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of Transportation
Urban Mass
Transportation
Administration

Installation of Existing Lift Systems for the Handicapped on Light Rail Vehicles

Prepared by
The Budd Company

May 1985
Final Report

UMTA Technical Assistance Program

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H. ~~Norman~~ Ketola, (Ketron), Arthur Lancaster (Budd), Frank Varker (Ketron)

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16. Abstract

This report documents the results of a three phase program to install an existing transit bus wheelchair lift system on a Boeing Light Rail Vehicle (LRV). Program activities included a review of lift requirements, evaluation of existing lift systems, analysis of the operational and structural implications of integrating existing or modified bus lift systems into current LRVs, the organization of a technical liaison committee, the selection of an existing lift system for integration into an existing LRV, and the installation of the lift in a test vehicle for operational demonstration.

It was concluded that the best lift system for demonstration was the Transilift installed at the forward door. A complete lift assembly was installed on a San Francisco Municipal Railway (MUNI) LRV, which was then subjected to a 4 month non-revenue service test on all 5 of MUNI's light rail lines. A total of 134 field tests were conducted using over 60 different locations with and without volunteer wheelchair users. The lift performed reliably in operational tests including areas of the MUNI system where grades are in excess of 1:12, and on highly crowned streets.

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PREFACE

This report was prepared by the Budd Company, Fort Washington, Pennsylvania under Contract DTRS57-80-C-00097 to the U.S. Department of Transportation, Transportation Systems Center (TSC), Cambridge, Massachusetts. The contract was sponsored by the Urban Mass Transportation Administration.

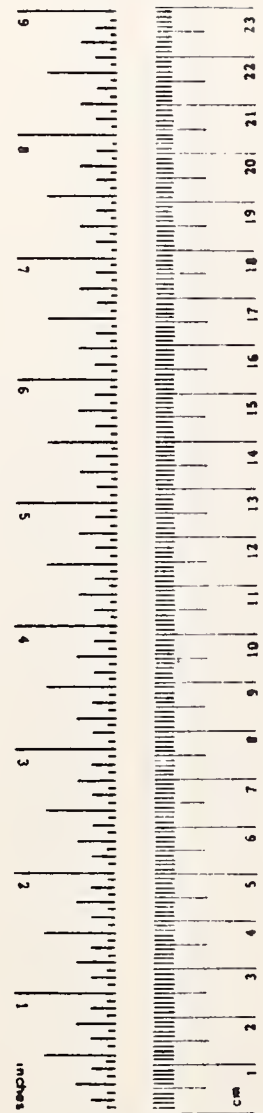
The objective of the contract was to evaluate the best wheelchair lift system for the handicapped on a Light Rail Vehicle (LRV). The program was carried out in three phases including a field test program conducted by the San Francisco Municipal Railway (MUNI).

The Budd Company wishes to thank all of the individuals who have contributed their time and information to the study effort. In particular, the efforts of Mr. Jeffrey Mora of UMTA in providing overall project guidance, and Mr. Jason Baker of TSC, the Project Technical Monitor were greatly appreciated. Mr. H. Norman Ketola and Mr. Frank Varker of Ketron, Inc., made substantial contributions to the preparation of this report.

METRIC CONVERSION FACTORS

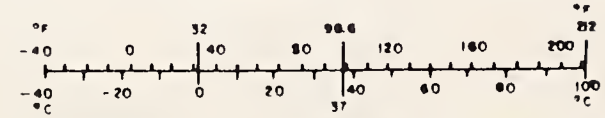
Approximate Conversions to Metric Measures

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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EXECUTIVE SUMMARY

This report documents the results of a three phase program performed by The Budd Company Technical Center to install an existing transit bus wheelchair lift system on a Boeing Light Rail Vehicle (LRV). Program activities included a review of lift requirements; evaluation of existing lift systems; analysis of the operational and structural implications of integrating existing or modified bus lift systems into current Light Rail Vehicles; the organization of an advisory technical committee; the selection of an existing lift system for integration into an existing LRV; and finally, the installation of the lift in a test vehicle for operational demonstration.

Trade-off studies of five candidate lift systems (all developed originally for bus application) were made and the adaptability of various car bodies to accept these lift systems was considered. Studies of boarding constraints and procedures as well as optimum location of the lift for boarding at various types of stations on selected transit systems were also factored into the trade-off evaluation.

It was concluded that the best lift system for demonstration on the Boeing LRV was the TransiLift installed at the forward door because the required modifications of the lift and the car body were minimal. With some structural modifications it was possible to increase the length of the standard TransiLift platform from 42 to over 50 inches. The standard length and longer platform versions of the TransiLift for the Boeing LRV were designed, fabricated, and tested at The Budd Company Technical Center in Fort Washington, Pennsylvania.

To minimize the disruptive effects of lift failures, the lift and its hydraulic power supply subsystems were developed to be modular units for easy removal and replacement. This allows a car to be kept in service using a replacement lift unit which can be installed in a maintenance facility in less than thirty minutes. The lift module, called a "pod", was designed to contain a complete working lift assembly ready for operation. After the pod is installed in a vehicle, four hydraulic connections complete the installation. The hydraulic module consists of two pumps and associated piping and wiring arranged

on a frame that is installed within the enlarged base of the seat nearest the lift. Since the lift and the power unit are modular, repairs can be contracted out and the units bench tested before being refitted into the vehicle.

To permit the lift to descend to ground level, the existing lower door track function on the Boeing LRV was reversed to place the track on the doors and the guide roller on the car structure. This design modification was demonstrated on a vehicle shell at The Budd Company Technical Center and incorporated into the field test car. A number of other minor vehicle modifications to access panel and equipment would be required in a production version.

The completed lift test assembly was proof tested at The Budd Company's Facility in Fort Washington, Pennsylvania with platform loads up to 1200 lb. which was the highest load allowed by adjusting the hydraulic pressure cut-out switches. Ultimate strength tests of all the critical lift components indicated that the maximum load capacity of the lift was several times greater than 1200 lb. The lift assembly installed in a vehicle shell was successfully tested at simulated ambient temperatures from $130^{O}F$ down to $-16^{O}F$ without any special preparations for lift operation at such extreme temperatures.

A complete lift assembly was installed on a San Francisco Municipal Railway (MUNI) LRV by MUNI's maintenance staff. This vehicle was then subjected to an extensive four month non-revenue service test on all five of MUNI's light rail lines. A total of 134 field tests were conducted using over 60 different locations with and without volunteer wheelchair users. The lift performed well in operational tests including areas of the MUNI system where grades are in excess of 1:12, and on highly crowned streets. Boarding islands with unobstructed widths of less than 60 inches posed problems due to the restricted wheelchair turning area caused by projection of the lift platform available. Islands with 45 inches or less of unobstructed width were deemed to be unaccessible because of this wheelchair maneuvering limitation.

A technical advisory committee with members from several transit systems, and members representing handicapped users, was formed to critique and advise the project management during the program. The committee offered excellent guidance in the compromises to be made by both operators and users in order to achieve a viable and useful lift system.

The modular "pod and socket" concept developed for the wheelchair lift system could be adapted to other systems on transit vehicles in order to gain some of the benefits in maintenance and reduced down time for the vehicle.

SECTION 1

INTRODUCTION

1. INTRODUCTION

This final report summarizes the activities in each phase of a three phase program which culminated in the installation of an existing wheelchair lift system for the handicapped on a Light Rail Vehicle (LRV). The work was conducted by The Budd Company Technical Center under sponsorship of the Urban Mass Transportation Administration through the U.S. Department of Transportation's Transportation Systems Center (DOT/TSC). This section of the report contains a brief background to the problems associated with accessibility on light rail cars, and a description of the project objectives, work program, schedule, and information on the Technical Committee which provide input to the project.

1.1 BACKGROUND

There are three basic approaches to providing accessibility to light rail cars from ground level or low platform stops:

1) Installation of a lift on a vehicle.

2) Installation of a wayside lift at a station.

3) Installation of a mini-platform at a station.

There are advantages and disadvantages to each of these solutions. The lift installation on the vehicle provides the most versatile approach, since the vehicle can be boarded at any stop which is accessible. For many existing systems which have extensive route operations in streets, the vehicle-borne lift is the only practical approach. The major disadvantages of a vehicle mounted lift are the dwell time for boarding/alighting, and the possibility of a lift being damaged or becoming inoperative while in an extended position. The latter problem might result in a service disruption.

The installation of a wayside lift at stations is an appropriate solution when there are only a limited number of stations. The advantage of a wayside lift is the transfer of the lift mechanism to a stationary setting which allows for additional flexibility in the lift design and should lead to a more maintenance-free design. The wayside lift as designed for the new Portland, Oregon light rail system automatically deploys a bridgeplate to cover the gap between the lift platform and the LRV floor. The wayside lift has the disadvantage of dwell time delays similar to the vehicle mounted lift and requires that the vehicle be positioned precisely to match the doorway with the lift. If the vehicle has to be stopped twice in order to separately board a wheelchair passenger, the dwell time increases significantly. In addition, when a wayside lift is out of operation, the station becomes inaccessible for boarding or alighting passengers which creates substantial inconvenience for handicapped passengers.

The mini-platform requires a ramp and handrails leading to the boarding area. It is only suitable for applications where there are a limited number of stations and where there is physical space available for construction of the platform. The obvious advantage of the mini-platform is the lack of any moving parts. Dwell time is reduced somewhat for a mini-platform loading as compared to a vehicle lift unless the vehicle has to make two stops in a mini-platform station. The major disadvantage of the mini-platform is the space requirement for installation of the ramp. A typical mini-platform would require a ramp 28 feet long and approximately 3 feet wide, to reach a 34 inch high platform. The platform itself would be about 3 feet by 6 feet.

Numerous previous studies have shown that no single solution to light rail accessibility exists for all light rail transit systems. The final report on the 321(b) light rail system accessibility study* recommended a mix of solutions in such cities as Pittsburgh, Cleveland, Boston, San Francisco, Philadelphia, and Newark. In most instances, the lift installed on the light rail vehicle, either on a retrofit basis or as original equipment, would be an important element in achieving system accessibility.

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*Crain and Associates, Summary Report: 321(b) Rail Retrofit Evaluation - Light and Commuter Rail Systems, Volume 1 (Revised), December, 1980.

The lift evaluation project was designed to serve the needs of all systems presently operating or planning a light rail system where accessibility is to be provided wholly or in part with lift equipped vehicles. The information and data generated will support all transit systems in adapting a wheelchair lift system to their requirements.

1.2 PROJECT OBJECTIVES

The objectives of the project were to: select and adapt an existing bus type wheelchair lift system to meet all the requirements of LRV operation; develop specifications and prepare drawings for a prototype lift system installation; and then, fabricate, laboratory-test, install, and evaluate the prototype on a Boeing light rail vehicle. In addition, other LRVs were to be studied, and specifications and drawings provided showing the installation of a lift or lifts in these vehicles. The lifts considered for this project were selected from lift manufacturers supplying lifts for use in transit buses. The adaptation and retrofit of a lift onto a light rail vehicle requires that reasonable modifications be allowed on both the lift and the vehicle in order to ensure a practical and reliable installation. It was not the intent of the project to develop a new lift design, but to develop technical specifications and guidelines useful to all transit systems considering adaptation and installation of wheelchair lift systems on light rail cars.

1.3 SUMMARY OF WORK PROGRAM

The contract originally called for a four phase work program. As the project progressed, the program was revised and later activities compressed, reducing the number of phases to three. The work activities for each phase are summarized as follows.

1.3.1 Phase I

Evaluate the lift designs that can be retrofitted with minimal modifications to existing LRVs (e.g. Presidents' Conference Committee or P.C.C. Car, Nissho Iwai-Kawasaki, Boeing, Breda) and recommend the most appropriate lift technology. The selection process was to consider all known lift designs in service or being tested on buses. Also to be taken into account were the requirements for LRV lifts based on consumer factors such as boarding/alighting and safety; and operational factors such as single or double-ended operation, high/low platform, left or right side boarding, and street or dedicated right-of-way operations. If possible, in order to maintain a competitive posture for transit systems purchasing lifts, more than one lift design would be identified as potentially applicable for installation on selected LRVs. During Phase I, a Technical Advisory Committee was to be established with representatives from interested or participating transit systems and wheelchair users.

1.3.2 Phase II

Detailed engineering designs, specifications, test plans, and drawings for the lift(s) recommended from the work in Phase I would be prepared, and the necessary modifications required to each of the vehicles could be detailed.

1.3.3 Phase III

Lift(s) would be procured, modified, installed, and statically tested on a Boeing LRV. To facilitate this process, the Massachusetts Bay Transportation Authority (MBTA) provided one half of an articulated Boeing LRV which was shipped to The Budd Company facilities in Fort Washington, Pennsylvania. Following a successful test program at the Budd facility, a lift installation kit would be prepared for a non-revenue service test at a light rail system. UMTA would then attempt to locate a transit system interested in testing the lift on an LRV under a separate grant project. The final project activity would be a non-revenue operational test of the wheelchair lift installed on an LRV at the selected transit system.

The approximate time schedule for the project was as follows:

Phase I Completion - August, 1981

Phase II Completion - January, 1982

Phase III
- o Completion of Prototype Design Installation - July, 1982
- o Completion of Non-Revenue Operational Test - July, 1983

1.4 TECHNICAL ADVISORY COMMITTEE

The Technical Advisory Committee for the Light Rail Vehicle Lift Project was formed to provide a mechanism for consumer and transit operator input. Transit operators were selected on the basis of their experience and familiarity with LRV operations and included: Boston, San Francisco, Cleveland, Pittsburgh, Buffalo, and Portland. Consumer representatives were selected on the basis of their understanding of the issues associated with LRV accessibility and included representatives from Boston, San Francisco, New York City, and Philadelphia. The Committee was convened in February, 1981. Their major activities were in-depth reviews and critiques of the Phase I activities at TSC, Cambridge, Massachusetts on February 4, 1981 and a review of the prototype vehicle installation at The Budd Company Technical Center, Fort Washington, Pennsylvania on August 4, 1982. Full details of the membership, attendance, and commentary by the Committee is contained in Appendix A of this report.

SECTION 2

REQUIREMENTS ANALYSIS

2. REQUIREMENTS ANALYSIS

The requirements analysis was divided into four areas all of which were interrelated. These areas were:

- Consumer (User) Factors covering such areas as boarding and alighting ease, safety, maneuverability, and companion capability.
- Lift Mechanism Factors covering mechanical and systems design factors, practices and standards, and physical requirements arising from the intent to use off-the-shelf hardware where possible.
- Vehicle Lift Installation Factors such as structural integrity, location and relocation of equipment, interference with or alteration to major sub-systems.
- Operational Factors such as single or double ended operation, high or low platform, street and dedicated right-of-way operation, left or right side boarding, environmental conditions, fare collection.

In the past, when the PCC car was virtually a standard configuration, the interaction between vehicle and operational factors could have been resolved relatively easy. Recent light rail developments have, however, led to a much wider variety of vehicle/operational situations which will require lift installation configurations to be determined on a case-by-case basis.

2.1 EXISTING DATA SOURCES

A significant body of research already existed in many of these areas although it was not all specifically related to LRVs and operations. Primary source documents used in this study were:

1) A Requirements Analysis Document for Transit Vehicle Wheelchair Lift Devices - Canyon Research Group, Inc.
2) Recommended Safety Guidelines for Lifts on Public Transit Vehicles - California Department of Transportation.
3) Evaluation Report on Five Wheelchair Lift Options for Installation on Transit Coaches - Seattle Metro.
4) Evaluation of the St. Louis Accessible Bus Service - Applied Resource Integration, Ltd.

5) The Feasibility of Retrofitting Elderly and Handicapped Lifts on Commuter and Light Rail Vehicles - Technology Research and Analysis Corporation.

6) Standard Design and Test Criteria for Safety and Quality of Automatic Wheelchair Lift Systems for Passenger Motor Vehicles - Veterans Administration.

7) California Highway Patrol Regulations - July 1979. These regulations specify compliance requirements for lifts on buses in California.

8) UMTA Section 321(b) Study.

9) Relevant documents, drawings, and specifications from lift and vehicle manufacturers.

2.2 SUMMARY OF REQUIREMENTS ANALYSIS

The results of the consumer, lift, and vehicle requirements research are summarized in Table 2-1 and are presented in Appendix B in the form of recommendations or criteria in terms of dimensions, loadings, stress factors, etc. The results of the operational factors research are directed toward the selection of the most suitable location for a lift installation for any given vehicle configuration.

During the course of Phase I, it became apparent that a few of the recommended criteria would create difficulties in the adaptation and retrofit of a lift onto an LRV. This is not particularly surprising, since the documented research was directed almost solely to the application of lifts on transit buses and the operational environment and constraints placed on a Light Rail Transit (LRT) system are substantially different from that of a transit bus. The recommended criteria which created difficulties are discussed below and a resolution presented.

2.2.1 Lift Platform Length

The recommended lift platform length of 59 inches proved to be the most difficult dimension with which to work. The sources used in the requirements analysis developed the 59 inch platform length criteria on the assumption that a 95th percentile wheelchair with an attendant should be accommodated. However,

TABLE 2-1. SUMMARY OF MAJOR LIFT REQUIREMENTS ANALYSIS

Wheelchair Size	-	Design to 95 percentile Overall length 43.25" Overall Width 26.25"
Platform Dimensions	-	Length: maximum up to 59" Width: recommended 35", minimum 30" Barrier: minimum of 3" over whole width Side Plates: minimum of 2" Ramp Angle: maximum slope of 1:6 (9.4 degrees) Discontinuity: maximum 0.25" vertical, maximum 0.625" horizontal Droop: maximum of 1:24 under 395 lb. load
Platform Motion	-	Maximum speed = 20 ft./minute Free fall speed = 30 ft./minute maximum Acceleration = 0.3 maximum with 375 lb. load
Design Loads	-	Design Lifting Load = 600 lb. Platform Static Deformation Load = 375 lb. (uniform) Safety Barrier Load = 300 lb. minimum parallel to platform and applied at top of barrier
Design Factors	-	Overall strength factor of 6
Static Test Loads	-	4 x design load without permanent deformation or damage rendering it inoperable 6 x design load without material failure for 2 minutes
Cyclic Test	-	Meet California Highway Patrol standard as a minimum requirement

existing bus lifts do not exceed 50 inches and the shortest is less than 40 inches. At the Phase I Review Meeting, consumer members of the Technical Committee voiced the opinion that the platform length could be much shorter and that accommodation for both an attendant, and a wheelchair on the lift was not required.

Based upon these inputs, it was decided that the platform length requirements would be relaxed such that the existing bus lift technology could be adapted to the requirements of an LRV in a practical and cost effective manner. For instance, the TransiLift which has a platform length of 43 inches in its unmodified form can accommodate a 95th percentile wheelchair, but not with an attendant. The unmodified TransiLift can be fitted into all Boeing and Breda LRV doorways without major structural modifications to the vehicle.

2.2.2 Lift Platform Ramp Angle

The ramp angle recommendation of 9.4 degrees maximum does not take into account the effective increase in ramp angle caused by deployment of the lift on crowned road surfaces. The ramp angle should, therefore, be 9.4 degrees maximum when deployed on crowned roads. This can be achieved through various techniques including minimization of platform thickness and/or extension of the platform out from the vehicle to the street.

2.2.3 Lift Platform Vertical and Horizontal Discontinuity

The recommended discontinuity of 0.25 inch vertical and 0.625 inch horizontal was not expected to be difficult to meet on the lift itself. However, the vertical gap between the ramp edge and the road surface is impossible to control and will no doubt often exceed 0.25 inches. The consumer representatives on the Technical Committee pointed out that much more severe discontinuities are routinely negotiated by wheelchair users in normal street use, and they felt that if it were necessary to relax these criteria, larger discontinuities could be tolerated.

2.2.4 Lift Platform Flexibility

The recommended maximum droop of 1:24 for a raised and extended platform under load is considered to be a sound value for the lift when it is raised, but greater droop would be an advantage when the lift is resting on the road surface to accommodate crowning. In the design of the prototype lift, an attempt was made to conform to this recommendation when the lift was raised, but also achieve higher flexibility when the lift was lowered and at rest. With this feature designed into the lift, it mitigates the effect of crowned streets. The crowned street/lift ramp angle problem is discussed more extensively in the later section on lift installation considerations.

SECTION 3

LRV LIFT INSTALLATION ANALYSIS AND EVALUATION

3. LRV LIFT INSTALLATION ANALYSIS AND EVALUATION

Two LRVs were studied in detail during the project. The first, the Boeing LRV, was built in two slightly different versions for Boston (MBTA) and San Francisco (MUNI). The second vehicle studied was the Breda LRV, currently being delivered to Cleveland (GCRTA). Other LRVs that were considered, but not studied in depth for lift installations included PCC cars and the SEPTA Kawasaki cars. The PCC cars, while still numerous, are 30 to 40 years old and are being retired at several systems. It was not possible at the time to obtain engineering data on the Kawasaki cars. However, visual inspection of a prototype vehicle showed that major structural changes would be required to the existing doorway. The doorway is divided into two single stream paths by a large stainless steel box member which is an integral part of the body structure.

3.1 INSTALLATION CONSIDERATIONS

The major technical problems to be encountered in lift installations on LRVs were defined in an earlier report, "The Feasibility of Retrofitting Lifts on Commuter and Light Rail Vehicles,"* and were confirmed by the detailed studies of the Boeing and Breda cars to be:

- o Structural modifications.
- o Under-step equipment displacement.
- o Above-floor equipment relocation.
- o Lift/door interface problems on some LRVs.
- o Multiple lift installations.
- o Lift auxiliary package location.
- o Electrical interfacing with higher auxiliary voltages on LRVs.
- o Seating changes.

* McInerney, F.T., Reference 5.

- Either-side boarding requirements for some operators.
- Island platforms.
- Crowned street operation.
- Level-entry boarding.
- Street platform widths.

To study the lift/LRV interface requirements, large-scale layouts (half-size) were made of each of the lifts selected for study and of the several doorways on the LRVs. Then, by superimposing the lift and LRV doorway drawings, the interferences between existing lifts and LRVs were clearly shown. After identifying the interface problems, it was then possible to examine potential solutions.

The most difficult situations encountered were potential structural modifications, underfloor equipment displacement, and above floor equipment and seat relocations. On the Boeing LRV, the bottom door track on the underside of the lower step conflicts with any potential lift installation.

Multiple-lift installation on an LRV, which might be required because of the bi-directional operational characteristics of the newer LRVs, does not in and of itself cause any problems, except for increased equipment relocation above and below floor, and thus competition for available space. Because multiple lift installations will more than likely be symmetrical on a vehicle (i.e. both front doors or pairs of side doors), the engineering details will be virtually identical for each lift. It would appear, therefore, that the cost of installing two lifts on an LRV, if required, will be approximately twice the cost of one lift installation.

