PTACV MARKETING SURVEY REPORT

AND

SYSTEM SUMMARY

PART I – HIGH SPEED GROUND TECHNOLOGIES

PART II – APPLICATIONS OF TACV TECHNOLOGY (General)

PART III – TECHNICAL DESCRIPTION

Prepared For

U.S. DEPARTMENT OF TRANSPORTATION

Contract No. DOT-UT-10031

By

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June 1976

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SYSTEM SUMMARY

PART I - HIGH SPEED GROUND TECHNOLOGIES

PART I
HIGH SPEED GROUND TECHNOLOGIES

Until the mid-1950's the United States led the world in high-speed rail service. That traffic has been steadily lost to air and auto travel. The quest to overtake the airplane in intercity passenger service has spurred the introduction of new high speed ground systems since 1960. What is needed is a transportation mode that is safer and faster than the automobile, with acceptable economy, energy consumption and environmental impact.

Worldwide, conventional rail systems have undergone extensive improvement until trains now on regularly scheduled runs average above 100 miles an hour in Japan and France. Intercity trips at over 90 miles an hour are offered in Great Britain, Canada, and the United States.

In the United States, premium rail performance is offered by the Metroliner trains, diesel or electric, and by the gas turbine Turboliner trainsets. Metroliner design speed is 160 miles an hour and the AMTRAK Turboliner is rated for 125 miles an hour. However, roadbed conditions or the network scheduling of mixed freight and passenger trains on the same track hold operating speeds below the design limits. International rail operations are ranked in this listing.

Country	Train	Trip Miles	High-Speed Rail Operating Speeds, MPH	
			Maximum	Average
Japan	104 Hikari	210	130	105
France	Etendard	63	125	102
United States	Metroliner	68	105	93
Canada	Turbotrain	310	95	90
United States	Turboliner	85	105	57
Great Britain	Rugby/Watford	65	100	90

The major cause for the poor performance of U.S. equipment is that it operates over the same rail as freight car traffic, while the Japanese equipment operates over a guideway dedicated to the high-speed passenger service. High-speed rail operations require new roadbeds, and system capital cost can equal that of more advanced technologies.

NEW TECHNOLOGIES

New technologies to provide high speed ground transportation were fostered by research programs of the U.S. Department of Transportation in the late 1960's. The growth of traffic over major intercity links could not be met with 50 mile an hour trip speeds of typical U.S. intercity rail operations. While rail cars are capable of speeds approaching 200 miles an hour, costs of maintenance of wheels and track rise sharply above 120 miles per hour. Rail ride quality also deteriorates at the higher speeds.

Three advanced concepts have been studied as alternatives to conventional rail transportation, and two of them have been carried through construction and extensive testing. The three concepts are: a vehicle propelled at high speed against low air resistance in an evacuated tube, the magnetically levitated vehicle, and the air cushion vehicle. The latter two have been demonstrated on test tracks.

THE MAGNETIC LEVITATION VEHICLE

In West Germany, Japan, the United States, Canada, and the United Kingdom, investigations have been made of the potential of a wheel-less vehicle suspended by electromagnetic forces, with a clearance from its guideway of an inch or more. Serious interest in this technology first arose in the mid-1960's.

There are two forms of magnetic suspension for transportation. The earliest approach levitates the vehicle by the force of attraction between the guideway rail and a magnet extending the length of the vehicle. It operates with a small clearance from the guideway, and requires a high-performance, fast-reaction control subsystem. German consortia have built experimental attraction-suspension vehicles, designed for 200 mile an hour intercity applications, which have exceeded 100 mph on short test tracks. The "Transurban", a vehicle designed for the 40 - 70 miles an hour speeds of urban applications, has also been tested in Germany.

The later technology utilizes coils mounted to the vehicle which induce currents in track-bed coils, and a magnetic force of repulsion which levitates the vehicle. The system tolerates larger clearances between the car and its guideway, but requires cryogenic superconducting coils. This technology appears to possess higher ride stability, but poor lift capability at low speeds. Scale models of this levitation have been demonstrated in Japan.

Since studies of magnetic levitation were begun some years later than those of the TACV, its capabilities have not been as fully tested and evaluated as air cushion concepts.

THE TRACKED AIR CUSHION VEHICLE

One of the most promising of the new systems would carry travelers in wheel-less cars, skimming 150 miles an hour over a level guideway slab on a film of air less than an inch deep. The car would be centered on the guideway by a guiderail which it straddled, thus the concept was named the Tracked Air Cushion Vehicle System (TACV).

Air cushion technology studies began in France in the mid-1950's, followed in the next decade by the development of the "Aerotrain". The technology has been demonstrated both as a high-speed intercity system, and as a moderate-speed urban transit mode.

The turbine-powered prototype of this TACV was an 80-passenger intercity car, which has achieved speeds to 250 miles an hour. It was followed by the construction of a smaller car for suburban service, which added to the design for its propulsion, a non-polluting linear electric induction motor (LIM), which has no moving parts. This 44-passenger car operates at 120 miles an hour. The present value of these French pioneering efforts is estimated exceed $30 million. Rohr Industries secured design rights to the French technology, and has continued the effort to perfect system performance through engineering and design improvements.

The outcome of two decades of international engineering is an automated passenger vehicle system which offers ride comfort unparalleled by any other ground transportation system, which is capable of speeds higher than is possible with any rail system and which is non-polluting to the environment. It competes favorably with air transportation when total trip time from city center to city center is compared as reflected in the following graph.

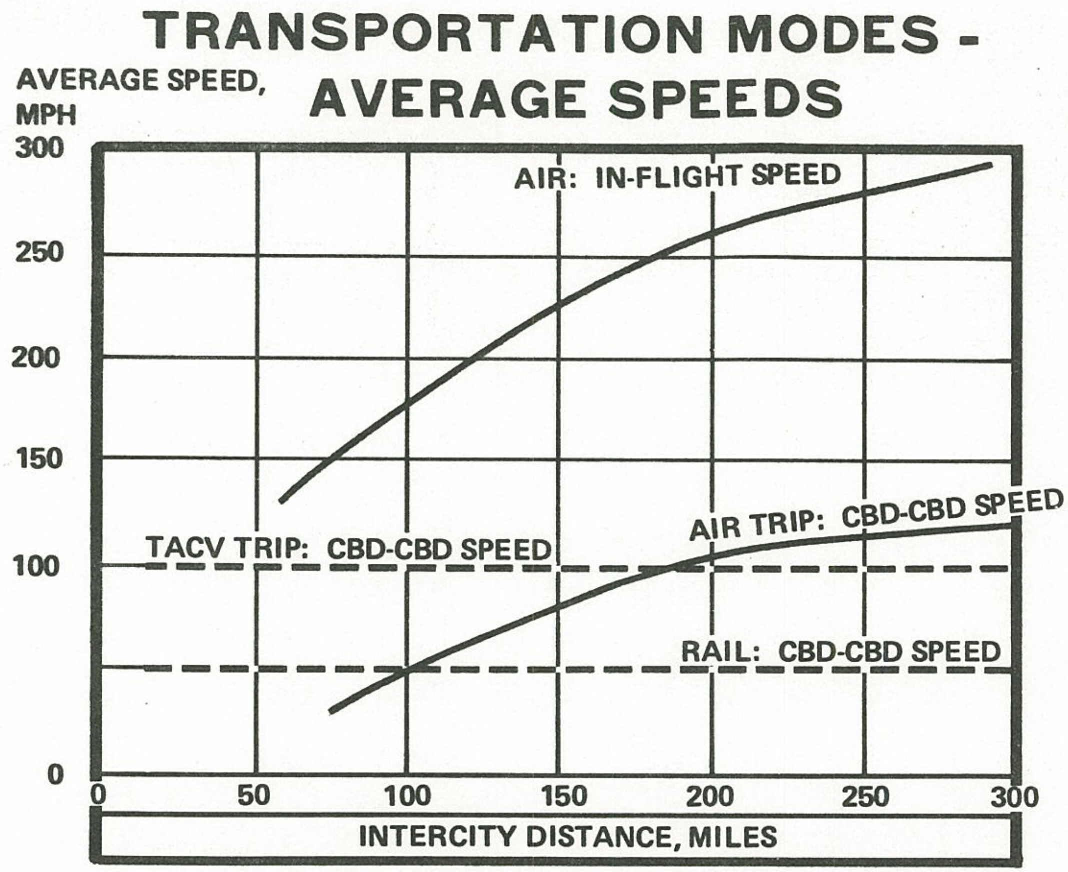

Figure 1-1. Transportation Modes -- Average Speeds

This luxurious service can be provided, on a fully self-supporting basis, at fares lower than air rates. By comparison, federal services to air passenger traffic amount to a subsidy of approximately $1.00 per 100 passenger miles, and the subsidy to AMTRAK exceeds $8.00 per 100 rail passenger miles.

The fare paid by a passenger on a public carrier depends upon the extent of such subsidy, the frequency of service, the total annual passenger traffic, and the method of financing the capital investment. For a route carrying 5 million passengers a year, the TACV break-even rate is estimated at $15.00 for a 100-mile trip, when the system is entirely debt financed. Some comparisons are made in the accompanying graph.

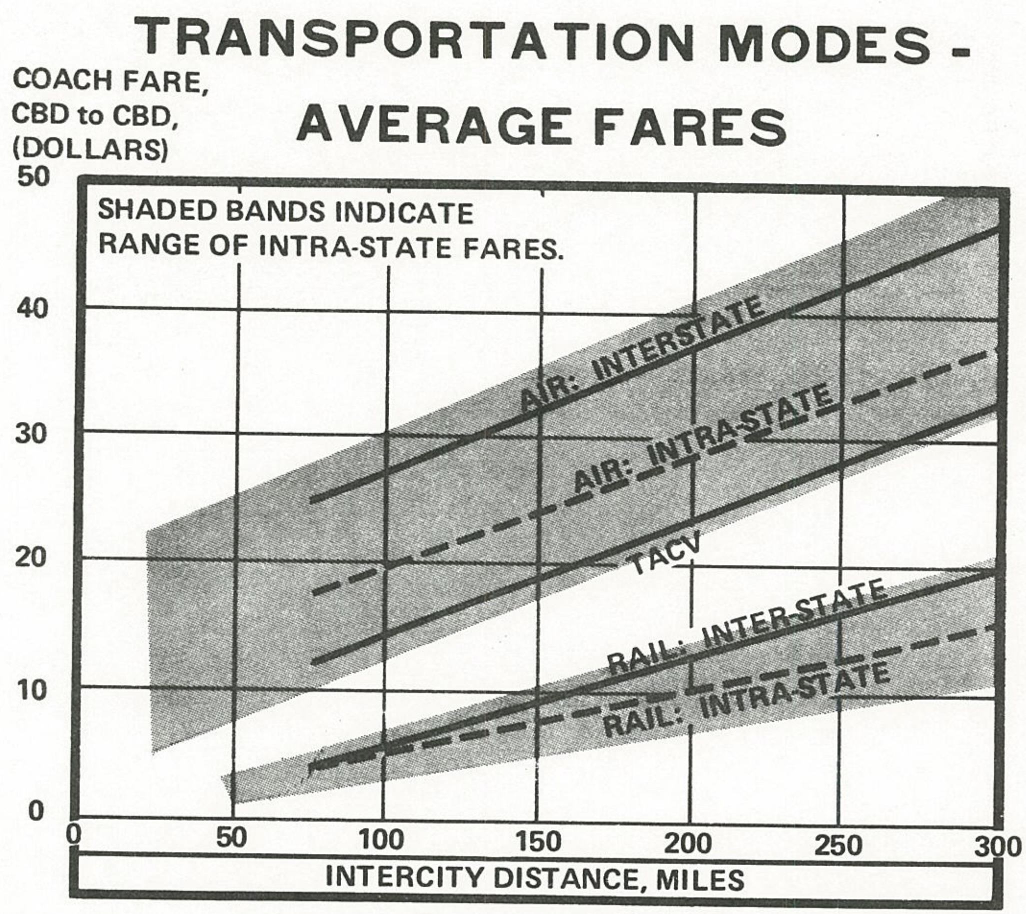

Figure 1-2. Transportation Modes -- Averages Fares

THE PROTOTYPE TACV PROGRAM

The design of a 60-passenger, 150 mile an hour TACV with linear induction propulsion was supported by the U. S. Department of Transportation (DOT), which awarded a contract to Rohr Industries in mid-1971. In the following year, another contract was awarded to build the 94-foot prototype, and by 1974 the vehicle was ready for tests at the Transportation Test Center (TTC) at Pueblo, Colorado. The vehicle reached the 145 miles an hour speed permitted by the length of its test track in 1976 and successfully completed the remaining tests of its performance and safety. The present value of the DOT/Rohr development effort is estimated to exceed $20 million.

The Prototype TACV (PTACV) and its subsystems are illustrated by the cutaway drawing of Figure 1-3. The performance objectives for the system are summarized in Table 1-1.

The primary mode of vehicle control at TTC is manual, but automatic start and stops have been demonstrated. To date, an insufficient length of guideway has been instrumented to permit full demonstration of automatic train control (ATC) capabilities at Pueblo. The same system is incorporated by Bendix Aerospace Corporation into their demonstration track at Ann Arbor, Michigan, where three vehicles are speed and route controlled to show merging, diverging, following, interlocking, station stop, station start, and emergency stop controls.

The Prototype TACV offers its passengers an extremely smooth-riding, high-speed means of overland travel with a cabin noise level of 82 dB(A). Test results of vehicle response to 100 mile an hour runs over the Pueblo guideway demonstrate its superior performance compared to other modes of ground transportation. This ride quality comparison can be seen in the following graph.

Safety belts are integral to each seat, and are of aircraft quality.

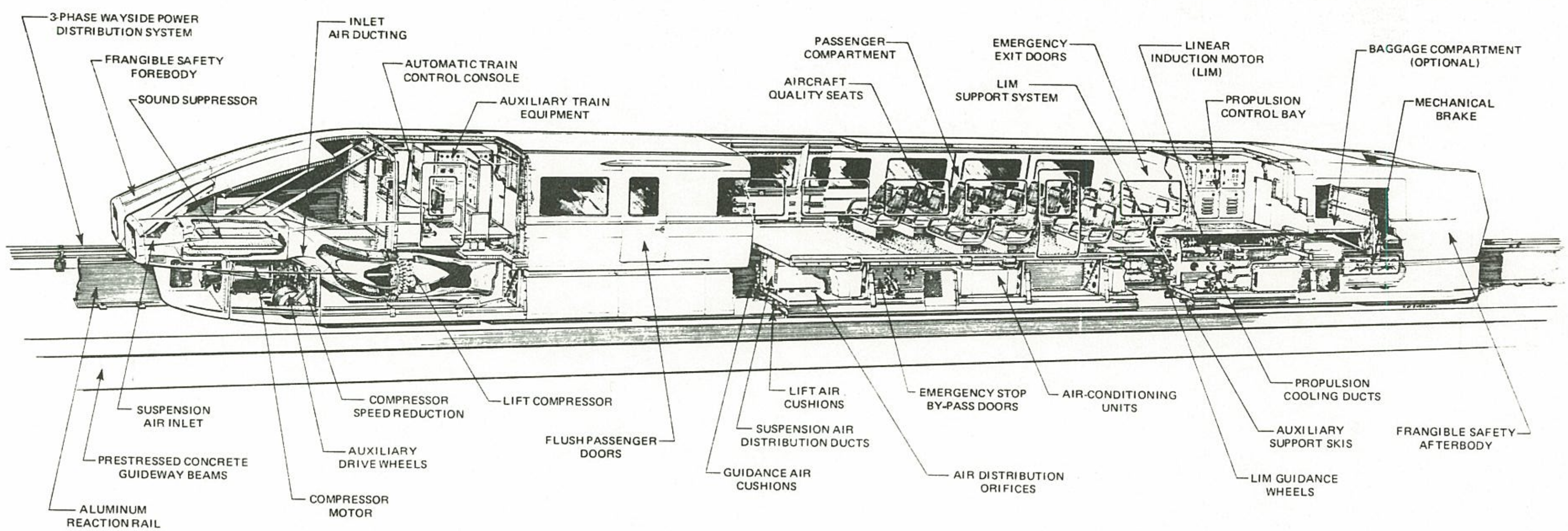

Figure 1-3. PTACV Perspective Cutaway View

Table 1-1

PTACV Performance Objectives

Function	Required
1. Satisfactory operation in:	
(a) Temperature range	-20^oF tp 120^oF
(b) Rain	2"/hour steady
(c) Winds (any direction)	30 MPH steady 60 MPH gusts
2. Safe storage (non-operating) in:	
Winds (any direction)	70 MPH steady 100 MPH gusts
3. Speed on 3% grade and 30 MPH headwind	
(a) Forward	150 MPH
(b) Reverse	30 MPH
4. Acceleration	
(a) Distance to go from start to 150 MPH up a 1.25% grade	1.75 miles
(b) Longitudinal - maximum	0.15g
5. Deceleration	
(a) Distance for maximum effort stop from 150 MPH (-1% grade and 30 MPH tailwind)	0.5 miles
(b) Normal brake effort	0.15g maximum
(c) Emergency stop effort	0.4g maximum
6. Ride Quality	
(a) Sustained acceleration:	
• Longitudinal	0.15g maximum
• Lateral	0.08g maximum
• Vertical	0.10g maximum
(b) Rate of change of sustained acceleration	
• Longitudinal jerk (maximum)	0.03g/second
• Lateral jerk (maximum)	0.03g/second
• Vertical jerk (maximum)	0.04g/second
(c) Maximum acceleration standard deviations (30 second sample period, 0.1 to 15.0 Hz band)	
• 120 MPH velocity	
--Longitudinal sigma	0.025g
--Lateral sigma	0.025g
--Vertical sigma	0.030g
• 150 MPH velocity	
--Longitudinal sigma	0.039g
--Lateral sigma	0.039g
--Vertical sigma	0.047g

Table 1-1 (Cont.)

Function	Required
(d) Maximum acceleration standard deviations for total of 5% of item 8 sample period:	
o 120 MPH velocity:	
--Longitudinal acceleration	0.05g
--Lateral acceleration	0.05g
--Vertical acceleration	0.06g
o 150 MPH velocity	
--Longitudinal acceleration	0.078g
--Lateral acceleration	0.078g
--Vertical acceleration	0.094g
(e) Spectral composition of acceleration (30 second sample)	Figure 2-2
7. Air conditioning cabin temperature (ambient 100^oF, 50% R.H.)	$72-77^o$ D.B.
8. Passenger Compartment Noise Level	65 dB(A)
9. Crew compartment noise level	75 dB(A)
10. External noise levels:	
(a) 50' ahead of vehicle, stopped	63 dB(A)
(b) 50' ahead of vehicle, cruise speed	73 dB(A)
11. Electromagnetic interference	Not to interfere with broadcasts or other communications
12. Emergency Egress Time (60 passengers plus crew)	90 seconds
13. Window impact protection	Baseball at 75 ft/sec
14. Positive vehicle grounding under all stop conditions	
15. MTBF	
(a) Major (system stoppage)	2000 hours
(b) Minor (reduced performance)	1000 hours

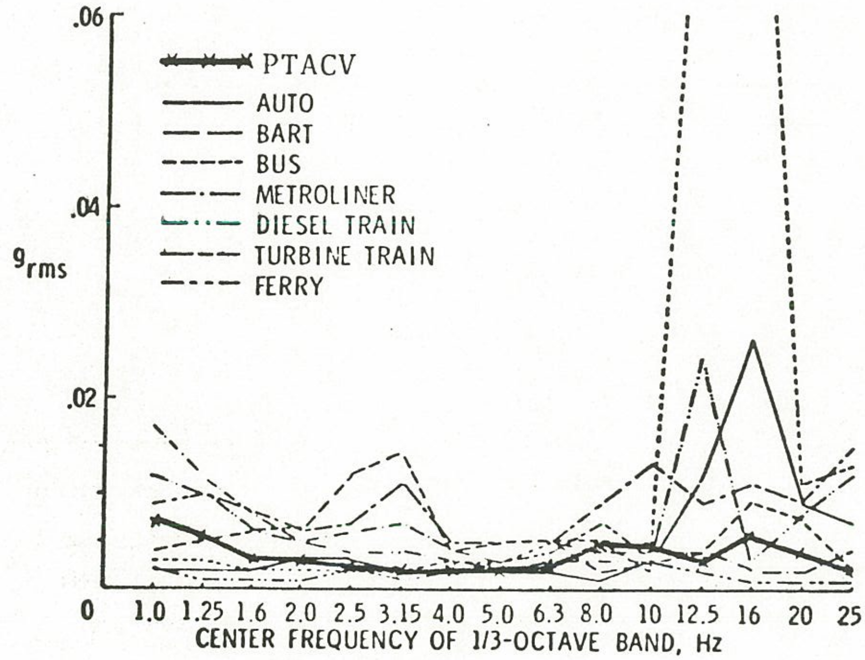

Figure 1-4. Lateral Response for Surface Vehicles (1)

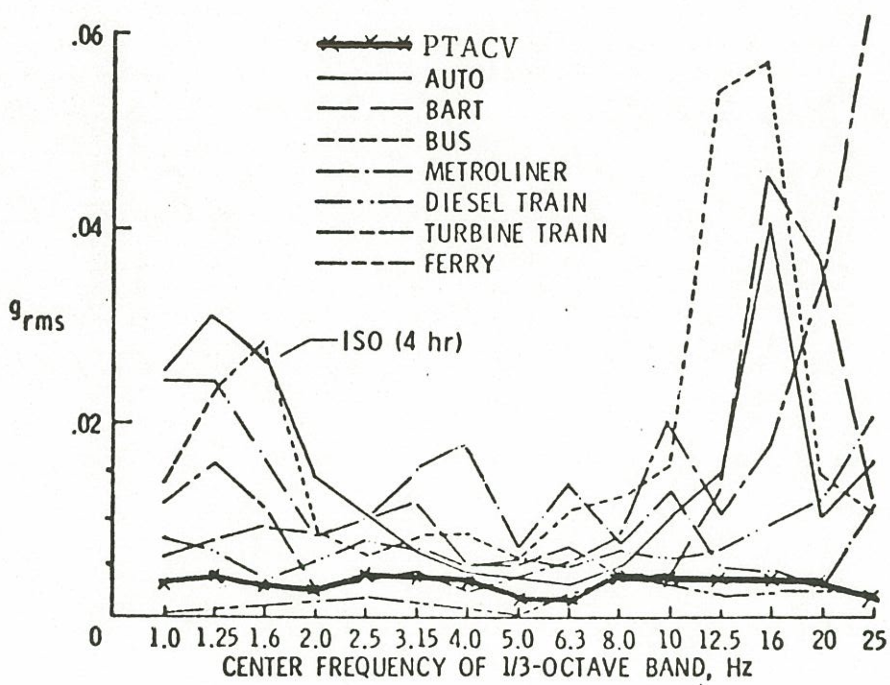

Figure 1-5. Vertical Response for Surface Vehicles

SOURCE: "Test Results Report: PTACV Ride Quality", Ensco, Inc.

