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THE FEASIBILITY OF RETROFITTING LIFTS ON COMMUTER AND LIGHT RAIL VEHICLES

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16. Abstract

This report examines some of the technical issues associated with the retrofitting of lifts for elderly or handicapped passengers on light and commuter rail vehicles. The U.S. inventory of LR and CR rail vehicles is established, and their characteristics that affect lift retrofit are examined. Lift technology is assessed as represented by existing bus lifts. The interface requirements between vehicles and lifts are developed, based on existing vehicle characteristics and on lift kinematic concepts. Ancillary issues of lift installations are examined in the final section.

The study found that it was technically feasible to retrofit lifts on several types of light rail and commuter rail vehicles, drawing substantially on existing bus lift technology.

17. Key Words
Elderly and Handicapped, Transit Vehicle Lifts, Light Rail, Commuter Rail

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PREFACE

This study was conducted under the direction of the Transportation Systems Center. It is part of a program to improve light and commuter rail vehicle accessibility for the elderly or handicapped. The program was sponsored by the Office of Rail and Construction Technology, Office of Technology Development and Deployment, Urban Mass Transportation Administration of the U.S. Department of Transportation. The work was performed as a technical supplement to the study mandated by Section 321(b) of the Surface Transportation Assistance Act of 1978. The findings are based on visits to the majority of sites listed in the report, on conversations with people at all of the sites, and on information supplied by the lift manufacturers.

The author is indebted to Mr. Ronald Kangas of the Transportation Systems Center and Mr. Jeffrey Mora of the Urban Mass Transportation Administration for coordinating work on other elderly and handicapped studies within their respective agencies and for knowledgeably providing contacts in the transit industry.

The study contacts designated by the transit systems as part of the Section 321(b) study supplied valuable technical information and referred the author to other individuals who could provide specialized information. The manufacturers of bus lifts readily provided technical information on their products and on the problem of equipping rail vehicles with lifts.

The author wishes to acknowledge the capable assistance of Custom Engineering, Inc., of Denver, Colorado, which made a study of existing bus lifts. Mr. Carlos de Moraes contributed a great deal to the bus portion of the study from his experience in the transit industry.

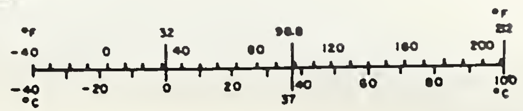
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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16. Abstract

The major objectives of this study were to determine if lift retrofit applications to rail vehicles are technically feasible, and if so, the extent to which existing bus lift technology can be utilized. This report examines some of the technical issues associated with the retrofitting of lifts for elderly and handicapped (E&H) passengers on light and commuter rail vehicles.

There are four major sections to this report. The first section develops the inventory of light rail (LR) and commuter rail (CR) vehicles in the U.S. by number and type. It addresses the characteristics of rail vehicles that differentiate them from buses and makes preliminary indications of which vehicles might be preferable candidates for lift retrofits. The second section assesses the existing bus lift technology. Descriptions of lift designs and operation obtained from manufacturers are presented. The third major section of this report develops the interface requirements between lifts and vehicles based on existing vehicle characteristics and on lift kinematic concepts. The final section examines ancillary issues of lift retrofits on rail vehicles, such as ancillary hardware modifications, safety and liability concerns, and concerns about costs and sources of required funding. This study found that it was technically feasible to retrofit lifts on several types of LR and CR vehicles, drawing substantially on existing bus lift technology. This report contains a list of references and numerous charts illustrating lift technology of manufacturers.

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1.0 EXECUTIVE SUMMARY

This study was performed under the direction of the Transportation Systems Center to assist the DOT activity in light rail (LR) and commuter rail (CR) vehicle accessibility for the elderly and handicapped.

The major objectives of this study were to determine if lift retrofit applications to rail vehicles are technically feasible, and if so, the extent to which existing bus lift technology can be utilized.

Discussions with lift suppliers showed that there are currently three generic concepts in service or under development:

- o Steps-to-lift conversion-some or all of the treads and risers are converted to a platform; the platform is then raised and lowered by a separate mechanism;
- o Partial step-to-lift conversion-the lift platform is stored intact, with part of it used as a step. As a lift, the platform is first moved into position then raised and lowered;
- o Lift independent of steps-the platform is stored intact, and the lift does not alter the steps in any way.

Each of the generic concepts has potential application to rail vehicles, both commuter and light rail.

However, there are significant differences between bus lift applications and rail applications:

- o Bi-directional Rail Vehicles are common,
- o Either-Side Platforms are often used, and
- o High and Low Platforms may be used on the same line.

Bi-directional vehicles, and either-side platforms, each require lifts on both sides of a vehicle for fully accessible service.

The use of both low and high platforms on some systems adds the requirement for level entry provisions, a feature not now provided by any lifts, but one which perhaps should be standard during future lift development projects.

Some conceptual lift applications were developed to support the conclusion that lift applications to rail vehicles are technically possible using existing bus lift technology.

However, the differences between light rail and commuter rail vehicles indicate that the development of one universal lift is unlikely for both types of vehicle. In addition, there are several different installation conditions on CR vehicles, in contrast to one basic condition on LR vehicles.

Light rail lift installations will be able to draw heavily on existing bus lift experience because the conditions are similar. Both LR and bus have two steps to a floor height of about 34". Door openings on LR vehicles are generally wider than those on buses. Three step entries to approximately 45"-52" floor heights will require most, if not all, manufacturers to increase the vertical range of their lifts as a minimum.

For commuter rail operations two lifts are required on each accessible vehicle because of bi-directional operation and either-side platforms. The optimum arrangement is lifts directly opposite each other on the accessible car. The three distinct lift locations to consider, each with its own unique lift installation conditions and constraints are:

- End stepwell locations,
- Center door high platform entrances, and
- Center door step entrances.

Each of the three CR installation conditions presents different lift requirements, but existing lift concepts that would suit each location have been identified and described.

An inventory of the U.S. LR and CR vehicle fleet disclosed that there are about 950 light rail vehicles in service or on order in the U.S. The commuter rail fleet is just under 4,500 vehicles, of which about 3,000 operate at low platforms at least part of the time. (The remaining 1,500 are esclusively high-platform vehicles.) To comply with Section 504 requirements, approximately half of the light rail fleet, and 15% to 25% of the 3,000 vehicle portion of the commuter rail fleet would need to be made accessible.

2.0 INTRODUCTION

Elderly and handicapped (E&H) accessibility to public transportation systems has been mandated under Section 504 of the Rehabilitation Act of 1973. Since then, there has been a continuing effort to develop technologies, devices and procedures which fulfill the requirements the act sets forth. In many instances new technologies have been implemented into revenue service, and associated start up problems have been experienced.

Several solutions have been proposed for E&H accessibility to public transit systems. Bus systems were among the first to implement technologies for E&H accessibility. The method universally used on buses is to provide platform lifts that can accept a patron in a wheelchair at ground level, and raise the person to the bus floor level where the person moves off the lift. Attention is now turning toward rail systems and to the provisions that are necessary to provide E&H accessibility to these systems. It is logical that one of the approaches to be considered is some type of lift, similar to those used on buses.

This report examines some of the technical issues associated with the future implementation of E&H provisions on rail vehicles, particularly with respect to the use of lifts, and associated issues caused by the presence and use of lifts.

There are four major sections to this report. The first, Section 3.0, develops the inventory of light rail and commuter rail vehicles in the U.S. by number and type. It then addresses the characteristics of rail vehicles that differentiate them from buses, insofar as lift applications are concerned, and makes some preliminary indications of which vehicles might be preferable candidates for lift retrofits. Finally, the approximate number of vehicles that need to be made accessible to comply with the Section 504 regulations is discussed.

The second major task, Section 4.0, assesses the existing bus lift technology. The problems experienced with lifts to date were obtained from several bus operators to determine the nature of problems that might be expected on rail applications. Descriptions of lift designs and operation were obtained from manufacturers, and it was found that there are three basic types of lifts now being developed by those in the industry.

This finding was important to the next effort in this project because it significantly reduced the number of combinations of lifts and vehicles that could be formed.

The third major task, Section 5.0, develops the interface requirements between lifts and vehicles. The differences between light rail and commuter rail vehicles indicate that the development of one universal lift is unlikely for both types of vehicle. In addition, there are three quite different installation conditions on CR vehicles, in contrast to one basic condition on LR vehicles. Conceptual lift installations based on existing lift designs are shown for each installation condition.

The final major effort, Section 6.0, examines ancillary issues of lift retrofits on rail vehicles. These issues are readily divisible into two categories. First is ancillary hardware modifications that will be needed because of lifts, such as seating modifications, restroom accessibility, etc. The second group of issues are much broader concerns surrounding accessible rail services that emerged during discussions with system operators, such as their need to know the effects of lift operations or system performance, safety and liability concerns, and concerns about costs and sources of required funds.

3.0 CHARACTERISTICS OF LIGHT AND COMMUTER RAIL CARS

The application of E&H lifts to buses has now accumulated several years of experience, but as yet no lifts have been applied to rail vehicles. San Diego Metropolitan Transit Development Board (MTDB) expects to take delivery of 14 lift-equipped Siemens-Düwag light rail vehicles in late 1980. These will be the first accessible LRVs in the U.S.

Rail vehicles are superficially similar to buses, with one or more sets of steps leading from ground level to the vehicle floor, but there are mechanical and operational considerations specific to the vehicles and operating systems that make it necessary to study each rail vehicle type in detail.

There are three generally recognized rail sub-modes, termed light rail, rapid rail, and commuter rail. For the purposes of the study, rapid rail systems are excluded because access is universally by high platforms/ level entry. The remaining two categories, LR and CR, and are characterized predominantly by step entry.

To provide E&H accessibility to LR and CR vehicles implies the need for lift devices that are functionally similar to those now used on transit buses. The obvious alternative, to provide high level platforms and level entries, does not eliminate the vertical accessibility problem, but merely transfers it to the station side of the system. In some situations this may be acceptable and preferable, but it is not a universal solution.

The locations of the transit systems and their categories are shown in Figure 3-1. Rapid rail cities are also identified for the convenience of the reader.

Prior to a detailed mechanical investigation of lift installations to rail vehicles, the vehicle population itself must be examined from two broad aspects. It is necessary to know how many vehicles exist by type and age, and then for those types that are new enough and numerically significant, the existing hardware characteristics that are expected to impact lift installation must be examined. Operational practices and vehicle designs are often interrelated, so discussions of operational considerations will be included where appropriate with vehicle characteristics.

FIGURE 3-1. U.S. TRANSIT OPERATIONS
LIGHT RAIL (LR) RAPID RAIL (RR) AND COMMUTER RAIL (CR)
(1979)

For both light rail and commuter rail vehicles, the mechanical and operational considerations that differentiate them from buses allow certain preliminary conclusions about lift installations in advance of detailed mechanical study. For example, the required number of lifts per rail vehicle can exceed the single lift per vehicle of transit buses, because of operational differences. In the final analysis, it may prove more feasible to alter operational practices than to make multiple lift installations. It is probable that such decisions will have to be made on a system-by-system, or even line-by-line basis.

There are three major vehicle to station interface differences between bus and rail that stand out. In the following discussions, it is important to understand that left and right on a vehicle are with respect to its direction of travel. "Platform" is used in the broadest sense, in that a platform associated with in-street operation of an LRV may be only an area in a street, without visible boundaries.

Bidirectional Vehicles

Vehicles that are designed to operate equally well in either direction of travel are defined as bidirectional, and examples occur on both light rail and commuter rail. The advantages are that vehicles or trains can be reversed at the end of a line by simply running through a switch to the return track and proceeding with the opposite end leading. This avoids the need for a loop or wye to turn the vehicle or train so as to keep one end always leading.

The disadvantage to bidirectional vehicles is that they are required to have doors on both sides even if the stations are always on one side of the vehicle; for example, outside platforms are always to the right of the vehicle with respect to the direction of travel. Provision of doors on both sides does not automatically mean that a vehicle is bidirectional. The MBTA Green Line (Boston) has some underground stations with left-side platforms but most of their PCC cars are unidirectional, even though they have doors on both sides.

Either-Side Platforms

Center and side platforms, which appear respectively as left side and right side platforms to a vehicle for a given direction of travel, also require doors on both sides of the vehicle. If a system is operated with bidirectional vehicles having doors on both sides, it then is common to take advantage of the fact by placing platforms on either side as dictated by other architectural considerations.

The major exception to the use of either-side platforms with bidirectional vehicles occurs with in-street operation. Vehicles operated in streets along with other vehicular traffic invariably load from the right side of the vehicle for safety reasons.

A special case of either-side platforms is a very limited number of both-side platforms, that is, stations where vehicles can be loaded from both sides. There are very few of these in use in light rail (MBTA North Station lower is one example and they have no direct effect on the provision of E&H facilities on vehicles, because the right side would presumably be used for the lift facility.

High and Low Platforms

The third major difference between bus and rail vehicles is the use on some systems of both high (level entry) platforms and low platforms. This imposes the requirement for both level entry provision and for steps on each vehicle. For the purpose of this study, it is the presence of the steps that translates into the need to define means of providing E&H accessibility.

At present there are three methods of interfacing with high or low platforms. The most common arrangement on commuter rail vehicles is trap doors that cover the stepwell at high platforms. The second method is the provision of separate doors near the center of the vehicle for use only at high platforms. In both cases the end steps serve in the conventional manner for low platforms. The series of commuter cars known as Silverliners and Arrows have end steps and high-level center doors, or at least structural provision for doors. (See Figures 3-9 and 3-10.) The combination of vehicle directional characteristics (uni- or bi-), platform location, and platform height, can be illustrated as shown in Table 3-1.

The third arrangement for interfacing with both high and low platforms, used on light rail only, is a high/low convertible step arrangement in which the step treads can be raised to floor level. At present, only San Francisco uses this method to enable the center doors on the Boeing LRV's to interface with the high platforms in the Market Street tunnel. At all other locations, the steps are in the more common configuration for boarding at street level.

TABLE 3-1. VEHICLE AND PLATFORM CHARACTERISTICS AND THE EFFECT ON ACCESS REQUIREMENTS: DOORS AND STEPS

	PLATFORM CHARACTERISTICS				
Vehicle Characteristics	Always to One Side	May be on Either Side	Low Only	High and Low	High Only
Unidirectional	1 Requires doors on one side only	3 Requires doors on both sides	5 Requires only vertical transition arrangement, i.e, steps and lift	6 Requires both vertical transition + level entry arrangements	7 Level entry only. No vertical transition arrangement
Bidirectional	2 Requires doors on both sides	4 Requires doors on both sides			

Notes:

1. Buses, and most PCC operations, with the exception of MBTA.
2. Rare, because of the artificial constraints imposed on station design.
3. Always rare, because of the artificial constraint imposed on vehicles. MBTA PCCs.
4. Common in commuter rail operations, some LR (SEPTA) and becoming more common in light rail with the advent of the Boeing LRV.
5. Buses, and once the standard for light rail and common for commuter rail; will continue for most light rail operations.
6. Also common on commuter rail, and now being used on new light rail installations (MUNI, Market Street in San Francisco).
7. Standard rapid rail practice, some commuter rail, and SEPTA Norristown (Red Arrow) Light Rail, but no E&H lift implications. Included only for completeness.

In addition to the three major differences described above, there are some operational practices and vehicle mechanical differences between rail and bus systems that are useful to understand.

Diesel-Hauled Trains

The historical practice with passenger and commuter trains is to operate with the locomotive leading the cars for both directions of travel (assuming basically a shuttle operation). At each end of the trip the locomotive is uncoupled from the front of the train, run to the rear end, and recoupled to the cars, thereby redefining the front end for the return trip.

Although the cars and locomotive(s) are bidirectional, the train considered as a unit is not, and rearranging the locomotive relative to the cars is functionally equivalent to turning the train as a unit. This practice is time-consuming and operationally restrictive, because a passing track must be available at each end terminus.

Push-Pull Trains

Bidirectionality does not require symmetry. A train can be operated with just one locomotive pushing or pulling; it does not require a locomotive at each end. It is, however, not feasible to operate from the locomotive with the locomotive at the rear of the train, primarily for safety reasons. Instead a control cab can be provided on the last car or first of the train depending on the direction of travel, and the locomotive controlled remotely from that station to push the train in the seemingly reverse direction. Such trains are known as push-pull trains, and they are rapidly becoming the preferred arrangement for commuter operations.

Push-pull equipment fleets are equipped with a multiconductor cable that runs the length of all cars in the fleet, so that the controls in the cab cars (typically 15-25% of a fleet) can be electrically connected to the locomotive control circuits. Although push-pull equipment can be run in Diesel-hauled trains, ordinary equipment that does not have a multiconductor trainline obviously cannot be run intermixed with push-pull equipment without negating the push-pull capability, because the trainline cannot be completed through the train.

A variant of push-pull operation without cab control cars is found on the Long Island RR portion of the New York Metropolitan Transit Authority (NY MTA). Old locomotives, the original engine, generator and motors removed, have been equipped with engine-generator sets to supply train lighting and heating power. These units, technically no longer locomotives, are used at the end of the train opposite the locomotive as control stations when operating in the push direction.

Electric Multiple Unit Equipment

On electrified lines it is convenient to use electrically powered cars and dispense with a locomotive for several reasons. Operational simplicity is gained, available propulsion capacity increases at the same rate as train length increases when cars are added, and having all axles motorized allows more rapid acceleration. Any number of cars can run as a train, and be controlled from one operating station in the lead car, hence the designation multiple unit, or MU equipment. MU equipment is always arranged to be bidirectional.

Single unit MU cars are provided with an operator's station at the diagonally opposite right front corners. A pair of units can be designed to share certain equipment if they are always run as a married pair. It is then necessary to provide only one operating cab on each of the cars, and the cars are always coupled so the cabs are in the extreme right front corners of the two-car set. Although each car of a married pair is not bidirectional, because of the single control station, they are bidirectional as a pair.

Diesel Self-Propelled Cars

The Diesel equivalent of electrically powered cars is frequently used on non-electrified lines, where traffic may not justify either electrification or locomotive and car trainsets. The controls on these cars are arranged like those of a single-unit EMU car, i.e., at the right front corners of the cars. Although there are now no married pairs of DSP cars, there are powered units without control stations that must be run with control-equipped units.

3.1 Enumeration and Description of Rail Cars

The principal reference source for the enumeration of vehicles was "Railway Passenger Car Annual, Volume IV, 1978-79," by W.D. Randall and Z.R. Hanson, a very complete set of equipment rosters for intercity, commuter, and transit passenger operations. Other publications and conversations with operators and builders served to confirm and update the information provided by the RPCA, particularly with respect to operational details, station arrangements, and future plans for the equipment.

3.1.1 Light Rail Vehicle Inventory

The two classes of operation, light rail and commuter rail, required considerably different approaches to data reduction. Light rail vehicles consist of only three types, PCC cars, Boeing LRVs, and miscellaneous others; there are only three firm orders, Philadelphia with Nissho-Iwai (Kawasaki), Cleveland with Breda, and San Diego with Siemens-Düwag. It was therefore straight-forward to summarize the vehicles on hand, on order, and scheduled to be replaced to arrive at the net fleet, as shown in Table 3-2.

This table reflects only existing vehicles or firm commitments to new vehicles. Although some systems are in various planning stages of new vehicle acquisition, these were judged too indefinite to include. Furthermore, the new purchases must be accessible as delivered, if solicitations are issued after January 1, 1983, according to the 504 Regulation of the Department of Transportation.

The table shows the numbers and types of vehicles that are expected to be in service in 1990 and hence are candidates for retrofit. Section 504 regulations exempt vehicles to be retired within ten years from retrofit requirements. The present light rail requirement is for 50% of the peak-hour fleet of vehicles to be accessible, with the accessible vehicles to be operated in preference over the non-accessible vehicles during off-peak hours. Thus, some operators will have the option of equipping only newer vehicles, and all operators have the option of diluting a non-accessible fleet with new accessible vehicles.

Power Considerations

There are two possible sources of power for lift operation on LRV's. All LRV's presently operate from a 600 VDC supply, and have a low voltage auxiliary supply on board to power control circuits and other low-power

TABLE 3-2. LRT SUMMARY OF VEHICLES IN-SERVICE, ON ORDER, AND SLATED FOR REPLACEMENT, 1 JULY 1979

TYPE:	PCC*			BOEING			KAWASAKI			BREDA			BRILL			SLC			DUWAG			OTHER		
CITY	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
Boston	236	-	136	135	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Newark	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Philadelphia																								
CTD	266	-	-	-	-	-	-	115	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Line 100	-	-	-	-	-	-	-	-	-	-	-	-	(19)[5]	-	-	(2)[5]	-	-	-	-	-	-	-	-
Lines 101.2	-	-	-	-	-	-	-	26	-	-	-	-	19	-	19	13	-	13	-	-	-	-	-	-
Pittsburgh	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cleveland	57	-	57	-	-	-	-	-	-	-	48	-	-	-	-	-	-	-	-	-	-	-	-	-
Detroit	-	-	-	-	-	-	-	-	-	-	-	-	1[1]	-	-	3[2]	-	-	-	-	-	2[3]	-	-
New Orleans	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	35[4]	-	-
San Diego	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14[6]	-	-	-	-	-
San Francisco	115	-	115	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Totals	798	-	308	235	-	-	-	141	-	-	48	-	20	-	19	16	-	13	14	-	-	37	-	-
Expected Number in Service through 1990		490			235			141			48			1			3			14			37	

*Although 308 PCC's are slated for replacement by the cities that own them, history indicates that some could conceivably be sold to other cities and serve many more years before scrapping. The Brill, SLC, and other older equipment is unlikely to continue in service elsewhere.

1. 1901
2. 1899
3. 1925 Lisbon, Portugal
4. 1923 (approximate) Perley-Thomas
5. Norristown High Speed Line; high platforms only; not included in totals
6. Ordered with lifts

A. Vehicles in Service

B. Vehicles on Order

C. To be retired

demands. It will be seen in the following section that most bus lifts now are hydraulically actuated, which implies that a motor-pump unit will have to be provided for rail applications. Depending on the power required and power available on a specific vehicle type, the motor may be able to be supplied from the low voltage source, which is easier and less costly, or may have to utilize the 600 VDC supply. The voltages available on the four most numerous LRV's in service or on order are shown in Table 3-3.

TABLE 3-3.

CHARACTERISTICS OF ELECTRICAL POWER SOURCES ON LIGHT RAIL VEHICLES

LRV	POWER SUPPLY CHARACTERISTICS	
	PROPULSION SUPPLY	AUXILIARY SUPPLY
PCC	600 VDC	30 VDC
Boeing	600	37 ½
Breda	600	
Kawasaki	600	

PCC Cars

With the exception of some MBTA PCC's and Red Arrow quasi-PCC's, all existing PCC cars are unidirectional and can load from only the right side. They are therefore identical to common transit buses in both arrangement and operation. E & H accessibility could be provided with one lift, and as with buses, the two obvious locations are the front door or the rear door areas. The technical problems of installation are addressed later. Except for the left side door, Figure 3-2 is representative of all unidirectional PCC cars. Interior seating arrangements vary considerably.

The MBTA PCCs have a third door approximately in the center of the car on the left side, as shown in Figure 3-2, to allow left side boarding in four Green Line underground stations, and the Ashmont station of the Red Line. Those stations are single-sided center-platform stations, without possibility of boarding passengers on the right side of a vehicle as the stations are now configured. Thus, to provide full accessibility to the MBTA system, both sides of a vehicle must be accessible to a given population. For MBTA, if vehicle lifts are needed for accessibility, and if all stations must be accessible, accessible vehicles will require a lift on both left and right sides.

Boeing Cars

The most numerous new LR vehicles are the recently constructed Boeing articulated vehicles for MBTA and Muni, Figure 3-3. These vehicles are fully bidirectional, and therefore have identical door arrangements on both sides. MBTA, as mentioned previously, has five stations that require left-side boarding. Muni, on the other hand, never used left-side boarding but will now utilize the left-side doors in their new Market Street tunnel, which has both center and side platform stations. In addition, the new tunnel stations are all level entry high platforms, so the Muni vehicles have a set of steps at each of the four center doors that can be raised to form a level entry floor. The traditional streetcar tapered or radiused ends, which are required to provide sufficient clearance between cars when passing one another on short radius curves, cause a significant gap problem at high platforms for doors located at the car ends. For that reason, Muni does not use the end doors at high platforms. Muni accessible LRV's will also require lifts on both sides because the vehicles are bidirectional.

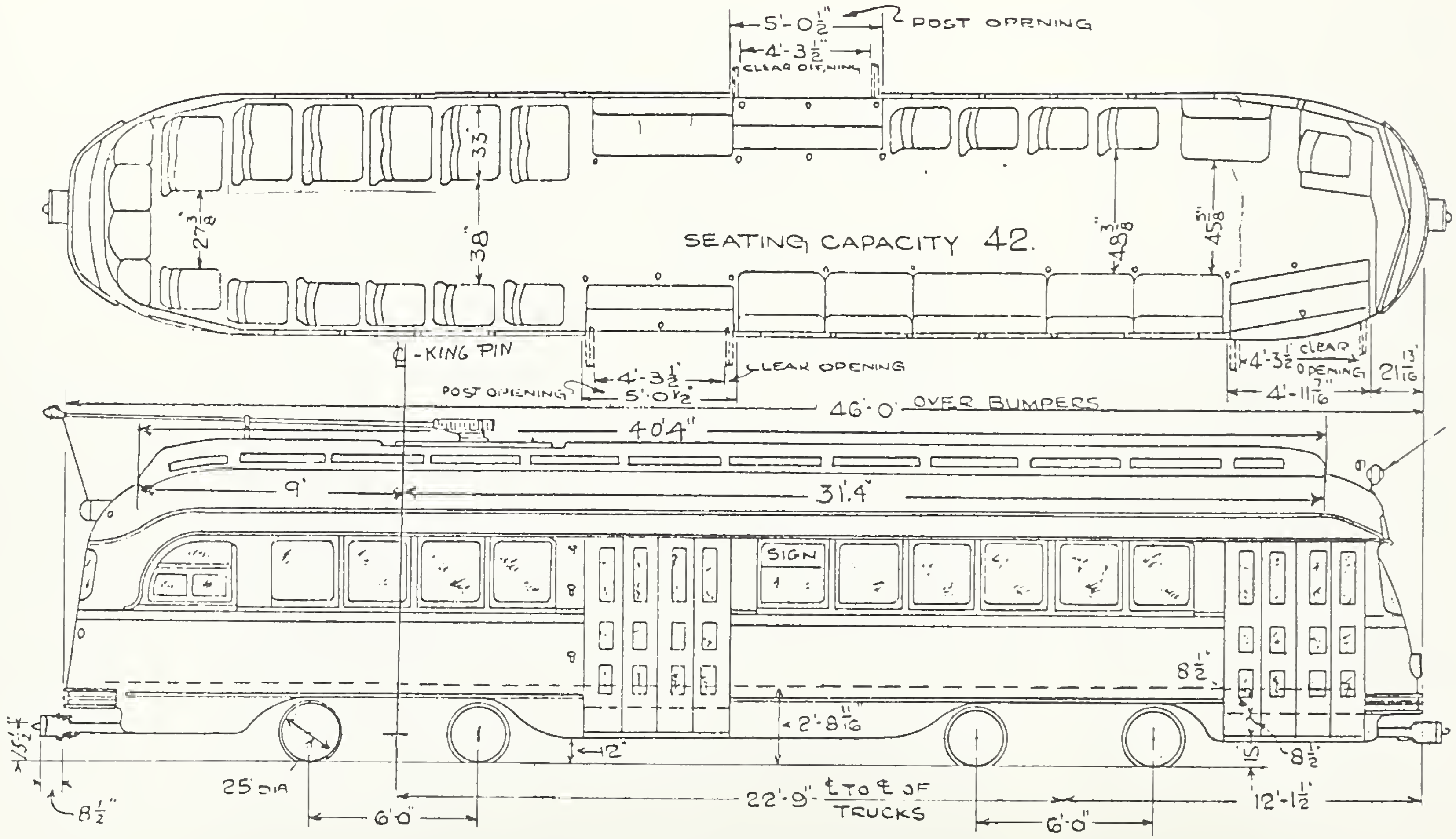


FIGURE 3-2. PCC CAR

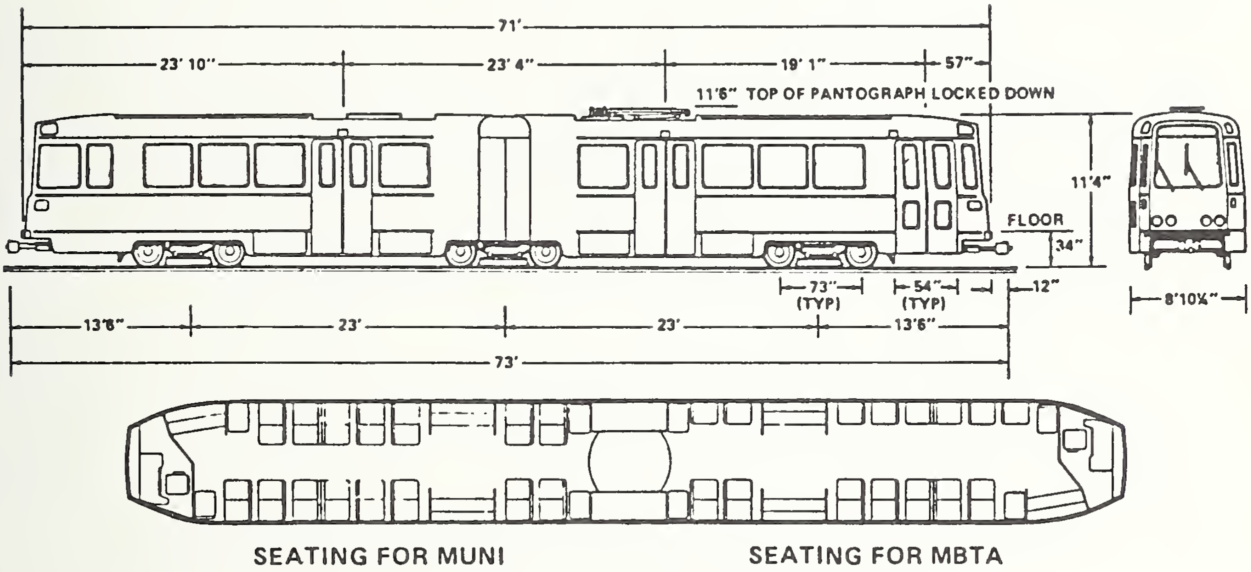


FIGURE 3-3. BOEING LIGHT RAIL VEHICLE

Kawasaki Cars

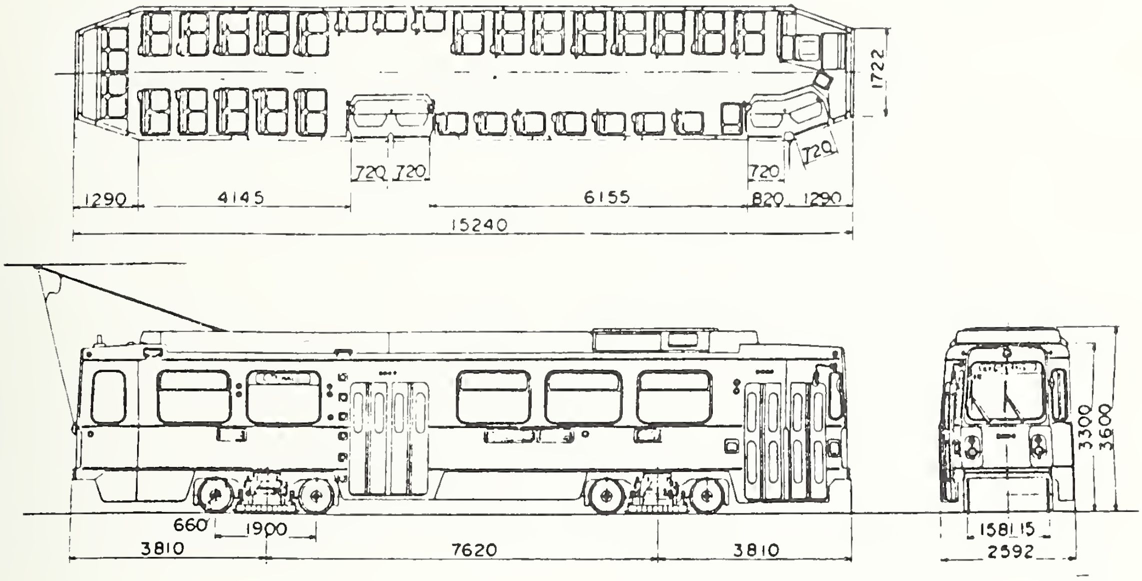
SEPTA Red Arrow Division will replace its bidirectional Brill and St. Louis Car quasi-PCC cars with bidirectional vehicles from Kawasaki, Figure 3-4. These cars will operate on the Media and Sharon Hill lines, 101 and 102. These lines require bidirectional vehicles because the terminals at Media and Sharon Hill are stub-ended. In addition, left side boarding is used at the 69th Street terminal and at Sharon Hill. They therefore require the door arrangement shown because all of the intermediate stops are right side boarding. At the 69th Street terminal, cars use both sides of a platform between the two tracks during rush hours. At Sharon Hill the single track terminus has a platform on only the left side relative to an arriving vehicle. Therefore, accessible vehicles will require lifts on both the sides.