One major concern in the lift installation is the projection of the deployed platform beyond the vehicle side. This projection creates two types of problems - the crowned street/lift ramp angle interaction and island platform clearance and are illustrated in Figures 3-1 and 3-2 respectively. Figure 3-1 shows that a person attempting to wheel onto the lift will face increasing difficulty as the platform projects further out on the crowned street because the effective ramp angle for entry increases as a function of the degree of street crowning and

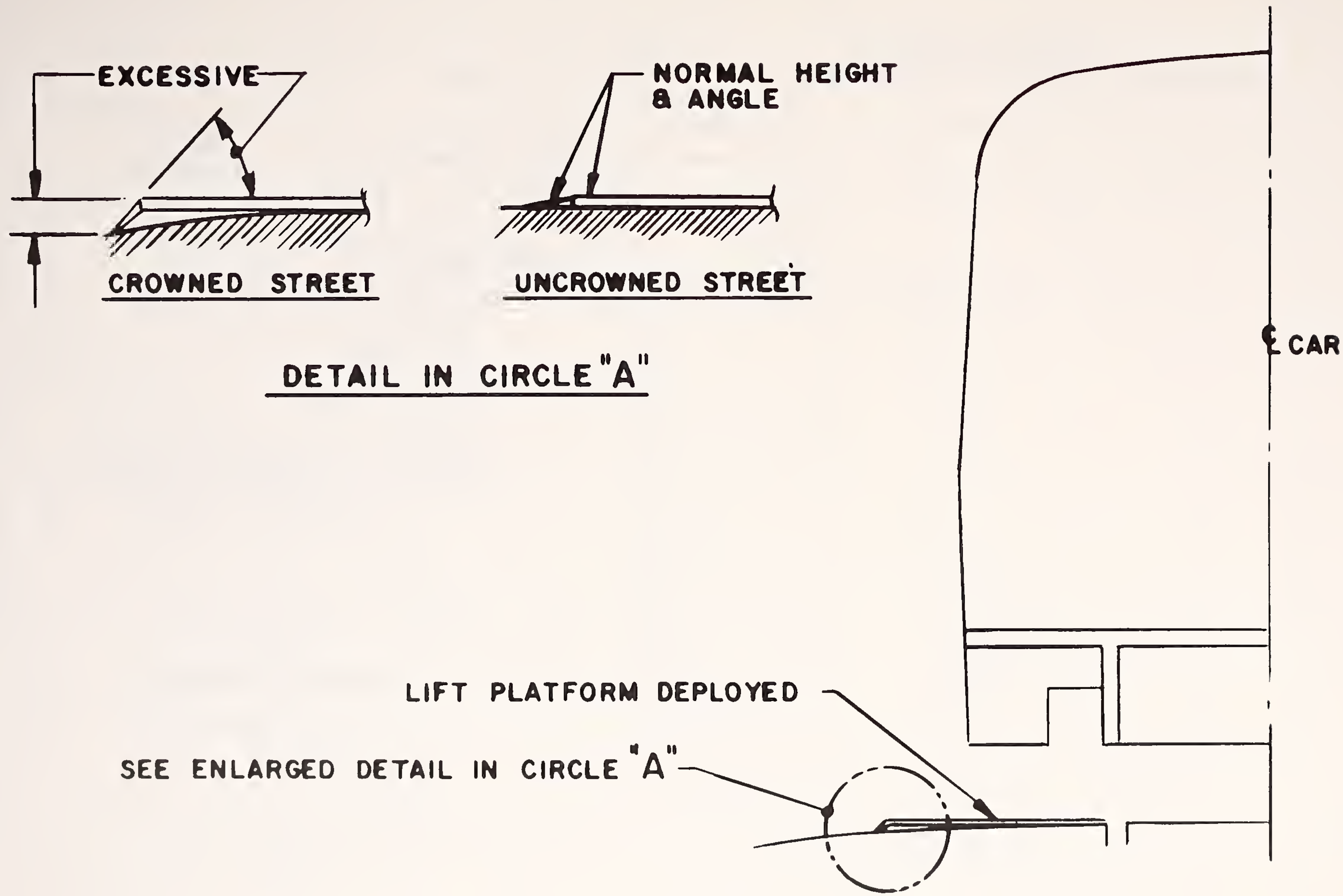


FIGURE 3-1. IN-STREET BOARDING

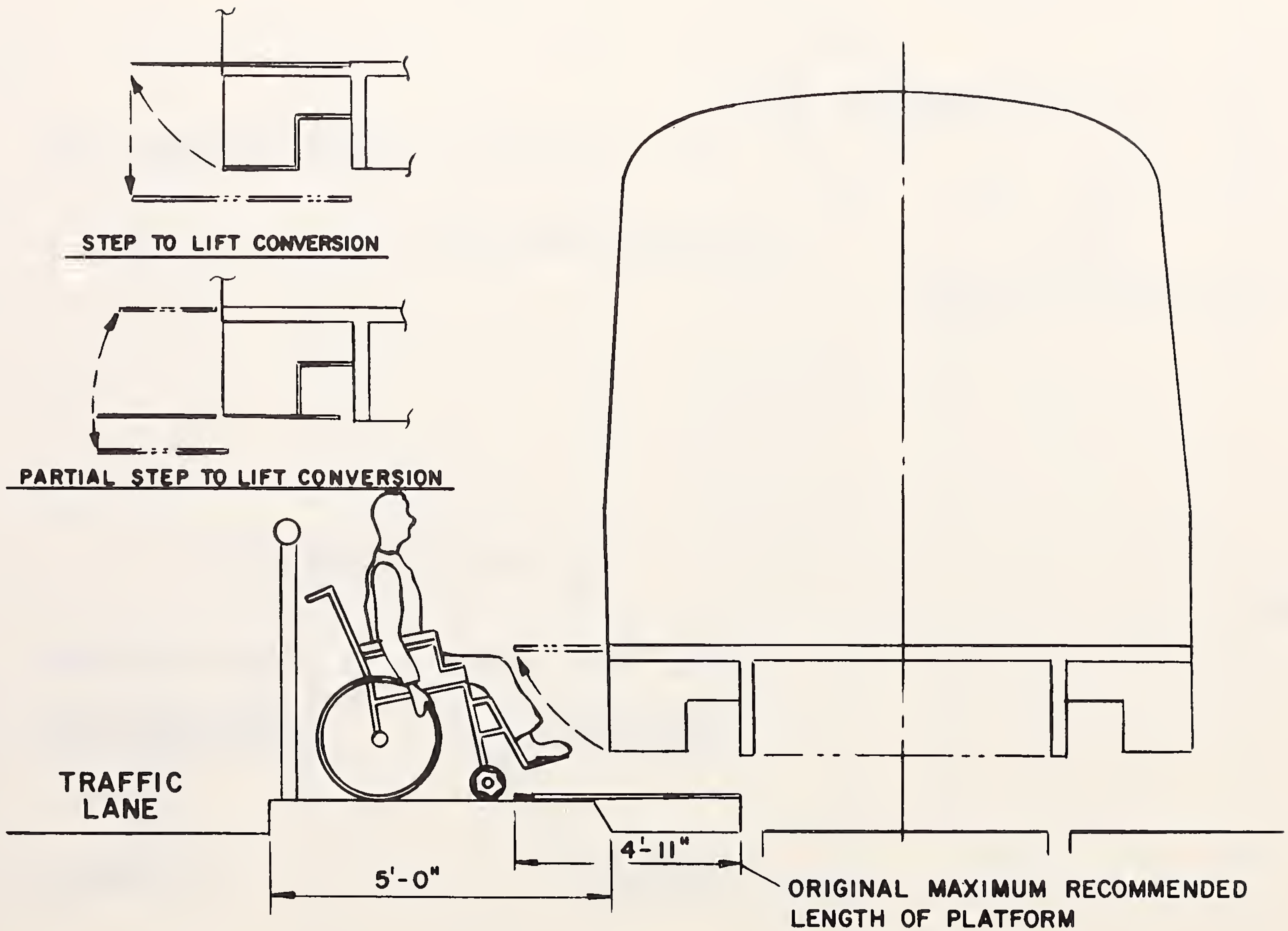


FIGURE 3-2. ISLAND PLATFORM BOARDING

extension of the platform. Even in those instances when the lift platform can "relax" somewhat to conform to the road surface conditions the overall effect on the boarding passenger is one of increased difficulty with the increased platform angle. Another way to improve the ramp angle problem is to have a thin lift platform which automatically reduces the entry angle, but this can only be done to the point where it does not affect other criteria.

The problems caused by the projection of the deployed lift platform makes the distinction between "elevator" and "arc motion" lifts very important. Elevator lifts raise and lower in a vertical path; therefore, the platform projection remains constant. Arc motion lifts are mechanically designed to lower the lift by traveling through an arc which causes the lift platform to extend further from the vehicle as it descends. The categorization of existing bus lifts into the two types is discussed in detail in the next section.

Figure 3-2 illustrates the problem which occurs at a typical island platform which is common on many of the existing LRT systems. The island platform is located in the street with one or more traffic lanes between the sidewalk and the platform. The width of the island platform is usually restricted to approximately 5 feet in order to allow sufficient room for the traffic lanes. In numerous instances the platform width can be considerably less than 5 feet. The problem with a platform which extends too far out onto the island is that a wheelchair passenger is left with little or no maneuvering room for entry onto the lift. Figure 3-2 shows that with an elevator type lift the passenger can, with some considerable maneuvering, enter onto the lift platform. It becomes impossible for the passenger to board with any type of lift that projects the platform further out when deployed. In this situation, the only alternative is an entry onto the platform from the side rather than directly forward. This solution creates other problems with regard to the passenger entryway into the vehicle from the lift platform, and as a consequence it was not pursued in any detail. In order to ensure that adequate consideration was given to alternative approaches to solving some of the above problems, the two manufacturers of lifts with arc motion (EEC and Lift-U) were provided with a set of vehicle drawings and their own lift drawn to the same size, along with a description of the limitations which were encountered. They were encouraged to review and critique the conclusions and suggest alternative approaches to the use of their lift designs. The elevator type lifts were the only ones finally selected for detailed consideration for LRV installation because of this necessity to minimize lift platform projection when deployed.

None of the lift designs considered in this project are suitable for use in the center doors of the MUNI vehicles. The center doors on the MUNI vehicles are equipped with a special high/low step design, for entry/exit at both street and high platform (level entry) stations. The center doors are the sole means of entering or exiting the vehicle at high platform stations. The problem is one of interference, since all of the lifts considered would extend well beyond the vehicle doorway as shown in Figure 3-3. In order to accommodate a lift in the center door of the MUNI cars it would be necessary to design a new lift which would incorporate the steps which rise for use at high platforms and a lift which could be deployed at low platforms or in-street operations. This type of step/lift/level entry unit would be useful in any new system or a modification to an existing which involves a combination of low and high platform boarding situations.

3.2 LIFTS

The manufacturers of all known passive bus lifts were contacted at the outset of this project for information on their existing lifts and to solicit their interest in this project. All except General Motors indicated their interest in supplying the necessary equipment for an LRV lift installation. The G.M. lift is used exclusively on G.M.'s RTS Series of buses and is not available separately. The five bus lift systems which were evaluated for this project were, therefore:

- Environmental Equipment Corporation (EEC) of San Leandro, CA.
- Lift-U, Inc. of Seattle, WA.
- Transportation Design and Technology (TDT) of San Diego, CA.
- TransiLift Equipment of Calgary, Alberta, Canada.
- Vapor Corporation of Chicago, IL.

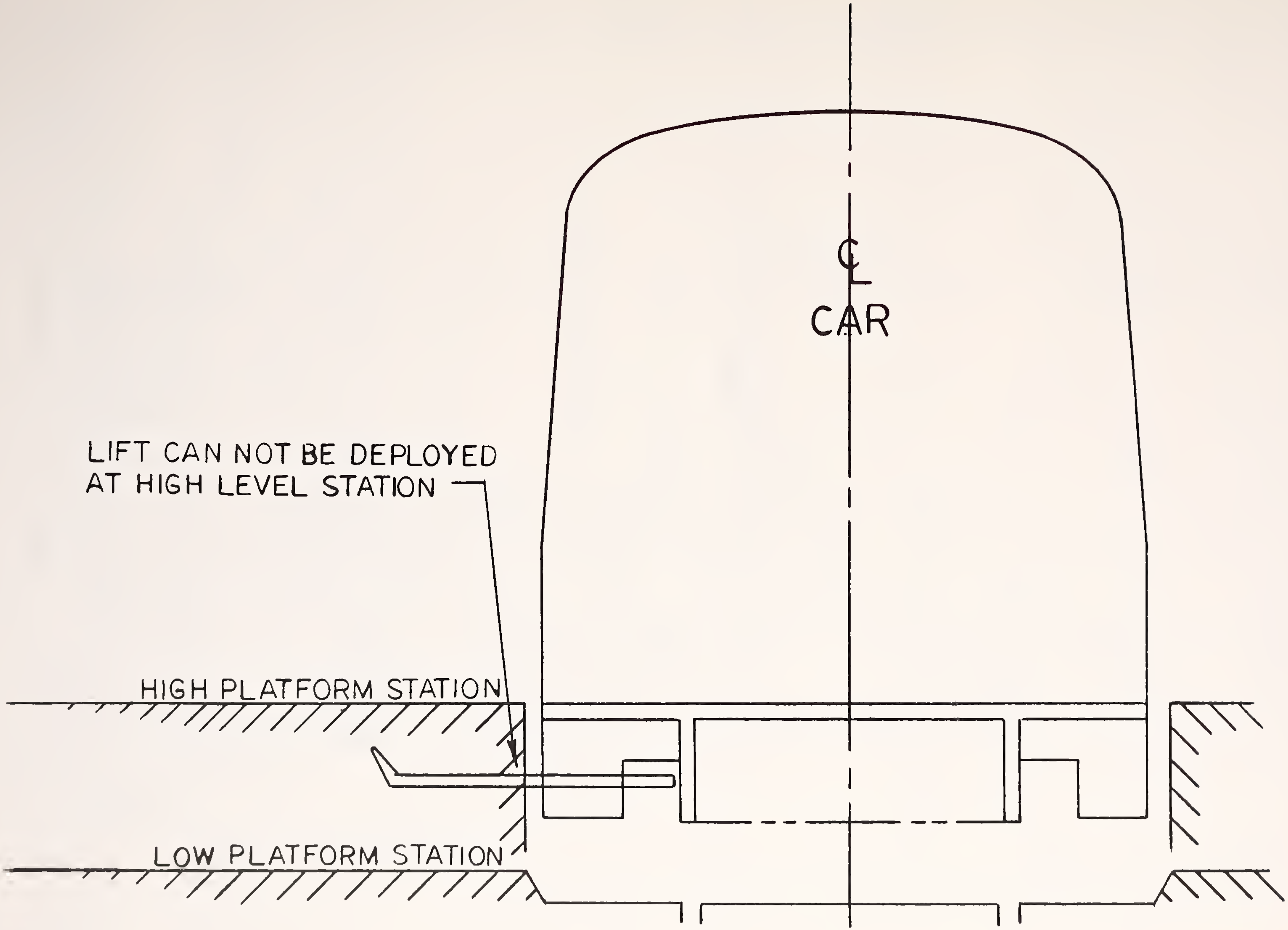


FIGURE 3-3. HIGH-LOW PLATFORMS

These existing lifts are all hydraulically operated, with 12 or 24 volt control circuitry. All of the lift manufacturers cited above employ designs where the lift forms all or a portion of the vehicle steps when in the rest position. In addition to the above, Collins Industries was developing a lift, but no installation had been made at that time and, therefore, it was not included in the evaluation. One exception to the standard bus lift technology was a lift being designed by Austin-Mac of Seattle for installation on the roof of the vehicle which would be completely independent of the steps when stowed. This lift is only in the prototype state, and because the roof package would seriously interfere with the overhead wire of an LRT system, it was not considered after the preliminary stage of evaluation.

Table 3-1 presents the significant physical dimensions and characteristics of these lifts and includes information on the GM and Collins lift for purposes of comparison.

Based upon the studies of the lift requirements and LRV lift installation considerations, the following four major requirements were established for a viable LRV retrofit lift.

- Minimum vehicle structural changes.
- Minimum platform projection from the side of the vehicle.
- Minimum platform thickness.
- Maximum conformability of the platform to the road.

The lifts considered in this project were all designed for installation in a vehicle doorway. The predominant characteristic of lift design which must be considered for LRV installation is the path of the platform. Three of the lifts, TDT, TransiLift, and Vapor, raise and lower in a vertical path, as an elevator. The remaining two, EEC and Lift-U, travel in an arc that increases the total platform projection from the vehicle as the lift moves vertically.

The evaluation of each lift system was based upon its suitability from an operational point of view, and its suitability for integration into LRVs. Each lift system is discussed from these aspects and cross sectional illustrations are

TABLE 3-1. CHARACTERISTICS OF EXISTING LIFTS

	MANUFACTURER						
CHARACTERISTIC	GMC	EEC	TDT	VAPOR	LIFT-U	COLLINS	TRANSILIFT
PLATFORM LENGTH INCHES	36	46	49	50	47	40	46
PLATFORM WIDTH INCHES	50	30	34	34	30	42	32
CAPACITY LBS.	600	600	600 · 1000 · ·	600 · 1000 · ·	1000	1000	600 · 1000 · ·
POWER REQUIRED	HYDRAULIC (PWR. UNKNOWN)	HYDRAULIC 1 1/4-2HP	HYD. OR ELEC, 2-2 1/2HP	HYDRAULIC 2-3HP	HYDRAULIC 2 HP	HYDRAULIC	HYDRAULIC 2 HP
AUXILIARY POWER REQUIRED	ELEC. 24 VDC AIR 100 PSI	ELEC.	ELEC. 12 VDC	ELEC. 12/24 VDC	ELEC. 12 VDC	ELEC.	ELEC. 12/24 VDC
ANTI-FOLD PROTECTION	DUAL SWITCHES	WEIGHT SENSOR	WEIGHT SENSOR	· · ·	DUAL SWITCHES	WEIGHT SENSOR	LOCKING SWITCH
BACK-UP OPERATING METHOD	HAND WINCH TO LIFT PLATFORM	MAN. PUMP SEPARATE VALVE	MANUAL PUMP	MANUAL PUMP	HYD. PUMP AND CRANK	MANUAL PUMP	MANUAL PUMP

· CONTINUOUS

MAXIMUM

· · · ELECTRONIC DEVICE UNDER DEVELOPEMENT included to show each lift in its extreme positions within an LRV. The figures also show the operating principles and physical configurations for each lift. The lift descriptions in the following subsections (3.2.1 through 3.2.5) are adapted from Reference 5.

3.2.1 Environmental Equipment Corp. (EEC)

In the stowed position, this lift forms 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 Figures 3-4 and 3-5.)

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. The lift mechanism must first travel upward before descending, therefore, the lift is not subject to drifting downward when stowed and no positive locking device is required. The EEC lift is not an elevator type lift, since the motion of the platform up and down is guided by pivoted arms resulting in a much greater projection of the platform beyond the side of the vehicle (see Figure 3-4).

3.2.2 Lift-U, Inc.

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

The operating principles of the Lift-U are shown in Figures 3-6 and 3-7. The front position 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