The lighting and decor of the vehicle reflect the industrial design goals of superior comfort and general interior attractiveness. The quality of furnishing can be seen in the details of the size and placement of windows and seats, the carpeting and ease of access at the entryways.

SYSTEM COSTS

All-inclusive costs for high-speed systems differ widely. Lowest capital requirement is for a rail system which operates over an existing right-of-way after upgrading the ride quality of track already in place. Highest investment is for an all-new route over irregular terrain, calling for bridges, tunnels and a high percentage of elevated guideway. To obtain the highest performance from a TACV installation, all-new construction is required. An estimate of a typical route cost for 1980 may be compared with published figures for a rail network. The marked inflationary trend of Japanese costs for successive segments added to that system is similar to the U. S. experience which has seen prices of both railroad equipment and general construction double since 1967.

SYSTEM	ROUTE LENGTH, MILES	FIRST YEAR OF SERVICE	SYSTEM COST PER ROUTE MILE, 1976 DOLLARS (a)	(MILLIONS) (b)
Japan Shinkansen	321	1964	5.7	4.0
Japan Shinkansen	100	1972	12.6	8.4
Japan Shinkansen	244	1975	19.7	15.1
U.S.A. - TACV	100	1980	----	12. (Est.)

(a) - Includes right-of-way, general expense, and interest and (b)

(b) - Includes only roadbed and tracks, electric facilities, and rolling stock.

OPERATIONS Costs of the TACV depend upon its operations policy. It may be a fully-automatic system, or a train attendant may be assigned to monitor its operation and to over-ride the automatic controls at his option. The prototype vehicle is operated singly. However, additional development will permit its entrainment. One single attendant will then be assigned for the full train consist. Other operating costs for passenger service will be comparable to premium rail routes.

MAINTENANCE Labor costs of interstate rail carriers have increased 30 percent, in constant dollars, since 1967. The inflationary trend makes low-maintenance systems particularly attractive over the life of revenue equipment. Costs of TACV maintenance are sharply lower than for high-speed rail systems. This economy reflects the attention given during the design process to minimizing potential vehicle down-time. Quickly replaceable modules are used to the maximum extent possible. Fault location techniques expedite the maintenance procedures.

The light pressure loading of the air cushion on the concrete bearing surface leads to minimal guideway maintenance. The high-cost repair and replacement of steel wheels, track ties and rail are eliminated, compared to conventional rail technology. Air cushion suspension eliminates the need for conventional truck maintenance. Since the initial deceleration from high speed is made by dynamic braking of the LIM motor, mechanical brake maintenance for the TACV is confined to the effects of wear at low speeds.

Mechanical maintenance requirements peculiar to the TACV are the replacement of the power collector elements which contact wayside power rails, and the renewal of lip seals of the air cushion skirts which wear against the guideway during occasional contact in operation. Thus, maintenance of way and equipment both are considerably less than for conventional rail maintenance.

ENERGY The energy consumption of a TACV compares favorably with that of an air transport. Exact energy consumption rates vary, for any vehicle, with the pattern of accelerations, decelerations, speed reductions to negotiate curves, various cruise speeds, aerodynamic drag, rolling friction, and number of stops which are performed during a trip. However, a general ranking may be made of energy usage by alternative transportation modes. It should be noted that the air transport and the turbine-powered rail car convert energy directly from fuel, whereas the remaining systems have losses which may exceed 50 percent of the original source fuel energy, before power reaches the propulsion subsystem of an electrified vehicle.

	Average Speed MPH	BTU Per Passenger Mile - Seats Half Occupied
Air transport	250	9000
Turboliner	55	4000
Diesel - Electric Train	50	1800

The prototype TACV has an energy efficiency approximately that of high-speed rail. A second-generation TACV of refined design for revenue operations can be expected to have an energy efficiency which exceeds that of high-speed rail.

	MPH	BTU/PM - (LF = 50%)
1976 Prototype TACV	100	4400
1980 Revenue TACV	100	2500

The ratio of passenger weight to gross vehicle weight of the TACV also compares favorably with that of other modes. Its structure is lighter than for rail, since it is not subject to the impacts and vibrations imparted by steel rail to steel wheels. The TACV air cushion suspension weighs less than the trucks and wheels of a rail car of comparable seating size. This ratio contributed to its energy efficiency per seat-mile.

	Passenger Weight as a Percent of Vehicle Gross Weight
Air transport	24
1976 Prototype TACV	21
Canadian Pacific Turbotrain	15
Metroliner	7

Electrified ground transport like the TACV furthers the national goal of reduced dependence on petroleum as a transportation fuel, since power utilities may generate electricity from coal-fired or hydro-electric plants.

NOISE The noise impact of the TACV is within the range of other forms of passenger ground transportation, although its average operating speed is nearly twice as great. The Prototype TACV meets Federal regulations for external noise for locomotives or powered cars.

	External Noise, dB(A)	Distance from Vehicle, Feet
1976 Prototype TACV at grade (125 mph)	95	100
Turbotrain on elevated track	75 - 85	50
Diesel-Electric on upgraded track	85 - 95	50

SAFETY The TACV is a "fail operational-failsafe" system. The reaction of the system is dictated by the nature of the malfunction or unscheduled incident. Operation is automatically adjusted to a condition which eliminates risk to passengers and equipment. If necessary, the vehicle will execute an automatic normal or emergency stop, a condition of "fail safe". During an emergency stop the weight of the vehicle is carried by skids, and no derailment can take place.

The energy absorbing frangible forebody of the vehicle affords a high level of passenger protection in the case of an impact with a foreign body on the guideway.

Fire protection and suppression is incorporated in the specifications for the TACV, with an automatic fire detection and extinguishing system provided for passenger safety. The power distribution system within the vehicle is grounded to prevent a safety hazard. Emergency exits from the vehicle operate from both inside and outside the vehicle and do not require the use of tools to open them.

The vehicle is equipped with instrumentation for monitoring and controlling the performance of the vehicle and its essential subsystems. Continuously monitored are car speed, cabin temperature, motor operation, brake status, door closure operations and the air cushion supply system flow rate.

THE TACV IN REVENUE OPERATION

The extensive two-year test and evaluation of the Prototype TACV now make possible the production engineering of a TACV for revenue operations. Although the present design is a high-speed vehicle, its superior ride quality and safety may equally be utilized for a moderate-speed urban transit system.

Preliminary design and evaluation have already been performed of those advances to the technology which will improve vehicle efficiency and lower system costs. Revenue operations will benefit from TACV modification into vehicles which are both bidirectional and entrainable. System costs will benefit from those changes, and from more economical air-flow circuits and motor control.

TECHNOLOGY REFINEMENT

ENTRAINMENT One of the earliest incentives to explore high-speed ground transportation was that existing intercity rail would not be able to carry the long-term traffic demand forecast for major megapolis and regional corridors.

The traffic capacity along a transportation lane is increased when the number of cars per train is increased, or when the average trip speed rises. To benefit from the speed capabilities of a TACV, it must also have the entrainment capability of ordinary rail systems. The revenue TACV, therefore, will provide safe and effective mechanical and electrical coupling of the cars of a train consist.

BIDIRECTIONALITY The prototype TACV propulsion subsystem has the technical capability of operation in the reverse direction at full design speed, 150 miles an hour. However, there are structural changes required to the attendant compartment of the vehicle, such that visibility is equally satisfactory in either direction of travel.

Bidirectionality will impose a revision to the air intake configuration, so that the air flow will be uniform to the cooling and lifting subsystems, regardless of vehicle heading.

AIR FLOW The air cushions for levitation and the cushions for vehicle guidance are separate in the prototype. Combination of these functions in a single system will reduce air flow losses and lower cushion energy consumption.

NOISE The major component of noise in the prototype is generated at the compressors. Replacement of the two existing compressors by four smaller units will reduce the source noise level and allow provision for greater noise attenuation.

A production vehicle would be considerably quieter than the prototype. Significant noise reduction would result from the optimization of the motor-updrive-compressor system, the reconfiguration of the air intake ducts and the redesign of the air distribution system immediately behind the compressors. Additionally, modifications to the plenum duct and passenger flow structure to achieve better isolation would further reduce passenger compartment noise. Crew compartment noise would be reduced by the redesign of the forward bulkhead and the provision of a specially isolated floor.

These noise reduction measures would reduce both the interior and the passby noise.

MOTOR CONTROL The test vehicle propulsion operates at constant-frequency with variable-voltage. The principles employed by Rohr in its corporate development program of a solid-state static-inverter to provide variable-frequency, variable-voltage (VF-VV) power to the linear induction motor, will permit design of more efficient motors, reduce propulsion system weight, and reduce energy requirements.

SYSTEM COSTS

A production engineering program applied to the existing TACV design will enhance the profitability of the system in revenue operation. The use of entrainment will raise traffic capacity per lane, and the potential annual passenger-miles of revenue. Bidirectionality will reduce land purchase requirements at terminals, since the trains will reverse direction for return trips without the necessity for turn loops. Round-trip times will be slightly shortened and the annual productivity of a train proportionately increased.

The greater efficiency of the air-flow circuits will lower energy consumption per vehicle-mile traveled. This saving, augmented by the efficiency of a VF-VV supply to the LIM subsystem may trim TACV operating expense up to 10 percent. Actual savings are dependent on route configuration.

PTACV MARKETING SURVEY REPORT

AND

SYSTEM SUMMARY

PART II - APPLICATIONS OF TACV TECHNOLOGY (General)

PART II/ TACV APPLICATIONS

The TACV is suited to a variety of applications. The LIM/Air Cushion technology can be incorporated into high-speed (intercity) or moderate speed (urban transit) systems. Some systems may be justified as clearly potentially financially self-supporting. Others may be responses to socioeconomic needs or political policies; the need for subsidy is foreseen, and acceptable to, the operating agency.

1. SELF-SUPPORTING SYSTEMS

1.1 HIGH SPEED

A system which is required to meet its full annualized capital and operating costs from the fare box and incidental revenues must:

- Attract high traffic density (passenger miles/route mile)
- Have route distances between major city stops, under 300 miles

Both these guidelines reflect that the high-speed TACV's most important competitor is the short-haul air line. An air line does not carry the capital recovery burden for its "guideway" that the TACV does. This investment must be amortized over a high volume of passenger miles, in order to allow a competitive fare to be charged. For non-stop trip distances greater than 300 miles, the air carrier can provide shorter central business district (CBD) to CBD trip times.

The capital cost to provide right-of-way and high-quality guideway is the largest single item of system investment, and ranges from 30 to 60 percent of the total. The cost is little affected by the type of vehicle which travels over the guideway.

The traffic at the financial break-even point is determined by a detailed iterative analysis of system costs, based upon specified levels of service and acceptable fares. Typical costs, however, have been developed by the Department of Transportation, and are shown in Figure 1-1.

The traffic productivity of high-speed equipment is optimum when trains travel the major portion of their trips at close to design speed. This augers against a route with "local service" characteristics of a suburban rail transit line, where station stops are frequent and inter-station distances are short. A compromise between the system goals of short trip times and many points of access to the transit service for the passenger, is the scheduling of both express and local trains. Off-line guideway spurs at each station permit express trains to by-pass "local" trains stopped at the way stations. Since the PTACV traverses 1.75 miles while accelerating to its 150 mph cruise speed, and an equal distance to decelerate to a stop, it is apparent that the longer the interstop separation, the closer trip average speed will approach vehicle cruise speed. The route profile is critical; winding routes and irregular terrain defeat an objective of high average trip speeds.

The traffic potential of an intercity link may be gauged by reference to traffic statistics for the competitive modes of transportation - short-haul air lines or premium service conventional rail lines. The TACV will capture some portion of that existing trip demand, and create new demand attracted by its superb ride quality.

1.2 MODERATE SPEED

The introduction of well-styled, comfortable riding and fast urban rapid transit systems in the San Francisco Bay Area and in Washington,

D. C. has raised the standards of public acceptance for suburban commuting and intra-city transit. The TACV carries these standards to a new level, and with a system design for this particular application, it becomes a candidate for transit applications in the 1980's.

Because of its lower cruise speed, the urban TACV would operate with reduced propulsion power. The use of a vehicle with fewer seats and standing room would be appropriate to transit service. The size, weight, and cost of vehicles then would be less than for the intercity vehicle. The guideway costs would be heavily dependent upon the decision to place a major part of the route at grade or elevated, but the structural strength requirements would be reduced.

2/ CANDIDATE APPLICATIONS

In the past three years, attention has been given to user applications of the TACV. Three types of applications became apparent. They are:

- Regional
- Airport Access
- Corridor

REGIONAL APPLICATIONS

2.1 DALLAS/AIRPORT/FT. WORTH

To date, the greatest interest shown has been in the Dallas/Airport/Ft. Worth route. This route, shown in Figure 2-1, is approximately 40 miles long with the Dallas/Ft. Worth airport about midroute. A total of 14 intermediate stops are planned between CBD terminals.

The terminals (Union Terminal-Dallas and City Center-Ft. Worth) would have line switching to permit bidirectional trains to changeover from inbound to outbound tracks. This shortens operating time as well as reduces the real estate required for vehicle direction change when compared to mono directional vehicles using loops or turntables for direction change. The proposed route would be two guideways main line and four guideways at 10 stations. The four guideway stations are to be utilized as passing stations, letting express trains go through while local trains are loading or unloading.

Trains would be operated with up to three vehicle per train at peak passenger hours.

2.2 LAX-PALMDALE

With the Los Angeles International Airport (LAX) approaching a saturation level of aircraft movements and satellite terminal capacities, relief of that congestion has been sought for some time. Nearby Ontario airport cannot accommodate if LAX is "socked-in. Palmdale Interantional Airport, with its good all-year visibility, has been proposed to alleviate the traffic congestion and, in bad weather, absorb all of LAX traffic. Palmdale has the expansion capability for this but does not have the capability at this time. Therefore, considerable attention has been given to provide that access capability.

A TACV route of approximately 65 miles could connect Palmdale to LAX. This route would be double guideway at all points. Single vehicles on headways of 90 seconds or somewhat shorter could be used. Should traffic density require it, trains of vehicles would be used. The vehicles can be more nearly copies of the PTACV since both terminals can utilize loops as turnarounds.

INTERCITY APPLICATIONS

Several intercity routes have been given attention.

2.3 WEST COAST CORRIDOR

A portion of the West Coast Corridor interconnects San Francisco, Sacramento, and Stockton. Traffic and route analyses have already been made to the terminal cities governments. This route is delta shaped in its configuration. The San Francisco-Sacramento portion is approximately 85 miles long and would roughly follow I-80, connecting San Francisco and Sacramento.

The entire corridor is shown in Figure 2-2. In the intermediate Vallejo (Benicia) area there are limiting grades and curves with a tunnel recommended north of Vallejo to minimize these speed limiting restrictions. North of Suison City, the topography is favorable to a TACV's high speed. Much of this route can be within the confines of I-80.

From Sacramento to Stockton (approximately 50 miles) much of the route would be within Route 99's right-of-way to minimize land acquisition requirements. Most of this route would be traversed at 150 mph giving a Sacramento-Stockton transit time of about 30 minutes. From Stockton to San Francisco, these are several candidate routes, but the one most strongly considered is a route of about 85 miles. There are some speed limiting curves in the route, the most prominent being in the approach to the Stockton station area. However, 150 MPH speeds should be reached in about 85% of the route.

2.4 LOS ANGELES/SAN DIEGO/TIJUANA (MEXICO)

This route is about 140 miles overall, the last 17 being between San Diego and Tijuana. The route would follow I-5 for the most part, but Anaheim, Santa Ana, San Juan Capistrano, San Clemente, Oceanside, and Del Mar would have stations instead of being bypassed (as I-5 does).

While the route has not been fully surveyed, there appear to be only a few points where the 150 mph potential cannot be utilized. Bidirectionality is recommended due to terminal costs in Los Angeles. Traffic can be handled by single car units but entrainment features should be incorporated.

2.5 TAMPA/ORLANDO/DAYTONA BEACH

This trans-Florida route, shown in Figure 2-3, is approximately 165 miles long. It follows I-4 for the most part and would have intermediate stations at Lakeland, Orlando, and Sanford. Future provisions for branches from Orlando to McCoy Air Force Base and Walt Disney World are being considered. This route is, in the main, gently rolling terrain and 150 mph speeds could easily be achieved. Again, traffic can be handled by single units, but entrainment features should be considered. Much of the route can be at-grade within the right-of-way of I-4.

Thus, route costs are minimized. Bidirectionality is recommended to reduce first costs of terminals in Tampa and Daytona Beach. If other counties join the effort, stations at Clearwater, St. Petersburg, Bradenton, and Sarasota could be added.

2.6 NEW ORLEANS/BATON ROUGE

This route, depicted in Figure 2-4, is about 85 miles in length, with intermediate stops at the new Southeastern International Airport and, possibly, Burnside. The first segment would be between New Orleans CBD and the airport. From there on, the route would, basically, follow I-10. Most of the route could be at grade but built upon pilings due to the marshy topography encountered. Speeds of 150 mph could easily be achieved since there are few grades encountered and few speed limiting curves would occur except in the terminal cities. Bidirectional vehicles should be used due to terminal costs. At present, single unit vehicles operating at 60 second headways could handle anticipated traffic. Thus, entrainment is not needed.

PLANNING FOR TACV: EXAMPLES

Planning for a transportation system proceeds in a series of basic estimates:

- Route alignment and station locations
- Passenger revenue traffic volume
- Annual schedule of service and operations plan
- Vehicles/trains to be purchased
- System capital cost
- Annual operating and maintenance expenses
- Capital grants and terms for debt finance of the remainder of the system investment
- Break-even fare rate
- Environmental impact

This planning process has been performed for two potential TACV applications, both of which provide high-speed access to major international airports from adjoining metropolitan areas. These studies were published in 1971 and 1974, but estimated costs have been adjusted for inflation factors, and are summarized in 1976 dollars. Specifications and costs for the two systems are given in Table 1.

The Dallas-Fort Worth Regional Airport is located approximately at the center of a 40-mile route connecting the two cities. The airport access route has been studied as a combined express and local service, with a total of 16 stations located along the route.