The single-ended unidirectional cars will be used by SEPTA to supplement its fleet of PCC cars on their City Transit Division (CTD). The right front doors are the same on both versions of the cars, so lift installation conditions would be the same on all cars for that particular location. Only one lift is needed on the right side of each accessible vehicle.

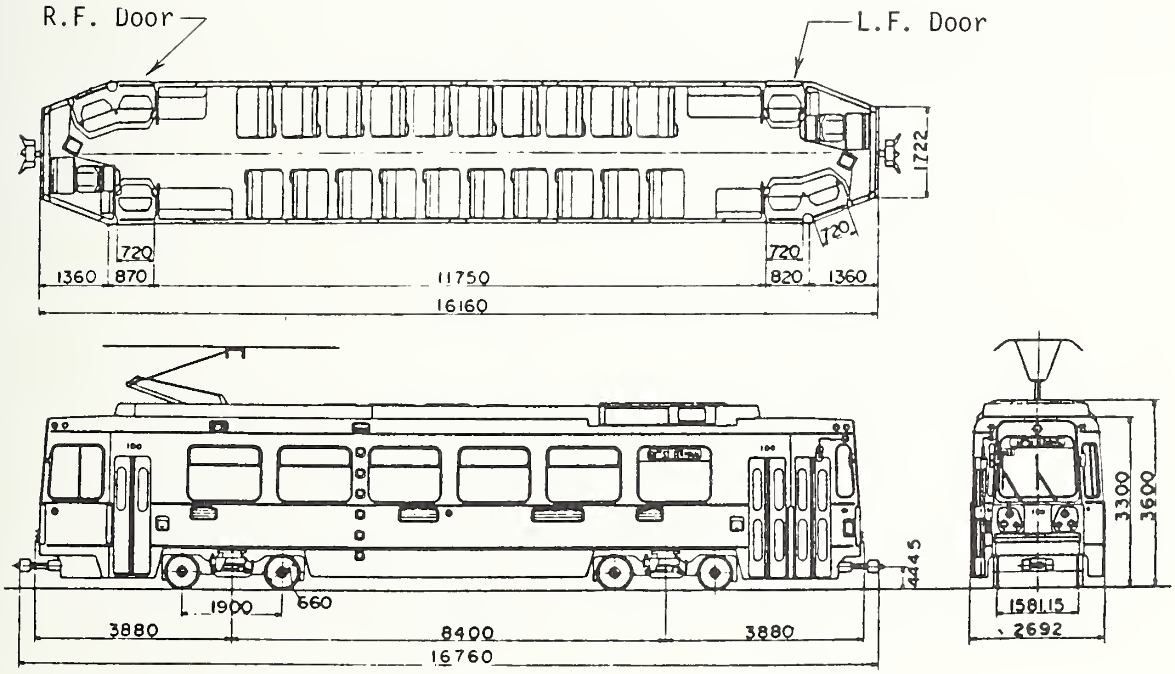
Breda Cars

The Breda Vehicles for Cleveland are similar to Boeing vehicles in arrangement, as shown in Figure 3-5. They are articulated vehicles, with doors on both sides for bidirectional operation. The major difference between the two is that the front right side entrances on the Breda vehicles are not angled with respect to the side of the vehicle, as they are on all of the other LRV's. This may present somewhat easier lift installation conditions, if the end door location is chosen.

Limited information is available on the Breda vehicles at this writing, and this evaluation may be subject to revision when more detailed drawings or the actual cars are available for inspection. Accessible bidirectional vehicles require a lift on both sides.



SINGLE-END CAR



DOUBLE-END CAR

FIGURE 3-4. KAWASAKI LIGHT RAIL VEHICLES FOR SEPTA

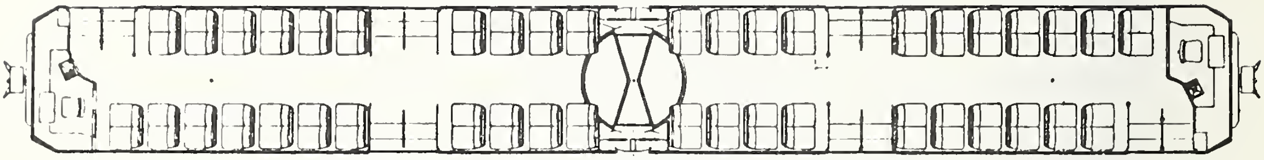


FIGURE 3-5. BREDA LIGHT RAIL VEHICLE - CLEVELAND

3.1.2 Commuter Rail Car Inventory

Commuter rail cars are a considerably more diverse group than light rail vehicles. There are several different modes of operation; Diesel-hauled, push-pull, Diesel self-propelled, and electric multiple unit cars. Conversions from one type to another are not uncommon; for example, EMU cars have been stripped of electrical propulsion equipment and converted to push-pull cars. Some commuter cars are converted intercity equipment, with the original interior arrangement reconfigured to a coach arrangement.

More analysis was required to summarize the commuter equipment even with the very complete rosters available in the RPCA. The final results disclosed that in spite of the many apparently different cars, there are large fleets of a surprisingly few types of vehicles. For example, despite the detail differences between Diesel-hauled, push-pull, and EMU cars, there is a group of vehicles encompassing all three types that were built utilizing the same basic vehicle structure. The commonality of structure could in turn benefit the engineering effort required to install lifts on these vehicles, to the degree that one common location can be agreed upon.

Some commuter lines operate exclusively from high-platform stations, similar to rapid rail systems. These cars are carried through the inventory of commuter rail vehicles for completeness, and to assure readers of this report that the high platform cars have been accounted for correctly.

The commuter rail vehicle rosters were first summarized for each operating authority by road numbers, years built, builder/type and description, and quantities in service. This first summary condensed the rosters from a car-by-car listing to one of more managable proportions, with the loss of little information other than previous owner lineage, mechanical history and editorial notes. The second summary classified vehicles by builder, operating authority, and year, or year and type, when a significant distinction can be made.

Table 3-4 presents the cars by type and population in decreasing order of size, for both high platform and low platform cars. The results show that there are eight numerically large classes of equipment, six of which operate from low or both low and high platforms, and a ninth miscellaneous category, consisting of less than 70 cars of a given type.

TABLE 3-4. ·COMMUTER RAIL VEHICLES IN SERVICE BY POPULATION SIZE, JUNE 1979

MAJOR VEHICLE CATEGORIES Numerical Rank	Operator: Number & Type	Low Platform Only or High/Low Platform	High Platform Only	TOTAL	DATE	Lift Retrofit Comments
1	Metropolitans/Cosmpolitans/GTE MTA: 1188 EMU, 8 GTE	---	1196	1196		Lift Not Required
2	Silverliners/Arrows MBTA: 60 PP MTA: 8 PP NJDOT: 155 PP 334 EMU SEPTA: 311 EMU	868	---	868		Good Candidates
3	Bilevels RTA: 635 PP 165 EMU Amtrak: 12 PP SP: 46 DH	693	165	858		Good Candidates
4	EL Coaches EMU	260	---	260		All Pre-1930, will be retired when Electrification is changed.
5	MTA Push-Pull Coaches (2800 series)	240	---	240		Possible candidates
6	Rail Diesel Cars (RDC) MBTA: 91 DSP MTA: 2 NJDOT: 20 SEPTA: 21 MDOT: 3 Chessie: 15 PC: 15 (11 leased to MTA)	167	---	167	Post 1950	Possible Candidates
7	MTA COACHES DH (1100 Series)	---	87	87		Lift not Required
8	MTA New Haven Cars - DH (2100, 2500 Series)	71	---	71		All pre-1948
9	Miscellaneous	717	---	717		
	TOTAL	3016	1448	4464		

Notes: EMU - Electric Multiple Unit; DSP - Diesel Self-Propelled; PP - Diesel-Hauled, Push-Pull; GTE - Gas Turbine/Electric; DH - Diesel-Hauled, Conventional

The criteria used for the preliminary identification of the candidate commuter cars for retrofit are:

- Number of identical or similar cars,
- Age of each group of a given type, and
- Condition of cars.

A numerically large population of a given type of car is advantageous to a retrofit program for two reasons. First, the one-time engineering costs for both the lift and the car installation can be amortized over the largest possible number of cars, which minimizes the cost per car. Second, it is desirable to maximize the production quantities for one type of lift, if possible, again to reduce the unit cost of each lift. The usual secondary benefits of standardization will also apply, such as reduced spare parts inventories, and less training required for both operators and maintenance people.

The age of each type of car, and hence condition, which is generally related to age, is important to any retrofit program. It is not cost-effective to invest substantial capital in cars with little useful life remaining. A national cut-off date of manufacture of about 1950 emerged from the inventory analysis, when cars were ranked by population size for each type. It was found that all of the large groups of cars were manufactured after 1950, with two exceptions.

A group of 260 EMU coaches for Erie-Lackawanna (4th in population size) were all manufactured prior to 1930. These cars will be withdrawn from service when the electrification is changed from 3000 VDC to 25000 VAC.

The 71 New Haven cars (8th in population size) are part of a much larger fleet of cars which were originally purchased by the New York Central Railroad, and the New York, New Haven and Hartford Railroad prior to 1948. The decreasing number of vehicles indicates that this group is approaching the end of its useful life.

Of the cars manufactured after 1950, very few were small orders that could not be identified as being similar to a larger group. Most of the miscellaneous cars were built prior to 1950.

The most probable candidate commuter cars for lift retrofit, as a result of the preceeding analysis, appear to be:

- Silverliners/Arrows; All post- 1958; 868 cars.
- Bilevels; 1950; 693 cars.
- MTA Push-Pull Coaches (2800 series); 1955; 240 cars.
- Budd RDC's; 1948; 167 cars.

The detailed distribution of the eight most numerous types of commuter cars is shown by type and operator, in Table 3-4. With the exception of the 260 Erie-Lackawanna cars, the four car types identified above are the most numerous low-platform cars.

The validity of identifying only the four above-mentioned groups can be strengthened by examining Table 3-4. To extend the number of retrofit candidate groups by one to include the 71 New Haven cars requires accepting over a factor of two reduction in group population, from 167 RDCs and accepting cars that are already over 32 years old. Both the New Haven cars and the RDCs are declining in numbers, and it seems more probable that the cut-off point would in practice move upward on the list to exclude RDCs, than downward to include the New Haven cars.

The identification of the four types of cars as being suitable for lift retrofit must be considered preliminary, as it is based only on the criteria discussed previously. Up to this point, the technical feasibility of retrofitting lifts has not been introduced into the identification of candidate cars. The technical issues will be examined in Section 5.0.

The significant finding from the vehicle inventory task is that all but three operating systems have vehicles from at least one of the four categories that appear to be good candidates for lift retrofits, based on number of vehicles and age. Systems with cars that probably cannot easily be retrofitted are SEMTA with 37 cars total; PAAC and P&LE (Pittsburgh area), 11 cars; and Los Angeles County RTD, with 8 cars. If it proves feasible to retrofit cars of the four groups with lifts, most of the operators have vehicles with which to begin a retrofit program. However, it must be cautioned that: a) an operator may not have enough candidate vehicles to achieve one accessible car per train; and b) even if there are sufficient candidates on a given system to achieve the one accessible car per train, there may be operational constraints against arbitrarily assigning a retrofitted car in with other equipment.

Table 3-5. COMMUTER RAIL VEHICLES BY OPERATOR AND MAJOR CLASSES

SYSTEM	COMMUTER RAIL VEHICLE TYPES: Metropolitan/ Cosmopolitans (High Platform)	Silverliners/ Arrows	Bilevels (High Platform)	Bilevels	El Coaches	MTA Push-pull Coaches (2800s)	Rail Diesel Cars (RDC)	MTA Coaches (1100s) (High Platform)	MTA New Haven Cars	Miscellaneous	Total Cars	Total Low Platform Cars	Total Retrofit Candidates	Accessible Cars Required as X% of Low Platform Total Cars: 15%	25%	*Denotes possible candidates for lift retrofit. Remarks
1 NJDOT	0	489*	0	0	260	0	20*	0	0	245	1014	1014	509	152	254	
2 RTA	0	0	165	647*	0	0	0	0	0	83	895	730	647	134	183	137 Cab Control Cars
3 SEPTA	0	311*	0	0	0	0	21*	0	0	113	445	445	332	67	111	
4 MTA	1196	8*	0	0	0	240	2*	87	71	51	1665	372	250	56	93	No Cab Control Cars
5 MBTA	0	60*	0	0	0	0	91*	0	0	118	269	269	151	40	67	15 Cab Control Cars
6 SP	0	0	0	46*	0	0	0	0	0	44	90	90	46	14	23	No Cab Control Cars
7 SEMTA	0	0	0	0	0	0	0	0	0	37	37	37	0	6	9	
8 MdDOT/Chessie	0	0	0	0	0	0	18*	0	0	7	25	25	18	4	6	5 Trainsets Now Used
9 PAAC/P&LE	0	0	0	0	0	0	0	0	0	11	11	11	0	2	3	
10 LA Cty. RTD	0	0	0	0	0	0	0	0	0	8	8	8	0	1	2	
PC	0	0	0	0	0	0	15*	0	0	0	15	15	15	2	4	11 RDCs on Lease to MTA
TOTAL	1196	868	165	693	260	240	167	87	71	717	4464	3016	1968	478	755	

Examination of Table 3-5 indicates that many system operators have sufficient cars with which to implement an accessible vehicle program, while confining conversions to one type of vehicle.

NJDOT, RTA, SEPTA, MTA, and SP have sufficient candidate cars from the Silverliner/Arrow, bilevel, or MTA 2800 series coaches to achieve 15% to 25% low-platform fleet accessibility. MBTA has 15 cab control retrofit candidate cars, but would have to draw the remainder from non-cab control cars or from their RDC fleet. MDOT/Chessie has sufficient RDCs to cover their requirement for 5 accessible trains.

SEMTA, PAAC, and LA Cnty. RTD would need to make a car-by-car determination of which cars might be suitable for retrofit. Such a study could best be made as preliminary engineering data becomes available from the study of lift retrofit for the larger fleets of cars.

As mentioned previously, it appears that the RDCs might justifiably be excluded from retrofit consideration, not only because of their age and declining numbers, but also because few operators need to depend on RDCs for conversion. An alternative approach to acquiring accessible cars would be needed for only a few operators, such as the acquisition of new accessible cars, but such an alternative might also be applicable to those operators who so not now have cars that appear to be good candidates for retrofit.

Power Considerations

There are several different characteristics of possible power sources for lifts on commuter rail cars. Unlike LRVs, many electric commuter cars except the RDCs have 3 phase, 60 hertz power available. The ready availability of commercial motors and switchgear for 3ϕ, 60Hz AC makes it probable that the AC supply would be chosen for primary lift power. Table 3-6 lists the available power sources on commuter rail vehicles. The auxiliary power sources may not be useful, depending on the power required when compared with power available.

TABLE 3-6:

CHARACTERISTICS OF ELECTRICAL POWER SOURCES ON COMMUTER RAIL VEHICLES

COMMUTER CARS		POWER SUPPLY CHARACTERISTICS	
		MAIN POWER	AUXILIARY POWER
Silverliner/Arrow	PP	480 VAC 3ϕ 60Hz	32 VDC
	EMU*	220 VAC 3ϕ 60Hz	32 VDC
Bilevels	PP	480 VAC 3ϕ 60Hz	—
	DH	110/220 VAC 3ϕ 60hz	—
MTA 2800 Series Coaches	PP	480 VAC 3ϕ 60Hz	—
Rail Diesel Cars	DSP	—	64 VDC

* The use of primary power at 11000 VAC is not appropriate for lift applications.

3.2 System Operations - Commuter Rail

The minimum acceptable level of accessibility on commuter rail, as mandated by the 504 regulations, is one vehicle per train, which implies the required number of accessible vehicles is equal to the maximum number of trains in service at one time, plus spares. An optimal approach would be to choose a group of cars for retrofitting that was numerically equal to or larger than the number of lift-equipped cars required, to minimize the engineering costs and to standardize on one lift design.

This approach is valid on some systems, but on others equipment cannot be redistributed at will because of operational restrictions, such as electrified and non-electrified zones. In locations such as New York and Chicago where operating authorities have consolidated several formerly private enterprise commuter lines, the equipment is usually kept on its original railroad.

The following operating descriptions are condensed for the purpose of attempting to develop the minimum number of vehicles that would need lift installations to meet the 504 requirements of one accessible car per train. Most operators contacted could not readily supply the number of peak-hour train-sets operated, but rather indicated how they planned to satisfy the 504 requirements. The usual preference is to equip one type or class of vehicle, for example, push-pull cab control cars, in the interest of minimizing engineering and standardizing components. In all cases, peak hour train-sets are fewer than peak hour trains, because the same equipment may make more than one run.

An exact number of cars to be retrofitted could not be developed, but a reasonable estimate of the lowest number of accessible vehicle requirements was established. Based on discussions with operators, it is estimated that 15% to 25% minimum of the low-platform cars will need to be made accessible, as a national percent. This estimate is subject to variation from system to system, because of variations in average train lengths, type of equipment (Diesel-hauled or self-propelled), operational restrictions, and spares required.

Table 3-5 shows the location by operator of cars from the four major low platform groups. It must be emphasized that these four groups appear to be good candidates for retrofit because of their numbers and relatively young ages. Detailed engineering analysis may rule some cars out of consideration in subsequent efforts. Also, the number of cars listed does not necessarily represent the number that must be lift equipped, because the existing accessibility requirements are for one vehicle per train.

New York-MTA and NJDOT

The New York area has by far the largest number of commuter rail vehicles, and the most complex operational restrictions imposed by various considerations. The MTA generally controls service east of the Hudson River and is comprised of several previous railroad operated commuter services: the Long Island Rail Road, the New Haven Railroad (NYNH&H RR) and the Penn Central Railroad, formerly the Pennsylvania Railroad and the New York Central Railroad. Commuter service west of the Hudson River is managed by the NJDOT, comprised of portions of the Erie-Lackawanna Railroad, Penn Central and Central Railroad of New Jersey. Much of the MTA and NJDOT trackage is electrified, but because the lines started out as separate entities there are three different electrification systems. These differences effectively prevent intermixing of EMU equipment; as a result equipment is confined to certain regions. Figure 3-6 shows schematically the two systems, the operating regions, and the type of equipment operated.

A significant condition found only in New York is the operation of commuter rail equipment in 3rd-rail zones. Although operations in the 3rd rail zones are all (with one exception) high-platform, and therefore would not involve lifts, Diesel-powered trains that operate through the 3rd-rail/high-platform zone into low platform zones would be lift-equipped. On the Poughkeepsie line, the electrification extends to Croton North, a low platform station. Electrified operation and high platforms extend only to Croton Harmon. Although there is no valid reason for a lift to be operated on the 3rd rail side of the train at Croton North, or at any other location within the two 3rd rail electrified zones, the lift system must be properly interlocked to prevent lowering a lift onto a third rail.

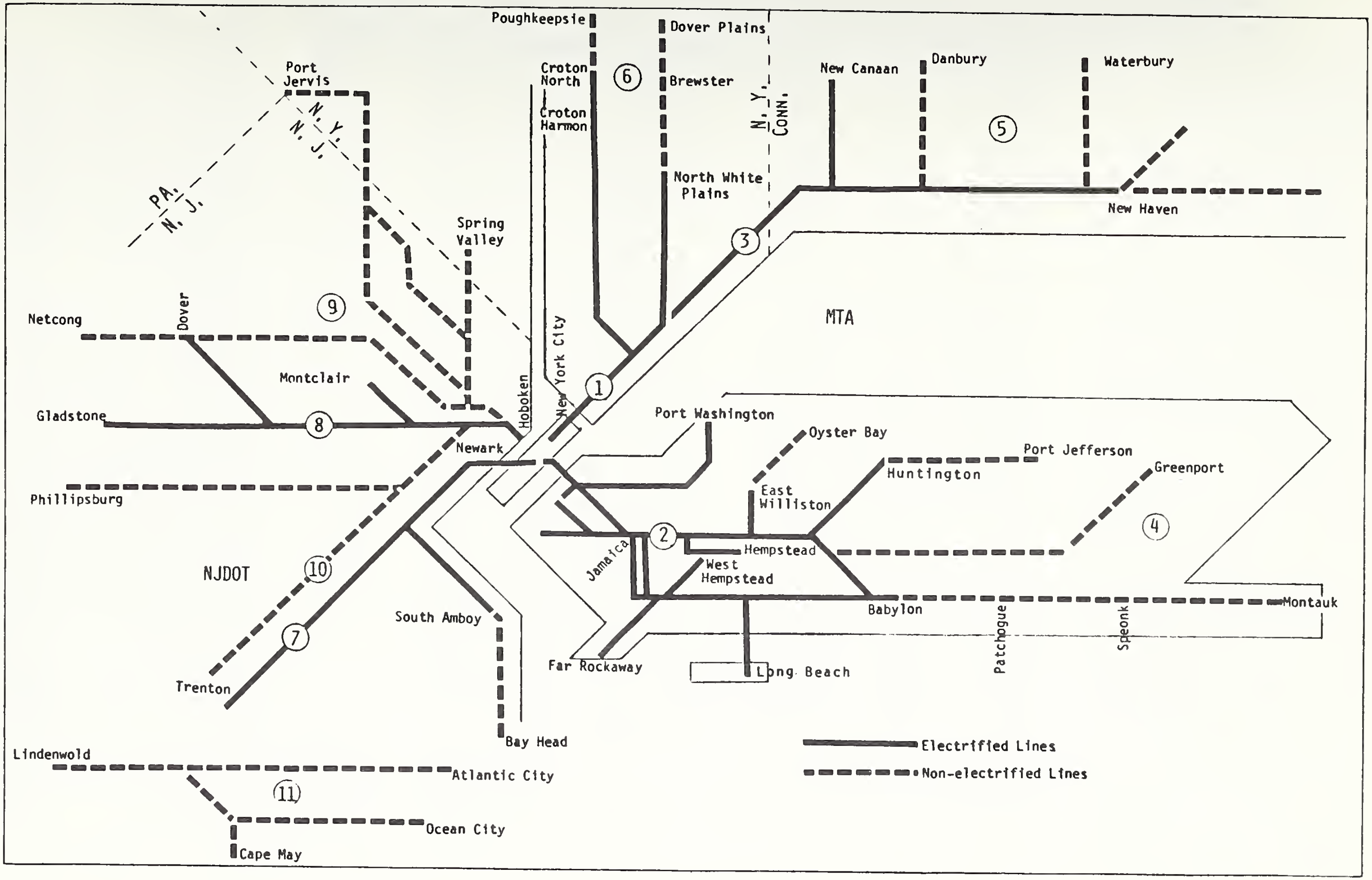


FIGURE 3-6. MTA AND NJDOT COMMUTER LINES

Figure 3-6 shows the New York MTA operations and New Jersey NJDOT operations. There are 11 areas or lines on which the equipment is either unique or different than that of an ajoining area or line. Although some differences effectively prohibit re-assigning cars, accessibility modifications may still be able to be restricted to only one type of vehicle. MTA and NJDOT are separate operating authorities, and do not intermix equipment.

The zones indicated in Figure 3-6 are described below.

MTA

1. All high platforms. Electrified, 600 VDC underrunning 3rd rail. Equipment is 178 M1a Metropolitans and 87 1100 series DH ex-Penn Central coaches. Zone 1 will be electrified to Brewster, and platforms will be converted from low to high level.

2. All high platforms. Electrified, 600 VDC overrunning 3rd rail. Equipment is 766 M1 Metropolitans.

3. All high platforms. Electrified, 11000 VAC 25 Hz catenary. Equipment is 244 M2 Cosmopolitans, which operate into NY City Grand Central Terminal on 3rd rail, zone 1. Zone 3 will be electrified to Danbury.

4. Low platforms. Non-electrified. Equipment is 2700 and 2800 series push-pull coaches on Oyster Bay, Port Jefferson and as far as Speonk; 2900 series Diesel-hauled coaches to Greenport and Montauk. Most trains originate at Jamaica, and therefore run partially within zone 2, which is 3rd rail electrified.

5. Low platforms. Non-electrified. Equipment is RDCs and 2500 series ex-New Haven coaches.

6. Low Platforms. Non-electrified. Equipment is RDCs; and Diesel-hauled 2000 series, 2160-3276, and 2800 series coaches.

NJDOT

7. Low Platforms. Electrified 11000 VAC 25 Hz catenary (will be converted to 25000 VAC 60 Hz as part of NE corridor project). Equipment is 146 EMU Arrows.

8. Low Platforms. Electrified 3000 VDC catenary (will be converted to 25000 VAC 60 Hz. Equipment is currently 260 Erie-Lackawanna EMU coaches, which will be retired when the electrification is changed to AC. Arrows on lease to Amtrak and MDOT will be recalled for service on this line.

9. Low Platforms. Non-electrified. Equipment is all push-pull.

10. Low Platforms. Non-electrified. Equipment is both push-pull and conventional Diesel-hauled coaches; will be replaced with new push-pull stock eventually.

11. Low Platforms. Non-electrified. Equipment is all RDCs.

The most numerous MTA coaches, the 240 2800-series ex-Long Island Rail Road coaches, built by Pullman Stnadard from 1955 through 1963, are presently operated in two of the three non-electrified zones of the MTA, zones 4 and 6 of Figure 3-6 . The possibility exists that accessible service could be implemented on all lines while restricting accessibility modifications to this one type of car. There are some trains now run with RDCs that would require a decision to either retrofit RDCs or to replace them with other accessible equipment.

NJDOT has the largest fleet of Silverliners/Arrows, both EMU and PP, with which to begin implementing vehicle accessibility. They have relatively few older coaches with which to contend, and they plan to eventually replace all older equipment with push-pull cars. The 20 RDCs now operated in zone 11, Figure 3-6 , would require special consideration, as mentioned above, either conversion or replacement. A significant problem for NJDOT exists in zone 8, Figure 3-6. The cars now in service on this segment are 260 Erie-Lackawanna cars built ca. 1930.

Philadelphia - SEPTA

The Southeastern Pennsylvania Transportation Authority operates commuter lines radiating from Philadelphia, comprised of former Pennsylvania Railroad and Reading Railroad operations. Most of the routes are fully electrified, as Figure 3-7 shows. Substantially all of the service is provided by Silverliners, some running as single units, some as married pairs. During rush hours, longer trains of Silverliners are assembled and run, along with trains of older cars. Non-electrified lines are usually operated with RDCs, with one push-pull train of older equipment on the line to Pottsville.

The large number of EMU cars and the operating flexibility that they confer make SEPTA reluctant to equip only part of the fleet for accessibility. It would become necessary to ensure that one of the special cars was on each train, and probably in a specific location within the train. SEPTA shortens and lengthens trains throughout the day to match capacity to demand,

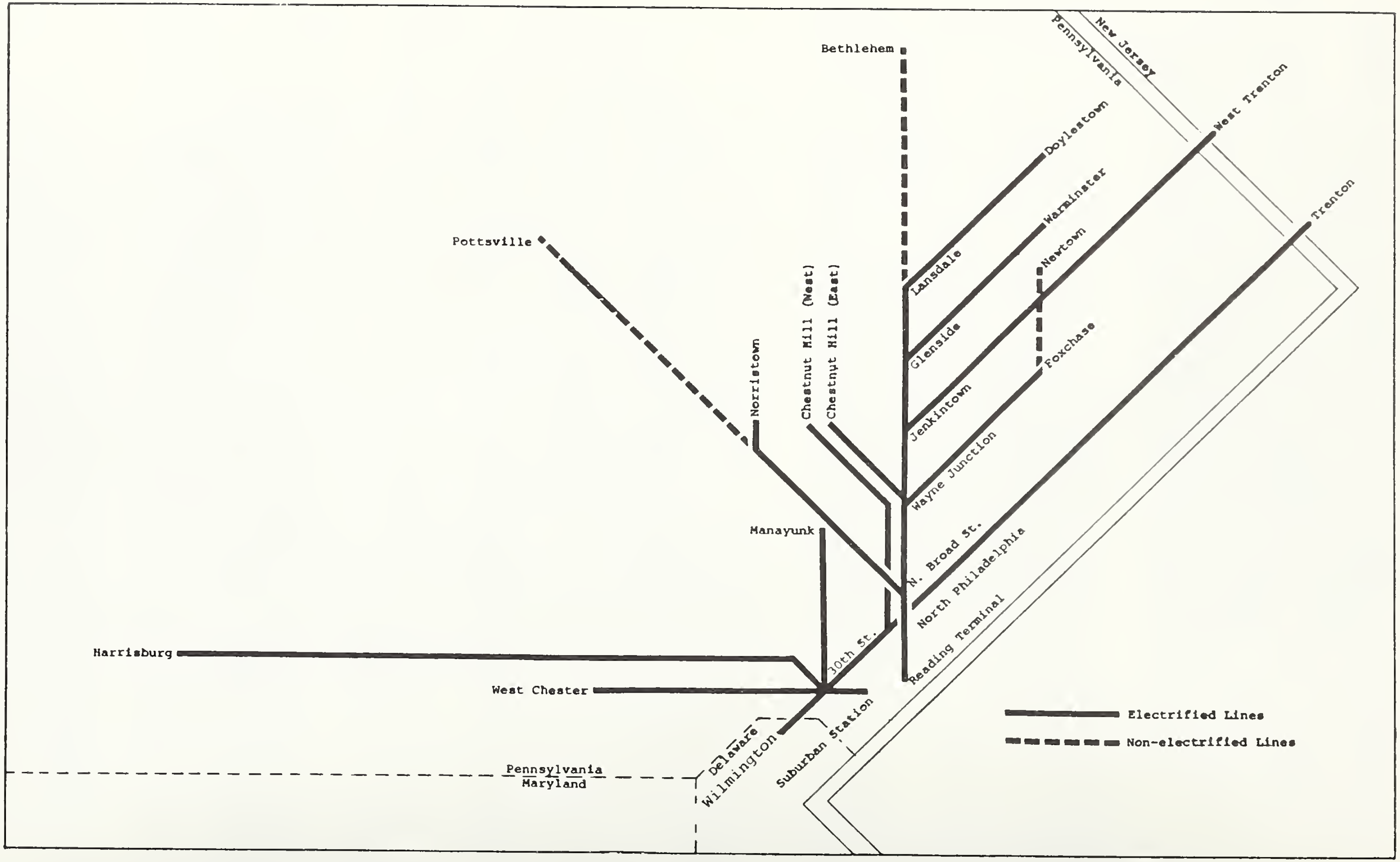


FIGURE 3-7. SEPTA COMMUTER LINES

to conserve car-miles and energy, and to make idle cars available for inspection and servicing. If only part of the fleet was accessible, those cars would necessarily accumulate higher milages because they would also have to be run off-peak as well as during rush hours to provide accessible service. At this writing SEPTA is of the opinion that all EMU vehicles would have to be made accessible for it to be feasible for them to provide accessible service.

The major decision required on the SEPTA system concerns operations on non-electrified lines, now operated primarily with RDC's. These lines would require making RDCs accessible, or replacing them with other accessible vehicles.

Chicago RTA

Chicago RTA has only two basic types of equipment with which to contend, low platform push-pull bilevel cars, and high platform EMU bilevels. None of the various push-pull fleets has cars better suited for lift installation than any other, hence there is no strong reason to reassign cars from one route to another. Quite the contrary, it is undoubtedly better to leave the car assignments as they are, because operations are contracted with eight private railroads in the area. Train crews are most effective with equipment with which they are familiar.

Chicago presently considers the cab control cars to be the preferrable location for accessibility modifications, although that location would still present operational problems in aligning an accessible car with the accessible zone on platforms. Figure 3-8 shows the Chicago RTA commuter lines. As all lines are presently operated with push-pull equipment (except for the electrified lines which are EMU equipment) the percent control cars to total car fleet is in the required ratio for normal operations. If the control cars are selected for accessibility retrofit modifications, one accessible car per train is assured. Approximately 22% of the RTA cars are cab control cars.