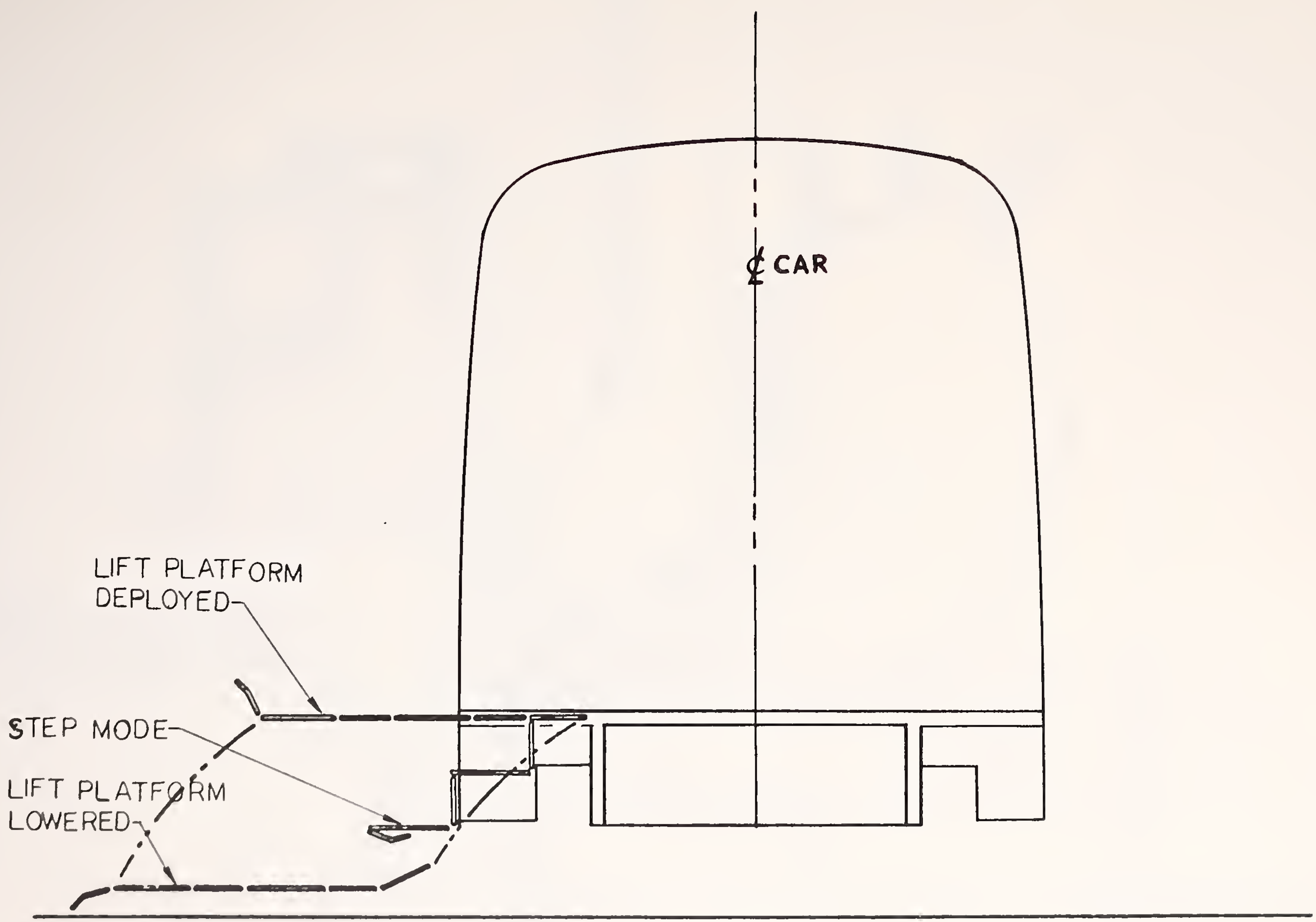


FIGURE 3-4. E.E.C. CROSS SECTION

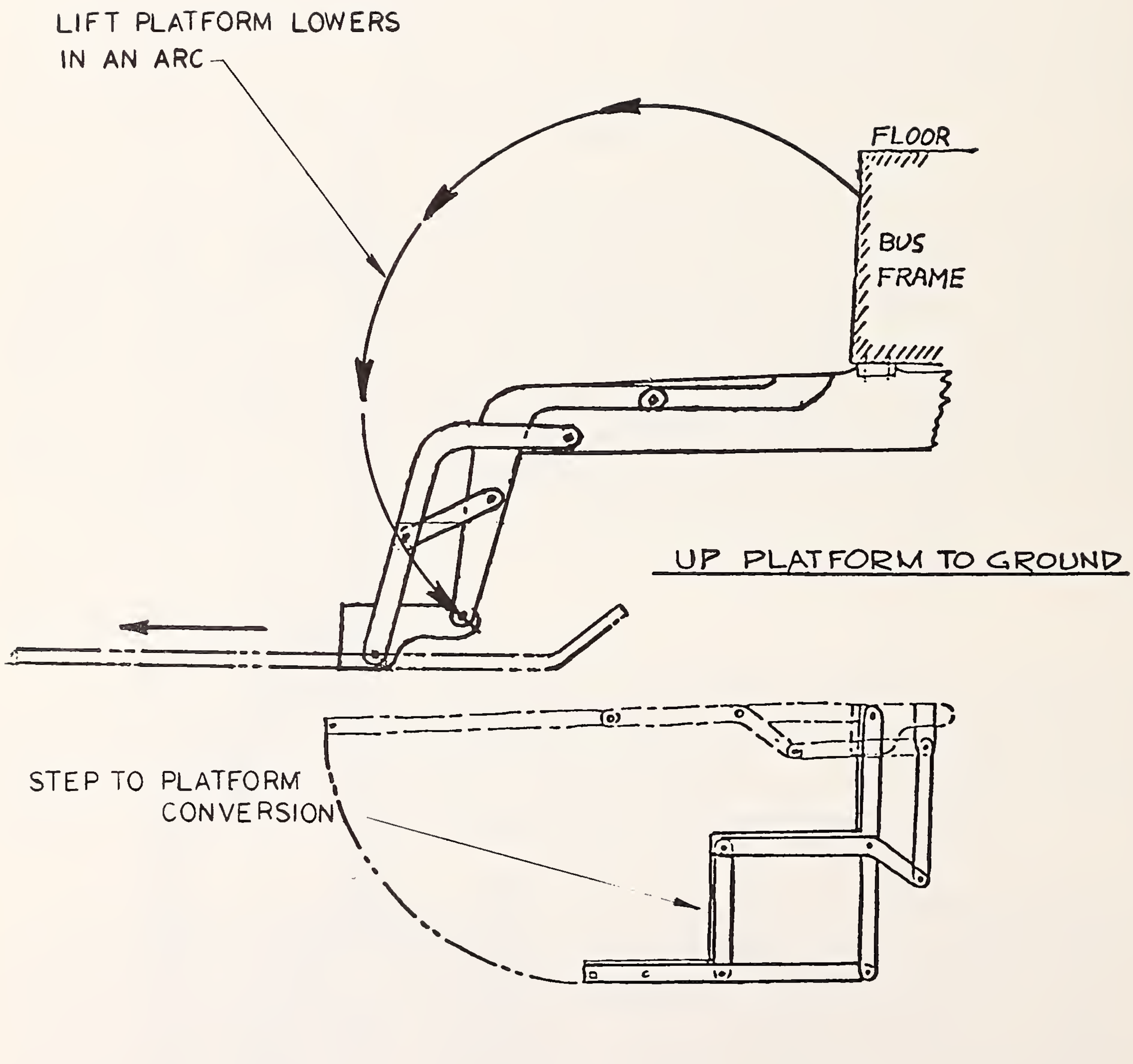


FIGURE 3-5. E.E.C. LIFT

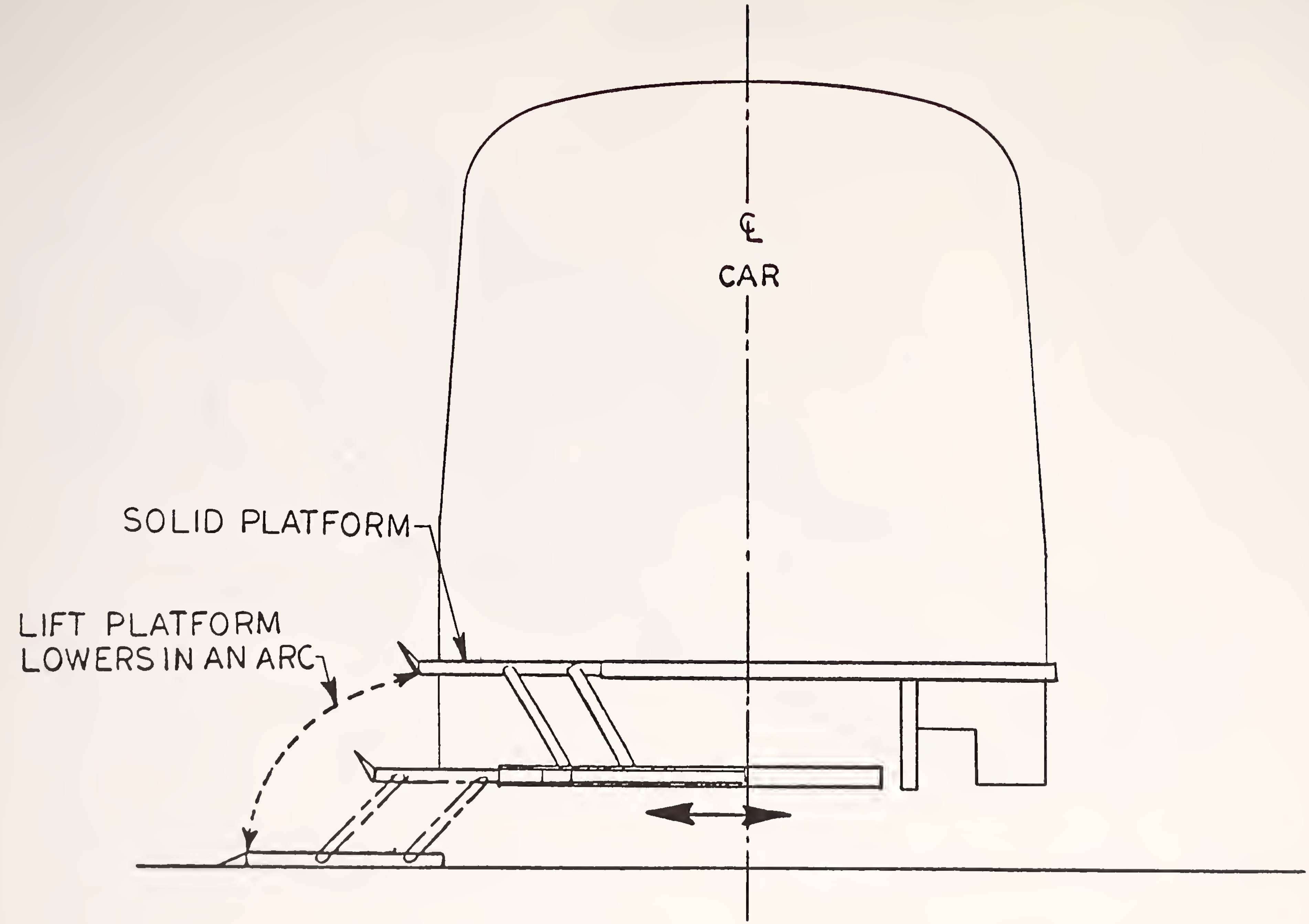


FIGURE 3-6. LIFT-U CROSS SECTION

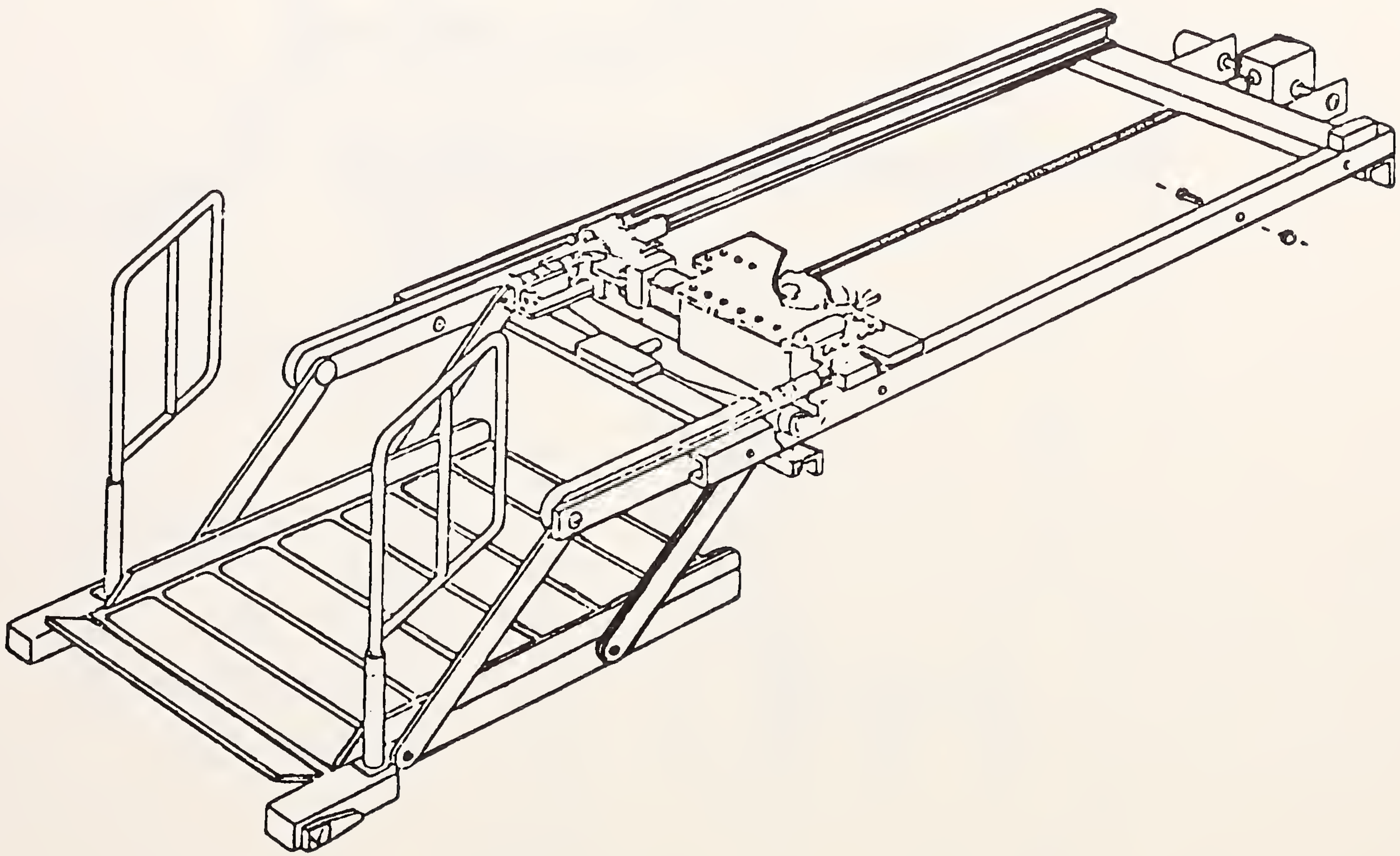


FIGURE 3-7. SCHEMATIC DIAGRAM OF LIFT-U

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. 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.

The Lift-U lift mechanism is mounted below the floor of a vehicle. Installation of this unit would require major changes to an LRV structure, and relocation of underfloor equipment. The Lift-U is not an elevator type unit, but is raised and lowered on pivoting arms resulting in a much greater projection beyond the side of the vehicle (see Figure 3-6).

3.2.3 Transportation Design and Technology, Inc. (TDT)

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. The retractable section is rather thick because it houses a hydraulic cylinder, which extends the 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.

A drawing of the lift is shown in Figures 3-8 and 3-9. 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.

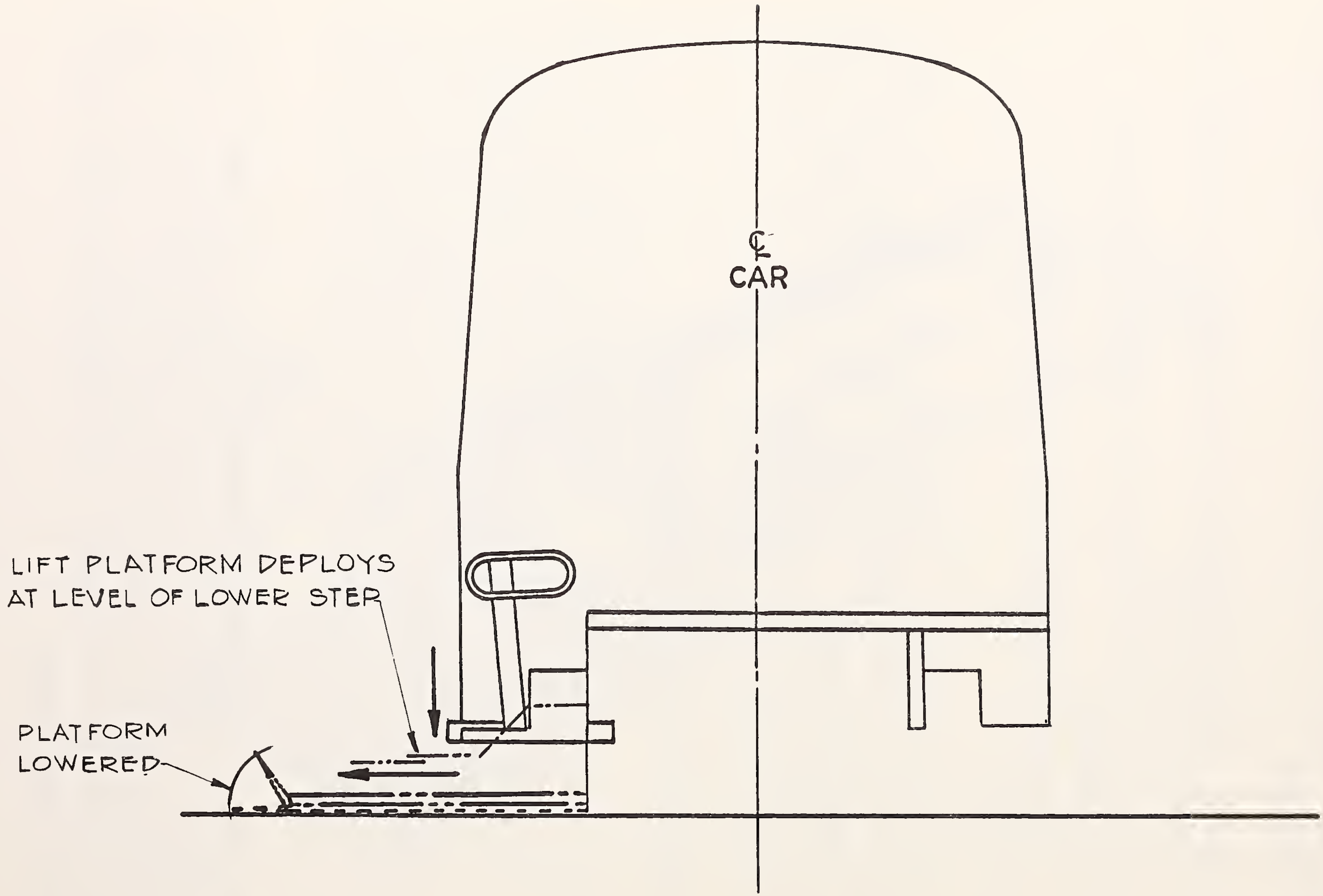


FIGURE 3-8. TDT CROSS SECTION

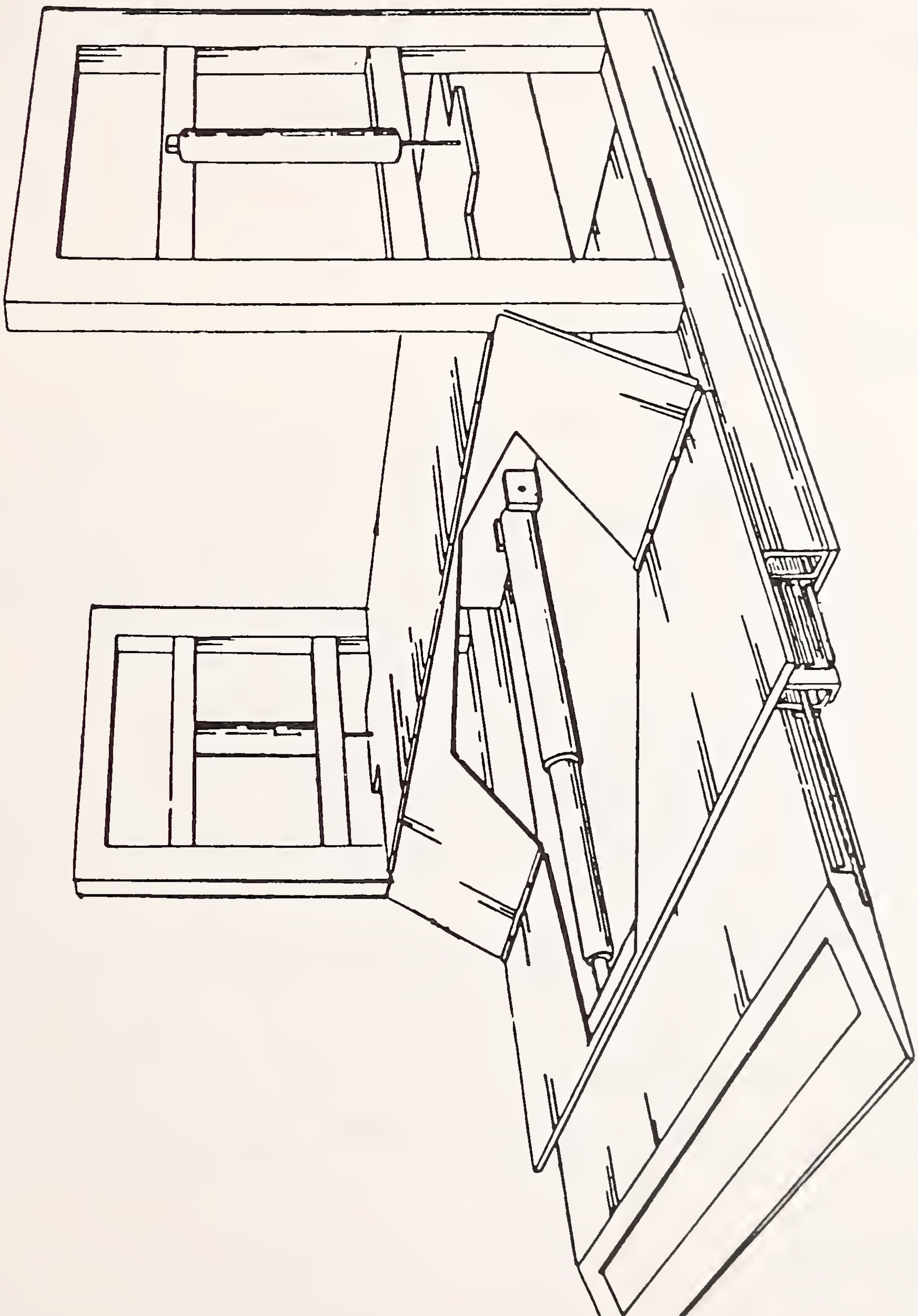


FIGURE 3-9. TDT LIFT

The TDT lift is an elevator type which raises and lowers with no lateral movement and, therefore, the projection beyond the side of the vehicle does not present a problem. The lift platform contains hydraulic cylinders and other mechanisms for deploying the platform which results in a thick and relatively rigid platform, characteristics which are not desirable in an LRV lift installation. All the elevator type lifts can be installed on the Boeing LRV without major structural changes. The TDT lift, however, has a projection back under the car frame which could cause problems on other vehicle installations (see Figure 3-8).

3.2.4 TransiLift Equipment, Ltd.

The TransiLift forms the lower two step treads and risers when in the stowed position. A significant difference between TransiLift and other lifts is that the members are only 1/2" thick, making for 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 hydraulic 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 stowed switch (#1) operated only when the lift is up and level with the bus floor (see Figures 3-10 and 3-11).

3.2.5 Vapor Corp.

The Vapor Travelift forms the treads and risers of the bottom two 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

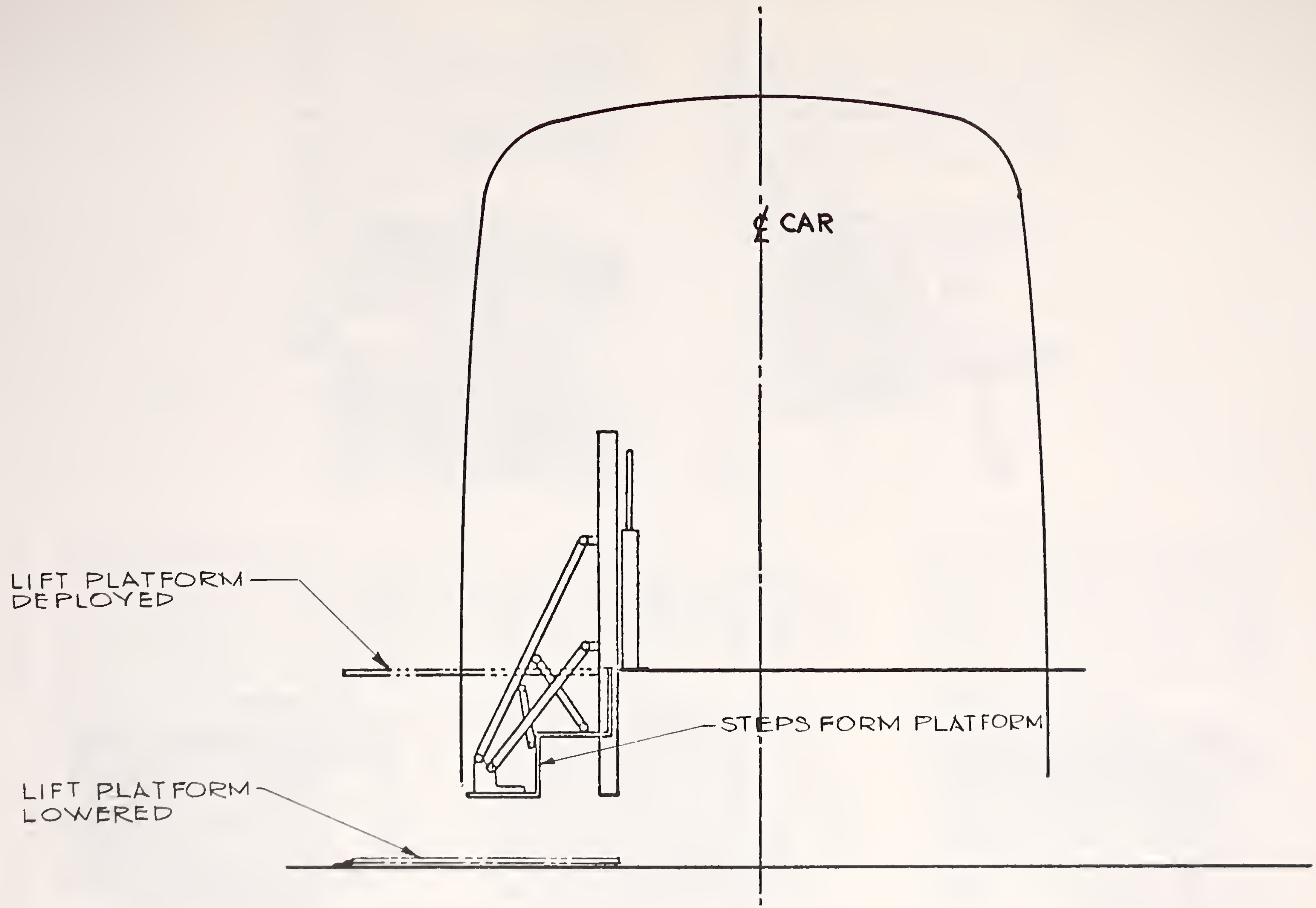
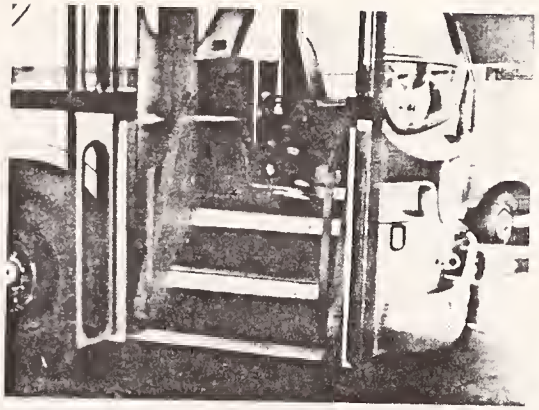
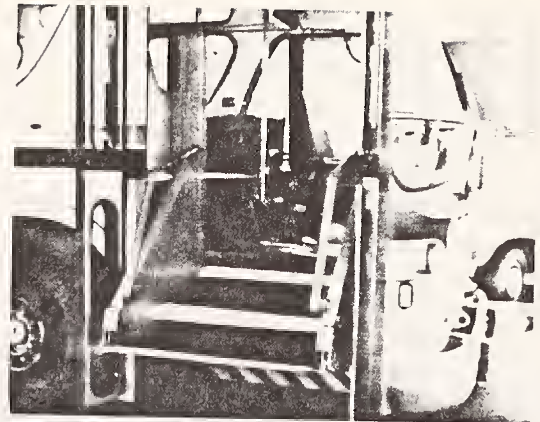


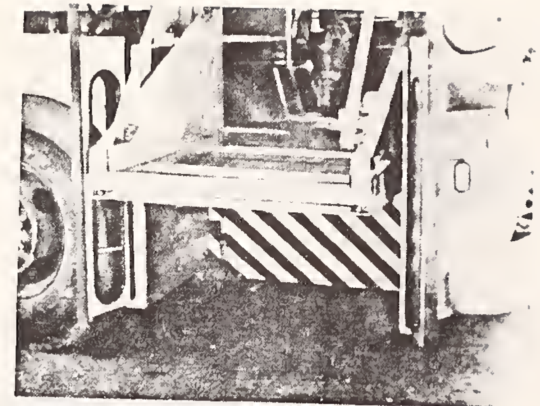
FIGURE 3-10. TRANSILIFT "X" SECTION



Step Mode — Doors Open
In the normally stored step mode, the handrails are useable by the ambulatory. The Transi-Lift bi-fold doors open clear of the lift well and do not interfere with the lift operation.

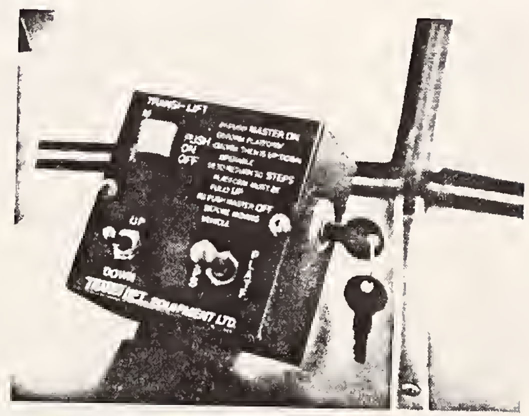


Forming Platform At Floor Level
The platform is formed at floor level to ensure that it will not jam against high curbs. It is in the constant view of the driver.



Clean Underneath
The lift and all its moving parts are installed completely within the vehicle to protect them from all weather elements and road conditions. This also provides ease of maintenance for all service points.

Easy Access
Effortless access for wheelchairs is accomplished because the lift has the capability to self level and conform to a slope or grade. The safety gate forms a ramp with a platform thickness of only 1/2''.



Control Panel
Transi-Lift is operated with only two dash mounted switches which are interlocked to eliminate operator error. The master switch provides power to the lift.

FIGURE 3-11. TRANSILIFT OPERATION

using a scissors mechanism as shown in Figures 3-12 and 3-13. 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 descent 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 vehicle if the second sensor fails to contact the ground before some other portion of the platform touches.

The Vapor lift is an elevator type lift and, therefore, has acceptable projection beyond the side of the vehicle. The platform is relatively thick and rigid and will not conform well to sloped or crowned road surfaces.

3.2.6 Summary of Bus Lift Application to LRV

There are no features on any of the five lifts that were studied that would restrict their use to buses only. In general, all of the lifts can be adapted to existing LRVs and the basic changes that are required to some are relatively minor. Lifts would be widened to use the full available LRV doorway width; treads and risers reconfigured to approximate the fixed LRV stops; electrical components changed to be compatible with the higher LRV auxiliary voltages of 30 to 37 1/2 VDC.

There is a more difficult installation problem with the two lateral motion lift designs (EEC and Lift-U). An attempt to retrofit these lifts into an existing LRV would require major equipment relocation or structural changes or both. These lifts could be more simply installed on new LRV designs, on which the stucture and equipment layout were made compatible with the lifts from the outset.

There was one system installing lifts on an LRV at the time the evaluation of bus lift application to LRVs was being conducted. San Diego purchased 14 new LRVs manufactured by Siemens-DuWag of Germany which were being equipped with a TransiLift. This installation was not considered as being representative of the type of lift retrofit which was the objective of this project. The San Diego installation was unique since there was no need to select a lift design which

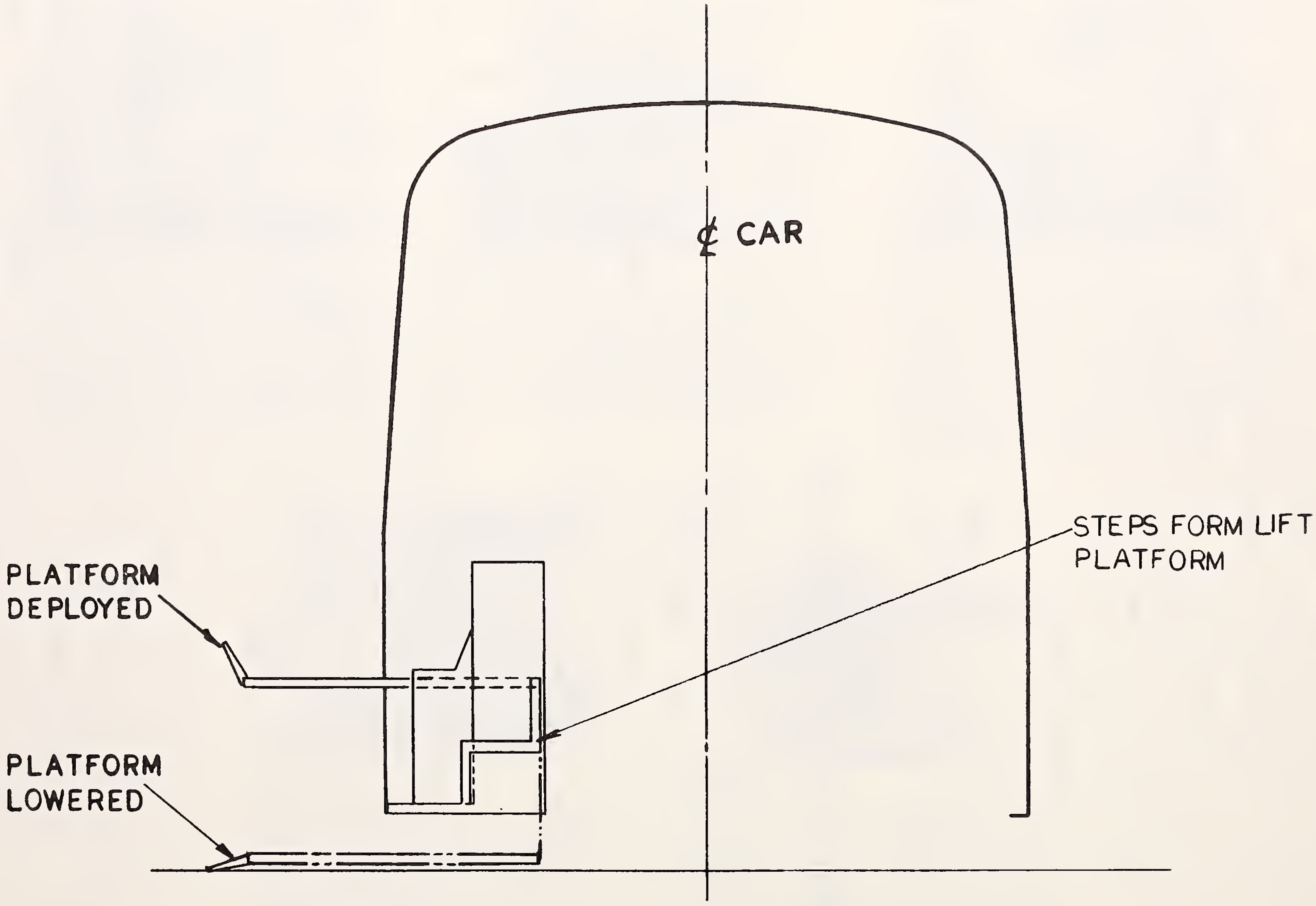


FIGURE 3-12. VAPOR TRAVELIFT

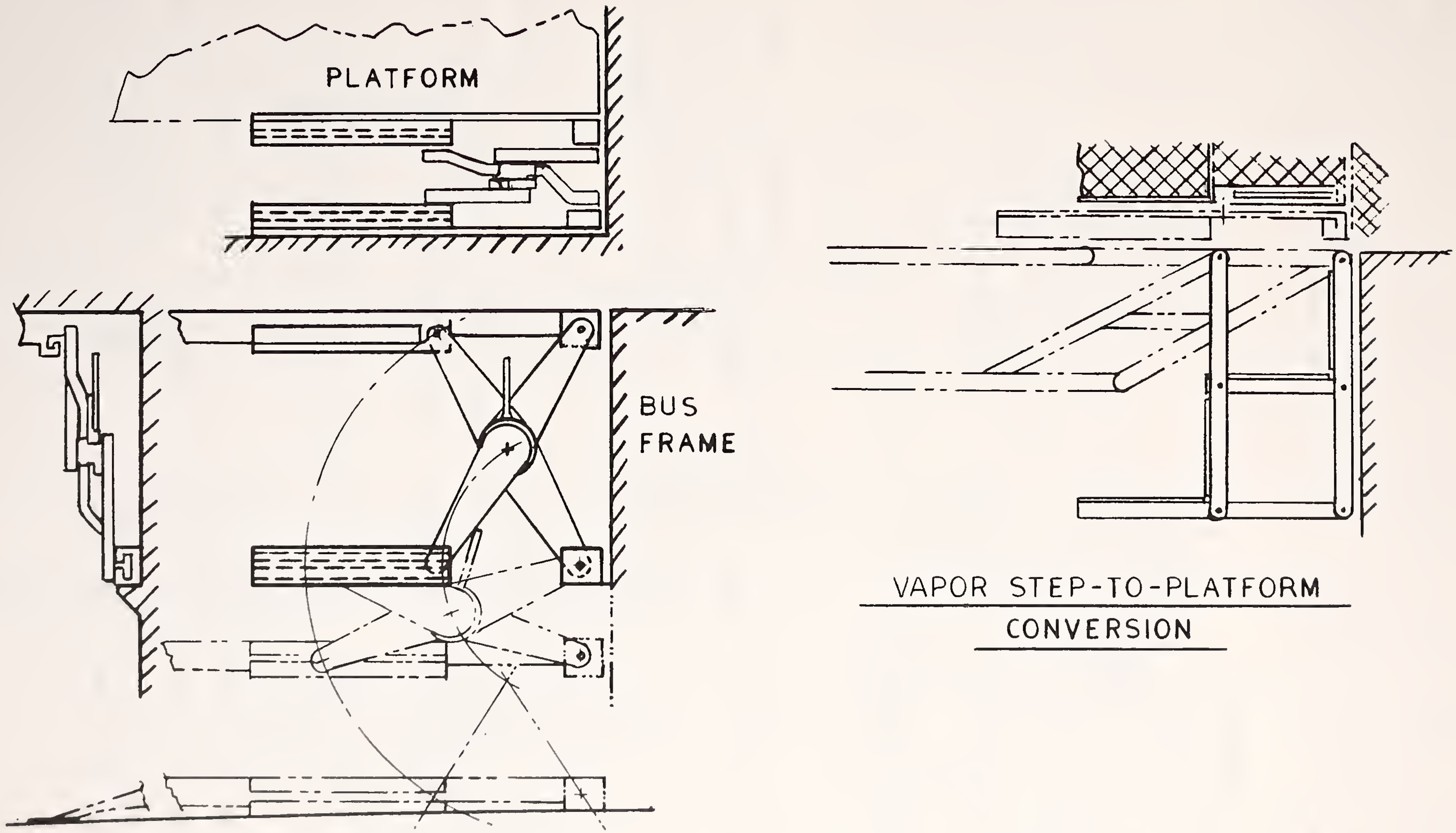


FIGURE 3-13. VAPOR LIFT

would fit into a broad range of vehicles. In addition, there was no attempt made to modularize the lift, and the TransiLift had to be modified such that it would fit into the standard DuWag car doorway design including the retractable first step arrangement. There was virtually no change made in the vehicle itself.

