Report No. UMTA-IT-06-0026-75-3

URRVS
• ASDP

SYNCHRONOUS BRAKE SYSTEM SPECIFICATION

DOT-UT-10007	URBAN RAPID RAIL VEHICLE AND SYSTEMS PROGRAM

Boeing Vertol Company
Surface Transportation Systems
Philadelphia, Pa. 19142

ADVANCED SUBSYSTEM
DEVELOPMENT PROGRAM

Prepared for

URBAN MASS TRANSPORTATION ADMINISTRATION
Office of Research and Development
Washington, D.C. 20591

THE BOEING COMPANY

VERTOL DIVISION · PHILADELPHIA, PENNSYLVANIA

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PREPARED BY Peter F Brown DATE 12-16-74
P. F. Brown

APPROVED BY J S Hazley DATE 2-5-75
J. S. Hazley

APPROVED BY R L Wesson DATE 2-13-75
R. L. Wesson

APPROVED BY ______ DATE ______

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A	Revised to be consistent with selected Synchronous Brake System Configuration. Corrections and changes made to account for the change from a hydraulic powered system to a pneumatic system. Provided data that was To Be Determined (TBD) in the original version (partial). Note - Retyping and changes in spacing occurred on sheets 26 through 37 (except for sheets with figures on them, sheets 28 and 33).	1/23/76	[illegible]

ACTIVE SHEET RECORD

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25						69					
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FORM 46283 (7/67)

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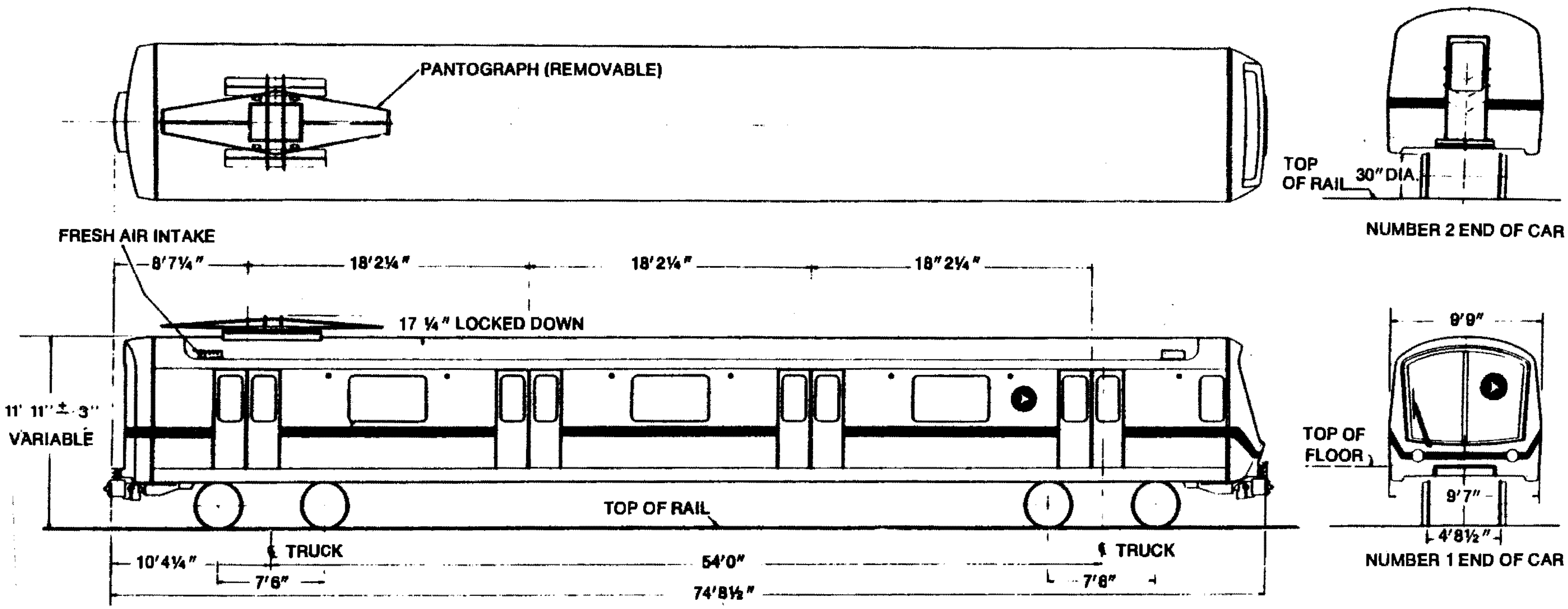

SOAC DESIGN CHARACTERISTICS

Length	75 Feet
Width	9.75 Feet
Minimum Track Curve Radius	145 Feet
Speed	80 MPH
Acceleration, initial	3.0 MPH/Sec.
Jerk Rate	2.5 MPH/Sec.^{2}
Power	600 VDC Nominal
Noise Level, interior.	spec 75 dBA @ 50 MPH actual 63 dBA @ 50 MPH
Noise Level, 50 ft wayside	78 dBA @ 50 MPH

Passenger Capacity (No. 1 car)

Seated	62
Nominal	100
Maximum (Service)	220

Passenger Capacity (No. 2 car)

Seated	72
Nominal	100
Maximum (Service)	265

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ABSTRACT

This document establishes the design, functional and test requirements for a Synchronous Brake System to be installed on the State-of-the-Art Car for test and evaluation by the Urban Mass Transportation Administration (UMTA) under the Advanced Subsystems Development Program (ASDP) portion of the Urban Rapid Rail Vehicle and Systems Program (URRV&S). The Boeing Vertol Company is systems manager for the URRV&S Program.

The proposed Synchronous Brake System is intended to improve the friction braking capability of the SOAC cars, in particular, and rapid rail vehicles in general, to equal that of the dynamic (electrical) braking system in current use.

The SOAC cars with the Synchronous Brake System installed will be tested and evaluated at the UMTA facilities, TTC. Pueblo, Colorado and on the transit properties in New York, Boston, Cleveland, Chicago and Philadelphia.

1.0 SCOPE

This specification comprises the detail requirements for the design, construction and testing of a synchronous control friction brake system for a rapid rail transit car. The evaluation of this system will be accomplished by utilizing the SOAC as a prototype test and demonstration vehicle. Data requirements, systems support and program management requirements are also included in this specification.

1.1 INTENDED USE

The requirements of this specification, unless otherwise specified, shall apply to the friction brake system on the modified SOAC. This modification will be accomplished as part of the Advanced Subsystem Development Program as defined in Report D239-10008-1, the detail specification for the modified SOAC.

The demonstration and evaluation vehicle will be tested at the DOT Transportation Test Center (TTC), Pueblo, Colorado, and demonstrated on selected portions of the following transit authorities:

	PROPERTY	LINE
a.	New York City Transit Authority (NYCTA)	A, D, E, and N
b.	Southeastern Pennsylvania Transportation Authority (SEPTA)	Broad Street
c.	Massachusetts Bay Transportation Authority (MBTA)	Cambridge-South Shore
d.	Chicago Transit Authority (CTA)	Skokie-Swift
e.	Cleveland Transit System (CTS)	Airport
f.	Others where compatibility exists	

1.2 ASDP VEHICLE (MODIFIED SOAC)

The basic vehicle characteristics of the existing SOAC are contained in Report No. IT-06-0026-73-2, the detail specification for the SOAC. The general characteristics of the ASDP vehicle are as follows:

MODEL DESIGNATION - Advanced Subsystem Development Program SOAC Test

NUMBER OF CARS - Two "A" cars

TYPE OF POWER SYSTEM - Electrical third rail
600 VDC nominal
400 VDC minimum
750 VDC maximum

NUMBER OF SEATED PASSENGERS - Car No. 1, Low Density: 62
Car No. 2, High Density: 72

2.0 DESIGN AND FABRICATION

2.1 GENERAL

This section defines the criteria for the design and fabrication of the Advanced Subsystems as well as the criteria for the existing SOAC transit car. The operational parameters, structural strength and environmental requirements are included.

2.1.1 Overall Dimensional Characteristics and Operational Parameters

2.1.1.1 Transit Car

The general arrangement drawings for the SOAC define the following dimensions with tolerances:

Length of car on centerline (over anti-climbers)	74 ft. 8-1/2 in.
Distance, center to center of trucks	54 ft. 0 in.
Truck Wheelbase	7 ft. 6 in. (existing truck)
Wheel diameter, new	30 in.
Width of car over side sheathing	9 ft. 9 in.
Width of car body at floor (without thresholds)	9 ft. 7 in.
Width over thresholds	9 ft. 7-1/4 in.
Width of side doors	50 in.
Height of side doors	6 ft. 3 in.

The transit car heights above the top of the rail for the transit properties are given in Table 2-1.

TABLE 2-1

ASDP TRANSIT CAR HEIGHTS ABOVE TOP OF RAIL FOR AN EMPTY CAR

(All Units are in Inches)

ITEM PROPERTY (HEIGHT OF)	NYCTA	SEPTA	MBTA	CTA	CTS
PLATFORM	42.4	46.0	47.5	42.0	39.0
(1&2) BOTTOM OF BASE PLATE	42.4	44.5	45.0	41.6	38.0
FLOOR	46.4	48.5	49.0	45.6	42.0
ROOF	145.4	147.5	148.0	144.6	141.0
PANTOGRAPH (LOCKED DOWN)				160.5	157.5

NOTES: (1) This is the present attachment structure for the existing SOAC secondary suspension airspring. Reasonable modifications to this structure will be considered.

(2) All heights are based on new wheels (or properly shimmed worn wheels) and unfailed suspension components.

The car and its equipment shall be designed to the NYCTA clearance lines. General arrangement, dynamic and equipment clearances shall be as indicated in the drawings listed below.

2.1.1.2 Track

Track Gauge	4 ft. 8-1/2 in.
Minimum lateral curve radius (at centerline of track)	145 ft. 0 in. (max. floor height) 295 ft. 0 in. (min. floor height)
Power collector dimensions	Variable (see Figure 2.1-1)

2.1.2 Weight

The anticipated modified SOAC vehicle design weights are given in Table 2-2.

TABLE 2-2

ASDP DESIGN WEIGHTS

AW0 - Empty Car Operating Weight 85,000 lb.

AW1 - Normal Load Car Weight 95,200 lb.

AW0 + 68 Seated Passengers at 150 lb. each = 10,200 lb.

AW2 - Full Load Car Weight 107,950 lb.

AW0 +

68 Seated Passengers @ 150 lb. each = 10,200

85 Standing Passengers @ 150 lb. ea = 12,750

22,950 lb.

AW3 - Crush Load Car Weight 130,000 lb.

AW0 +

68 Seated Passengers @ 150 lb ea = 10,200

232 Standing Passengers @ 150 lb ea = 34,800

45,000

Estimated Maximum Truck Weights (Tot. for Two) 26,000 lb.
(This is included in the tabulations above)

Except where specified different, assume a uniform car body weight distribution.

2.1.3 Drawings

The following drawings provide general arrangements and equipment clearances for the existing SOAC vehicle, and are included as Appendix 1 of Report No. IT-06-0026-73-2.

2D35006 General Arrangement, High Density Car
2D35007 General Arrangement, Low Density Car
2D35018 Dynamic Clearance Diagram
2D45044 Car Equipment Clearances

The following drawings are listed for the existing SOAC equipment. The drawings marked with (*) are expected to be modified based on the Advanced Subsystems selected.

2D35001	Design Cross-Section
2D20001	Final Assembly, Placards and Paints
*2D08200	Truck, Final Assembly
*2D08300	Axle Assembly
*2D08400	Axle Journal, 6 x 11
*2D08402	Wheel, 30"
*2D08306	Truck Pipe and Cable Assembly
*2D08320	Height Adjustments for Platform Variations
2D20000	Car Body Assembly
2D21001	Structural Assembly
2D30300	Roof-Ceiling Assembly
2D30700	Cab Partition Assembly
2D31133	Floor Assembly
2D31141	Roof Assembly
2D35029	Pantograph Installation
2D35005	Structural Bulkhead
2D35019	Structural Assembly, No. 1 End
*2D30100	Underframe Assembly
2D31000	End Weldment
*2D35012	Anchor Rod Bracket Assembly
*2D35014	Underframe Equipment Arrangement
2D22200	Drawbar Installation
*2D31524	Air Piping and Cable Support Assembly, Coupler 1
*2D31525	Air Piping and Cable Support Assembly, Coupler 2
*2D35043	Pipe Schematic
2D21200	End Assembly, No. 2 End
2D35048	Pantograph Conduit, Circuit Breakers and Hostler Receptable Installation
2D22300	Side Door Installation
2D22800	Side Window Installation
2D25300	Window and Side Sign Installation

2D35001	Design Cross-Section (Continued)
2D23200	Panel Installation, Interior
2D31100	Panel Assembly, Interior
2D35069	Panel Assembly, Interior, Car No. 2
2D23300	Heater Installation
2D23700	Seating and Flooring Installation
2D24000	Lighting Installation
2D24400	Cab Interior Finish Installation
2D24700	Low Ceiling Frame Installation
1C24800	Low Ceiling Panel Installation
*2D25000	Wiring Installation
2D25200	End Door Installation, No. 2 End
2D31015	A/C Unit, Thermostat and Speaker Installation
2D31037	Headlight and Tail Light Installation, No. 1 End
*2D35049	Handbrake Installation
2D35070	Windshield Wiper Installation, No. 1 End
2D35095	Application of Vertical Panels and Front Dash, Cab
2D35072	Final Assembly, Exterior Paints
3W-16120	Side Door (O.M. Edwards Co.)
3W-16237	End Door (O.M. Edwards Co.)
2D40003	Glass, Side Window
2D45035	Glass, Side Window, Side Sign
2D40237	Glass, Side Door
2D40240	Glass, End Door
2D40248	Glass, Cab Door
*2200027	Propulsion System (Garrett)
*2000754	Drive Unit Assembly (Garrett)
2014606	Auxiliary Power Motor/Alternator (Garrett)
*2000434	Auxiliary Power Control (Garrett)
*2007002	Brake System (Garrett)

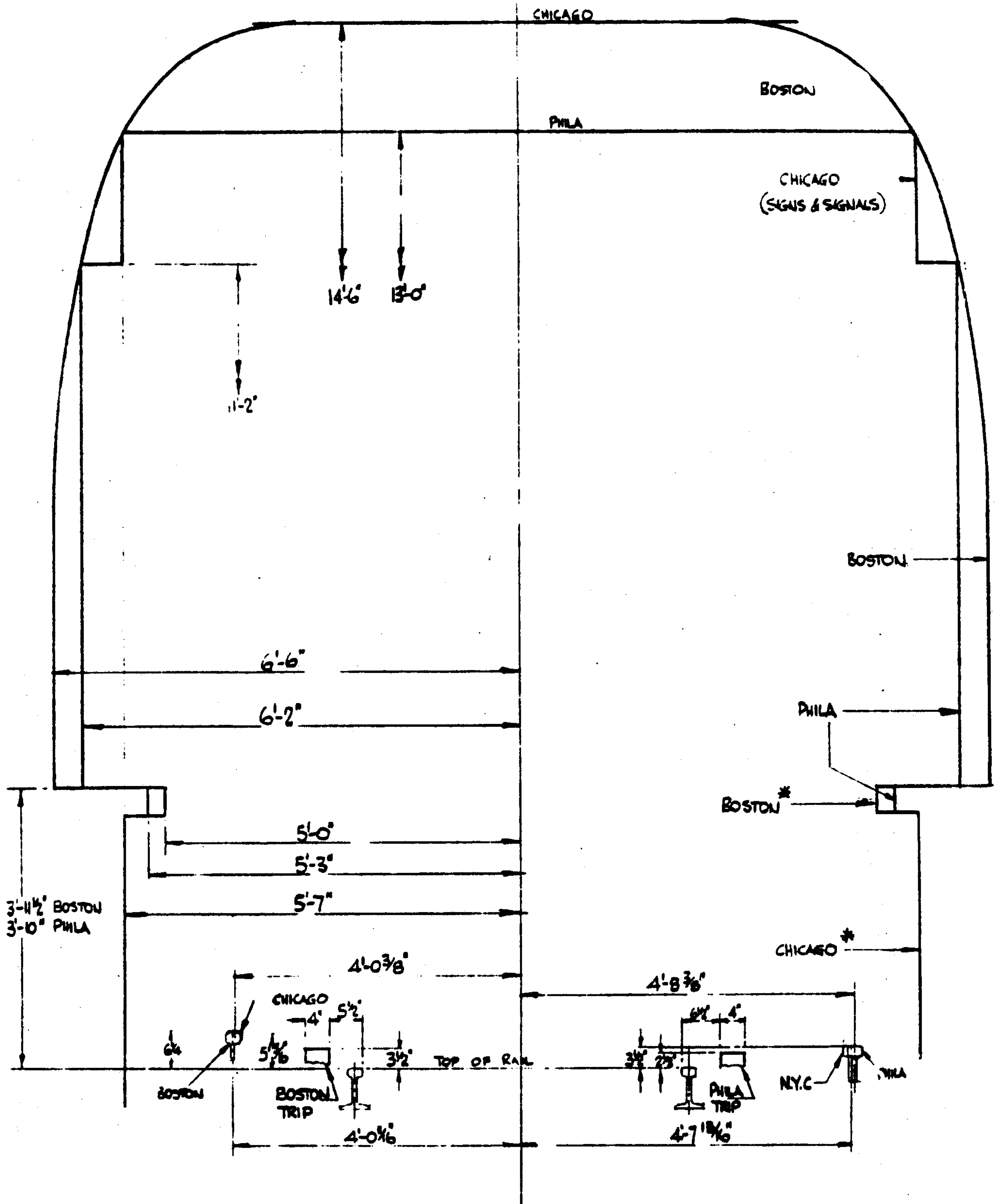
2.1.4 Applicable Documents and Drawings

The following documents and drawings form a part of this specification to the extent specified herein. In the event of conflict between the detailed contents of paragraphs, Boeing Vertol will determine precedence.

Boeing Vertol Document IT-06-0026-73-2 "Detail Specification for State-of-the-Art Car" is applicable for details regarding the original car system design.

DOCUMENT NO.	TITLE
D174-10026-1 through	SOAC Engineering Test Report
D174-10031-1	SOAC Final Project Report - Volume 1
D239-10000-1	Self-Synchronous Propulsion System Specification
D239-10001-1	Improved Ride Quality Monomotor Truck Specification for the URRV, ASDP

DRAWING NO.	TITLE
SK239-10000	Truck Equipment Clearance Envelopes for Advanced Subsystems
S-79119	P-Generator Panel
S-79120	P-Generator Panel Schematic
S-79136	Speedometer Schematic
S-79110	Master Controller
S-79111	Master Controller Schematic
(No drawing number)	Isometric Drawing of SOAC Car Body Equipment



* IT IS ASSUMED THAT THE PLATFORMS IN CHICAGO CAN BE TEMPORARILY MODIFIED FOR THESE LIMITS.

FOR INFORMATION ONLY

COMPOSITE CLEARANCE OUTLINE
Figure 2.1-1

2.1.5 Clearance Requirements

The installed equipment clearances shall conform to the existing SOAC clearance criteria as shown in Figure 2.1-1 and drawings 2D35018, 2D45044, 2D35014, and SK239-10000. Curve radius shall be as specified in paragraph 2.1.1.2.

2.2 PERFORMANCE CHARACTERISTICS

2.2.1 Electric Propulsion System Performance

The SOAC ASDP electric propulsion system shall provide vehicle performance characteristics as specified in Boeing Vertol Document D239-10000-1, Self-Synchronous Propulsion System Specification. The nominal voltage will be 600 VDC with operating extremes of 400V and 750V. All onboard equipment and systems shall function within the cited extremes. System performance requirements shall be met at 600V.