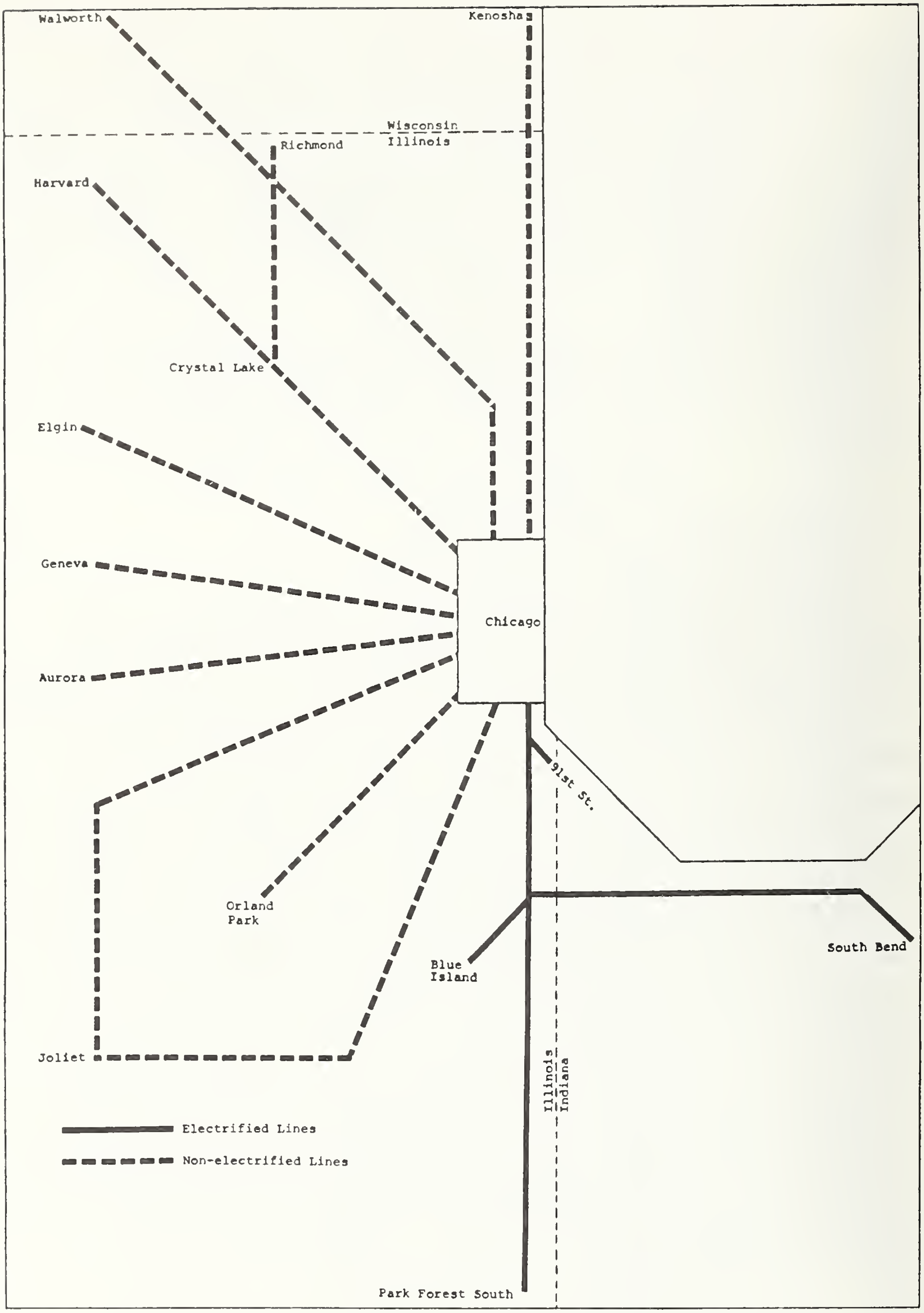


FIGURE 3-8. RTA COMMUTER LINES

Other Systems

The remaining communter systems are smaller than those previously discussed, and except for MDOT, usually do not have equipment - imposed operating restrictions. As a result, most of the smaller systems could achieve fleet accessibility by retrofitting just one type of car. Unfortunately, all systems except MBTA have only RDCs from the group of candidate cars for retrofit, or no cars from a candidate group. (SP operates bilevels, but is currently exempt from the accessibility requirements of Section 504 because it does not receive Federal aid. As this situation is subject to change, the SP cars have been included in all tables and discussions in this report.)

MBTA has 60 new push pull cars of which 15 are cab control cars. They are presently planning to convert their 87 RDCs to push-pull cars, with about 25% to be cab control cars. However, if accessibility modifications were restricted to the 15 control cars of the 60 new cars, there would not be sufficient accessible cars.

MDOT is currently using leased Arrows from NJDOT, but their own fleet consists of 18 RDCs and 7 miscellaneous DH coaches. MDOT is studying the possibility of making RDCs accessible, and may proceed independently with retrofit.

Three systems, SEMTA, PAAC, and LA Cnty. RTD will need special consideration for accessible cars. Although they do not now have cars from one of the groups identified as good retrofit candidates, it is possible that a retrofit lift package developed for one of the candidate groups might be adaptable to cars of these three systems. Alternatively, in view of the age and dissimilarities of the existing cars, it might be more practical to procure new accessible cars to add to the existing fleet.

3.3 Commuter Rail Cars

This section describes the major groups of commuter cars. Illustrations are provided as well for reference, because later discussions on lift retrofits focus primarily on the car mechanical configurations that now exist. As mentioned previously, high platform commuter cars are included only for completeness.

Silverliners/Arrows

Discussion with the builders and operators confirmed that several subgroups comprise the single largest group of low platform commuter cars, although built by four companies for four operating authorities over the period from 1958 to the present. Figures 3-9 through 3-11 show cars known variously as Silverliners, Arrows, or just commuter coaches, that are fundamentally very similar in construction and dimensions. There are 868 cars represented by these three figures (Figs. 3-9 to 3-11), which are structurally similar in the vicinity of the end steps. There are detailed variations that will be documented in the following section, but two significant ones are readily apparent from the figures.

First, many of the cars are always run as married pairs, Figure 3-10. To provide for E&H access to what amounts to a single 190 ft. vehicle, lifts would be required on only one of the cars. The second significant feature, apparent in Figures 3-9 and 3-10 is the center door or door plug that exists on most of the cars. If doors are provided, they are used only at high level platforms. It is apparent that lifts serving these doors would not have to form steps. This aspect will be developed in detail later.

Figure 3-11 shows Pullman-built cars ordered by NJDOT and MBTA. These are locomotive propelled push-pull cars, not electric MU as the preceeding cars. Recent orders for cars of the Silverliner/Arrow type do not have visible door plugs, but the cars are structurally ready to receive center doors by removing the skin at the door opening.

The NJDOT push-pull cars of this type are distinguished from the majority of the cars by having end doors designed for step-entry only, not level entry. It will be seen in later discussions that low doorways cause an operational problem for lifts at those locations, because standing lift patrons can impact the top of the doorway unless precautions are taken.

Bilevels

The second largest group of similar cars is the 647 bilevel or gallery cars operated by the RTA in Chicago, with the only other examples being the 46 bilievels on the Southern Pacific in San Francisco - San Jose commuter service. Figure 3-12 shows the general arrangement of the 693 bilevels operated at low-level platforms. (The high-platform Illinois Central electric MU cars, now owned and operated by RTA, are shown in Figure 3-13

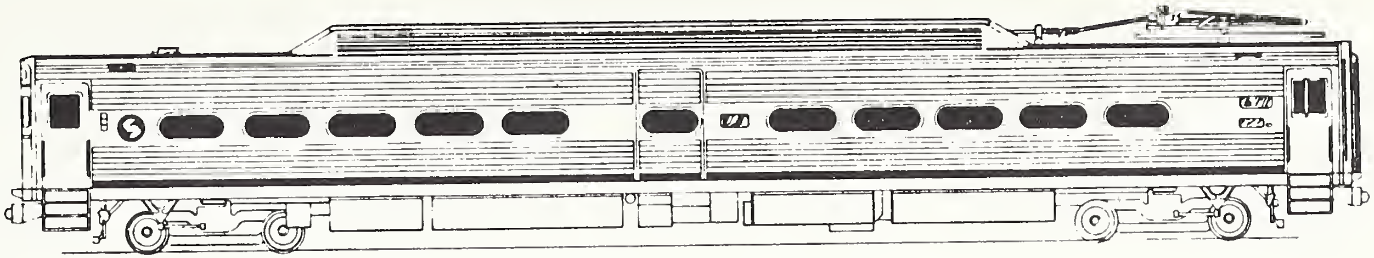


FIGURE 3-9. SILVERLINER IV - SEPTA

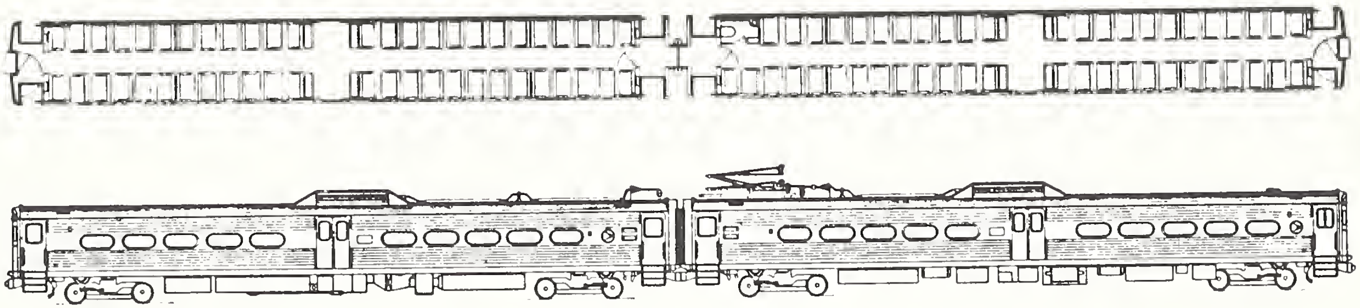


FIGURE 3-10. ARROW II, MARRIED PAIR - NJDOT

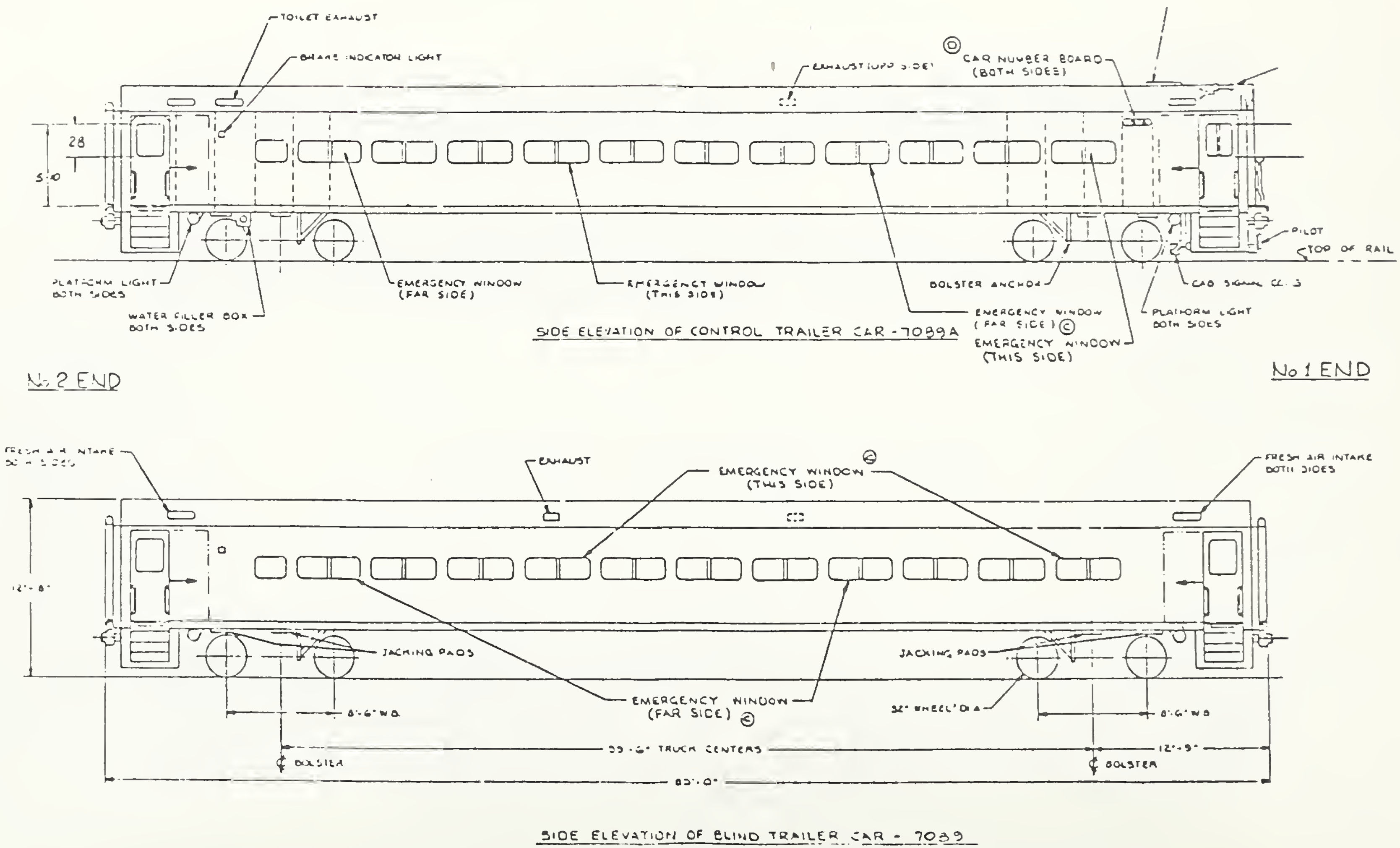


FIGURE 3-11. COMMUTER COACH - NJDOT, MBTA

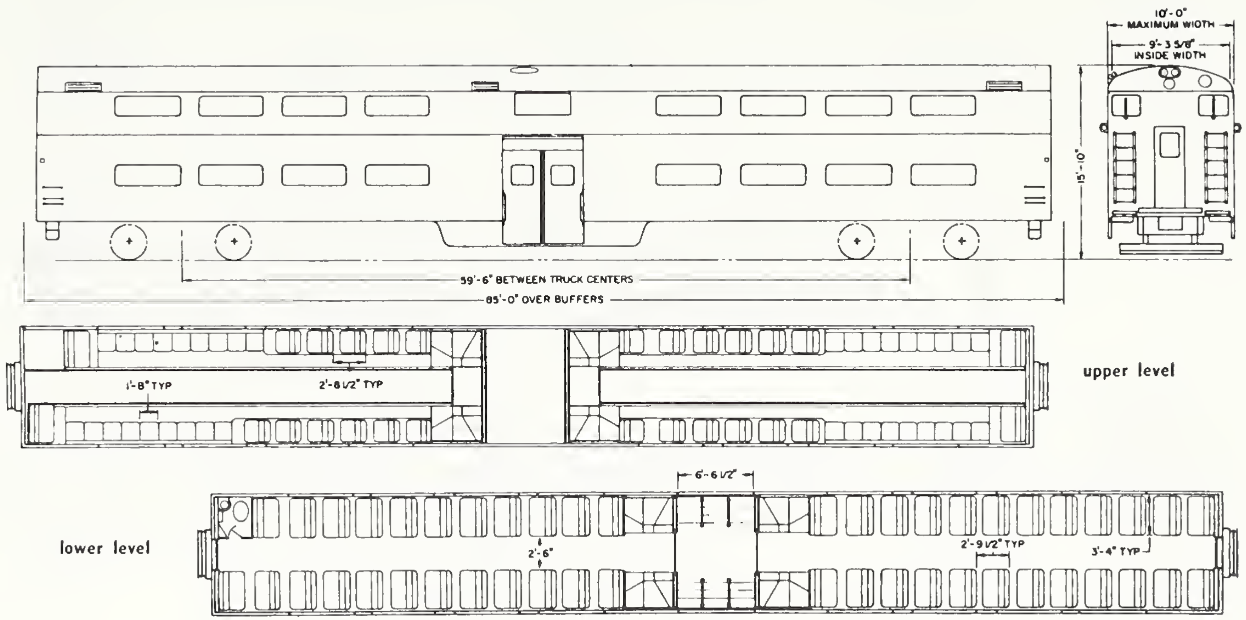


FIGURE 3-12. LOW PLATFORM BILEVEL COMMUTER CAR - RTA

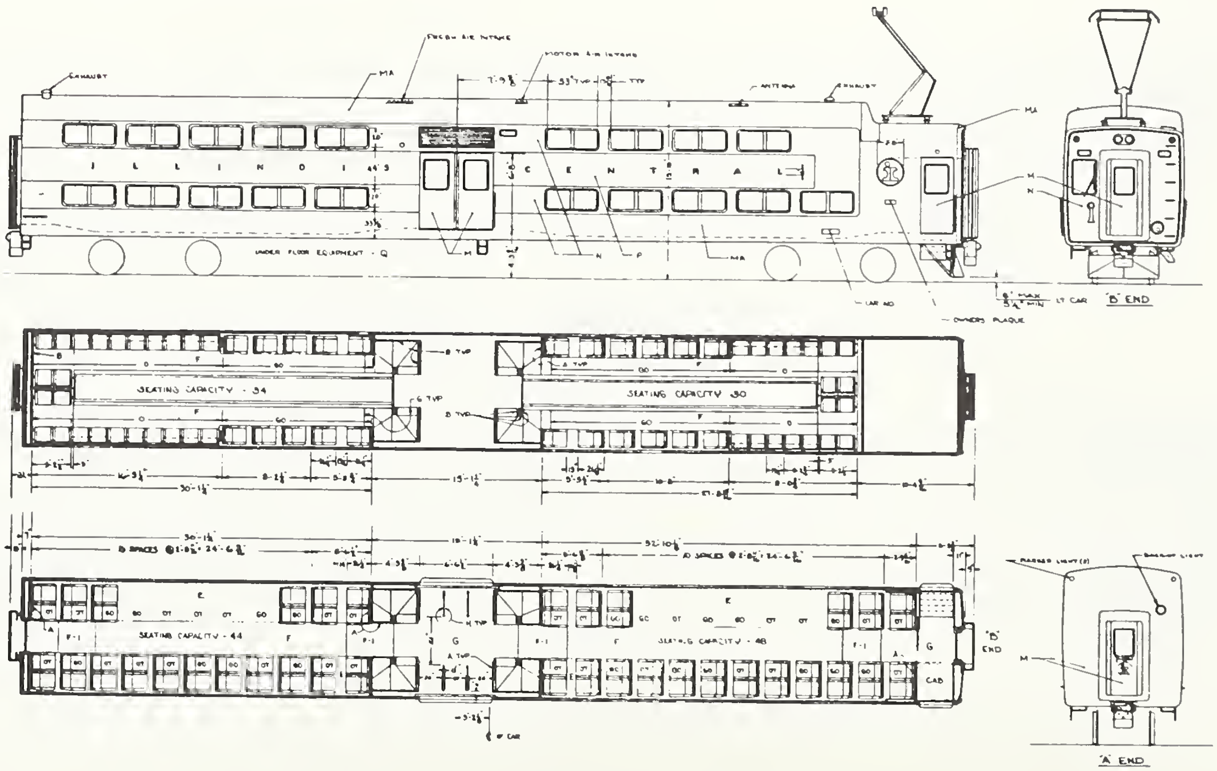


FIGURE 3-13. HIGH PLATFORM BILEVEL COMMUTER CAR - RTA

to identify this group of 165 cars. Lifts are not required on high platform cars, hence they are not included in the 693 low-platform total). The 647 RTA low platform bilevels are all push-pull cars, whereas the 46 SP cars are not. Some are rest-room equipped, however, the rest-room is always at the end of a car, never adjacent to the center doors. As with the NJDOT cars just mentioned, all of the bilevels have low doors intended for step entry only, and the same considerations apply.

MTA Push-Pull Coaches

The MTA push-pull coaches are 1950s Pullman cars that are being converted to push-pull from their original electric MU arrangement. The ends are all identical in construction in the step area. They do not have provision for center doors.

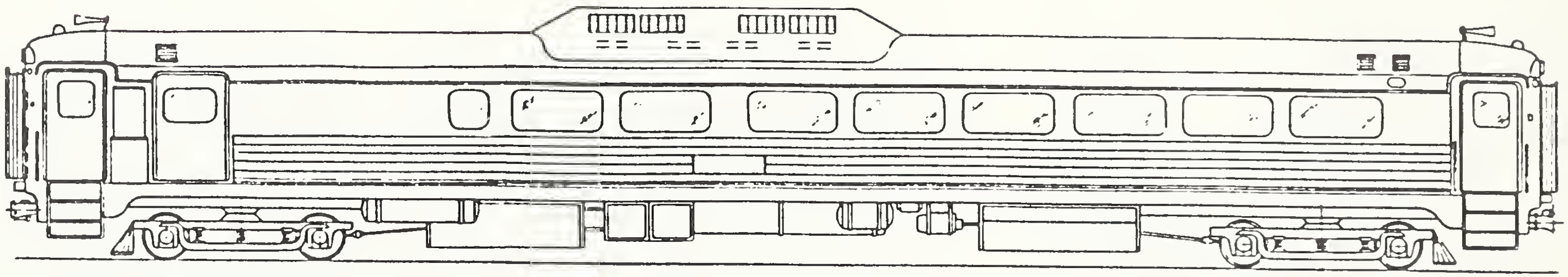
Rail Diesel Cars

The smallest significant group of low platform vehicles is the 167 remaining RDCs of the approximately 400 built by Budd from 1949 through 1962, Figure 3-14. The MBTA plans to convert its RDCs to non-powered push-pull coaches. MBTA plans to retain most indefinitely, which is technically possible because they are stainless steel construction.

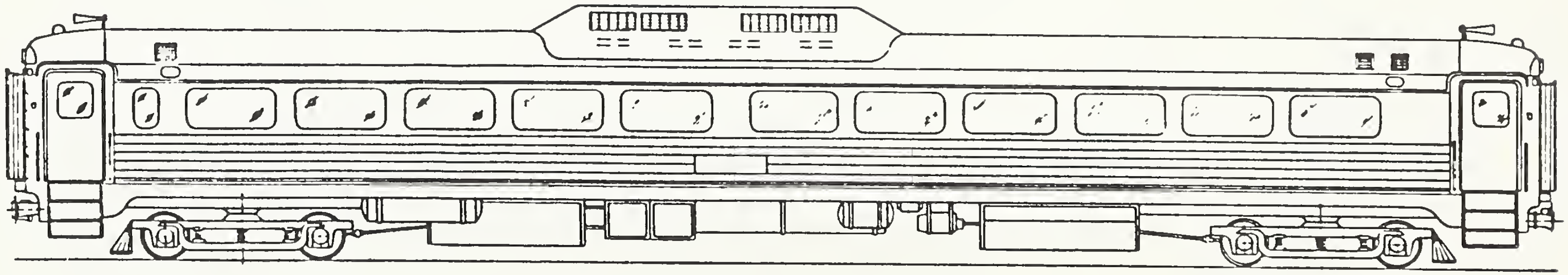
The newest generation of Diesel-powered self-propelled commuter cars to be built by Budd are designated SPV-2000. They are generally the same body configuration as the electrically-powered metroliners and non-powered Amtrak Amcoaches, Figure 3-15. Although there are only ten SPVs now on order for Connecticut DOT, they are included here because it is believed they may eventually be numerically significant. The existing ten SPVs are being built without special accessibility features, although future orders could be accessible.

Metropolitan-Cosmopolitan (High Platform Only)

The single largest group of similar cars is operated by the New York MTA. The 1196 Metropolitans, M1 and M1a, and Cosmopolitans, M2, are all high level platform, and are included here only for completeness, Figure 3-16. There were 8 gas turbine/electric cars built to the same configuration as the Metropolitans. The 4 GE GT/E cars are now standard EMU cars, without turbines, and the 4 Garrett GT/E cars are out of service at this writing.



RDC - Baggage compartment/coach



RDC - 1 Full coach seating

FIGURE 3-14. BUDD RAIL DIESEL CAR (RDC)

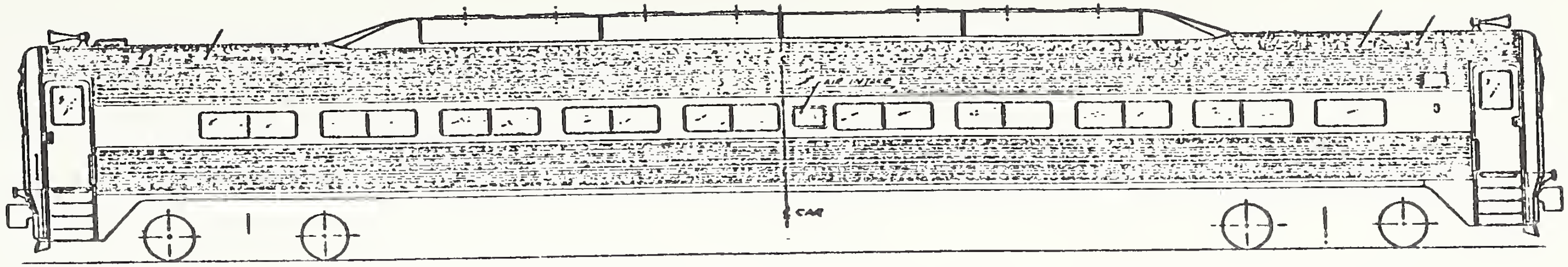


FIGURE 3-15. SPV-2000

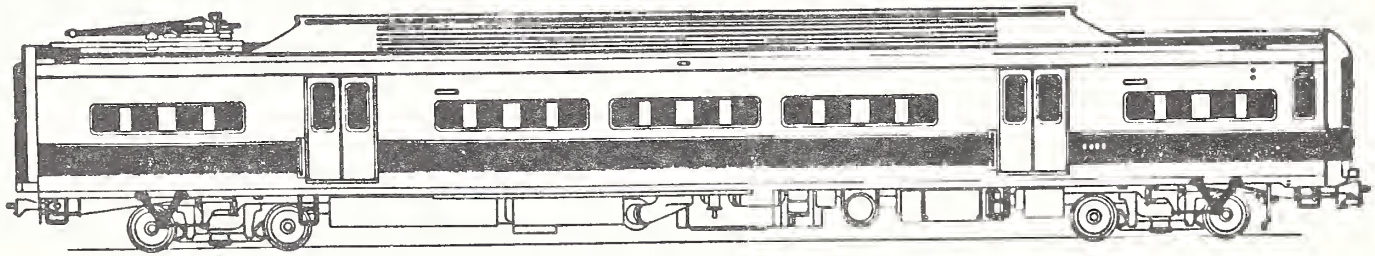


FIGURE 3-16. METROPOLITAN/COSMOPOLITAN - MTA

MTA Coaches (High Platform Only)

This group of coaches are now operated only on lines that have all high platform stations, although they have the conventional high or low platform arrangement, a trap door for high platforms over the stepwell. They were not included in this study.

4.0 EXISTING LIFT TECHNOLOGY

The second phase of this project was an examination of existing bus lifts. There were two broad objectives of this phase. The first was to determine the nature of operating experiences to date and the relevance of those experiences to rail installations. The second objective was to determine the generic characteristics of each lift as they related to rail applications.

Lifts now in service on transit buses are all of the type termed passive. Passive lifts are those which are not moved in any way for use by ambulatory patrons; they may or may not be steps in the passive mode. In contrast, active lifts must be operated at every stop, either as lifts, or just to clear the doorway to permit access by ambulatory patrons. Active lifts are now used only on private vehicles, or specialized services. This project was directed at an examination of only passive lifts.

This section looks first at the operational experience to date of lifts on buses. Then, in preparation for examining lift applications to rail vehicles, the operating concepts of each lift are classified into one of three generic types. The last portion of this section is a description of the operation of each passive lift currently in service or under development.

4.1 Operational Experience on Buses

The review of lift experience on buses disclosed a number of problem areas, as might be expected with a rapidly evolving technology. The only strictly bus-related problem concerns the requirement and degree of difficulty in maneuvering the bus to the correct lateral distance from a curb or other obstruction. Rail vehicles, on the other hand, will experience a corrollary problem, which is a complete inability to maneuver laterally to suit lift extention requirements. Most of the problems do not appear to be strictly bus-related, and therefore they could reappear in rail applications unless steps are taken to eliminate them. The most common problems encountered with early lifts are discussed below.

The most common problem with lifts was downward drifting of the unit when stowed. This problem quickly became apparent with early lifts that were held up and stowed only by trapped hydraulic fluid. Most recent versions of lifts that are susceptible to drifting are mechanically locked. One approach, for example, is spring-engaged, pneumatically withdrawn pins that immobilize the lift when it is not in use.

Parallel with drifting problems, which were caused by the inability to keep hydraulic fluid trapped indefinitely in a portion of the circuit, were hydraulic system leaks. These were caused by road shock and vibration and mechanical misalignment that caused seals to wear and leak. Also, leaks were found to occur because of seals that had dried out due to infrequent operation. The continuing improvement in designs has reduced seal wear, and seals can be prevented from drying out by operating the units on a regular basis, such as at the start of a shift.

The most difficult problems are caused by the lift exposure to the environment. It was found that both mechanical and electrical components need improved protection from road dirt, water, snow and ice. In some cases, sensitive micro-switches became inoperative due to dirt, and units with exposed tracks were susceptible to rapid dirt accumulation in the tracks which resulted in accelerated wear.

All lifts examined use sensitive edges of some form to stop the motion of the lift when it encounters an object. The required sensitivity seems to necessarily result in an edge or device that is not as rugged as the remainder of the lift. As a result, sensitive edges are prone to more rapid deterioration and failure than the remainder of the lift. Sensitive edges can also be damaged if run into curbs by an operator.

Most of the existing lifts are powered with sufficient force to partially lift the corner of the bus if the downward sensitive edge or sensor fails, or if the sensor fails to contact the ground before some other portion of the lift. If sufficient downward force is applied to the lift, it can be permanently distorted, resulting in misalignment, and possibly causing jamming during operation. Misalignment was mentioned previously as one cause of excessive seal wear and hydraulic leakage.

Corollary problems are also caused by lift installations, particulary in retrofit situations. Doors usually need to be widened and modified to interface with the lift unit; and bus structural improvements may be required to adequately carry the weight of the lift unit. All retrofitted units to date have been installed in bus front doors, but bus approach angle is reduced by some front door lift installations. Front door lifts are particularly vulnerable to damage in collisions; the situation is aggravated if lift installation reduces the structural integrity of the frame or bumper.

A third type of problem encountered is operational problems. Some are institutional; others are caused by existing lift designs. The problems are being actively addressed by the lift manufacturers. The lift controls are judged to be too complicated by some individual operators because of the number of controls, or sequence of operation. Some lifts are suitable only for wheelchair patrons, but not ambulatory handicapped, because no handrails are provided; on those lifts with handrails that are nominally suitable for ambulatory persons, a standing lift patron can strike the top of the doorway when being lifted. This is a retrofit problem, and need not occur on new installations if door height is increased along with the other modifications necessary for lift installation.

Not all lifts are positively prevented from being stowed when a passenger is on them. Some designs incorporate a weight sensor to detect the presence of a person on the lift, and use that information to prevent the platform from being stowed. Others use two separate switches that must both be activated and held to stow the platform. This is a common method of guarding against accidental operation of a device in many situations. A report by the Municipality of Metropolitan Seattle found the ability to fold a platform with a passenger on it to be undesirable, and excluded those lifts from use on the Seattle System. (34)

Center door lift installations were initially less acceptable to some users and operators than front door installations. Acceptance is growing as experience is gained with center door lifts. There are some state and/or system operator imposed restrictions against a driver leaving the operator's station while on duty. However, present system operators with center door lifts report no unresolved conflicts with such restrictions.

The ramp angle on the edge of some lift platforms is too steep for some wheelchair users. This is an acknowledged problem that is being addressed by the manufacturers affected. They are trying to either reduce the platform thickness, or lengthen the ramp portion, or a combination of the two approaches.

The problems encountered with lifts are not shortcomings in the concepts of operation of a design, but rather concern the execution of details of the design. It appears that the transit environment is harsher than that which the manufacturers initially anticipated. Most manufacturers of lifts have now gone through more than one iteration in design, and the state-of-the-art is definitely improving.

The following sections will examine the generic operating concepts of lifts, and then the specific kinematics for each manufacturer.

4.2 Description of Lift Operating Concepts

At this writing there are nine manufacturers with passive lift designs in various stages, from conceptual design through hardware deployment. The study of lifts and their operation disclosed that there are only three basic concepts that existing lift manufacturers are developing. Figure 4-1 schematically shows the three approaches.

The first and most common method of operation is to convert the steps to the lift platform, and then to raise and lower the platform. It is significant to observe that the step-to-platform mechanism is independent of the elevating mechanism. This means that changes in the step-to-platform mechanism, such as might be required for rail applications, need not alter the elevator portion of the package. Conversely, changes to the elevator mechanism, to gain more range, for example, do not require alterations to the step-to-platform mechanism.

All but one of the lifts in the first category of Figure 4-1 raise and lower their platforms vertically, in the manner of an elevator, without any lateral component. The exception, EEC, uses a parallelogram approach which moves the platform on an arc. It is therefore a sub-class of the first category (step-to-platform conversion) having features in common with the second category, (Lift-U) and one lift of the third category (Budd), which are discussed in the following paragraphs. The latter two mentioned lifts also utilize parallelogram mechanisms which move the lift platform on an arc, not vertically.

The first advantage of some parallelogram arrangements is that they will not drift downward in the step or platform configuration as will other lifts, because of the slight rise from the rest position that is necessary before the lift begins to decend. The second advantage is their ability to extend over structures that cannot or preferrably should not be removed. In buses, it becomes possible with lifts such as EEC or Lift-U, to leave a strut in place to strengthen the right front corner. Vertical path lifts require that the bumper and its supporting structure be cantilevered from the back of the lift elevator shaft to the right side of the bus. It will be shown in section 5.0 that the ability to extend over structure has advantages in rail applications because certain commuter rail vehicles have structural members that cannot be removed.