Table 1

SYSTEM SPECIFICATIONS AND COSTS

SPECIFICATIONS	Dallas-Ft. Worth Airport Access: Express	Dallas-Ft. Worth Airport Access: Local	Los Angeles Airport Access
Capacity			
Peak passengers in one direction per hour	5600	3000	1675
Traffic			
Passengers per year Million	36.9		6.8
Passenger miles per year Million	641.5		83.5
Route			
Route length Miles	39.9		16.2
Passenger stations	6	16	3.
Operations			
System revenue hours per day	19		20
Average train speed, including station stops MPH	92	49	59
System vehicle miles per year Million	24.9		2.74
System load factor Percent	43		51
Energy, KWH/year Million	550		94.3
Equipment			
Fleet size	161		15
Vehicles per train	6	4	1
Seats per vehicle	60		60
Vehicle Performance			
Cruise velocity MPH	150		150
COSTS $ Millions (1976 Dollars)			
System investment	600		200
Annual power expense	12.4		1.1
Annual Expense, Other	20.8		5.5
Annual depreciation reserve	Excluded		Excluded
Annual debt service expense	Excluded		Excluded

In 1980 traffic exceeding 36 million passengers a year is forecast[1]. The investment cost was estimated in a separate study[2]. All-inclusive system investment is estimated at $15.0 million a route-mile.

The costs adjusted for inflation suggest that annual direct operating costs (1976 rates) would amount to 5.2¢ per passenger mile, under the operating plan which was developed for the system.

Another potential application which also was the subject of two years' analyses by consultants and local agencies is an airport access line extending 16 miles northward from Los Angeles International Airport in the direction of the site of a future Palmdale Intercontinental Airport[3]. The investment cost for the guideway was the subject of a detailed engineering analysis[4]. Expressed in 1976 rates, the double-track elevated system, at times rising 90 feet above ground level to cross freeways and other features of the terrain, is estimated to cost a total of $12 million a route-mile. Annual direct operating costs (1976 rates) would amount to 7.9¢ per passenger mile.

Costs at other specific sites will be dependent upon the key characteristics of the projected system. Investment is heavily influenced by the nature of the terrain, and the percentage of guideway which must be elevated or installed in tunnels or cuts. Operating costs are sensitive to the passenger load factor (passenger miles/seat miles), frequency of service, number of cars per train and the variability of traffic demand from hour to hour during the day, among other factors. In general, the two cases cited above compare favorably with the capital costs of the Shinkansen lines built in Japan over the past 10 years.

Based upon design analyses at the time of these planning studies, power requirements were estimated. The annual energy consumption rates of Table 1 include passenger station, maintenance shop, control center and general offices lighting and air conditioning loads, in addition to the energy supplied to the vehicles. Energy per car-mile for the Texas system was less at the Texas site than at Los Angeles, since vehicles were entrained, and aerodynamic drag losses were reduced.

System energy usage is pro-rated at 2900 BTU per passenger mile for the Texas operation, and 3800 BTU per passenger mile for the Los Angeles shuttle.

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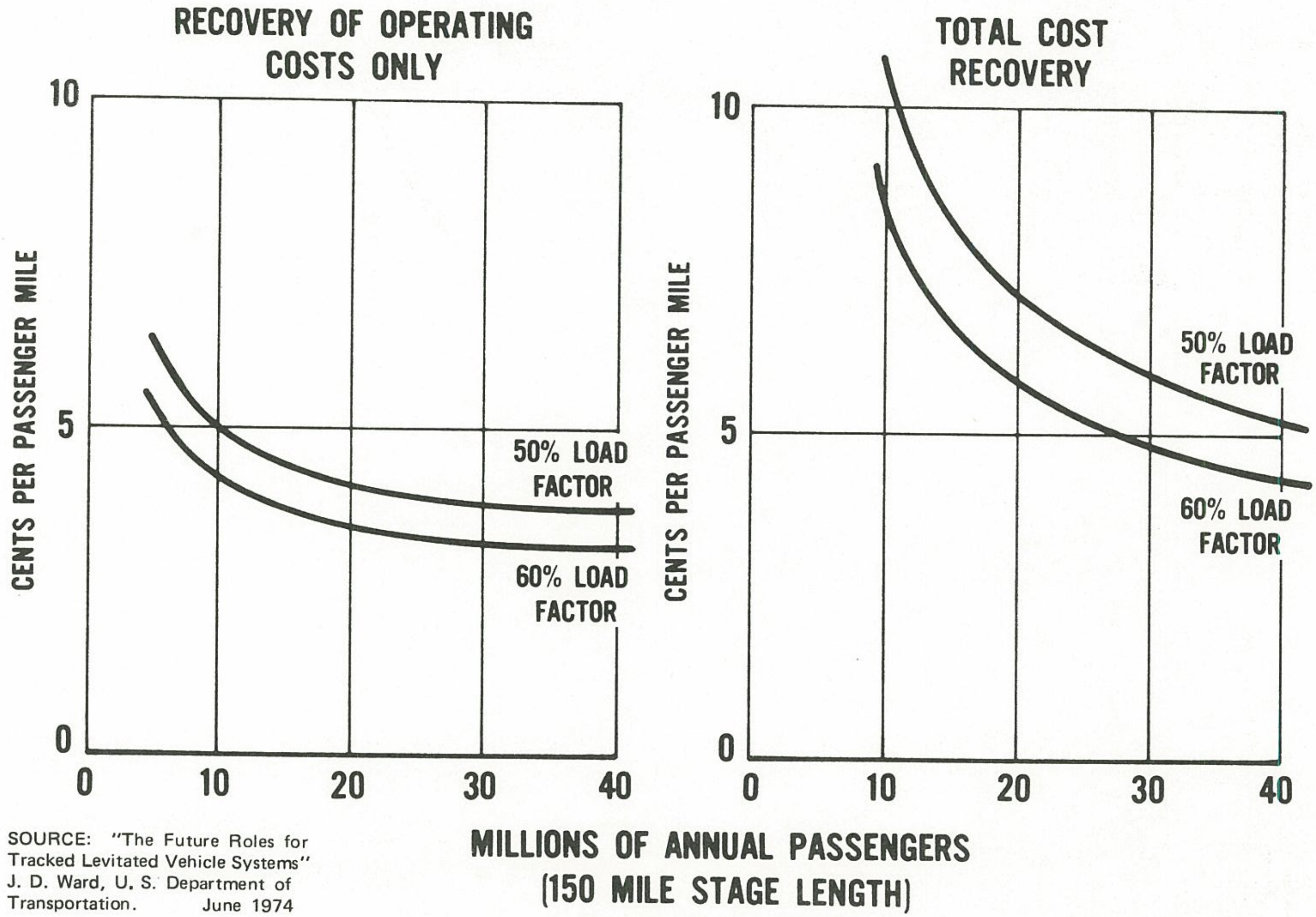
[1] "Section V - Revenue and Operating Costs: Urban Tracked Air Cushion Vehicle Transportation System for Dallas-Ft. Worth Airport Route", Alan M. Voorhees & Associates, Inc. January 1974.

[2] "A Preliminary Engineering Report on the Dallas/Fort Worth Regional UTACV System", Parsons, Brinckerhoff, Quade & Douglas, Inc., November 1973.

[3] "Los Angeles International Airport System: 60-Passenger Tracked Air Cushion Vehicles", ER: 903-RED-4010, Aerotrain Systems, Inc., a subsidiary, Rohr Corporation. March 1971.

[4] "High Speed Ground Transportation Airport Access Route Study", Kaiser Engineers for Los Angeles Department of Airports, June 1970.



SOURCE: "The Future Roles for Tracked Levitated Vehicle Systems" J. D. Ward, U. S. Department of Transportation. June 1974

Figure 1-1. Typical TACV Costs

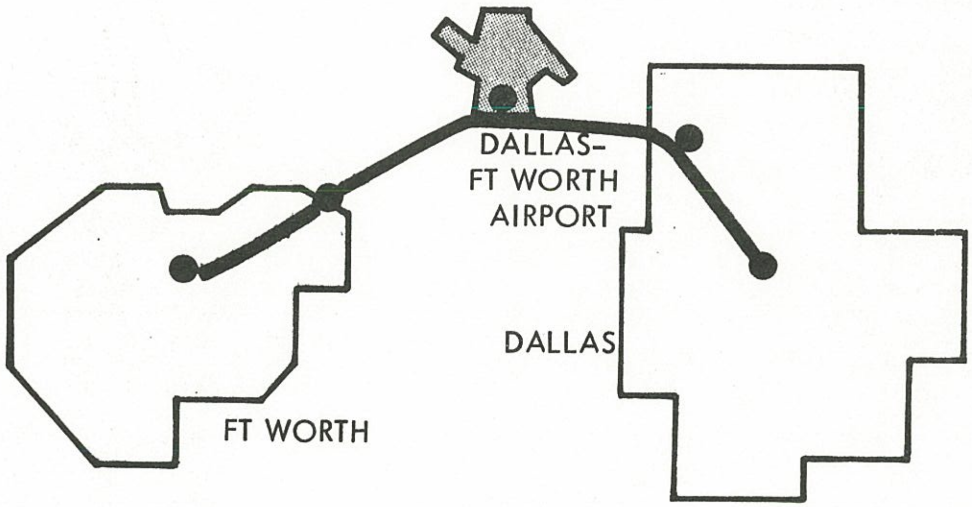


Figure 2-1. TACV Dallas—Fort Worth Corridor Line Haul

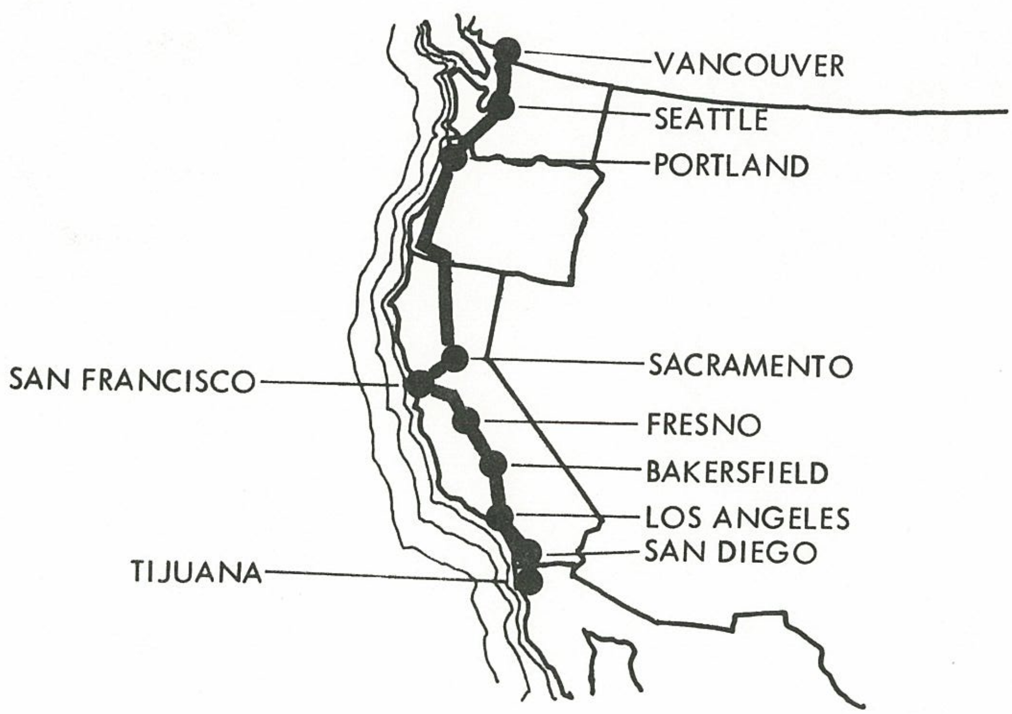


Figure 2-2. West Coast Corridor

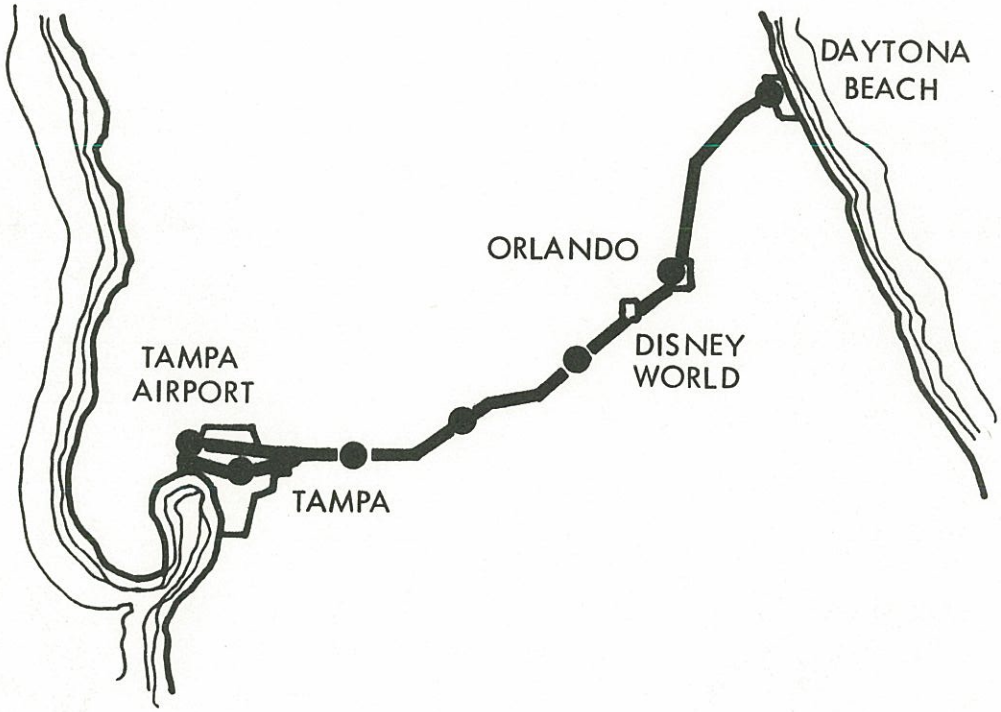


Figure 2-3. TACV High-Speed Corridor Line Haul – Central Florida

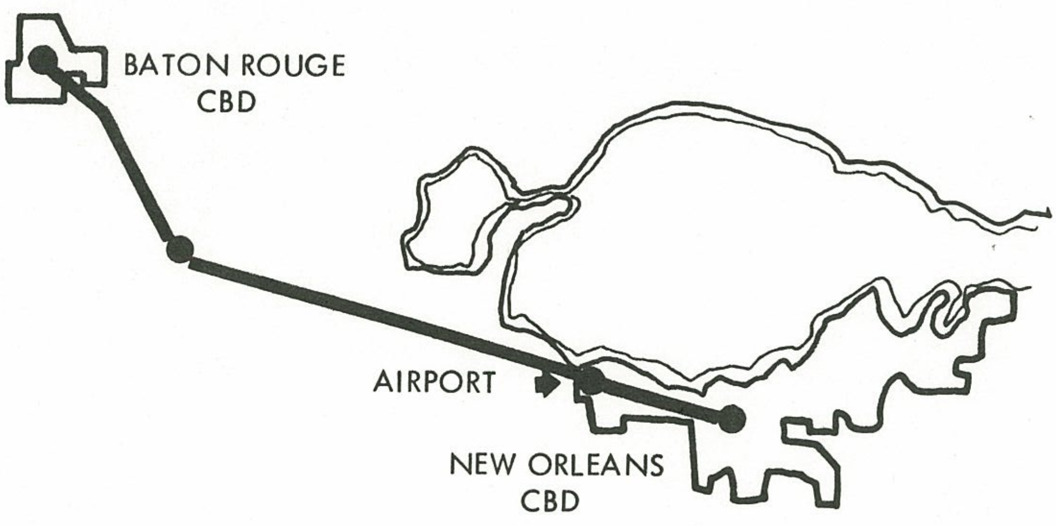


Figure 2-4. TACV High-Speed Corridor Line Haul – Louisiana

PTACV MARKETING SURVEY REPORT

AND

SYSTEM SUMMARY

PART III - TECHNICAL DESCRIPTION

PART III
TECHNICAL DESCRIPTION

1/ INTRODUCTION

This part contains a synopsized system description of the Prototype Tracked Air Cushion Vehicle (PTACV) as tested at the U.S. Department of Transportation's Transportation Test Center at Pueblo, Colorado (TTC-Pueblo). The descriptions summarize the construction, performance, and tests of the vehicle primarily. A more abbreviated description of the ancillary wayside and communications equipment is furnished so that the whole system can be readily visualized.

A short section at the end briefly describes pertinent improvements which should be made on the prototype system as tested which would make it more suitable for public use in revenue operation.

2/ SYSTEM DESCRIPTION

2.1 PTACV

2.1.1 VEHICLE DESCRIPTION -- This Section describes the vehicle now being demonstrated at TTC-Pueblo.

The primary subsystems shown are:

- Three-phase power distribution system
- Frangible safety forebody
- Automatic Train Control (ATC) console
- Auxiliary Train Equipment (ATC Rack)
- Passenger Compartment
- Linear Induction Motor (LIM)
- Propulsion Control Bay
- Mechanical Brake
- Frangible Safety Afterbody
- Auxiliary Support Skis
- Air Conditioning System
- Emergency Stop Bypass Doors
- Suspension Air Ducts
- Lift Air Cushions
- Guidance Air Cushions
- Air Compressor System

- Auxiliary Drive System
- Air Inlet System
- Guideway
- Reaction Rail

Subsystems not shown in Figure 2-1 are:

- Fire Detection/Suppression
- Auxiliary Drive Hydraulic System
- Emergency Batteries
- Battery Power Supplies
- 120 VAC Output Inverter
- Power Distribution Switchboard
- Auxiliary Power Transformer
- Power/Propulsion System Auxiliaries
- Communication Subsystem
- Brake Hydraulic System
- Variable Voltage Power Conditioning Unit (VVPCU)
- Power Collection Subsystem

The PTACV weighs 64,000 pounds is 95 feet overall, 10-1/2 feet wide, and 10-1/2 feet high. It is an all electric vehicle with a capacity of 60 passengers and their baggage. Because it is all electric, it is a non-polluting vehicle. Its primary power is 3-phase at 4160 volts brought on-board from the wayside power rails by a multi-brush collector.

The LIM and its Power Conditioning Unit utilizes power at 4160 volts as does the air compressor motors which power the air sustention and guidance systems. The hotel load of the vehicle is powered by the auxiliary transformer which reduces 3-phase, 4160 volts to 3-phase 208 volts and to single phase, 120 volt power, which is then controlled by circuit breakers in the power distribution unit prior to being applied to the various subsystems. Vital control, lighting, and ventilation systems are operated from battery power.

Much of the PTACV carbody is constructed with a honeycomb sandwich panel developed by Rohr. Figure 2-1 shows part of the structure using this material, which results in a very light, strong structure with a high degree of rigidity.

Extruded aluminum in special shapes is used for longeron members. These are manufactured to be compatible with the honeycomb panels to make an integrated structure.

2.1.1.1 The frangible safety forebody serves two functions. It houses much of the air intake system plus auxiliary drive system, and a major portion of the impact energy is absorbed by the deformation of the forebody in case of collision.

2.1.1.2 The crew compartment is located between the forebody and passenger compartment. The crew compartment contains the following subsystems:

- ATC
- Auxiliary Train Equipment
- Fire Detection Panel
- TV Receiver (closed circuit)
- Power Distrubition Switchboard
- Auxiliary Power Transformer
- Power/Propulsion System Auxiliaries (PPSA)

There is normally only one person required on board for manual operation of the vehicle and the crew compartment is the attendant's station. All equipment is laid out for easy observation and control from his ATC console position.

The ATC equipment is housed in the Train Attendant's Console and the ATC rack. The console contains the direction control, speed control, brake control, door control, and communications controls as well as all the indicators required to monitor safe operation of the vehicle. The rack contains the power supplies, a Hewlett-Packard 2100A computer, the vehicle interface control unit (which creates compatible signals between operating systems), the P/A amplifier and the radio transceiver.

The PPSA is a rack-mounted system of relays and logic to control the sequences of actions between the ATC, the variable voltage power conditioning unit, and power switchgear contained in the propulsion control bay. These are the controls required to safely apply power to the LIM, to control the jerk rate of current change to the LIM, to control direction of LIM thrust, and to differentiate between thrust/brake operation and direction selection.

The power distribution switchboard is used to control the hotel loads of the vehicle via the operation of circuit breakers addressed to the various subsystems.