2.2.1.1 Design Duty Cycles

The maximum acceleration and braking at car weight AW1 shall be obtained utilizing a duty cycle based on the operating profile illustrated in Figure 2-1. The maximum capability thermal design of the motor and associated controls and blended friction brakes shall be such that this duty cycle may be repeated over a 30-minute time period, including a 20-second station dwell time after each cycle. Brake blending is defined in paragraph 2.2.2.1.6. The thermal design and rating of the propulsion and friction brake equipment shall be based on the ACT-1 Synthetic Transit Route on

VEHICLE OPERATING PROFILE

(SINGLE CAR,

Car Weight: AW1 = 95200 lb.

Station Spacing (Avg.) = 1.32 miles

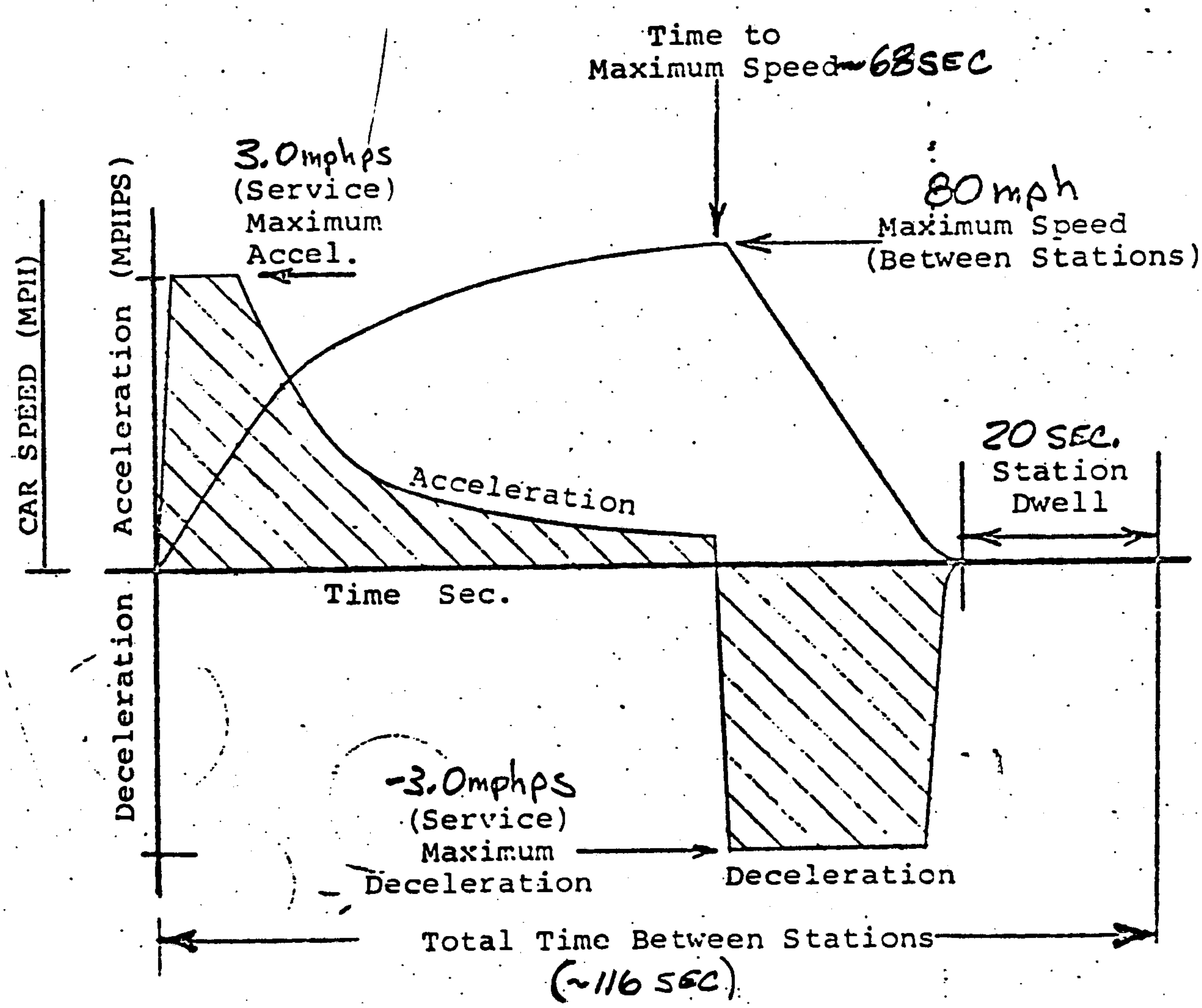


Figure 2-1

the TTC, Pueblo, Colorado test track. Track profile, alignment, station stops, and speed limits are contained in the Appendix I drawings. Due to the relatively high empty weight of the SOAC prototype vehicle, the thermal ratings of the propulsion system may be based on AW1 since this weight is within the range of loaded car weights of anticipated ACT-1 vehicles. Friction brake thermal design shall be based on AW2, using friction braking only. Consideration shall be given to the duty cycle requirements of the demonstration transit properties at actual SOAC-ASDP car weights up to AW2. Data on the property duty cycles will be available following the SOAC demonstration tour; however, it is anticipated that the ACT-1 synthetic route with AW2 weight will provide the most severe cycle for the friction brake system.

2.2.1.1.2 <u>Propulsion System</u> - <u>Continuous Duty Cycle</u>

The vehicles shall be capable of continuous maximum service performance operating singly or in a two-car train at AW1 on the transit route and operating conditions as specified in Appendix I. Round trip time shall not be greater than 39 minutes with no turnaround time allowance between the clockwise and counterclockwise runs. A 3-minute turnaround is allowed at the end of the round trip. Performance level shall be full service acceleration and braking, with maximum car speeds per Appendix I.

2.2.1.2 <u>Definition of Standard Train</u>

2.2.1.2.1 The standard train shall consist of two self-propelled A cars. Performance of each car operated separately shall be as specified in Paragraphs 1.6 and 2.2.2.

2.2.1.2.2 For performance purposes, the assigned weight of each car in the standard train shall be defined by symbols. The weight in pounds shall be the weight of the cars as produced. The figure used in the performance evaluation testing shall be based on the empty car operating weight as determined from the actual weight of the two prototypes.

The baseline design weights of the car shall be defined as follows:

Light Car Weight - AW0	85,000 lb.
Normal Load Car Weight - AW1	95,200 lb.
Comprises:	
AW0 plus	
Seated Load (Avg.) (68 passengers at 150 lbs. each)	10,200 lb.
Standing Load (Avg.) (0 passengers at 150 lbs. each)	0 lb.
Full Load Car Weight - AW2	107,950 lb.
Comprises:	
AW0 plus	
Seated Load (Avg.) (68 passengers at 150 lbs. each)	10,200 lb.
Standing Load (Av.g) (85 passengers at 150 lbs. each)	12,750 lb.
Crush Load Car Weight - AW3	130,000 lb.
Comprises:	
AW0 plus	
Seated Load (Avg.) (68 passengers at 150 lbs. each)	10,200 lb.
Standing Load (Avg.) (232 passengers at 150 lbs. each)	34,800 lb.

2.2.1.3 Condition of Standard Train

The acceleration, speed, and braking performance shall be met with new wheels of 30-inch diameter. The maximum deviation of wheel diameter due to wheel wear shall be (TBD) inch on any truck and two inches on any car. With fully worn wheels of 28-inch diameter, the standard train shall be capable of the sustained speed required in paragraph 2.2.1.6.

2.2.1.4 Condition of Roadbed

2.2.1.4.1 The performance requirements for acceleration, speed, and deceleration shall be met using dry, standard quality track.

2.2.1.4.2 Ride quality, vibration and noise criteria shall be demonstrated on track conditions around the Transportation Test Center UMTA rail transit test track at Pueblo, Colorado.

2.2.1.5 Climatic Conditions

The capability to perform within the performance requirements of acceleration, speed and deceleration as defined, shall not be affected by the climatic conditions in the areas of operation, including the year-round prevailing conditions at the Pueblo test site. The performance requirements contained in the following paragraphs are specified for an atmospheric pressure of 29.92 inches of Hg, 59°F, and zero wind. Maximum car speed capability shall not be affected by headwinds of up to 15 mph. Environmental conditions for equipment design are contained in paragraph 3.4.

2.2.1.6 Performance Summary for Standard Train

Maximum Design speed (level, tangent track)	80 mph*
Nominal Initial Acceleration (AW1)	3.0 mphps*
Nominal Deceleration: (up to AW3)	
Blended Braking (80 to 0 mph)	-3.0 mphps*
Service Friction Braking (80-0 mph)	-3.0 mphps*
Emergency Friction Braking (80-0 mph)	-3.5 mphps*
Maximum Combined Dynamic/Friction Braking	-3.2 mphps*
Jerk Rate, Normal Acceleration and Braking	2.0 mphpsps*
Time to Reach 60 mph (AW1)	38 seconds*
Distance Travelled in 20 seconds from start (AW1) (From controller input signal)	700 Feet*
Balancing Speed on 6000-foot long, 3 percent adverse grade (Aw1)	70 mph*

*Acceptance test criteria

2.2.2 Deceleration Requirements

2.2.2.1 Service Braking System

2.2.2.1.1 The deceleration performance of the car shall be as follows for all car weights up to AW3 at speeds up to 80 mph:

Maximum Full Service Braking	3.2 mphps
Nominal Full Service Braking	3.0 mphps*
Minimum Full Service Braking	2.8 mphps

Braking performance estimates shall include train resistance for zero wind and motor and gear losses. (See Figure 2-2 for Braking Diagram.) Brake system design criteria shall be based on motor and gear losses only.

2.2.2.1.2 Deviation from nominal full-service braking of 3.0 mphps shall not exceed ± .2 mphps, and the average braking effort over any 5-second time period shall be within 5 percent of nominal full service braking, under control of the load-weighing system.

2.2.2.1.3 Both service friction braking and regenerative/resistive/friction blended braking systems shall be capable of developing the performance specified in Paragraphs 2.2.2.1.1., 2.2.2.1.2 and Figure 2-2. This requirement is deleted for the electric resistive brake system below its fade point of approximately 15 mph. (See Figure 2-3 for blended braking time-distance diagram.)

* Acceptance Test Criteria

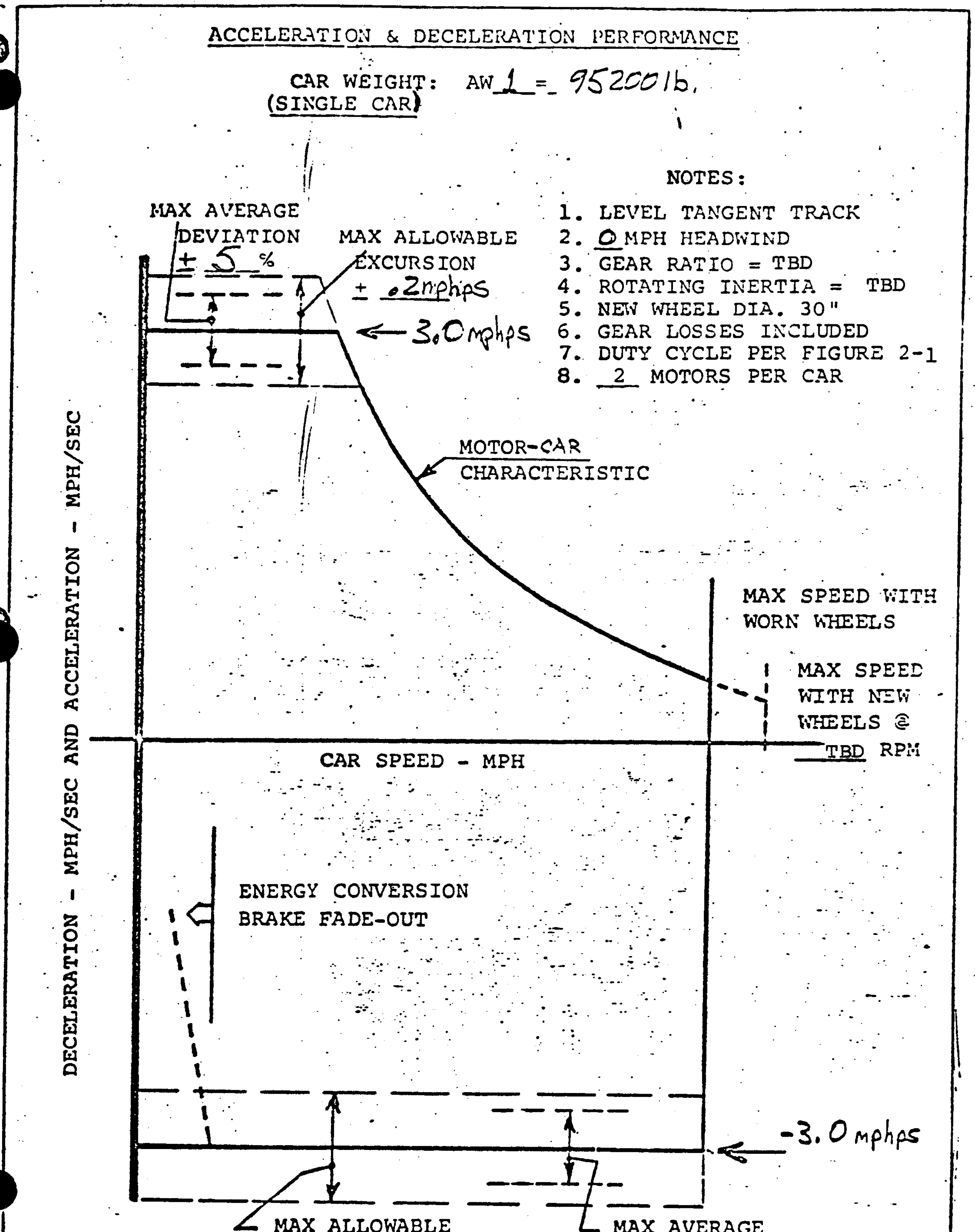

ACCELERATION & DECELERATION PERFORMANCE
CAR WEIGHT: AW 1 = 95200 lb.
(SINGLE CAR)
NOTES:
1. LEVEL TANGENT TRACK
2. 0 MPH HEADWIND
3. GEAR RATIO = TBD
4. ROTATING INERTIA = TBD
5. NEW WHEEL DIA. 30"
6. GEAR LOSSES INCLUDED
7. DUTY CYCLE PER FIGURE 2-1
8. 2 MOTORS PER CAR
MAX AVERAGE DEVIATION ± 5 %
MAX ALLOWABLE EXCURSION ± .2 mphps
3.0 mphps
MOTOR-CAR CHARACTERISTIC
MAX SPEED WITH WORN WHEELS
MAX SPEED WITH NEW WHEELS @ TBD RPM
CAR SPEED - MPH
DECELERATION - MPH/SEC AND ACCELERATION - MPH/SEC
ENERGY CONVERSION BRAKE FADE-OUT
-3.0 mphps
MAX ALLOWABLE EXCURSION ± .2 mphps
MAX AVERAGE DEVIATION ± 5 %

Figure 2-2

TIME AND DISTANCE TO STOP

CAR/TRAIN WEIGHT: UP TO AW 3 = 130,000 lb.

NOTES (SINGLE CAR,

1. LEVEL TANGENT TRACK.
2. DECELERATION PER FIGURE 2-2.
3. NEW WHEEL DIAMETER.
4. INCLUDES DEAD TIME AND JERK LIMITS

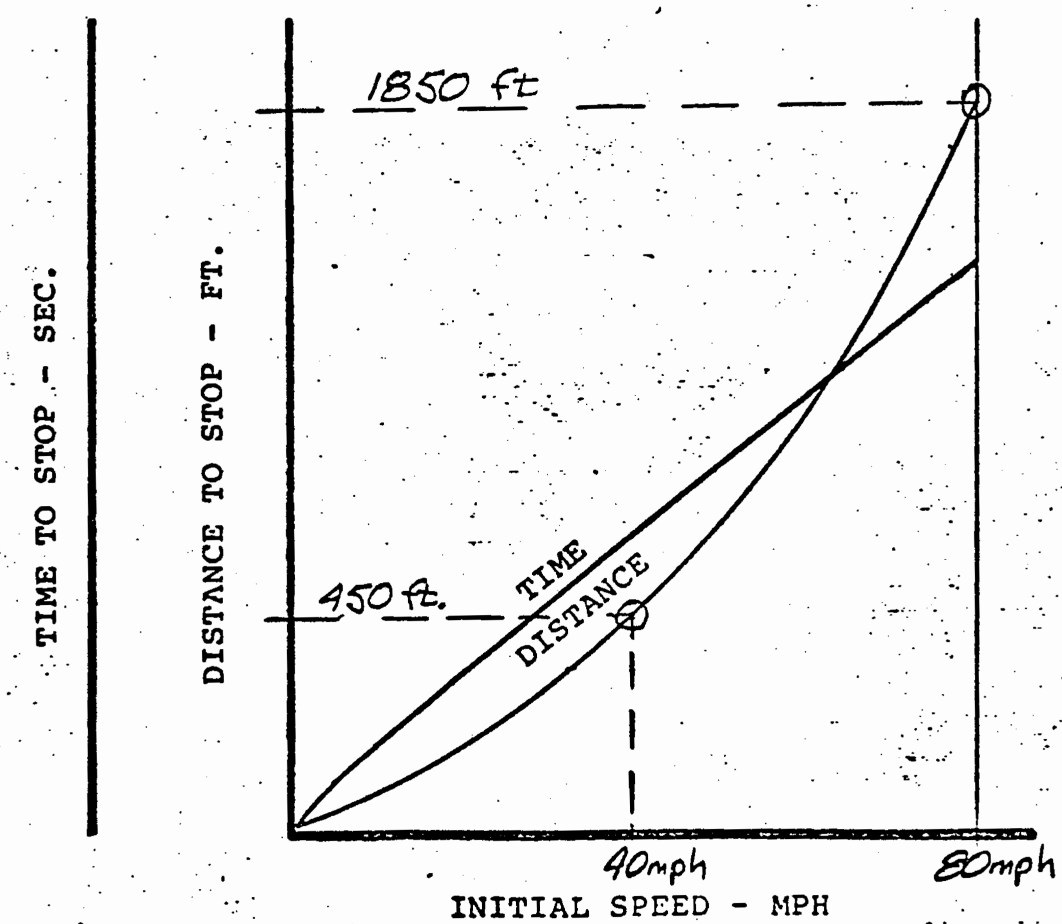


FIGURE 2-3

FORM 46284 (2/66)

2.2.2.1.4 The friction braking system operating alone shall be capable of completing one round trip of the ACT-1 Pueblo route within material design limits and the nominal average deceleration performance (v/t) specified in Paragraph 2.2.2.1.5 with a 5 percent performance tolerance. The car weight shall be AW2; performance level shall be maximum, including one emergency rate stop from 80 mph immediately following the station stop resulting in the highest brake temperatures. Equipment replacement shall not be required.

2.2.2.1.5 Either service braking system (blended, or friction only) shall be capable of the following performance at car weights up to AW3:

Initial Speed	Average Deceleration (1)	Distance to Stop
40 mph	-2.8 mphps	450 ft.*
80 mph	-2.7 mphps	1850 ft.*

2.2.2.1.6 Brake Blending

The friction brake system shall receive a fail-safe feedback indication of electrical braking effort (or rate) on a per truck basis, compare it with braking effort (or rate) request, and supplement with friction braking effort as required. Regenerative electrical braking shall be available from maximum speed to at least 25 mph; resistive braking to approximately 15 mph. In the high-speed range, regenerative braking may be supplemented with resistive braking as required to maintain commanded braking effort. Resistive braking shall be available to 15 mph or less, fading to zero resistive braking effort

(1) Average deceleration = Initial speed divided by time from BRAKE signal to time of stop; BRAKE signal to be a step controller input at a constant initial speed.