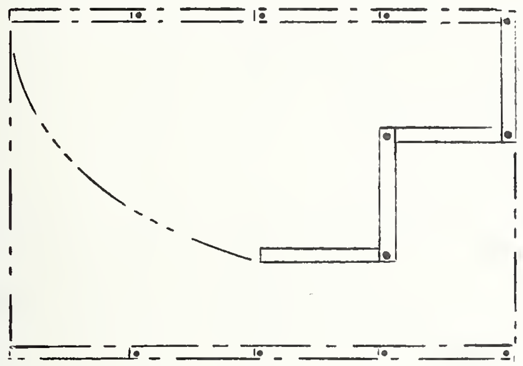
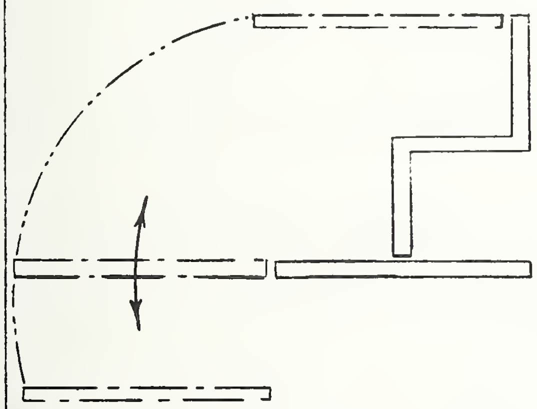
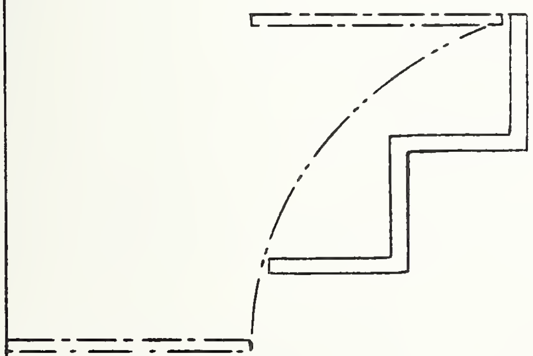
1 	STEP-TO-LIFT CONVERSION Steps convert to lift platform, usually with some form of parallelogram mechanism. Vertical movement is provided by some other means, completely independent of platform formation mechanism. Ex: GM, Transilift, TDT, Vapor (EEC moves out and down on an arc, not vertically)
2 	PARTIAL STEP-TO-LIFT Some portion of the steps are also part of the lift. This is an intermediate approach between full step conversion, and completely separate lift platform. Ex: Lift-U
3 	LIFT INDEPENDENT OF STEPS The lift platform is completely separate from the steps, and is not stowed as part of the steps. Some can serve either side of a vehicle. Ex: Austin, Budd, Transport Canada

FIGURE 4-1. BASIC APPROACHES TO E & H LIFT MECHANISM KINEMATICS

The second category of Figure 4-1 is of significance because the lift platform is stored intact, and although part of it is used as a step, the platform does not form steps. This is a simplification that potentially can be exploited to control maintenance cost, if the remainder of the mechanism is not so complex as to offset gains in platform simplification. Although Figure 4-1 shows the platform stored at the lowest step location, this is not an inherent limitation of the concept.

This approach is possibly of value in applications where structural or other constraints prohibit the installation of the vertical lifts of the first category. As previously mentioned, the parallelogram mechanism approach used by Lift-U also has the ability to extend over vehicle structural elements that should remain in place.

The third category lifts in Figure 4-1 are those that do not alter the conventional steps in any way. Rather, the lift platform (if there is one) is stowed out of the path of ambulatory patrons. All of these are currently in the developmental stage; none are yet deployed. The advantages of lifts in this category are that changes to the vehicle for lift installation can be greatly minimized.

It is instructive to have the lifts categorized by generic concept types as illustrated in Figure 4-1, because it is then easier to examine lift applications to rail vehicles, which are described in Section 5.0. The identification of generic types of lifts that can possibly be retrofitted, instead of specific brands, could allow more latitude in working with suppliers in a hardware lift retrofit project.

Table 4-1 lists characteristics of existing lifts for specific models. The most significant characteristic in terms of rail applications is the universal use of hydraulic power to supply the primary lifting force. The peak power required is as high as 3 hp, which could place restrictions on the sources of power available on rail vehicles. As a minimum, a motor-pump unit may be required to convert electrical energy to hydraulic. Auxiliary electrical power is required at much lower levels to actuate valves and relays. Only one lift requires auxiliary air.

All units now provide a manual method of retracting and stowing the lift, a prime requirement for rail service. Most of the remaining characteristics would be subject to change for rail installations. Although only one lift is shown for each manufacturer, several offer more than one model.

TABLE 4-1. CHARACTERISTICS OF EXISTING LIFTS

CHARACTERISTIC	MANUFACTURER					
	EEC	GM	LIFT-U	TDT	TRANSILIFT	VAPOR
Weight, lbs	650-700	600	620	550	700	600
Width, in.	34½	50	48	50	39	48½
Platform, L X W, in.	40 x 34	35 3/4	48 x 42	50 x 34	43 x 33	50½ x 34
Capacity, lbs.	600	600	1000	600 cont 1000 max	600 cont. 1000 max.	600 cont 1000 max.
Power Required	Hydraulic 1½ - 2Hp	hydraulic (pwr unknown)	hydraulic 2 Hp	hyd. or elec 2 to 2½	hydraulic 2 Hp	hydraulic 2-3 Hp
Auxiliary power required	elec	elec 24 VDC air 100 psi	elec 12 VDC	elec 12 VDC	elec 12/24 VDC	Elec 12/24 VDC
Cycle time/Lift time, sec.	35/ 10-11	35/7-9	26/8	36/12	35/14	45/10
Anti-fold Protection	weight sensor	dual switches	dual switches	weight sensor	locking switch	electronic device under development
Back-up operating method	man. pump separate valve	hand winch to lift platform	hyd. pump and crank	manual pump	manual pump	manual pump

In the following sections, the operation of individual lifts is briefly discussed.

4.2.1 Environmental Equipment Corp. (EEC)

In the stowed position, this lift is the stair treads and risers. The stair configuration is transformed into a platform by means of a pair of parallelogram linkages. Platform formation is provided by a hydraulic cylinder and a mechanical drive train mounted under the bus floor. The operating principles are shown in Figure 4-2.

A second parallelogram linkage moves the platform from the bus floor level to the ground. The first movement from floor level is upward and outward over the apex from whence it continues an outward and downward movement to the ground. Because the lift mechanism must first travel upward before decending, the lift is not subject to drifting downward when stowed, therefore a positive locking drive is not required. The design incorporates a level sensor to maintain a true level platform, rather than a position parallel to the bus floor, when the bus is on the side slope of a highly crowned road. At ground level, the lift assumes the slope of the ground on which it rests, which facilitates loading and off-loading the platform on sloping ground.

The lift also incorporates a hand rail for those standing on the lift for ingress and egress, however, if the doorway vertical opening is not high enough, it is possible for a standing passenger to strike the top of the doorway when being lifted.

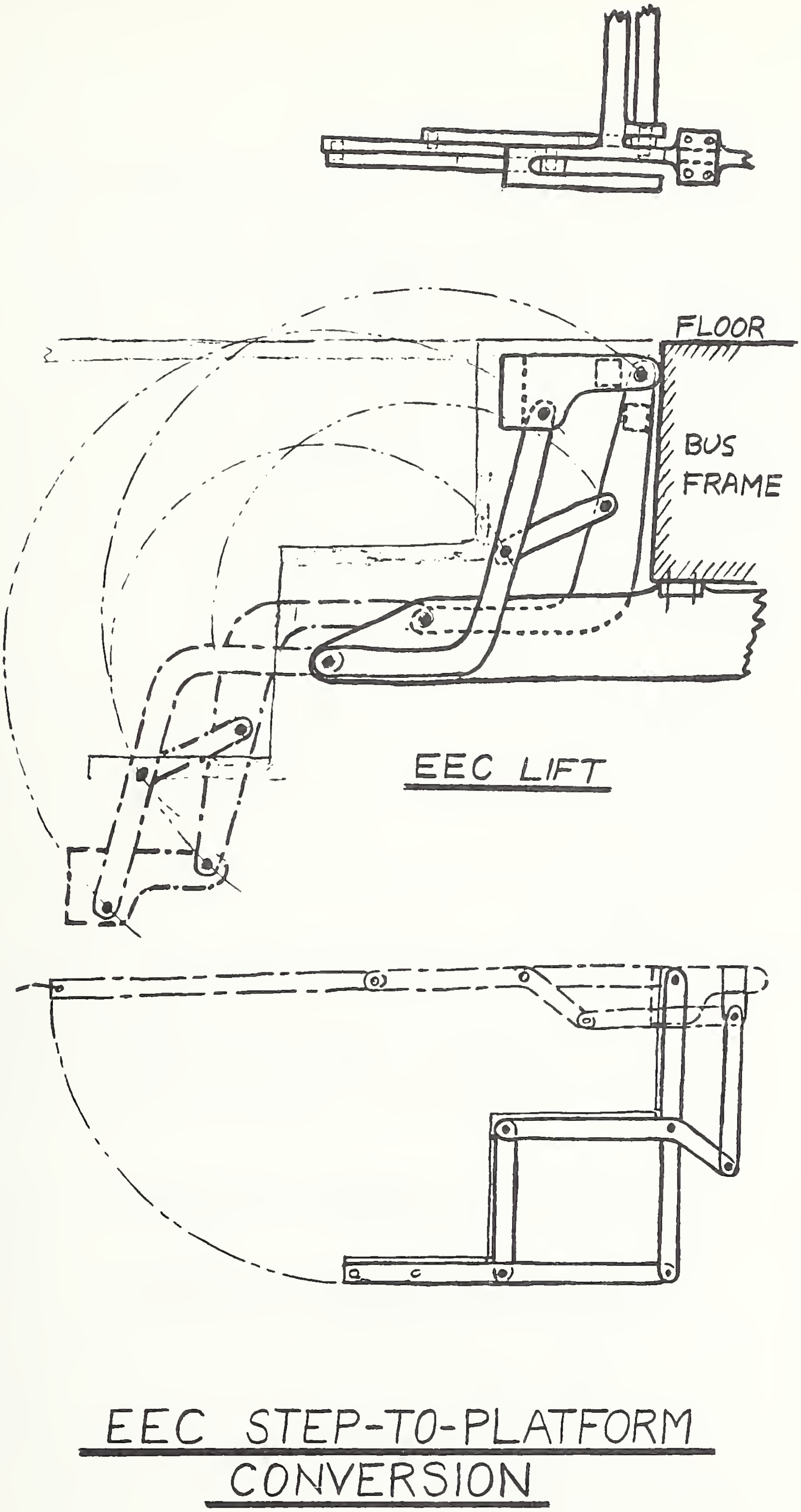


FIGURE 4-2. EEC E & H LIFT OPERATING PRINCIPLES

4.2.2 General Motors Corp. (GMC)

The GM lift uses a combination of a parallelogram linkage and a four-bar linkage to effect the step to platform conversion, as shown in Figure 4-3. Then the platform can be raised and lowered vertically, guided by V-grooved rollers running on a mating track. When not in use, the lift is locked in the stair configuration, and locked vertically so it cannot drift downward.

The GM design utilizes all three power systems that are available on their buses. The power steering hydraulic system is used to extend the platform, and then to raise and lower it. The air system (historically provided for brakes, doors, windshield wipers) is used to power the locks and safety gate/ramp. The hydraulic and pneumatic valves are electrically activated from the bus electrical system.

Because of the center door location of the lift and its controls, GM has provided a somewhat different control sequence than is usually used with front door lifts, to lock the accelerator and brake when the operator is away from the driver's station. The operating sequence is as follows:

- Apply parking brake.
- Open center door (from driver's seat). This locks the brake and accelerator.
- Turn the lift key switch to the on position. This energizes the lift controls and locks the center door in the open position.
- Remove the key from the switch at the driver's station, and unlock the control panel cover at the lift with the same key.
- Operate the lift through its complete cycle for boarding or alighting:
    - Deploy platform at floor level (alighting passenger would enter onto platform at this point).
    - Lower platform.
    - Lower restraint safety gate to ramp position (alighting passenger leaves or boarding passenger enters onto platform).
    - Raise restraint safety gate.
    - Raise platform (boarding passenger leaves platform and moves to securement area.)
    - Restore platform to steps.
- Lock control panel cover, return to driver's station and turn lift key switch to off position.
- Close center door.
- Apply service brakes, release parking brake.

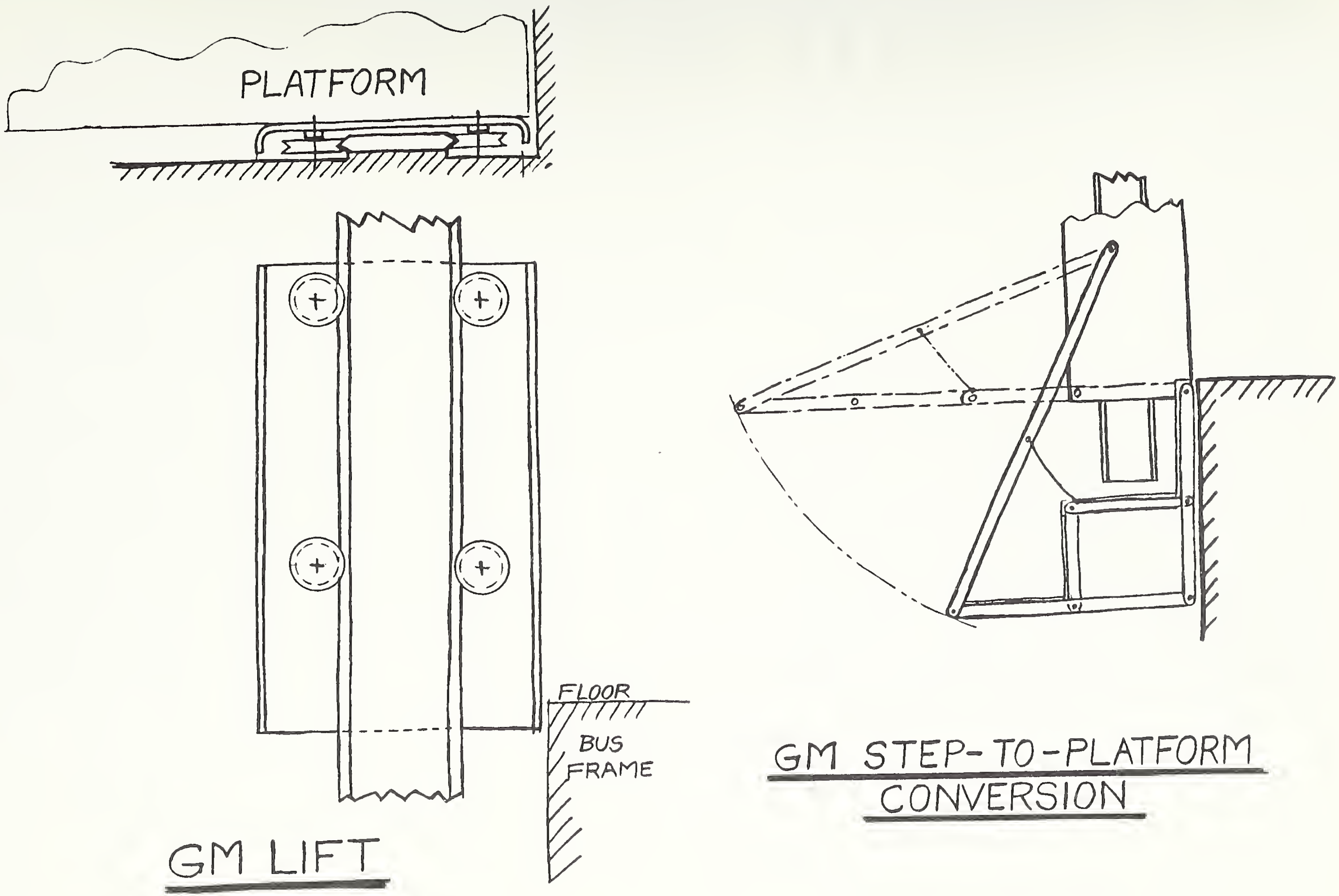


FIGURE 4-3. GMC LIFT OPERATING PRINCIPLES

The lift operation portion of the sequence is generically the same as that of all other lifts. The remaining portion immobilizes the controls to prevent someone from tampering with them while the operator is away from the driver's station. With front door lift installations, the operator does not leave his normal station to operate the lift.

The sequence of operations for the GM lift has been explained in more detail than for the other lifts because it is relevant to situations that will be encountered on light rail vehicles for certain lift installation locations. Section 3.0 discussed left side boarding on some LRVs, and in Section 5.1, the possible lift locations on LRVs will be developed in more detail. It will be seen that many of the possible installation combinations result in at least one lift that is too remote to be operated from the normal driving position, and an approach similar to that used by GM will be necessary to enable the vehicle operator to leave the normal driving station.

4.2.3 Lift-U, Inc.

The Lift-U lift unit is contained in a relatively thin package that extends almost the width of a bus, because it stows the lift platform intact, not as steps. By contrast, units that form steps usually utilize the entire vertical depth of a stepwell, but do not extend much inboard of the top riser.

The operating principles of the Lift-U lift are shown in Figure 4-4 . The front portion of the platform is the lower step in the lift stowed position. To use the lift, the platform is extended outward from the channels. Then it can be raised and lowered on the four side arms that constitute a pair of parallelogram linkages. In the stowed position, the lift is not subject to drifting outward, because it is effectively locked by the screw-thread that extends and retracts it. It is prevented from drifting downward by wedge-shaped tabs on the front corners of the platform that engage the channels when the platform is retracted.

The motions of the lift are hydraulically activated. Hydraulic power can be provided by the bus power steering pump, a separate engine-driven pump, or an electrically driven pump. The lift controls are electrical, with only three functions:

- Power on/off (this locks the brake and accelerator and energizes the lift controls).
- Lift deploy/stow (this extends the platform or retracts it).
- Lift up/down.

There are two separated stow switches, which must both be activated to retract the platform. The dimensions and other characteristics are summarized in Table 4-1 .

Seattle Metro operates one prototype lift on a 35' GM coach. This is a special service vehicle on which the lift was retrofitted. They also have ten production versions of the lift in regular service on two routes. These lifts were mounted on the buses by the bus manufacturer, Flyer of Winnipeg, Monitoba. Three have been in operation since March, 1979, and seven more since the end of August, 1979. One hundred and forty-three lifts are on order to be mounted on new Flyer coaches by the bus manufacturer. Two hundred and twenty-five others will be retrofitted on Diesel buses and trolley buses currently operating in the system.

Some modifications had to be made to the lifts currently in oper-

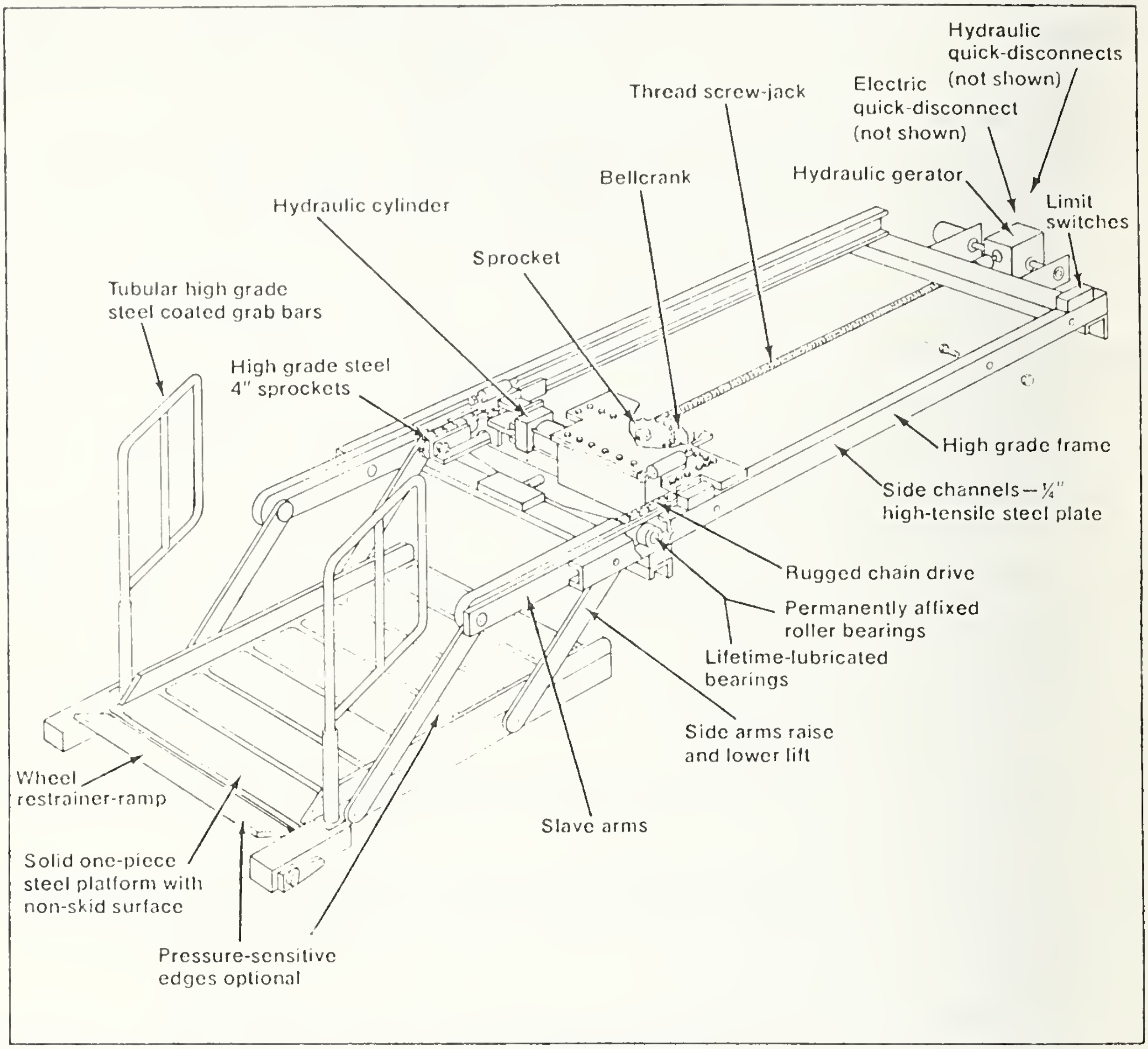


FIGURE 4-4. LIFT - U OPERATING PRINCIPLES

ation. This consisted of shortening the front support member. Seattle also experienced hydraulic problems initially, which have now been resolved. One mechanical problem has not been corrected. Seattle and the manufacturer are studying a problem regarding the operation of the safety gate on the end of the lift. It is converted into a loading-unloading ramp by a sensor when the lift hits the ground. However, Seattle estimates that about 40% of the time the mechanism does not work and the wheelchair must be lifted over the ramp.

As with other lifts, a problem exists for standing passengers because of the height of existing doorway openings on buses. It is possible for a standing patron to strike the top of the doorway when being lifted, unless the patron stands near the outboard edge of the platform. In the raised platform position it is then necessary for some patrons to stoop to enter into the bus.

The mounting location of the Lift-U unit, under the frame of the bus and somewhat below the bottom step, causes a reduction in the approach angle of the bus. (The approach angle of a vehicle is defined as the maximum angle of an upward ramp that the vehicle can approach and negotiate without any part of the vehicle forward of the front wheels contacting the ramp. A similar definition applies to the departure angle, and crest angle.) A reduction in approach angle causes the lift unit housing to contact the road in some locations.

Seattle has little ice or snow, hence, they have limited experience with lift operation in that environment. However, they have experienced no difficulty with lift operation from normal road dirt and grime. They have not experienced any problems with drivers damaging the lift by running the lift into curbs. Whether this is due to the basic design and operation of the lift, the few lifts in operation, or their driver training program, could not be determined.

MUNI's experience with this lift is similar to that of Seattle's. The ramp angle on their lift is 12^{o}. They did report that some wheelchair occupants had trouble with that high an angle in boarding the lift.

4.2.4 Transportation Design and Technology, Inc. (TDT)

This company has more lifts in service with the properties contacted than any of the other manufacturers. They were also the first in large scale deployment of their lifts. Typically, the first company with a new technology experiences many start up problems that benefit those who follow. Lift deployments have been no exception to this experience.

The TDT lift, in its stowed position, forms the treads of the first two bus steps and the riser between them. The lift platform is formed from these sections, plus a retractable section housed under the bottom step tread when the lift is in the stowed position. This retractable section is rather thick because it houses a hydraulic cylinder, which extends the retractable sections to a fully deployed position along a slide assembly, causing the lift platform to be formed. Vertical motion of the platform is controlled by two hydraulic cylinders mounted in towers on both sides of the lift inside the bus. These cylinders also serve to partially extend the lift. Hydraulic power is provided by the bus power steering pump or by a separately mounted pump and motor. Electrical power is provided by the bus electrical system. A drawing of the lift is shown in Figure 4-5.

The controls consist of four switches, a two-position switch to extend or stow the platform, a three-position switch to raise or lower the platform; a three-position switch to deploy or retract the platform; and a three-position switch to raise or lower the safety gate at the outboard end of the platform. The three-position switches return to the off position when released.

The San Diego Transit Authority has five prototype lifts that have been in service on GMC 5301 Diesels for 2½ years. These lifts were mounted on the buses by TDT. Although San Diego had no severe problems, they did have initial installation problems. Maintenance problems with the slide mechanisms were also reported, resulting from road dirt accumulation on the slides, which are located under the bus floor. Problems with lifts drifting in the stowed position have been corrected by the addition of mechanical locks.

Their most severe existing problem is drivers running the lift into the curb and damaging it. Whether this is a basic design problem or a driver training problem could not be determined.

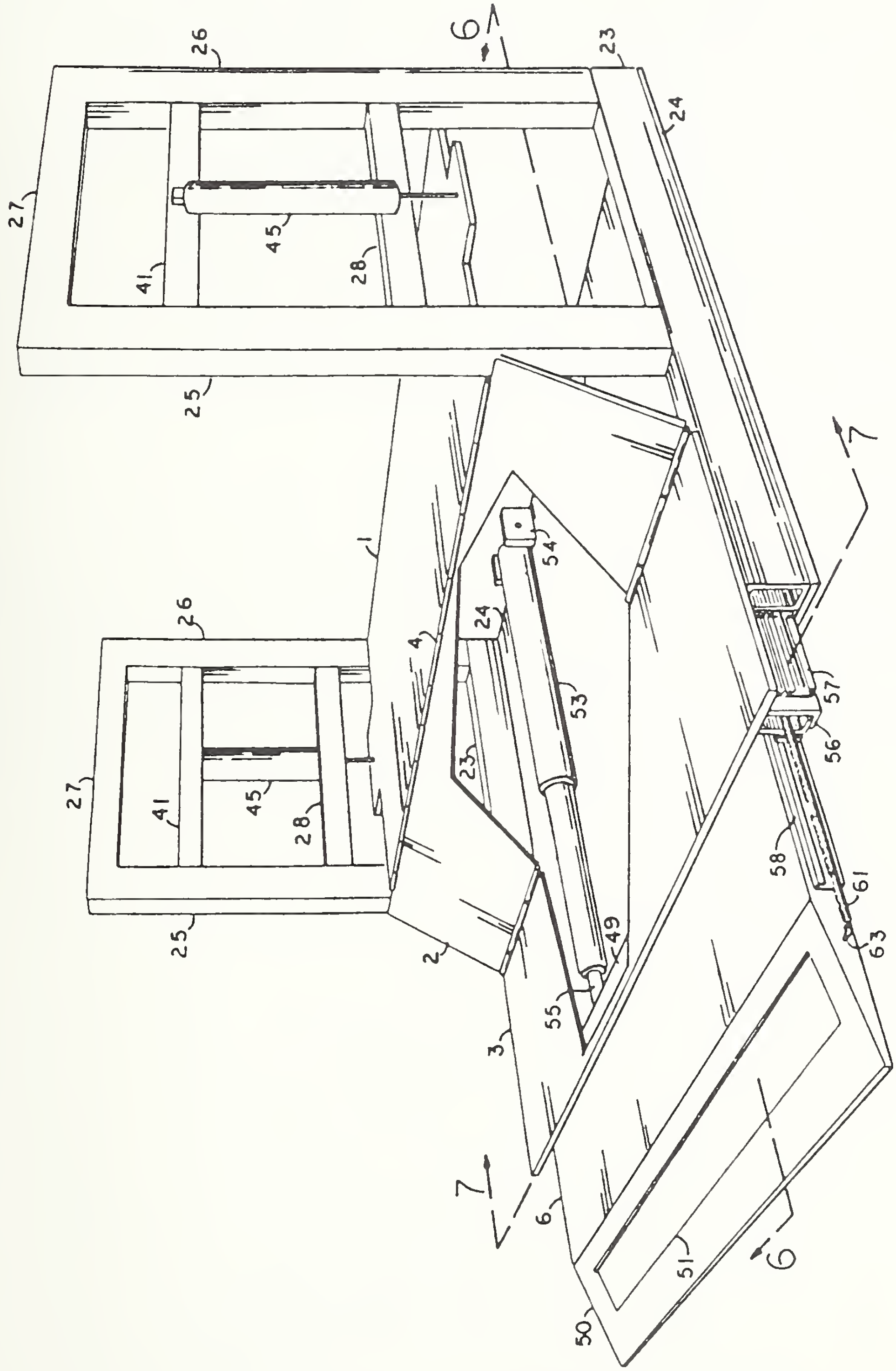


FIGURE 4-5. TDT LIFT

Southern California Rapid Transit District (SCRTD) has 200 TDT lifts mounted on AMG buses that were delivered two years ago. However, they are not currently in service. These lifts have experienced drift and are currently being fitted with mechanical locks both for the step and platform configurations. After this retrofit program is complete, a trial demonstration program will be initiated with twelve buses to develop reliability and maintenance experience.

RTD, in Denver, Colorado, has eighteen TDT lifts mounted in Flxible buses. They report problems with both hydraulic and electrical system reliability. Hence, although in place for quite some time, RTD has not used the lifts in general service. A retrofit program is currently underway. When completed, the lifts will be used in a trial demonstration program.

Bi-State Development Agency (St. Louis) has had 157 units in Flxible buses since 1977. Their experiences have been fully reported in a separate study. (13)

4.2.5 Transi-Lift Equipment, Ltd.

This lift, as is the case with other lists reported on herein, forms the lower two bus step treads and risers when in the stowed position. A significant difference, however, is that the members are only ½" thick, making this an extremely thin platform which is easy for the wheelchair patron to board. When activated, two internally mounted hydraulic cylinders transform the steps into the platform configuration. Another pair of internal hydaulic cylinders raise and lower the platform through a set of roller chains. Descent stops upon contact with the ground and the safety gate is lowered for wheelchair access to the platform. The manner in which the lift is lowered permits it to align itself to the slope of the ground surface. Hand holds, which move with the lift, are mounted on both sides of the lift.

Control of the lift is through two switches mounted on the dashboard. The first converts the steps into the platform and back to the stair configuration. The second lowers and raises the platform. They are interlocked through relay logic to prevent operator error. Hence, the second switch can only be operated when the platform has been formed, and the stow switch (#1) operated only when the lift is up and level with the bus floor. Hydraulic power is provided by the bus power steering system, and electrical power by the bus electrical system.

4.2.6 Vapor Corp.

This lift forms the treads and risers of the bottom two bus steps in the stowed position. Hydraulic cylinders located in towers on both sides of the platform control the operation of the lift. One pair of cylinders form the platform. The other pair of cylinders raises and lowers the platform vertically, using a scissors mechanism, as shown in Figure 4-6. The lift has two sensitive edges (airwave sensors). The sensor on the outboard edge of the ramp stops the lift if an obstruction is contacted as the platform is extended. The second sensor is on the underside of the platform at the outboard edge, to stop the desent of the lift if an object is encountered, or when the lift is on the ground. Because the lift is powered down, it has the capability of lifting the bus if the second sensor fails to contact the ground before some other portion of the platform touches. Hydraulic and electrical power are provided by the bus power steering and electrical systems, respectively.

Washington Metropolitan Area Transit Authority (WMATA) has 130 Vapor lifts mounted on Flxible buses for regular service. They also have another 20 mounted on minibuses for downtown circulator service. The lifts were installed by the bus manufacturer so WMATA has no installation experience. In initial service operation they experienced a number of hydraulic problems, including leaks. However, these have since been eliminated. WMATA also experienced leaks resulting from seals drying out because of rather infrequent use of the lifts. In order to correct this the drivers are instructed to operate the lifts in the morning prior to beginning their runs.