The Auxiliary Power Transformer is used to change the primary voltage of 3-phase, 4160 volt power to the 120/208 volts for the hotel loads.

The fire detection panel contains lights, switches, and amplifiers. The lights indicate which major division of the vehicle has been detected to contain smoke or fire. The amplifiers make that detection. The switches are used to detonate squibs which act as values to release the fire suppressant gas to the location of the fire.

The TV receiver (and selector switch) permits the operator to monitor closed-circuit TV cameras located in the nose and tail compartments. This gives the operator vision of the guideway as the vehicle approaches the section under observation.

2.1.1.3 The 60 passenger (30 seat assemblies) passenger compartment is the midsection of the vehicle. There are two normal access doors plus an emergency exit door at each end.

The vehicle is air conditioned to maintain an interior temperature between 68 and 75^{o}F when the outside ambient ranges from -20 to +95^{o}F. The conditioned air enters the compartment through ports around the entire periphery of each window, providing high volume at low velocity at a low noise level.

All windows are tinted LEXAN panels which have a high impact resistance.

Seats are custom molded, padded, and equipped with aircraft type seatbelts. The assembly is bolted to the floor for maximum strength. Coordinated colors are used throughout the interior decor.

The interior materials are either fire suppressant or self-extinguishing to enhance the safety of the vehicle.

The normal access doors are 40-inch wide single plug doors. They are fitted with pressure sensing mechanisms to prevent door closure when the doors are not fully cleared by people or objects. When pressure is sensed, the doors recycle in 7 seconds to the fully open position and then reinitiate a closure operation. The doors are on the left side only.

2.1.1.4 The propulsion control bay is between the passenger compartment with the baggage compartment. It contains the isolation switching apparatus (ISA), the forward-reverse switching apparatus (FRSA), the VVPCU, and an autotransformer. The ISA is the main power switch on the vehicle. It connects, or isolates, rail power with the vehicle. The FRSA shifts two of the three-phase connections to the LIM to control the direction of thrust. The VVPCU controls the amount of thrust that the LIM generates.

2.1.1.5 The frangible safety afterbody houses the baggage compartment and supports for the hydraulic portion of the mechanical brake as well as the tail lights and rear view TV camera.

Its construction is similar to the forebody and is designed to absorb the major portion of the impact energy due to a crash by deforming in two directions, laterally as well as longitudinally.

2.1.1.6 The underbody is made up of three rectangular sections, each fabricated with the aluminum skinned honeycomb panels for light weight and high strength. The underbody is the key element in the carbody design forming the backbone of the structure. It has auxiliary functions including:

- Acts as centersill for the floor assembly
- Provides equipment compartments
- Supports the LIM
- Mounts the brake assembly subsystem
- Provides lift and guidance cushion foundations
- Contains air ducts and plenums
- Supports the air compressor and motors
- Mounts air inlet ducts
- Supports the fore- and afterbody units
- Provides cable wireways
- Mounts emergency stop skids and auxiliary drive supports.

The rectangular sections consist of a 6" thick floor with two large duct sections hanging below the floor and separated along the centerline to form a tunnel astride the reaction rail. The guidance cushions are anchored to the inner faces of this tunnel so that the cushion lips conform to the reaction rail surfaces. The bottom members of these duct sections support the lift cushions and skids. The outer wall of the ducts, the vehicle floor, and an extension of outer wall of the ducts, the vehicle floor, and an extension of the bottom members form the side equipment bays. Air conditioners, air blowers, the emergency stop bypass doors, batteries, power collector supports, and wireways are located in these bays.

In the forward part of this structure, the outer box is eliminated to make room for the air compressors (single stage axial fans) and the air stream transition sections which direct air flows to the forward lift cushions, center and aft lift cushions, and the guidance cushions.

In the aft section, the tunnel is widened to allow room for the LIM and mechanical brake assemblies to follow horizontal curves of the guideway reaction rail.

Five lift cushions on each side are anchored to the bottom of the ducts so that the cushions face the guideway surface and the lips are free to follow deviations of the guideway surface.

Figure 2-2 shows the PTACV in fabrication using honeycomb paneling for the floor, air plenum assembly, bulkheads, and roof. Figures 2-3 through 2-45 are a series of photographs showing steps of fabrication, equipment mounting and location, and preliminary test setups as defined in the listing below.

Figure 2-3	Vehicle Side Paneling and Stiffeners in Place
Figure 2-4	Air Compressor Installed Below Forward Bulkhead
Figure 2-5	Frangible Forebody being Installed over Air Ducts
Figure 2-6	Forebody being Placed in Final Position
Figure 2-7	Ancillary Equipment and Left Side Cushion
Figure 2-8	500-foot Test Guideway, Chula Vista, California
Figure 2-9	Transporting PTACV to Test Guideway
Figure 2-10	Placing PTACV on Inspection Jacks
Figure 2-11	Right Side Sustension Cushions Underneath Vehicle
Figure 2-12	Close-up of Guidance Cushion Assembly
Figure 2-13	Linear Induction MOtor (LIM) Ready for Installation in Aft End
Figure 2-14	LIM in Place Showing Windings Without Protective Covers
Figure 2-15	LIM Completely Installed with Mechanical Brake in Foreground
Figure 2-16	Mechanical Brake Assembly
Figure 2-17	LIM Support Tunnel and Anchor Brackets
Figure 2-18	Close-up View of Support Tunnel and Bracket
Figure 2-19	PTACV Lowered onto Test Guideway
Figure 2-20	PTACV Astraddle Guidebeam on Test Guideway
Figure 2-21	Power Collection Assembly, PTACV
Figure 2-22	Power Collector Ready for Insertion into Wayside Power Rail Assembly
Figure 2-23	PTACV Without Left Side Skirts Being Instrumented for Tests at Chula Vista
Figure 2-24	PTACV in Test Jig with Lifting Bracket
Figure 2-25	Blower Installation
Figure 2-26	Blower with Service Cover Removed
Figure 2-27	Air Conditioning Unit Closed
Figure 2-28	Air Conditioning Unit with Service Cover Removed
Figure 2-29	Main DC Power Supply

2.1.2 PERFORMANCE -- Table 2-1 shows significant vehicle performance parameters. The design objectives, demonstrated PTACV performance values, and the projected revenue vehicle performance are shown in this table for each parameter.

The graphs shown in Figure 2-42 were compiled from actual test data on the PTACV and prepared by ENSCO, Inc., an independent contractor, to compare ride comfort accelerations measured in several types of transportation.

2.1.3 OPERATIONS DESCRIPTION

2.1.3.1 Normal Operation -- The ATC equipment is designed to permit safe operation of the vehicle up to 150 MPH in the forward direction in either the manual or automatic mode of operation. Speed constraints for safety imposed by guideway curves and station stop profiles. Geo-reference

TABLE 2-1

VEHICLE PERFORMANCE

	Performance Objective	PTAV Performance	Projected Revenue Vehicle Performance
1. Speed	150 MPH	142 MPH	150 MPH
2. Acceleration			
a. Distance to cruise speed. 0-15 MPH on 1-1/4% grade with no wind.	1.75 mi	1.75 mi	1.5 mi
b. Maximum acceleration	.15 g	.14 g	.15 g
3. Deceleration			
a. Emergency stopping distance from 150 MPH on 1% down-grade with 30 MPH tail wind.	.5 mi	.5 mi	.5 mi
b. Device braking	.15 g max.	.15 g max.	.15 g max.
c. Emergency stop	.4 g max.	.3 g max.	.4 g max.
4. Ride Quality			
a. Sustained acceleration			
• Longitudinal	.15 g max.	.14 g max.	.15 g max.
• Lateral	.08 g max.	.08 g max.	.08 g max.
• Vertical	.10 g max.	.10 g max.	.10 g max.
b. Jerk			
• Longitudinal	.03 g/sec.	.03 g/sec.	.03 g/sec.
• Lateral	.03 g/sec.	.03 g/sec.	.03 g/sec.
• Vertical	.04 g/sec.	.03 g/sec.	.03 g/sec.
c. Maximum Acceleration Standard deviation 95 percentile lead			
• Vertical	.05 g @ 120 MPH	.042 g @ 100 MPH	.09 g @ 150 MPH
• Lateral	.05 g @ 120 MPH	.045 g @ 100 MPH	.08 g @ 150 MPH
d. Spectral composition of acceleration (See Figure 2-46 and 2-47).			

Table 2-1 (Cont.)

	Performance Objective	PTAV Performance	Projected Revenue Vehicle Performance
5. Cabin Temerpature for Ambient Air < $90^{o}F$	$72 - 77^{o}$	$72 - 77^{o}$	$72 - 77^{o}$
6. Passenger Compartment Noise Level	65 dB(A)	82 dB(A)	76 dB(A)
7. Crew Compartment Noise Level	75 dB(A)	88 dB(A)	82 dB(A)
8. External Noise Level			
a. Stationary			
1) 50 ft. ahead of vehicle	63 dB(A)	83 dB(A)	77 dB(A)
2) 50 ft from centerline on side	63 dB(A)	84 dB(A)	78 dB(A)
b. Moving noise level			
1) 50 ft. from centerline on side	73 dB(A)	95 dB(A)	85 dB(A)
9. EMI	Not to interfere with communications	No significant interference	No interference
10. Energy Utilization			
a. Propulsion efficiency at cruise speed	Not specified	50%	77%
b. Energy requirements BTU/passenger mile @ 50% load factor 100 MPH average speed over 25 mile route	Not specified	4400 BTU passenger mile	2200 BTU passenger mile
c. Sustention power	567KW	560 KW	400 KW

points are detected by on-board vehicle sensors once every second when travelling at a nominal safe speed. The train control system utilized these reference points to establish safe speed limits. Any overspeed greater than 120% of nominal speed will cause an emergency stop signal to be activated.

The ATC has route operation stored in memory so that all arrivals, dwell times, and departures are automatic. The ATC can recover schedule deviations within the safety constraints by changing the vehicle performance levels within the range of -50% to +110% of nominal and by adjusting dwell times at stations.

The vehicle is designed to reach 150 MPH in the forward direction in either the automatic or manual mode of operation. There is no automatic reverse operation. From a safety viewpoint, a maximum reverse speed is controlled to 35 MPH. From purely a propulsion viewpoint, the vehicle could reach 150 MPH in reverse; however, visibility limitations, air inlet design, and cushion configuration are all factors in keeping the reverse speed to 35 MPH.

2.1.3.1.1 Automatic Mode -- In the automatic mode, the attendant selects forward direction, initiates start, and all other operations are then sequenced automatically.

After the assigned dwell time for the station has been expended, a "door close" chime is sounded. Ten seconds later, the doors are commanded to close.

When the ATC senses that both doors are closed, the auxiliary drive wheels are extended to contact the guideway. Once firm contact is obtained, the auxiliary drive is commanded to move the vehicle to 5 MPH at an acceleration of 2.8 feet per second per second. At 5 MPH a signal is generated to cause LIM energization reaction of auxiliary drive wheels, and removal of auxiliary drive power. The LIM is the sole source of thrust at all speeds above 5 MPH. The auxiliary drive can only be initiated when the vehicle is at "zero speed."

Braking effort of the LIM is limited to speeds above 20 MPH. At 20 MPH and below, the mechanical brake is used since it has better response and more accurate control at low speed.

The speed of the PTACV is calculated from two sources: (1) on-board instrumentation determining the rate that the vehicle is traversing the reaction rail, and (2) measuring the deviation from a precise one-second interval of the passage of the vehicle from one passive position indicator (PPI) to the next PPI. The PPI's are permanent magnets imbedded just below the guideway surface so that a PTACV travelling at a nominal safe speed will pass one PPI each second. For safety, the two velocity calculations are made each second and the higher value is used as a reference for speed control. Thus, a signal is generated which calls for (1) a continuation of the same thrust level to maintain velocity, or (2) an increase of thrust level ot increase speed, or (3) a reduction in thrust level to reduce speed slowly, or (4) an application of braking effort to reduce speed quickly.

At intervals (not necessarily equal) geographic reference points are sensed by the ATC. These geo-references are two closely-spaced PPI's which are normally passed by the PTACV at a 1/10 second interval. This permits the ATC to update its position determination and cross-check the position with stored data.

Three closely spaced PPI's are used as station stop berthing indicators. This permits a closely controlled station stop using a programmed mechanical brake application triggered after the vehicle passes the three PPI groups at a 2 MPH velocity. Stop indexing is accurate to within ± 1 foot of the programmed start.

After station stop ("zero speed") is achieved, the doors open automatically and the dwell time programmed for that station is initiated. This completes a full cycle of operation from one station to the next.

All of these functions (except automatic high speed velocity control) have been demonstrated at TTC-Pueblo.

2.1.3.1.2 Manual Mode - The same sequence of events must take place in this mode as those described in 2.1.3.1.1, with the exception that auxiliary drive wheel retraction, end dwell, and berth stop signals are manually generated.

Forward or reverse direction is selected by pushbutton. The pushbutton is lighted when the function is accomplished. The direction selection activates both auxiliary drive and LIM drive logic for forward thrust effort and LIM drive alone for braking effort.

When the end dwell indicator light goes out, the attendant pushes the "doors close" pushbutton. When the "doors open" light goes out and the "doors close" light is lit, the attendant can initiate vehicle motion.

To do this, the attendant must rotate the thrust/brake controller handle 90^o from its spring-loaded position. This deactivates the "deadman switch" and permits manual control to proceed. This 90^o position must be maintained or the vehicle will come to an emergency stop.

Having maintained the 90^o rotation of the controller handle, the attendant moves it forward in a slot. This activates the auxiliary drive and the vehicle is propelled forward to 5 MPH at the prescribed acceleration. When 5 MPH is reached, the auxiliary drive is deactivated and the LIM drive is energized.

Full forward position of the controller handle causes full thrust power to be applied to the LIM. As the controller handle is brought toward its central position, less thrust is commanded to the LIM. At the controller's center position, a "coast" mode is achieved with no brakes or thrust commanded. As the controller is brought toward the attendant, increasing braking effort is commanded until, at the rearmost position, peak braking effort is commanded.

In this manner, the vehicle's velocity is controlled by the attendant. An "overspeed" (120% nominal speed) is still detectable by the ATC and, should it occur, such detection will result in an emergency stop.

For a station stop, the attendant reduces speed to 2 MPH. The reception of the 3 PPI group signal will result in an automatic brake stop at the station.

In addition to vehicle motion control, the attendant controls:

- Communications via P/A system
- Communications via transceiver
- Phase monitoring of LIM voltage and current
- Sustention vent closure
- "Creep" mode (2 MPH by auxiliary drive)
- Manually initiated "emergency stop"
- Radio volume
- Radio squelch
- P/A volume
- TV camera selection (front or rear)
- TV monitor controls
- Fire suppression system

2.1.3.2 Degraded Operation -- There are two levels of degraded operation. The first level (detected by the ATC) permits continued automatic operation in the event that one or two on-board tachometers is lost. All other control malfunctions result in second level detection and cause either a "line stop" (normal braking) or an emergency stop. In either of these events, the attendant must evaluate the type of malfunction and determine whether it is safe to proceed under manual control or to radio for assistance.

Malfunctions which can result in the vehicle proceeding after fault detection are:

- Recovery from "LIM Overtemperature"

- Recovery from an unscheduled vehicle grounding
- Recovery from an unscheduled "doors open" condition
- Recovery from an "overspeed" condition
- Recovery from a "sustention motor overtemperature" condition
- Recovery from a "sustention air flow no-go" condition
- Recovery from a "LIM no-go" condition
- Recovery from a "computer no-go" condition
- Recovery from a "brake system no-go" condition
- Recovery from a "primary power no-go" condition

2.1.3.3 Safety Aspects -- Personnel safety is the prime criterion used in the vehicle design. Equipment survival is secondary.

Basic vehicle design requires the use of self-extinguishing or fire resistant materials wherever possible.

Windows are strong enough to survive the impact of a baseball hitting normal to the pane at 75 MPH.

A fire protection system uses manual extinguishers in the attendant's and passenger cabins. Remotely activated suppression devices are located in unattended enclosed areas containing electrical equipment.

Emergency evacuation doors and pathways are designed so that the vehicle can be emptied of people in less than 90 seconds from a stopped vehicle.

All electrical equipment is of a "dead front" design.

Protective devices such as fuses, circuit breakers, isolation transformers, thermal relays, interlocking breakers, self-discharging capacitor circuits, a common point grounding bus, and positive vehicle grounding at "zero speed" are a point of the design. Equipment status is monitored at a central point.

An energy absorbing frangible forebody and afterbody unit is integrated into the vehicle to reduce crash impact damage.

Passenger safety in normal operations includes the following facilities:

- Safe ingress and egress through wide doors. Doors recycle when they detect an obstacle during their closing cycle.
- All passengers are seated in deep seats which have seat belts integral to the seat structure.
- The vehicle is grounded to the reaction rail before passenger doors can open (preventing electrical shock due to either electrostatic generation or electrical leakage).
- Make-up air is temperature controlled.
- Prevention of vehicle starts until all doors are interlocked "closed" and proper direction has been selected.
- Continuous communications to a central controller is available and periodically monitored.

Passenger safety in emergency operations is assumed by:

- ATC causing an emergency stop due to any of the following conditions:
  - -- No-go status of any of seven equipments centrally monitored.
  - -- Emergency stop requested by the computer or radio monitor or manually from the attendant's console.
  - -- Doors open while running.
  - -- Wheels not retracted when speed is over 20 MPH.
  - -- Vehicle grounded while running.
  - -- Sustention vent not closed.
  - -- Speed control circuit open.
  - -- Direction status no-go.
  - -- Berth index point overrun.
  - -- Zero speed 20 seconds after automatic start.
  - -- Speed less than 7 MPH 60 seconds after automatic start.
- Vehicle grounded during emergency stop.
- Emergency exit paths and doors available to passengers at emergency stop.

- Vital circuits become battery-powered when rail power is lost.
- Radio communication to central control point maintained by battery power.
- Passengers kept fully informed as to status and emergency procedures by battery-powered P/A system.

The guideway is susceptible to damage from external sources and is a hazard itself to personnel, animals, or equipment nearby. Therefore, the guideway and right-of-way must be fenced, except when safely elevated, to provide protection from encroachment by any outside vehicle, person, animal, or windblown debris. Protection from falling or thrown objects is necessary at overpasses, tunnels, or other crossings where such danger exists.

A protective cover is provided over the power rail assembly to further provide safety and protection.

"Danger--High Voltage" warning signs are placed every 500 feet in an optimum visibility position on the protective cover.

2.2 GUIDEWAY AND RIGHT-OF-WAY DESCRIPTION

The guideway is comprised of:

- Supportive real estate
- Foundation
- Piers (if used)
- Beams (if used)
- Running surface
- Reaction rail
- Reaction rail anchors
- Power rails
- Grounding system
- Primary power secondary distribution system
- Power rail supports

- Power rail covers
- Power rail expansion joints

The guideway running surface must be relatively smooth. Either concrete or asphalt can be prepared as running surfaces and both have been used at TTC-Pueblo. Standard highway construction practices produce a satisfactory guideway structure.

Figure 2-43 shows the PTACV guideway under construction at TTC-Pueblo. Note that sections of the inverted "T" reaction rail have been placed in the approximate positions, ready to be welded together. Also note the uncapped studs used for anchoring the reaction rail. An asphalt running surface is yet to be applied to the concrete base.

Figure 2-44 shows the PTACV running on the finished guideway at Pueblo. The 3-phase, 4160 volt power rails and insulator supports are visible under the open mesh safety cover. Note that there is a 6-inch gap between the ground and lower portion of the mesh cover. This gap allows small animals and small pieces of debris to pass under the structure so it doesn't collect on the guideway.

2.2.1 REACTION RAIL -- Sections of the 33 inch high aluminum reaction rail can be seen in Figure 2-45. The guidance cushions utilize about 90% of the vertical surface as a reaction plane. The LIM passes over the upper 2/3 of the rail in using the rail as the propulsion secondary element.

The raction rail is an aluminum extrusion in lengths of approximately 90 feet. Its cross section design combines structural strength (for maximum reactive loads) with electrical characteristics needed for thrust requirements.

2.2.2 POWER RAILS -- Figure 2-22 shows the three power rails mounted in their insulated support brackets. The right side of the PTACV faces the open section of the support. The power collector assembly and its support are operated through the opening of the support.

The power rail itself is a deformed I-beam of aluminum and has a "W" - shaped cap over which the power collector brushes pass. The "W" cap is stainless steel to reduce brush wear.