*Acceptance test criteria

at full stop. All brake blending shall operate under the jerk rate limits of paragraph 2.2.4.1. Combined braking shall not be less than service friction braking.

2.2.2.1.7 Regenerative-resistive electrical braking shall be controlled such that priority is given to regenerative braking. In the event the third rail is non-receptive to the total regenerated current, the control logic shall attempt to maintain the highest amount of regeneration by blending with resistive braking on a shared basis or per truck basis. Friction brake blending shall be available at all times and shall complete the stop following electrical brake fade-out. The presence of a non-receptive line shall never result in the development of less than the commanded (blended) brake rate. Transitions between regenerative, resistive and friction braking shall not lengthen the stopping distance of Paragraph 2.2.2.15 more than (TBD) percent.

2.2.2.2 Emergency Brake System

2.2.2.2.1 The nominal emergency friction braking deceleration rate shall be adjustable between 3.5 mphps and 5.5 mphps for purposes of test and evaluation. The rates shall be available up to 80 mph using friction brakes only. The brake rate shall be set at 3.5 mphps initially. The above rates shall be achieved up to a car weight of AW3, under control of the load-weighing or rate control system, inclusive of the translation error of car weight to load-weighing output signal. For design purposes, the 3.5 mphps brake rate shall be used; however, the system shall have a short-term capacity of 5.5 mphps at weights up to AW1. Functional requirements are contained in paragraph 3.1.1.3. All rates shall be maintained within a ±10 percent tolerance throughout the speed range.

2.2.2.2.2 The emergency friction braking system without dynamic

braking shall be capable of the following performance at car weights up to AW3 (spin-slide system disabled - nominal rate of -3.5 mphps):

Initial Speed	Average Deceleration[1]	Distance to Stop
40 mph	-3.4 mphps	370 ft.*
80 mph	-3.4 mphps	1420 ft.*

*Acceptance Test Criteria

2.2.2.2.3 Two methods of applying emergency brakes shall be provided: Mode A, through the normal service brake control at the adjustable rates of Paragraph 2.2.2.2.1, and Mode B, through a separate control system which will supply direct pressure for the nominal 3.5 mphps rate. For test and evaluation purposes, certain types of emergency brake commands shall be sent through the service brake control system; other types shall be sent to the normal emergency brake system without slide control. The details of the command logic shall be defined during the design phase. (See Paragraph 3.1.1.3 for functional requirements.)

2.2.2.2.4 The emergency stop mode of train operation shall provide an irretrievable full stop of the car or train.

2.2.2.2.5 The friction brake system shall have the fluid storage capacity sufficient to allow 20 full-service brake (pressure) applications at an AW3 car weight following loss of pressurization power source with brake supply reservoirs/accumulators at minimum cut-in pressure. Brake applications shall be made at the rate of 1 per 90 seconds and held on for 35 seconds.

1. Average deceleration = Initial speed/time from BRAKE signal to time to of stop.

2.2.2.2.6 At a car weight of AW3 the friction brake system shall have the capacity to complete five full emergency rate stops from 80 mph within a 15-minute period. Equipment replacement shall not be required. (The brake rate shall be nominal -3.5 mphps.)

2.2.3 Wheel Spin-Slide Protection

2.2.3.1 General

The spin-slide system shall detect spins and slides whether they are random or synchronous. The wheel spin-slide protection system shall be fail-safe in design and construction. The normal failure mode of the system shall be such as to render the wheel spin-slide system ineffective and allow the controller command to be sent to the brake system. The spin-slide system shall not allow braking to be removed for more than 3 seconds. If this limit is exceeded the system shall be bypassed and full commanded braking effort restored. The spin-slide systems shall operate on both electrical and friction braking systems and during acceleration.

2.2.3.2 Efficiency

The electric traction system shall contain a spin-slide control subsystem capable of producing the following efficiencies for random slips during testing on wet rails in the speed range from 10 mph to 80 mph.

Electric Braking:	90 percent
Acceleration:	90 percent

SLIP-SLIDE PROTECTION SYSTEM EFFICIENCY

$$\text{Efficiency} = \frac{\text{Area } (A_2)}{\text{Area } (A_1 + A_2)} \times 100\%$$

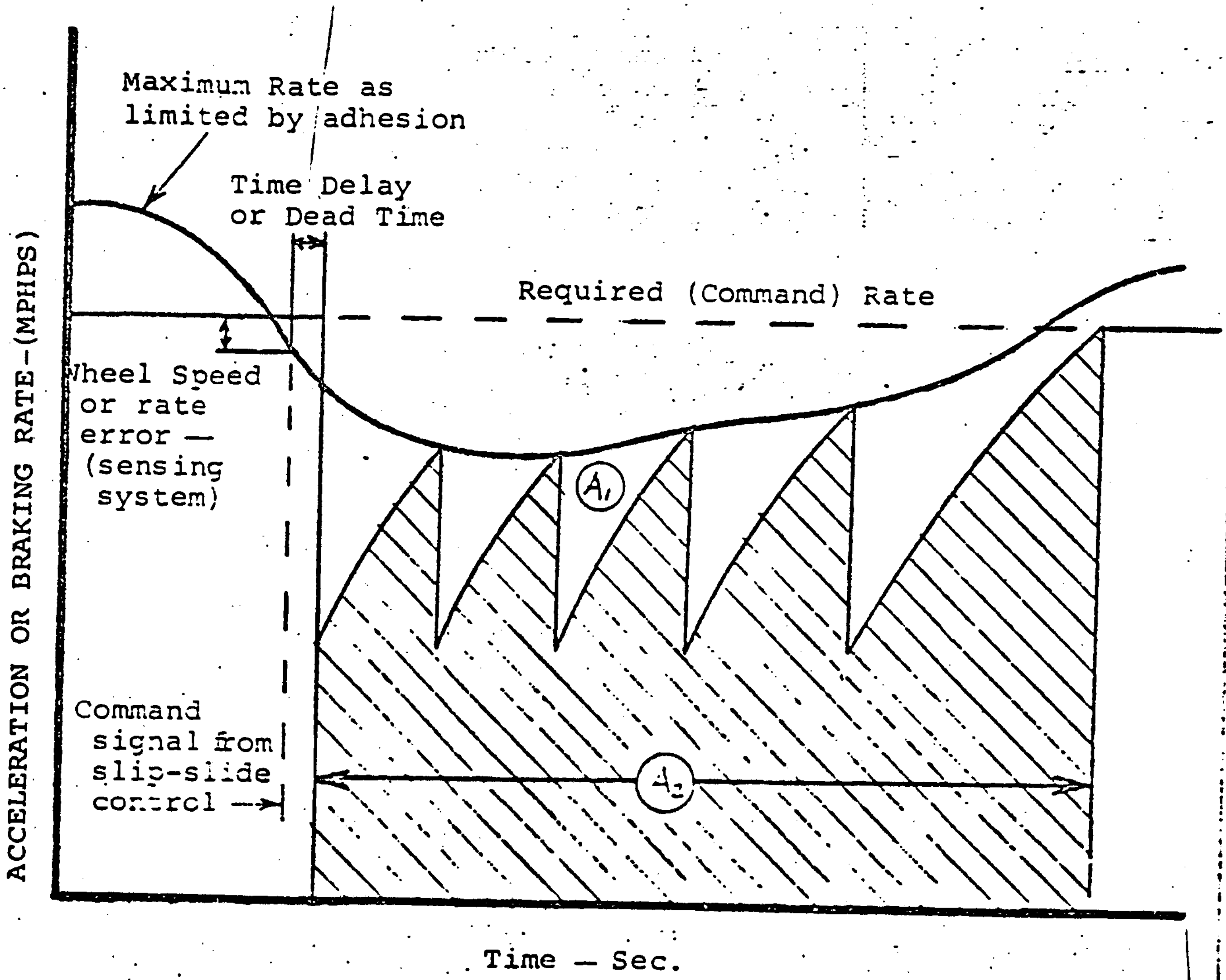


Figure 2-4

The service friction brake system under the above conditions shall produce an efficiency of 95 percent. The efficiency, as defined in Figure 2-4 is equal to the actual change in speed expressed as a percentage of the maximum change in speed dictated by the limit of adhesion during any continuous sequence of the wheel spin-slide protection system.

2.2.3.2 Operation

The spin-slide protection system shall function properly with differences of up to 2 inches in diameter among the wheels of a car. The system shall detect wheel slips in acceleration or braking whether random or synchronous.

2.2.3.2.1 Propulsion System

Upon detection of a wheel spin or slide the spin-slide system shall reduce the tractive or braking effort on the affected truck. Release of tractive effort need not be jerk limited; reapplication of tractive effort shall be jerk limited. Consideration shall be given to an "adaptive" feature which will quickly reapply tractive effort to less than full command level (percentage of previous slip value) followed by a slower increase to full or some percentage command level. This control shall apply to both acceleration and deceleration. The threshold values of wheel speed difference or wheel acceleration rates shall be consistent with the above efficiency requirements.

2.2.3.2.2 Friction Brake System

The friction brake subsystem shall contain an adhesion control system which shall effectively synchronize the applied brake pressure with the resulting wheel/car deceleration rate or input command rate. This requires essentially a continuous control feature which "follows" the available rail adhesion synchronously rather than an "ON-OFF" control which releases and reapplies or pulses the brakes. Consideration shall be given to methods of making the continuous or synchronous control feature available to the electric traction system. The friction brake system spin-slide efficiency shall be a minimum of 95 percent throughout the speed range of 10-80 mph. The friction brake system spin-slide system shall function throughout the speed range of the cars.

2.2.3.2.3 The wheel slide protection system shall be functional under all braking commands except a Mode B emergency brake application. The system shall be so arranged that failure of any component of this system shall not prevent development of a full emergency brake application. For test purposes it shall be possible to allow the friction brake continuous rate control system to function during emergency brake (Mode A).

2.2.4 Jerk Rate

2.2.4.1 The maximum rate of change of acceleration or deceleration of each car in the standard train shall not be more than 2.0 mphps/second under all normal ATC or MTC control signal changes. Jerk rate limitation shall be inherent in the propulsion and braking system.

2.2.4.2 The jerk rate limits of Paragraph 2.2.4.1 shall apply to power and braking applications and reapplications, but not to release of tractive effort during normal function of the wheel spin-slide systems, or reapplication of power following third rail gaps.

2.2.4.3 Jerk rate limiting for braking shall be fail-safe in design such that failure of the system shall not reduce the maximum available braking rate during deceleration.

2.2.5 Control Response (DEAD) Time (Exclusive of Motorman)

The maximum allowable response times for all detection and control systems for propulsion and friction brake systems shall be as follows:

Control Signal Change (ATC and/or MTC) (Signal to response)	.50 sec.*
Acceleration and Deceleration Modulation (Spin-slide system dead time)	.05 sec.*
Friction brake dead time in response to change in controller brake command (Step or ramp input; signal to response)	0.15 sec.

The friction brake system shall have the capability to respond to changes in braking command of $\pm .25$ mphps from any steady command within the full control range from zero to full-service rate. Friction brake response characteristics for application, release, and reapplication of braking effort shall be consistent with the overall braking requirements of Paragraph 2.2.2 and the slip-slide system performance and operating characteristics of Paragraph 2.2.3.2.2 as dictated by the synchronous control system.

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*Acceptance Test Criteria

2.2.6 Car Load-Weighing System

2.2.6.1 The load-weighing system shall provide electronic signals proportional to the load on each truck to both the traction system and dynamic-regenerative and friction braking system controls. The accuracy of the load-weighing system shall permit compliance with the acceleration and braking requirements of Paragraph 2.2.1.6 and 2.2.2.1.2 respectively, and the emergency braking requirements of Paragraph 2.2.2.2.1.

2.2.6.2 The load weighing signal shall modify the tractive effort signal (P-signal) within the propulsion control such that the initial acceleration rate and acceleration-speed characteristics associated with any input command are maintained for car weights from AW0 to AW1. The load-weighed braking rates resulting from any command input shall be constant for weights up to AW3.

2.2.6.3 The load weighing system shall be fail-safe in design to ensure that any failure of the system or any loss of air spring pressure to the system shall result in no less than that braking level which is being commanded. To protect against degradation of braking effort caused by loss of air spring pressure the load weighing system shall respond to the higher of the pressures sensed by each truck. In the event of total loss of air suspension the braking command rate for that truck shall be to the AW3 weights.

2.2.7 Tractive Effort Reference

2.2.7.1 The tractive effort reference shall be the existing SOAC analog current signal (trainlined) varying linearly between 0 and

1.0 amp D.C. The resulting control reference and car characteristic shall be shown in Figure 2-5.

2.2.7.2 The tractive effort reference shall be interpreted by the friction braking system such that full service braking is commanded at P-signals from 0 to 0.1 amp D.C. Braking effort shall be within the $\pm$.2 mphps tolerance throughout the control range from .45 to .10 amps over the speed range from 0 to 80 mph. (Reference Figure 2-6). Paragraph 5.1 describes the SOAC master controller.

2.2.8 Traction Resistance

For design purposes the traction resistance of the SOAC vehicles shall be calculated based on the following modified Davis equation.

$$TR = 1.3W + 29n + .045\ WV + [(.0024) + (N-1)\ (.00034)]\ AV^2$$

where: TR = Resistance, Total, LB
W = Weight per train, TON
n = Number of Axles per train
V = Train Speed, MPH
N = Number of cars in train
A = Frontal area of lead car = 115 ft^2

2.2.9 Handbrake/Parking Brake Requirements

The parking brake shall be capable of holding a crush loaded car (AW3) on a 5 percent grade for a period of 30 days without pneumatic or electrical power applied to the system.

2.2.10 Performance Ground Rules

The following items define the basis for the design of the friction braking system:

a. All braking rates shall be based on level tangent dry track, except as otherwise stated.

STATE-OF-THE-ART CAR TRACTIVE EFFORT REFERENCE

(600 VOLTS dc)

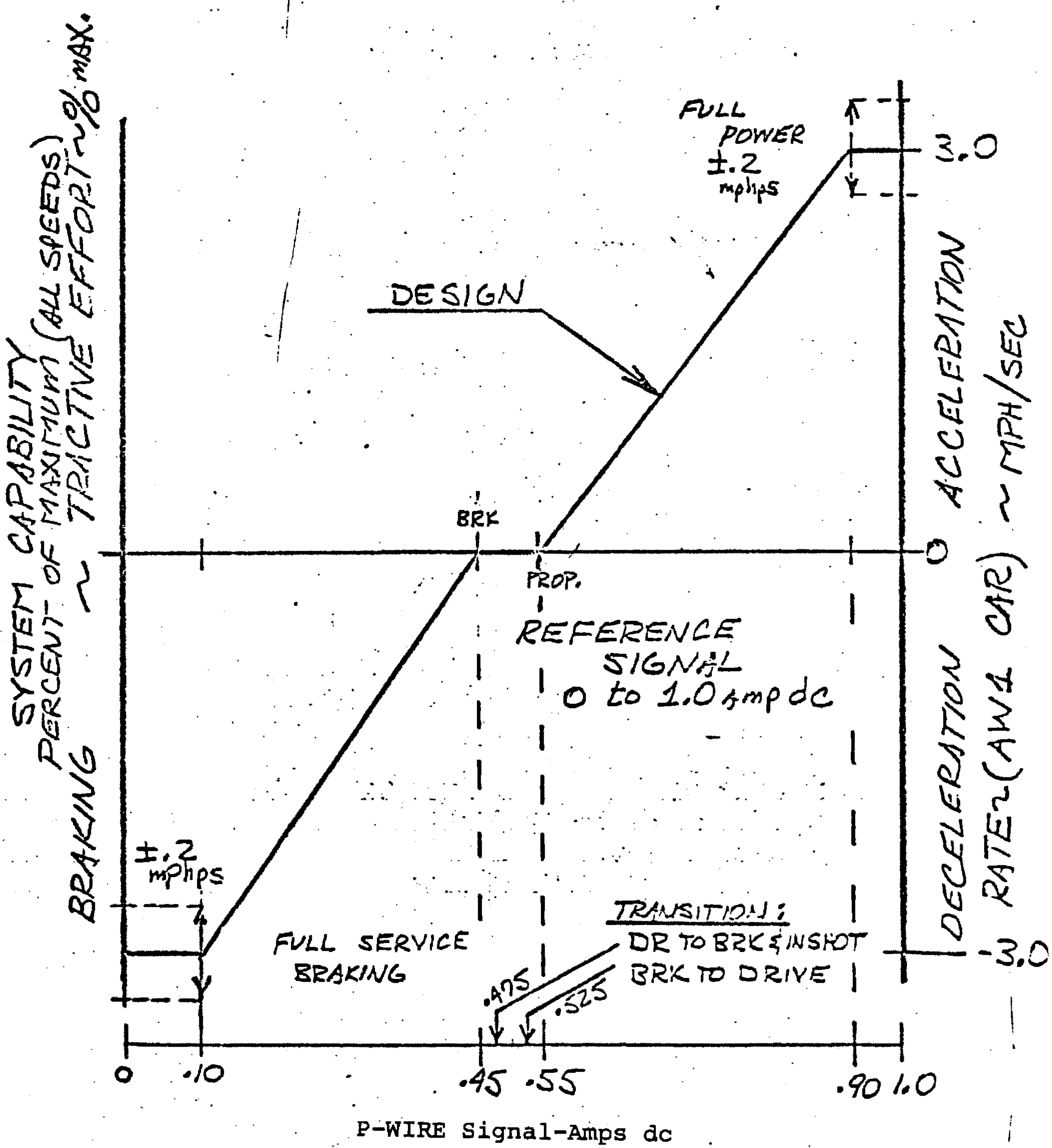


FIGURE 2-5

b. All braking rates shall be based on actual AW3 car weight of 130,000 lb. (AW3 = AW0 + full passenger load = 85,000 lb. + 45,000 lb.).

c. Braking rates shall not include train resistance but may include motor and gear losses.

d. New wheel tread diameter shall be 30 inches nominal. Maximum differences from average of any axle speed on car shall not exceed 3.5%.

e. Braking rate shall be assumed to be measured at car axles without consideration of vehicle suspension characteristics.

f. Vehicle braking rates shall be available over the full operating speed range.

g. For the calculation of inertia effects, the standard values shall be used (100 lb/ton/mphps) unless the actual effective weight of the rotating machinery exceeds 10% of the vehicle actual empty weight. In this case the actual effective weight of the vehicle shall be used.

2.2.11 Performance Data Submittal

The friction brake supplier shall submit all performance data required to substantiate the system's capability to meet the performance requirements of Section 2.0. The data shall be analytical or empirical and shall include, but not be limited to, the data requirements tabulated in Section 7.0.

3.0 SYSTEM CHARACTERISTICS

3.1 FUNCTIONAL CHARACTERISTICS

3.1.1 Braking Control

In the service mode the vehicle operator shall initiate all propulsion and braking system modes and rate commands in either selected car direction. The resulting trainlined propulsion control signal will be an analog DC current varying from 0 to 1.0 amps. This analog signal will be generated by the existing Garrett-SOAC equipment. The propulsion system shall interpret the trainlined control signals and provide the proper brake application signal(s) to the friction brake system. The service friction brake system shall act as a backup service brake, blending with the electric brake as required.

3.1.1.1 Propulsion

The control system shall provide the operator with the capability of making up or breaking the propulsion circuit (contactors) in accordance with the current values in Figure 2-6; drive to brake at .475 amps; brake to drive at .525 amps. In the propulsion mode the control system regulates the tractive effort of the car.