WMATA reports the Vapor lifts to be relatively maintenance free, and they have had no trouble with rain and road dirt affecting lift operation. Their main problems have been with the driver operation of the lifts, which includes extending the lift into curbs and a difficulty in understanding the control console even through the buttons light up for the next sequence. The fact that it is not always the next button on the console apparently causes the driver confusion. The Vapor control console has 11 pushbuttons to control lift, arranged as shown:

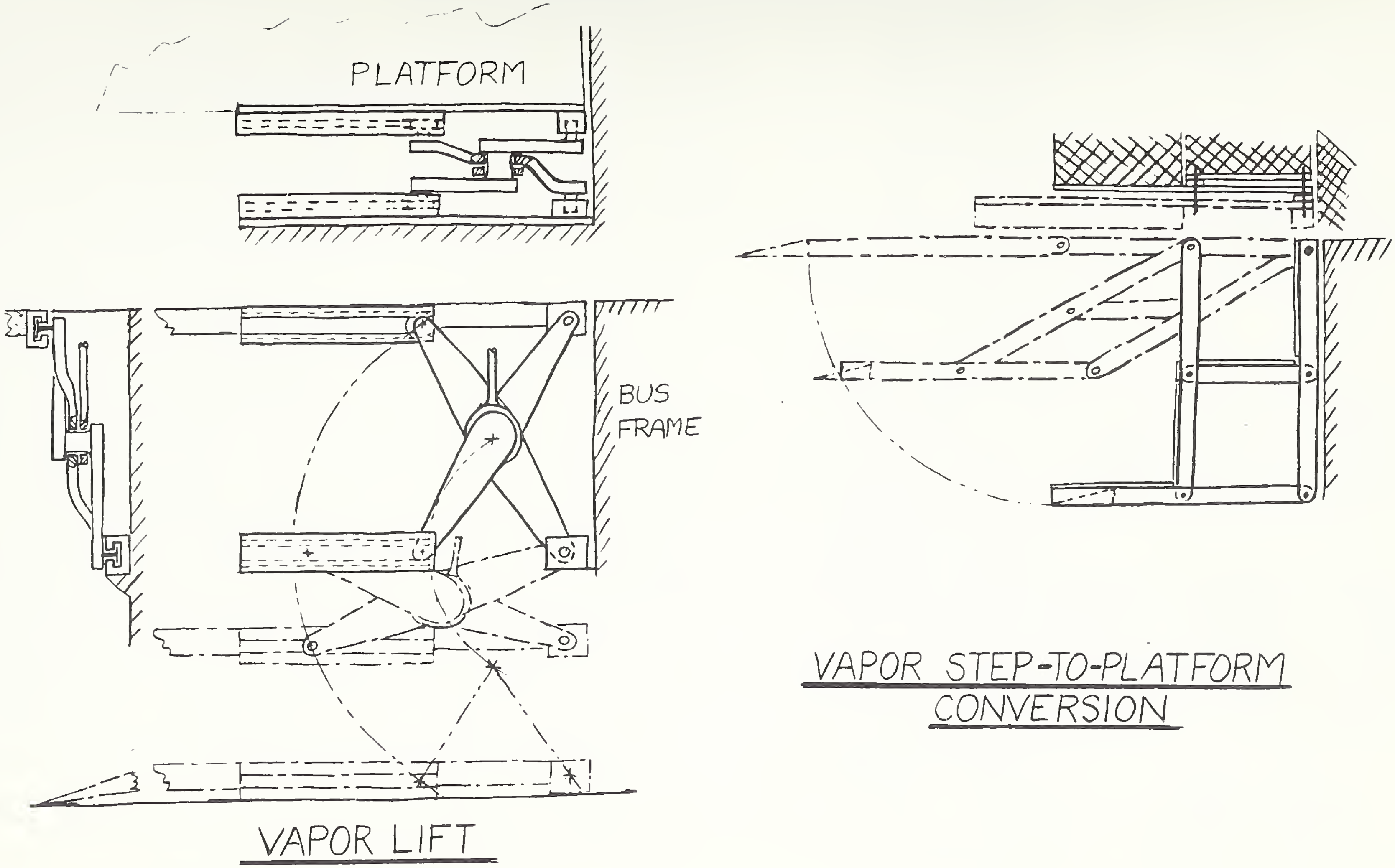
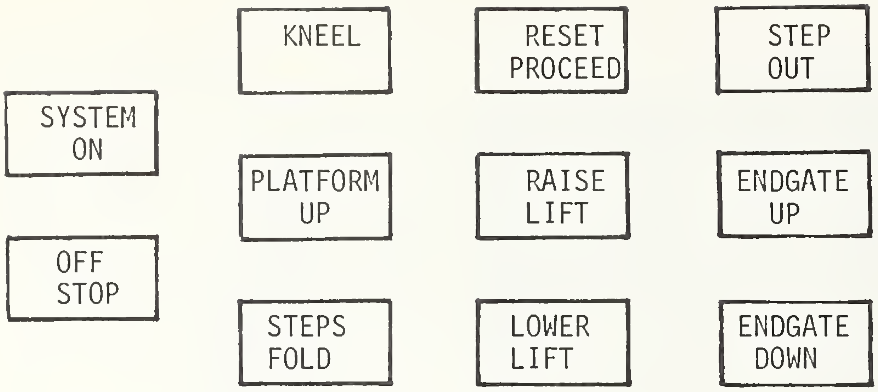


FIGURE 4-6. VAPOR LIFT OPERATING PRINCIPLES



The number of control functions for the Vapor lift are necessarily similar to those of other manufacturers, because step-to-platform lifts have only a limited number of actions they can perform. The numerical difference in numbers of controls for Vapor is due to the use of push buttons, instead of two-or three-position switches.

4.2.7 Other Lift Designs

Three additional lift designs which are not as yet in production are discussed in this section.

Austin Lift

This lift is in the prototype stage at this time. This design avoids alterations to the steps. The mechanism is designed to be stowed on the bus roof over the entrance door. The platform first extends sideways out of the housing, then descends to street level to accept the patron (see Figure 4-7). Details of the activating mechanism are not yet available.
The benefit of the overhead concept is that the mechanical systems are sheltered from the elements by being enclosed within the vehicle passenger area and do not intrude into space required by other vehicle systems.

Transport Canada

This is also an overhead lift (Figure 4-8). A working prototype is presently being assembled. This concept does not utilize a platform in its function; instead, the wheel chair is attached to an overhead gantry which utilizes a cable/sling arrangement to lift the wheel chair and passenger. The benefits of this concept are the same as the Austin lift. This lift is also one of two lifts that have been conceived primarily for rail applications.

Budd Company Lift

This concept was also primarily designed for rail service. It uses a parallelogram action to maintain a level platform. After use, the platform stows itself as the trapdoor on a commuter rail vehicle. The lift must be operated at each stop if non-E&H passengers wish to use the entrance, (Figure 4-9).

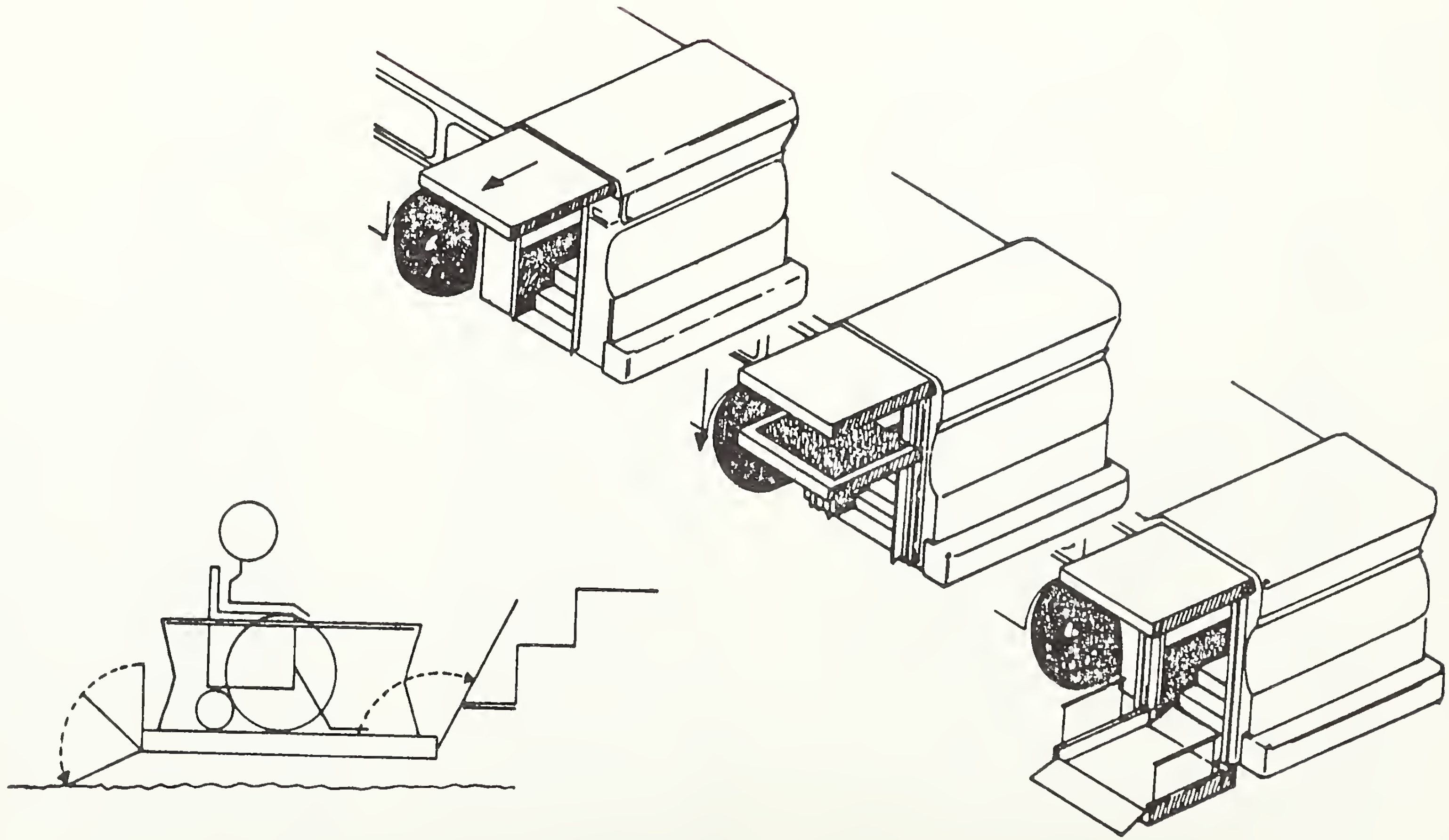


FIGURE 4-7. AUSTIN LIFT

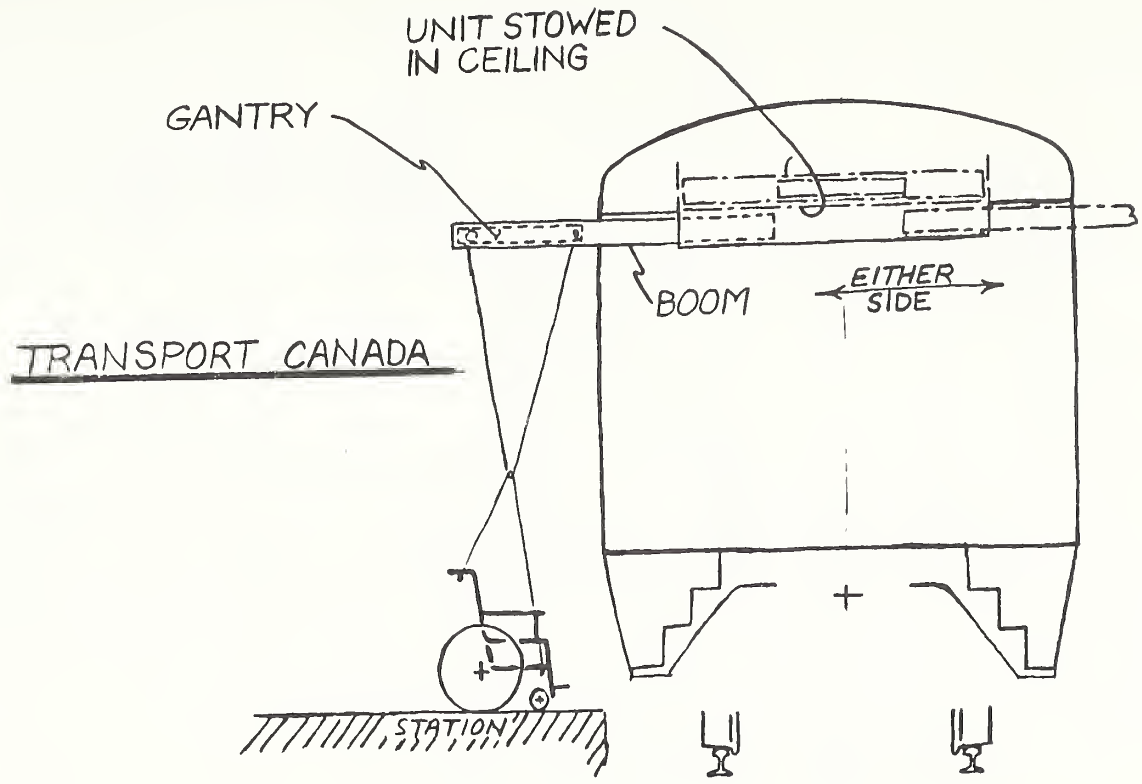


FIGURE 4-8. TRANSPORT CANADA LIFT

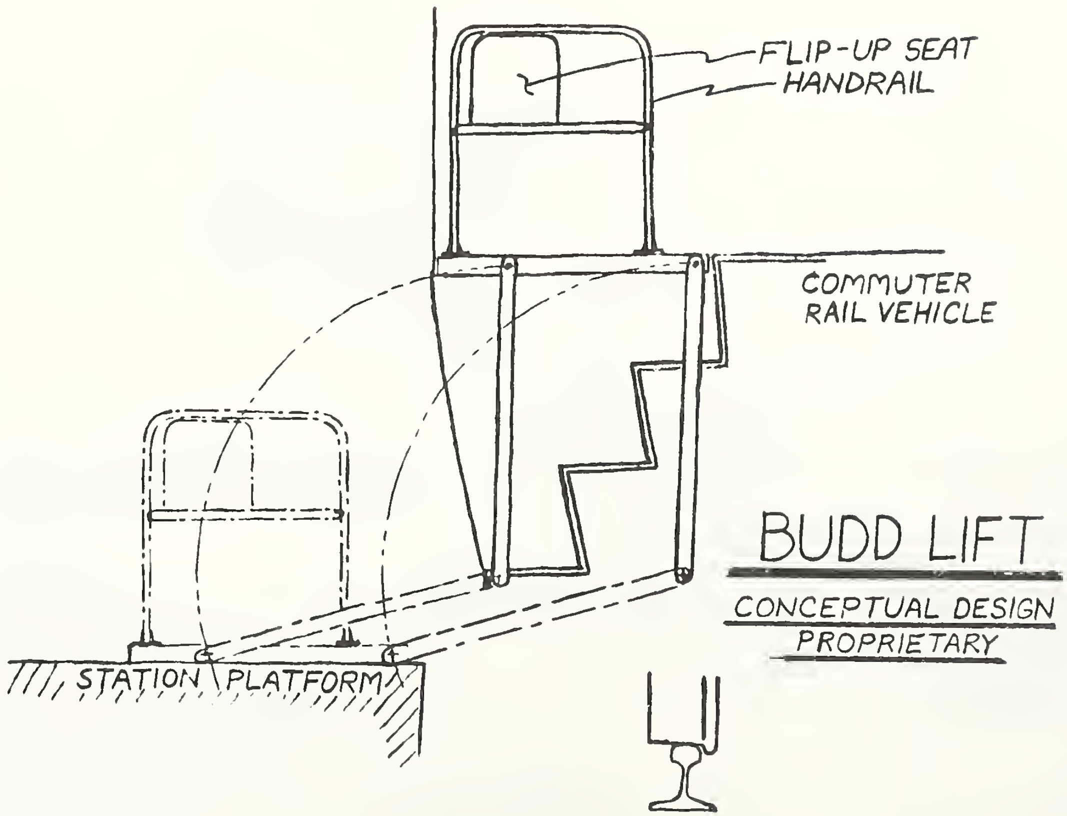


FIGURE 4-9. BUDD CO. LIFT

4.3 Bus Experience Summary

A review of the operational experience with lifts on buses, disclosed problems that are characteristic of new technology development. The most common specific problems encountered were:

- o Hydraulic system leaks,
- o Inadequate protection of sensitive components from the environment,
- o Electric motor failures,
- o Sensitive edge failures,
- o Downward drift of unit when stowed, and
- o Lifts jam due to misalignment.

Corollary problems are also caused by the lift, particularly in retrofit situations, such as:

- o Doors usually need to be widened and modified to interface with the lift unit;
- o Bus structural improvements may be required to adequately carry the weight of the lift unit;
- o Bus approach angle is reduced by some front door lift installations;
- o Front door lifts are particularly vulnerable to damage in collisions; the situation is aggravated if lift installations reduced structural integrity of the frame or bumper.

A third type of problem encountered is operational problems. Some are institutional; others are caused by existing lift designs. These include the following:

- o The lift controls are judged to be too complicated by some individual operators,
- o Some lifts are suitable only for wheelchair patrons, but not ambulatory handicapped,
- o On those that are suitable for ambulatory persons, a standing lift patron can strike the top of the doorway when being lifted,
- o Not all lifts are positively prevented from being stowed when a passenger is on them,
- o Center door lift installations are less acceptable to some users and operators than front door installations, and
- o The ramp angle on the edge of the platform is too steep for some wheelchair users.

Each of the above problems could be a potential concern for rail retrofit applications, in either the LR, CR, or both areas.

The most significant rail-specific lift problem that was identified concerns failures, for any reason, of the lift when it is extended. Because of the much more limited passing ability of rail systems, compared to bus systems, lift units on rail systems must have a secondary means for operating and stowing the lift. Most manufacturers now provide a manual secondary method of operation on their bus lifts and thus is a fundamental requirement for all rail lift installations.

5.0 LIGHT AND COMMUTER RAIL LIFT TO VEHICLE INTERFACE DEFINITION

To develop the lift-to-vehicle interface definition it is necessary to examine individual vehicle types. Section 3.0 developed the inventory of U.S. rail cars and showed that there are large numbers of certain types of vehicles, even though some types have been built by more than one builder and are owned by several operators. Section 4.0 described the existing bus lifts, and more important, the lift concepts now in use. This part of the report examines existing vehicles and existing lift concepts in an effort to determine the degree to which current lifts are usable for rail vehicle retrofits.

The problems encountered with retrofitting lifts on rail vehicles are somewhat more complex than installing lifts on buses. It appears that most rail vehicles will require more than one lift per vehicle as they are presently configured and operated, and the multiple installations may not be the same, depending on the locations chosen. Only on paired lifts (opposite each other) or diagonally symmetrical locations are the two installations likely to be mechanically the same. The importance of having installations alike, if possible, to control costs extends from the initial design work through installation to maintenance and parts inventories.

One of the objectives of this study is to determine if one lift design is universally applicable to rail vehicles, or alternatively, to determine the minimum number of designs that would be necessary and sufficient. A retrofit program is of a finite, determinable magnitude. It is not certain that lift solutions developed for a retrofit program will be desirable for new production vehicles, because of the greater range of options available to a vehicle designer when it is known from the outset that the vehicle must have certain accessibility features. Therefore, it is desirable to maximize the utilization of existing lift technology.

In a project involving items as complex as lifts and rail vehicles, it would be unrealistically hopeful to expect the identification of an existing lift, by manufacturer and part number, that is suitable for application to existing rail vehicles. Thus, the utilization of existing technology will be seen to be substantially utilization of concepts, rather than utilization of details.

For the preliminary examinations of the lift-to-vehicle interfaces, the vehicle types are examined to see if there are sufficiently strong similarities that will allow some broad conclusions to be made. These broad conclusions in turn will hopefully suggest those situations which are promising for lift retrolift and those situations which are probably unfeasible for retrofit, at least with the present state-of-the art in lifts.

The following sections examine the lift application conditions and impediments, first for light rail vehicles and then for commuter rail vehicles. Although there are hardware interface problems, as expected, lift concepts that are potentially suitable for each situation are identified.

5.1 Lift Applications to Light Rail Vehicles

Figures 5-1 and 5-2 show the conditions existing on PCC cars and the Boeing vehicles that directly affect lift installations at any given doorway. Reference to these drawings will be useful to understanding the following discussion.

On light rail vehicles, lifts must not infringe on the truck swing clearance, analogous to the wheel clearance that must be maintained on bus front door installations. The truck swing clearance is considerably larger than the wheel movement experienced on a bus. If couplers are used on light rail vehicles, the swing is always extreme compared to commuter rail vehicle couplers. Of course, there is no similar device on buses with which to contend. Thus, on many light rail vehicles, a front door lift is constrained to fit and operate between the truck and the coupler swing clearances. All of the Boeing vehicles have couplers, as do the Boston and Cleveland PCC cars and as will the Breda and Kawasaki cars.

Light rail vehicles universally have wider door openings than buses, which for most lifts means that the door openings will not have to be enlarged. At most doors, the major constraints are under-step equipment, structure inboard of the step, and equipment or truck bays fore and aft of the steps.

On each of the vehicles, there is equipment under some of the steps that would have to be relocated. On PCC cars with couplers, a switch referred to as the drum switch is located under the front steps as shown in Figure 5-1. This switch is also arranged to turn air valves. The combination of electrical switches and air valves are moved in unison manually to effect

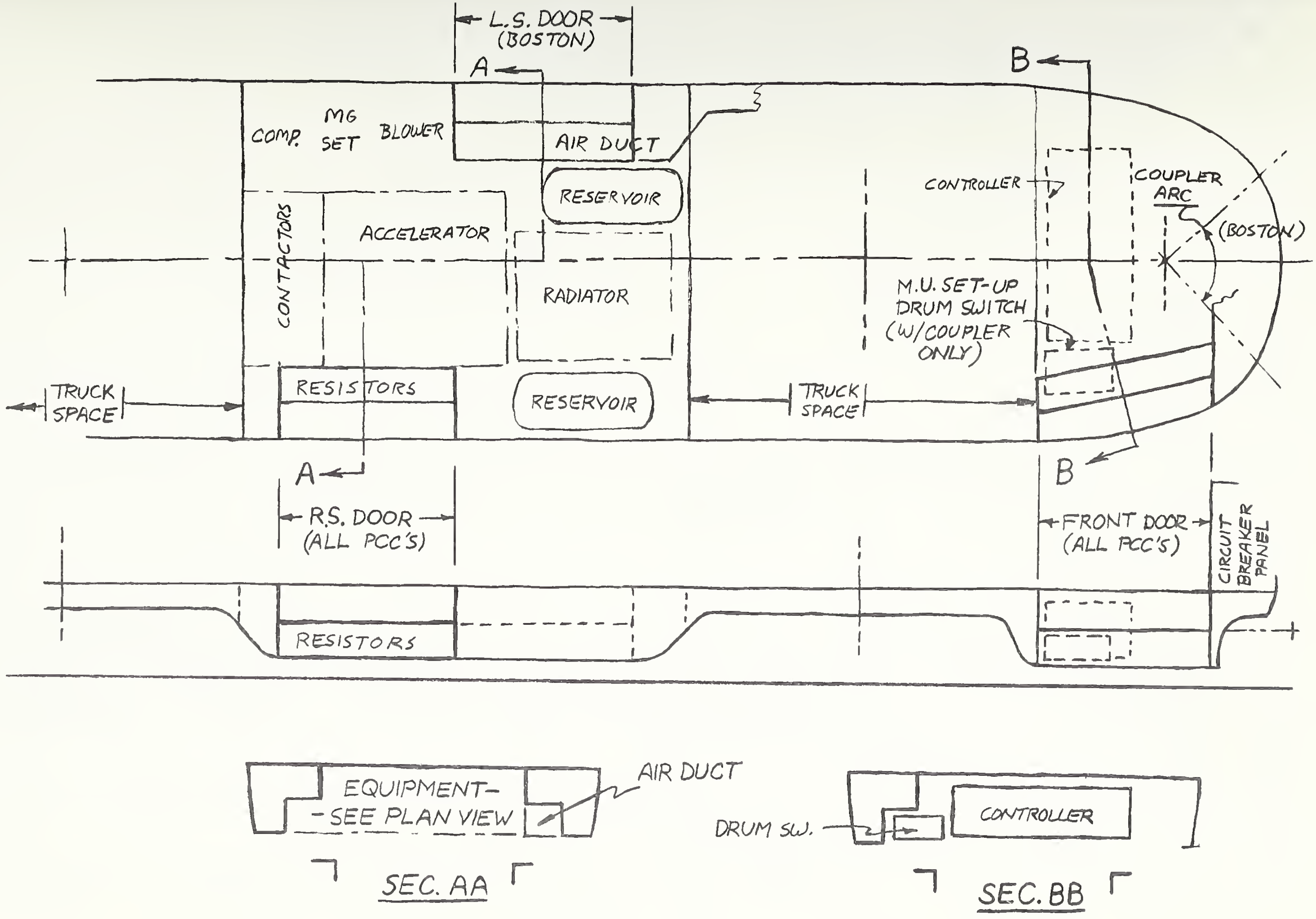


FIGURE 5-1. LIFT APPLICATION CONDITIONS - PCC VEHICLES

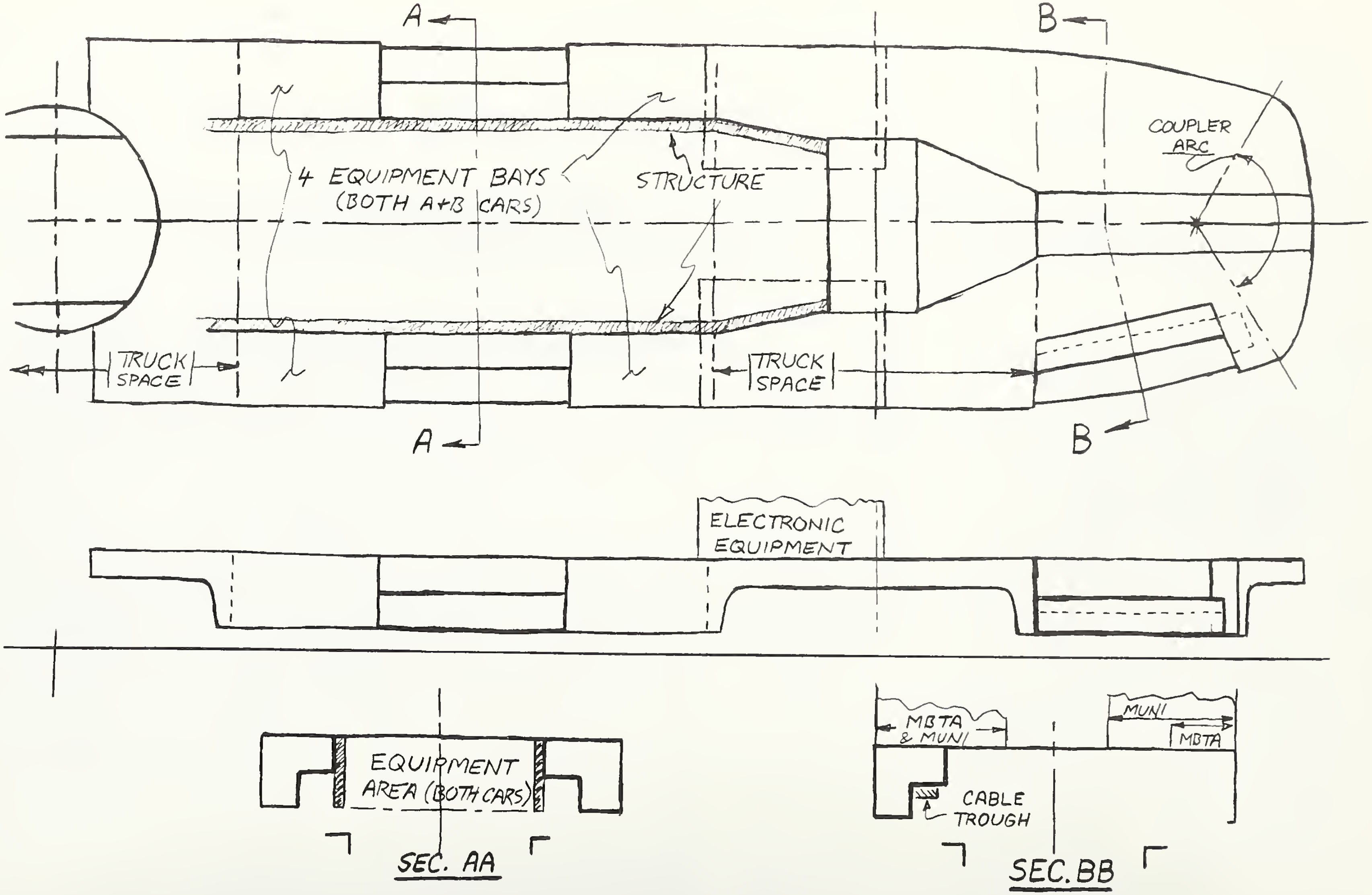


FIGURE 5-2. LIFT APPLICATION CONDITIONS - BOEING

the change-over from single unit to multiple unit operation. For a front door lift installation on a PCC car with a drum switch, it would be necessary to relocate the drum switch and air valves, perhaps separately, away from the step area.

Similarly, at the right side center door, there are resistors under the steps that would need to be relocated. The left side center doors on the MBTA PCC cars present the most difficult problem. The air duct below the upper step is in the path of any lift, however there is no readily apparent location to which the duct can be relocated.

The Boeing vehicles have a cable trough under the front steps on both ends that would need to be relocated for front door lift installations. On the San Francisco vehicles, the high/low step assemblies at the center doors constitute a major interface problem for lifts at those locations. Not apparent from Figure 5-2 is the nature of the bottom door tracks on the Boeing vehicles. The lower door tracks for the Boeing plug doors are under the bottom tread at all door locations. A lift installation at any door on the Boeing vehicle must address the door/lift interface.

The conditions existing on the Breda and Kawasaki vehicles are not as well known because these vehicles are still under construction, and none are available for inspection at this time. However, based on some structural drawings and photographs, the preliminary finding is that they will also present equipment relocation requirements as a minimum. The structural restrictions that may exist are less well known, and may ultimately have a stronger impact on lift installation than equipment relocations.

It is generally possible to clear a stepwell on the four LR vehicles (Boeing, Breda, Kawasaki, and PCC cars) from the front to back end, and inboard to the top riser. (Unfortunately, the natural orientations, left/right, front/back, are at 90° for stepwells and vehicles. The reader must be careful to be sure of orientation in each step of the discussion.) The object on each vehicle is to obtain a clear rectangular 3-sided opening from floor height to the ground for a lift installation. Any lift which can use an opening of that configuration is conceptually suitable for light rail vehicles.

Because of in-street operations, and island type low platforms, the lifts for light rail vehicles need to be mounted so that they project as little as possible from the side of a vehicle. At low island type platforms, there must be sufficient space between the end of the platform and the back edge of the platform to maneuver a wheelchair into position for moving onto the lift. With no fence on the back edge of the platform the edge-to-lift distance must be wide enough to provide room to manuever plus an adequate safety margin. However, it is not known at this time what constitutes an adequate safety margin.

Figure 5-3 shows the conditions existing at platforms as used in San Francisco, with the Boeing vehicle, and minimum lift dimensions assumed. It is readily apparent that only the largest platforms would be suitable for use with even minimum dimension lifts. On existing U.S. light rail vehicles, the front door is at an angle with respect to the side of the vehicle. A lift installed in the front door would present a slightly more favorable approach angle, but the improvement would not be sufficient to solve the problem of safe access to the end of the lift on most platforms, as Figure 5-4 shows. However, it is possible to cut away part of a safety island so that a lift could drop directly onto the street level.

More common than island platform stops are mid-street stops, where passengers board from and alight on the roadway. For lift operations, the lift must be able to accomodate the conditions caused by the crowned road surface. Figure 5-3 illustrates the two important considerations: the lift should be able to droop to follow the road surface, and the entrance ramp should have as flat a slope as possible to minimize the increase added to the road slope at that point.

At mid-street stops, boarding and alighting passengers are exposed to the hazard of automotive vehicles passing the LRV on the right side. However, because the boarding/alighting activity associated with a lift necessarily extends further from the side of an LRV, the exposure of lift patrons may be greater than that of ambulatory patrons.

Light rail vehicles are universally powered from a 600 VDC supply, with a 30 VDC auxiliary system supplied from an on-board conversion system. Thus, the primary source of power on light rail vehicles is electrical. A lift may be able to use either voltage, or may be restricted to the 600 VDC supply if the maximum power required is too great for the 30 VDC supply. Existing bus lifts require about 2 kw maximum. Although LRV's may eventually have more than one lift per vehicle, it does not appear that more than one will be in use at one time.

