opened. This is a vital relay which responds to the loss of brake pipe pressure and initiates emergency braking.

(3) I arm Unbalance

A condition has existed which has caused the currents to the two trucks on the vehicle to become unequal by greater than the specified tolerance.

(4) Input Overcurrent

The system has drawn excessive (overtolerance) current from the input line.

(5) Chopper Overcurrent

The chopper has conducted current in excess of its specified capability. (NOTE: This may occur either in the drive or brake modes)

(6) Traction Overcurrent Relay

One or both of the traction motor overcurrent relays has functioned due to excessive (overtolerance) current.

(7) Drive Overcurrent Relay

Excessive (overtolerance) current as occurred in the drive contactor circuit causing drive contactor overcurrent memory to be set

(8) Differential Overcurrent Relay

The differential overcurrent relay has functioned indicating more total current is entering the propulsion system than is being conducted in the ground return leads. This condition is indicative of a fault of the ground returns to car chassis.

POWER SUPPLY MONITOR

In the right hand row of the section directly underneath the right hand meter is the Power Supply Monitor. Red lamp on this monitor indicates the out of tolerance of the power supply voltage (+15V and -15V). The jacks may be used with external instrumentation to determine the exact voltages present in the logic power supply.

APPENDIX B

SOAC MAINTENANCE INSPECTION PLAN

SOAC MAINTENANCE INSPECTION PLAN

DAILY

Operator
De-energized
Air Compressor
Check Oil Level, Drain Intercooler

Operator
Energized
Radio/Communications
Check Operation

Operator
Energized
Wheel Brake Unit
Check for Correct Operation during Functional Test

WEEKLY

Operator
Energized
Brakes
Check the gap between brake shoe and wheel, 5/16 in. gap should be maintained. Check brake shoe for lining thickness. 1/2 in. minimum.

Mechanical
De-energized
Main Reservoir
Drain Reservoir of Water

MONTHLY

Mechanical
De-energized
Wheels
Inspect wheels for cracks, flat spots, spalls, wear, high flange, thin flange, false flange, grooves, heat marks, elastomer condition, built-up tread, etc.

Carbody-Exterior
Inspect carbody for damage, loose or missing parts. Check for graffitti.

Air Diffusers
Inspect for loose, missing, broken parts, and hardware. Check adjustable vanes for freedom of movement.

Coupler
Lubricate coupler mechanism. Check filter for water, drain, inspect air lines for tightness, inspect electrical connections for security. Inspect electrical contacts.

MONTHLY (CONTINUED)

Mechanical
De-energized
Parking Brake
Check fluid level.

Air Compressor
Check oil level, check for oil leaks, check mounting for security, drain intercooler.

Gear Unit
Check oil level. Inspect for oil leakage.

Trucks
Inspect leveling valves for secure mounting and loose missing hardware.

Trucks
Inspect air bags for wear, chaffing, cuts or deflation.

Trucks
Inspect side bearing wear surfaces for wear or damage.

Inspect shock absorbers for secure mounting, loose, missing hardware and oil leaks.

Inspect bolster anchor rods for loose fittings and cracked, worn or aged rubber pads.

Air Conditioning
Clean or change air filters, grilles and screens.

Check compressor and compressor motor mounting bolts for Tightness.

Check evaporator blower motor and condenser fan motor for secure mounting and free rotation.

Check evaporator blowers and condenser for tightness on their shafts and for free rotation.

Clean surface of condenser coil.

Mechanical
Energized
Carbody - Interior
Inspect interior for damage, loose missing parts. Inspect seats, carpet, walls, windows, doors for graffiti, damage, excessive soiling

MONTHLY (CONTINUED)

Mechanical

Energized

Door Operator

Inspect emergency handle for free operation. Check lock pawl operation. Check actuation of door lock switch, inspect limit switches Ls1, LS2, LS3, LS4, LS5, for adjustment and operating. Check operation of each door operator. Check operation of individual master key switch.

Check the following for proper operation signal, push buttons, screw, key switches, signal lights.

Air Conditioning

Operate the air conditioning units and check the oil and refrigerant levels. Inspect for oil leakage.

Electrical

De-energized

Pantograph

Inspect carbon slide shoes for wear and condition, check condition of shunts.

3rd Rail Shoe

Inspect for wear contact shoe shunt assembly, check contact pressure.

Propulsion Control

Check, clean air filters. Check connectors as required, check for open/loose connections, broken components. Check operation of power contactors in auxiliary power unit by hand.

Motor-Alternator

Clean dirt from commutator covers and surrounding area. Remove covers and wipe dirt from brush holders and commutator banding. Inspect commutator for roughness, high, low, or flat spots, inspect motor alternator mountings for loose, missing hardware.

Traction Motors

Inspect brush length, clean dirt from commutator covers and surrounding area, remove covers and wipe dirt from brush holders and commutator banding.

Inspect commutator for roughness, high or low spots, or flat spots. Inspect motor mountings for looseness, inspect motor leads for damage, deterioration.

Battery

Inspect battery fluid level. Clean battery as necessary.

MONTHLY (CONTINUED)

Electrical
De-energized
Air Conditioning
Inspect control panel, clean surfaces of the terminal connections of any dirt filings, etc.

Energized
Carbody - Interior
Inspect interior lights for operation. Check annunciator.

Carbody - Exterior
Inspect exterior lights for operation.

Propulsion Control
Check operation muffin fans.

Air Conditioning
Check operation of units.

APPENDIX C

TEST LOG, SOAC SIMULATED DEMONSTRATION

TEST LOG - SOAC SIMULATED DEMONSTRATION

RUN #		MILES RUN CAR #1	MILES RUN CAR #2
1	July 23, 1973	78	78
2	July 23, 1973	95	95
3	July 24, 1973	20	20
4	July 24, 1973	-	42
5	July 25, 1973	-	158
6	July 25, 1973	-	82
7	July 25, 1973	40	-
8	July 26, 1973	119	119
9	July 26, 1973	49	49
10	July 27, 1973	-	158
11	July 27, 1973	-	22
12	July 28, 1973	120	-
13	July 28, 1973	140	-
14	July 30, 1973	80	-
15	July 30, 1973	80	-
16	July 31, 1973	100	-
17	July 31, 1973	100	-
18	July 31, 1973	80	-
19	August 1, 1973	-	-
20	August 2, 1973	-	101
21	August 2, 1973	-	60
22	August 3, 1973	-	79
23	August 3, 1973	51	51
24	August 4, 1973	-	-
25	August 4, 1973	-	131
26	August 4, 1973	32	32
27	August 6, 1973	118	118
28	August 6, 1973	88	88
29	August 7, 1973	45	45
30	August 8, 1973	89	89
31	August 9, 1973	79	79
32	August 9, 1973	138	138
33	August 10, 1973	123	123
34	August 10, 1973	138	138
35	August 11, 1973	50	50