3.1.1.2 Coasting

The coasting mode of the system shall provide a removal of power to the traction motors with the propulsion system in the drive or brake mode according to Figure 2-6. When in the brake mode at less than .475 amps the motors shall act as essentially unloaded generators. Inshot pressure may be supplied to the friction brake system at less than .475 amps as required to meet the response times of paragraph 2.2.5.

3.1.1.3 Blended Braking

In the braking mode the control system shall provide the operator with the capability of continuously varying vehicle deceleration from a minimum rate of .25 mphps to full-service rate. The master controller will provide a command signal to both electric and service friction brake systems. The electric brake system may provide friction brake control signals as specified in paragraph 3.1.3. A control subsystem within the propulsion system shall define and control the operation of regenerative or resistive braking as specified in paragraph 3.1.4.

3.1.1.4 Emergency Braking

The emergency brake mode of control shall provide for an irretrievable full stop using friction brakes only. For test and evaluation purposes two methods of emergency brake control shall be provided:

a. Brake control independent of the normal service synchronous control.

b. Brake control utilizing the adhesion control (spin-slide) characteristics of the synchronous control system.

Method "a" shall bypass the service brake control and apply brakes to the nominal 3.5 mphps rate of paragraph 2.2.2.2.1. Method "b" shall use the service brake control features, shall be adjustable for test purposes (-3.5 mphps to -5.5 mphps). Both methods shall be irretrievable.

The emergency brake shall be activated using the master controller power lever, emergency stop pushbutton, passenger and motorman's emergency pull cables, complete loss of battery power, track trip cocks, and separation of cars in train. All of these actuation

methods shall either break an emergency continuity wire (trainlined) or vent the brake pipe (trainlined) directly or remotely. The existing SOAC brake system is equipped with a brake pipe. The selection of either a continuity wire or brake pipe (or a hybrid version) will be determined during the detailed design phase. The contractor shall propose a system which best meets the performance and functional requirements of this specification. The propulsion system shall be disabled during all emergency brake applications (either methods "a" or "b"), by a power knockout switch to be supplied by the friction brake contractor.

3.1.2 Jerk Rate Limiting

The jerk limiting subsystem shall be provided by the propulsion system supplier and shall accept the analog signal from the master controller and condition it such that the traction or braking effort commanded from the propulsion or friction brake system is limited to a maximum equivalent rate of change of 2.0 mphps in response to a step controller input in either drive or brake mode. If the rate of change of master controller P-wire signal is less than the equivalent of 2.0 mphps then the tractive or braking effort commanded shall follow the master control signal. The resulting jerk rate shall be independent of the magnitude of the change in master controller signal. Jerk rate limiting shall apply to power and braking applications and reapplications when controlled by the wheel spin-slide system. Jerk rate limiting shall not apply to the following conditions:

a. Emergency brake applications
b. Release of power or braking under spin-slide control

A jerk limited brake effort command signal will be made available to the service friction brake subsystem as required. Special signal conditioning, if required by the friction brake system, shall be provided by the friction brake supplier.

3.1.3 Friction Brake Control

If required, the propulsion system shall provide a fail-safe control signal to the service friction brake which is proportional to the difference between the master controller-commanded brake effort and the brake effort contributed by the electric brake system. This signal shall be supplied on a per truck basis.

3.1.4 Regenerative-Resistive Brake Blending Control

The propulsion system provides an electrical brake control function which operates to maximize the amount of power regenerated to the line during all blended service braking stops. When the line is not receptive to the regenerated power, the control places a resistive load in the braking circuit to maintain the master controller commanded deceleration and minimize friction braking. The blending control either shares regenerative-resistive power continuously on each truck, or on a per-car basis by placing one truck in regenerative and one in resistive braking. The control decision to attempt regeneration is made a sufficient number of times per stop such that overall regeneration is maximized.

3.1.5 Speed Sensing

The propulsion-drive system supplier shall provide a tachometer gear and a mount for an electromagnetic pickup on each truck to sense the axle speeds of each truck. The input for the tachometer will be approximately 100 gear teeth per wheel revolution. The friction brake system supplier will be responsible for pickup and processing of this signal. A DC voltage analog of speed may be required for other car systems, the friction brake system supplier shall provide such a signal if required (the load impedance is estimated to be a minimum of 20 $K\Omega$).

3.1.6 Wheel Spin-Slide Protection

The propulsion system includes provisions to protect against wheel spins in acceleration and wheel slides in electric braking on each car whether random or synchronous. The control circuit

interfaces with the truck mounted speed sensors as noted in Paragraph 3.1.5. Provisions shall be made for a control circuit interface with the friction brake system as required.

Slip-slide control authority shall be transferable between the propulsion and friction brake systems by means of a switch(s) located in control cabinets.

A dynamic means of transfering slip-slide control shall be provided such that slip-slide control will be done by the propulsion system above TBD mph and by the friction brake system below TBD mph. This is anticipated to be the normal control arrangement in service.

The propulsion system spin-slide control circuit functions under the following conditions:

3.1.6.1 Wheel spins during acceleration (Propulsion):

a. reduce tractive effort - non-jerk limited
b. correct wheel spin
c. reapply tractive effort under jerk limit control (may be adaptive control per Paragraph 2.2.5.2)
d. efficiency per Paragraph 2.2.5.2

3.1.6.2 Wheel slides during service braking (electric braking):

a. reduce braking effort - non-jerk limited

b. correct wheel slide

c. reapply braking effort under jerk limit control (may be adaptive control per Paragraph 2.2.5.2)

d. efficiency per Paragraph 2.2.5.2

The above conditions apply to the resistive electric braking mode. The electric brake control may revert to resistive braking on a per truck basis from regenerative braking during any wheel slide sequence.

3.1.6.3 Provisions shall be provided for complete cancellation of electric braking on a per car basis and transfer to all friction service braking for both test and evaluation purposes, and as a possible service operating mode. In the cases where wheel slides in braking are controlled by the synchronous friction brake system,

the electric brake effort shall be removed upon detection of the first wheel slide. The friction brake system shall then assume the full brake command as modified by the adhesion control system. Consideration shall be given to reapplication of the electric brake after a specified time following correction of the slide if braking adhesion can be maintained at the commanded deceleration rate.

3.1.7 Load Weight Compensation

A control signal is provided on a per truck basis, which is proportional to the load on each truck. The source of this signal is the air spring suspension pressure on each truck. The propulsion equipment provides the means of interpreting the air suspension pressure, converting to electronic signals, and controlling the propulsion system in both drive and braking modes such that the acceleration rates of Section 2.0 are maintained as specified. In the deceleration mode, load weight compensation shall be provided from AWO to AW3 for both blended and service friction braking as well as emergency friction braking. Service brake load weighing shall be inherent in the brake system or may be derived from the propulsion control system as required. The emergency load weigh system shall be provided by the brake contractor and shall be independent of the propulsion control signal. The brake contractor shall propose either a pneumatic or pneumatic/electronic emergency load weigh system as applicable.

3.1.8 Calibration for Wheel Wear

Provisions shall be included in the friction brake control system to correct for the effects of wheel diameter variation upon velocity detection and rate detection. Consideration shall be given to an adjustment which will maintain the nominal rates of Paragraph 2.2.2. For service friction (blended) braking this function may be provided by the propulsion control system.

3.1.9 Roll-Back Protection

A control function shall be provided by the propulsion contractor to prevent undesirable car motion during the transition from brake to drive at zero car speed. This function shall prevent either forward or reverse rolling motion until sufficient tractive or braking effort is generated by the propulsion system in response to the master controller command. Details of this control function shall be presented to Boeing for approval, and will be made available to the friction brake contractor.

3.1.10 Rate Adjustments

The friction brake system shall be adjustable within the full service rate tolerances of Paragraph 2.2.4.1.1. This adjustment capability shall be provided within the equipment to be supplied by the friction brake contractor.

3.2 SYSTEM PHYSICAL CHARACTERISTICS

Specific physical characteristics of equipment such as size, weight, and mounting dimensions and stiffness must be approved by Boeing Vertol Engineering before any hardware is manufactured.

3.2.1 Truck-Mounted Equipment

All truck-mounted equipment (brake discs, calipers, control valves, piping, etc.) shall conform to the clearance dimensions as generally outlined in Boeing Vertol Drawing SK239-10000.

3.2.2 Underframe-Mounted Equipment

Equipment mounted beneath the car will be either mounted directly to the underframe of the car (via appropriate vibration mounts as required) or placed within environmental equipment enclosures. The equipment shall replace the existing AiResearch equipment as listed in Paragraph 3.2.4 and Drawing 2D35014.

3.2.3 Equipment Mounted Within Car

Electronic control equipment such as control logic circuits may be mounted within the operator's cab. The available space will be determined by Boeing Vertol. Cab-mounted equipment weight shall not exceed 100 pounds.

3.2.4 Items to be Removed from SOAC Underframe (Drawing 2D35014)

Item (Includes Support Assemblies)	Between Sta. No's.	Code	Car Side
Truck Connector Box	195 - 212	2	Center
Brake Unit	198 - 234	1	A-Side
D.C. Chopper	212 - 270	1	CTR
Inlet Air Duct	270 - 306	1	CTR
Vaneaxial Fan		1	
Filter	270 - 306		B-Side
Jet Pump			
Unit Propulsion (Power) (Power Control Unit PCU)	234 - 315	1	A-Side
Input Reactor	320 - 356	1	A-Side
Control Unit-Propulsion (Propulsion Power (Control Unit, PPCU)	372 - 414	1	B-Side
Smoothing Inductor	380 - 414	1	CTR
Resistor Grid (Brake) (2 Grids)	486 - 558	1	A&B Sides
(NOTE: M-A Start Resistor Grid Remains on Car; Not Shown on Drawing)			
2 CU.FT. Reservoir (Brake Supply)	540 - 554	3	CTR
2 CU.FT. Reservoir (Brake Supply)	558 - 585	3	B-Side
Vaneaxial Fan	664 - 683	1	B-Side to CTR
Filter			
Jet Pump			
Ducting			
Brake Unit	666 - 702	1	A-Side
Truck Conn. Box	686 - 706	2	CTR

CODES

(1) Completely remove and replace with supplier's new equipment.

(2) Retain function; may be modified by supplier to his specifications.

(3) May be removed pending final selection of brake system.

3.3 Product Assurance Characteristics

3.3.1 Reliability

Reliability definitions pertinent to the following characteristics are given in Paragraph 3.3.5.

3.3.1.1 Synchronous Hydraulic Brake System Reliability Goals

The following reliability requirements are established for the ASDP brake system, on a single car basis as:

SYSTEM	MTBF/MDBF
Synchronous Hydraulic Brake System	5000 hours MTBF or 135,000 miles MDBF

3.3.1.2 Reliability Plan

A comprehensive plan setting forth the reliability program that will be followed for development of this system shall be submitted for approval 30 days after contract go-ahead. This plan shall, as a minimum, identify the organization responsible for managing the reliability program and how the Contractor will achieve the reliability objectives during design, test, manufacture, and service. The plan shall further describe how compliance by subcontractors to their reliability objectives will be assured. Comprehensive progress reports detailing the implementation of the approved plan shall be submitted to Boeing as part of the Monthly Progress Report.

3.3.1.3 Reliability Analyses

3.3.1.3.1 MTBF/MDBF Prediction Analysis

A reliability analysis shall be made on the final design. This analysis is to demonstrate that the system will meet the required reliability goals specified above in Paragraph 3.3.1.1. The

analysis shall contain, as a minimum, a description of the data base; actual experience (wherever possible) failure rate data; adjustment factors where used; rationale for factor use; reliability block diagrams; system failure/success criteria; and system MTBF/MDBF. Note that where empirical failure data is not available, failure information may be derived from other valid sources for similar equipment, providing the experience operating hours is high.

The analysis shall be submitted for approval 15 days before the final Design Review. The analysis shall be updated at the completion of the qualification testing. The updating shall make use of test data, and failures occuring in test and configuration changes.

3.3.1.3.2 Failure Mode and Effects Analysis (FMEA)

An FMEA shall be performed as part of the design process. This analysis shall be updated to reflect the final design and shall be submitted, for purchaser approval 15 days before final design review.

FMEA shall consider, as a minimum, the failure modes and effects of the occurrence of these modes upon the brake system and car operation(s). The brake system components listed in Section 5.0 shall be given primary consideration.

3.3.1.4 Reliability Reporting

All failures that occur during the testing and demonstration shall be discussed in the Progress Reports (Paragraph 3.3.1.2) and reported by failure reports. These failures shall be classed by component and mode. Probable cause of failure shall be assigned following failure analysis. The above reliability

plan (Paragraph 3.3.1.2) shall include a discussion of the failure reporting procedures and success/failure decision criteria, to be used.

3.3.2 Maintainability

The ultimate objective of the ASDP maintainability program is to design a brake system that has high availability and low cost of ownership. System and equipment shall be designed to provide optimum maintenance, troubleshooting, component removal and repair.

3.3.2.1 Subsystem Requirements

The following maintenance requirements have been established for the synchronous hydraulic brake system. These values must be considered maximum allowables and it shall be an objective of the supplier to reduce task times and frequencies to a minimum.

MAINTENANCE TASK	DIRECT MH/TASK
Basic Inspection	2.0 MH/Car
REMOVE AND REINSTALL TASKS	
o Friction Brake Control Valve (Dump Valve)	0.5 MHRS/UNIT
o Brake Application Unit and Supply Module (Servitrol)	1.5 MHRS/UNIT
o Brake Caliper	3.5 MHRS/UNIT
o Brake Pads	0.25 MHRS/UNIT
o Brake Disc (Split)	2.0 MHRS/UNIT

3.3.2.2 Maintenance Concept

It shall be the intent of the supplier to provide a system based on the "on-condition" concept. Specific features that effect the concept shall be identified and those critical features that preclude its attainment shall be identified. The contractor shall develop in coordination with and deliver to the purchaser, a com-

prehensive maintenance concept which shall contain plans for the ASDP brake system inspection, repair, overhaul and preventive maintenance actions. The levels of skills of manning, scheduling, facilities, and special equipments needed shall be concisely described.

The Maintenance Concept shall define the extent to which overhaul, repair and maintenance shall be performed at the Contractor's facilities during and after the program. The use of Contractor maintenance shall be governed by the following criteria:

a. The need for specialized facilities and tools that are not available at a typical maintenance shop.
b. The need for special or highly skilled personnel.
c. Tasks that would be done infrequently and would require a significant amount of technical data that would not otherwise be provided.

The final maintenance concept shall be submitted for approval 30 days prior to delivery of cars to TTC.

3.3.2.3 Maintenance Analysis

A comprehensive maintenance analysis shall be performed on the maintenance tasks noted above, Paragraph 3.3.2.1 and others that may be identified during this program. The analysis should show detailed steps required for each task and the estimated manhours that may be required.

This maintenance analysis shall be submitted for approval 15 days before final design review.

3.3.2.4 Fault Isolation/Troubleshooting Plan

A Fault Isolation/Troubleshooting Plan shall be developed and implemented by the Contractor's designers. This plan shall detail fault isolation and troubleshooting aids installed on the vehicle.

This plan shall describe fault isolation methods that will enable the repairman to successfully locate failures to the extent that the failure can be corrected by an on-car repair or by replacement of the failed module.

These fault isolation methods shall recognize the capability to connect a shop-located fault diagnostic unit to the car to check out the ASDP brake system.

This plan shall be submitted for approval at least 15 days prior to final design review.

3.3.2.4 Maintainability Checklist

In addition to the maintainability requirements listed in previous paragraphs, the following checklist will be used during the design of the ASDP brake system.

a. Fault Isolation/Troubleshooting aids shall include:
   - o Systematic Fault Isolation procedures
   - o Built-in test points and equipment, as necessary
   - o Plug-in test equipment capability

b. All test points, modules, wire junctions, pipes, tubing, etc., must be identified by nameplates, color coding, number coding, or other means to assist the maintenance repairman.

c. Assemblies or components that are functionally interchangeable shall be physically interchangeable between cars. Assemblies or components that are not functionally interchangeable shall not be physically interchangeable. Keyed

connectors and wiring shall be used throughout the system.

d. Standard commercially available components and hardware of proven reliability shall be used whenever possible.

3.3.2.5 Maintainability Demonstration Test

A maintainability demonstration test shall be conducted during the simulated Service Test Program. The test shall consist of demonstrating the tasks listed in Paragraph 3.3.2.1. The tasks to be demonstrated will be performed by a team of the Contractor's personnel. The demonstration shall be monitored for validity of procedures and conformance to manhour expenditure.

The Contractor shall submit the test plan for approval 30 days prior to the delivery of the cars to the TTC, Pueblo, Colorado. The test plan may allow advantage to be taken of actual maintenance operations that are required during the test program to fulfill the needs of the maintainability tests.

3.3.3 Systems Safety

The contractor shall establish and maintain a System Safety Program based on the guidelines of MIL-Std-882. The program shall assure that system safety is integrated into all phases of design, production, and operation of the brake system and that hazards are methodically evaluated and controlled.

3.3.3.1 System Safety Plan

A System Safety Program Plan to incorporate the System Safety Program (Paragraph 3.3.3) shall be prepared and submitted for approval 30 days after contract go-ahead. The plan shall describe an integrated system safety effort within the total program and shall include but not be limited to the following:

a. Identification of safety-related system requirements/ criteria.

b. Specific information showing how the Contractor will meet the safety requirements during development, manufacture and operation of the system.

c. Procedures for problem identification and resolution.

d. Procedures for recording and reporting the status of actions to resolve problems.

e. Utilization of historical safety data to take advantage of previous experience.

f. Organization responsible for managing the safety program.

g. Description of hazard analysis procedures and techniques that shall be used.

h. Milestone chart outlining task accomplishment and report submittal.

3.3.3.2 System Safety Criteria

System designs and operational procedures should consider, but are not limited to the following:

a. Avoiding, eliminating or producing hazards that are identified by analysis, design selection, material selection or substantiation.

b. Controlling and minimizing hazards to personnel, equipment, and material which cannot otherwise be avoided or eliminated.

c. Incorporating failsafe principles where failures would disable the system or cause personal injury, damage to equipment, or inadvertent operation of critical equipment.

d. Locating equipment components so that access to them by the required personnel during operation, maintenance, repair or adjustment shall not require exposure to hazards such as entrapment, chemical burns, electrical shock, cutting edges, sharp points, or toxic atmospheres.

e. Avoiding undue exposure to operating and/or maintenance personnel to physiological and psychological stresses which might cause errors leading to mishaps.

f. Providing suitable warning and caution notes in operations, assembly, maintenance, and repair instructions and distinctive markings on hazardous components, equipment or vehicles for personnel protection. These shall be approved by the procuring activity.

3.3.3.3 <u>System Safety Precedence</u>

Actions for satisfying safety requirements in order of precedence are specified below:

a. Design for minimum hazard during all operational phases. The major effort throughout the design development shall be to select appropriate safety design features; fail-operational, failsafe, etc.

b. Safety-devices - known hazards which cannot be eliminated through design selection shall be controlled through the use of appropriate safety devices.

c. Warning devices - where it is not possible to preclude the existence or occurrence of an identified hazard, devices shall be employed for the timely detection of the condition and the generation of an adequate warning signal. Warning signals and their application shall be designed to minimize

the probability of incorrect personnel reaction to the signals and shall be approved by the purchaser.

d. Special procedures - where it is not possible to reduce the magnitude of a hazard through design or the use of safety and warning devices, the contractor shall develop other special procedures. Precautionary notations shall be approved by the purchaser.