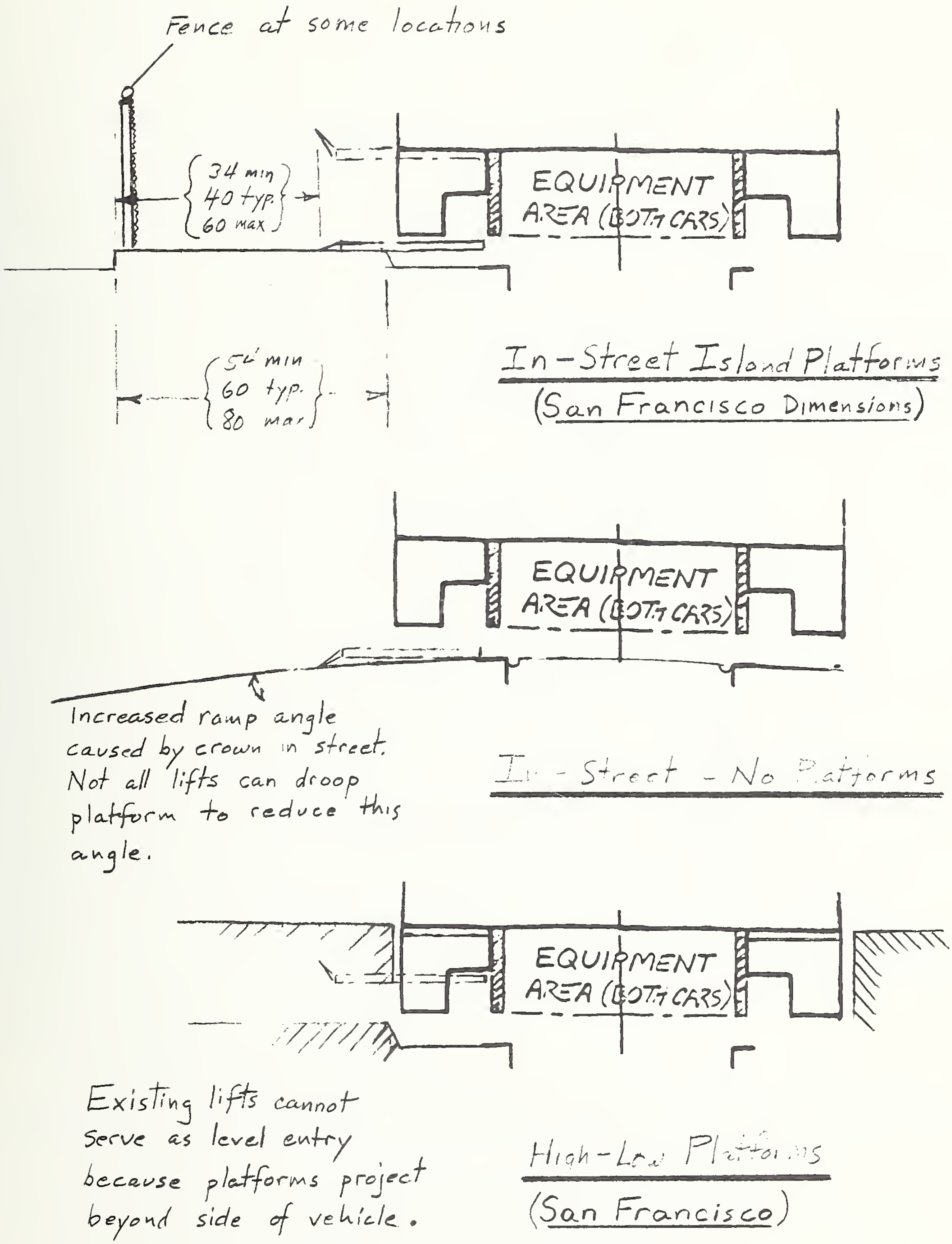


FIGURE 5-3. LIGHT RAIL LIFT APPLICATION CONSTRAINTS

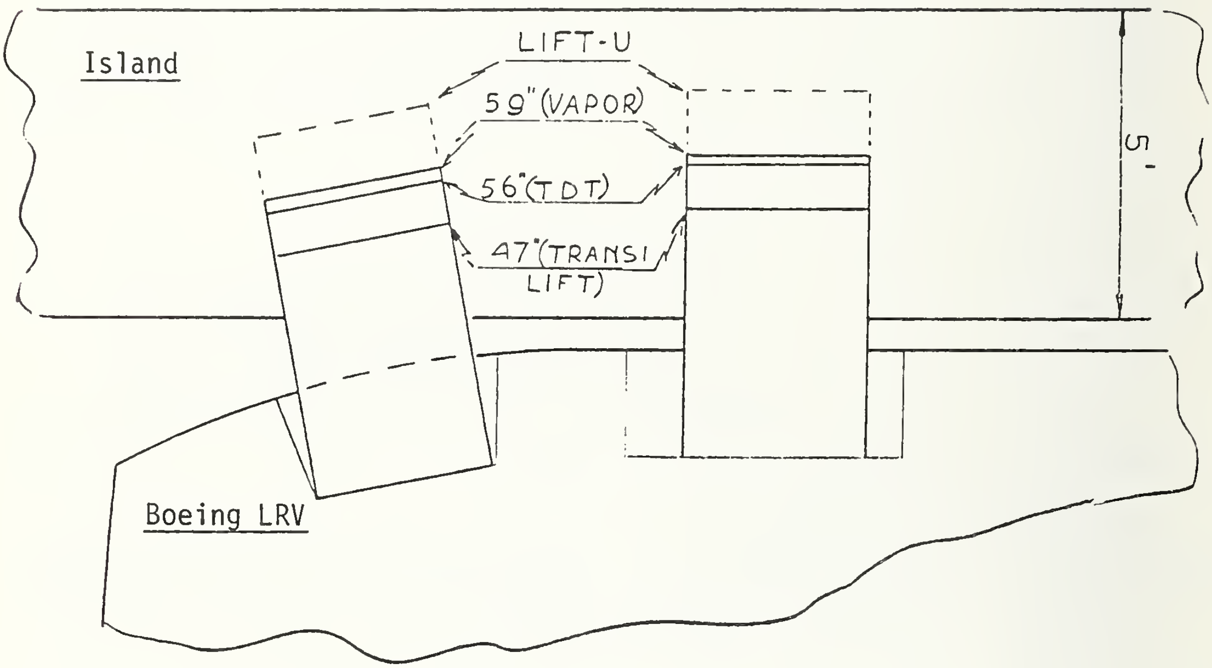


FIGURE 5-4. BOEING LRV AT ISLAND PLATFORM

5.1.1 Number and Location of Lifts - Light Rail

Some light rail systems now in operation operate bidirectional vehicles, and also have stations on either side of the track. Section 3.0 and Table 3-1 explained how certain door arrangements are forced by these operational practices. In a similar manner, lift locations are also forced by the same operational requirements if full accessibility is to be provided. The basic requirement for bidirectional vehicles and/or either-side platforms is for doors on both sides and, therefore, lifts on both sides of the vehicle. There are two additional considerations that are applicable to lift installations when bidirectional operation and either-side platforms indicate a requirement for more than one lift per vehicle.

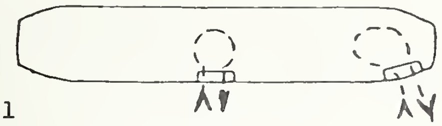
The first item is the remoteness of the lift from the vehicle operator, also an issue on buses. GM located the lift on its Model RTS-11 bus at the center door. This arrangement has been questioned because the driver must leave his seat to operate the lift, and at some stops it can be difficult to manuever the bus close enough to the curb to enable the handicapped passenger to alight on the sidewalk.

The second item concerns the length of the path within the vehicle that must be provided and negotiated by a handicapped individual entering one side and exiting on the other, defined here as the cross-over path. In Figure 5-5 same-side entry and exit is represented as a short loop within the vehicle. In both cases, the ideal shortest path may be lengthened by the requirement to get to and from the securement area that must be used during transit.

Figure 5-5 develops the possible lift location combinations for unidirectional, same-side entry vehicles, through bidirectional, either side entry, articulated light rail vehicles. The two considerations used to develop Figure 5-5 are nearness/remoteness of lifts to the operator, and cross-over path length. As can be seen, these two considerations are always in conflict if cross-over possibility is required (either side entry) because the door closest to the operator, the right front door, has no useful corresponding door on the left side. (The only vehicles with left front doors are the existing Brill and SLC cars of the Red Arrow Division in Philadelphia, but because the left side doors are located between the driver's station and the truck, they are only about half the width of the opposite right side door. The double-ended Kawasaki vehicles on order for Philadelphia, Figure 3-4, will have a similar door arrangement, however the left side doors in all cases are much too narrow for a lift installation.) Working through to bidirectional, either-side, articulated vehicles, up to four lifts per vehicle could be required if the minimum distance from the operator requirement is held to be valid. This conclusion has clear cost impacts, both capital and maintenance.

The desirability of minimizing the cross-over path length within the vehicle seems self-evident. The shortest path length will minimize the inconvenience to both the handicapped and non-handicapped passengers, particularly during peak times when there are many standees. It can be difficult for even non-handicapped passengers to make their way from one entrance to another for exiting during rush hours. Although handicapped passengers may avoid travelling during the peak rush hours if at all possible, a system that assumes such travel patterns in the design stage then tends to impose those travel patterns when built.

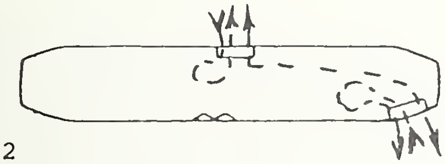
Minimizing the path length within the vehicle also disrupts the least amount of seating. On light rail vehicles with 2+2 seating, such as on the San Francisco Boeing LRV, the aisle width is too narrow for wheelchair passage. Figure 5-5 does not directly address the effect of lift location on seating. It is clear, though, that access to a securement area (or areas) must be provided. It is assumed that the securement area would be as close as possible to the lift locations. In addition to changing seat arrangements, some equipment now located beneath seats on the Boeing vehicles might have



1

- Uni-directional
- Single-side entry

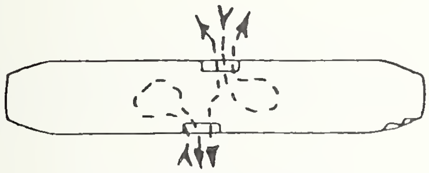
Only one lift per vehicle is required. The rear door lift is remote from the operator, who must leave his seat to operate it.



2

- Uni-directional
- Either-side entry

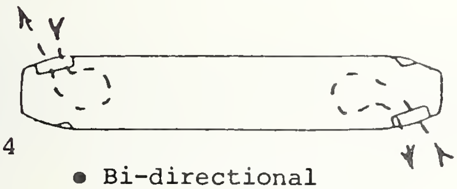
Two lifts per vehicle are required for full accessibility. The left side (LS) lift is necessarily remote from the operator. Passengers crossing over have a rather long path that must be full wheelchair path width.



3

- Uni-directional
- Either-side entry

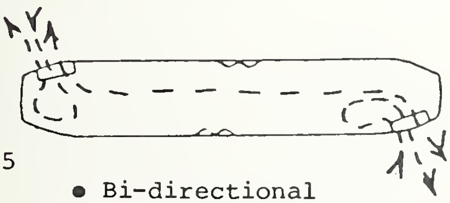
Also requires two lifts per vehicle. Both are equally remote from the operator, but the cross-over path is as short as possible.



4

- Bi-directional
- Single-side entry

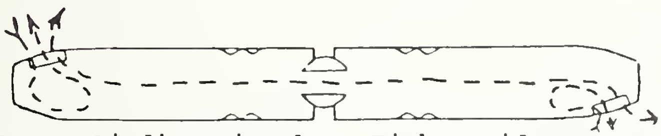
Two lifts per vehicle are required, but no connecting path is necessary because no cross-over is possible with single side operation.



5

- Bi-directional
- Either-side entry

Similar to above, but forces the longest possible cross-over path, and the LS lift is clearly very remote from the operator.

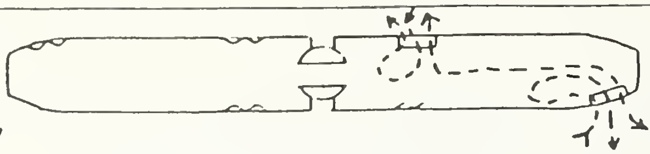


6 • Bi-directional • Either-side entry

Same as 5 above, but for articulated vehicle.

FIGURE 5-5. ENUMERATION OF POSSIBLE LIFT LOCATIONS
Uni- or Bi-directional Vehicles
Single or Either Side Boarding

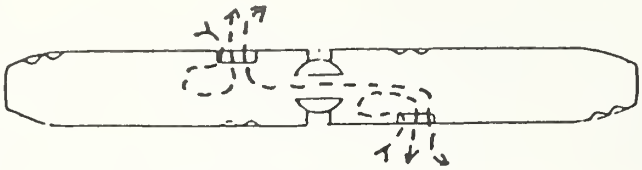
7



- Bi-directional
- Either-side entry

Shorter cross-over path, but very remote from operator for one direction of travel

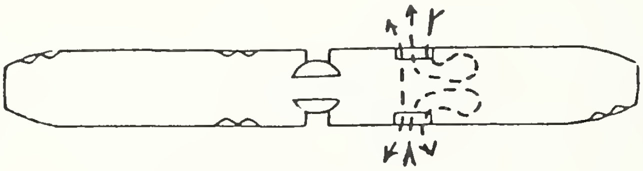
8



- Bi-directional
- Either-side entry

Similar to 7, short cross-over path, one lift is still remote from operator for both directions of travel.

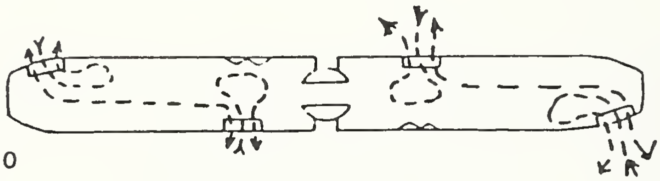
9



- Bi-directional
- Either-side entry

Similar to 3 above. Shortest cross-over path, both lifts equally remote from operator.

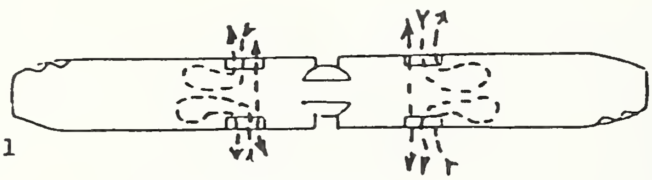
10



- Bi-directional
- Either-side entry

Symmetrical arrangement of 7, requiring four lifts per vehicle to minimize remote location of lifts for both directions of travel.

11



- Bi-directional
- Either-side entry

Symmetrical arrangement of 9, requiring four lifts per vehicle to minimize remote location of lifts and to provide shortest possible cross-over path.

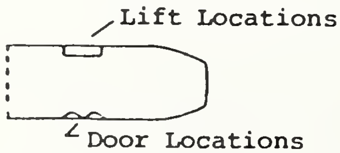


FIGURE 5-5. ENUMERATION OF POSSIBLE LIFT LOCATIONS
Uni-or Bi-directional Vehicles
Single-or Either Side Boarding

to be relocated, depending on the final lift arrangement selected. As Figure 5-2 shows, the San Francisco vehicles have a larger cubicle for electronic equipment under the paired seats on the left side.

The optional location for lifts on LRV's will depend to some extent on local preferences if the decision is not forced by site requirements. The preliminary conclusions that can be drawn regarding lift location are:

- Bidirectional vehicles require a minimum of two lifts for full accessibility,
- Either side low-level boarding requires a minimum of two lifts, with an accessible interconnecting path,
- Lift proximity to the driver and the minimum cross-over path are always in conflict for either side boarding, and
- On bidirectional, articulated vehicles up to four lifts per vehicle could be required to satisfy minimum path length and proximity to driver requirements.

This section examines only low platform boarding requirements. In the following section, the additional constraints imposed by high platform level entry boarding are examined.

5.1.2 Mixed Platform Heights - Light Rail

The combination of low and high platforms introduces an additional factor to be accommodated in lift design and application on light rail and commuter rail vehicles. In addition to serving as a lift or as stairs, a device must also be provided to form a level entry-way to the vehicle. Two possible generic solutions are steps, lift, and level entry arrangement all in one doorway; and steps and lift separate from the level entry doorway. The advantage in the latter arrangement is the gain in some simplicity in the step/lift area at the expense of an additional door or doors. However, the high level door or doors can be located over a truck, if desired, whereas steps cannot possibly be allowed to infringe on the truck space. Figure 5-6 shows a proposed version of the Canadian Light Rail Vehicle (CLRV) arranged with a separate high level entry over the front truck.

San Francisco Muni operates at either-side high level platforms in the Market Street tunnel, and Pittsburgh light rail upgrading plans include high level platforms at some stations. It is probable that high platforms will become more common for light rail systems, where they can be accommodated, because boarding and deboarding is much quicker and more convenient from level entry platforms.

There are currently no light rail operators faced with either-side low and either-side high platforms. San Francisco Muni has studied the lift and level entry arrangements that might be used on the Boeing vehicles on their system, which is unique in its entry combinations with right-side low and either-side high platforms. Figure 5-7 shows five entry arrangements under consideration. High-low entry arrangements are complicated to some extent on the Boeing vehicle because of the plug door arrangement. Because clearance for the door must be provided between the vehicle and high platforms in addition to the standard dynamic clearances, the car floor to platform gap is considered to be large by San Francisco , and movable gap closing devices may be required for the accessible door locations.

Although the high-low step arrangement is not directly part of the lift study, it is appropriate to discuss the high-low arrangement in the context of its impact on lift installations. For the San Francisco Boeing LRVs, the inability to provide a satisfactory level-entry condition in conjunction with a lift installation at the center doors may constrain lift installations to the front door locations.

On the Boeing vehicles, the four center steps are powered so that the operator can remotely convert them to the level entry position. The low-to-high and high-to-low sequences are required once for each vehicle, for half of the high-low steps, for each round trip. Lift operation, in contrast, is expected to occur much less frequently. One major design requirement that must be addressed by new high-low arrangements is how to move the steps safely with people on them. The present Boeing arrangement is considered safe to operate under those circumstances because its clearances and pinch points are similar to those of escalators. It seems desirable that the requirements for safe remote operation of the level entry provision be retained if lifts are used at those locations, even if the operator must leave his seat to operate the lift, because it is expected that the step to level entry operations will greatly exceed the number of lift operations.

It is not necessary at this point to specify that a level-entry provision be part of, or separate from, the lift function. However, there are no existing lift manufacturers that have addressed the level entry condition. The remote operating level entry provision in combination with a lift could constitute a major hardware development project.

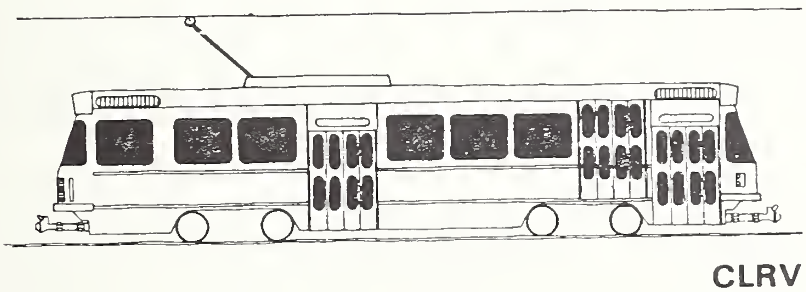
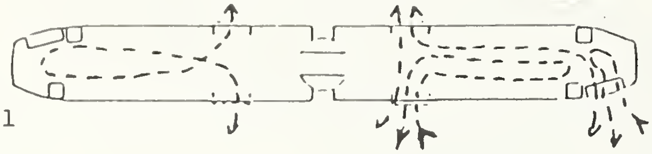


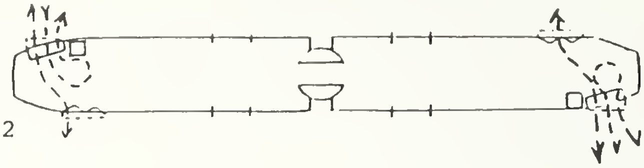
FIGURE 5-6. THE CANADIAN LIGHT RAIL VEHICLE WITH A PROPOSED HIGH PLATFORM ENTRANCE

1



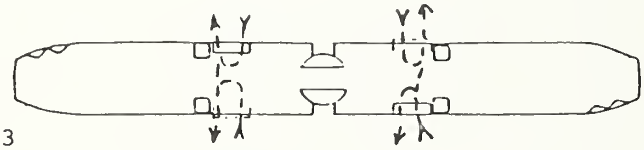
Lift at front doors, step extensions at middle doors. Lift is close to operator, long in-vehicle path to high-platform exits. Very long path for all high-platform trips, from doors to securement area and back.

2



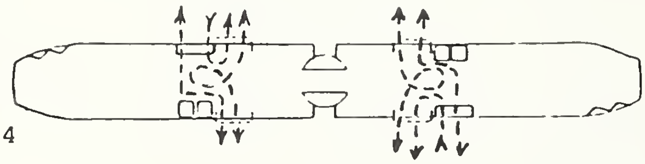
Lift is close to operator, and all path lengths are short.

3



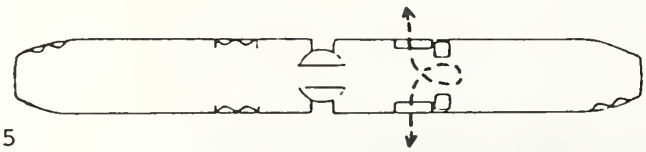
Short path lengths for all trip combinations, but lift is quite far from operator. Minimum seating changes.

4



Short path lengths for all trip combinations, as above, but lift is only marginally closer to operator.

5



Lifts in one end only; lifts are quite remote from driver in one direction of travel, but path lengths in vehicle are very short

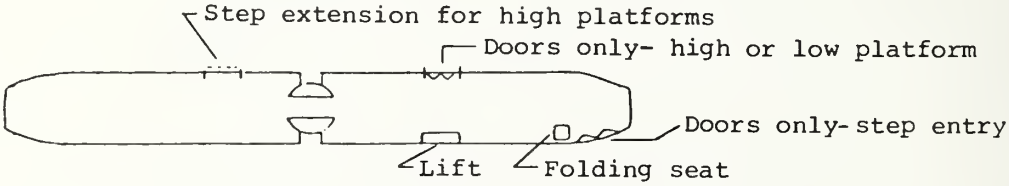


FIGURE 5-7. ENUMERATION OF POSSIBLE LIFT LOCATIONS
Bi-directional Vehicles
Single-Side Low Level Boarding
Either-Side High Level Boarding

The application of lifts to light rail vehicles appears technically feasible. The major problems that must be resolved, as discussed, are equipment relocations, multiple lift installations, and high-low entry conditions. Existing lift concepts that use hydraulic actuation must interface with the LRV electrical power, but there do not appear to be any fundamental obstacles to lift installations on LRVs.

The following section examines lift applications to commuter rail vehicles. The commuter rail questions are similar to the LRV lift issues. The major differences that appear are due to operation in trains of cars, greater floor heights, and much more variations in car configurations. The larger cars do, however, permit the consideration of more varied sollutions than are possible with light rail vehicles.

5.2 Lift Application to Commuter Rail Vehicles

There are a great many different commuter rail vehicles when considered in detail, but there are only three basic installation conditions. An understanding of the three basic conditions will provide the necessary foundation for examining any specific family of cars, or single car, to any level of detail through to final design of a lift installation if desired.

5.2.1 End Door Locations

Because bus lifts, in their relatively short span of existence, have been applied at existing door/step locations, it is logical to look at similar locations on rail cars to see if a similar solution is appropriate. Figure 5-8 shows the conditions existing in the vicinity of the end steps on the Silverliner/Arrow series of cars. Most other commuter cars are similar in design.

The end doors on most cars are typically 36" wide, although the existing clear opening is usually less because doors and handrails intrude on the opening. Three or four steps are used, but the floor height is always about 52" above the rail. There is a swinging or sliding door leading from the end vestibule to the interior of the car. The collision posts are located either side of the end passageway doors. Locomotive hauled cars, push-pull cars, and electric MU or Diesel self-propelled cars are all basically similar in the end step area.

Electric MU cars run as married pairs, and push-pull control cars, are equipped with operating controls in the right front corner. Single unit cars have controls in the diagonally opposite right front corners, as in Figure 5-8. Inboard of the inner end walls, all cars utilize some or all of the four corners for equipment, such as air conditioning units and toilets. Under the steps are the airbrake and signal pipes that pass the length of the train. In addition, non-EMU cars have either a steam-heat line or heavy cabling for electric heat. Push-pull cars have a multiconductor cable that runs the length of the train, so the locomotive can be controlled from the cab car when operating in the push mode. Figure 5-9 shows the stepwell area; Figure 5-10 shows the inter-car airlines and electric power and control cables for push-pull cars.

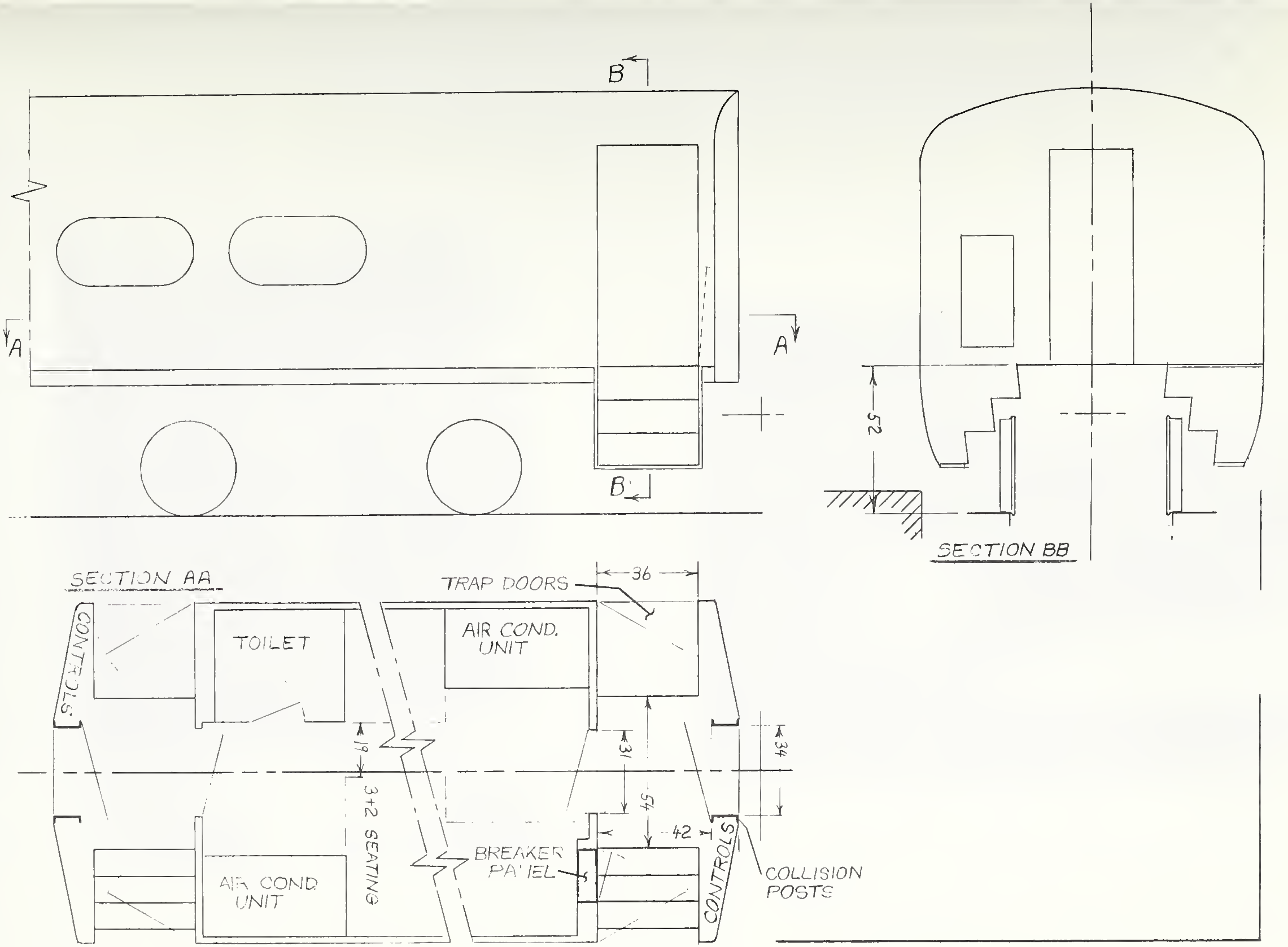


FIGURE 5-8. ELECTRIC M.U. COACH - SILVERLINER/ARROW TYPE - END VESTIBULE AREA: E & H LIFT APPLICATION CONDITIONS AND CONSTRAINTS

FIGURE 5-9. STEPWELL AREA ON MBTA PUSH-PULL CARS

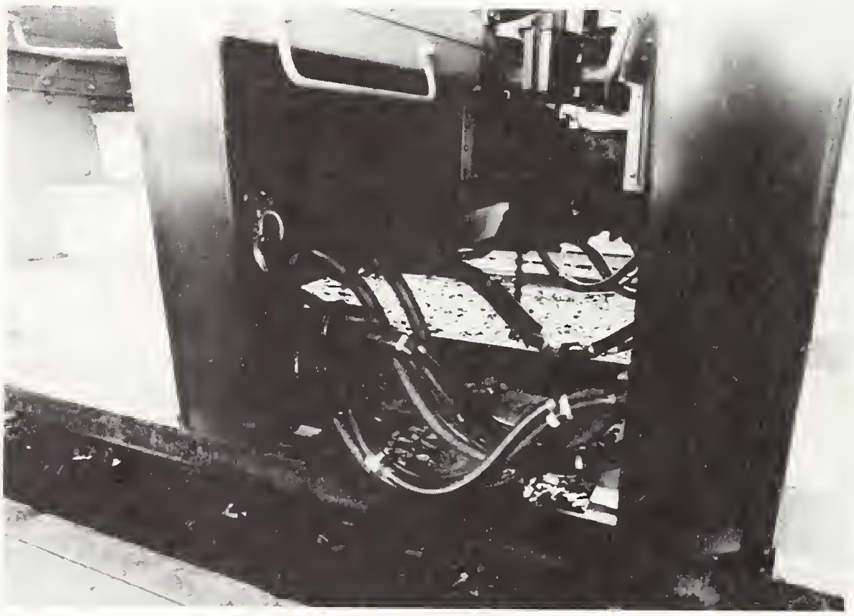


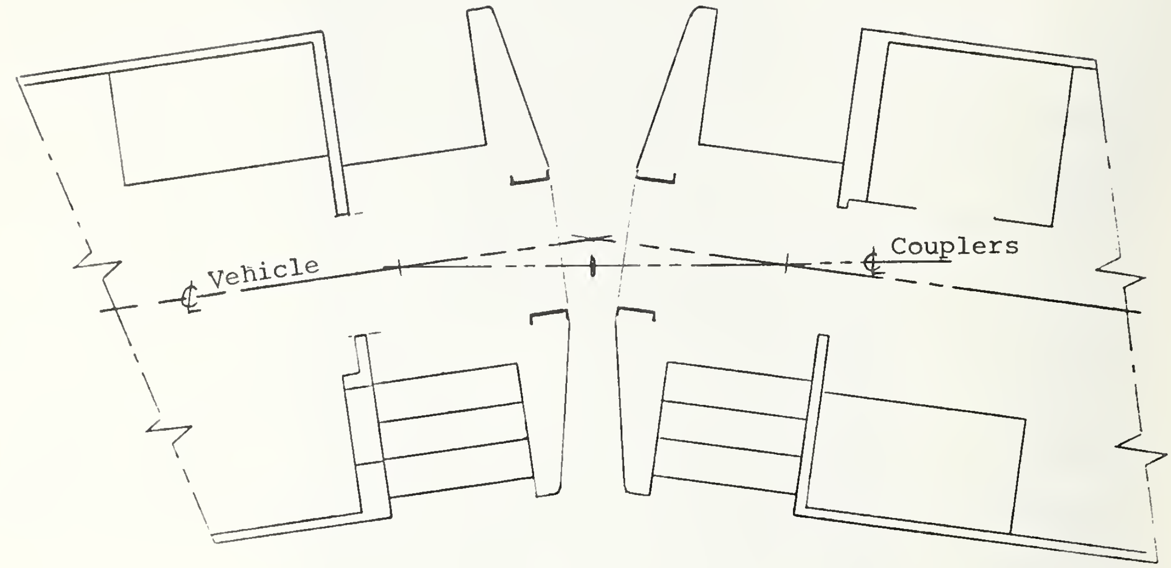
FIGURE 5-10. INTER-CAR CONNECTIONS ON MBTA PUSH-PULL CARS

The end coordinates of each trainline and jumper cable lengths are chosen to ensure proper operation on tangents and curves when the cars are coupled. The amount of slack provided in these components is designed to prevent them from going taut on minimum radius curves in one direction, and to prevent them from dragging on the rails in the other direction. To move a given line from one location would require the same change on all cars, so that all cars could be intermixed indiscriminately and be properly coupled in all respects (i.e., air, electric, not just mechanical.)

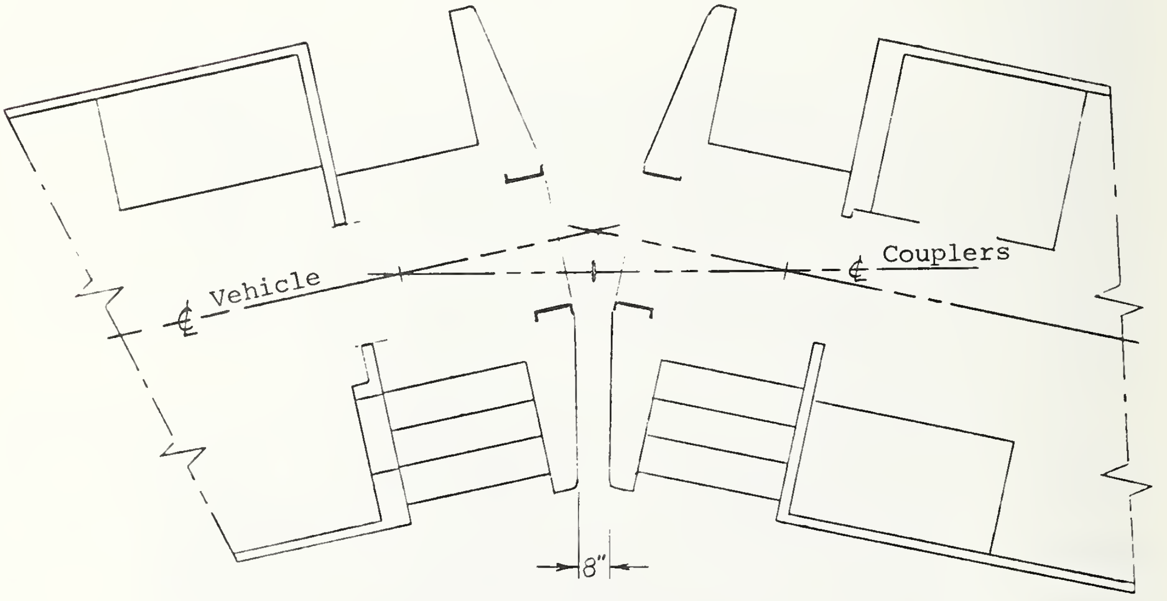
To achieve a 30" minimum, 35" recommended width of platform, a lift installation at the end step location would require somewhat more width than the existing 36" stepwell, because of the mechanism requirements of most lifts. To enlarge an existing stepwell would require moving either the inboard or outboard side of the steps and vestibule area. In the inboard direction (lengthwise toward the center of the car), there are the obstacles described above, and illustrated in Figure 5-8.