3.3 VEHICLES CONSIDERED

The LRVs considered as candidates for installation of a lift included the Boeing, Breda, and Kawasaki. The PCC car was also studied. With the exception of the Kawasaki vehicle, the project team was able to collect drawings and other data necessary to make a detailed evaluation of door dimensions, floor area and layout, structure, accessories and other items which might be affected by a lift installation. As indicated earlier, due to the lack of detailed data the Kawasaki LRV was dropped from further consideration in the project as was the PCC car.

Half-scale drawings of the doorway areas for the Boeing and Breda vehicles and of the selected lifts were prepared in order to allow for the evaluation of the impact of various lift installations. It was found that the Boeing LRV front stepwell depth (toward the centerline of the car) could be increased significantly without frame modifications to reduce the lift projection from the vehicle because the frame is narrowed as it approaches the drawhead. The Boeing LRV center stepwells, in contrast, cannot be deepened without undertaking frame modifications. Figure 3-14 shows the Boeing frame arrangement and the location of equipment spaces for both the MUNI and the MBTA configurations.

On the Breda LRVs, the front doorways at each end of the vehicle are parallel with the side of the car. Counting the two center doorways, the Breda LRV has six identical doorways per car. The center sills of the Breda cars are parallel along the whole length of the car and, as a result, lift installation conditions are the same for any of the six doorways. Like the center doorways on the Boeing cars, the Breda stepwell depth at any doorway cannot be increased without incurring frame modifications. Figure 3-15 shows the Breda frame structure.

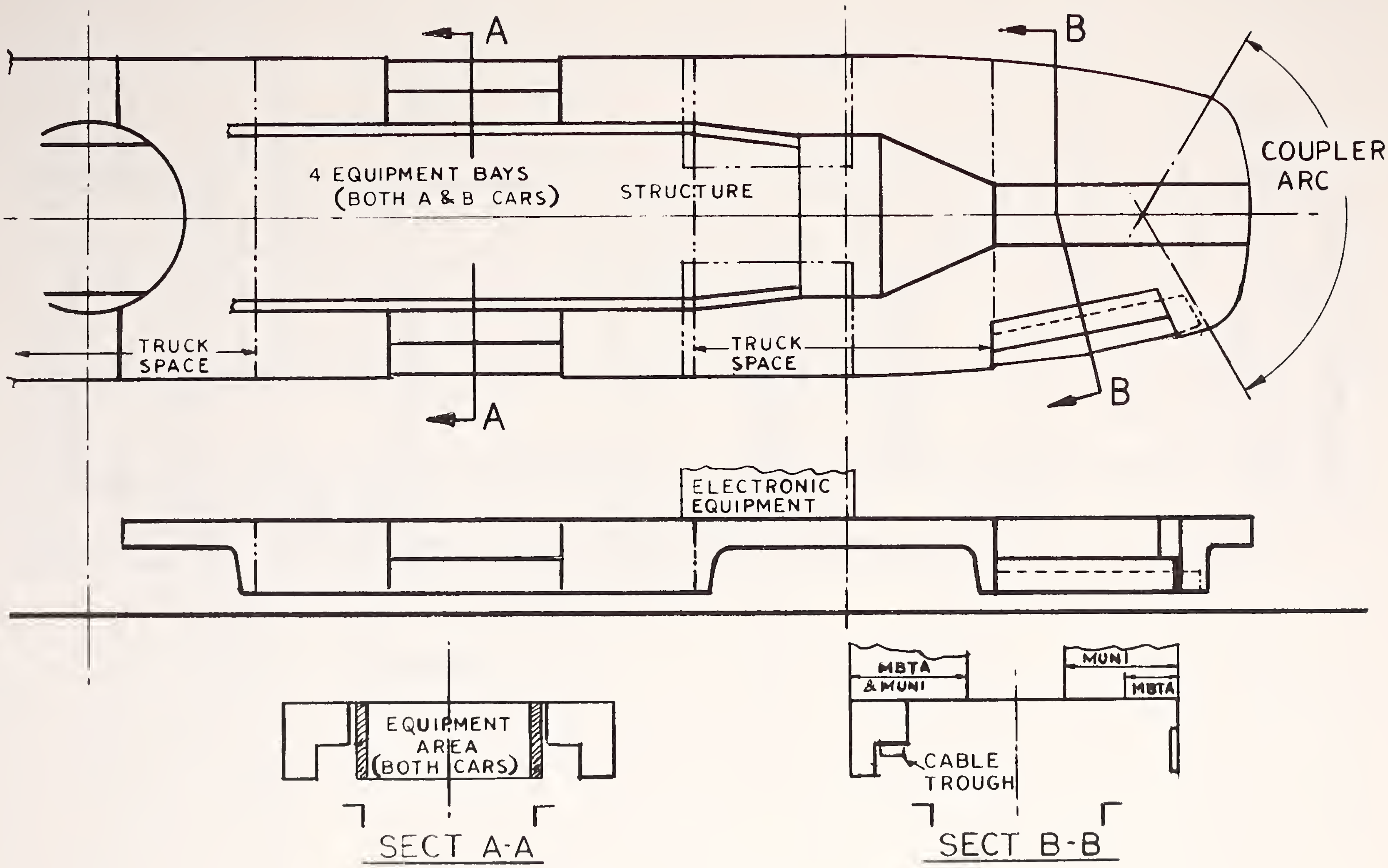


FIGURE 3-14. BOEING LRV FRAME STRUCTURE AND EQUIPMENT SPACES

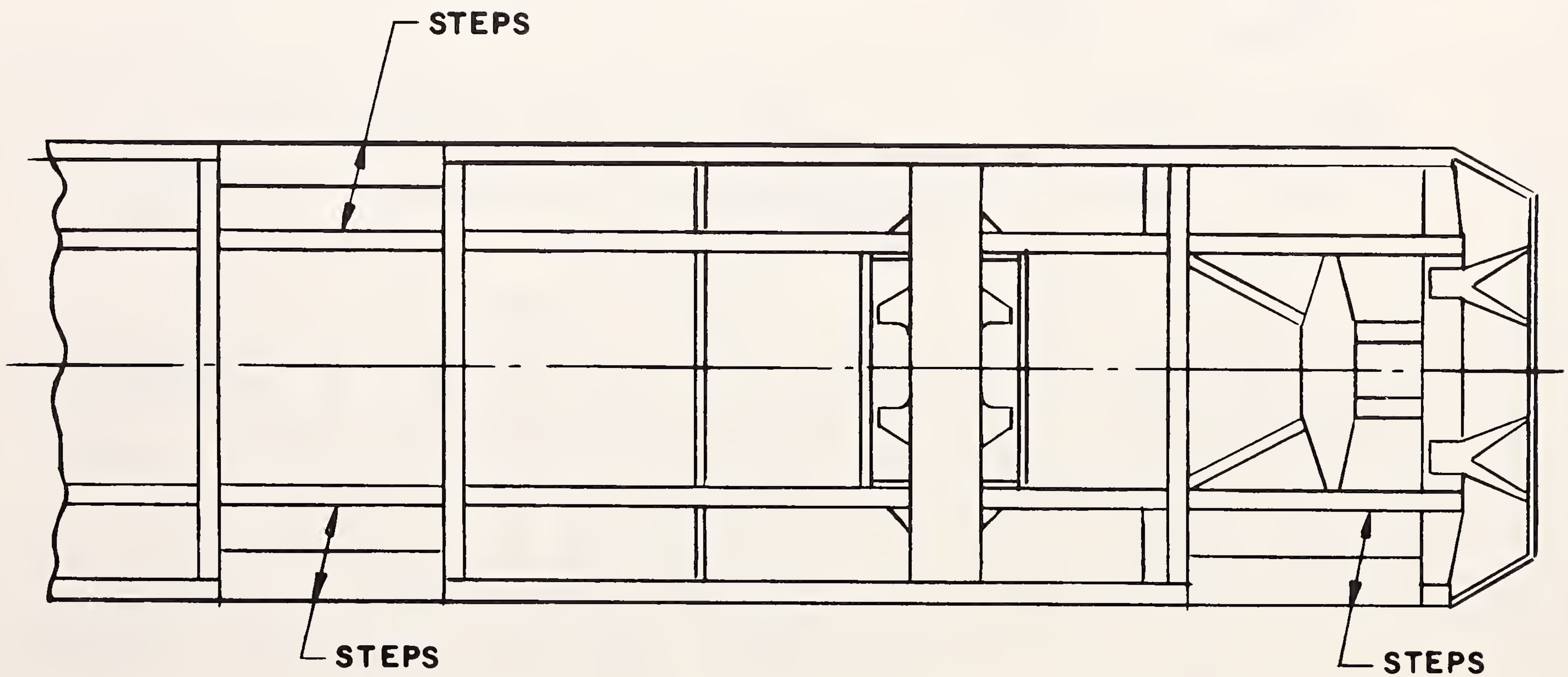


FIGURE 3-15. BREDA FRAME STRUCTURE

3.4 EVALUATION AND RECOMMENDATIONS

The lift, the vehicle, and the operating environment should all be considered in selecting a final configuration. Since the final goal of the project was to demonstrate a prototype installation in a Boeing vehicle, only the considerations affecting that installation will be discussed in this section. The factors affecting lift installation in the Breda LRV are presented in Appendix C.

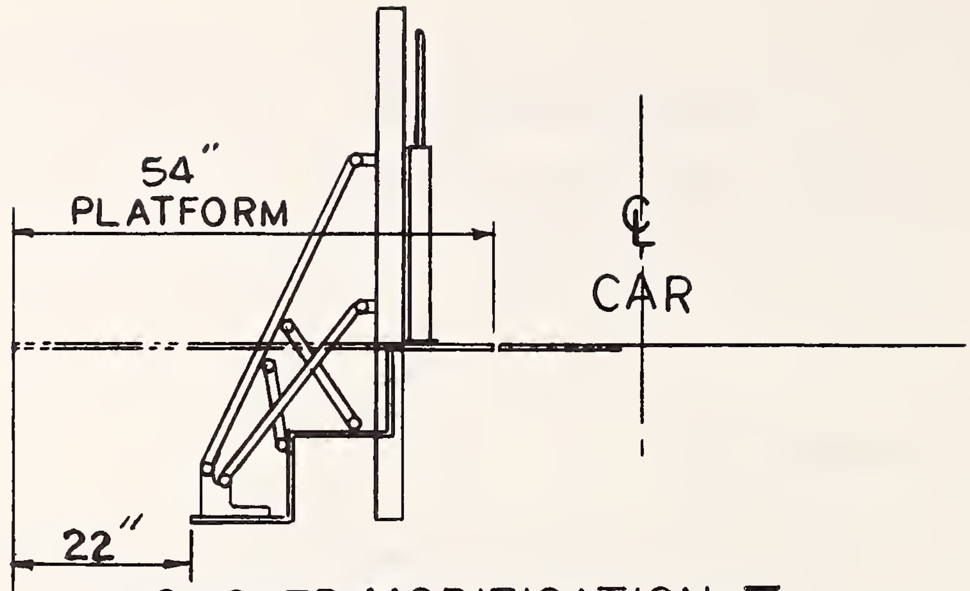
3.4.1 LRV Lift Recommendations

Study of the two LRVs and five existing bus lifts disclosed several ways in which lifts could be installed. Of the three vertical-path elevator type lifts, only TransiLift appeared to have advantages for a prototype installation when considering the factors of:

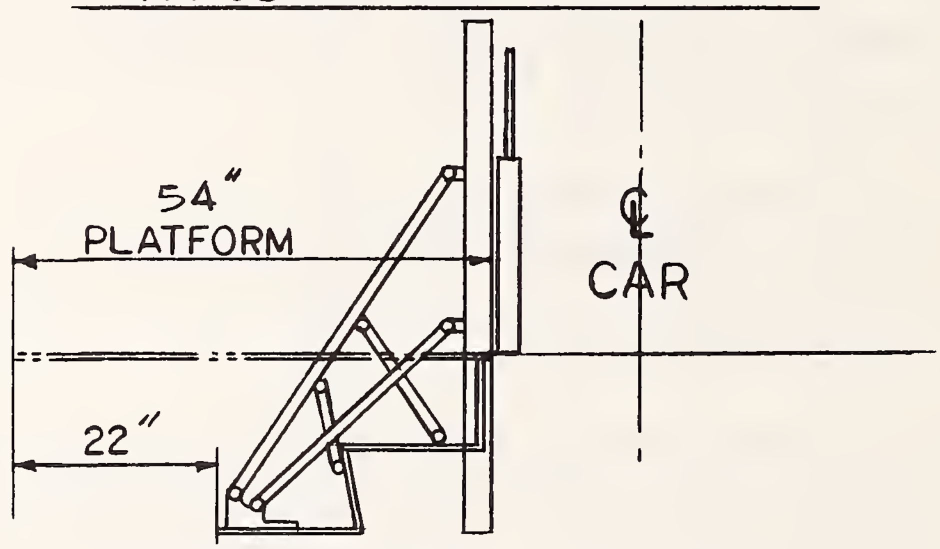
- o Minimum structural modifications.
- o Minimum lift platform projection from vehicle centerline.
- o Minimum lift platform thickness.

The TransiLift unit has the thinnest platform of any of the three elevator lifts. TransiLift also indicated a willingness to make reasonable modifications to their unit if required to suit LRV retrofit installations. The preliminary study of this unit in the Boeing LRV front doorway indicated that some relatively simple changes would make a satisfactory lift installation. Therefore, the TransiLift was determined to be the lift design concept which provided the best combination of lift characteristics for testing in a prototype LRV installation.

The existing TransiLift tread and riser dimensions corresponded closely to the Boeing step dimensions and would fit into the present stepwells, but the platform was only about 42 inches long. Consequently, the TransiLift was studied further to identify modifications which would help in improving its overall acceptability. Figure 3-16 shows the progression of the modifications considered based upon the existing TransiLift arrangement. Both Modifications 1 and 2 were directed toward increasing the lift platform length.



PROPOSED MODIFICATION II



PROPOSED MODIFICATION I

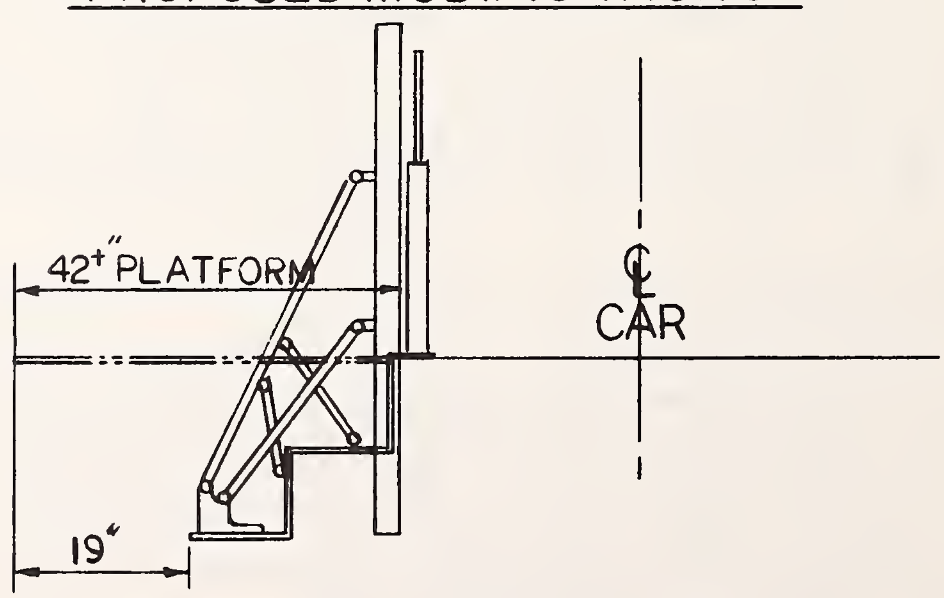


FIGURE 3-16. EXISTING ARRANGEMENT TRANSILIFT CROSS SECTION

The first proposed modification, shown as number 1 on Figure 3-16 would involve deepening the front stepwell on the Boeing cars and lengthening the TransiLift tread dimensions to create a 54 inch platform length including safety gate. Note that the increased length is gained almost entirely within the vehicle and the platform projection from the vehicle is practically unaltered.

Figure 3-17 shows the plan view of Modification 1 with the proposed wide tread unit in the front door of the Boeing LRV. Widening the treads moves the lift towers inward and reduces the width available to the wheelchair user for maneuvering onto or off of the lift. This arrangement required reworking the bulkhead (and the fare box) immediately behind the driver's position to provide sufficient clearance for a wheelchair. In addition, changing the tread dimensions of the unit made it necessary to reconfigure the platform actuating linkage.

The second proposed modification, shown as number 2 on Figure 3-16, leaves the operating mechanism unaltered and improves the tower to bulkhead clearance over the preceding modification. Platform length is gained by adding a third horizontal tread to the lift at the top, which appears to be part of the floor when in the step configuration and which is part of the platform in the lift configuration. Figure 3-18 presents a plan view of Modification 2 which clearly shows the improvement in clearance for movement of the wheelchair. The apparent third tread is actually at floor level in the step configuration. Because the towers are in their original location relative to the movable steps, that is, closer to the side of the car, there is sufficient clearance between the towers and the operator's bulkhead without modifying the bulkhead. Adding a non-pivoted third tread to the lift is a straight-forward modification that involves only structural design without kinematic considerations. It was expected that by having the lifting point forward of the rear edge of the 54 inch platform, which reduces the cantilevered length, that droop and spring back characteristics should be as good as on the original 42 inch cantilevered lift platform.

3.4.2 Boeing Lift Location Recommendation

Level entry boarding is used only by the San Francisco Municipal Railway (MUNI) in the new Market Street subway, and its Boeing LRVs are provided with a

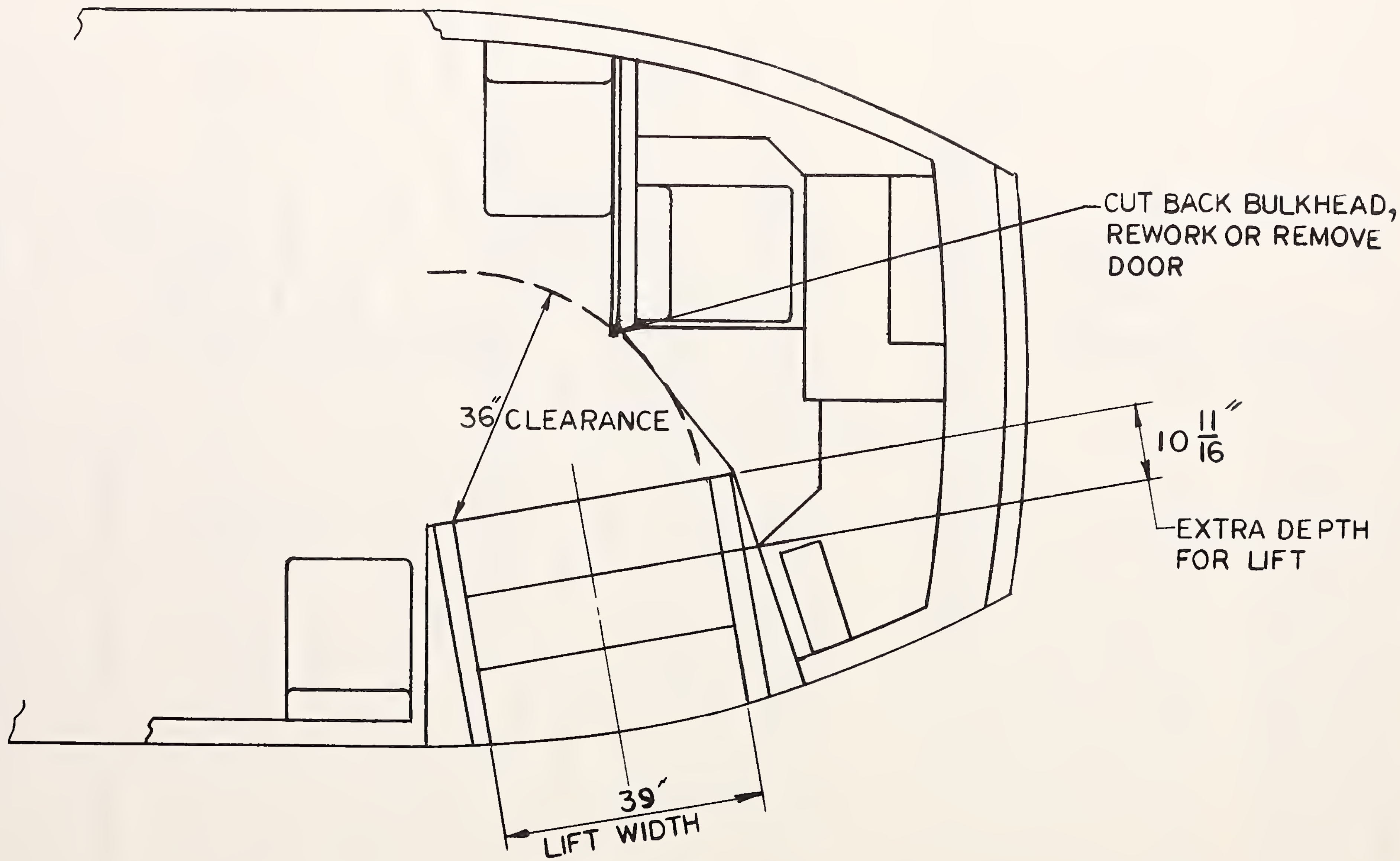


FIGURE 3-17. MODIFICATION 1 - TRANS-LIFT MBTA & SFMR

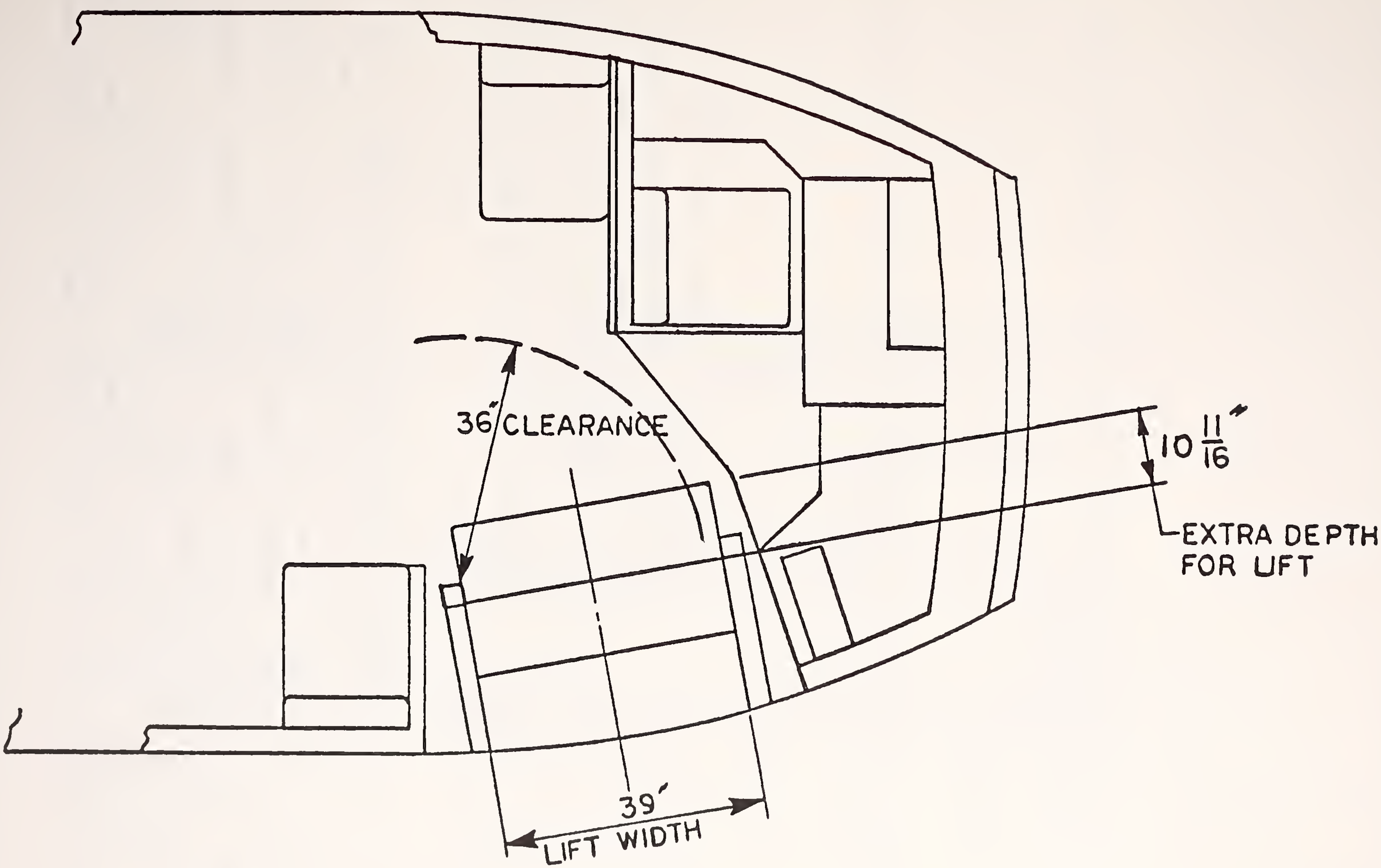


FIGURE 3-18. PROPOSED LIFT ARRANGEMENT MBTA & MUNI

movable step arrangement at the four center doors. With this arrangement, the two step treads can be raised to floor level to allow boarding from high level platforms. These are the only doors that can be used in the subway stations. The Massachusetts Bay Transportation Authority (MBTA) operation in Boston allows the use of both left and right side street level boarding in some stations and made it necessary to consider how to provide either side accessibility. Using lifts, the two options were:

- o Traversing the entire length of the vehicle to use the rear door lift, which is on the left of the car (two lifts per LRV at the extreme end doors); or
- o Providing additional lifts at the left center doors (four lifts per vehicle).