Special expansion joints are required for the power rails. It is a multi-finger slip joint so designed that the brushes never leave the retaining confines of the three-rail "delta" nor do they lose current carrying capability while passing over the expansion joint.

The power rails are supplied with power from substations. The input to the substations can be any voltage but its value is probably set by the utility company's distribution voltage. Within the station is a transformer, a lightning discharge system, busbars, grounding system, and monitoring units, protective devices, and supervisory control equipment.

2.2.3 RIGHT-OF-WAY REQUIREMENTS

2.2.3.1 General -- The general arrangement of an operating guideway was illustrated in Figure 2-44. It is to be noted that there is only one element of the guideway system that needs to be installed with precision, and that element is the reaction rail.

Concrete running surface can be constructed using good highway practices, using asphalt or portland cement concrete. Thus, there are no special costs in subbase or running surface construction at grade levels.

Overpasses or underpasses must be used on PTACV guideways since unguided gaps in the power or raction rails cannot be tolerated for grade crossings.

The guideway may be constructed at grade (least cost), elevated (middle cost), or below ground (greatest cost). In the case of elevated guideway, double "T" or box beams of spans from 50 to 100 feet can be used. These spans, together with single column supports, can combine safety with pleasing appearance. Where the elevated structure is used, the right-of-way can be landscaped to improve appearance and use. In below ground construciton, the cross section must be large enough to provide free travel of the TACV without hindrance from air compression due to fast-moving vehicles in a confined space.

2.2.3.2 <u>At grade Right-of-Way</u> -- The right-of-way must have good security fences at its lateral boundaries. These boundaries must be wide enough to prevent tossing of objects onto the guideway. The fences should be equipped with "No Trespassing" and "Danger--High Voltage" signs. The security fence should not only be able to keep animals and people from access to the right-of-way, but also to keep objects from being thrown onto the right-of-way. It should be designed to permit passage of small windblown debris.

2.2.3.3 <u>Elevated Right-of-Way</u> -- Security fences would not be required provided the structure is high enough to prevent easy access.

2.2.4 SWITCH FACILITIES -- There are two candidate types of switching for a TACV system, i.e., (1) rotating beam and (2) transfer table.

The rotating beam type utilizes a very large and long box structure which has the facilities (track, reaction rail, power rails, etc.) needed for a straight through path on one side of the box and equivalent facilities for a turnout route are on another side of the structure.

The transfer table has both route facilities on a single surface. It requires more operating space than does the rotating beam.

Figure 2-48 is a sketch showing the transfer table concept proposed for the PTACV guideway at TTC-Pueblo.

The switch shown has a turnout radius of 1500 feet and no superrelevation. That combination will restict operating speed through the turnout to 50 MPH.

The design requires 65 seconds for a full operating cycle. This cycle is tied into automatic train control (ATC) so that the switch cannot be operated unless the vehicle is more than 100 seconds away, or a safe stopping distance from the switch.

For safety, the reaction rail is aligned and locked into position, the power rails aligned and locked into proper position, and the power circuit breakers closed before the ATC will permit the vehicle to traverse the switch area.

The cycle of operation is as follows:

- ATC gets a route change request.
- ATC determines that a route change can be effected safely.
- The reaction rail alignment locking pins are retracted.
- The power rail circuit breakers are tripped open.
- The power rail alignment locking pins are retracted.
- The power rail hinged sections are opened to prevent arcing.
- Transfer motors are energized and the table moves to its opposite position.

- The power rail hinged sections are returned to normal.
- The power rail alignment locking pins are locked.
- The power rail circuit breakers are closed.
- The reaction rail alignment locking pins are locked.
- ATC checks to determine that above steps are properly completed.

o ATC generates signal to permit traversing the switch.

All mainline switches must be interlocked with the ATC to guarantee fail-safe system operation.

All route feeder sections must likewise be interlocked with the ATC to support a fail-safe system operation.

2.3 OTHER SYSTEM ELEMENTS

2.3.1 COMMAND AND CONTROL -- Command and control systems are comprised of those elements which, when operating properly and in unison, form an ATC system. The system used at Pueblo is a vehicle centered, computer-controlled ATC. That ATC is designed for a single vehicle route PTACV system. A multi-vehicle, multi-route TACV would have exactly the same vehicle-borne equipment as the PTACV plus an additional communication system.

The multi-vehicle, multi-route ATC system requires a "System Central" where a computer monitors all vehicles' status and schedules. If all vehicles were operating normally, system central would issue route interlocking commands and make all safety checks. If there was an aberration in the performance of one or more vehicles, the system central would issue speed and schedules changes to permit safe operation of the system. Safety is a criterion overriding schedule. This is an element of "Line Supervision" that is never permitted to be executed by on-board ATC equipment.

The additional communication system previously indicated, is recommended to be a "wiggly-wire" inductive loop application in which a continuous string of identical loops are buried in the upper surface of the guideway. An on-board antenna permits reception of data from inductive loops and transmission of data to the loops. By counting the number of loops detected from a known point, a redundant system of vehicle location is thus available. This "wiggly-wire" system has been quite successfully used by the German Federal Railways in the Hamburg district.

The ATC system proposed by Rohr is a modular arrangement using the tested and proven PTACV ATC as a base. The other elements have also been proven in actual system applications. By providing certain redundant circuits, a single failure will not cause system stoppage.

A radio in the PTACV permits voice communication between the vehicle and any control station within the system.

2.3.2 STATIONS -- There was no requirement for a passenger station at TTC-Pueblo. Design concepts are contained in Urban Tracked Air Cushion Program, Phase I, Report 1.17, "Baggage and Passenger Handling Facility."

Figures 2-49 Downtown Terminal and 2-50 Waystation are taken from that report, and they represent central stations designed to handle 3,000,000 and 1,750,000 passengers annually. The Downtown Terminal has ground, mall, mezzanine, and boarding levels.

The ground level has:

- Engrance lobby
- Exit lobby
- Ticketing and check-in facilities
- Baggage handling facilities
- Baggage claim area

- Coffee shop
- Telephones
- Restaurants
- Office areas
- Operations equipment areas
- Employees' lunch room
- Employees' locker room
- Maintenance shop

The mall level is an open area leading to external shops and to concessions. It provides an additional waiting area of scenic enchancement.

The mezzanine level is not accessible to passengers but is where baggage is sorted and containerized for delivery. It is also the area where debarking passengers' baggage is taken from containers and dispatched to the baggage claim area.

The boarding area is the waiting room for embarking passengers and the receiving area for debarking passengers. It contains baggage facilities for loading and unloading the TACV.

2.3.3 MAINTENANCE -- System maintenance is of two major types:

- Routine
- Emergency

Routine maintenance of the vehicles is carried out at a shop which should have:

- An inside hoist to lift the vehicle for undercar inspection and repair.
- Inside work areas where the vehicle can be examined and repaired after the power rails have been de-energized.

- An umbilical power cord system to permit powering all but propulsion equipment.
- Forklifts, cranes, or similar machines to handle vehicle equipment.
- A special LIM handling dolly for holding, lifting, or positioning a LIM.
- A hydraulic test bench.
- Normal shop equipment such as a lathe, drillpress, portable drills, etc.

Routine maintenance of the guideway consists of:

- Inspection to check for reaction rail alignment, hold-down, and physical condition.
- Power rail inspection for alignment, insulator conditions, insulator washdown requirements, expansion joint condition, guard cover conditions, etc.
- Security fence condition.
- Guideway running surface condition.
- Power feed condition.
- Power line condition.
- Signal line condition.
- Wayside control sytem status.

Emergency maintenance criteria are applied to both the vehicle and the guideway. The immediate problem is how to move a stalled vehicle to a point where the system can regain normal operation. The solution is totally site dependent and involves:

- Sidings to which a disabled vehicle can be moved.
- Equipment to move a disabled vehicle.
- A method of handling or evacuating passengers.

The number of sidings is purely a guideway design function. Such sidings could exist at stations and at intervals between stations.

The moving of a disabled depends on the design of a rescue vehicle and the TACV involved. The rescue vehicle may be able to utilize a compressor to permit usage of the TACV's lift and guidance cushions or use multi-wheeled dollies to slip under the emergency skids of the TACV or to power the TACV's own compressors by "short power" umbilical in which event the disabled TACV would be electrically isolated from the secondary power distribution system.

The rescue vehicle would serve as either a pusher or tractor to move the TACV.

3/ TACV POTENTIAL IMPROVEMENTS

3.1 GENERAL

Two major benefits were derived from the successful testing of the PTACV at Pueblo. The first is the demonstrable hardware system that carries 60 passengers at speeds approaching 150 MPH. The second is how to incorporate improvement features directly applicable to high density, short headway TACV systems. This section is allocated to those improvement features.

3.2 FEATURE DESCRIPTIONS

3.2.1 BIDIRECTIONAL CAPABILITY -- There are combinations of real estate requirements (high cost land at CBD terminals) and traffic density (short headways) that put the PTACV in a non-optimum position.

The recognition of the above conditions together with vehicle improvement studies (Urban Tracked Air Cushion Program--Phase II--System Engineering Design Studies -- Report 2.15; Tracked Air Cushion Vehicle Program -- Reduced Power Consumption; and Tracked Air Cushion Vehicle Program -- Suspension Energy Reduction Study) resulted in the concept of a bidirectional vehicle depicted in Figures 5-1 and 5-2. This vehicle utilizes the same guideway as PTACV but incorporates several changes.

Examination of Figure 5-1 shows a basic vehicle with train attendant's cabs on both ends of the vehicle. This feature provides low-drag streamlining and houses automatic train control (ATC) equipment in addition to providing attendant facilities for manual control of the vehicle should such operation be desired. Externally, the cabs support radio antenna, headlights, tail lights, warning lights, clearance lights, and attendant viewing windows.

Shown at the center of the roof are four air intakes, only two of which are used at any one time. The two that are used face the direction in which the vehicle is travelling. This permits optimum air ingestion with up to 50% recovery of the available ram air effects.

3.2.2 ENTRAINMENT -- Figure 5-2 depicts two bidirectional vehicles (one cab each) coupled back-to-back. An inflated constant contour diaphragm is used between vehicles to maintain the streamlining of the vehicles. Two couplers are used, one on each side of the reaction rail. The couplers are cross-connected hydraulically to maintain a constant separation distance at the centerline, regardless of the degree of curvature encountered. The couplers include electric trainlining facilities as well as mechanical acceptance of limited twist from car-to-car.

The dark areas of Figure 5-2 are considered machinery areas (attendant's cab included) while light areas are passenger cabins. As can be seen in Figure 5-2 the basic passenger vehicle has the air intakes, intake valves, air compressors, the LIM, the power conditioning system, and the power collection system located symmetrically about the vehicle center rather than towards the ends. The unit body has no "end" configurations or facilities other than couplers, passageways, diaphragms, and attachment facilities for the attendant's cabs. There are two passenger doors on each side.

The vehicle has aisleways so passengers can walk the entire train length. The central machinery compartment in each vehicle has the same aisle width as the passenger compartment. Each passenger compartment has doors at both ends to reduce noise and air leakage.

3.2.3 AIR SYSTEM DIFFERENCES -- Figure 5-2 illustrates the configuration of the air intake ducts and the unique "swinging" valve used to control the incoming air flow. The use of four small air compressors with integral motors instead of two large compressors is also shown.

The Suspension Energy Reduction Study was a computer evaluation of a different air cushion system. In the PTACV, the lift and guidance air cushions were separate entities fed from a common plenum, which also fed the LIM cooling air ducts.

The new concept makes use of a newly designed lift cushion which also contains the guidance cushion. The air is fed to the guidance cushions and then, in series, to the lift cushions. The new design eliminates a discharge of guidance cushion air to the outside and reduces the lift cushion discharge periphery by about 40%. Thus, the total air flow required to operate the vehicle is less than 50% of that needed by the PTACV. Some development work is required, but preliminary analysis is extremely encouraging.

3.2.4 PROPULSION SYSTEM DIFFERENCES -- The PTACV uses a constant frequency (60 cycle) variable voltage propulsion system. The use of this variable voltage, variable frequency propulsion system increases LIM efficiency and reduces total propulsion system weight. These changes result from units developed for the Rohr Industries ROMAG personal transit system. The propulsion system for TACV can use ROMAG variable frequency, variable voltage units as building blocks to a total propulsion control system. The ROMAG units were demonstrated in 1974 and are well into the proofing cycle with several incorporated improvements.

Thus, the weight reduction and increased LIM efficiency are dual benefits. A smaller LIM can now perform equally well as the heavier PTACV LIM.

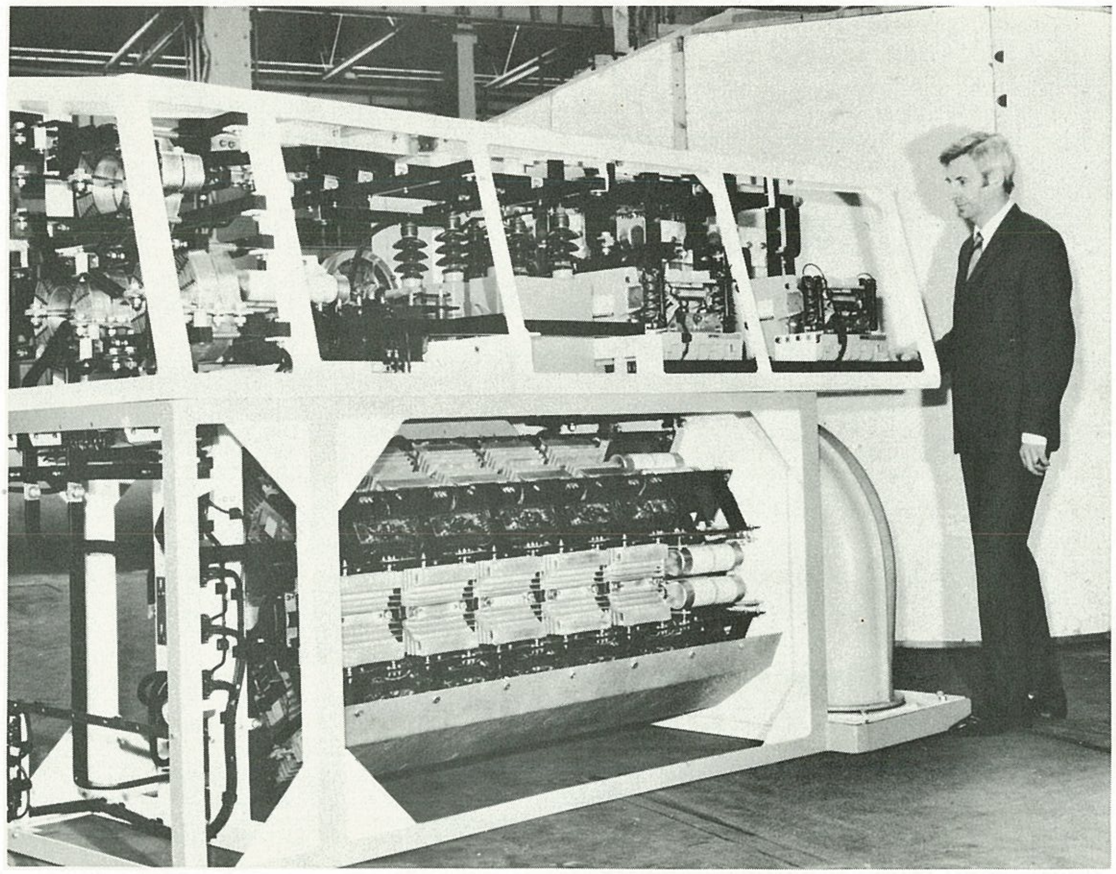
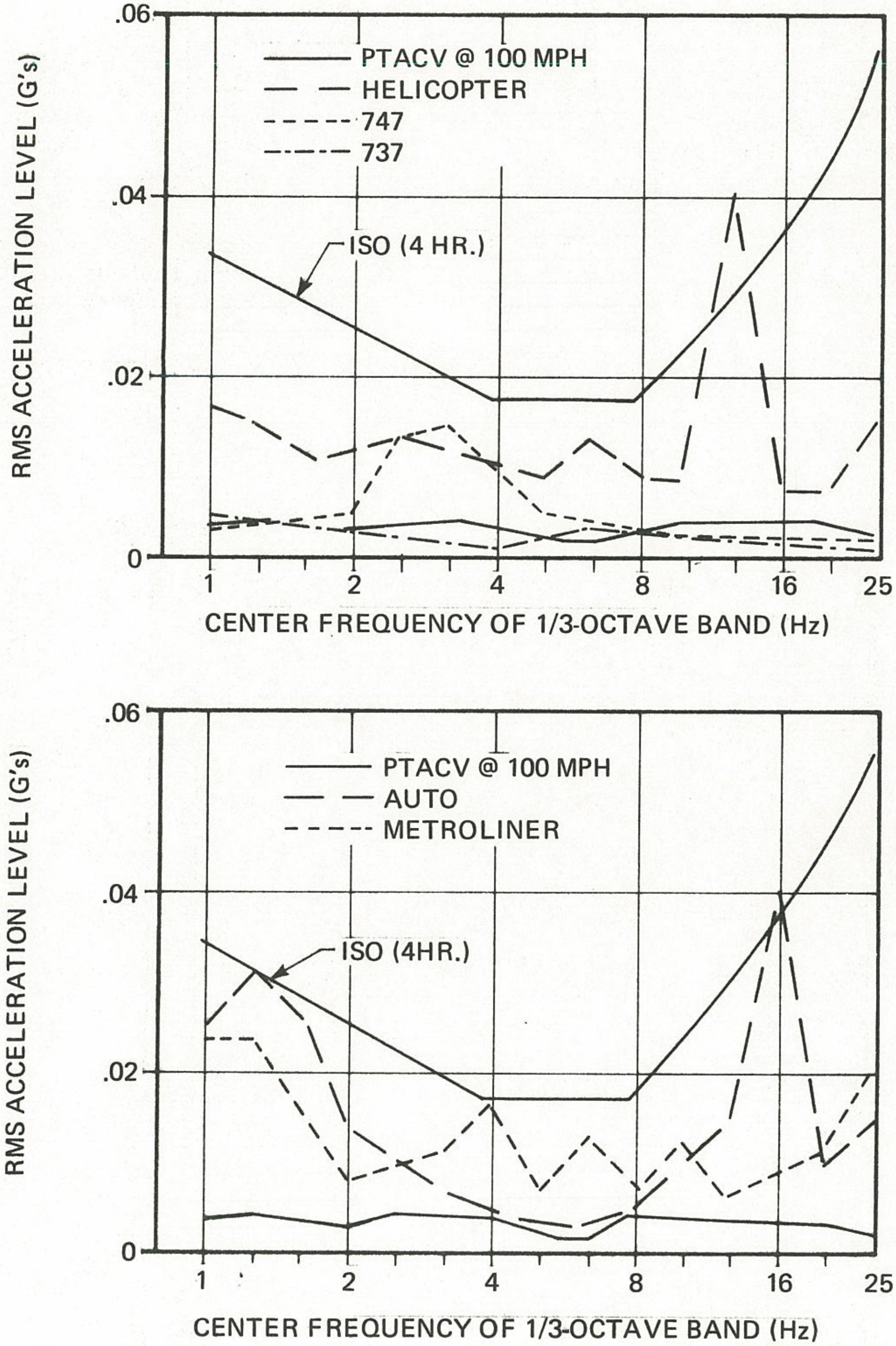


Figure 2-41. Variable-Voltage Power Conditioning Unit



* Data taken from Stephens, David, "Review of Measured Vibration and Noise Environments Experienced by Passengers in Aircraft and in Ground Transportation Systems," NASA Langley Research Center, 1975 Ride Quality Symposium.