3.3.3.4 Safety Analyses

Safety analyses will be performed to identify hazardous conditions for the purpose of their elimination or control. The safety analyses shall be submitted 15 days before the final design review and updated at the program completion. These milestones shall be indicated in the System Safety Program Plan (Paragraph 3.3.3.1).

3.3.3.4.1 Subsystem Hazard Analysis

A subsystem hazard analysis shall be performed to assess the hazards related to the operations and failures of the brake subsystem. The analysis shall consider all modes of failure and the effects of these failures on safety. The hazards effect shall be classified in accordance with MIL-STD-882. In addition, all hazards shall be evaluated and a safety assessment shall be made. The safety assessment shall be substantiated by identified means of controlling the hazards.

3.3.3.4.2 Fire Hazard Analysis

An analysis shall be performed that identifies all possible ignition sources (eg. hot disc.) and all flammable materials

used in the system. Flammability and smoke characteristics shall be identified for all flammable materials and the rationale of materials selection shall be given.

3.3.3.4.3 Maintenance Hazards

Sources of injury to maintenance personnel shall be identified and precautionary maintenance procedures shall be developed and documented.

3.3.3.5 Safety Testing

Safety requirements will be included in appropriate test plans.

3.3.3.6 Training

Safety information on approved methods and procedures shall be provided for the training of system operation and maintenance personnel. Protective devices and emergency equipment where used, shall be identified and included in training.

3.3.4 Additional Items

3.3.4.1 Spares/Replacement Items Identification Program

The Contractor shall define a comprehensive spares/replacement items program which will identify the long-lead, peculiar expendable and non-expendable spare parts required for the support of the vehicle at Pueblo test site, and at all other demonstration sites.

This program shall be consistent with the maintenance concept of Paragraph 3.3.2.2 above. It shall be submitted to the purchaser at least 30 days prior to the maintainability demonstration of this system on the car.

3.3.4.2 Publications

Publications shall be comprehensive, with adequate P/N identification.

3.3.4.2.1 General

The publications shall be in a form consistent with the prototype procurement. All publications shall be in loose leaf form, on good grade paper with punch holes reinforced with plastic, cloth, or metallic material. Five or seven ring binders are acceptable in lieu of reinforced paper.

All manuals shall be 8-1/2 inches wide by 11 inches high. All covers shall be resistant to oil, moisture, and wear to a high degree commensurate with their intended uses. Diagrams and illustrations shall not be loose or in pockets. Diagrams and photo reductions to fit manual pages shall be readable after reduction.

3.3.4.2.2 Organization

The manual shall be a Running Maintenance and Servicing manual. The system shall be treated as a whole and not as a grouping of disassociated parts. The material in the manual shall be similarly organized and indexed.

The manual shall be subdivided, to the extent required by the subject matter, into the following topics:

- o General Subsystem Description and Operation
- o Block Diagrams
- o Signal Flow Diagrams
- o Functional Schematics
- o Functional Wiring and/or Piping Diagrams
- o Troubleshooting Techniques
- o Lubrication and Cleaning, including frequency, method and trade identifications of recommended materials: component location and description.
- o Inspection and maintenance standards including, if applicable, wear limits, settings, and tolerances.
- o Installation and Removal
- o Test and Evaluation

The Running Maintenance and Servicing Manual shall enable the maintainer to have with him, in convenient form, all information needed for on-car servicing, including lubrication, inspection, running maintenance and adjustment, and on-line trouble diagnosis.

3.3.4.2.3 Submittal

The Running Maintenance and Servicing Manual shall be delivered concurrently with the prototypes.

Following the issue of the publication, the Contractor shall provide revised pages covering any changes, whether required by change of design or of procedures or due to error, and the revision shall be kept current during the test period.

3.3.5 Product Assurance Definitions

a. Independent Failure - The failure of a system, component, piece of equipment such that it is incapable of performing

its function as specified and which would delay a car on its operating schedule or which would require return of the car to the yard or shop for repair and which would result in unscheduled maintenance. Failures are not independent when they are caused by the failure of another component, abuse or incorrect maintenance procedures.

b. Mean Time (Distance) Between Failures, MTBF (MDBF) - The mean operating time (or mileage) between independent failures. These terms are expressed mathematically as:

$$\text{MTBF (MDBF)} = \frac{\text{Quantity of Independent Failures}}{\text{Total Operative hours (Mileage) for failed/non-failed items}}$$

c. Failure Rate - The frequency of failures, expressed as failures per hour, (failures per thousand miles) etc. Failure rate is the mathematical reciprocal of MTBF (MDBF). An average speed of 27 mph shall be assumed, to convert MTBF to MDBF.

d. Schedule Reliability - The probability (expressed as a decimal fraction) of completing a scheduled run on time, with the assumption that only certain vehicle equipment failures interrupt the schedule. The run (a complete pass from one extreme of the system to other) shall be considered "on time" if no more than one-half of the headway is lost during rush hour traffic.

3.4 ENVIRONMENTAL CONDITIONS

3.4.1 Climatic Conditions

The friction brake system shall be designed for a normal service life of 30 years surface and subway operation in the following environment:

a. Maximum free stream ambient air temperature - 125°F

b. Maximum undercar ambient air temperature - 150°F

c. Minimum ambient temperature - -25°F

d. Average annual precipitation - 40 inches

e. Humidity - 2% to 100%, including conditions where condensation takes place in the form of both water and frost.

f. Salt - coastal air environment associated with Boston (MBTA) (20% salt-laden mixtures)

g. Altitude - sea level to 5000 ft.

h. Sand and dust - as encountered at the demonstration properties of Section 1.1 and the TTC, Pueblo, Colorado.

i. Water spray - conditions associated with heavy rain and car washing.

3.4.2 Induced Environment

The system shall be capable of operation as defined during any logical combination of induced environments defined below in conjunction with the climatic environments defined above.

3.4.2.1 Vibration and Shock

Car body-mounted equipment support structure should be designed to avoid the first and second body bending frequencies of 8 Hz and 15 Hz respectively. The following vibration and shock criteria shall be utilized for the preliminary design of the equipment and its mounting.

Final design criteria for truck and axle-mounted components will be supplied as based on the selected truck configuration. Car body equipment mounting strength shall be as specified in paragraph 4.9.

Car body Equipment*	- .4g vibration at up to 100 Hz
	- 6g longitudinal shock
	- 3g lateral and vertical shock
Truck Frame Equipment*	- 6g vibration at up to 100 Hz in all directions
	- 15g vertical shock
	- 10g longitudinal and lateral shock
Axle-Mounted Equipment*	- 8g vibration at up to 100 Hz in all directions
	- 100g vertical, lateral and longitudinal shock

*All loads to be independently applied at point of attachment to car body structure.

3.4.2.2 Radio Interference

The friction brake system shall be designed to operate in the noise environment specified in Figure 3-1.

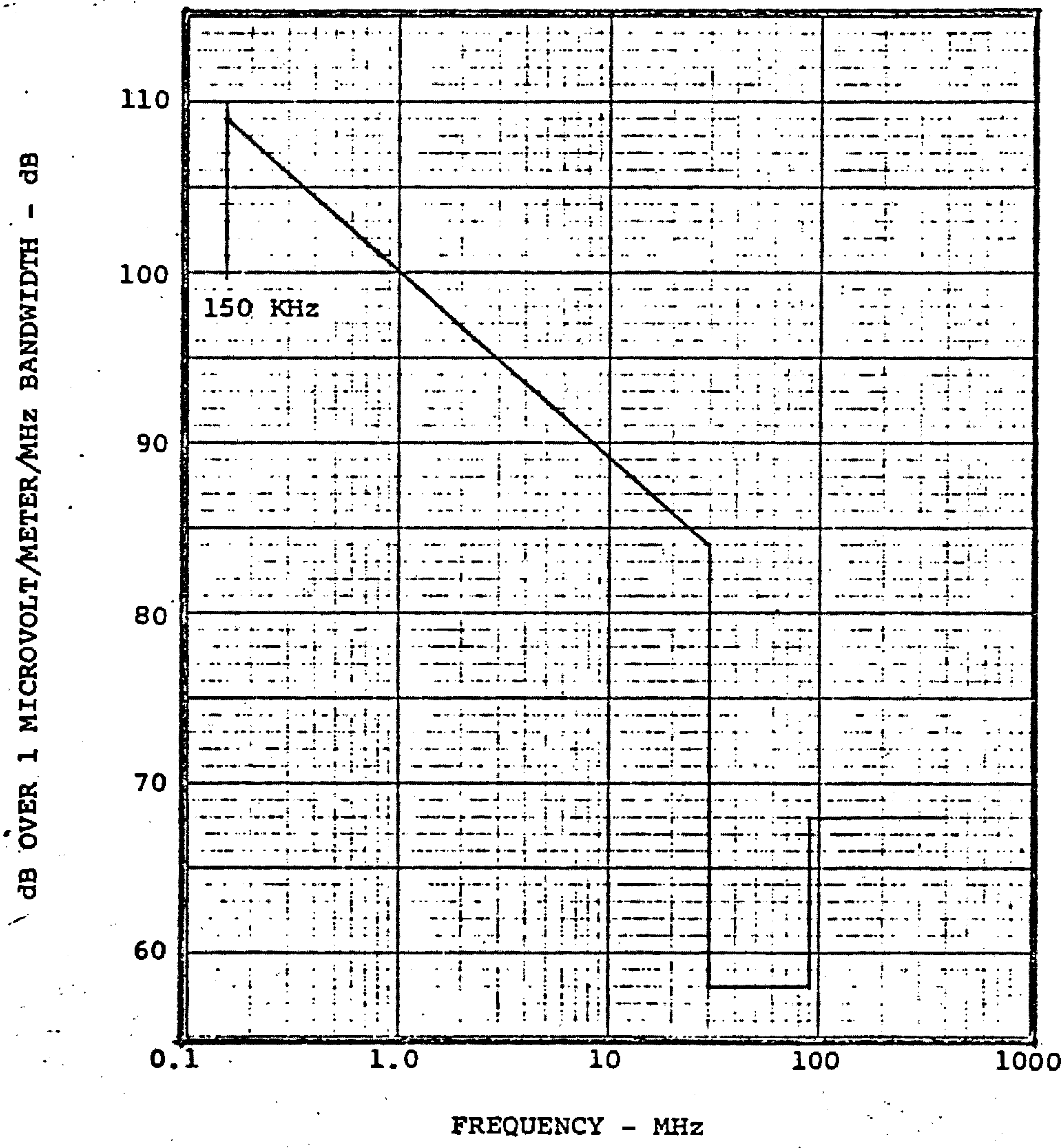
3.4.2.3 Voltage Transients

System 600 VDC equipment shall be suitably protected to withstand voltage transients resulting from line gaps, load surges, switching and faults typical to its intended use on the Section 1.1 properties and the TTC, Pueblo, Colorado. Specific requirement is that all system equipment operating from 600 VDC primary power shall be capable of withstanding input voltage transients of ±3000 volts peak with a duration of up to 500 microseconds. Equipment operating from the 230-volt, 3-phase, 60 Hz auxiliary power shall be designed to withstand the tolerances associated with the auxiliary power system defined in paragraph 6.2.2. Equipment operating from the low voltage DC or battery power supplies shall withstand the transients associated with the existing SOAC equipment outlined in paragraph 6.2.3.

3.4.3 Generated Environment

3.4.3.1 Vibration

All car body-mounted, truck frame-mounted and truck axle-mounted components shall be designed to have structural integrity and be operationally reliable for infinite life in the vibration environment at the point of attachment of the component. In addition, these components shall be designed to prevent unacceptable vibration inputs to the attachment structure.



RADIO FREQUENCY INTERFERENCE GOALS

FIGURE 3-1

Where rotating components are installed, the vibratory force output of those components shall be such that the vibration environment specified for component design shall not be exceeded. The contractor shall guard against the creation of harmful and annoying secondary vibrations caused by interaction of the rotating component with the mounting structure.

The vibration spectrum at the point of attachment shall be defined to reflect the fundamental forcing frequencies and the forcing levels at these frequencies throughout the operational range of the vehicle. The component structure and mounting shall be designed to prevent amplification, through component resonance, beyond a level twice that at the attachment point.

All equipment mounted in the cab shall be free from resonance to avoid annoying audio and visual distraction.

3.4.3.2 Radio Frequency

The friction brake system equipment shall not cause interference, either onboard or to the wayside, in excess of the limits specified in Figure 3-1.

3.5 SYSTEM WEIGHT

The total weight of the brake system components listed in the paragraph 3.5.1 table shall not exceed the following (components delivered by the brake system vendor):

a. Car-mounted equipment - 527 lbs.

b. Truck-mounted equipment - 3765 lbs.

c. Total system - 4292 lbs.

The weight of equipment shall include all necessary enclosures. The mass moment of inertia of all rotating components of the truck-mounted equipment shall be given in tabular form as part of the data submittal of Section 7.0.

3.5.1 Components for Weight Statement

"The brake contractor shall supply an itemized list of the components and weights of the equipment he intends to supply." Components shall consist of, but not be limited to, the following: (reference Section 5.)

- Electronic Control Components (itemized)
- Brake Application Units and Components
- Handbrake Components
- Synchronous Control Valve
- Trainlines (if applicable)
- Brake Calipers, Actuators and Pads
- Slack Adjusters
- Brake Discs
- Protection and Monitoring Components
- Cab-Mounted Gauges
- Additional Components as required

3.6 SYSTEM NOISE

Components of the propulsion and friction brake systems defined herein shall not produce audible noise levels exceeding the levels defined below. If operating equipment does not meet the noise limits, an approved means of sound attenuation shall be provided as an integral part of the equipment. Acoustic devices, if applicable, shall have maintenance cycles coordinated with those of their related equipment maintenance. The definition of noise and the test criteria shall be as specified in Paragraphs 3.6.1 and 3.6.2 of this specification.

3.6.1 Component Requirements

Equipment noise measured prior to installation shall not exceed the levels of Table 3.6-1.

TABLE 3.6-1

EQUIPMENT NOISE LEVELS PRIOR TO INSTALLATION ON CAR

SYSTEM	TEST CONDITIONS		NOISE LEVEL REQUIREMENTS
	MEAS. DIST. (FEET)	EQUIP. OPER. CONDITION	(dbA)
TRACTION MOTOR	15 ft. from center in any direction.	Maximum noise condition.	75 dbA
PROPULSION SYSTEM GEARING	15 ft. from center in any direction. (1 gearbox/coupling)	Maximum noise condition.	82 dbA
OTHER COMPONENTS	15 ft.	Maximum noise condition.	65 dbA

3.6.2 Definitions

a. Sound Pressure Level - The sound pressure level in decibles is defined as 20 log p/p_o where p is the measured rms sound pressure and p_o is the reference pressure, 0.0002 dyne/cm^2.

b. Reported Sound Pressure Level - The sound pressure level to be reported in satisfying this specification shall be the arithmetic average of the measured minimum and maximum levels as measured on the slow meter position, provided the difference between the average and maximum is 3 db or less. If this difference is greater than 3 db, then the level to be reported shall be obtained by subtracting 3 db from the maximum level.

c. Auxiliary Systems - An auxiliary system is any mechanism or structure other than the car body, traction motor, or propulsion system gearing which performs a function at some time during the operation of the car; e.g., heating and air conditioning system, pumps, car door operation, motor alternator, air compressor or hydraulic power unit, fluorescent lamps and ballasts, and braking system.

d. Pure Tone or Narrow Band - If the sound pressure level of any one-third octave band exceeds the level in the adjacent one-third octave band by 5 db or more, that band shall be considered to contain pure tone or narrow-band components.

e. If this equipment noise contains pure tone or narrow band components as defined in d, above, the requirements of Table 3.6.-1 shall be lowered by 5 db.

4.0 DESIGN AND CONSTRUCTION

4.1 MATERIALS, PARTS AND PROCESSES

Materials, parts and processes used in the manufacture of the friction brake system shall be of high quality, suitable for the purpose intended and shall conform to USASI and/or ASTM specifications.

The use of lightweight materials and weight-saving designs shall be exploited to the greatest extent possible. Non-magnetic materials shall be used throughout except where magnetic materials are essential. Metals shall be of the corrosion-resistant type, or suitably treated to resist corrosion due to any of the environmental conditions defined in paragraph 3.4. Unless suitably protected against electrolyte corrosion, dissimilar metals in contact shall be avoided.

4.2 ELECTRICAL WIRING REQUIREMENTS

4.2.1 Wire and Cable

All electrical conductors smaller than No. 4 AWG shall be Tefzel insulated wire rated for 1000 VDC. All electrical conductors No. 4 AWG and larger shall be Exane insulated wire rated for 2000 VDC minimum.

Single and multiconductor wire shall be constructed as follows:

a. Conductors shall be annealed, tinned copper wire conforming to the requirements of ASTM Specification B33-63, "Tinned Soft or Annealed Copper Wire for

Electrical Purposes". Class K stranding shall be used for Size No. 16 AWG to No. 8 AWG, and Class H stranding shall be used for larger sizes.

b. Each conductor shall be separately covered with insulation.

c. Insulation shielding shall be a separate or common shield over multiconductor cable if required.

d. A non-concucting separator shall be applied between the conductor and the insulation or conductor for sizes greater than No. 5 AWG.

e. The capacities of all wire applications shall conform to the National Electric Code standards.

f. Shielded wire is to be per MIL-W-22759/16, "Wire, Electric, Fluoropolymer-Insulated Tin Coated Copper".

   1. The shield shall be tin coated copper wire strands.
   2. The outer jacket shall be clear ethylene-tetrafluoroethylene copolymer (ETFE), 150°C.
   3. Color identification of respective wires in the multi-conductor assemblies shall be provided.

For high temperature applications (150°C to 260°C) an abrasion resistant teflon insulated wire shall be used.

4.2.2 Wiring Assembly and Installation Techniques

The following standards shall apply to all wiring:

a. All wiring shall be performed by or under the direction of an experienced wireman.

The wireman shall be provided

with appropriate tools for skinning insulation, cutting, tinning, soldering and attaching mechanical or compression-type terminals to the conductors.

b. Care must be taken in removing insulation from the conductor to avoid nicking of the wire or strands of the conductor.

c. Wire in ducts and conduit shall be free of kinks, insulation abrasions and insulation skinning.

d. All wiring shall be at least equal to that specified in the latest revision of the National Fire Protection Association's National Electrical Code (A.N.S.I.-Cl).

e. All circuits and branches must be separable by means of terminal boards to isolate when searching for grounds. Soldered connections are not acceptable. All circuits subject to annual high potential test shall be so arranged that they can be conveniently set up for said test.

f. Insulation resistance to ground of all nominal 32 volt control wiring when measured individually either with a 500 volt meter, a resistance bridge instrument or the voltmeter-ammeter method shall be at least ten megohms. Insulation resistance to ground of all wiring normally operating between 32 and 600 volts shall be ten megohms minimum when measured in the same manner.

g. Wires which operate at potentials differing by 50 volts or more shall not be placed in the same conduits, raceways,

ducts, or junction boxes and shall not be cabled together. All wiring connected to a given piece of electric apparatus shall be insulated for the highest voltage so connected.

h. Where it is impossible to avoid having wires at different voltage in the same enclosure, the wires shall be physically separated with the higher voltage taped separately. Wires connected to transient-generating apparatus such as un-suppressed contactor coils shall not be run adjacent to wires carrying signals to, from or between semi-conductor circuits. Where space restrictions make separation im-possible, shielded wire shall be used for all conductors involved.

i. Pulling compound, if used, shall be non-conductive, non-hygroscopic, non-odorous and not attract vermin.

j. All auxiliary (non-traction) 600 volt wiring shall be protected under all circumstances. No wire shall be connected to a source capable of supplying current of sufficient magnitude to destroy the wire without having protection.