The impacts of these constraints together with the potential lift modifications are discussed in the following section.

3.4.2.1 MBTA Light Rail Vehicle

The Boston light rail system has four stations that require left side boarding for passengers: Haymarket, Kenmore, Government Center and one of four tracks at Park Street. Left side lifts imply the use of either two or four lifts per car on bi-directional LRVs. For either side entry, the two-lift arrangements all have undesirable operational characteristics related to driver supervision and passenger movement. Operationally, four lifts with two located at the ends and two in the center are preferred.

To install Modification 1 of the TransiLift at the center doorway of the MBTA Boeing LRV would require significant modification to the frame, to create more depth in the stepwell. The original TransiLift would fit without serious modifications to the car. Another solution could be used for the four left side boarding stations, which actually number only seven boarding locations. For wheelchair users, the only alternative to left entry to an LRV is some form of level entry which is analogous to entry on rapid rail vehicles. Figure 3-19 shows one possible high platform arrangement, reached by either a ramp of sufficient length or by a small station platform-based lift. Some LRV operators

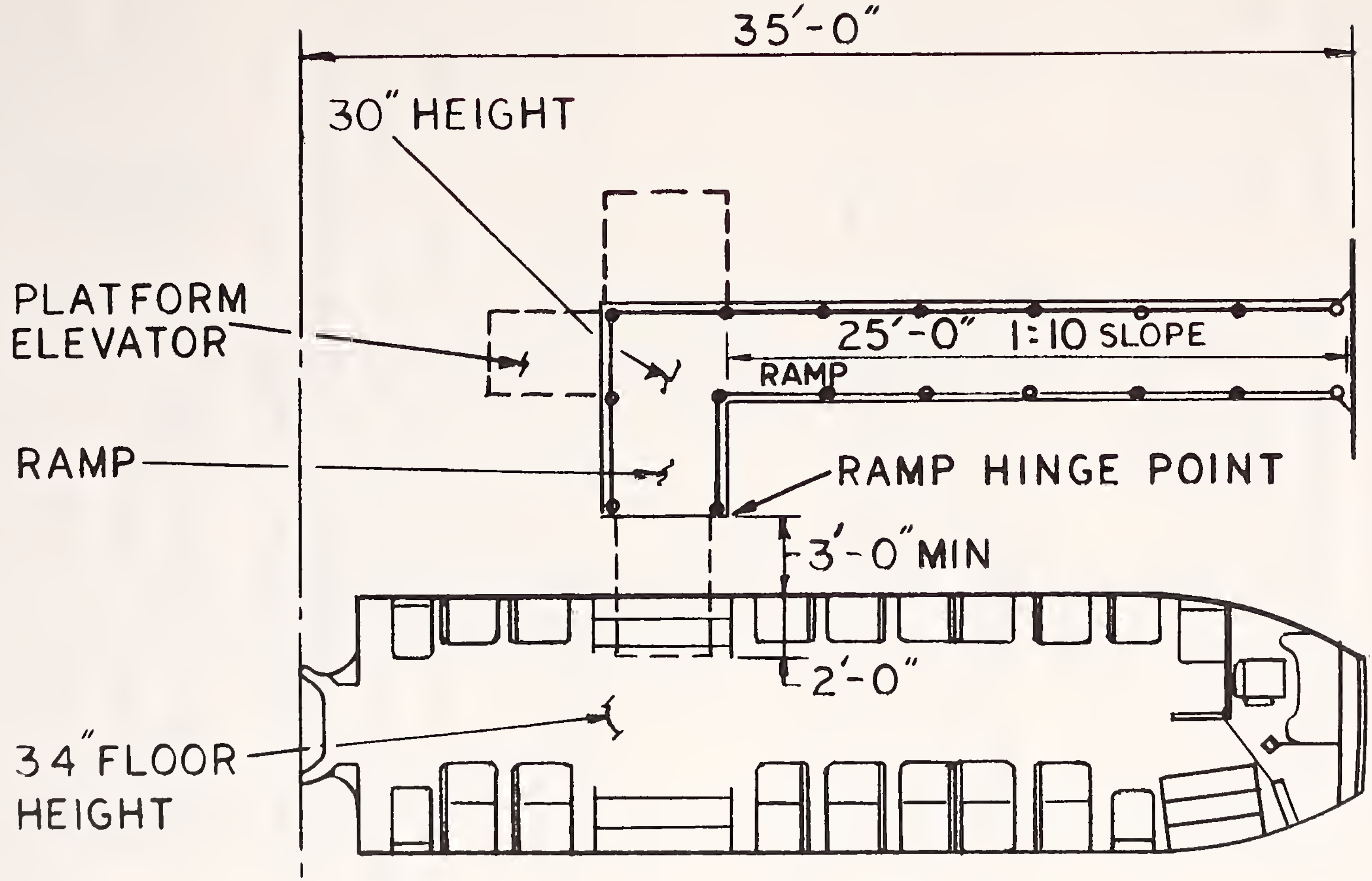


FIGURE 3-19. HIGH PLATFORM ARRANGEMENT USING MINI-PLATFORM RAMP-ELEVATOR

are considering wayside lifts as a complete alternative to vehicle-mounted lifts. Tri-Met in Portland, Oregon is procuring wayside lifts for its new light rail line.

The major advantage to wayside elevated platforms or lifts for left side accessibility is the 50% reduction in number of vehicle lifts required. For Boston, four to seven mini-platforms or wayside lifts would save approximately 135 vehicle lifts. The major disadvantage of the mini-platform is the operational restriction caused by the requirement for accurate car stopping to interface with a fixed mini-platform. If the car has to stop twice, there is also a dwell time problem. The disadvantage of the wayside lift would be similar.

The internal changes on the MBTA cars are minimal because they use 1+2 seating, as shown in Figure 3-20 and the path between the front and center doors can be traversed by a person in a wheelchair. The only significant internal modification required would be the removal of several seats to create a wheelchair securement area.

3.4.2.2 MUNI

The operational requirements of MUNI are somewhat different from those of Boston. All low-level (street) boarding in San Francisco is on the right side of the car. In the Market Street Subway, all stations are high platform (level entry), and only the center doors are used for boarding. The end doors are not used in the subway (and were not provided with high/low steps) because they are on the tapered car ends and would not interface correctly with the platforms. Figure 3-21 shows the existing layout of the MUNI cars.

Because of the high/low step arrangement at the four center doors, these locations were not seriously considered for lift applications. No lifts currently combine the step/level entry/lift functions into one unit. Thus, only a front door lift application is practical. A lift installation in the front door of the MUNI LRVs is essentially the same as the installation in the MBTA LRVs.

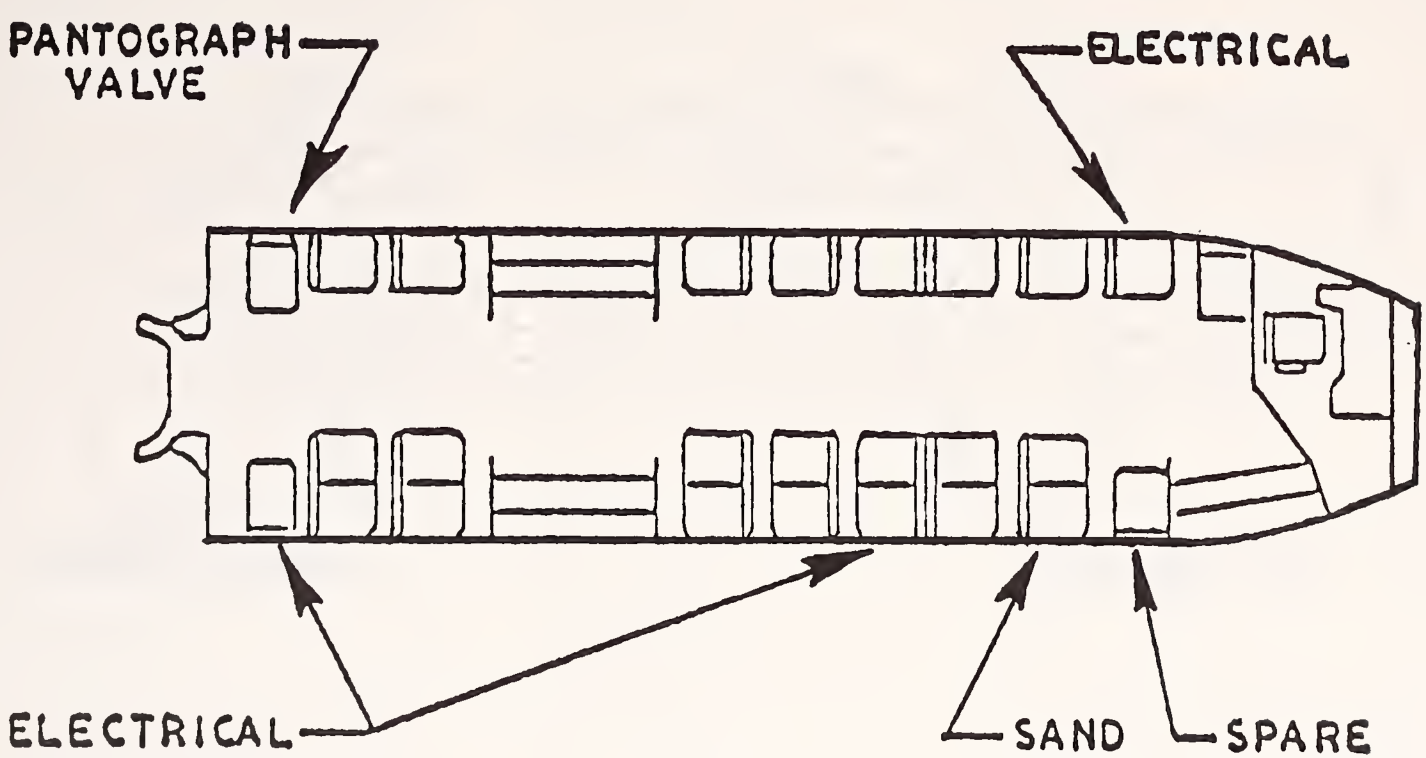


FIGURE 3-20. SEATS & UNDERSEAT EQUIPMENT - MBTA

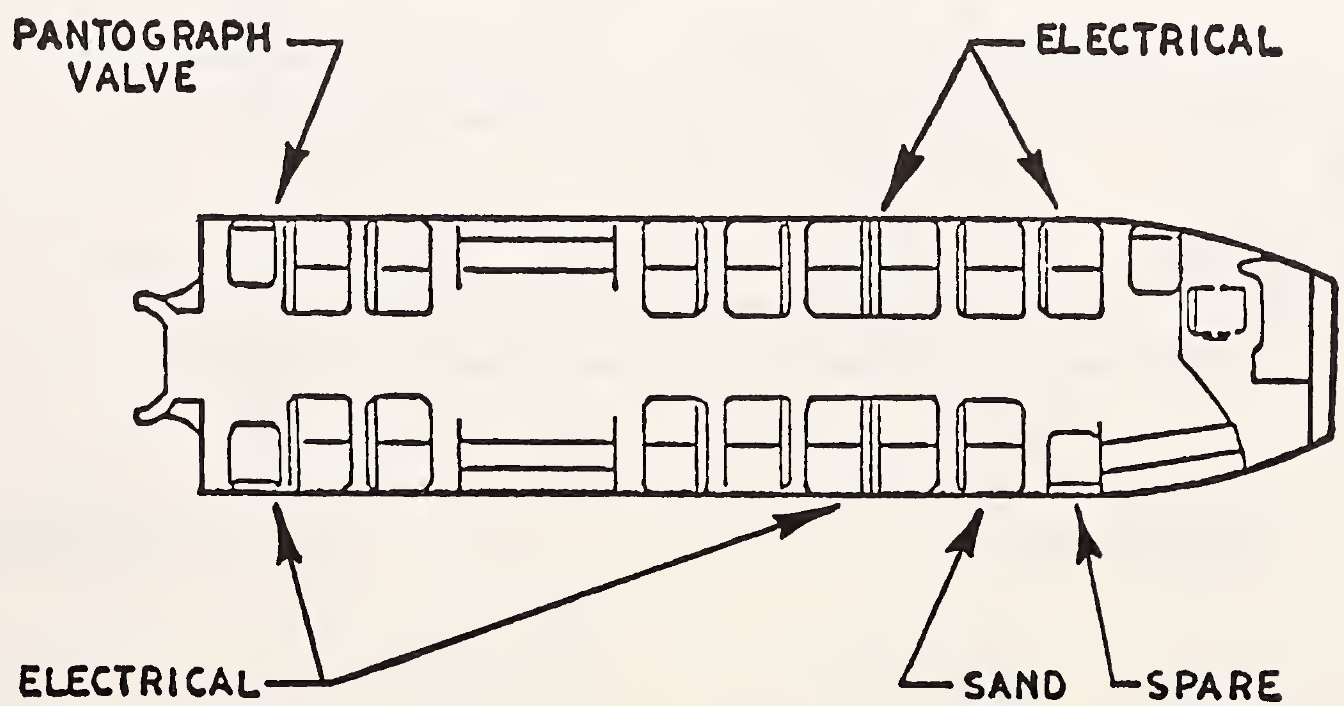


FIGURE 3-21. SEATS & UNDERSEAT EQUIPMENT - MUNI

The major difference between the MUNI and MBTA lift applications appeared when considering the front door to center door accessible path requirement. As in Boston, a front door entry to center door exit may be necessary in San Francisco. However, the existing 2+2 seating on some cars will not allow a wheelchair to pass and there is a significant amount of electrical and electronic equipment under all four of the back-to-back double seats (see Figure 3-21). Therefore, it will require a major effort to relocate sufficient equipment to allow 1+2 seating, as used in Boston, in any production arrangement.

It is possible to achieve aisles as wide as 35 inches on the MUNI cars by narrowing the seats to the limit of the equipment boxes. Because these narrowed seats would be only about 1 1/2 the width of a single seat, they would have to be bench-type seats instead of the individual contoured seats now used. It is recognized that the resulting 1 1/2 + 1 1/2 arrangement does not equal 1+2 seating. For any final design a number of revised internal arrangements would have to be considered such as is shown in Figure 3-22.

3.4.3 Door Modifications - Boeing LRV

The major problem encountered with lift installation on the Boeing car is the conflict with the lower door track which is on the underside of the lowest step. Because a lift must be able to descend from floor level to track level, a clear three-sided elevator shaft without obstruction must be provided.

Two design approaches are possible on the Boeing LRV: 1) modification of the existing door design; or 2) replacement of the existing doors with an entirely different type. Outward opening bi-fold doors, for example, usually do not have a lower door track and are often used with lift installations on buses. Doors of this type could be used in place of the plug doors in Boston at any door location because there are no high platforms. In San Francisco, different doors could be used only at the front doorways because the front doors are not used at the high platform stations. The plug doors are the only type which will work with the high/low steps and which will open at high platforms, due to the limited door to platform clearance. Replacement of the entire door arrangement was rejected as a design approach since it is a more costly approach and it is not

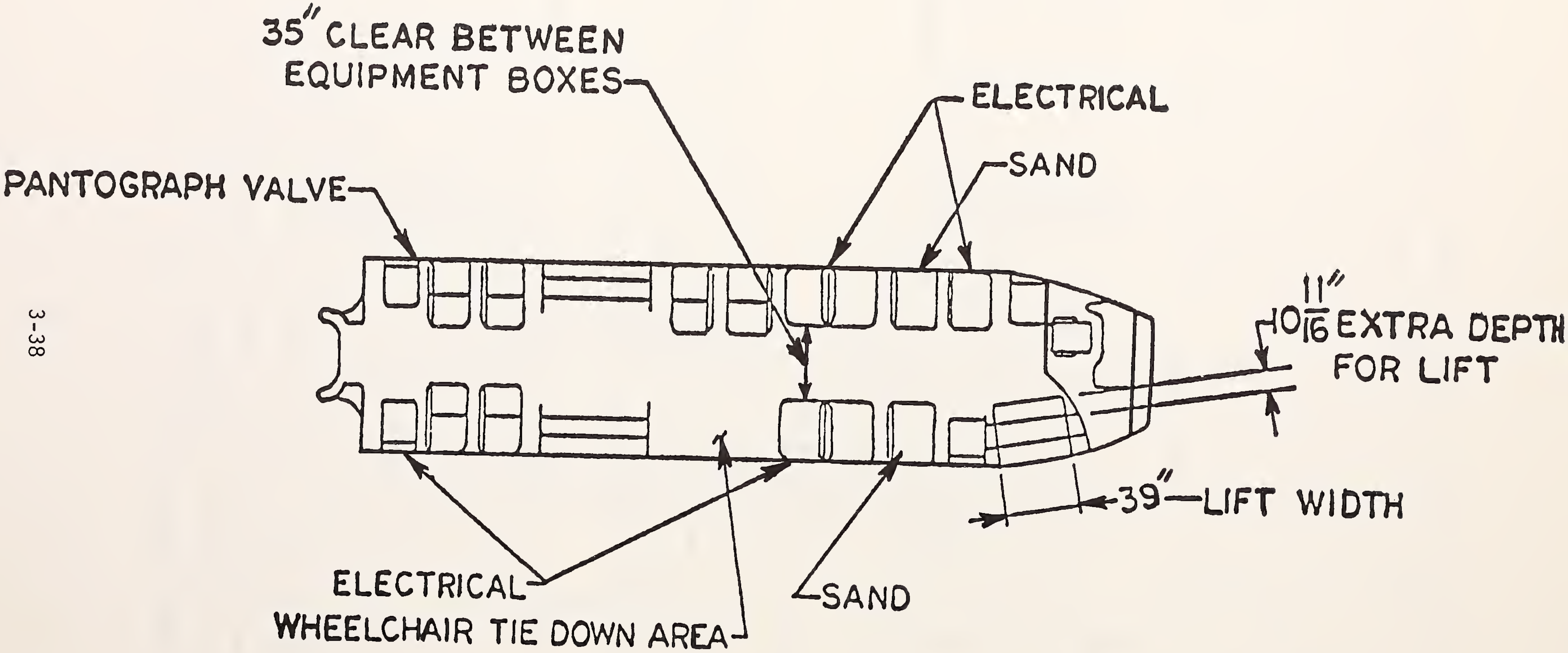


FIGURE 3-22. PROPOSED LIFT & SEATING ARRANGEMENT MUNI

required for lift installation. Replacement of the doors for other reasons was being studied by MBTA and the Vapor Corporation during the project, but was not studied in depth under the lift installation project.

Modification of the lower track on the Boeing doors appeared practical because the door vertical support and actuation is provided by the center and top tracks. The lower track provides only lateral guidance and, perhaps most importantly, lateral restraint against passenger loads when closed (see Figure 3-23). To minimize the cost and extent of rework generated, a solution that utilized as much of the existing door design was preferred. It appeared possible to use the present Boeing doors in conjunction with a lift by altering only the bottom track arrangement. Figure 3-24 shows the existing lower track arrangement, and a proposed modification that is functionally equivalent to the lower track, but causes no obstruction when the doors are open. Fundamentally, the proposed modification simply exchanges the position of the guide rollers and track. Instead of having the rollers on the doors and the track on the car structure, the rollers would be placed on the car structure and tracks would be placed on the doors. Thus, when the doors open, the tracks would be simultaneously moved out of the lift's vertical path.

As shown in Figure 3-24, the required shape of the on-door tracks is not simply half of the on-car track. Because the outboard edges of the plug doors must immediately move outward as the doors begin to open, the tracks must be substantially perpendicular to the doors at the outboard edges and, thus cannot provide any force perpendicular to the car side to hold the doors in when they are closed. This necessitated adding an auxiliary hold-in link, which is also shown in Figure 3-24. The hold-in link becomes taut only in the last increment of motion as the door closes. In any other door position from partly to fully open, the track on the door provides the necessary perpendicular restraint. The hold-in link must be able to shorten itself as the door opens and can be either a telescoping tube-type structure or a cable; devices that accept a tension load only at the maximum extension.