Before enlarging the stepwell in the other direction, it is necessary to examine the operating conditions of cars coupled on curves. Figure 5-11 shows two like cars on 300 and 200 foot radius curves, which are encountered in yards and shop areas. It can be seen that the beveled ends found on all cars are clearly functional. Starting in the design stage, cars are assumed to be coupled as close together as possible to produce convenient car-to-car walkway conditions for trainmen and passengers. Then it is observed that at about a 300 foot radius, square car ends would come into contact, which would cause car damage or derailment. Therefore, the ends are beveled as much as necessary to prevent contact at the design minimum radius, with an allowance for draft gear compression, plus a positive residual clearance.

Lift installation in the end stepwells can be seen to be constrained by some major considerations, which although not unsolvable, would require some time-consuming modifications. Generally, more width is needed in the doorways, and if vertical lifts are to be used, all equipment and lines now under the steps must be displaced toward the centerline of the car. Each trainline, even though displaced by lift alterations, must return to its original coordinates on the end of the vehicle. The location would be very congested, both above the floor and below, on EMU and Diesel self-propelled cars in which there is an operator's station at the stair location.



300 Ft. Radius



200 Ft. Radius

FIGURE 5-11. TWO 85' CARS COUPLED ON 200' AND 300' RADIUS CURVES

In addition, the end of car location for lifts would also be inconvenient for handicapped patrons in wheelchairs because of the limited space in which to make a 90° turn from the lift into the interior door. There would be some delay to ambulatory passengers from lift operation at an existing door location, but with trains of increasing length (and therefore with more doors), there might be a tendency for people to board through the next closest door.

If a lift installation at the end step location is desired, one way to gain extra width of stepwell (i.e., length of car) would be to completely sever an end through the doorways, move the end structure, and replace structure and skin as required, Figure 5-12.

Up to a foot of length could be added before end mismatch begins to become severe on a 200 foot radius, Figure 5-13. All car overhangs (truck centerline to coupler pulling face) are not now the same, nor are locomotive and car overhangs the same, nor do all vehicles have the same overhang on both ends. Two tight-lock couplers, when joined, function as a pin-ended link that angles from pivot to pivot as required. As long as the demands for lateral swing are within the limits provided, and if train-line connections can accomodate the extra offset, no problems are encountered. It is also necessary to check the end alignment conditions for the worst cases of spirals, tangent to curve junctions without spirals, and reverse curves.

It appears technically feasible to install lifts at end stepwells on commuter cars, although there are some significant problems encountered. The problems are all basically caused by the very constrained space available. The following section examines a center door location that is available on the Silverliner/Arrow series of car, which may prove to be more desirable for many reasons than are end door locations.

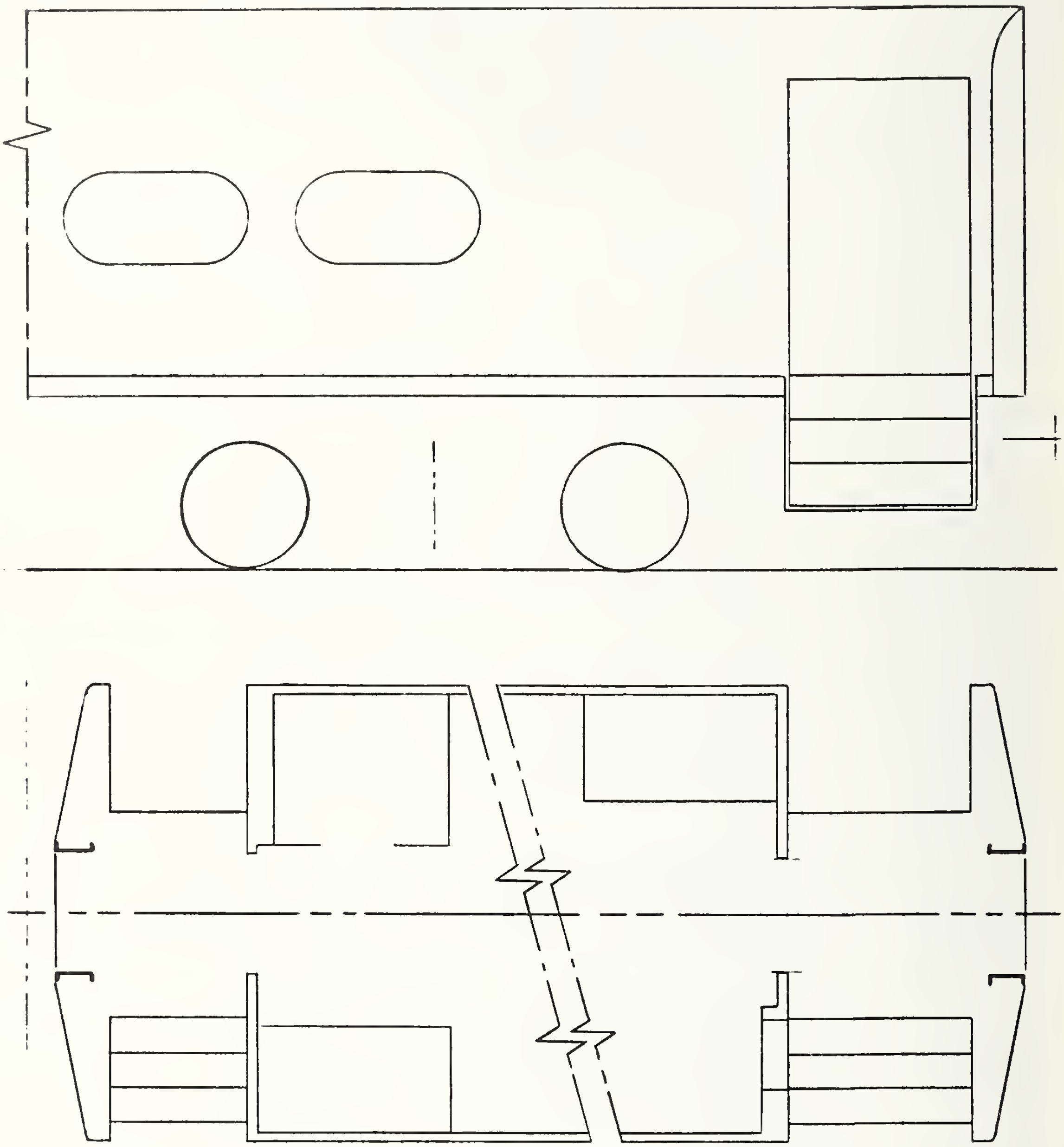
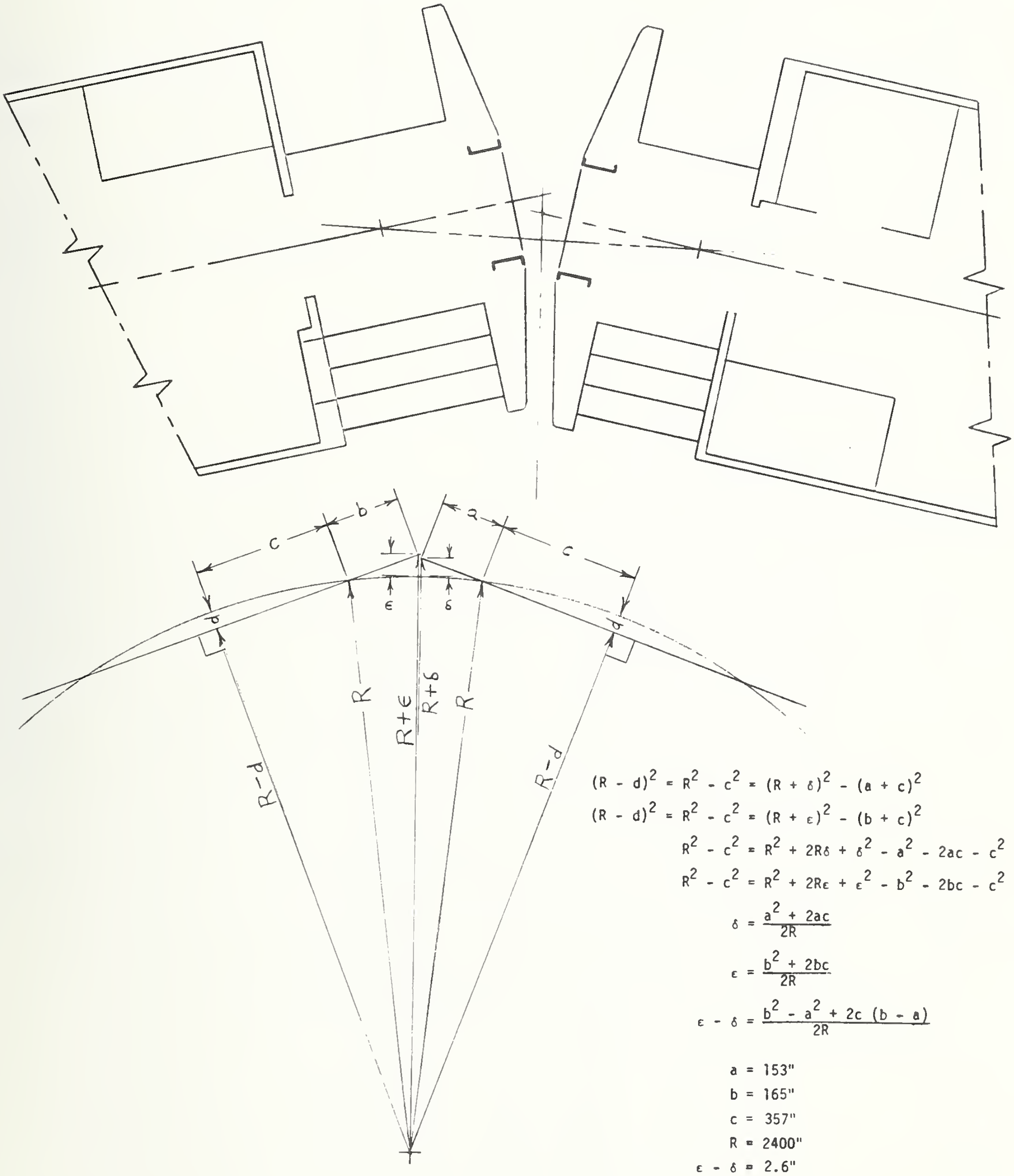


FIGURE 5-12. LENGTHENED END VESTIBULE ON COMMUTER RAIL VEHICLE



$$(R - d)^2 = R^2 - c^2 = (R + \delta)^2 - (a + c)^2$$

$$(R - d)^2 = R^2 - c^2 = (R + \varepsilon)^2 - (b + c)^2$$

$$R^2 - c^2 = R^2 + 2R\delta + \delta^2 - a^2 - 2ac - c^2$$

$$R^2 - c^2 = R^2 + 2R\varepsilon + \varepsilon^2 - b^2 - 2bc - c^2$$

$$\delta = \frac{a^2 + 2ac}{2R}$$

$$\varepsilon = \frac{b^2 + 2bc}{2R}$$

$$\varepsilon - \delta = \frac{b^2 - a^2 + 2c\ (b - a)}{2R}$$

a = 153"
b = 165"
c = 357"
R = 2400"
$\varepsilon - \delta$ = 2.6"

FIGURE 5-13. TWO 85' CARS COUPLED ON 200 FT. RADIUS CURVE - ONE LENGTHENED PLATFORM

5.2.2 Center Door Locations

The largest group of similar cars, Silverliners, Arrows, and the new MBTA cars, have doors (or structural provision for doors) approximately in the middle of each side, Figure 5-14. This location serves high platforms, or is held ready for future high platforms on lines that do not now have them. The center doors are either single or bi-parting sliding doors, that open a four-foot doorway. As Figure 5-14 shows, these doorways open directly to the interior of the car; there are no additional doors to negotiate as on the ends. On cars not now using the center doors, seats are provided the full length of the car. On the most recent cars of this type the structural framing is in place, but the opening is skinned over. It is not a major modification to open the doorway.

There is equipment located under the center doorways, but conditions are somewhat less cramped than on the ends. Equipment, piping and wiring can be relocated without consideration for adjacent car interfaces, unlike the ends, although this does not guarantee easy or inexpensive modifications. The equipment in the center area is much larger, heavier and more complex than that at the ends. The changes that would be required are very dependent on the lift proposed for installation in that area. Structural modifications are generally impractical, even if technically feasible. For example, the center sill and side sills cannot be cut without incurring a major rebuilding effort to transfer stresses around the excised member. However, since there are lifts that might work at the center doors without necessitating major surgery on the car, it is useful to consider the center doors further.

Section 4.0 described various kinematic concepts of lifts, among which were those that stored a lift platform intact, and moved the platform into the operating position when required. Lift-U has operating lifts of this type on buses. This concept appears appropriate for a lift that is to serve a level-entry doorway where they are no steps.

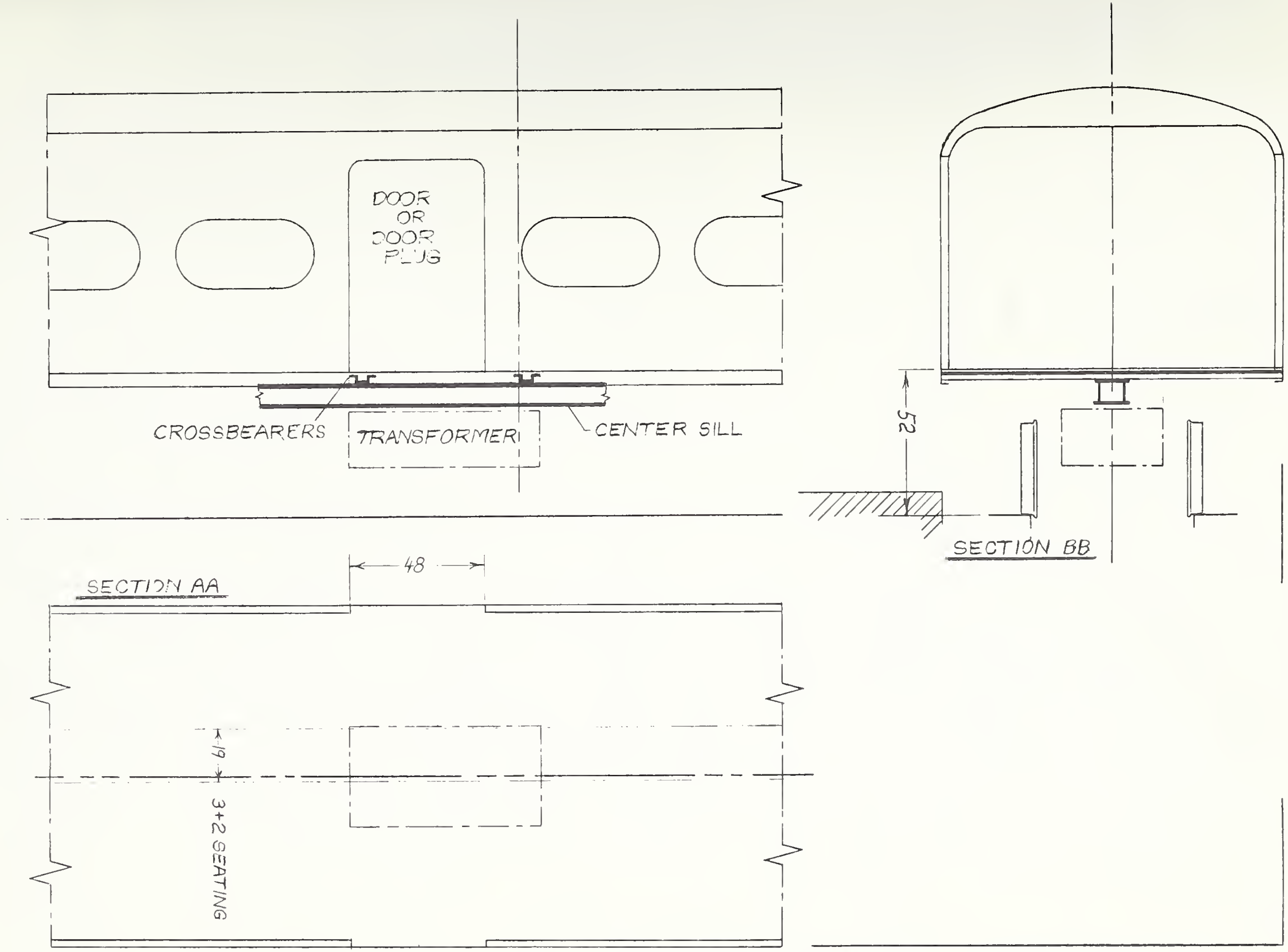


FIGURE 5-14. ELECTRIC M.U. COACH - SILVERLINER/ARROW TYPE - CENTER DOOR AREA: E & H LIFT APPLICATION CONDITIONS AND CONSTRAINTS

Center door locations have several strong advantages over the end door locations for lift installation:

- Wider opening with which to work, 48" vs. 36".
- Major structural modifications can be avoided.
- Somewhat easier equipment relocation problems.
- No conflict with vehicle operating controls on EMU cars.
- No requirement for lift to form steps.
- Lift patrons use same doorway for low and high platforms.
- Does not impede ambulatory access at end steps.
- Minimizes expected dwell time penalty associated with lift.

In addition to mechanical advantages, there are attractive operational advantages to locating lifts at level entry doors, such as the center doors on the Silverliners/Arrows. An increase in dwell time can theoretically be avoided or at least minimized at low-level platforms when the lift is used. At a low-level platform, a lift patron can be boarded, using the lift at the center door, while the ambulatory passengers use the end stairs in the normal manner, without any delay for a lift cycle. Clearly, no ambulatory person is delayed by the lift operation at the center door because the center door is inaccessible to ambulatory persons at low platforms. At high platforms, all passengers use only the center doors for level entry and egress, and the lift does not need to be called into operation for handicapped passengers. The car-to-platform gap problem must be addressed for level entry conditions.

The mechanical advantages of locating lifts away from the end doors becomes evident when considering the group of self-propelled cars: RDC's and single-unit EMU's. These vehicles have a set of controls for the engineer at the right front corner for each direction of travel, and a simplified set of controls for the fireman on the left front corners. The wall behind the engineer usually has an electrical locker with associated control equipment packaged in it. To install a pair of lifts of adequate width in either end means intruding one pair of control stations and electrical locker at the minimum. The fireman's stations with, fewer controls, may be able to accept some lifts, but to utilize only fireman's stations means the pair of lifts would necessarily be at diagonally opposite corners. This arrangement requires a clear path of wheelchair width the length of the vehicle to make possible cross-over journeys.

The mid-side location for lifts is under study by several operators as the preferred lift location, notably by Maryland Department of Transportation and VIA in Canada for their RDC's. Baggage cars, with their wide side doors, have attracted attention for possible conversion to coach compartments with space for handicapped riders. Figure 3-14 shows a version of an RDC with a baggage door. The door is located directly over a truck, which is less convenient than a door located away from the trucks; never-the-less, MDOT has this version of RDC's under study for possible application of lifts.

It may be concluded that center door lift applications on Silverliners/ Arrows should be considered in more detail, in preference to end door installations. The 240 MTA 2800 series cars and the 167 RDC's do not have similar center doors, and a detailed structural analysis would be required to determine if center door opening could be made. The major group of cars remaining are the bilevel cars, which have some significant differences from conventional coaches. These will be examined in the following section.

5.2.3 Bilevel Cars

Although the bilevel cars are also center door cars, they are distinquished from the previously discussed cars by having steps at the center entrances, and by having no alternative entrances to consider. There are currently no bilevels that operate at both low and high platforms. The arrangement in the area of the center doors is shown in Figures 5-15 and 5-16. There are two doorway widths in use, 78 inches and 66 inches.

It is immediately apparent that the available doorway width is much greater than that of conventional end step locations. The rail-to-floor height is only about 45 inches, compared with the 52 inch floor height of conventional cars. Because all low-entrance bilevels are either Diesel-hauled or push-pull cars, there is relatively little under-floor equipment in the area of the steps. The major structural restriction to observe in any modifications to the step area is that the side sills should remain intact. If they are to be cut to install a lift, the forces in them must be carried around the opening in a satisfactory manner.

Unlike conditions at center entrances on conventional cars, there is an additional set of doors to negotiate to gain access to either end of the car. On existing cars these are sliding bi-parting doors, manually opened, gravity closed. These could present a problem for a handicapped person to open, depending on the physical ability of the individual.

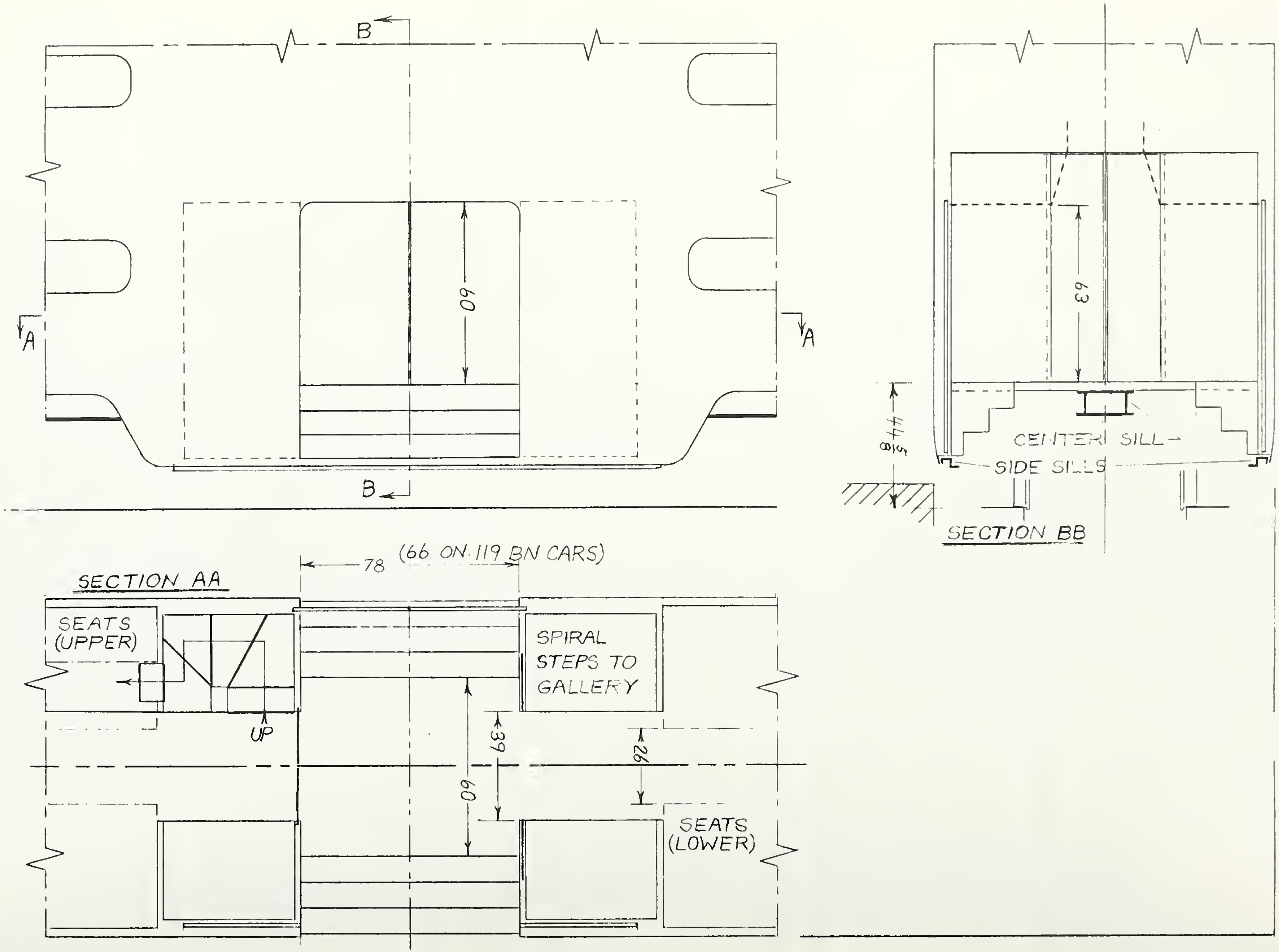


FIGURE 5-15. BILEVEL COMMUTER COACH - CENTER DOOR AREA: E & H LIFT APPLICATION CONDITIONS AND CONSTRAINTS

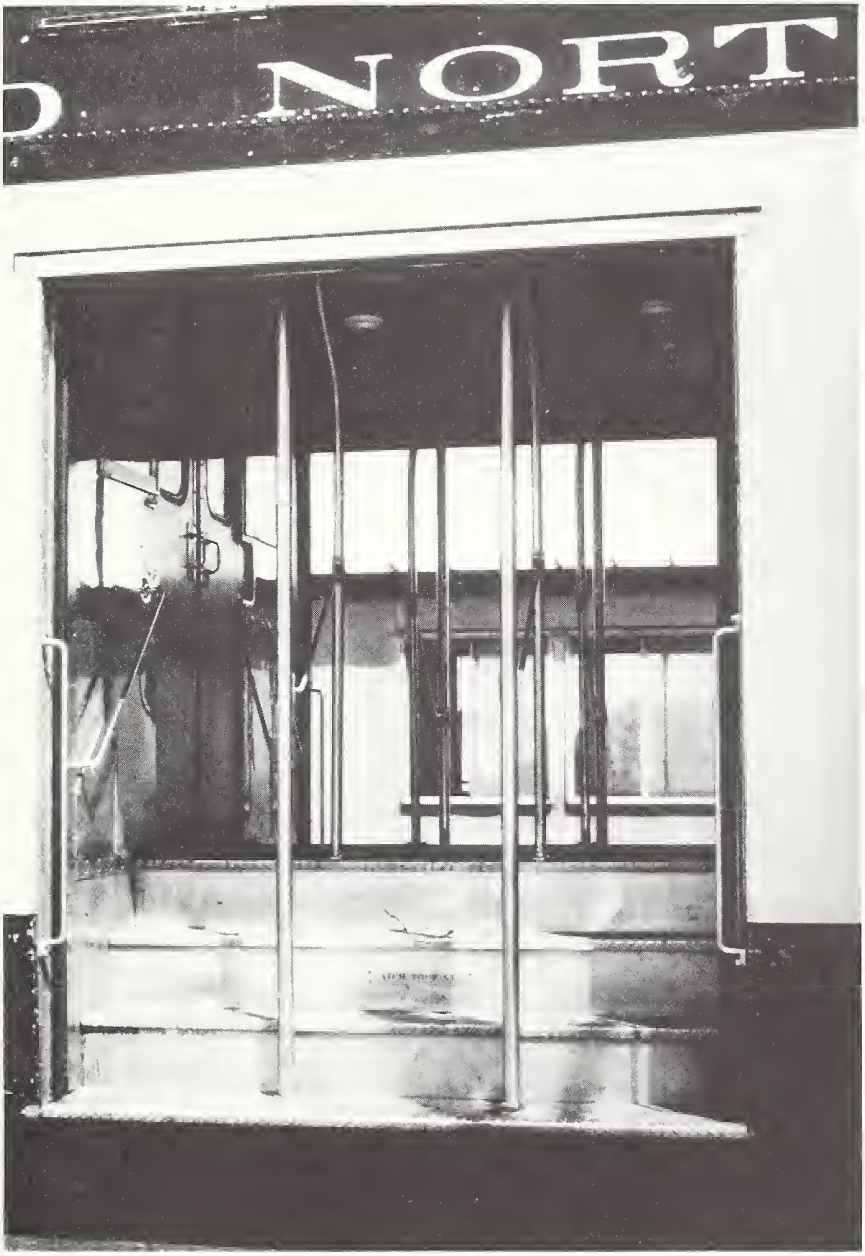


Photo - Jeffrey Mora

FIGURE 5-16. CENTER ENTRANCE ON BILEVEL COMMUTER COACH

A standing lift patron, for example, someone using a walker, would experience a problem with low door height on the bilevels. On buses and rail vehicles not originally designed for level entry, adequate door height was calculated using the step at the portal as the zero reference. If the floor level is projected over to the doorway, which is in effect what the lift platform does in the raised position, there is much less than a normal height doorway remaining. A person standing at the door portal on a lowered lift could bump into the top of the door frame when raised if precautions are not taken.

5.2.4 Number and Location of Lifts Per Car - Commuter Rail

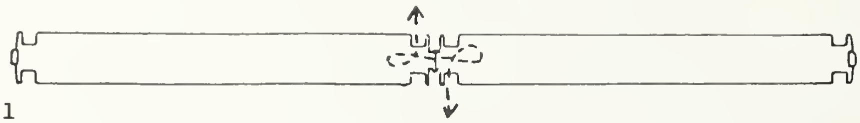
The possible locations of lifts on commuter cars are presented in Figure 5-17. There are no commuter operations where only single-side entry would be suitable. Consequently, the major consideration is how to best arrange the required lift on each side. The operator of the lift will need to be a member of the train crew, who, except for the engineer and fireman, in practice has no fixed station in the train. There is then no single location closest to the roving members of the crew, and the optimal lift location within a single car would be one that minimizes the cross-path length within the vehicle. As Figure 5-17 shows, the only practical arrangements are lifts directly opposite each other. If lifts are not opposite each other, they must be connected with an accessible path. On all commuter cars, existing aisles are considerably less that the 35" width recommended for wheelchair accessibility. Hence, enlarging aisles would necessitate removing one row of seating.

As developed in the preceeding sections, lifts located at the ends of conventional commuter cars present some difficult problems. Where their use is possible, center door locations offer both mechanical as well as operational advantages.

To ensure accessibility to each commuter train, as required by the Section 504 regulations, the minimum number of lifts per train is two, because of the vehicle bidirectional characteristics. As developed above, the best arrangement is lifts paired opposite each other, because of the use of either-side platforms. This provides one lift for each side of the train, the minimum arrangement that achieves functional accessibility for each train.

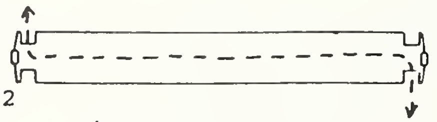
Having established a minimum of two lifts opposite each other, the next consideration for lifts on commuter rail is the development of a rational for the location of the lifts in the train. For the convenience of the lift patron the single lift position per side on the train should preferrably appear consistently at the same platform location, and the lift location should be marked on the platform so the user can position himself before the arrival of the train.

Operationally, the lift should ideally be kept at the same location in a train of given length so that the engineer could position it at the



1

Diagonally symmetrical arrangement on two cars or married pairs. Short cross-over path length, but crossing through vestibule is not desirable.

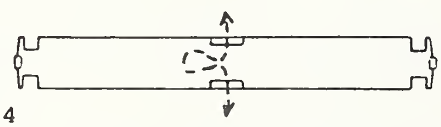


2

Diagonally symmetrical arrangement on one vehicle. Long internal cross-over path requires full length wide aisle with attendant loss of seating.

3

Arrangement for single unit or married pair of vehicles with end doors. Short cross-over path length and little seating loss.



4

Center door arrangement for cars with center entrance only (bi-levels) or combination end and center entrances (Silverliners , Arrows).

FIGURE 5-17. ENUMERATION OF POSSIBLE LIFT LOCATIONS ON COMMUTER RAIL VEHICLES
Bi-directional Either-Side Boarding

designated location on each platform. Knowing the train length, the engineer could position the lift correctly by controlling the train stopping position relative to markings on the platform.

Operators that currently use push-pull equipment universally indicate that the control cab car is the preferred location for lifts, because the lift presence and location is assured without introducing any new operational problems. The number of control cabs provided must always exceed the number of trains to be operated in a push-pull mode by the reserve requirements. If control cabs were all lift-equipped, the lift requirements would also be approximately met.

There are also significant disadvantages to using the control cab car as the one accessible vehicle in a train. Trains of maximum length have only one possible stopping alignment when platform length equals train length. For a maximum length train, the last car will be at the greatest possible distance from platform access and stations, which are usually centrally located. The distance to the accessible car is therefore maximized to the detriment of the lift patron, and constitutes a particularly adverse situation in inclement weather.

Conversely, short trains are usually stopped convenient to the station area. To stop a short train so that the control car is at the same location as the control car of a long train would be inconvenient for all patrons.