4.2.3 Wire Terminals

Conductors shall preferably be attached to terminals by mechanical means. Where possible, the terminals used on conductors of No. 10 AWG size or smaller, shall be of the insulating type and shall be so designed as to securely grip and hold the insulation on the conductor.

4.2.4 Electrical Connectors

External connections shall be carried through an environmental type connector. The specific insert arrangement to be used shall be approved by The Boeing Vertol Company. For the larger wire sizes (No. 10 AWG and above) direct connections to screw-type terminals are preferred.

4.2.5 Wire and Terminal Marking

All electrical conductors, whether individual wires or cables, shall be assigned circuit designations. On all individual wires and the exterior of all cables, these designations shall take the form of an embossed and colored stamping. This marking technique shall not in any way cause damage or otherwise render ineffective, the conductor or its insulation. The individual conductors within any cable shall be appropriately color coded and full reference to these color codes shall be included on all documents relating to the cables.

Prior to manufacture of any wiring harnesses, the supplier shall submit wiring diagrams showing detail interconnecting wiring for the purpose of coordinating the wire identification code for individual wires and cables.

Markings shall be placed at close intervals for a distance of 18 inches at the terminal ends of all individual wires and cables and at intervals of not more than every 3 feet for the remainder of the wire or cable length.

All electrical connection terminals whether strip type, plug, socket, etc., shall be assigned circuit designations. The identification code for terminals must be approved prior to manufacture of equipment. The markings shall be of a type that are permanent in nature and readily identifiable after all connections are in place.

4.2.6 Wiring Installation

All wiring shall be installed to minimize physical damage to individual wires, cables and terminations. Chafing shall be prevented by routing and clamping bundles to prevent contact with edges of equipment and structure.

Harnesses secured with nylon Ty-Wraps shall have the Ty-Wraps trimmed and located to eliminate any hazard to personnel from sharp edges. Ty-Wraps shall be applied with the proper tool to prevent damage to wire insulation.

4.3 IDENTIFICATION AND PRODUCT MARKING

A nameplate shall be securely attached to the exterior of each system component and shall be marked in accordance with standard rail industry practice.

4.4 WORKMANSHIP

All workmanship shall be of the highest grade and shall conform to the best manufacturing practices in all respects. All work shall be performed by qualified workmen and mechanics, highly skilled in each particular trade or craft.

All parts shall be free from sharp edges and burrs that might injure persons or damage clothing.

4.5 INTERCHANGEABILITY

All components bearing the same manufacturer's part number shall be physically and functionally interchangeable.

4.6 EQUIPMENT COOLING

System equipment shall be designed for self or forced ventilation (air) or forced cooling (liquid) consistent with its intended operating and environmental loads. Equipment requiring forced-air ventilation or liquid cooling shall be designed with adequate thermal margins or protection devices such that the equipment does not fail during any degraded undetected forced cooling conditions.

4.7 PACKAGING

Modular design principles shall be employed to the greatest extent practical. Modular design is defined as packaging electrical or mechanical components together in replaceable subassemblies according to the logical function they perform and using standardized dimensions and components to achieve flexibility in use. All components shall be arranged to ensure adequate heat rejection. Heat producing components shall be compartmentalized as necessary for the protection of sensitive devices. Vital circuits and critical static devices shall be placed to obtain optimum thermal and vibrational stability.

Standard, commercially available industrial components, that meet the operational and life requirements of the specification shall be used wherever possible, particularly in the case of items that require replacement at predictable intervals. Components or subassemblies requiring occasional removal shall be plug-in units adequately identified and keyed to prevent misapplication. Adjustment points required for SOAC equipment shall be readily accessible, adequately identified, and self-locking by approved methods to prevent inadvertent operation and drift.

4.8 CIRCUIT PROTECTION

The brake system shall be provided with the capability to protect itself against any of the following conditions either singly or in combinations:

Loss of third rail power

Over voltage

Under voltage

Over current

Differential current

Loss of speed sensing

The system may use control logic or power contactors to remove power or prevent the application of power in the above conditions. Protection shall also be provided for other operating conditions as required by the brake system. Reset capability shall be defined by the brake contractor.

4.9 EQUIPMENT STRENGTH

4.9.1 Car Body-Mounted Equipment

4.9.1.1 The equipment and the equipment supporting structures including such items as mounting brackets, bases, draw slides and retention systems, must withstand, without permanent deformation, the following independent load factors applied to the individual equipment centers of gravity:

Longitudinal Load = 6g

Vertical Load = 3g

Lateral Load = 3g

These load directions refer to the car body axes; i.e., longitudinal is forward and aft.

4.9.1.2 The equipment support shall be capable of withstanding the following independent loads without exceeding the ultimate load capability of the material after the loss of structural integrity of any single support. The deflection of the equipment under these loads shall not allow that equipment to violate the clearance lines of Drawing 2D45044.

Longitudinal Load = 6g

Vertical Load = 3g

Lateral Load = 3g

These load directions refer to the car body axes; i.e., longitudinal is forward and aft.

4.9.1.3 The equipment subcontractor must supply to the purchaser, on request, the forces applied to the car structure that result from operation of that equipment or from maintenance personnel working on, installing, or removing that equipment.

The individual equipments shall be capable of withstanding extreme levels of manloading resulting from abusive maintenance practices or operator applied forces.

4.9.2 Truck- and Axle-Mounted Equipment

The vibration and shock criteria of paragraph 3.4.2.1 shall apply as modified by the values supplied by the truck manufacturer. The load factors shall induce no permanent deformation in the equipment or supporting structures.

5.0 MAJOR COMPONENT CHARACTERISTICS

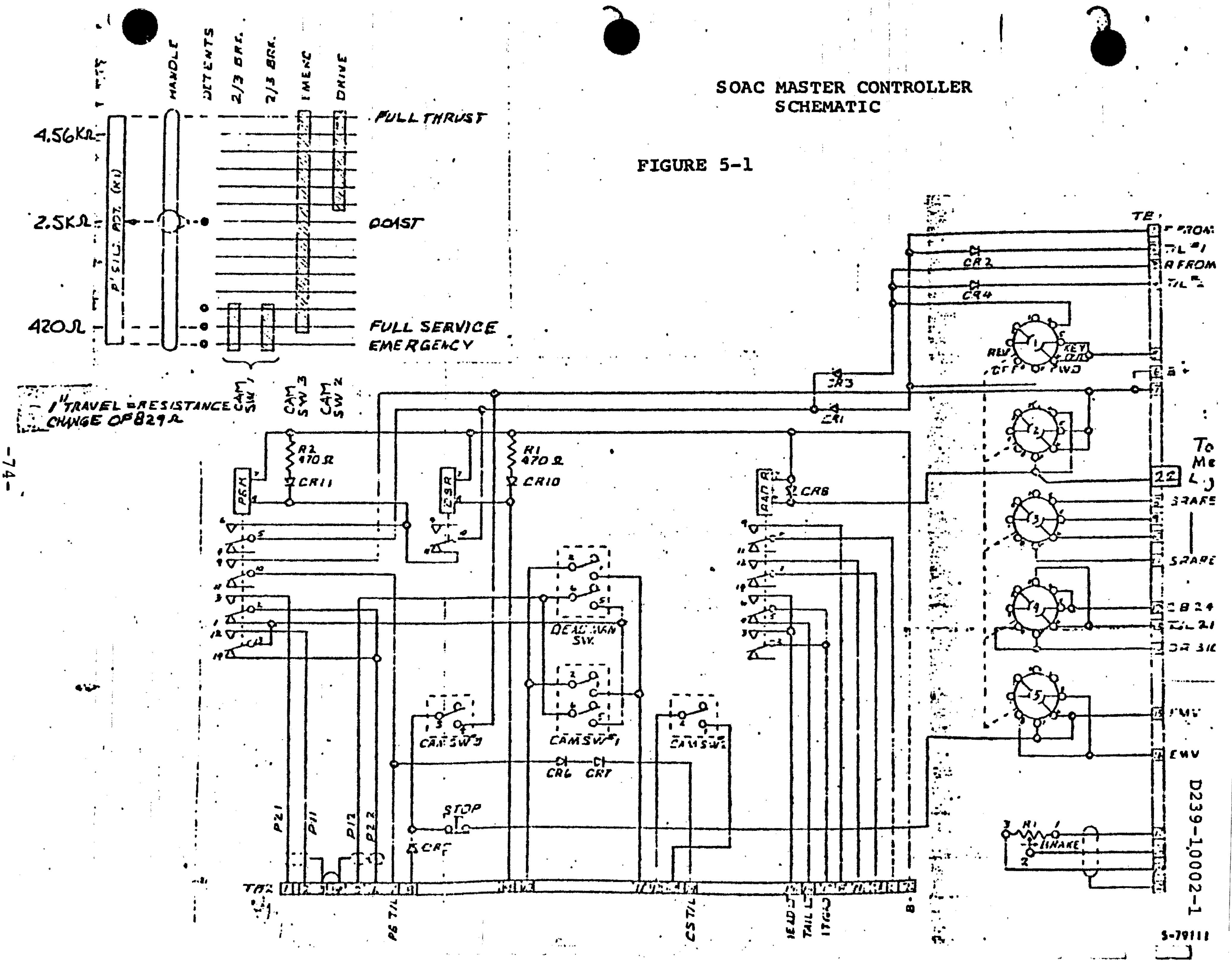
All components associated with the friction brake system shall operate satisfactorily when subjected to the encountered duty cycle, performance characteristics and environmental conditions specified herein. The minimum major component design characteristics are as described below. Where an item is described in general terms but not in complete detail the best general practice shall be followed and only materials and workmanship of first class quality shall be used. The system supplier shall provide detail component design specifications or suitable equivalent of all proposed major components.

5.1 MASTER CONTROLLER

An all electric type, single power handle, manual master controller, installed in each operating cab, will provide the interface between the operator and the total positive (propulsion)/ negative (braking) traction system via the low level electronic logic equipment. The existing SOAC master controller, P-signal generator, direction control key switch, and speedometer-speed maintaining system may be utilized to control the propulsion and friction brake systems. The trainlined P-wire analog current signal and car and controller signals will be retained. The propulsion system will interface with these electronic signals as necessary to interpret the directional control, and P-signal from the master controller. Detailed

SOAC MASTER CONTROLLER SCHEMATIC

FIGURE 5-1



electrical interface values will be provided to the contractor during the design phase of the program. Figure 5-1 illustrates the basic master controller schematic, the analog P-signal is shown in Figure 2-6, and the cam switch closures are nominally as follows:

Cam Switch SW#1 - Closed in full service and emergency braking; open in less than full service braking and in coast-drive.

Cam Switch SW#2 - Closed in drive, open in coast and brake.

Cam Switch SW#3 - Open in emergency brake initiated by master controller handle; closed all other times.

5.2 ELECTRONIC CONTROL EQUIPMENT

The friction brake contractor shall supply the necessary electronic control equipment to provide interpretation of the propulsion system brake rate command, dynamic brake feedback signal (if required), and air suspension pressure (if required). The control equipment shall contain all the signal conditioning, logic and protection circuits as required to control the application of friction braking effort as commanded by either master controller, dynamic brake feedback signal, or emergency brake devices. The input and output signals and functions of the control equipment and any necessary trainlined functions and signals shall be completely defined by the brake supplier. The electronic control equipment shall be configured so that the system is closed loop using brake rate (wheel accelerations) as the primary feedback parameter to achieve synchronous brake control. Certain functions of this control equipment may be installed in the cab of each car, with space allocation to be determined by Boeing Vertol. The control equipment shall have the ability to provide friction brake effort on a per truck basis.

The electronic control equipment shall contain all the functions required to control the friction brake in the service mode and in the two emergency brake modes; methods "a" and "b" of paragraph 3.1.1.3.

5.3 PNEUMATIC POWER SUPPLY

The pneumatic power supply shall be provided by the present SOAC air compressors. Filtration and drying characteristics of the pneumatic power supply are the responsibility of the friction brake system supplier.

5.4 BRAKE APPLICATION UNIT-SERVICE AND EMERGENCY BRAKE SYSTEMS

A brake application unit shall be supplied on a per-truck basis. The following minimum functions and components shall be supplied in each truck unit. The brake application unit for the hand-braked truck will contain the additional functions noted in Paragraph 5.5. The brake application units shall receive inputs of pneumatic, air suspension pressure and electrical control signals and shall supply outputs of emergency brake pressure and service brake pressure in two separate lines. Input-output data requirements are listed in Section 7.0.

5.4.1 Air Suspension Pressure-Operated Regulating Valve

This valve shall be provided within each application unit and shall accept inputs of pneumatic pressure (power) from the main reservoir and air pressure from the truck air suspension system. The values of air suspension pressure over the range from AW0 to AW3 will be supplied to the brake contractor. This valve shall provide car weight-proportioned pneumatic pressure to two parallel brake circuits: service and emergency.

The function of the regulating valve must be coordinated with the propulsion system contractor. The valve shall respond to loss of air suspension pressure as required by Paragraphs 2.2.6.3 and 3.1.7.

5.4.2 Truck Cutout Valve

Each application unit shall have a truck cutout valve which is either manually or remotely operated by a key switch. Pneumatic

pressure from the air suspension pressure operated regulating valve shall pass through the cutout valve to the two braking circuits.

5.4.3 Charging Magnet Valve

One application unit shall contain one normally de-energized charging magnet valve. This valve is energized by a trainline wire to obtain charging of the brakepipe, provided the train is stopped as determined by zero speed detection within the electronic control unit.

5.4.4 Emergency Magnet Valve

One application unit shall contain one normally energized emergency magnet valve. This valve shall prevent the application of emergency brakes unless it becomes de-energized. The emergency brake pressure passing through the emergency magnet valve shall result in the load-weighed braking rates required in Section 2. Interaction between simultaneous application through both the emergency and release magnet valves shall be analyzed by the contractor.

5.5 BRAKE APPLICATION UNIT, ADDITIONAL ITEMS FOR HANDBRAKED TRUCK

The application unit for the handbraked truck (one per car) shall contain all the functions/components described in Paragraph 5.4 and the following additional items.

5.5.1 Handbrake Magnet Valve System

The handbrake magnet valve system shall provide the functions of apply, exhaust, lock and lock exhaust for each handbraked truck. These valves shall control the remote operation (apply and release) of the handbrake.

A pressure switch shall be provided to indicate that the handbrake is applied at or above a braking force of (TBD) pounds per truck. A mechanically actuated brake release indicator is also required.

5.5.2 Handbrake Apply/Release Pump (Manual)

A manually operated handbrake pump shall be supplied for each handbraked truck. A pump shall be designed to supply sufficient pressure through the double-check valve and pressure switch noted above to apply or release the handbrake. The pump shall be mounted in a position accessible from within the car which will be determined by Boeing Vertol and the brake contractor. The operation, number of strokes to apply/release, handle forces, and seal requirements shall be defined by the brake contractor and approved by Boeing Vertol.

5.6 SYNCHRONOUS CONTROL VALVE SYSTEM

The synchronous control valve system is comprised of an analog modulating valve on each brake application unit, and a digitally operated valve (application, lap, release) for each axle. These valves are controlled by the brake electronic control unit. The analog modulating valve responds to the brake rate command signal by supplying the appropriate air pressure to the brake cylinders. The electric brake effort is subtracted from this pressure by the electric blending feedback valve. Positive or negative changes in brake pressure required by the brake rate feedback control are made by electric blending/feedback valve. The digitally operated valve (dump valve) will upon command
1) apply brake pressure to the brake actuators on a truck,
2) lap off and hold the existing pressure in the actuator or
3) exhaust the pressure. This valve will be normally de-energized. De-energized will be the apply state. Operation of the dump valve will be controlled by the brake electronic control unit; it will respond to rapid changes in wheel accelerations and velocity differences between trucks.

5.7 TRAINLINES

The brake contractor shall define the discreet trainlines required by his brake system. The signal content and operating function of each trainline shall be described. Use of the existing SOAC propulsion control (P-wire) trainline and the brake pipe shall be coordinated with the propulsion supplier and Boeing Vertol.

5.8 CALIPER, BRAKE PADS AND ACTUATOR

The brake contractor shall supply the brake calipers, pads and actuators as required to meet the performance requirements of Section 2.0. The caliper/actuator system shall be mounted to the truck in a manner approved by the truck supplier and Boeing Vertol. A basic clearance envelope is presented in sketch SK239-10000. However, details of the ASDP truck will not be available until the truck is selected. The brake contractor shall propose a desirable mounting system which will be coordinated with the truck design. The structural static and fatigue design loads of the caliper/actuator shall be based on the performance and design route requirements of Section 2.0.

5.8.1 Brake Caliper-Actuator

The brake caliper shall be of either automotive-type construction or separate actuator-caliper type construction. The final space available on the truck may limit the caliper type selected. The caliper system shall include an automatic slack adjustment feature which will maintain an essentially constant pad-to-disc clearance throughout the pad wear range. The operation of the slack adjuster and the pad-disc clearance shall be defined.

A spring-applied brake feature shall be considered for use as a parking/handbrake on the one truck set or as an emergency brake backup on both truck sets. Provisions shall be made to mechanically hold off the spring at the actuator. The operation of this system shall be defined under the data requirements of Section 7.0.

5.8.2 Friction Pads

The friction pads shall be designed for operation with the selected brake disc material at temperatures associated with the performance requirements of Section 3.0. Average pad life shall be 25,000 miles of operation with blended brakes on the ACT-1 Pueblo route (Appendix) at a car weight of AW2 (actual). The pad material and speed-temperature-friction characteristics shall be described by the brake contractor. Pads shall be replaceable without removing the caliper or disc assemblies.

5.9 BRAKE DISCS

Brake discs shall be supplied on a one - or two-disc per axle basis; a single, vented disc per axle is the desired configuration. Final space allocations will not be available until a truck is selected; however, the maximum space is indicated in SK239-10000. The discs and materials selected shall be compatible with the elevated temperatures and loads associated with the performance requirements of Section 2.0. The materials, stress levels and allowable stress at elevated temperature shall be provided as part of the Section 7.0 data requirements. The disc configuration shall be a split-disc type for ease of removal and replacement on the axle.

5.10 HYDRAULIC FLUID

The brake contractor shall provide a fire-resistant, non-corrosive hydraulic fluid similar to Royco 751 or Royco 782 or alternately one of the synthetic base class. Consideration shall be given to the effects of leakage onto car equipment and hot brake discs. The physical properties of the selected fluid shall be defined in detail by the brake contractor.

5.11 PROTECTION AND MONITORING CIRCUITS

The brake system shall include a brake alarm circuit which shall detect and display to the motorman the presence of a malfunction within the brake system. An indicator light shall be used for this display. In addition, the friction brake contractor shall propose a fault-monitoring panel which will display the type of problem which caused the motorman's display to activate. Parameters monitored shall include, but not be limited to:

- o Low pneumatic power supply pressure
- o Dragging parking/handbrake
- o Brake cylinder pressure on truck (presence)
- o Truck cutout valve position
- o Electronic control status

5.1.2 CAB-MOUNTED GAUGES

The brake contractor shall supply pressure transducers and cab-mounted gauge(s) as required for the proper operation and monitoring of the brake system. This equipment including connectors shall be approved by the purchaser.

5.13 PROPULSION POWER KNOCKOUT SWITCH

The brake supplier shall provide a power knockout switch which will remove power from the propulsion systems whenever the car or train is put in the emergency brake mode.

5.14 EQUIPMENT TO BE SUPPLIED

The brake contractor shall provide an itemized list of equipment, including weights, for the equipment proposed. Where possible, outline drawings or layouts and system schematic drawings shall be included in the proposal.