3.5 SUMMARY OF RECOMMENDATIONS

Study of lift installation requirements on existing LRVs and consideration of various features of existing bus lifts indicated that the TransiLift unit was

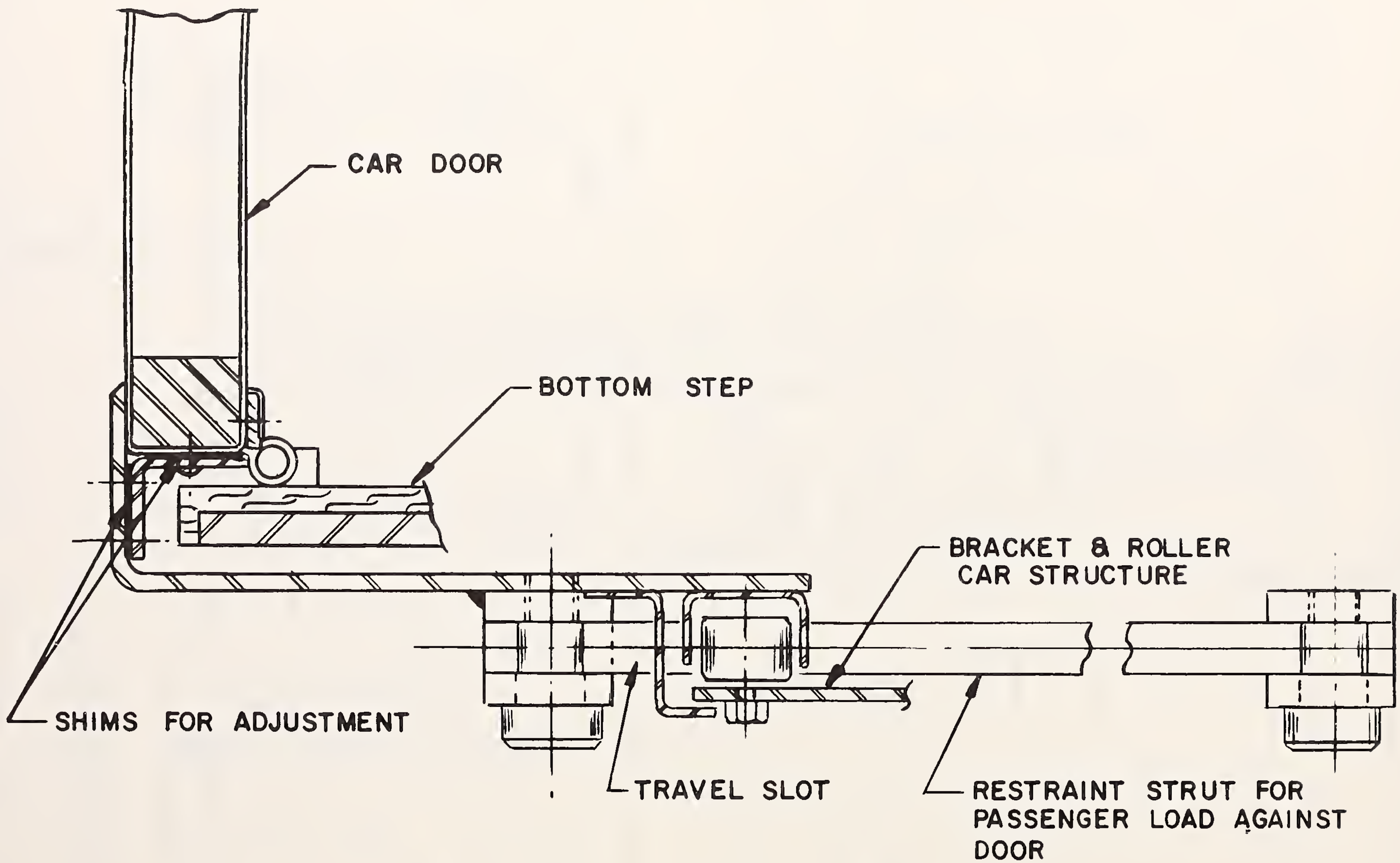
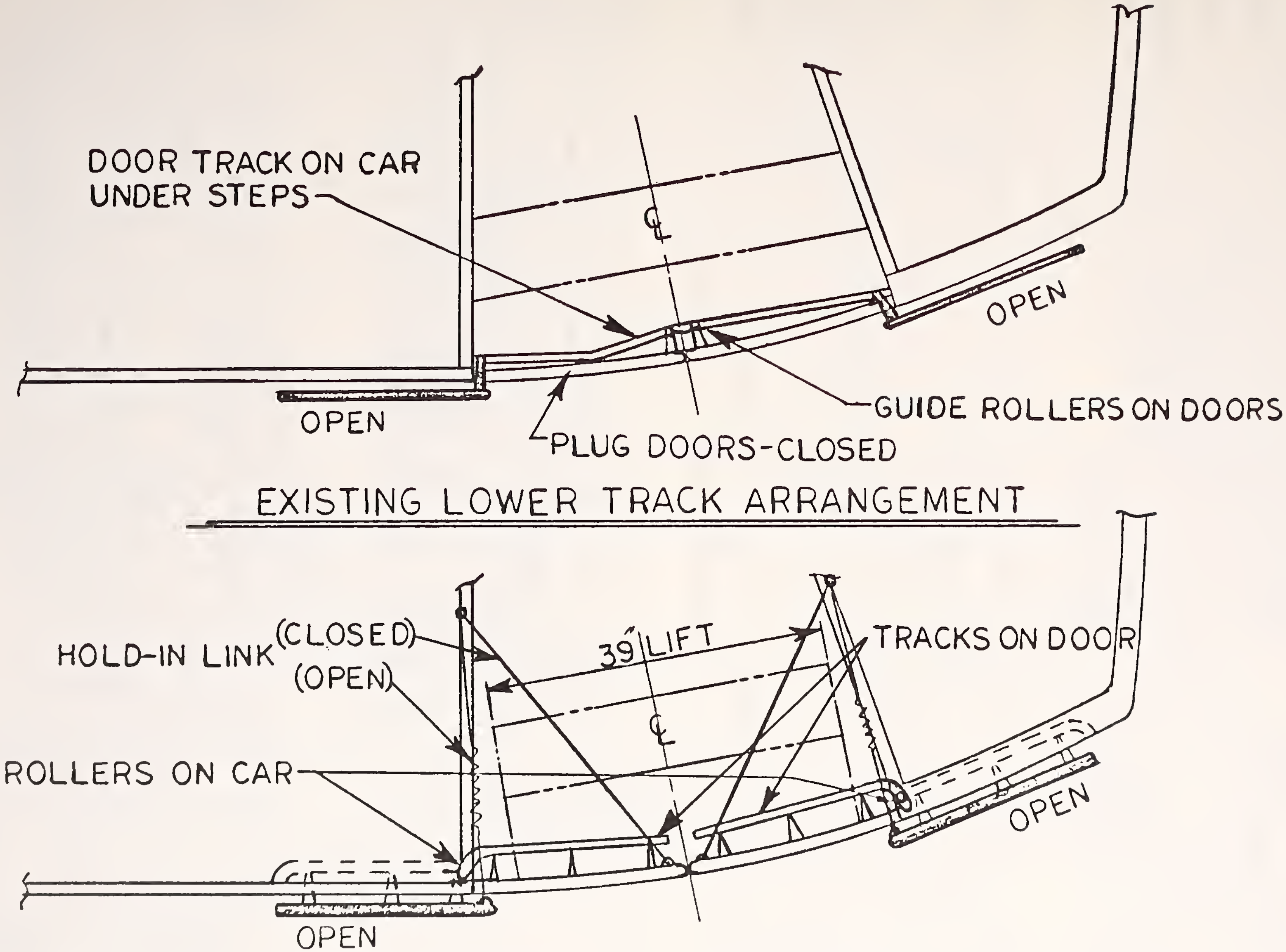


FIGURE 3-23. CROSS SECTION OF LOWER DOOR TRACK ON BOEING LRV



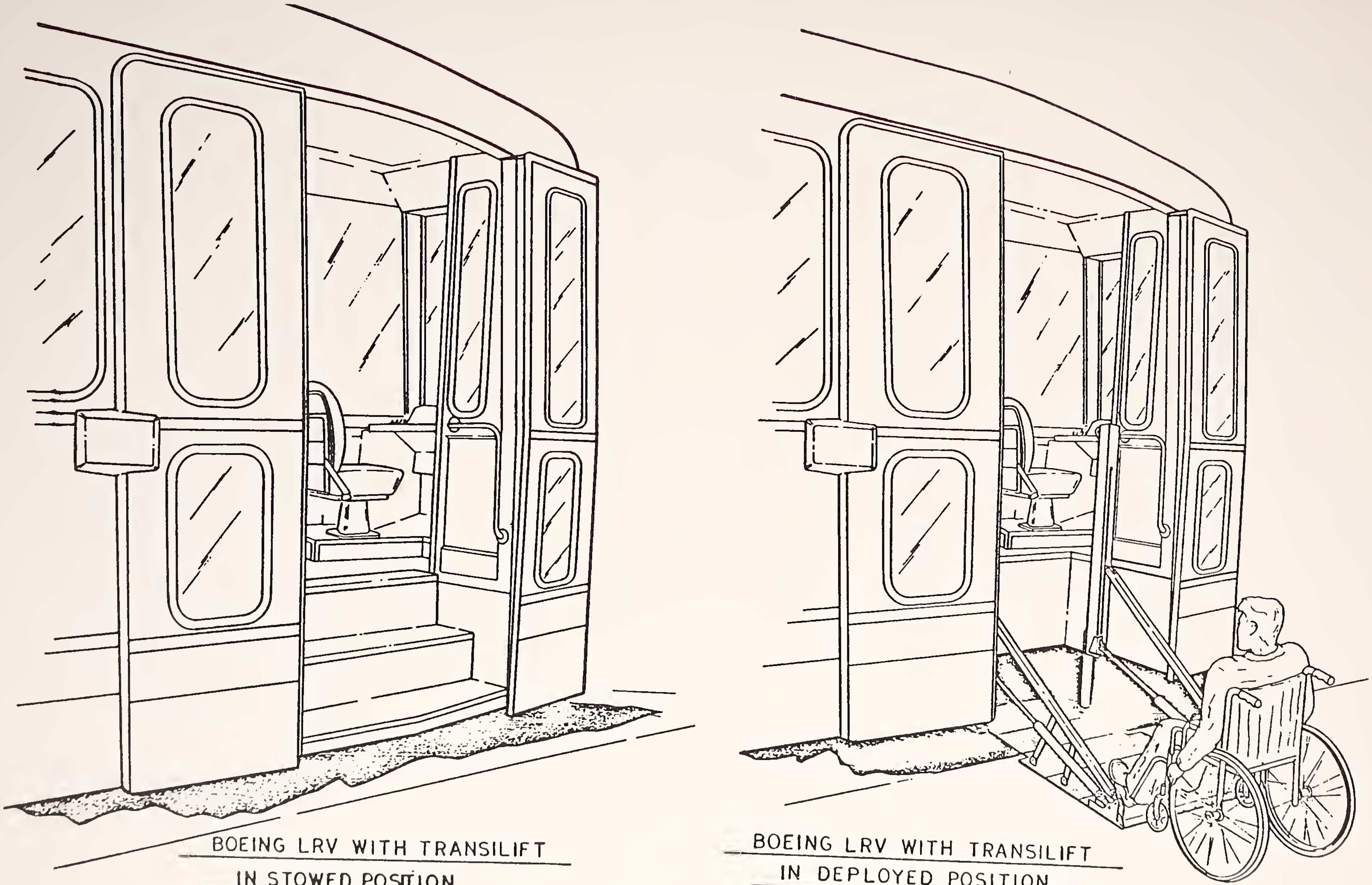
NOTE: Proposed Lower Track Arrangement Provides Unobstructed Vertical Lift Path, No Change To Top & Center Tracks. Applicable to MBTA & MUNI

FIGURE 3-24. BOEING LRV-FRONT DOOR ARRANGEMENTS the preferred design for prototype installation and test. The TransiLift unit had the thinnest platform available, would conform to moderate street crowns, and could be modified in a simple manner to lengthen the platform if necessary. The standard TransiLift with the 42 inch platform can be installed at any doorway in both the Boeing and Breda LRV with no major structural modifications. The modified TransiLift unit, with the long platform (54 inch), can best be installed in the front door of the Boeing LRV (see Figure 3-25). There are major structural problems which preclude installing the long platform design in the center door of the Boeing car or in the Breda car.

Therefore, it was decided that the detailed design for the demonstration installation would be for a front door installation on the Boeing with a TransiLift unit modified as shown in Figure 3-16, Modification 2. The unit would be mounted in such a way that the top step could operate with the lift platform or remain as a fixed part of the car floor. The lift could then be demonstrated as a standard 42 inch platform lift or as a long platform 54 inch lift, since the extension of the platform does not change the operation of the lift and allows the procurement of a lift that is standard except for the width.

The maximum reliability and maintainability of the lift was of great concern, since the use of hydraulics on a rail vehicle was seen by some operators as requiring a maintenance function which is not currently available in light rail system shops. Therefore, in order to minimize the requirement for skilled hydraulic mechanics, it was decided that the prototype installation would be designed to be completely modular so that a failed unit could be removed as a unit and replaced with a new one.

Also of concern was that a lift failing in the deployed position would cause the vehicle to block the track resulting in a major delay in service. In order to minimize this potential problem, the lift would be equipped with a hand-operated emergency retraction system. However, in the event that the lift is jammed, the platform alone or the complete lift would be quickly removable, by a repair crew, by virtue of the modular construction. If a lift was not replaced in the vehicle, a set of temporary steps to fit the lift opening would be provided with the repair crew.



BOEING LRV WITH TRANSILIFT
IN STOWED POSITION

BOEING LRV WITH TRANSILIFT
IN DEPLOYED POSITION

FIGURE 3-25. BOEING LRV

SECTION 4

BOEING LRV INSTALLATION

4. BOEING LRV INSTALLATION

This section provides an overview of the major work activities which were completed during Phase 2 of the project which was limited to the installation of the TransiLift on the Boeing LRV.

The basic TransiLift lift design uses two treads and two risers to form the platform, which results in a platform about 42 inches long. As outlined earlier in Section 3.4.1, it is possible on the Boeing LRV to increase the platform length to about 54 inches by using part of the vestibule floor surface in forming the lift platform. Essentially the lift platform is now formed by three treads and two risers, as shown in Figure 4-1. Consequently, the vehicle modifications were planned to include this modification in order to demonstrate both the two-tread versions of the TransiLift design and, thereby, to determine if the shorter platform is acceptable. It should be noted that in most LRV retrofit situations, it is impractical to achieve a sufficiently large lateral dimension for installation of a three-tread lift because of a frame member immediately behind the top riser. However, it appears possible to install two-step lifts in most existing LRVs.

4.1 VEHICLE MODIFICATIONS

The nature and extent of modifications to the vehicle were established early in Phase II in order to set practical limits on the lift hardware installation.

4.1.1 Front Doorway

The maximum feasible modification to the front doorway was determined to be removal of the front steps from wall-to-wall, and partial removal of the immediately adjacent floor. A structural analysis of the existing and modified vehicle doorway was made to compare the stresses for normal loads and for collisions at the right front corner. As expected, the stresses for normal loads, including the additional weight of the lift, are not significantly increased.

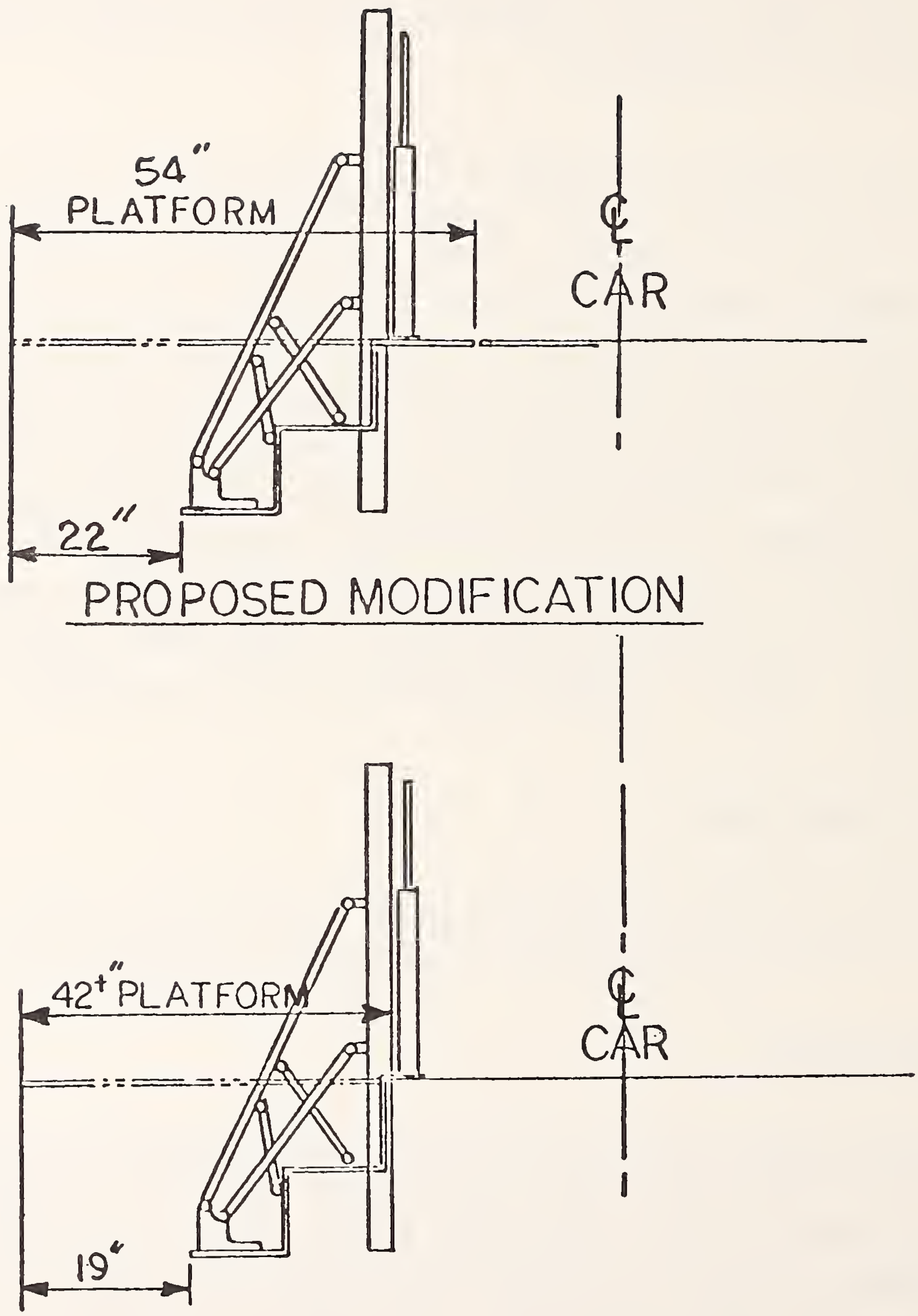


FIGURE 4-1. EXISTING ARRANGEMENT TRANSILIFT CROSS SECTION

The first test of the vehicle structure involved measuring the distortion that occurred at the doorway when the steps were removed. It was found that virtually no movement occurred, demonstrating that the steps did not contribute to carrying any static structural loads. For collision loads, the lift structure itself effectively replaces the integral steps, because the lift steps are able to transfer compression loads as easily as the integral steps. It is necessary to accept some slight structural deformation to close the clearances at the side of the steps before they become effective in compression.

4.1.2 Front Doors

The minimum door modification was identified as a change to the bottom track to allow the lift to descend as outlined earlier in Section 3.4.3. It was determined that a relatively simple mechanism inversion on the bottom track potentially solved the door problem. It was not necessary to alter any other parts of the door, nor to change the operating principle and mechanism.

At first only the modified lower track arrangement was applied to the doors on the LRV shell. The lateral stiffness of the lower door edge was evaluated with the doors closed, and was found to be inadequate, indicating the need for the lateral hold-in link originally proposed. With the hold-in link applied, the door lateral stiffness was good, approximately the same as the door stiffness prior to modification.

The hold-in link is a rod with one end slotted to allow a reduction in the door-to-anchor distance as the door opens. A turnbuckle is provided so that the length of the rod can be conveniently adjusted to properly hold the door closed.

4.1.3 Secondary Modifications

The installation of a lift in the Boeing LRV forced some modifications because of interferences that are not otherwise associated with the lift. The two areas of interference are the wiring runs and junction box underneath the existing steps, and the lift structure above the floor level is in the front of an electrical panel on the front wall.

The wiring runs were relocated toward the center of the frame to clear the back of the lift enclosure. The junction box was reduced in size, but reapplied in substantially the same location.

The side panels on the lift partially obstruct the door on the electrical panel with the lift in the raised and stowed position. By reshaping the door to the electrical panel, it is possible to open it without difficulty. The only obstructed items are two 37 1/2 volt auxiliary power outlets, which are not used.

4.2 LRV LIFT INSTALLATION

The installation of the TransiLift design in an LRV requires consideration of three basic systems: mechanical, electrical, and hydraulic, of which only the first two have interfaces with the vehicle. The lift hydraulic system is a self-contained powerpack and is independent of the vehicle except for its physical location and the attachment of piping or hose runs. The design of each of the three systems will be discussed separately.

In addition to the installation of the lift and hydraulic module, there are some additional changes necessary in a retrofit to relocate equipment, wiring and cabling, and miscellaneous details to rework that would not occur in an original equipment installation.

4.2.1 Lift Installation - Mechanical Design

There were two options considered for lift installation on the right side of the Boeing LRV: the angled right front door, or the side doors between the trucks and, as outlined earlier, the front door was selected for the lift installation. Structurally, the front door location on the Boeing LRV offers significantly better conditions than the center door for lift installation because the frame narrows toward the coupler at the end of the car. As a result, the modifications to the vehicle are relatively straightforward and substantially without major structural impact. Because of the narrower frame, it is possible to use much more of the width of the car for lift platform length which minimizes platform projection from the car.

The front stepwell on the Boeing car is wedge-shaped (i.e. the lowest step is the widest, the second step slightly narrower). To adapt a lift to this location it is necessary to have the sides of the opening parallel because the lift mechanism linkages for extending and elevating the platform must operate in parallel planes. An unrelated shortcoming of many existing lifts and existing bus lift installations is that installation and removal of a lift is time-consuming because of the number of hydraulic and electrical connections that must be made, and because the lift unit itself must be installed and removed in several pieces. The current design, however, effectively addresses both problems.

The lift installation designed for the Boeing vehicle uses a subassembly designated as a "pod" to contain the assembled lift, and the pod is also the transition structure from the lift shape, with parallel sides, to the wedge-shaped vehicle opening. In addition to containing the completely assembled lift, the pod allows the lift to be completely wired and piped, with the minimum number of connections remaining to be made from the pod to the vehicle chassis. The pod-to-chassis mechanical connection is a static, bolted joint. The pod concept allows rapid initial lift installation in the LRV, and also rapid removal of the lift for servicing, if desired. If lift modification or replacement becomes desirable during the life of the LRV, it will be easier to make changes in the lift-to-pod interface, preserving the pod-to-vehicle interface, because such changes can be completed and tested off the vehicle.

The pod concept forms the basis for application of a standard lift to several vehicles, by designing pods with standard lift-to-pod interfaces, and varying the pod-to-vehicle interfaces to suit each vehicle. In the event that a lift/pod unit were not immediately repairable and no replacement were available, it would be easy to substitute an inexpensive static step unit in the vehicle to allow the vehicle to continue in service. Of course, vehicle accessibility would be lost temporarily with a static step pod in place of a lift pod.

The pod structure is a sheet metal assembly that serves as the frame onto which lift components are mounted, such as the lift towers and the safety plate at the back of the lift. The pod is mounted as a single unit into the vehicle. Figure 4-2 shows the pod unit without equipment mounted on it. The pod has

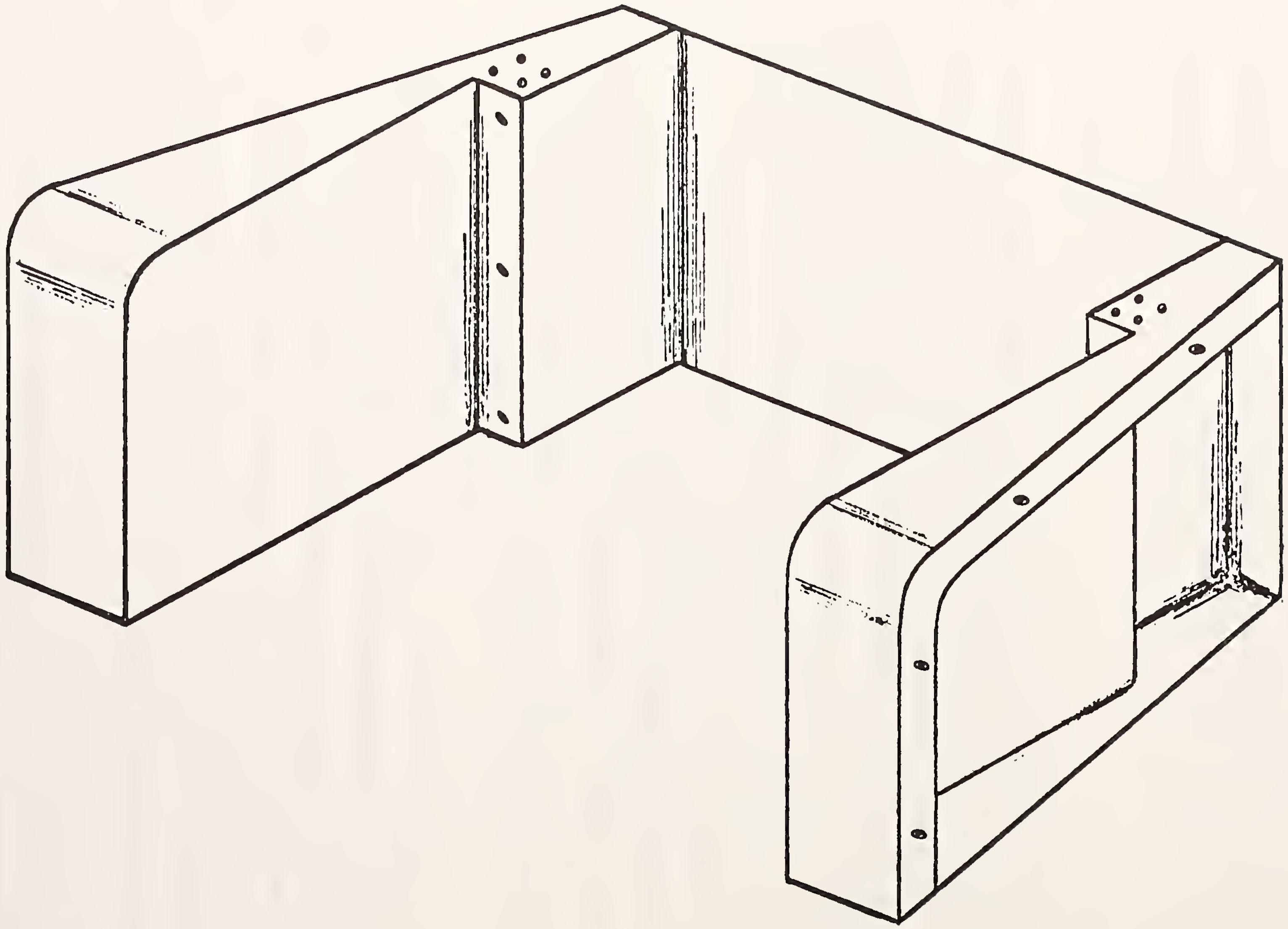


FIGURE 4-2. LIFT POD STRUCTURE

sufficient strength and stiffness to hold the lift unit in proper alignment independent of the vehicle. If hydraulic power and electrical controls are connected, the lift can be test cycled without the pod being installed in a vehicle.

The modifications to the vehicle structure at the front stepwell to accept the pod are shown in Figure 4-3. The major change to the car structure involves moving the upper channel inward at the top step (floor level) to allow a longer lift platform. The new side sheets are an extension of the existing side sheets, which now exist only above the steps and are not continued below and behind the steps. The lower channel is added to stiffen the lower in-board corner of the side sheets. The wiring and junction box now under the steps need to be relocated, but this change has no structural impact.

Figure 4-4 shows a fixed step pod structure. It is intended that the steps and handrails be integral with the pod unit; not removable as with lift components. The complete pod would serve as a dedicated one-piece temporary replacement for any lift that must be removed from a vehicle for extended servicing.

4.2.2 Hydraulic Module

The hydraulic power for the TransiLift is supplied by two separate motor/pump units for platform extension and platform elevation. The use of separate motor/pump units reduces the hydraulic circuit complexity and increases reliability. There are no flow directing valves in the two-pump system. One pump is dedicated to the platform/step function, and the other pump is dedicated to the raise/lower function. The motor/pump direction of rotation is reversed electrically to select between steps or platform and raise or lower. The components for the LRV installation are the same as used on bus installations, except that 36 volt motors are substituted for the 12 volt motors used on buses.