If cars other than control cars are selected for lift installations, an operational problem develops in trying to keep a lift at a given location within a train, for example, at the middle of the train. Train lengths are changed through-out the day to adjust seat supply to normal ridership requirements, to conserve fuel, and to make cars available for routine maintenance. With Diesel hauled equipment, it is not now necessary to arrange cars in any specific order. With push-pull equipment, it is necessary only to insure that a control car is at the extreme end; excess control cars may be located indiscriminately within the train. EMU equipment is arranged with an operating station at each end of the smallest unit normally added to or subtracted from a train, so there is now no restriction on train make-up. In each case, maintaining the location of a specific type of car at a specific in-train location adds an operational constraint to be satisfied.

Double-stopping might be postulated for long trains, once at the optimum full train-to-platform alignment, and again at the accessible car to accessible boarding zone alignment. Unfortunately, the requirement for this practice occurs exactly at the times when such a procedure is least tolerable. Trains are at their longest during rush hours, and run on very short headways. The additional stop plus the lift cycle time might exceed the shortest rush hour headways in use on busy systems. In addition to the delay experienced by a given train, following trains would also be delayed because of the requirement to maintain minimum train separations. At inbound terminals, trains are berthed at specific locations, deboarded, and moved out to storage locations on tight schedules. A late arriving train can leave terminal operations disrupted for the balance of a rush hour.

Although blanket schedule increases could be postulated, they would cause problems because trains are not allowed to run ahead of schedule. Slowing operations to accomodate lengthened schedules would result in degraded service as perceived by existing commuters, and a real decrease in line capacity for the operators.

The entire aspect of the impact that accessibility features will have on schedules and operations needs detailed study because of the undetermined magnitude of the effects.

There are several conclusions that may be drawn regarding lift locations within a train. As previously discussed, two lifts per car are required, and the best arrangement of a pair of lifts is directly opposite each other. However, there is no strong preference for end or center door locations on a car when considering the train as a whole; rather the more important consideration is lift location within a train.

User considerations, not hardware considerations, favor lifts approximately in the middle of the train. Operational considerations, in contrast, favor lifts on an end car, such as a cab control car, because the lift location is simultaneously assured when a cab control car is placed in the correct position on a train. It seems clear that the question of lift location within a train cannot be satisfactorily answered in a hardware oriented study.

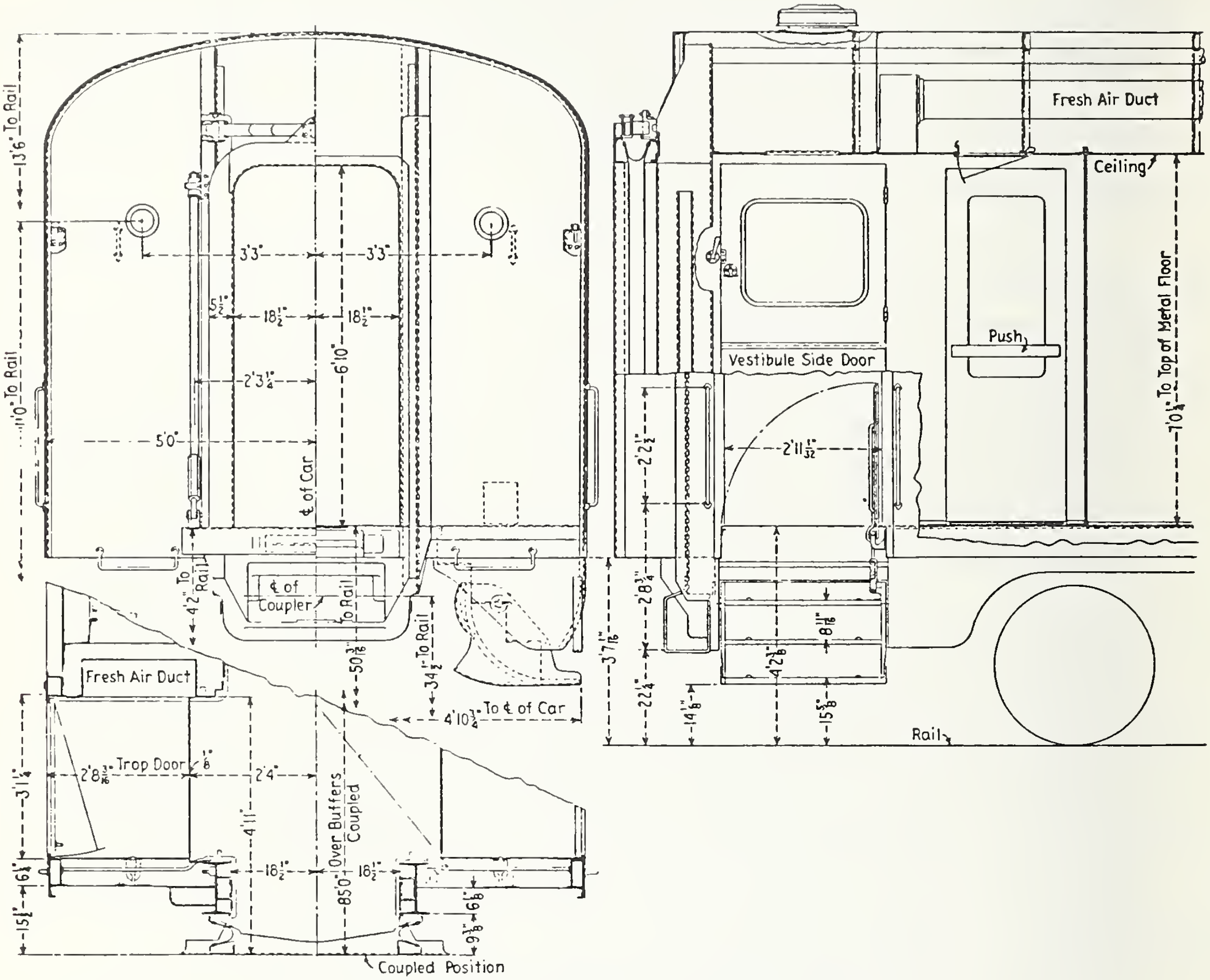
5.2.5 Mixed Platform Heights - Commuter Rail

The combination of high and low platforms poses problems on commuter rail equipment similar to those of light rail. Functionally, the same three access modes must be provided: level entry from high platforms, step entry and lift entry from low platforms. The solution now in common use is a manually operated drop-down trap door over the step-well that effects the conversion to a level entry arrangement, as shown in Figure 5-18. The use of trap door arrangements could be continued if passive lifts are provided. Since manually operated trap doors are now considered satisfactory, there seems to be no reason that the level-entry provision must be provided by the lift assembly on commuter rail vehicles.

At this writing, the commuter rail lift question has not been addressed in depth by those active in the lift industry, and buses do not require level entry provision. Consequently, none of the available lifts offer a combination lift/level entry provision. Budd, a rail vehicle manufacturer, has a conceptual design for a lift that utilizes the trap door plate for the lift. In effect, they combine the level entry provision and lift, as contrasted with the current practice of most manufacturers combining steps and lift.

It might be implicity assumed that commuter rail lifts will be installed at existing step locations, directly paralleling bus and most probably light rail practice. However, the narrow steps, the presence of vehicle operating controls on some types of cars, and the narrow door from the vestibule to the corridor are all impediments to installing lifts at the end doors. On commuter rail vehicles, it is more feasible than on light rail and buses to consider lift locations other than at existing doors with stairs, with the intent of separating the lift/step/level entry to achieve mechanical simplicity.

It would be unnecessarily restrictive to conclude that all three access modes must be provided at one access location on commuter rail vehicles, especially at an end door location. Existing practice on SEPTA with Silverliners is to use the end doors for low platforms, and both end and center doors for high platforms for non-handicapped passengers. As discussed previously, the Silverliner/Arrow series of cars all have provision for center doors that are an attractive alternative to the end door for lift applications.



End framing arrangement of vestibule end for Penn Central passenger cars.

FIGURE 5-18. TRAP DOOR ARRANGEMENT ON COMMUTER COACH (REF. 4)

The preceeding discussions have indicated that lift retrofits on light rail and commuter rail vehicles are generally feasible. In the following sections, some conceptual installations will be presented, based on existing lift concepts.

5.3 Conceptual Solutions

In the examination of available or proposed lifts and existing vehicles, one objective was the identification of one lift or lift concept that would be applicable to all type of rail vehicles for which lift retrofit was desired. A second-best result, assuming that one lift design was not possible, would be to show what would be the minimum number of concepts required to satisfy the retrofit requirements of the existing vehicle population.

In this lift retrofit study, the basic premises are:

- Compactness of installation is desirable.
- Maximum mechanical simplicity is required.
- Certain parts of vehicle structures are inviolable.
- Applicable lifts are restricted to existing kinematic concepts.

Based on the above premises and previously discussed analyses of each retrofit situation, it appears that one lift design will not be universally applicable. The upper limit can probably be restricted to four lift concepts, and possibly only three, if the end steps on commuter rail vehicles are bypassed from consideration.

The requirements for four different lifts are generated by the entry conditions on light rail and commuter rail vehicles, which can be reduced to four basic conditions, as described earlier. Table 5-1 is a summary of the single light rail and three commuter rail entryway conditions with only those constraints that prevent any two from sharing a common lift design.

5.3.1 Light Rail Installation

Light rail vehicle lift applications can in all probability be accomodated by one basic design of lift. The light rail requirements are very similar to those of buses; in fact, existing bus lifts of certain manufacturers are close to being suitable for installation.

The first major mismatch, comparing what exists to what is preferred, is in width of the units. LRV's have doorways approximately 50" wide, and buses usually less. It is clearly desirable to widen lifts to use the

TABLE 5-1 THE FOUR SIGNIFICANT LIFT APPLICATION CONDITIONS FOR RAIL VEHICLES

THE FOUR SIGNIFICANT LIFT CONDITIONS FOR RAIL VEHICLES	SERVICE AND APPLICATION CONDITIONS FOR E&H LIFTS					LIFT FUNCTIONAL SPECIFICATIONS
	FLOOR HEIGHT ABOVE RAIL; ABOVE PLATFORM	WIDTH OF DOORWAYS	NO. OF STEPS ON VEHICLE	COMBINATION OF HIGH AND LOW PLATFORMS	MAJOR CONSTRAINTS	
	(Note 1)	(Note 2)	(Note 3)	(Note 4)	(Note 5)	(Note 6)
Light Rail Vehicles	~ 34"; same	~ 50	2	Some (S.F.)	End of lift should project as little as possible from the side of the vehicle	1. 2-step lift, elevator type, with level entry provision 1a. Same, without level entry
Commuter Rail Vehicles - End Stepwells	~ 50-52"; same	~ 36	3	Some	Narrow doorway; wiring and piping under steps. Vehicle operating controls on some cars	2. 3-step lift, with level entry provision, elevator or other concepts. 2a. Same, without level entry. 2b. Void - use center doorway
Commuter Rail Vehicles - Center Doorways (Level Entry)	~ 50-52" same	~ 48	None at level entry doorways	(Note 7)	Floor cannot easily be cut to accommodate inset vertical lift	3. Platform lift - steps not required. Cannot cut floor or side sills
Commuter Rail Vehicles - Center Stairs (Bilevel Cars)	~ 44" same	~ 78	3	No, low only	Structural member under doorway cannot reasonably be cut to accommodate vertical lift	4. 3-step lift, must clear bottom side sill. Level entry not required. Elevator type not applicable.

NOTES

1. The floor height above platforms determines the minimum range of travel for a lift. For both light rail and commuter rail vehicles, a lift must work down to street level, which is also rail height. Commuter platforms can actually extend into a city street. Of course, good lift designs would provide some excess travel.

2. The width of doorway indicates the degree of difficulty of providing for a 30" minimum, 35" recommended clear width of lift (Canyon Research Group Report). Most lifts require some width in addition to the clear platform width for mechanism requirements. (The width of the platform is in the direction parallel to length of the vehicle, by convention.)

3. The number of steps must be served correctly by each lift proposed for each location. This does not necessarily mean that each lift must convert all of the steps to a lift, if some alternate suitable principle is proposed.

4. The combination of high and low platforms on one system indicates the combination of level entry, lift, and step access that must be provided for each vehicle. Each doorway must be considered separately; all access modes do not have to be provided at all doorways. Each specific combination of access modes indicates, but does not dictate, what lift concepts would be appropriate.

5. These are not the only problems for each lift installation, but rather the ones that serve to inhibit the development of one single lift design.

6. These specifications are very condensed, to show that certain constraints favor selection of four maximum, three minimum lift concepts (if lifts for commuter rail end steps are foregone) to retrofit existing vehicles. Alternatively, the lifts for bilevels, with the addition of level entry provisions, could serve in end stepwells.

7. Center doorways are now used only at high platforms, by ambulatory passengers. No passengers now use the center doors at low platforms. An E&H lift installation (one that did not form steps) at the center door location would serve only handicapped passengers at low platforms, and both handicapped and ambulatory passengers would use the doorway at high platforms.

existing space. For lift patrons, widening the platform makes it easier to maneuver onto it, and for ambulatory patrons, maintaining stair width maximizes flow during boarding and alighting. One lift manufacturer has affirmed that widening their units several inches would present no problems.

Figure 5-3 shows several conditions that a light rail lift will have to interface with. For in-street stops, Figure 5-3a, it is desirable to minimize the lift projection from the vehicle for the best match to the road surface, and to minimize the hazard to the lift patron from other traffic that might pass on the right side of the LRV. It will be necessary to minimize lift projection at island platforms, so the lift patron has room to maneuver onto and off of the lift between the back fence or open back edge of the platform. Some systems, such as MBTA, have similar tight conditions at underground and elevated stations.

Because LRV's have no lateral maneuverability like buses, it appears desirable to first consider lifts that minimize the platform projection. There are several lifts that meet this condition. Light rail vehicles have about the same floor height as buses, and most are two-step entries, like buses. There is therefore good reason to first examine the existing two-step vertical path bus lifts to determine which might be applied to LRV's with a minimum of modifications.

Although there are no lift installations on light rail vehicles in service, San Diego Metropolitan Transit Development Board has ordered 14 Siemens-Düwag U-2 LRVs with lifts. The lifts, which will be installed at only one front door on each of the bidirectional vehicles, are being built by Transilift, of Calgary, Alberta. Although similar to the basic Transilift design, the San Diego LRV lifts have an additional step that is unfolded at each stop, to lower the first step and provide a three-step entry for ambulatory passengers.

The design has been strengthened because of the anticipated higher vibration environment on an LRV, and electrical modifications were necessary to adapt to the 600 VDC electrical system for primary lift power. Further, the clear width of the platform has been increased to 42".

5.3.2 Commuter Rail Installations

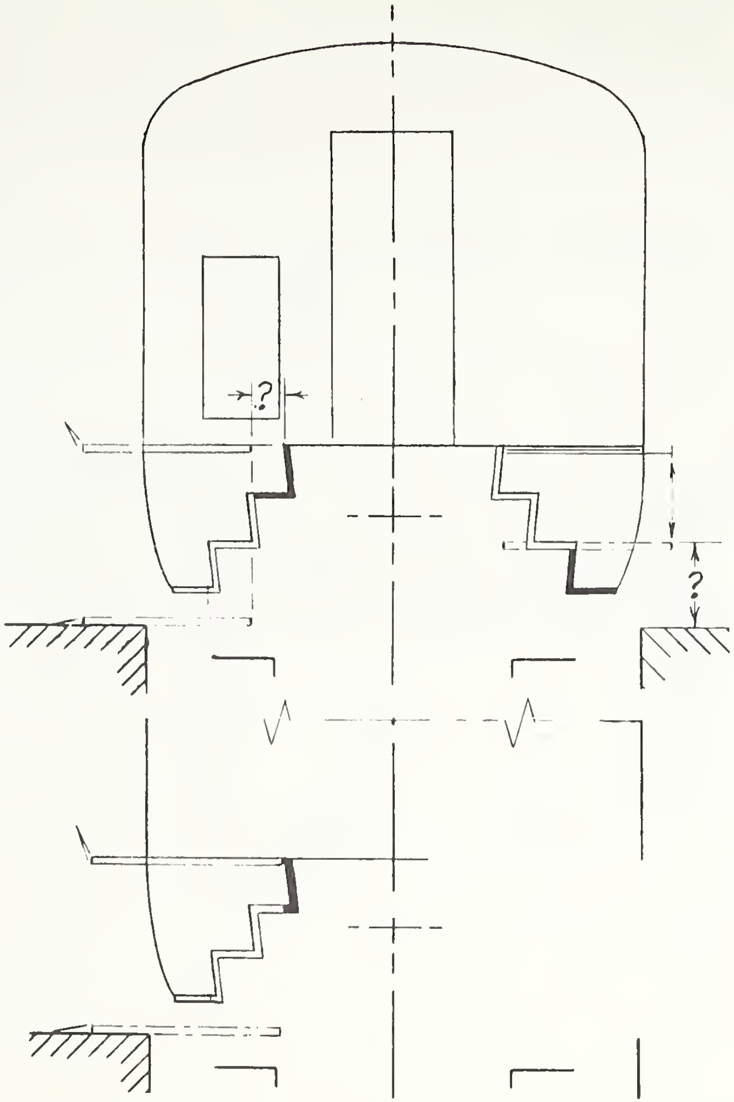
Two of the major differences between light rail and commuter rail lift installations are vehicle floor height and number of steps to gain entry. Extending the operating range would not be difficult for most lift manufacturers, but the three-step entry causes more fundamental problems. Figure 5-19A shows the two methods of installing a two-step lift in a three-step entryway. In both cases, the lift is not usable; either a gap-filler is required or the bottom step must be moved to allow a clear vertical path.

The minimum requirements for a lift in a three-step entryway is the conversion of 3 treads and 2 risers to a lift platform, Figure 5-19B. Figure 5-20 illustrates the manner in which two existing lift concepts could be used at three-step entrances. Both would avoid disturbing the bottom step and structure in that vicinity, which is necessary on the bilevel installation that is shown. Bilevel cars carry a portion of the underframe stresses through the side sills immediately under the bottom steps.

On bilevel cars, which have 5½ to 6½ ft. door openings, it will be necessary to decide between a very wide full doorway lift, or a partial width lift. A partial width unit would seem preferrable at this point, because of the smaller size of the unit, and because it would leave part of the doorway still usable by ambulatory patrons when the lift was in operation.

The center doors on Silverliners and Arrows present the last option for lift installation on commuter rail vehicles. These doors are now used at high-level platforms only, and therefore have no steps.

Figure 5-21 shows that a lift installed at the center door would not have to form steps or a level-entry device over a stepwell. At present, Lift-U and some active lifts offer a lift of this concept. A lift unit of the Lift-U type should be suspended approximately midway between the floor and rail height so that the platform does not begin to travel under the vehicle at the bottom of its arc. An additional advantage of this type of installation is that the lift can be positioned before the door is opened, and closed immediately after the patron is inside, minimizing the door open time in inclement weather.



A. The application of a 2-step lift to a 3-step entry has fundamental obstacles. Converting 2 treads and 2 risers to a lift platform leaves either a gap (left section) or an unacceptable obstruction (right section).

B. The minimum conversion to provide a clear vertical path for this class of lift is 3 treads and 2 risers.

FIGURE 5-19. TYPICAL COMMUTER RAIL 3-STEP ENTRY

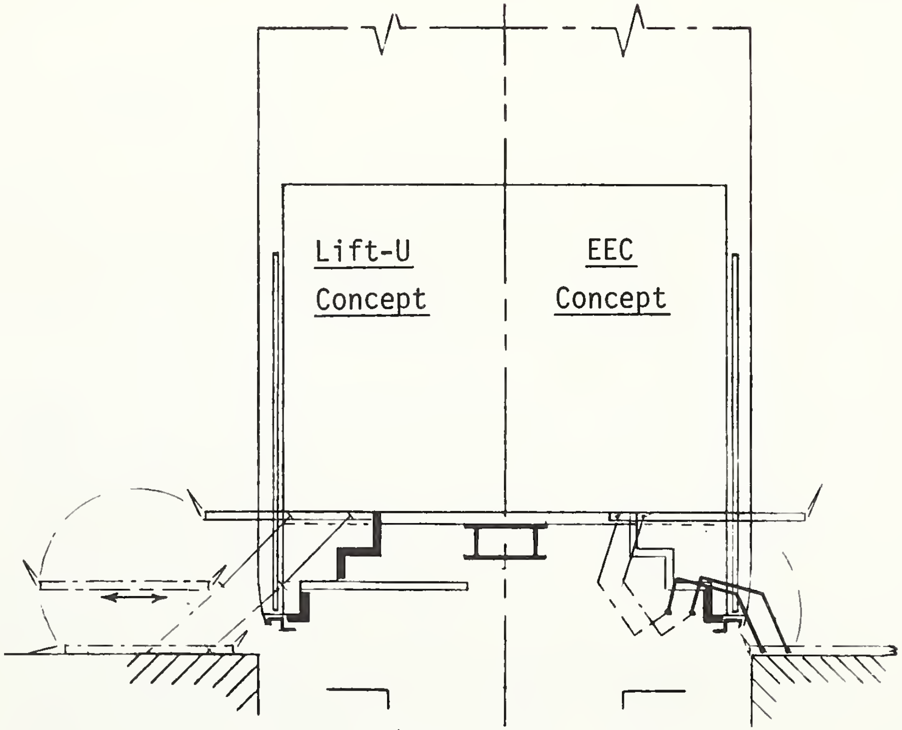


FIGURE 5-20. BILEVEL CENTER STEPS

NOTE:

There are two lift concepts currently available that could be applied without requiring the side sill to be cut away.

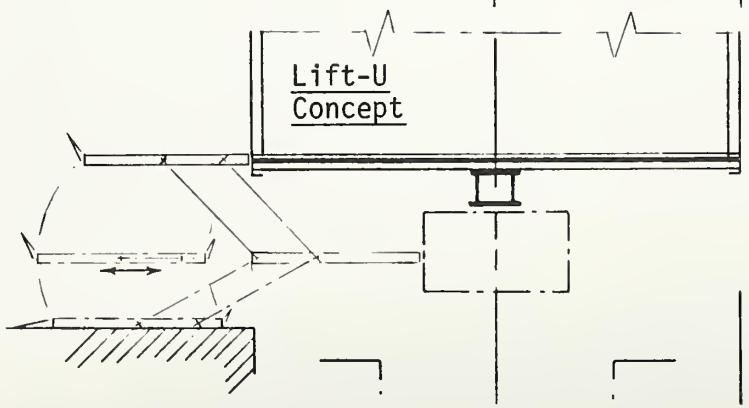


FIGURE 5-21. HIGH PLATFORM ENTRANCE

NOTE:

A platform lift only applied at the center entrance, now existing on the Silverliner/ Arrow commuter cars.

5.4 General Conclusions

It is now reasonably certain that lift retrofits on a sufficient number of existing rail vehicles to achieve functional vehicle accessibility are feasible, given the existing lifts available and the various installation locations possible on vehicles. Some conceptual installations have been described to strengthen the conclusion that lift installation is technically possible for each of the four substantially unique conditions that exist, which are:

- Light rail vehicles,
- Commuter rail vehicles - end stepwells,
- Commuter rail vehicles - center doorways (level entry), and
- Commuter rail vehicles - center stairs (bilevel cars).

In all probability, the easiest answers to the lift application question are in the hardware area, because the dimensions of the problem can be determined with accuracy. The vehicles exist, and any aspect of them can be quantified. The characteristics of existing specific lifts are known, and several generic appraoches to lift designs can be described. The function requirements of lift, step and level entry access to rail vehicles can be accurately stated.

It is then sound engineering to conceptualize solutions of specific and generic lifts applied to specific vehicles, and determine what changes are necessary to each component to achieve a workable solution on paper. Vehicles will have to be modified; some proposed solutions will undoubtedly require more extensive modifications to the vehicle as a result, and will cost more than others. Lift designs will have to be reviewed and modified, as none of the existing lifts are a plug-in fit on a rail vehicle. Lift vertical range for commuter rail vehicles, number of steps accommodated, and the level entry aspect are three major differences between existing bus designs and rail requirements.

Thus, other interfaces need to be considered. Many existing lifts utilize the available power steering hydraulics of buses to actuate the lifts, but light rail and commuter rail cars are universally without hydraulics. To interface lifts with electrical systems, motor/pump units will have to be supplied, or lifts will have to be modified to use electric actuation devices in place of hydraulic ones.

Existing doors are frequently incompatible with lifts on bus applications, and rail applications will have similar door problems. The door problem will have to be addressed on a case-by-case basis for each combination of lift design and installation site on a vehicle.

Internal changes to seating arrangements are not complicated, and modifications can be made, perhaps with some seat loss. The question of wheelchair securement remains unresolved. While securement devices are indicated for LRVs by analogy with bus practice, commuter rail vehicles have performance characteristics more closely resembling rapid rail systems which now do not provide securement devices.

The question of accessible restrooms on commuter rail vehicles would appear to be unrelated to lift technical issues. However, the question will need to be addressed when selecting cars for lift installations, and in deciding on the lift locations within a car.

The technical feasibility is one facet of accessible rail transportation. Other concerns are expressed, though, concerning the long term operational feasibility of lifts. Some of the questions raised will be discussed in the following section.

6.0 ADDITIONAL CONSIDERATIONS

There are other considerations to lift installation and lift services that are peripheral to the hardware issues. These considerations are nevertheless lift-associated because they are generated by the presence of the lift, but not necessarily solved when the narrowly defined lift installation is completed. Examples range from additional interior changes that are required to accomodate wheelchairs to very broad questions of possible liability changes for the system operators, or the nature of emergency egress provisions that are necessary and possible.

The additional considerations may be approximately divided into two groups. First are the additional engineering details that can be relatively easily defined and solved to produce a well-executed state-of-the-art lift installation. Ideally, a lift patron would be able to board and exit the vehicle at the same stops as others, and travel as comfortably and as safely as others. The details necessary to accomplish a journey are fairly well understood from accumulated bus experience.

The second group of additional considerations includes the larger issues: safety of patrons both on the lift and during the journey, emergency egress provisions, the nature of the operators' liabilities due to the increased level of care required by the handicapped, and the entire cost spectrum associated with accessibility.

6.1 Additional Engineering Aspects

Completion of the lift installation does not complete the vehicle accessibility task. In addition to the lift, the lift patron needs a wheelchair-accessible area on the vehicle and possibly an anchoring arrangement. On rail vehicles, the only additional requirement that appears is the necessity on some systems to be able to exit from the opposite side of the vehicle, which implies that two lifts must be linked with a fully accessible path.

Seating alterations are necessary as the minimum internal change on almost all vehicles examined. MBTA LRV's, with their wide aisles, are the only exceptions. In all cases there will be a net decrease in the number of seats but more standee room, hence more vehicle capacity. The magnitude of the decrease depends on five variables:

- For both light rail and commuter rail:
  - Amount of wheelchair-accessible area per access location,
  - Single or both-side lifts, and relative placement, and
  - Seating recoverable with fold-down seats.
- For light rail only:
  - Single or double-ended arrangements on bidirectional light rail vehicles.
- For commuter rail only:
  - Restroom access provisions on commuter rail vehicles.

On commuter rail, rush hour trains, the seating loss will be relatively little as a fraction of the total train seating. Additional losses will be incurred if restrooms are enlarged to make them accessible. The major social impact of seating change on commuter rail is that journeys are often much longer than on light rail, and therefore the gain in floor space is not realistically useful as standee space. An objective of commuter rail service is a seat for each patron.

6.2 Non-Technical Issues

Lift-equipped accessible rail vehicles will impact every aspect of a transit system operation to some degree. Discussions with operators indicated that they expect the major effects to be in system performance, equipment reliability, ability to maintain uniform safety for each patron, liability exposure, and cost.

6.2.1 System Performance

The major operational consideration expected to be generated by lift installations on light rail and commuter rail vehicles is an unfavorable impact on adherence to schedules. Lift cycle times are reported to be on the order of 1½ minutes for each boarding or deboarding operation. Vehicle dwell times are much shorter, even during rush hours, and existing headways on some high density LR and CR lines are less than 3 minutes. Lift operations under these circumstances will necessarily extend dwell times and could cause local schedule perturbations. This need further study.

The expected effects on a vehicle or train schedule when a lift is operated lead to the question of fleet size expansion. Each operator will need to determine for each route the magnitude of demand for lift services that exist. Then each operator must determine if additional vehicles and drivers will be required to maintain service and capacity at the baseline level that existed before the accessibility modifications were put into effect.

6.2.2 Reliability

A significant advantage that buses have over rail vehicles is the ability to pass a disabled vehicle at any point on a route. Rail vehicles, on the other hand, have very limited passing opportunities. Consequently, they depend heavily on each vehicle reliably completing its trip, but in addition, they have a well-developed ability to push or pull failed vehicles to clear an obstruction. There are very few failures that can disable a rail vehicle to the extent that time-consuming measures are necessary to permit it to be move it out of the way.

Mechanical devices can be expected to have many failure modes, and operational experience to date on buses indicates that lifts are no exception. Although the state-of-the-art is constantly improving, as demonstrated by continuing bus experience, the failure mode that will be particularly detrimental to rail operations will be an inability to retract a deployed lift, a known failure mode on buses. Lifts will be the first application of a device to rail vehicles that extends out of the equipment clearance diagram as normal operating practice. As such, a lift failure in the extended position would effectively prevent most trains from moving until the device could be retracted, because an extension outside of the clearance diagram carries the risk of hitting lineside objects.

6.2.3 Safety

Unlike bus and light rail operations with a single operator for both the vehicle and a lift, there is an opportunity in commuter rail for serious mistakes that must be guarded against. Most of the commuter operators are of the opinion that lifts should be interlocked with train circuits to inhibit train operation if the lift is in any position other than fully stowed. Many doors are now interlocked for the same effect, but the practice is not universal. The hazards, though, of moving a train with a door open are significantly less than the hazards associated with an extended lift.

An extended lift, with or without its passenger, would constitute a serious hazard to anyone on the platform if the train were in motion.

This leads most operators to conclude that lift operation must prevent train operation. On equipment with door interlocks, it is straightforward to use the same circuits to verify that lifts are fully stowed.

On equipment without trainlined electrical circuits, basically Diesel hauled coaches, the wiring would have to be added throughout all cars to communicate a signal to the locomotive control circuitry that a lift was deployed. Alternatively, it might be possible to develop a system confined to only the lift accessible car.

One ever-present problem with safety items, such as electrical interlocks, is the occurrence of indicated but not real failures that prevent operations from continuing. This is the basic reason many operators do not interlock doors on commuter equipment, in addition to the relatively low risk involved. A deployed lift, though, is a more serious matter for both the lift patron, other patrons and equipment. The strategy that seems to be indicated is a three-step approach to safety and reliability:

1. Prohibit train operation in a positive manner when the lift is deployed.
2. Provide a reliable back-up system to enable a lift to be operated and retracted in the event of all probable primary failures.
3. Allow the train crew to override erroneous safety indications once they have determined that no hazard exists.

Coupled with safety issues to be resolved with regard to lift operation are the operators' concerns of increased liability exposure occasioned in the course of serving handicapped patrons. It is difficult to assess the liability questions accurately in advance of actual operating experience with a system. At this writing, no (bus) operator has reported an increased insurance rate due to serving handicapped patrons.

Possibly the best way to view liability associated with lifts is to ask what is different about carrying handicapped passengers compared with carrying the general public? There are two fundamental differences:

- Handicapped patrons are in need of greater care, and
- Personalized service is offered during lift operation.

There is a normal standard of care expected of a common carrier. This standard is arguably higher for the handicapped. In the course of a trip the risk is greater for a handicapped passenger at several points:

- access/egress, due to
    - equipment failure, or
    - operator negligence; and
- in transit, due to tie-down failure, and
- in anomalous situations.

For ambulatory patrons, the risk exposures and accident rates are quite well established historically. But for handicapped patrons, the risk exposure has never been defined.

6.2.4 Costs

Transit operators face many more concerns over accessibility provisions than just mechanical feasibility, which is relatively easy to assess. The broader aspects of accessibility, and much harder to define, are the various standard cost components that will be incurred. Operators express concerns about additional costs that may be incurred if schedules are degraded, which may require additional equipment to cope with slower turn-around times.

Ownership costs appear from two sources. First, there is the cost of acquiring the lifts, and second, the cost of additional vehicles, if required to maintain system performance levels.

Maintenance costs are generated in the same manner. First, and most easily definable, is the direct maintenance for the lifts themselves. The second aspect of maintenance cost will be extra vehicle maintenance occasioned by any fleet increases that are necessary to maintain existing service levels and the additional maintenance caused by the equipping of the fleet with lifts.

Operating cost for lifts themselves are projected to be very small. The amount of electric power used to run lifts will be infinitesimal when compared with the total power requirements of any system. Measurable operating costs are first incurred because lifts increase vehicle weight. On buses, it has been demonstrated that fuel mileage is reduced and right front tire wear is increased on lift-equipped buses, when compared with the same non-equipped bus type on the same routes. It is expected that LRV power consumption would be measurable under similar conditions. Steel wheel life might be more tolerant of increased tare weight than are tires. Commuter rail operations would probably not be able to measure the effect of increased weight.

The largest component of operating cost is labor. The first aspect of potential labor increases will be directly proportional to any increases in the peak-hour fleet in service: each additional light rail vehicle requires an additional driver. On commuter rail, an additional crew member is added at certain increments of train size, primarily for ticket collection. A train-by-train analysis would be required to determine which runs would require an extra man if an extra car were added.

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APPENDIX

REPORT OF NEW TECHNOLOGY

The work performed under this contract determined that existing bus E&H lift concepts and technology could be utilized as a starting point for light rail and commuter rail lift installations.

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