5.15 LOCOMOTIVE HAULING PROVISIONS

The existing SOAC airbrake equipment contains a locomotive hauling triple-valve unit to power and control the tread brakes while the SOAC is in a locomotive hauled consist. The brake contractor shall propose a Locomotive Hauling system to perform a similar function with the Advanced Subsystems Development Program Friction Brake System. The existing SOAC brake pipe, triple valve and one supply air reservoir may be retained if required.

6.0 INTERFACES

The following mechanical and electrical interfaces exist between the friction brake system defined herein and the SOAC and its related subsystems. Additional interfaces and/or additional interface details that are not specifically defined will be resolved mutually following contract award. The vendor shall include in his proposal a definition of all the related external interfaces. Electrical interfaces shall be completely defined to include signal accuracy, signal power capability levels, etc.

6.1 MECHANICAL INTERFACES

6.1.1 Truck-Mounted Equipment

All truck-mounted friction brake equipment (discs, calipers, control valves, piping, etc.) shall conform to the clearance dimensions as outlined in Boeing Vertol Drawing SK239-10000. Equipment attachment points shall be mutually agreed upon by the propulsion, the truck and the friction brake suppliers as well as the purchaser.

6.1.2 Underframe-Mounted Equipment

Interfaces between car mounted system equipment and the SOAC are defined in Paragraph 3.2.4 and based on drawing 2D35014. The brake supplier shall provide all equipment enclosures required for the brake system. Enclosures shall be designed for mounting to the SOAC underframe in the areas where AiResearch equipment is removed. Equipment mounts shall include all required resiliency for vibration isolation. Equipment mounts shall be supplied by the brake system contractor. The type of mount and detailed configuration shall be coordinated with the purchaser.

6.1.3 Cab-Mounted Equipment

The brake supplier shall coordinate with the purchaser on the detail design of the cab-mounted equipment and enclosures.

6.1.4 Pneumatic Power and Control

An air pressure signal, supplied by the SOAC suspension system, proportional to air spring pressure, will be supplied by the purchaser to enable the system to modify brake effort in accordance with vehicle weight. The air spring pressure will reflect the supported weight on each truck with a repeatable accuracy of plus or minus five percent on any vehicle (truck-to-truck variation). The basic main reservoir pressure will nominally vary between 130 psi and 150 psi.

6.2 ELECTRICAL INTERFACES

6.2.1 High Voltage DC Power

All equipment contained within this specification that is designed for nominal 600 VDC operation shall also be designed to operate with normal voltage variations (400V to 750V) and power isolation gaps without damage or failure of the equipment to function as specified.

The 600 volt DC power will be applied to the brake equipment (as required) through existing SOAC equipment consisting of either two third rail shoes or single pantograph (mutually exclusive transfer switch) equipped with a surge arrestor. The existing SOAC main knife switch and fuse will be utilized.

6.2.2 Auxiliary Power

The existing AiResearch motor-alternator set and controls will be retained. The equipment is rated at 125 Kw (continuous) with 230 ± .5% volts (L-L), 3Ø, at 60 ± 3 Hz. This source may be utilized by the friction brake supplier for brake equipment, etc. Detailed interface definition will be coordinated with the supplier during the design development.

6.2.3 Low Voltage DC Power (LVDC)

The low voltage DC power supply, battery, and battery charger will be the existing SOAC equipment. The operating voltage is nominally 37.5 VDC. During anomaly conditions (line gaps, LVDC power supply failures) the battery shall supply LVDC power to the equipment. Battery voltage during this condition will range from 28 to 44 VDC. Specific interfaces will be coordinated during the program.

6.2.4 Friction Brake Control (Optional)

As an option the propulsion system shall provide an analog signal to the friction brake subsystem proportional to the dynamic brake effort being generated. The signal level shall range from zero (no dynamic brake effort) to a higher level (corresponding to a dynamic brake effort equal to 100 percent of command). The specific signal definition shall be coordinated during the program if this feedback signal is deemed necessary by the purchaser.

The propulsion system shall provide, as an option, circuit closures to the friction brake subsystem following detection of wheel slippage during the braking mode. The circuit closures shall enable independent braking effort modulation on each truck (Ref. Paragraph 2.2.3.2.1).

6.2.5 Control Trainlines

The existing SOAC master controller and related trainline logic will be retained as described in Paragraph 5.1. In addition to the 0 to 1.0 amp DC analog signal, several circuit closures from controller cam switches may be available (drive, brake, emergency).

Interfaces with these trainlines and closures shall be coordinated during the program. The propulsion system shall interpret the emergency trainline and shall cut out all propulsion or electric braking effort in response to a signal change.

6.2.6 Synchronous Dynamic Brake Control (Optional)

As an option the brake system shall supply a signal to the propulsion system from the brake control valve system which will be proportional to the difference between actual and required braking effort. The dynamic brake control system shall respond to this wheel rate error feedback signal. This feedback control system shall be utilized as a test installation as an option.

7.0 DOCUMENTATION REQUIREMENTS

7.1 COMPONENT AND SYSTEM DESIGN SPECIFICATIONS

Detail design specification packages stating nominal component or system mechanical, electrical and functional values and operating characteristics shall be provided for each of the components and systems specified in Sections 3.0, 4.0 and 5.0. Specifications shall be included for, but not limited to, the items of paragraphs 5.2 through 5.12. Each design specification package shall contain the following items:

- o Design description
- o Layouts, envelope drawings
- o Block diagrams
- o Schematics
- o Parts lists
- o Interface/Compatibility
- o Analysis/Requirements
- o Input/Output characteristics and tolerances (performance)
- o Protection requirements
- o Design goals: performance, rating, weight, size, etc.
- o Reliability requirements - analysis method, etc.
- o Materials and processes description
- o Test point and test requirements
- o Maintainability requirements
- o Safety and human factors requirements
- o Failure modes and effects analysis plan
- o System adjustment points
- o Component definition and ratings

7.2 SYSTEM DESIGN SUBSTANTIATION REPORTS

7.2.1 Vehicle Brake Performance Substantiation Data

The contractor shall submit estimated data to substantiate the performance characteristics of Section 2.2. The submittal shall include all pertinent data and criteria used to derive the associated performance. The data submitted shall address the following areas.

Spec. Paragraph	Items
2.2.2.1	Service braking capability; rates; tolerances; stopping distance; brake blending technique; thermal capacity.
2.2.2.2	Emergency braking capability; rates; tolerances; with and without spin-slide control; stopping distances; thermal capacity.
2.2.3	Spin-slide performance estimates. (per Figure 7-1)
2.2.4	Jerk rate limiting technique.
2.2.5	Dead time and response time characteristics throughout operating pressure-car speed range.
2.2.6	Load weigh (regulation) effects and requirements for service and emergency braking.
2.2.9	Handbrake/parking brake capability.

INPUT PARAMETERS FOR CALCULATION OF SLIP-SLIDE PROTECTION SYSTEM EFFICIENCY

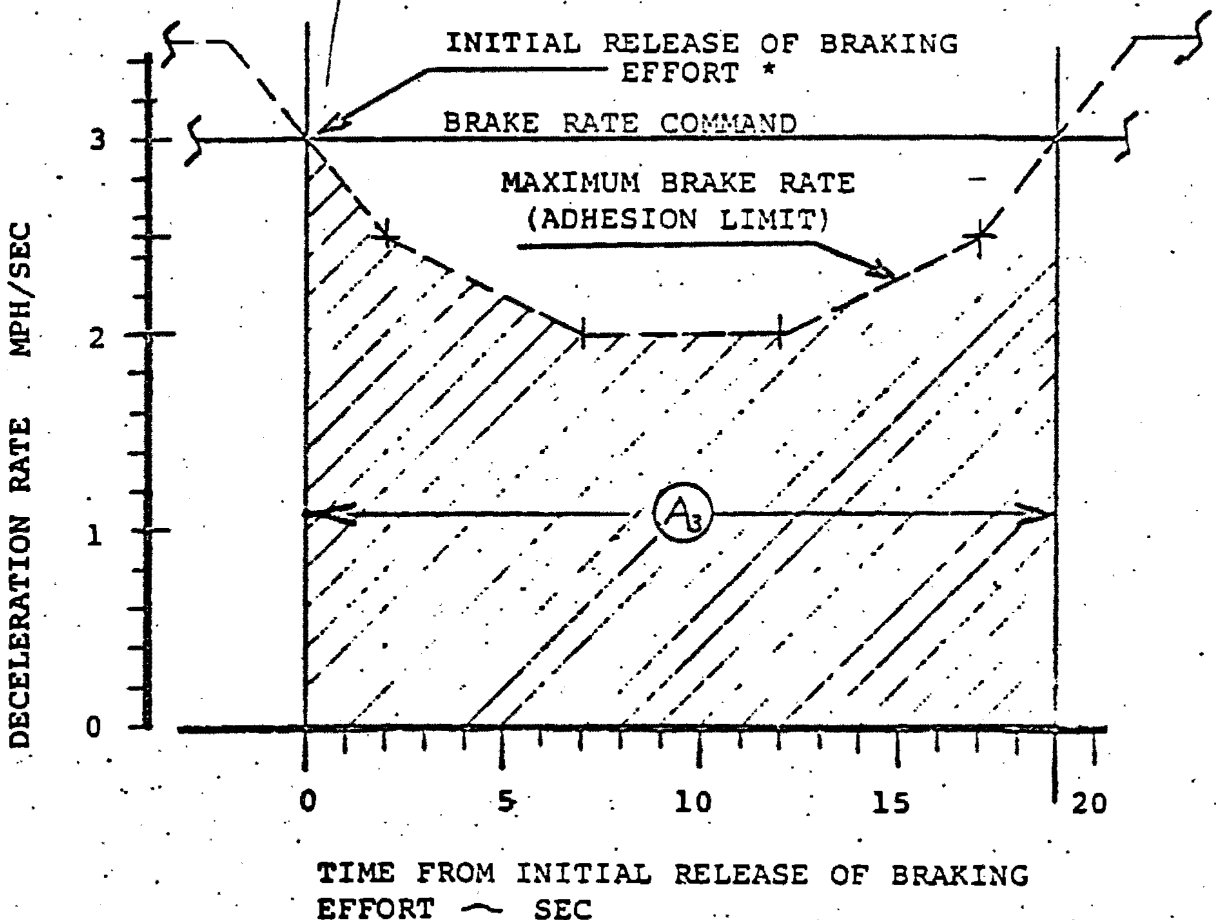
ONE AXLE SLIPPING

REFERENCE FIGURE 2-4 : A3 = A1 + A2

AREA A3 = MAXIMUM ACHIEVABLE DECELERATION = 43.5 MPH

$$\text{EFFICIENCY} = \frac{\text{AREA A2 (FIG. 2-4)}}{\text{AREA A3}} \times 100\% \quad \frac{\text{(MPH)}}{\text{(MPH)}}$$

CAR SPEED = 80 MPH AT t = 0



NOTE: * FOR SYSTEM CYCLING AFTER THE FIRST RELEASE OF BRAKING EFFORT, APPLY ALL DETECTION (SPEED) CRITERIA, DEAD TIME, JERK LIMITS, AND SYSTEM RESPONSE CRITERIA TO EACH RELEASE/APPLICATION OF BRAKE EFFORT.

FIGURE 7-1

7.2.2 System Definition and Operation Data

The contractor shall furnish to the purchaser descriptions of the functioning of the friction brake system controls, power supplies, calipers, actuators, control valves, slack adjustors, and brake discs. Detailed descriptions shall be provided for the following, and shall include detail drawings, diagrams, and analysis to assist in defining the system operation and the validity of the system safety analysis.

Spec. Paragraph	Items
5.2	Input/output signal content and accuracy; trainlines required; control logic and electronic control unit characteristics.
5.3	System performance characteristics; power-speed-flow-rated pressures; min-max-nominal pressures; precharge pressure storage volumes and pressures; alarm and relief pressures; input power requirements, weight, size, etc.
5.4	Input/output signal and power-flow characteristics; load regulating characteristics and failure effects.
5.5	Handbrake on-off pressure, control and indication characteristics; handpump capacity (strokes)

Spec. Paragraph	Items
5.6	Input/output electrical and pneumatic characteristics; response at low and high pressures and low and high deceleration rates; dynamic characteristics; jerk limit effects. Track speed feedback design, accuracy, response, and failure modes and effects.
5.7	Trainline requirements-signal content isolation, etc.
5.8	Brake caliper design data; dimensions, piston areas, normal force pressure relation, design fatigue loads, mounting requirements; pad material, life, dimensions, wear, friction coefficients; slack adjuster operation; spring application forces. Operational information.
5.9	Brake disc design, allowable loads, design stress, temperature; mounting requirements; alignment; materials; experience on similar applications.
5.10	Physical properties of selected fluid, flammability, corrosiveness, etc.
5.11 and 5.12	Description of function and operations of indicating and protection devices; required guage indication; test points; adjustment points.

7.2.3 Brake Disc Thermal Analysis

The contractor shall provide analytical substantiation of the acceptability of the brake disc structural and thermal characteristics in accordance with the performance requirements of Section 2.0. Thermal and structural analysis may be based on existing dynamometer and service experience as modified by the proposed disc design.

7.2.4 Mechanical Stress Analysis

The contractor shall provide an analysis of the loads within his components and the loads imposed on the truck by his system. This analysis shall be coordinated with the truck contractor and Boeing-Vertol; and shall be submitted to and approved by the purchaser prior to fabrication.

7.2.5 Product Assurance Substantiation

The contractor shall submit to the purchaser the product assurance reports outlined in Paragraph 3.3.

7.3 OVERALL TEST PLAN

Submittal of an overall propulsion component, subsystem, and vehicle system test plan is detailed in Section 8.

7.4 DETAILED TEST PROCEDURES

The submittal of detailed test procedures for components, subsystems and the vehicle system is outlined in Section 8.

7.5 TEST RESULTS REPORTS

See Section 8.

7.6 FINAL PROJECT REPORT

A final project report shall be submitted to the purchaser upon completion of the design and test phases of the program. This report shall contain basic descriptions of the items of Paragraph 7.2.2 and shall detail the design and test phases of the brake system program as well as the test results to substantiate the design performance and operational goals.

7.7 SYSTEMS EVALUATION DATA

The contractor shall provide the data necessary for the completion of the systems evaluation of Section 9.0.

8.0 TESTING

8.1 GENERAL

The general testing requirements shall be based on Section 17 of the Guideline Specification for Urban Rail Cars (IT-06-0027-1).

The complete brake system, its subsystems and their components, shall be subjected to a comprehensive test program to:

a. Substantiate the design and performance characteristics.

b. Assure operational compatibility with the SOAC system.

The contractor shall conduct the test program in accordance with the following requirements.

8.1.1 Test Plan

An overall test program plan shall be prepared containing all tests necessary to demonstrate that the systems will perform satisfactorily under all specified operating conditions. The plan shall include an outline of the test program, test equipment and facilities to be used, and any additional data required to illustrate the test program, including a detailed testing schedule listing significant milestones in the test program. The test plan shall be submitted to the purchaser for approval prior to the initiation of the test program to provide a basis for measurement of contractor technical achievement during program implementation.

8.1.2 Detailed Test Procedures

A detailed test procedure for systems and components shall be prepared and submitted to the purchaser for approval prior to the start of the testing required by this section. The basic vehicle test procedures shall be developed in accordance with DOT/TSC Specification GSP-064, wherever possible.

The test procedure shall outline each test to be conducted and shall refer to the applicable requirement of the detail specification. The procedure shall specify test objectives, success/failure parameters, the number of units to be tested, sequence of testing, equipment to be used for testing, test specimen configuration instrumentation requirements, description of test setup, test methodology to be used in performance of test, type of data/report to be issued, and, if an outside testing agency is to be used, the name and location of same.

8.1.3 Sequence of Testing

The order of testing to be conducted shall be specified by the contractor.

8.1.4 Test Completion and Standards for Interpretation

The system development and qualification tests will be considered complete when the following requirements are fulfilled.

8.1.4.1 Test Components

Components to be used for testing must be representative of production components. Any deviations from this requirement

must be subject to approval from the purchaser. Components used for testing must be clearly identified as test components and, at the completion of testing, disposed of in accordance with the directions of the purchaser.

8.1.4.2 Final Test Report

A final test report shall be prepared documenting the results obtained and submitted for approval. The report shall be identified by a contractor document number and shall refer to the contractor part number and serial numbers of the test hardware. All pertinent test results (as well as a discussion of any deviations from the approved test procedure) shall be included. The test report shall also include any photographs and any additional data necessary to support the test results. Vehicle test data shall be presented in accordance with DOT/TSC Specification GSP-064, wherever possible. Supplier test reports shall be approved by the contractor prior to submittal to the purchaser.

8.1.4.3 Test Failure and Discrepancy Analysis

In the event that failures occur during any testing, a failure report shall be submitted to the purchaser. This report shall identify the unit being tested, identify the cause(s) of failure, indicate whether corrective action is necessary, and the extent of such action. Where no change is determined necessary, justification for the decision shall be provided.

Where a failure occurs during testing, the testing shall be suspended pending evaluation by the purchaser as to the effect on testing completed and the need to conduct additional tests using the reworked parts.

8.2 REQUIRED TESTS

8.2.1 Engineering Test and Evaluation

The contractor shall conduct engineering tests and evaluation as required to support design and development of the system to establish his own confidence in design. Equipment operation and operating and maintenance procedures shall be verified.

8.2.2 Component and Subassembly Acceptance Tests

The seller shall conduct acceptance tests on all components and subassemblies in order to determine their suitability for use in the friction brake system. These tests shall include and comply with the following:

a. Visual inspection and dimension check.

b. Functional demonstration compliance with design specifications.

c. Acceptance tests shall have no detrimental effect on the operational life of the item.

d. The contractor shall allow Boeing Vertol and their customer to witness any or all acceptance testing.

e. Adequate records shall be maintained to establish that all required acceptance tests were conducted and that discrepancies were recorded and satisfactorily resolved.

8.2.3 Component and Subassembly Qualification Tests

Component and subassembly qualification tests shall be conducted by the contractor as specified by the purchaser and shall include, but not be limited to, the following representative items:

- o Electronic Control Equipment - Components
- o Pneumatic Power Supply - Components
- o Brake Application Unit - Components
- o Synchronous Control Valve
- o Caliper and Actuator
- o Brake Pads
- o Brake Discs
- o Protection and Monitoring Components
- o Miscellaneous Equipment as Required

The types of tests shall be based on, but not limited to, the following areas:

a. Proof Pressure
b. Vibration and Shock
c. Environmental
d. Noise Level
e. Thermal Capacity
f. Storage Capacity
g. Response
h. Linearity
i. Endurance
j. Fatigue
k. Weight
l. EMI-RFI
m. Electrical
n. Protection Systems

The above tests shall be performed on components or subsystems as applicable.

8.2.4 Subsystem Laboratory Tests

A complete friction brake system (one truck or one car as applicable) shall be assembled in a manner to allow instrumented tests on a laboratory dynamometer that will simulate the mass of the transit car. These tests shall provide quantitative data on the operation and performance characteristics of one complete system. Data substantiating the performance requirements of Section 2.2 and application areas of paragraph 8.2.3 shall be derived from these system tests. The test plan and detailed procedures shall describe the development and compliance tests to be performed.

8.2.5 Vehicle System Tests

The contractor shall assist in the overall vehicle development, specification compliance and simulated demonstration test program at the UMTA Rail Transit Test Track, DOT High Speed Ground Test Center, Pueblo, Colorado. The brake system contractor shall be responsible for the following:

a. Assist in preparation of detail test procedures.

b. Assist in specification and preparation of instrumentation parameters and recording system.

c. Supply vehicle system test points and transducers as required to show compliance with paragraph 2.2.2 and other requirements. Failure to meet design objectives is subject to rework by the seller.

d. Provide field engineering services for setup, adjustment, and operational assistance during the test program.

e. Provide data acquisition, reduction and analysis support during compliance.

f. Assist in preparing test results report.