*Figure 2-42. Vertical Response, PTACV Vs. Land and Air Vehicles**

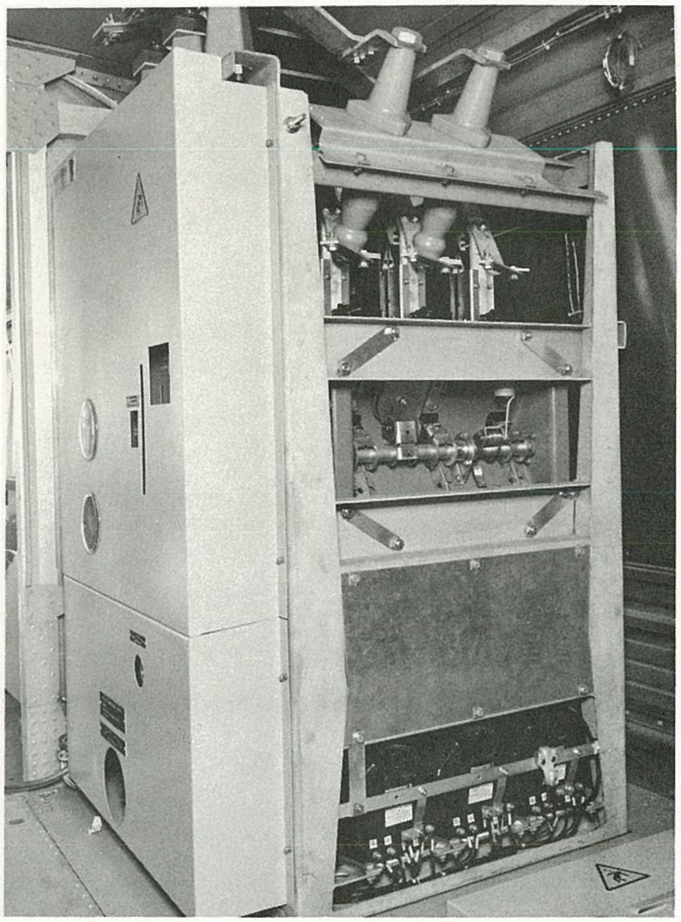


Figure 2-39. Main Power Isolation Switching

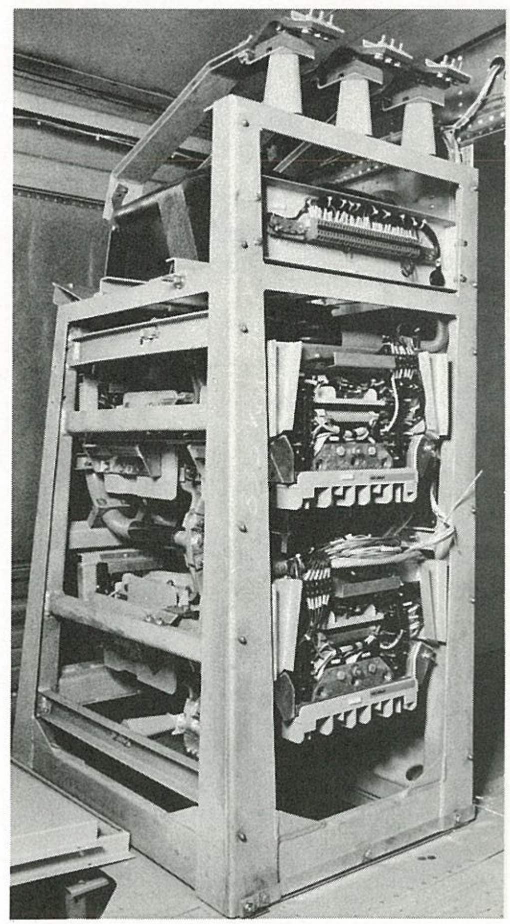


Figure 2-40. Forward/Reverse Switching Apparatus

Figure 2-32. Train Attendant's Console

Figure 2-33. Train Attendant's Seat

Figure 2-34. Automatic Train Control Equipment Rack

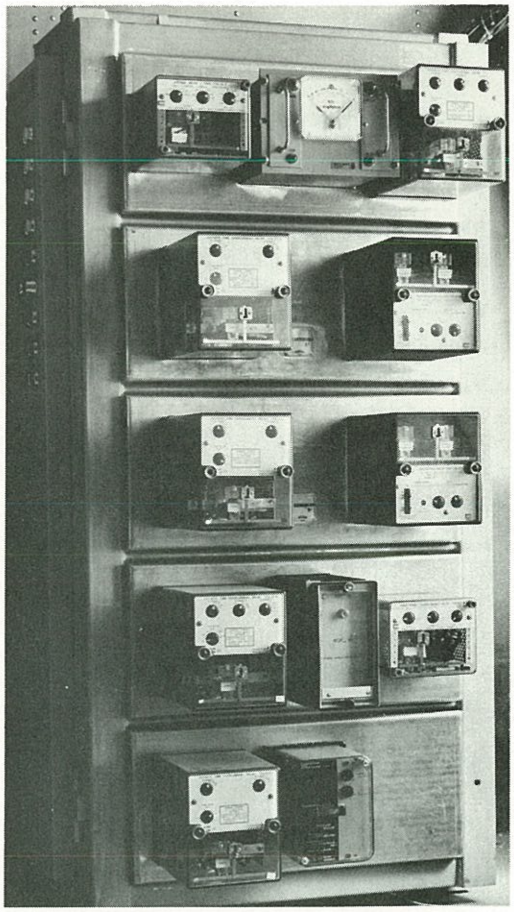


Figure 2-35. Relays, Power Propulsion Switching Auxiliaries

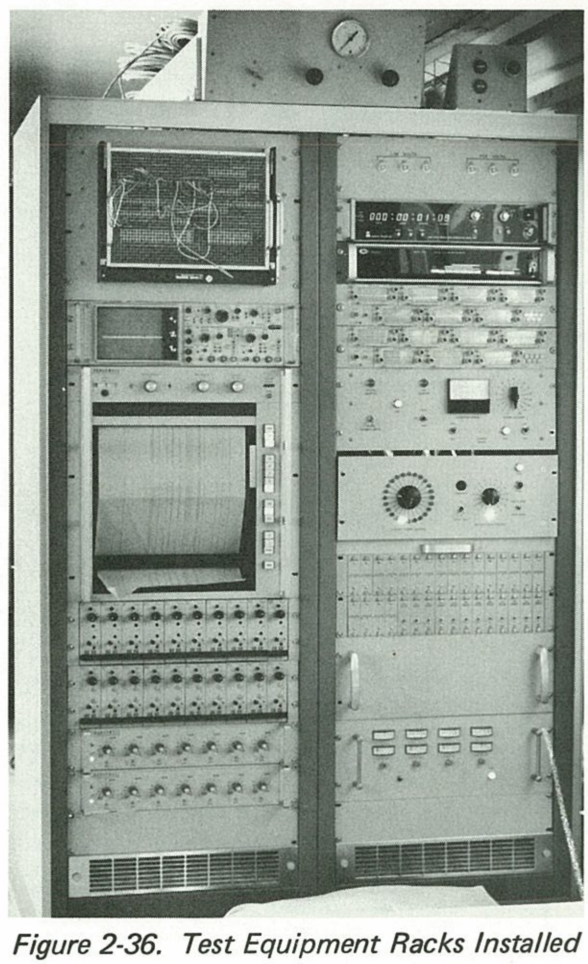


Figure 2-36. Test Equipment Racks Installed

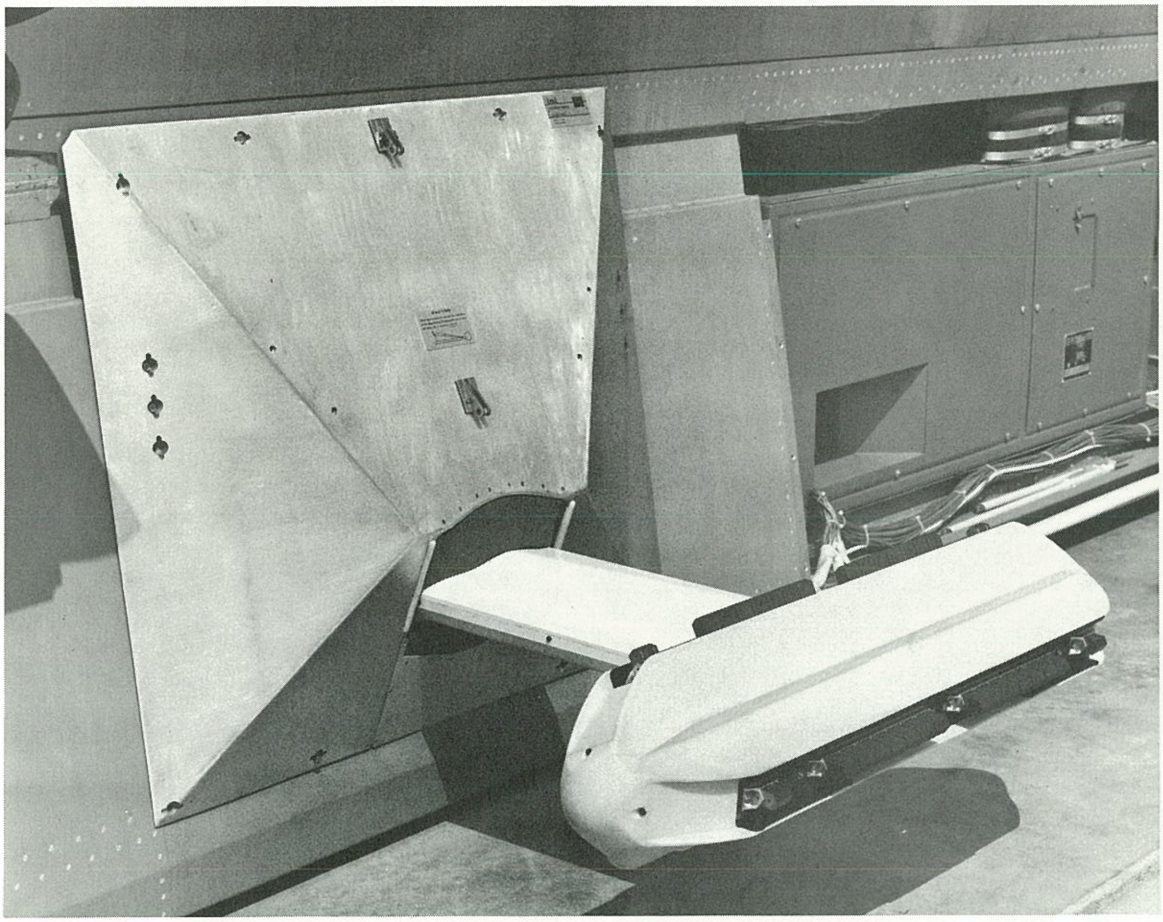


Figure 2-21. Power Collection Assembly

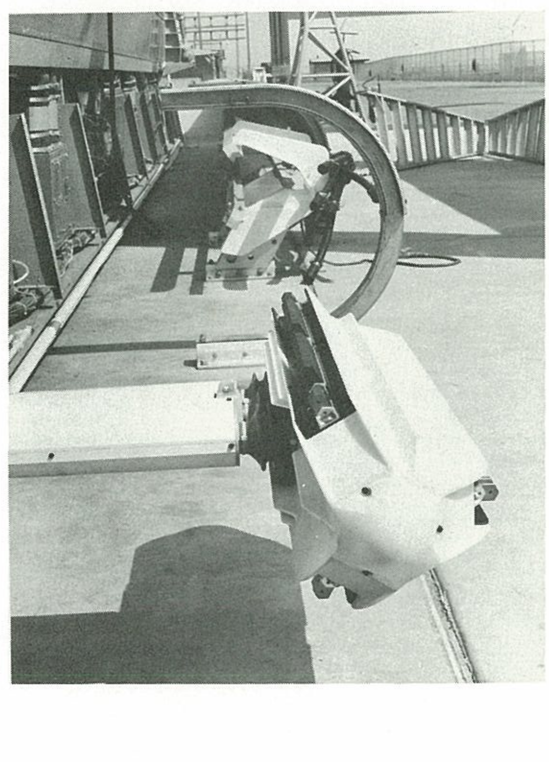


Figure 2-22. Power Collector Ready for Insertion Into Wayside Power Rail Assembly

Figure 2-25. Blower Installation

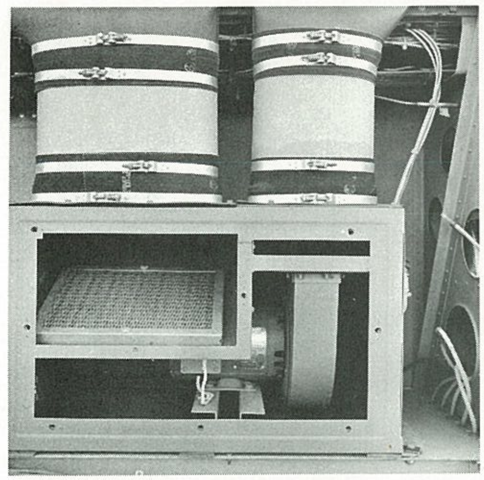


Figure 2-26. Blower; Cover Removed

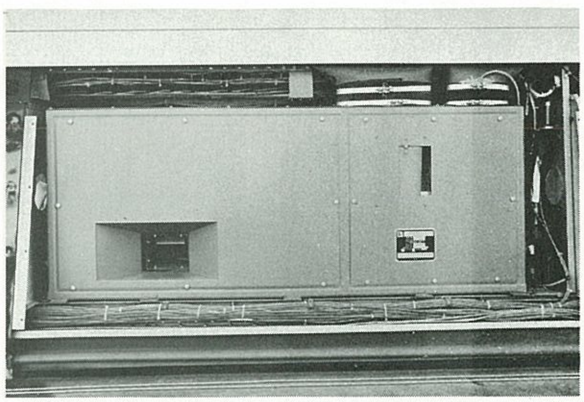


Figure 2-27. Air Conditioning Unit

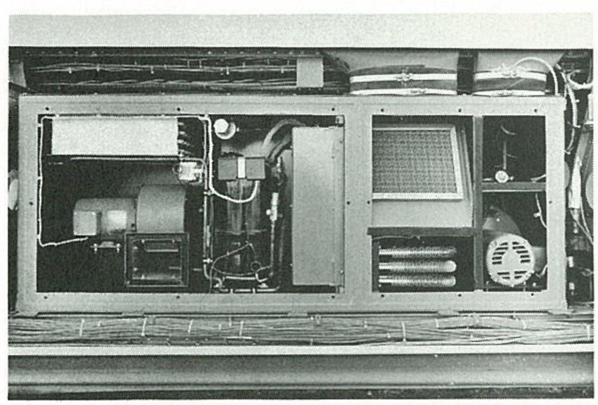


Figure 2-28. Air Conditioning, Cover Removed

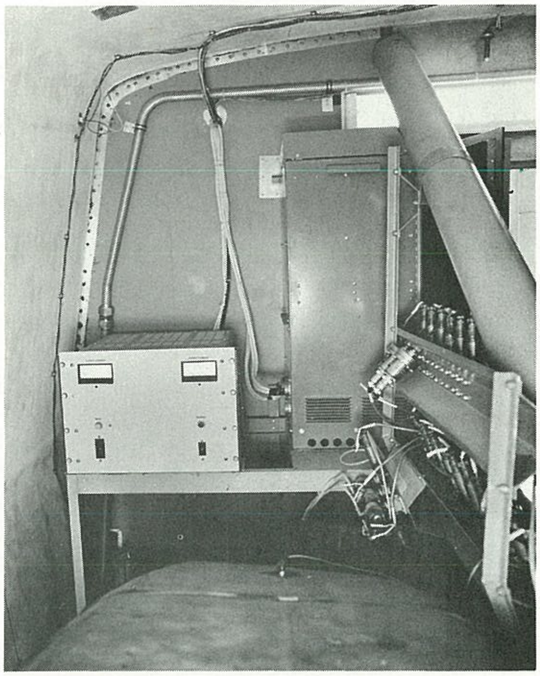


Figure 2-29. Main DC Power Supply

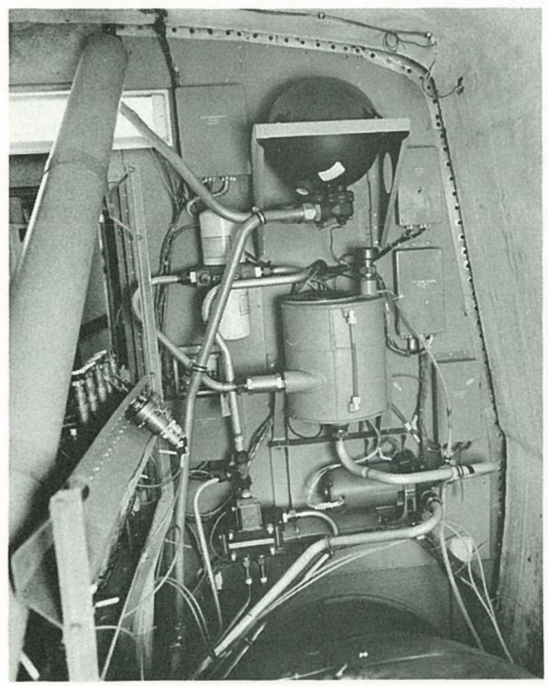


Figure 2-30. Forward Compartment, Showing Fire Suppressant Sphere and Auxiliary Drive Hydraulics.