To simplify the hydraulic module to lift piping, the two flow dividers and two junction blocks have been moved to the lift pod as shown schematically in Figure 4-5. This change halves the number of lines from the hydraulic module to

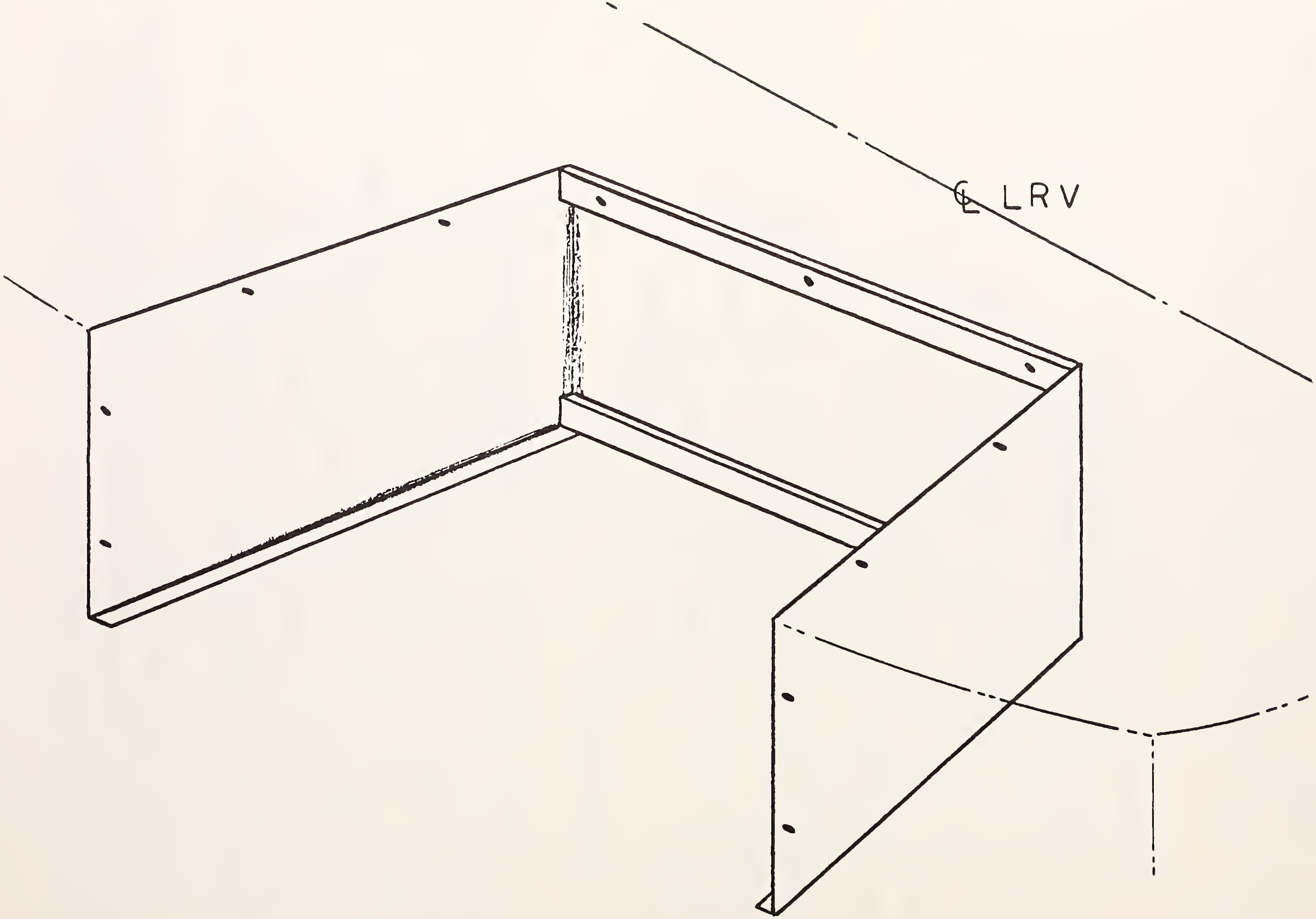


FIGURE 4-3. VEHICLE STRUCTURE AT STEPWELL TO ACCEPT LIFT POD UNIT

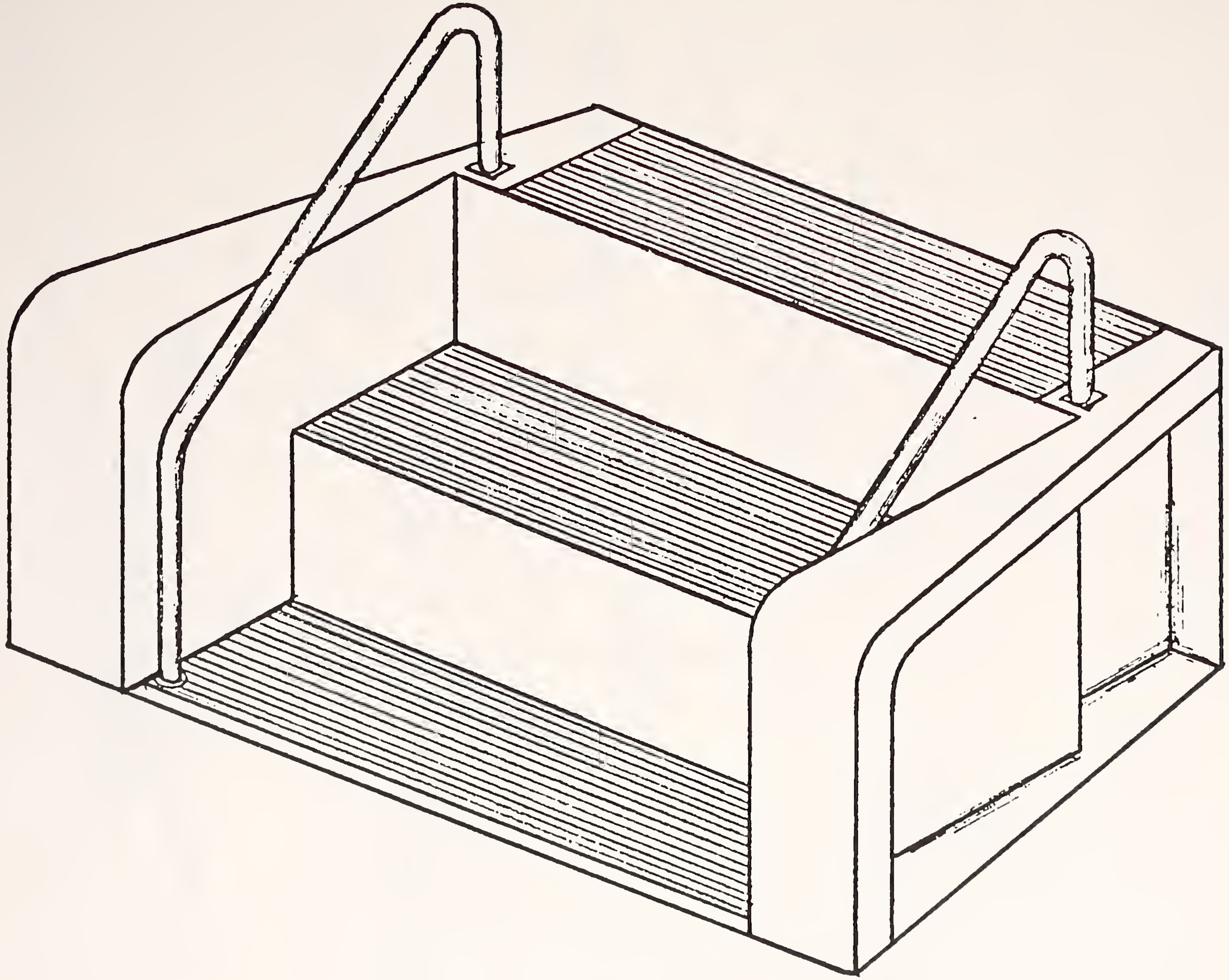


FIGURE 4-4. FIXED STEP-POD STRUCTURE

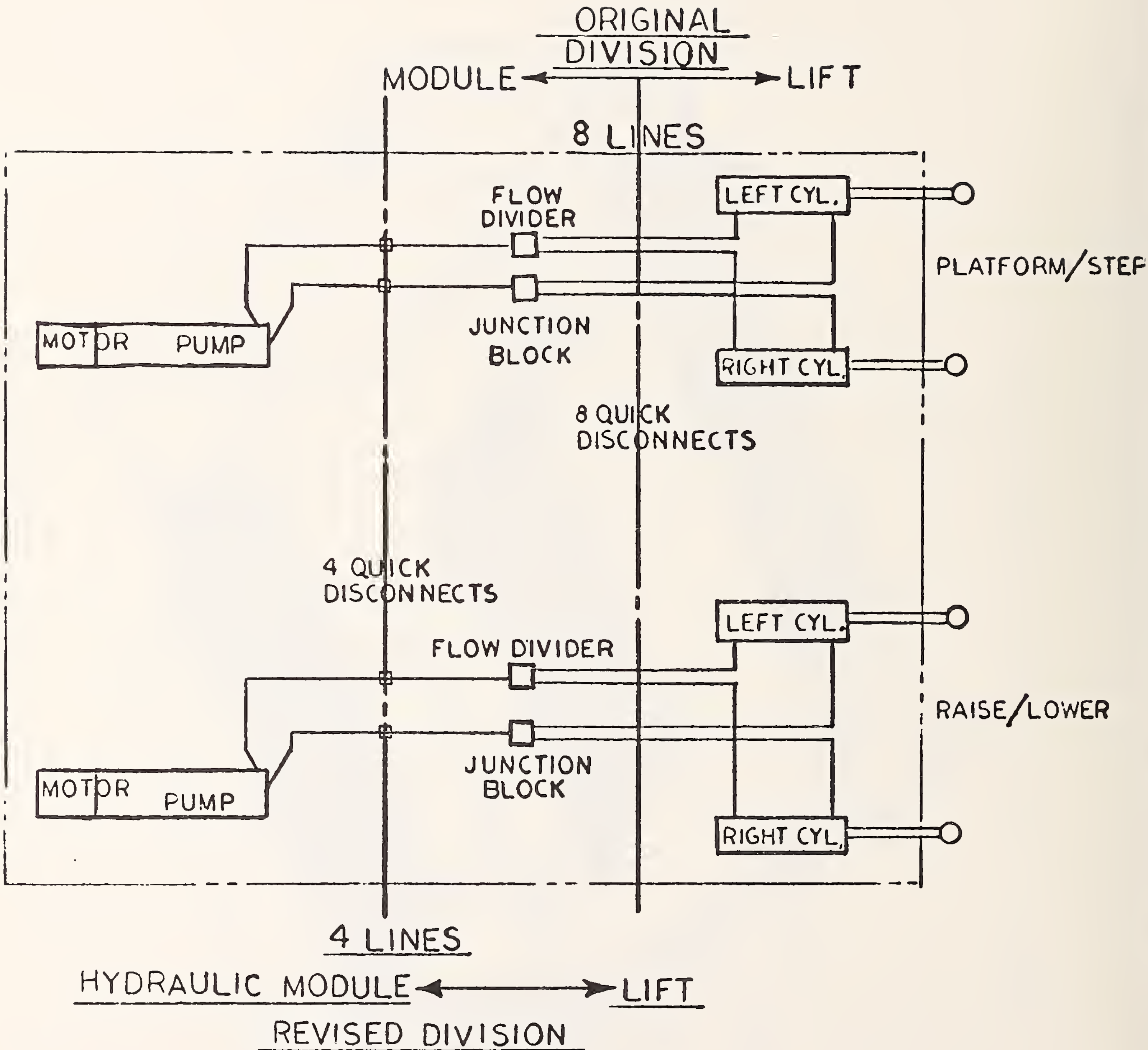


FIGURE 4-5. HYDRAULIC SCHEMATIC - PHYSICAL RELOCATION OF FLOW DIVIDERS AND JUNCTION BLOCKS

the lift from eight to four and reduces the number of components in the hydraulic module.

Moving the flow dividers and junction blocks from the hydraulic module to the pod enables the remaining components to be installed under the single transverse seat adjacent to the front doorway (see Figure 4-6), which minimizes the length of piping runs to the lift. This location makes the hydraulic module readily accessible for servicing or removal, and in addition, the location is ideal for manual hydraulic operation of the lift.

To install the hydraulic module under the seat (see Figure 4-7), the seat base must be enlarged to the full dimensions of the seat cushion. The hydraulic module is assembled on a frame which is readily removable. To prevent hydraulic fluid leaks from seeping out into the passenger area, the new seat base has an integral floor and drain to ensure that any free hydraulic fluid drains outside the passenger compartment to a separate collection sump. Unlike the static step replacement for the lift module, no substitute base is required if the hydraulic module is removed.

4.2.3 Electrical Installation

Power to the lift is supplied by the 37 1/2 volt auxiliary power system. The lift power and control electrical system is fully interlocked with the vehicle electrical system to prevent improper lift or vehicle operation. The fundamental requirements for lift operation are:

1) Doors fully open.

2) Brakes applied.

3) Propulsion power application prohibited.

The basic vehicle logic is such that the lift has to interact only with the doors to achieve the necessary safety conditions, and the necessary logic checks are reduced to:

1) Doors closed - lift inoperable.

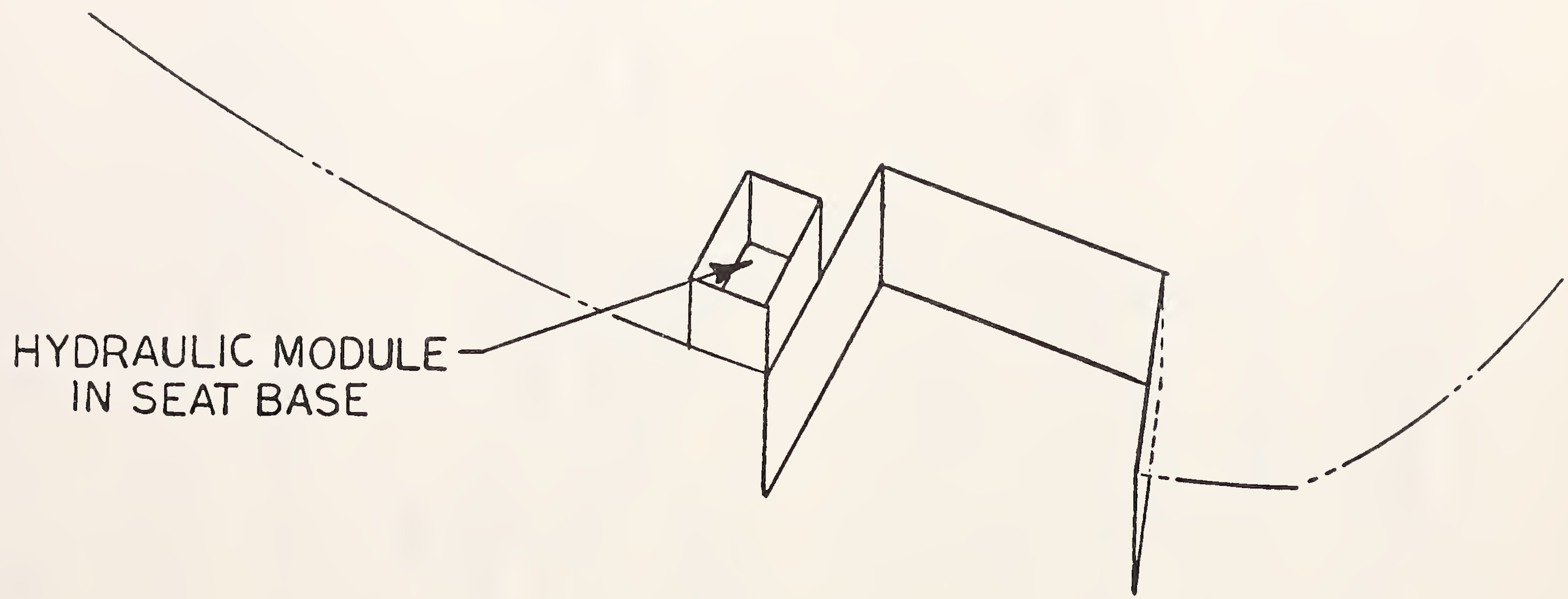


FIGURE 4-6. HYDRAULIC MODULE LOCATION

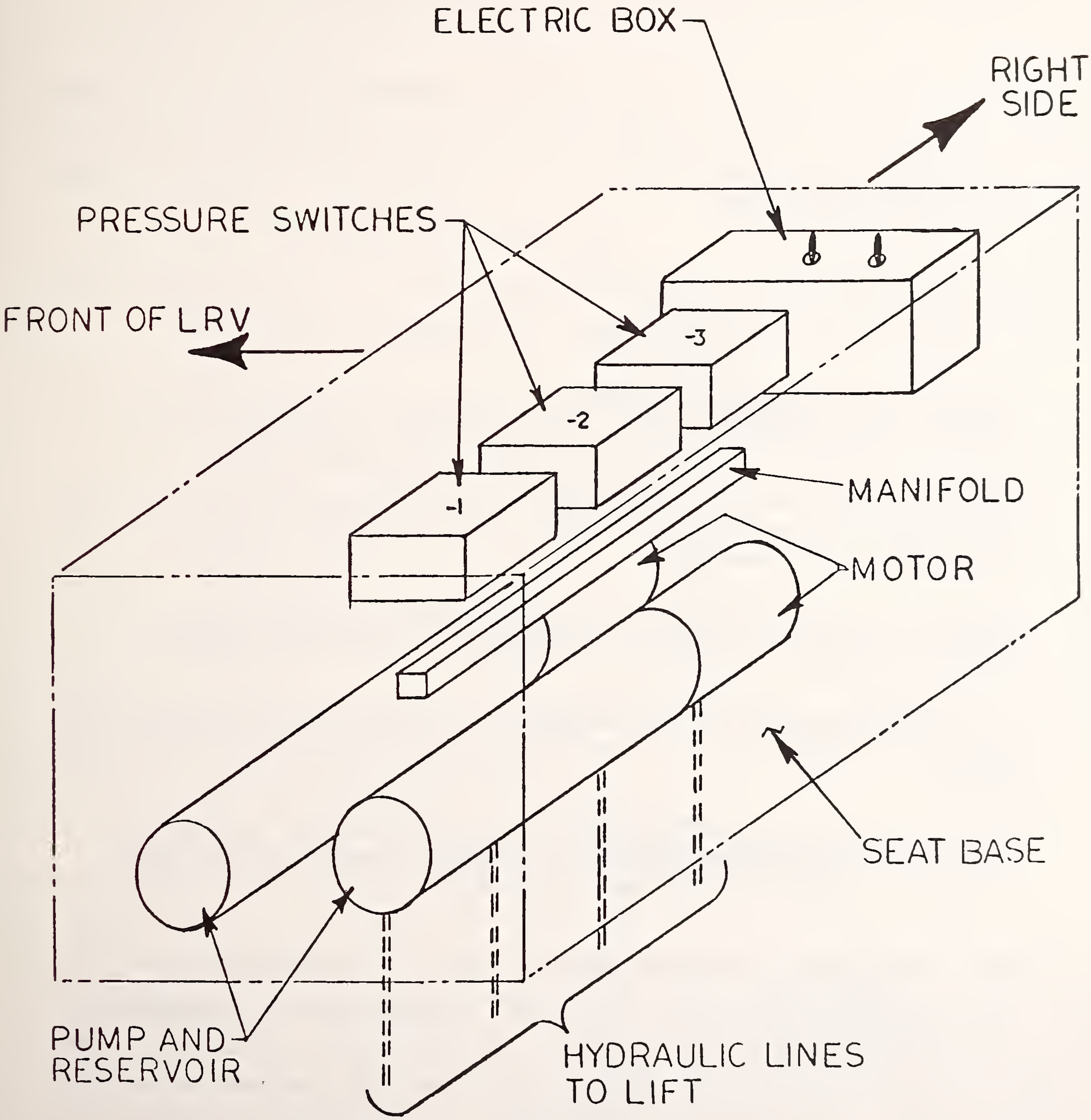


FIGURE 4-7. HYDRAULIC MODULE PHYSICAL ARRANGEMENT

2) Doors open - lift operable (existing control logic ensures that propulsion power is off and brakes are on if doors are open).

3) Lift fully stowed and lift power off - door closing permitted.

4) Lift power on or lift unstowed - door closing prohibited, and control transfer prohibited.

The significant features of the electrical schematic are shown in Figure 4-8. The TransiLift package is the portion of the diagram within the heavy dotted line. The vehicle manufacturer (or retrofitter) supplied portions are shown within light dotted lines.

The circuit is basically as used by TransiLift for bus installations, with some minor changes for the LRV installation. The specific changes are:

1) Power for the lift control and actuation is obtained from the battery bus "EES 1A" through a circuit breaker, and application of power to the lift is controlled by a power contactor "LPC."

2) The lift master control switch "LMCS," used to pick up "LPC" is interlocked with two leaf "full open" contacts, because the doors are independently powered.

3) Internal to the TransiLift circuit, a connection is added to energize the control circuitry when power is applied to the single positive terminal.

4) A lift stowed switch "LSS" is added to the "close" solenoid circuit to prevent the doors from closing when the lift is not fully stowed.

5) A lift bypass switch "LBPS" is provided to override the "LSS" in the event of a switch malfunction, to enable the doors to be closed if the lift is physically clear of the doors.

The most significant difference between bus lift malfunctions and rail vehicle lift malfunctions is that lift malfunctions on a rail system which prevent the vehicle from being moved result in a line blockage. Experience with bus lifts, to date, shows that some failures are in the position sensing switches with the lift and not physical lift malfunctions. To minimize delay caused by false failures, a failure override switch is incorporated into the electrical schematics for the lift installation. The override switch bypasses the normal lift stowed position sensors on the lift, and it would be used in the case of a

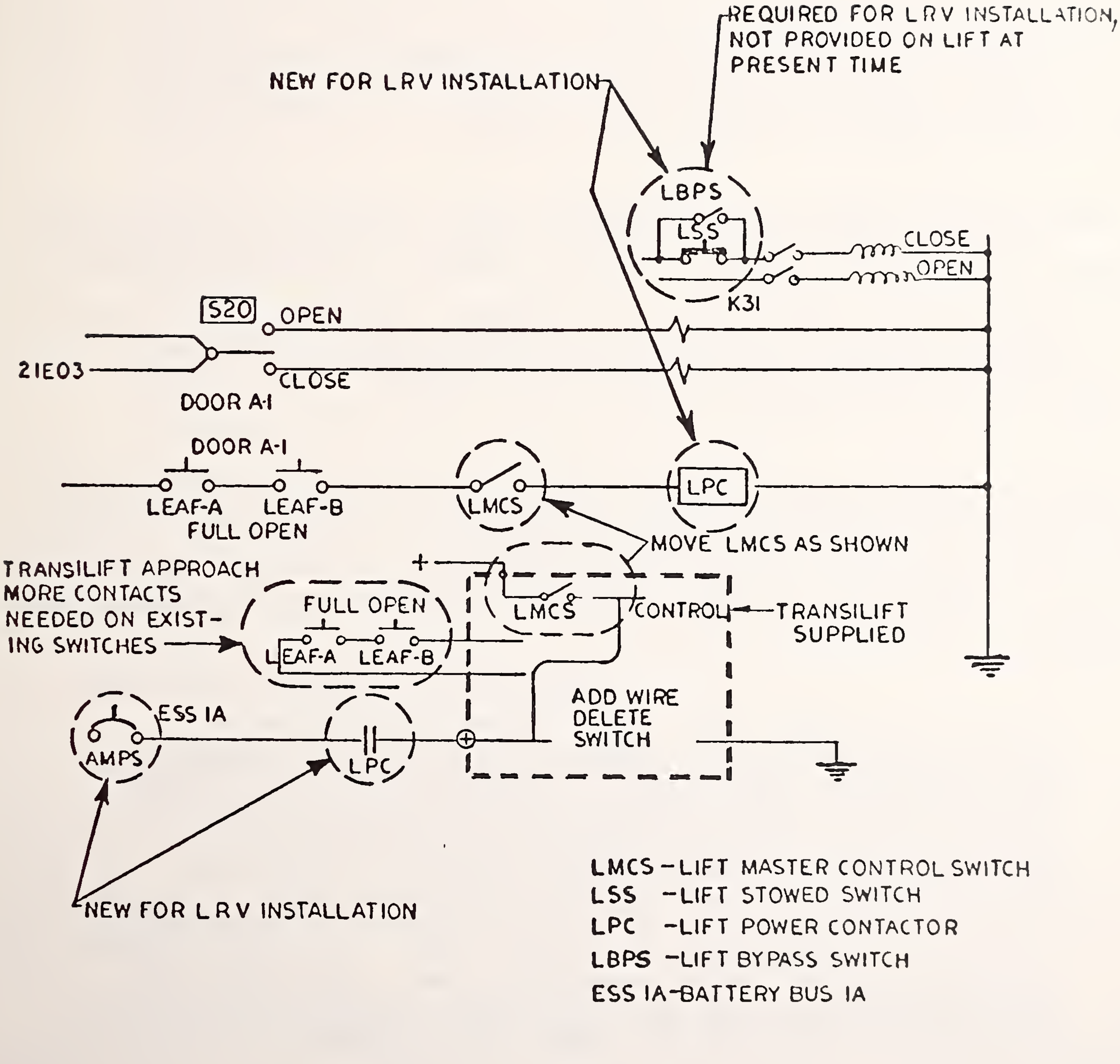


FIGURE 4-8. PRELIMINARY ELECTRICAL SCHEMATIC

malfunction that prevented the lift from being raised and fully stowed. Failure override switches are used on some bus lift installations by other lift manufacturers.

As its name implies, use of the lift bypass switch (LBPS) bypasses the lift interlocks to allow the LRV to move regardless of lift position. The provision of an LBPS is somewhat controversial because there is a concern that the LBPS will be misused, specifically in situations in which the lift fails deployed, or worse, fails at ground level. A vehicle in motion with a lift deployed is a hazard to people on the wayside standing within about 2 feet of the vehicle, and a lift failed at ground level is virtually certain to be damaged further if a driver carelessly moves a vehicle in this condition.

The primary intended use of the LBPS is only to bypass failed interlocks when the lift is clearly stowed. It is of secondary importance to be able to move an LRV with a lift partially or fully deployed, because an LRV will usually not be able to complete its run before the unstowed lift interferes with clearances and forces the car to a halt.

Several ways of imposing greater control of the LBPS function have been considered. They may be broadly divided into two categories, hardware alternatives, and software alternatives. Hardware alternatives are additions to the vehicle controls which enforce actions or conditions that are tentatively postulated to be safer than the basic LBPS:

- Enforced low maximum speed. This control action requires a specific speed value to be obtained from an existing tachometer, and requires entry into the vehicle propulsion circuitry with the speed value information to effect control of speed. At this stage in the project, it seems ill-advised to directly enter the propulsion control circuitry simply to retrofit lifts to LRVs.