8.2.5.1 <u>Preparation and Functional Test</u>

The cars will be prepared for test. Any fabrication or reassembly remaining will be accomplished. This activity will occupy a timespan of approximately four weeks and will include the following:

a. Instrumentation installation, checkout and calibration.

b. Functional test of all systems on each car and when coupled as a two-car train.

8.2.5.2 <u>Preliminary Test and Adjustment</u>

Preliminary testing will be accomplished to set all system rates to their proper values and to debug the train prior to data acquisition. This activity will occupy a timespan of approximately four weeks and will include the following:

a. Car roll check and initial startup.

b. Operational checkout at various speeds for shakedown and correction of problems.

c. Preliminary evaluation of acceleration, braking, speed maintaining, noise levels, vibration, startup and shutdown characteristics.

d. System adjustments as required to establish a performance baseline consistent with the specification.

8.2.5.3 Engineering Testing

Engineering tests will be conducted to establish the vehicle performance limits. Carborne instrumentation will be utilized to obtain recorded test data. Testing will cover the vehicle weight range, speed range and voltage range. This activity will occupy a timespan of approximately eight weeks and will include the following:

a. Acceleration and braking
b. Speed limits and maintaining
c. Ride quality (vibration)
d. Noise levels
e. EMI/RFI (radio frequency/electromagnetic interference)
f. Energy consumption

8.2.5.4 Simulated Demonstration

Simulated revenue service testing will be conducted as a proof test of the hardware prior to demonstration in five cities. Approximately 5,000 miles of two-car train operation will be accomplished on a simulated transit route layed out on the UMTA Rail Transit Test Track. The simulated demonstration will verify the effectiveness of the maintenance plan that will be used to support the car during the public demonstrations and will produce the initial indication of service life of the modified car and its advanced subsystems. This activity will occupy a timespan of approximately six weeks.

8.2.6 Vehicle and Advanced Subsystem Acceptance Tests

The contractor shall support Boeing Vertol as necessary during the final acceptance testing of the vehicle and its subsystems. This activity will occupy a timespan of approximately two weeks and will include the following:

a. Acceleration
b. Braking
c. Speed maintaining
d. Automatic train operation
e. Ride quality

All friction brake system components must be in their final or production configuration before final acceptance testing will be accomplished.

9.0 EXPERIMENTAL DESIGN COMPARISION

The primary purpose of the Experimental Design Comparison is to provide a clear and concise method of comparing friction brake systems of today with this new Synchronous Brake System. This comparison will provide a means of understanding the Qualitative, as well as, the Quanitative values of the new system. It will also provide a cost analysis, as well as, benefits so that appropriate trade studies can be accomplished.

These comparisons will be made with several existing or competative systems. It is expected that Boeing will be responsible for this comparison, but it will require the Brake System suppliers support in providing cost and technical data of their system.

The Brake System elements to be included in the comparison are:

- Deceleration and Stopping Distance - Service (Dry and wetted rails)
- Deceleration and Stopping Distance - Emergency (Dry and wetted rails)
- Schedule Service Performance
- Precision Station Stopping
- Pad Life
- Acoustics - Exterior
  - Component Criteria

- o Reliability
- o Maintainability
- o Availability
- o System Costs
  - o Acquisition
  - o Operation and Maintenance

APPENDIX I

ACT-1 SYNTHETIC TRANSIT ROUTE

PUEBLO TRACK

PROFILE, SPEED LIMITS, STATION STOPS

ACT-1 SYNTHETIC TRANSIT ROUTE
HSGTC PUEBLO

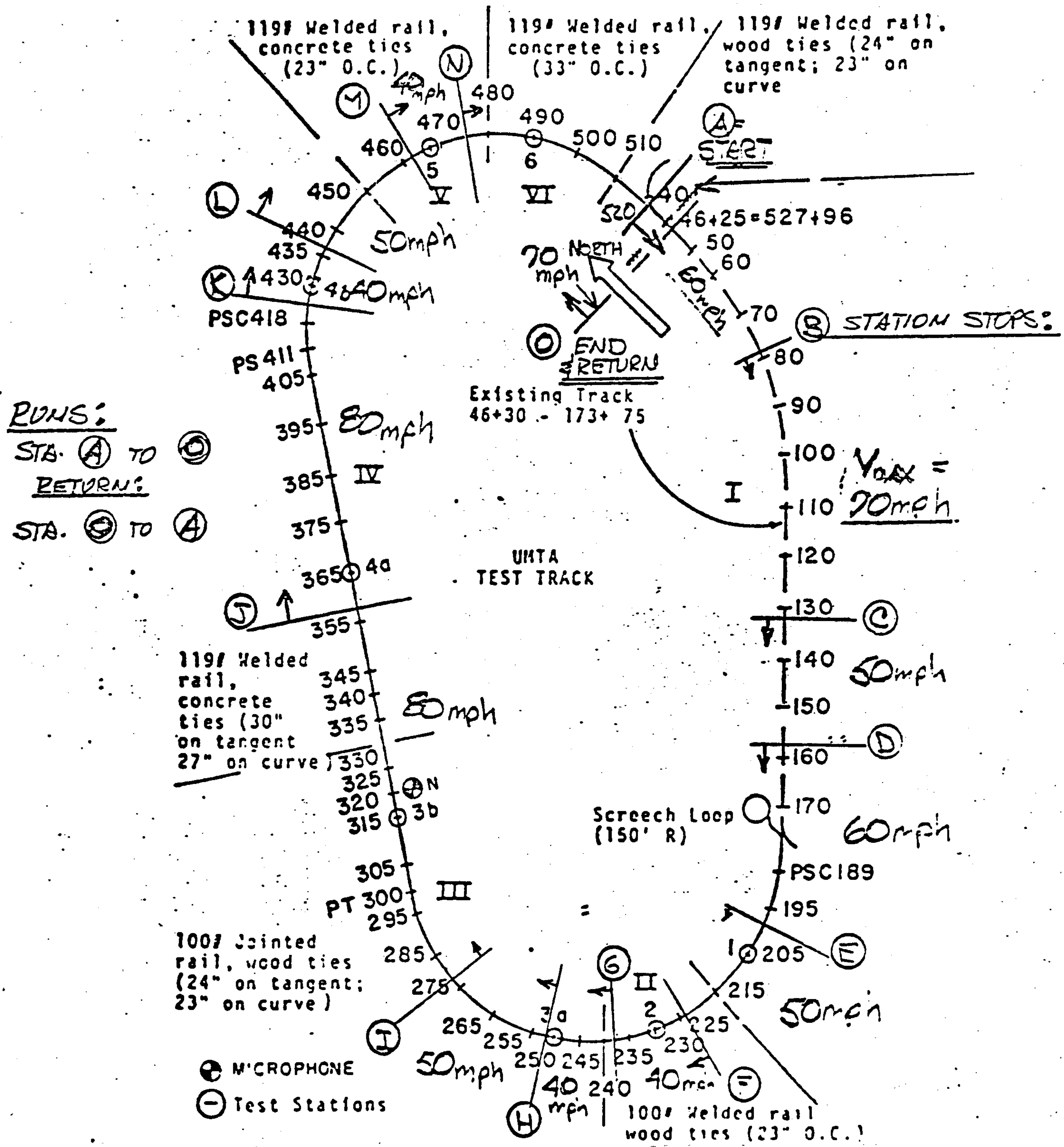


FIGURE I-1

TRACK PROFILE

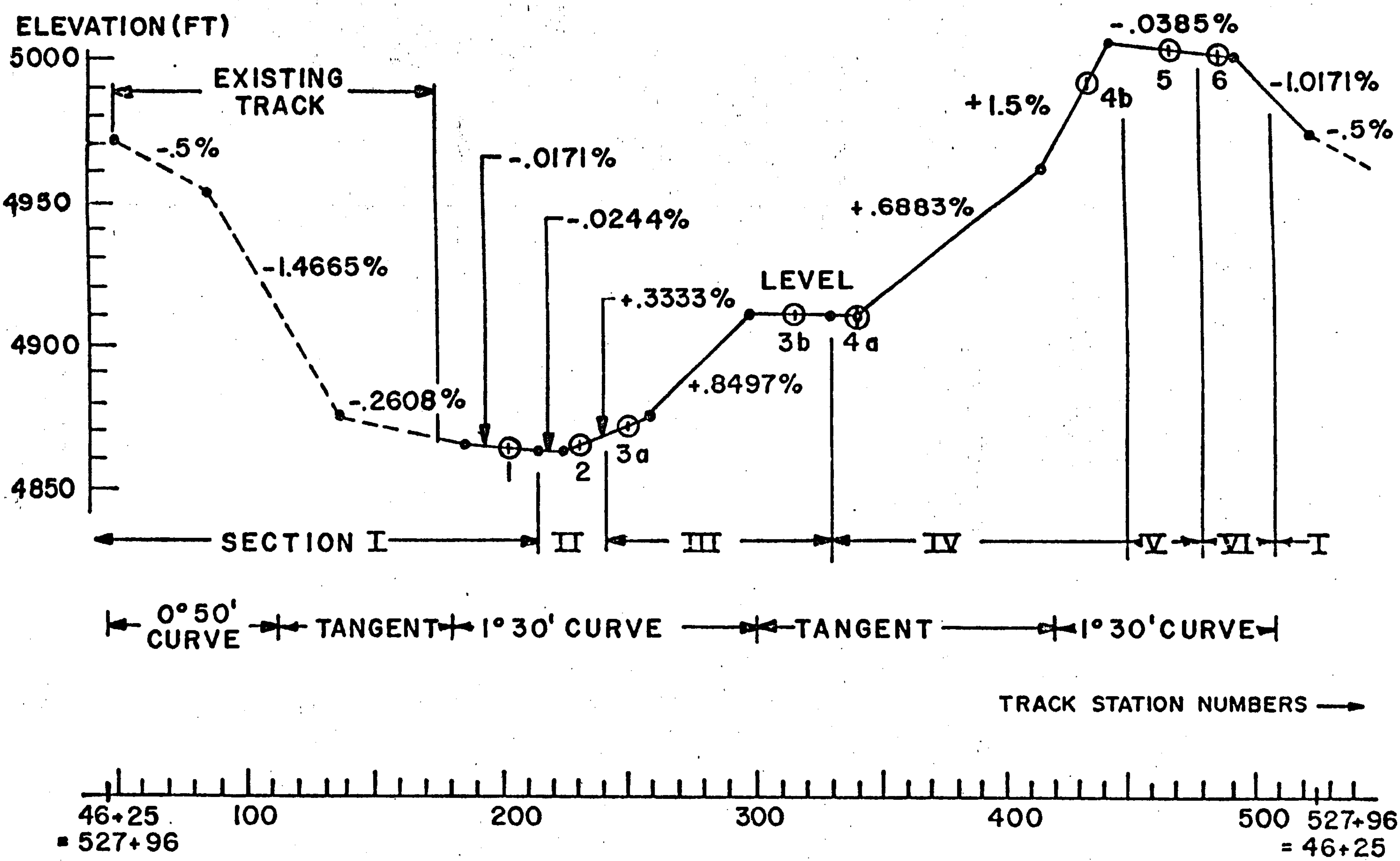


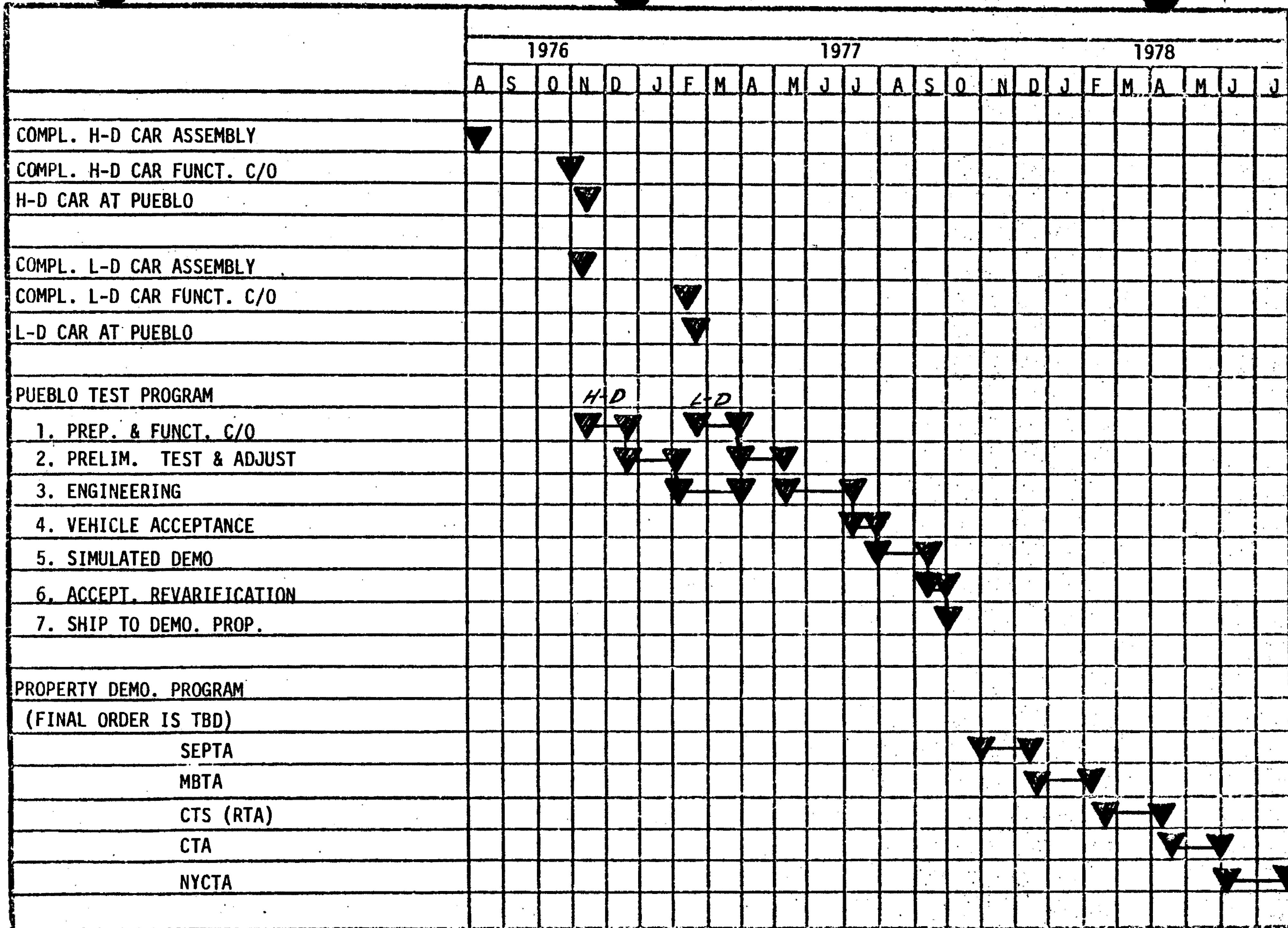
FIGURE I-2

ACT-1 SYNTHETIC TRANSIT ROUTE
80 MPH PUEBLO TRACK
TABLE I-1
CLOCKWISE RUN

TRACK STATION NUMBER (ft)	TOTAL DIST. (mi)	TRACK SPEED (mph)	GRADE (%)	CURVE (Deg.)	STATION STOP LETTER
52171=4000	0	60	-.5	0	A
4625	.118	60	-.5	.835	
7960	.750	70	-.5	.835	B
8520	.856	70	-1.466	.835	
11250	1.373	70	-1.466	0	
13250	1.750	50	-1.466	0	C
13700	1.837	50	-.261	0	
15800	2.25	60	-.261	0	D
18000	2.652	60	-.261	1.50	
18650	2.775	60	-.017	1.50	
19840	3.000	50	-.017	1.50	E
21500	3.314	50	-.024	1.50	
22450	3.500	40	.333	1.50	F
23860	3.750	40	.333	1.50	G
25120	4.000	50	.333	1.50	H
26000	4.167	50	.850	1.50	
27760	4.500	80	.850	1.50	I
29950	4.915	80	0.	0.	
34100	5.701	80	.688	0.	
35680	6.000	80	.688	0.	J
41500	7.102	80	1.500	0.	
42000	7.197	80	1.500	1.50	
42280	7.250	40	1.500	1.50	K
43600	7.500	50	1.500	1.50	L
44500	7.670	50	-.038	1.50	
46240	8.000	40	-.038	1.50	M
47560	8.250	70	-.038	1.50	N
49400	8.598	70	-1.017	1.50	
51000	8.902	70	-1.017	0.	
52795	9.241	70	-.500	0.	
52840	9.250	70	-.500	0.	0 & STOP

Counterclockwise run is from Station 'O' to "A"

ACT-1 PROGRAM SCHEDULE



Boeing/Vertol ACT-I Program Termination Liability Schedule
(Excludes Pueblo Testing and 5 Property Demonstration Tour Costs)

	P.O. CS200088 -- Change 2			Changes	Total
	(Ref. Only) Total Liab. (# In Millions)	Garrett Share of O'Run ($ In Thousands)	Gov't Term. Liab. ($ In Millions	Gov't. Term. Liab. ($ In Thousands)	Gov't. Term. Liab. ($ In Millions)
March 1976	17,400	-0-	17,400	72	17,472
April 1976	17,800	-0-	17,800		17,872
May 1976	18,200	159	18,041		18,113
June 1976	18,574	309	18,265		18,337
July 1976	18,950	459	18,491		18,563
Aug. 1976	19,200	559	18,641		18,713
Sept. 1976	19,325	609	18,716		18,788
Oct. 1976	19,450	659	18,791		18,863
Nov. 1976	19,530	691	18,839		18,911
Dec. 1976	19,580	711	18,869		18,941
Jan. 1977	19,620	727	18,893		18,965
Feb. 1977	19,660	743	18,917		18,989
Mar. 1977	19,700	759	18,941		19,013
April 1977	19,740	775	18,965		19,037
May 1977	19,780	791	18,989		19,061
June 1977	19,829	811	19,018	72	19,090

INCLUDES FEE $232,000

3-31-76 "A" Rev.

Boeing/Vertol ACT-I Program Termination Liability Schedule

(Excludes Pueblo Testing and 5 Property Demonstration Tour Costs)

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April 1977	19,740	775	18,965		19,037
May 1977	19,780	791	18,989		19,061
June 1977	19,829	811	19,018	72	19,090

INCLUDES FEE $232,000

Boeing/Vertol ACT-1 Program Termination Liability Schedule

(Excludes Pueblo Testing and 5 Property Demonstration Tour Costs)

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Boeing/Vertol ACT-1 Program Termination Liability Schedule

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April 1977	19,740	775	18,965		19,037
May 1977	19,780	791	18,989		19,061
June 1977	19,829	811	19,018	72	19,090

INCLUDES FEE $232,000

3-31-76 "A" Rev.

Boeing/Vertol ACT-I Program Termination Liability Schedule
(Excludes Pueblo Testing and 5 Property Demonstration Tour Costs)

P.Q. CS200088 -- Change 2				Changes	Total
	(Ref. Only) Total Liab. (# in Millions)	Garrett Share of O'Run ($ in Thousands)	Gov't Term. Liab. ($ in Millions	Gov't. Term. Liab. ($ in Thousands)	Gov't. Term. Liab. ($ in Millions)
March 1976	17,400	-0-	17,400	72	17,472
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