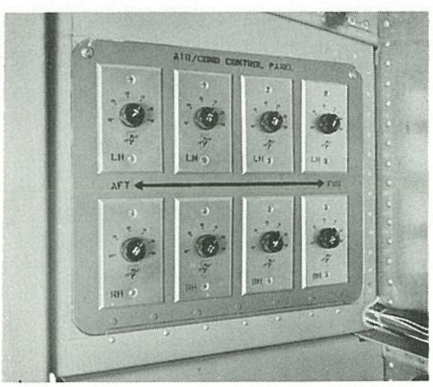


Figure 2-31. Air Conditioning Control Panel, Crew Compartment Aisle

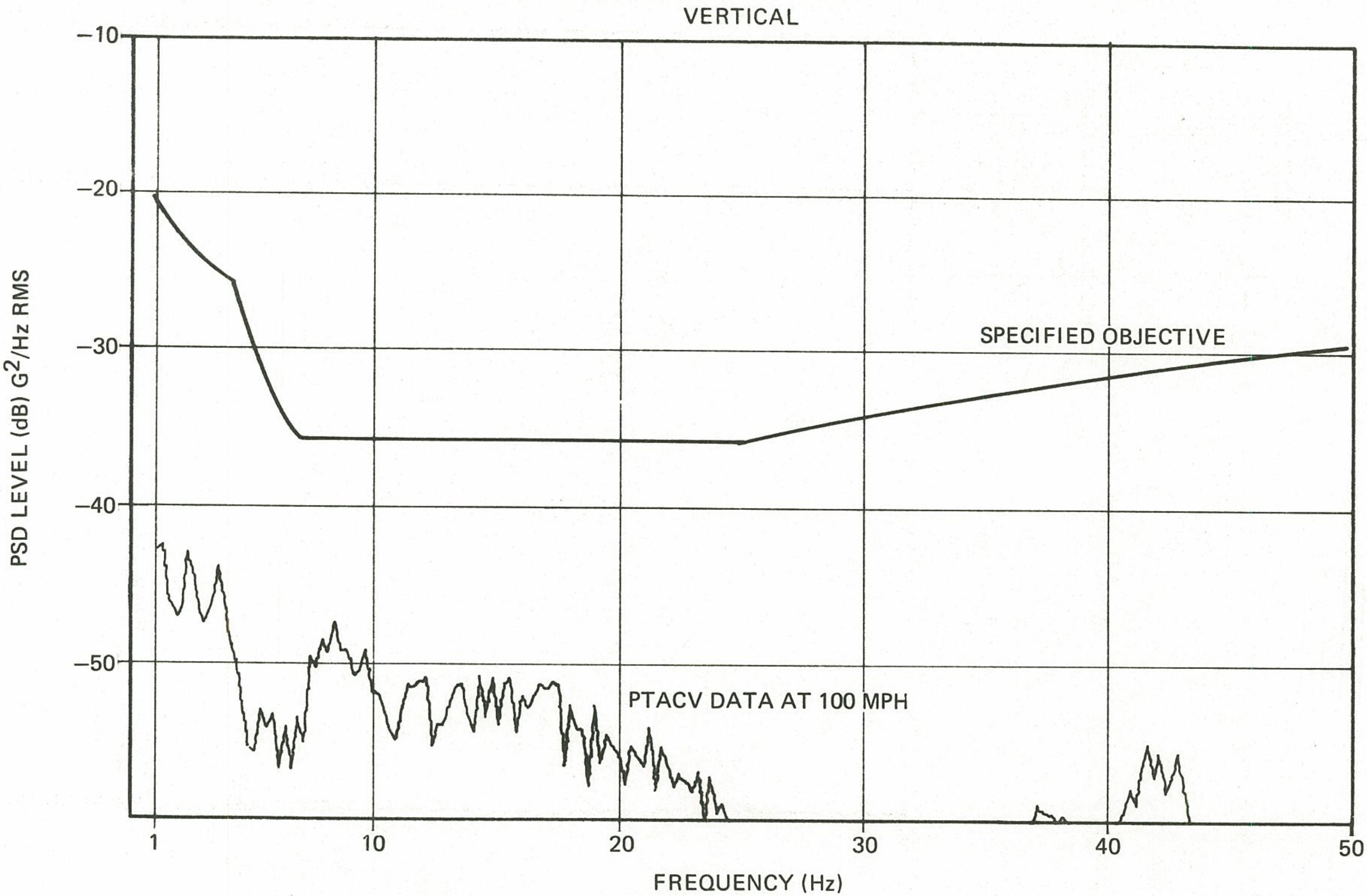


Figure 2-46. Comparison of Specification and PSD for Vertical

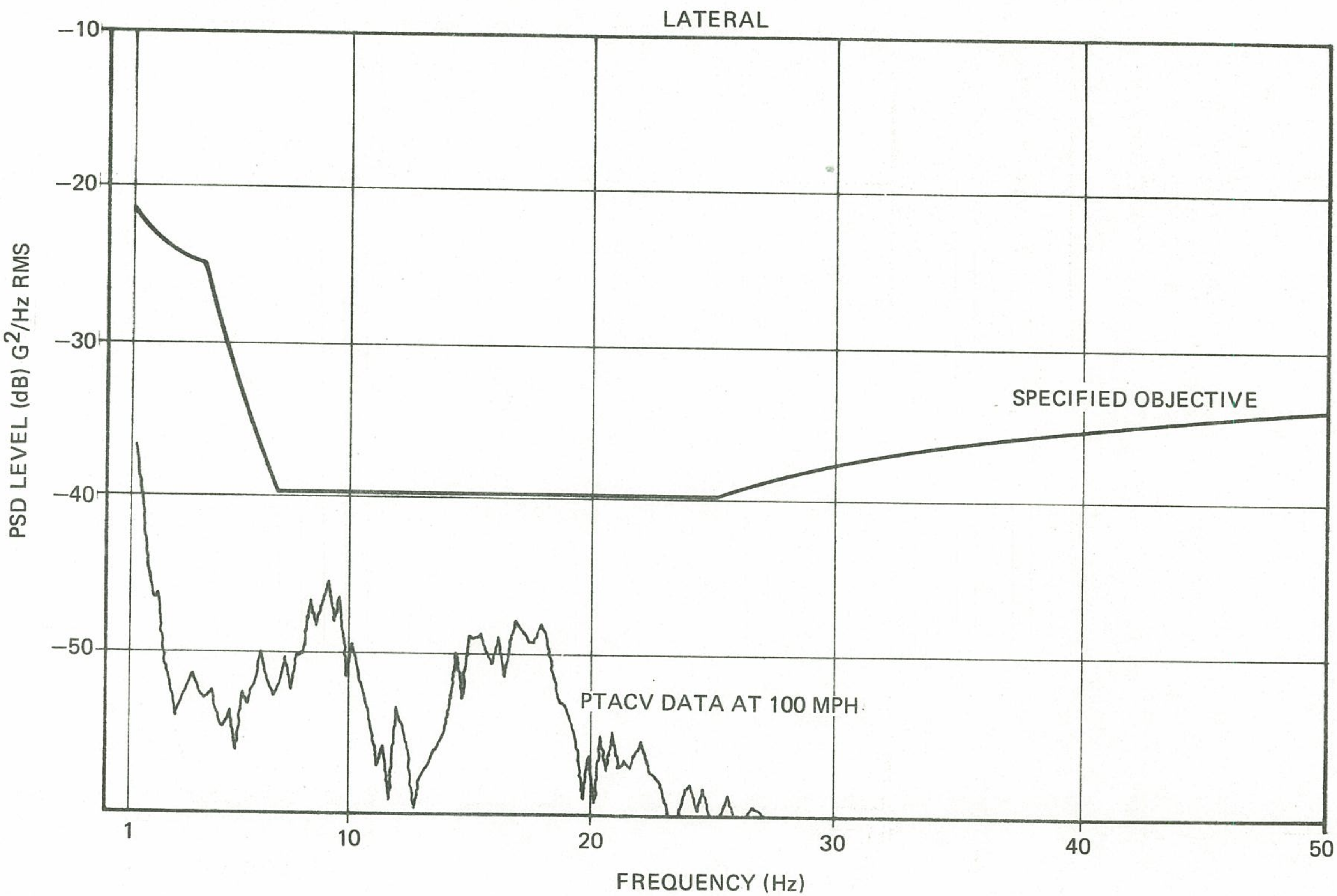


Figure 2-47. Comparison of Specification and PSD for Lateral

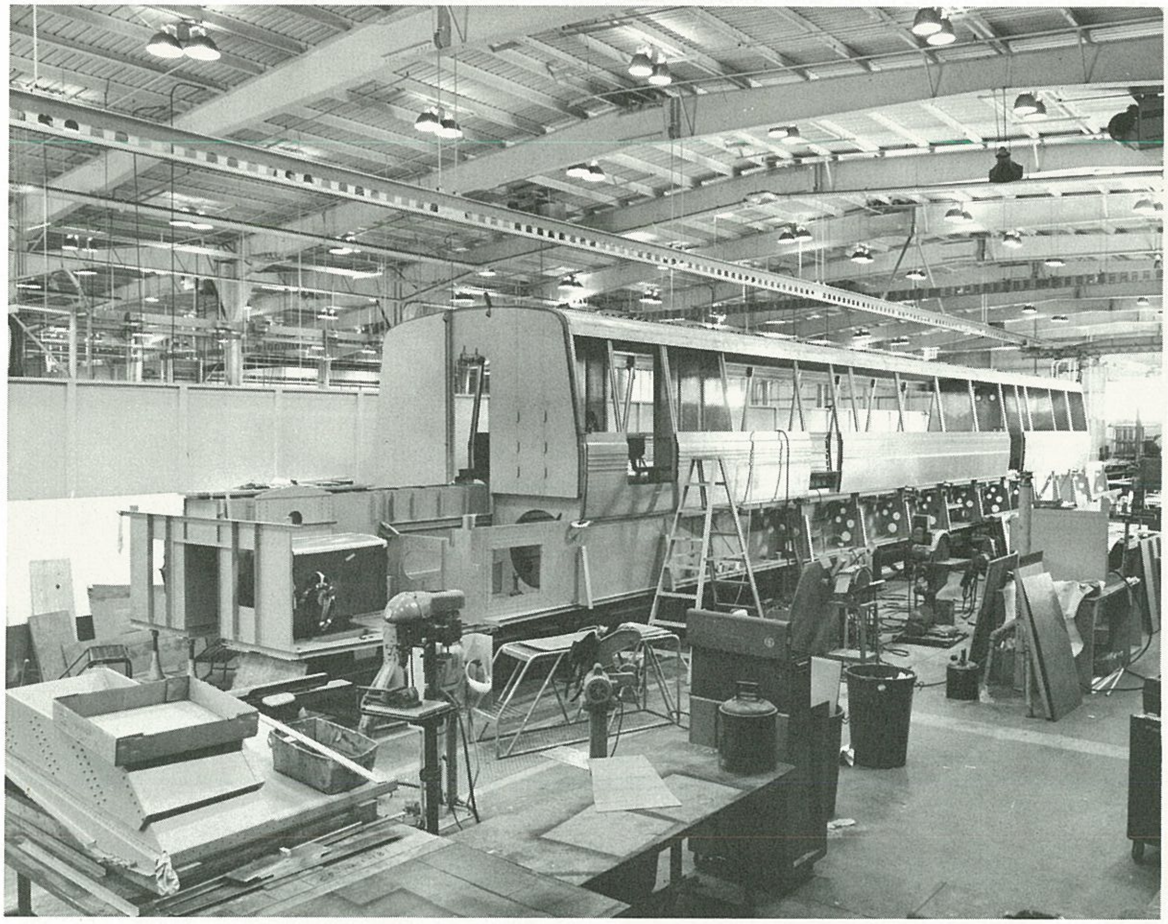


Figure 2-1. Carbody Construction Using Honeycomb Sandwich Panels

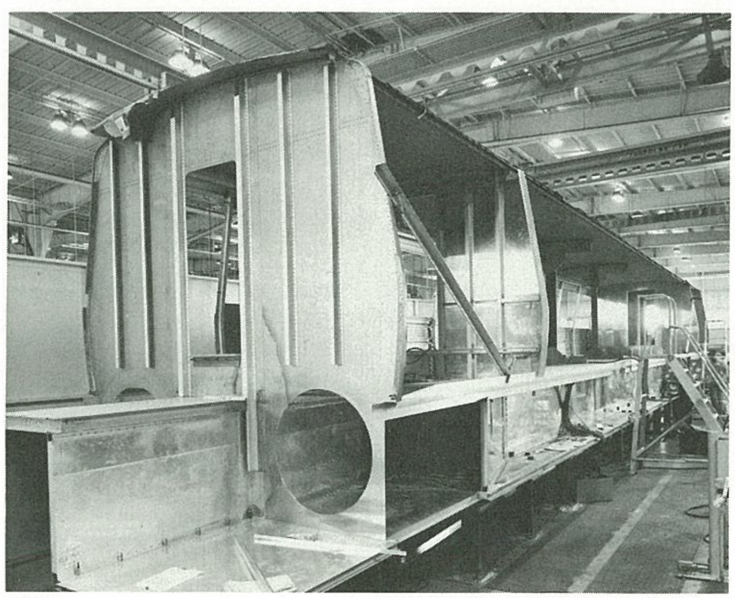


Figure 2-2. Vehicle Fabrication Showing Use of Honeycomb Paneling

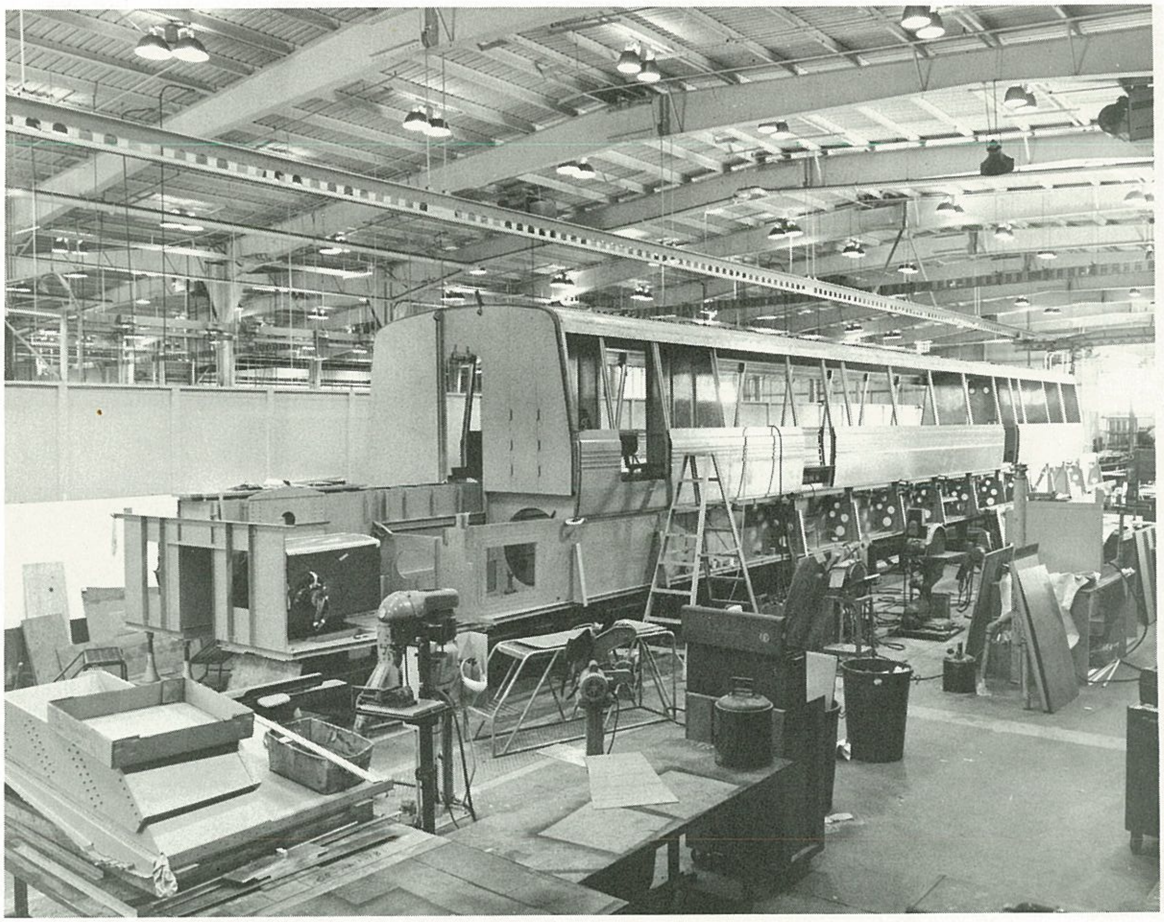


Figure 2-3. Vehicle Side Paneling and Stiffeners in Place

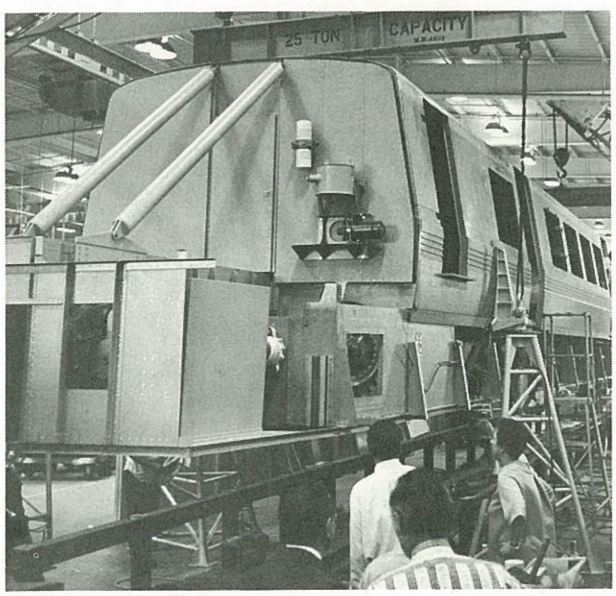
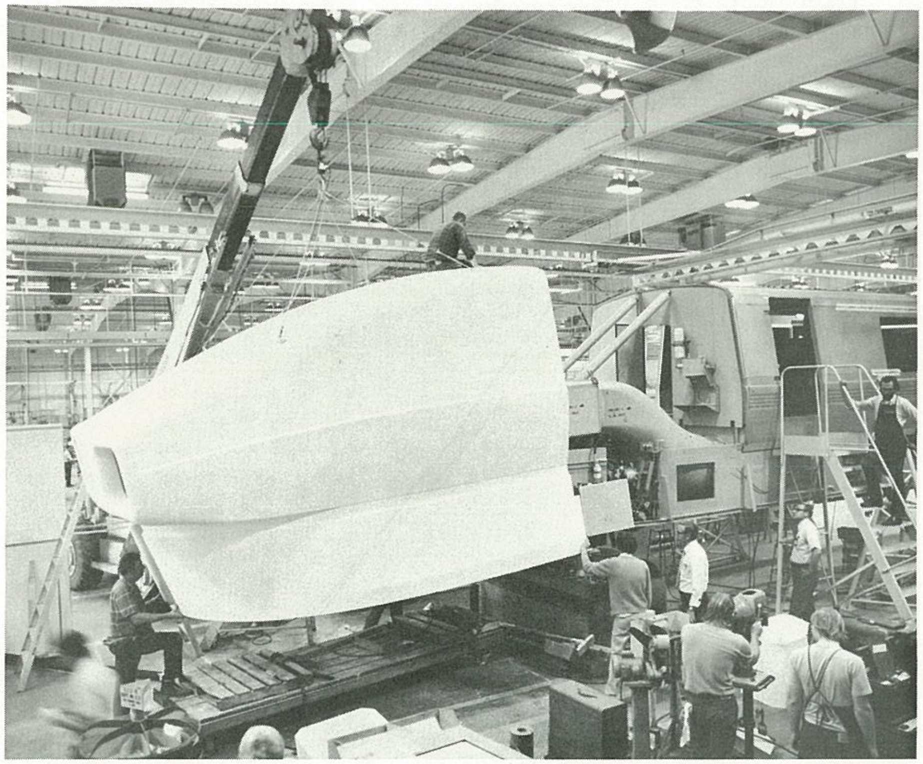


Figure 2-4. Air Compressor Installed Below Forward Bulkhead



Fiugre 2-5. Frangible Forebody Being Installed Over Air Ducts

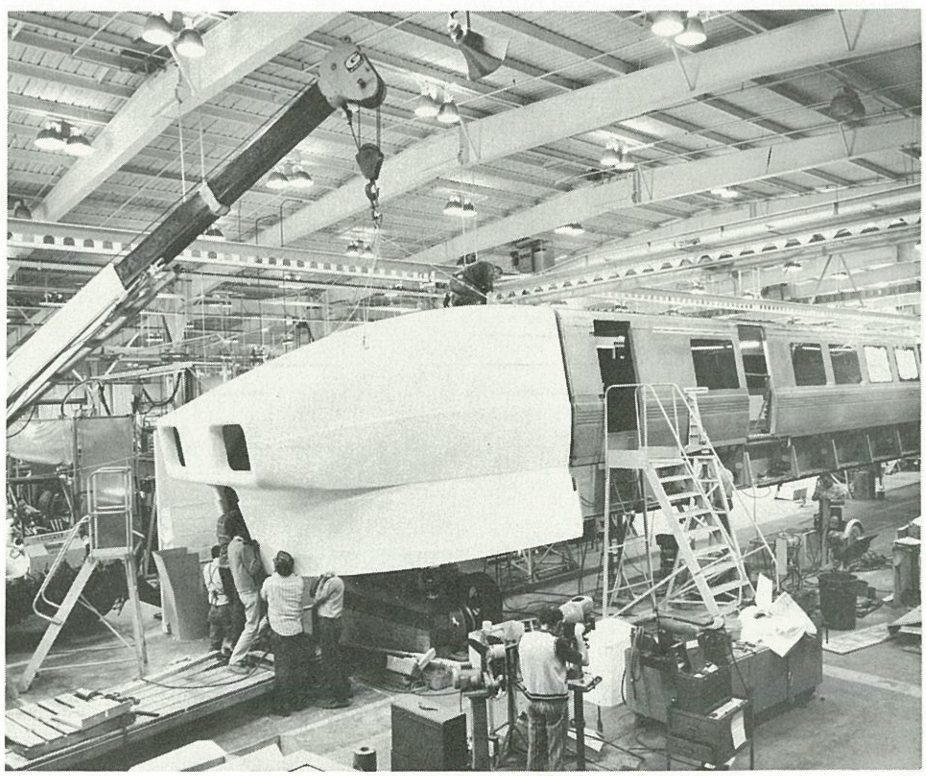


Figure 2-6. Positioning Forebody for Installation

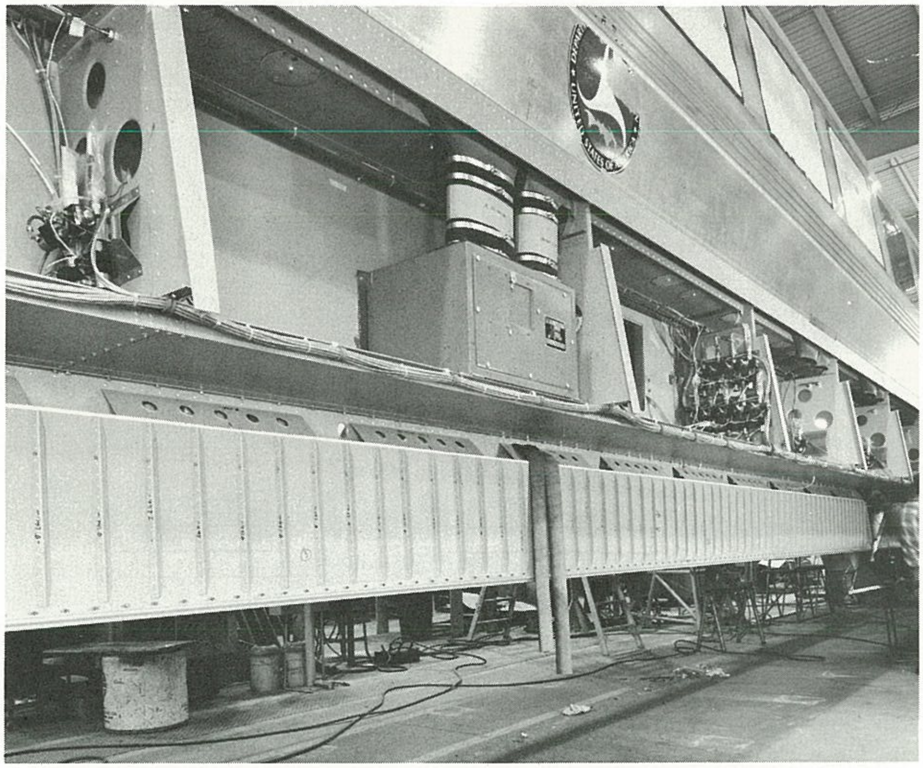


Figure 2-7. Ancillary Equipment and Left Side Cushion

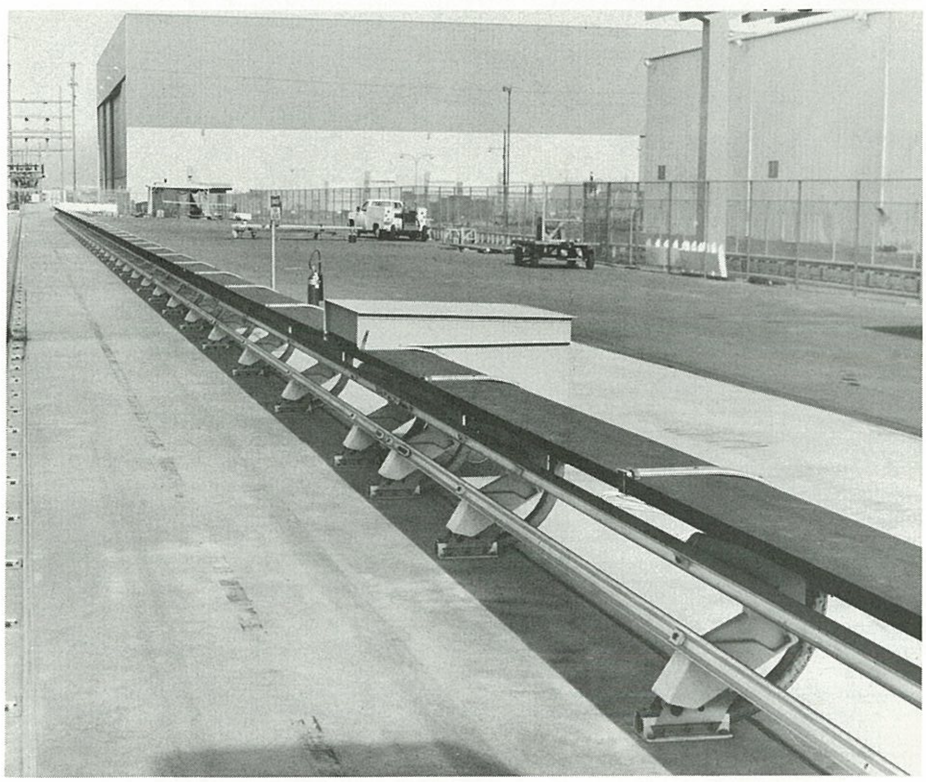


Figure 2-8. 500-Foot Test Track, Chula Vista, California

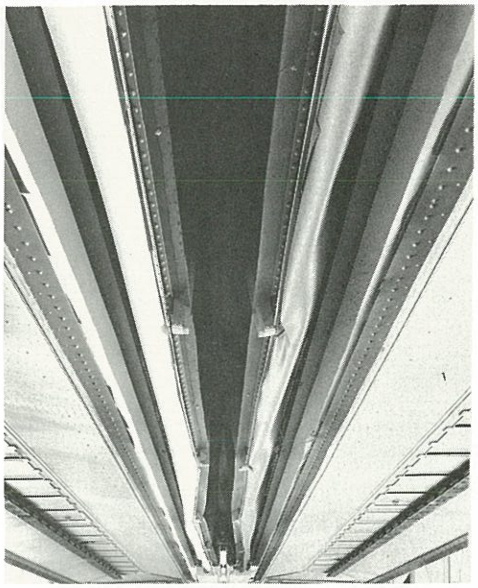


Figure 2-12. Closeup of Cushion Assembly.

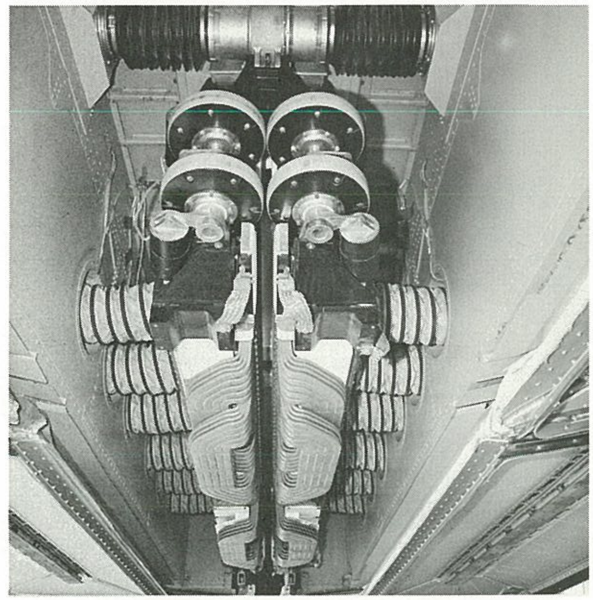


Figure 2-14. LIM In Place (Covers Removed)

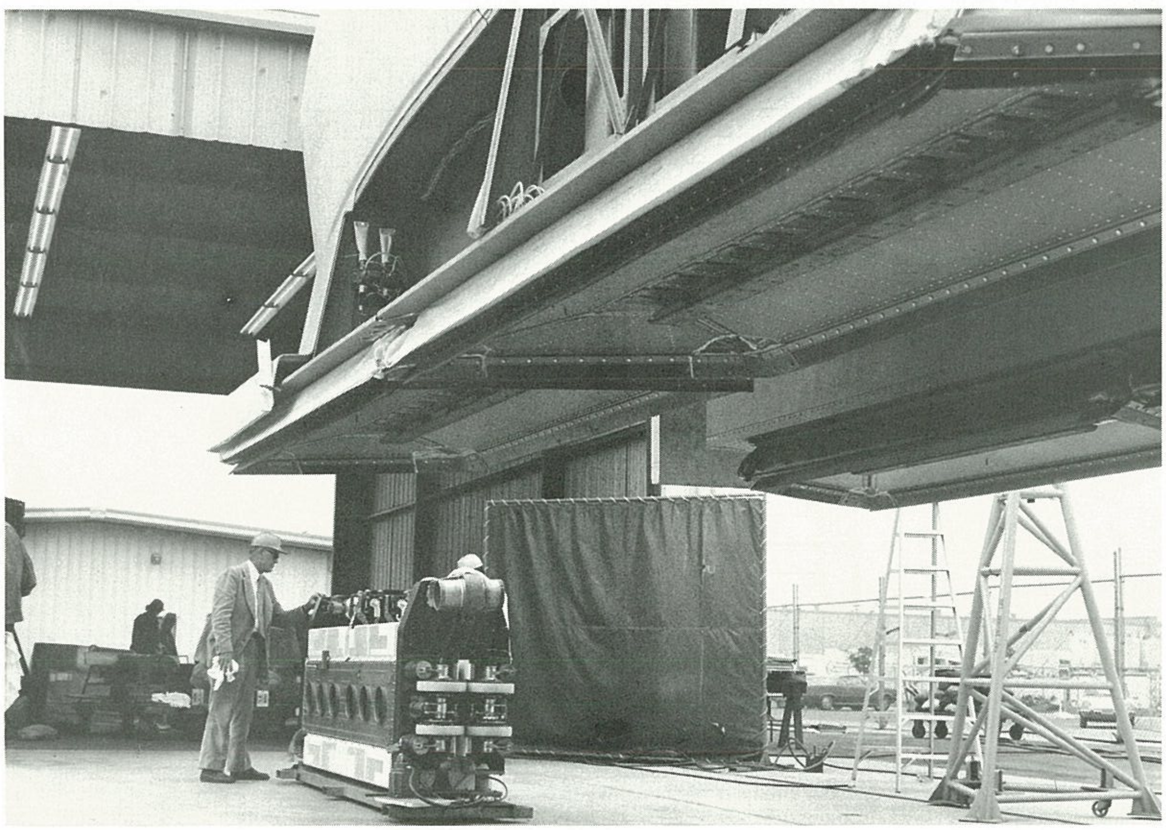


Figure 2-13. Linear Induction Motor (LIM) Ready for Installation at Aft End

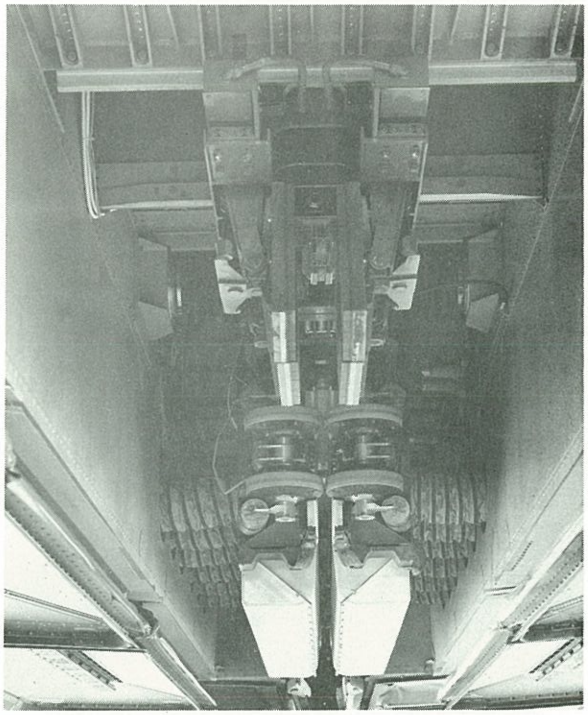


Figure 2-15. LIM Installed (Mechanical Brake in Foreground)

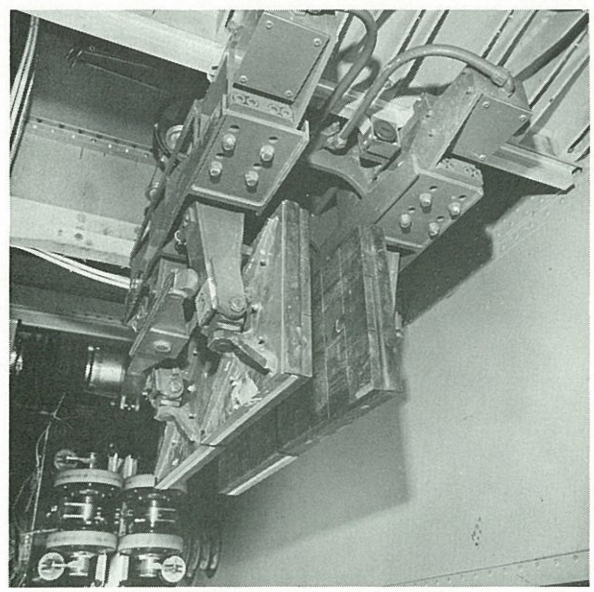


Figure 2-16. Mechanical Brake Assembly

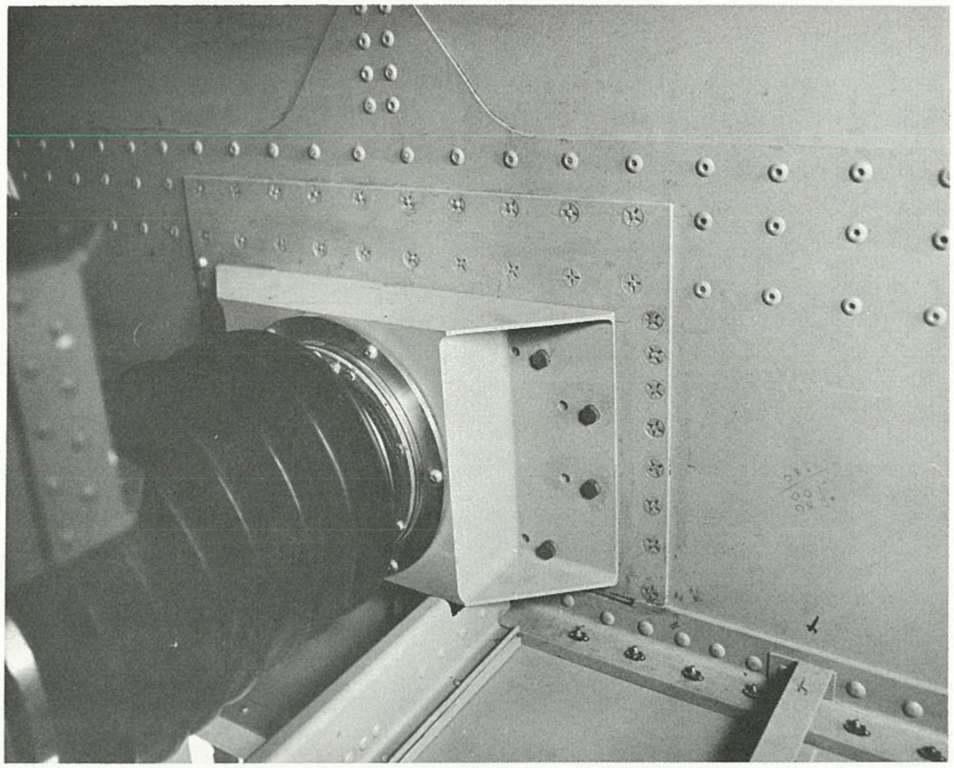


Figure 2-17. LIM Support Tunnel and Anchor Brackets

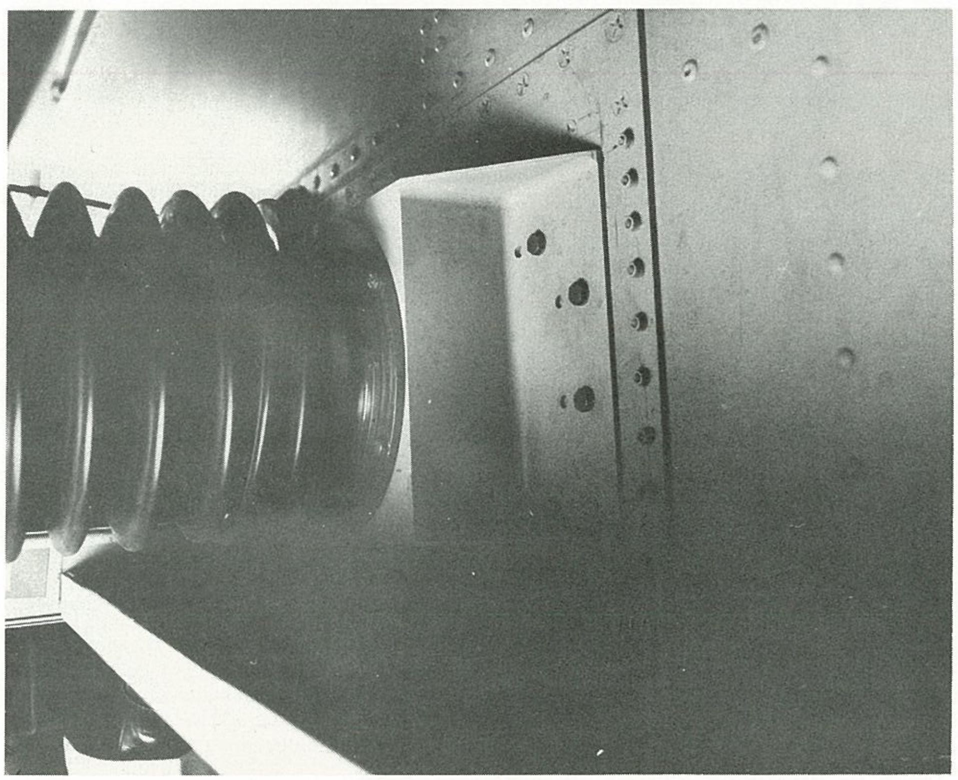


Figure 2-18. Closeup of Support Tunnel

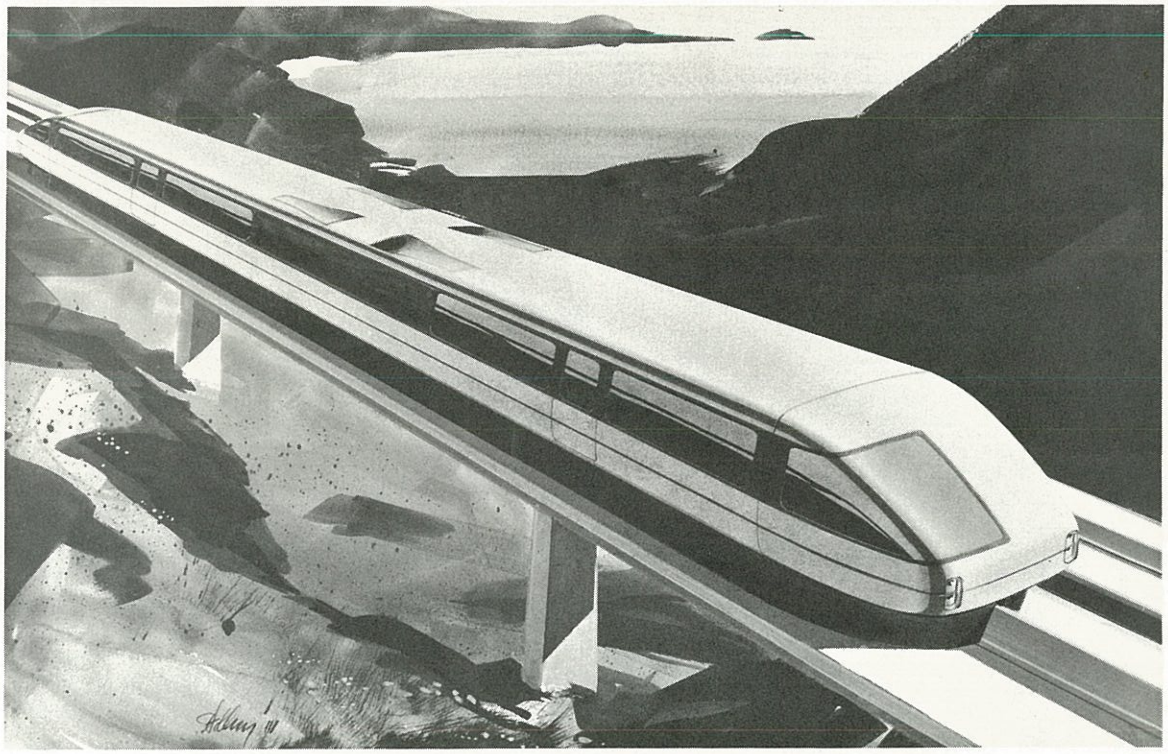


Figure 5-1. Conceptual Rendering, Bi-Directional PTACV

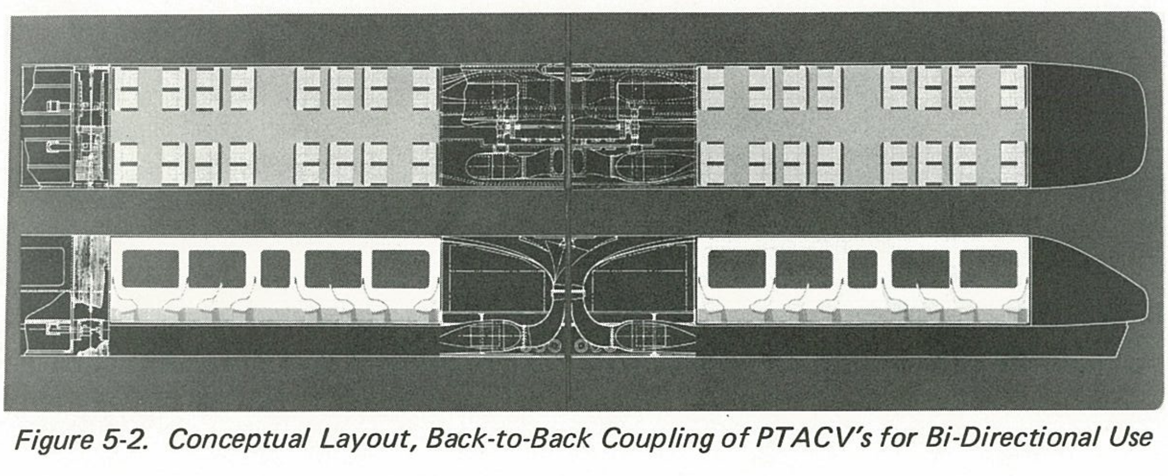


Figure 5-2. Conceptual Layout, Back-to-Back Coupling of PTACV's for Bi-Directional Use