- Timed power applications. This control action is relatively easy to achieve and implement by inserting a timer in the proposed LBPS location, and using LBPS to actuate the timer. The vehicle could only move while the timer was timing down, requiring the driver to reactuate LBPS to proceed for another time increment.

- Warning horn or other audible signal. This control action would be very easy to implement. Its purpose would be to warn bystanders that the vehicle is moving with the lift deployed.

Software alternatives are basically procedural controls applied to the use of the LBPS that do not require any additional changes to LRV circuitry, although some of the alternatives use a minimal amount of hardware to enforce procedures:

- Basic LBPS with discretionary call-in before use. This procedure in the minimum addition that could be applied to an LBPS with free access. With this procedure, the driver would be required to call in all lift problems before using the LBPS unless the lift were clearly and unmistakably stowed. In the latter case, the failure would be known to be in the interlocks, not the lift hardware.

- Basic LBPS with mandatory call-in before use. With this procedure, the driver would be required to call the dispatcher for all lift difficulties before proceeding. The driver could be instructed to proceed, or to await the arrival of a supervisor, depending on the situation reported.

- Sealed LBPS with or without mandatory call-in. As above, but a sealed switch assigns responsibility for the integrity of the seal to each driver; if the seal is broken, it must be reported and explained.

- Locked LBPS with mandatory call-in. A locked switch accessible only to supervisory personnel. This procedure parallels procedures now used with the manual controls on bus lifts on some transit properties.

The procedural controls or hardware alternatives chosen will probably be the province of each operator. The choice appears to be dependent on the level of training and responsibility that each operator accords to its drivers.

4.3 CONSTRUCTION AND INSTALLATION SEQUENCE

To ensure that the prefabricated lift modules can be installed rapidly in vehicles, all the pods will have to be identical at the pod-to-vehicle interface within close tolerances, as will all vehicle sockets. In practical terms, full interchangeability must be achieved between the vehicle, lift modules and static step modules.

To achieve interchangeability, it will be necessary to construct the lift modules and static step modules on a fixture that duplicates the vehicle mounting surfaces. Similarly, the new mounting surfaces in the vehicle for the lift module will have to be installed to a fixture representative of a lift module. Thus, it follows that the lift module fixture will mate with the vehicle mounting surface fixture.

The fixture and module/mounting surface construction sequence can begin at any of several points, but it is advantageous to begin with the most critical component. In this project, the available space within the vehicle controlled the design process, but within the confines of that space there was relatively unlimited freedom to configure a lift in any desired manner.

After removing obstructing details on the vehicle as shown in the before and after stepwell pictures in Figure 4-9 and 4-10, the construction sequence will begin with installation on the vehicle of the pod mounting surfaces. The necessary additional structure was carefully installed on the test shell to ensure dimensional accuracy, squareness, and parallelism of the mounting surfaces.

The next step was construction of the prototype pod in place on the vehicle mounting surfaces. This procedure ensured that the pod mounting surfaces are an accurate negative of the vehicle mounting surfaces.

Finally, the prototype pod was removed from the vehicle and from each of the two mating parts a fixture was constructed that is the negative of the mounting surfaces of the two parts. Specifically, the vehicle is used to produce a fixture that represents a pod (mounting surfaces only), and the pod is used to produce a fixture that represents a vehicle (mounting surfaces only). Figure 4-11 illustrates the construction sequence.

The first use of the two fixtures was for construction of the second pod and a static step unit (from the vehicle representation) and the pod representation was used to install mounting surfaces in the vehicle selected for the field demonstration portion of the program. Using fixtures instead of freehand assembly, it will be possible to guarantee that the second pod (or static step module) will fit into the field modified vehicle (without problems) on the first try at assembly.

FIGURE 4-9. STEPWELL BEFORE REMOVING OBSTRUCTING DETAILS

FIGURE 4-10. STEPWELL AFTER REMOVING OBSTRUCTING DETAILS

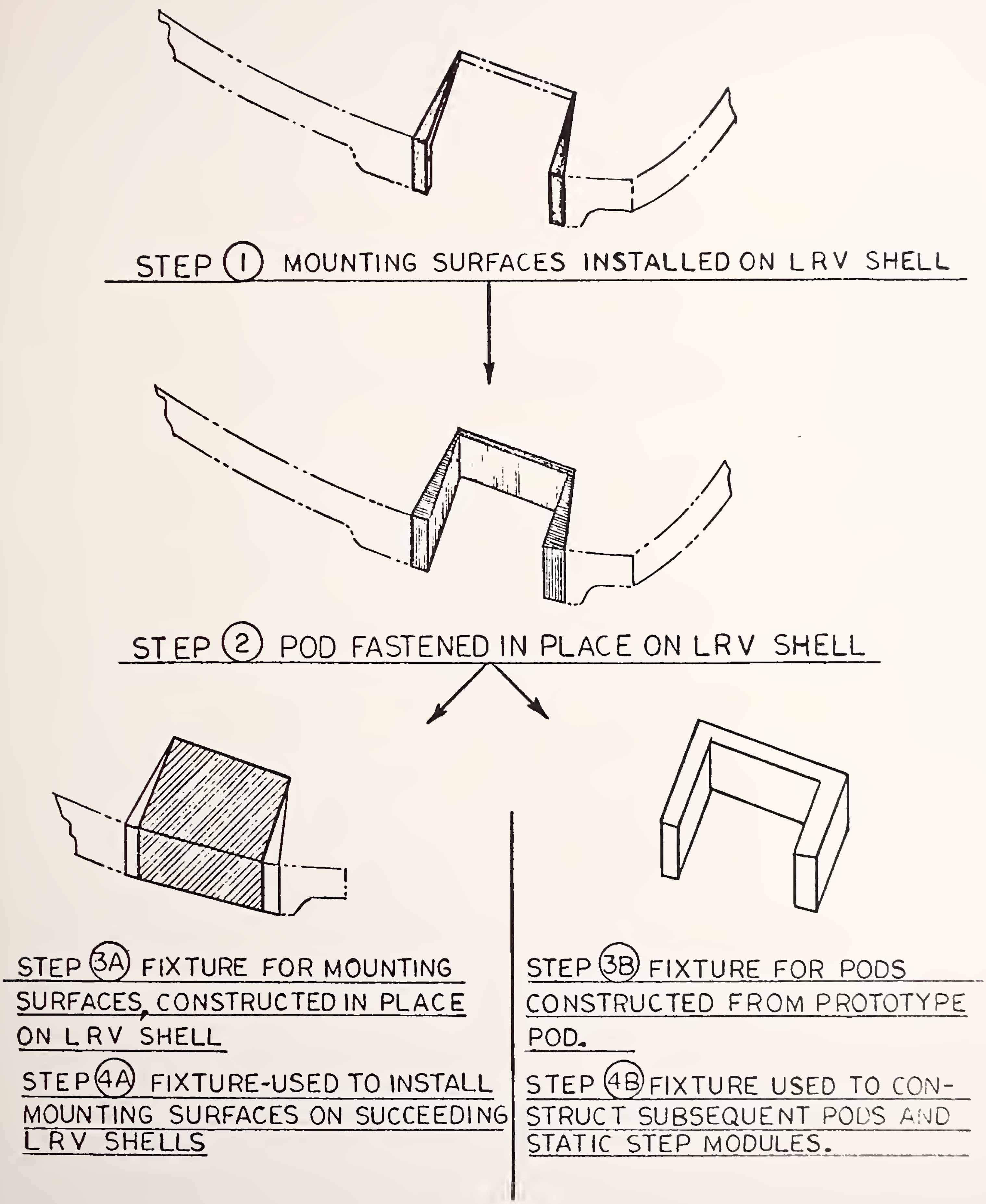


FIGURE 4-11. CONSTRUCTION SEQUENCE

SECTION 5

TEST AND DEMONSTRATION PROGRAM

5. TEST AND DEMONSTRATION PROGRAM

The prototype lift installation and available components were subjected to a static test program at the Budd Company's Technical Center facilities to ensure that the there was an adequate margin of mechanical strength in the installation and to explore the temperature extremes for satisfactory lift operation.

A complete kit of lift and installation assemblies was shipped to San Francisco, California where it was installed in the front end of one of the MUNI Boeing LRVs by MUNI maintenance personnel under Budd Company supervision. The lift-equipped LRV was subjected to four months of field testing in non-revenue service and to consumer evaluations. A full report of the field testing activities and consumer evaluations was produced by MUNI, and is included as Appendix D to this report.

The following sections summarize the major testing and test results together with some specific conclusions and recommendations based on the field test program.

5.1 STATIC TESTING

The static testing program contained three basic elements; test of the complete lift with various platform loads and overloads; ultimate stength tests of key lift components to ensure an adequate margin of safety; and hot and cold tests to determine the temperature range over which the lift would work properly.

5.1.1 Platform Load Tests

The lift platform was uniformly loaded with weighted 10" x 10" boxes and successfully cycled with loads of 395 lb., 600 lb., and 1200 lb. respectively. At the highest load the pressure limiting switches had to be adjusted to permit the lift to operate. Therefore, in actual operations the lift would be safely inhibited from accepting such an overload.

The deflection of the platform at the rear, center, and front edge was measured under the 395 lb. load. The average figures recorded were:

Rear 1/8 inches

Center 3/8 inches

Front 7/8 inches

The deflection was observed to be mainly due to the increased tension at the hinged joints and most of it occured during the first 100 lb. of load with only small further increases to full load. The average slope of the platform was less than 1:50 based on the observed deflections, and is well within the 1:24 limit proposed in the lift design criteria (see Section 2.2.4).

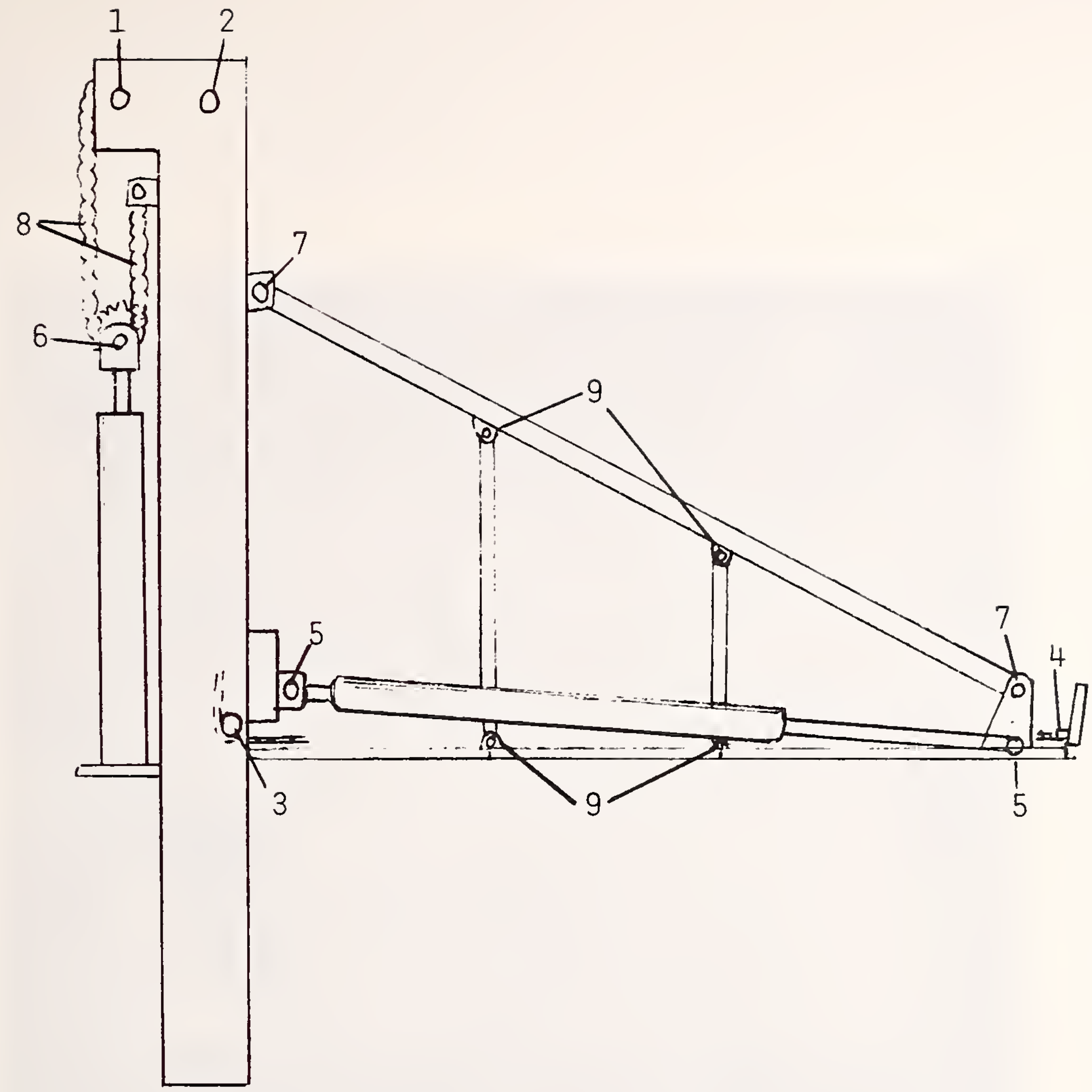
5.1.2 Component Strength Tests

Tests were made of the ultimate tensile strength of critical lift components, comprising the various pinned joints and cable and chain assemblies. The results are shown in Figure 5-1 together with a schematic of the lift to illustrate their location. Because of the limited number of components available the results are generally of single components although for the chains they are an average of two tests. It is evident from the values recorded that the component load capacities are adequate for the application, as would be expected from the use of a standard bus lift that is operationally proven. However, without a more extensive statistical sample of test results it would be premature to make any judgement as to specific safety factor values.

5.1.3 Ambient - Temperature Tests

To allow a test to be made in simulated low and high temperature environments, the lift and the doorway were enclosed in a chamber that was fabricated from 4" thick styrofoam slabs as shown in Figure 5-2. Thermocouples were positioned inside the chamber at heights of 1, 3, and 6 feet above the ground level, and connected to a direct reading meter. Air circulation was achieved through a small propeller fan which could be switched on and off.

No special pre-test preparation was done on the lift in the way of cycling or lubrication procedures. For both the cold and hot tests a four hour pre-test soak period was used.



Item	Component	Failure Load
1	Lift chain idler sprocket pin and bearing	9,400 lb.
2	Inner column upper pulley pin	8,400 "
3	Safety gate cable pulley pin	3,210 "
4	Safety gate cable end assembly	4,100 "
5	Platform cylinder clevis yoke pin	7,200 "
6	Lift cylinder sprocket pin	9,700 "
7	Platform radius arm pin	6,820 "
8	Lift chain assembly	3,260 "
9	Platform support stringer pins	3,140 "

FIGURE 5-1. RESULTS OF COMPONENT FAILURE TESTS

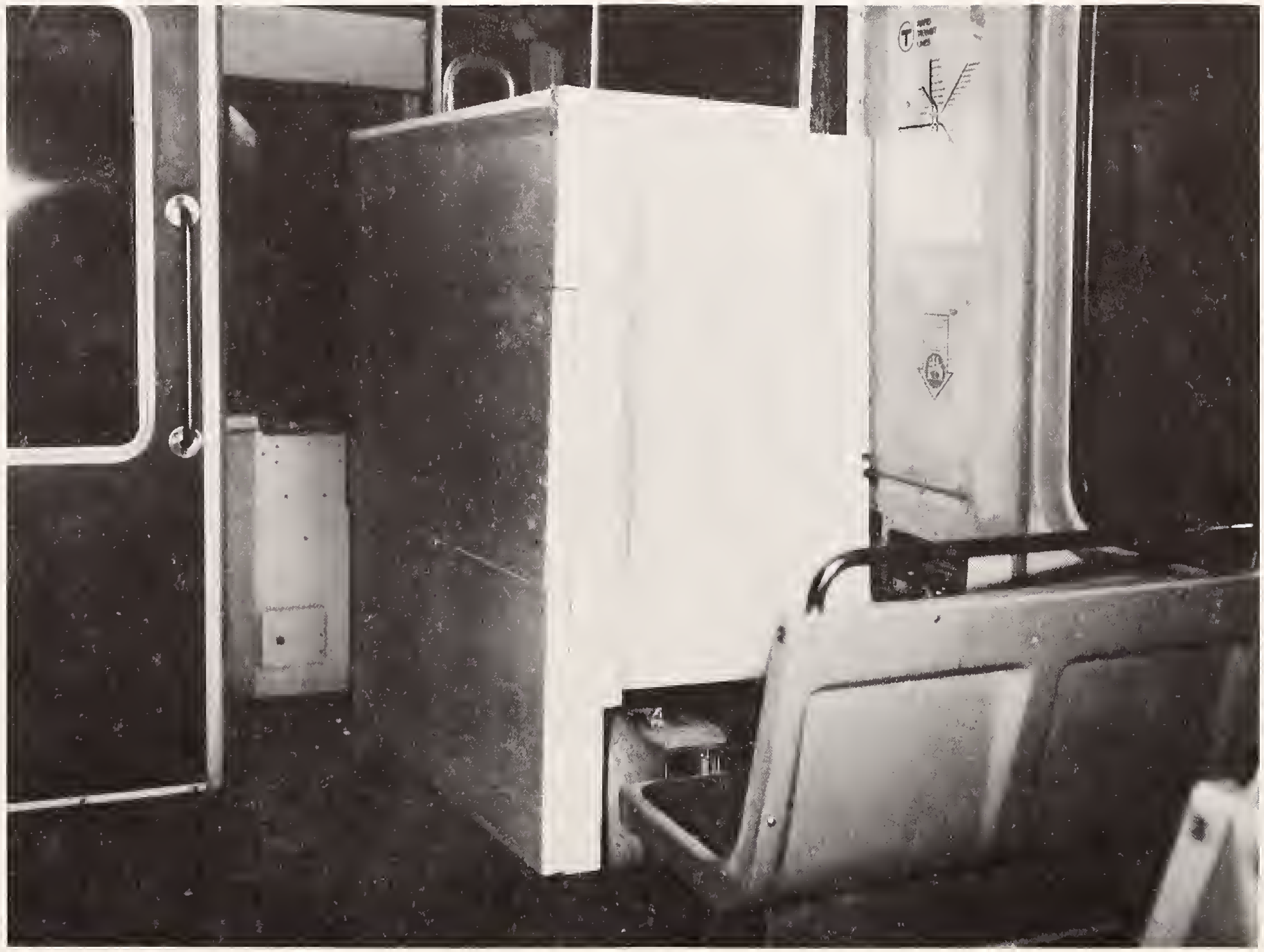


FIGURE 5-2a. ENVIRONMENTAL TEST CHAMBER - VEHICLE INTERIOR

FIGURE 5-2b. ENVIRONMENTAL TEST CHAMBER - VEHICLE EXTERIOR

5.1.3.1 Cold Test

For the cold test, 500 lb. of dry ice was used to lower the temperature to $-20^{o}F$ ($-29^{o}C$). At this temperature, the lift would not deploy with the hydraulic pressure switches set at their normal cut-out pressures. Examination of the lift indicated that contraction of the piano-type hinges on the step/riser joints was causing binding upon the hinge pin. It is possible that the lift could have been made to operate by raising the cut-out pressure or by jolting the lift to overcome the sticking forces.

The chamber temperature was allowed to slowly rise at the rate of $2^{o}F$ per hour and after another unsuccessful attempt to operate the lift at $-18^{o}F$ ($-28^{o}C$) the lift worked properly at $-16^{o}F$ ($-27^{o}C$). This performance in cold temperature was considered to be satisfactory since the lift was not given any special preparation and, in practice, the interior of the vehicle would be maintained at a much higher temperature than that of the external ambient.

5.1.3.2 Hot Test

Upon completion of the cold test the dry ice was removed and convection heaters were used to bring the temperature up to $130^{o}F$ ($55^{o}C$) for four hours prior to testing. No problems were encountered in operating the lift at this high ambient temperature.

5.1.4 Conclusions and Recommendations

The testing demonstrated that the lift had adequate load capacity, rigidity, and mechanical strength to be reliable in service. This was later confirmed by the field test program. Some further development is needed to ensure reliable working at very low temperatures; however, it should be noted that bus versions of this basic lift have been successfully operated in the severe winter climates of the prairie provinces of Canada.

5.2 FIELD TESTING

The installed TransiLift was tested with and without wheelchair user volunteers in non-revenue service from March 7 through July 7, 1983. The lift performed well throughout with 134 field tests conducted at more than 60 locations on all five of MUNI's light rail surface lines. The materials in this section are extracted from MUNI's test report (Appendix D) and summarize the major activities and findings.

5.2.1 Operating Environment

The 130 vehicle light rail fleet operations include a five mile subway tunnel with nine underground stations, seven of which are located under Market Street. The LRV lines emerge from subway to surface level operation at the Duboce Portal (where they divide into the N-Judah and J-Church lines) and from West Portal at the end of the Twin Peaks Tunnel (dividing into the L-Taraval, K-Ingleside, and M-Ocean View lines). These surface lines (Figure 5-3) evolved over a period of several decades, with the Twin Peaks Tunnel itself being opened to streetcar traffic in 1917. While modernized in many respects, the MUNI-Metro reflects the compromises which must be made in a dense and compact urban environment with a wide variety of terrain. Metro surface lines operate on both flat terrain and steep hills. They are found in exclusive, semi-exclusive, and totally non-exclusive rights-of-way. Where street width has permitted, passenger loading islands of varying heights and widths have been constructed. Other streets are narrower and passengers must board directly from the street pavement. These street surfaces represent a variety of street crown conditions.

5.2.2 Boeing LRV Configurations

The interiors of MUNI LRVs are configured to seat either 68 or 52 persons. The higher seat capacity vehicle has rows of double transverse seats on both sides of a 27 inch aisle which is only marginally adequate for wheelchair passage. The lower capacity vehicles have double transverse seats on one side and a row of single transverse seats on the other side. Their wider aisle easily accommodates wheelchairs. A car of this type was chosen as the test vehicle.

Currently, wheelchair users on MUNI LRVs are requested to station their chairs in a center stairwell area on the side with raised stairs, adjacent to the forward wind screen where they would receive maximum protection in the case of a sudden stop. This area is 15 feet from the test lift location in the front

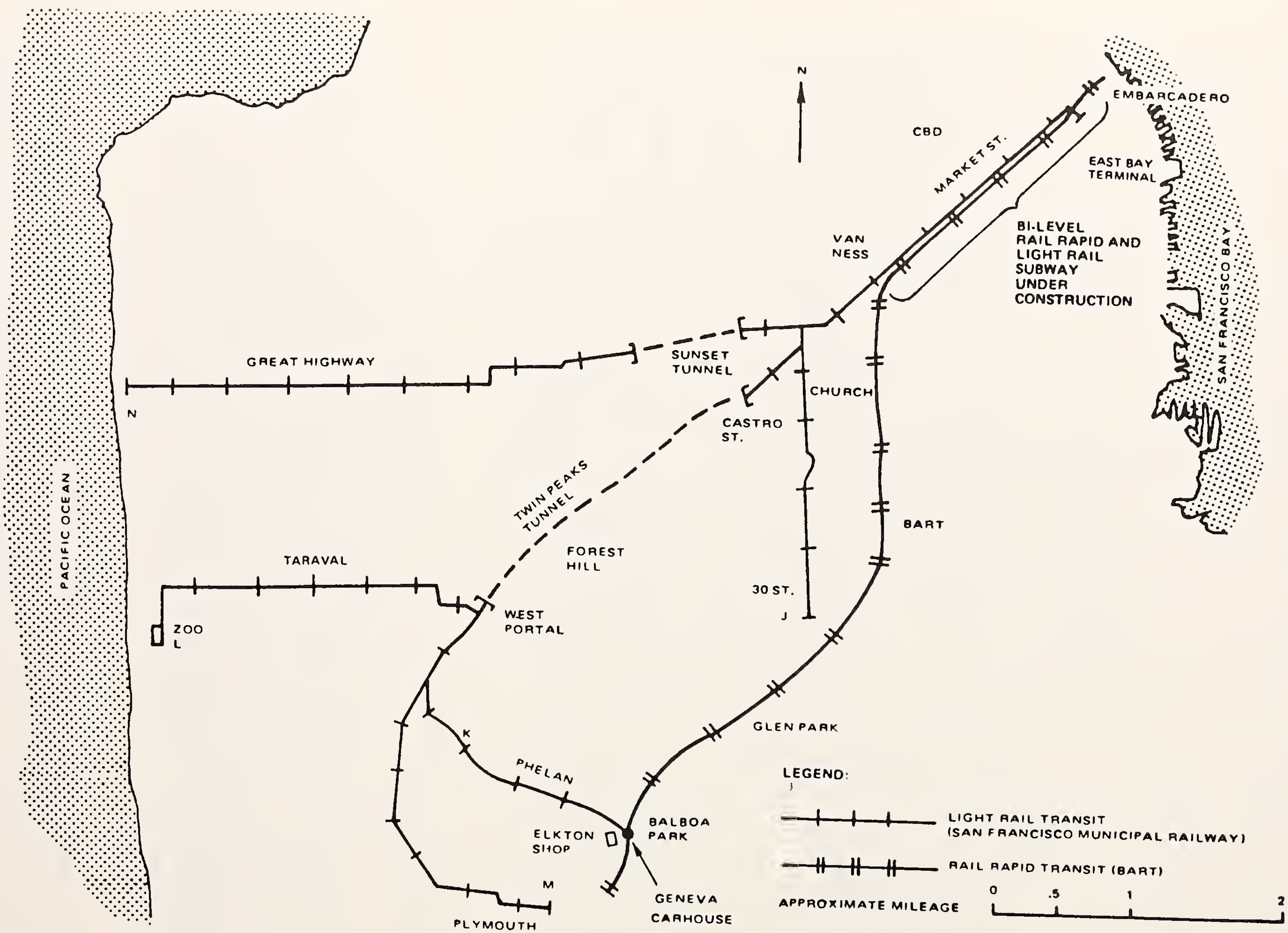


FIGURE 5-3. MUNI ROUTE MAP

doorwell. MUNI employs a cross-over rather than a turnaround at its downtown subway terminal and thus two lifts per LRV would be required for revenue service, one at each lead end.

5.2.3 Schedule of Activities at MUNI

The overall schedule of activities during the installation and testing of the lift may be summarized as follows:

- o February, 1983 -- Lift received from the Budd Company.
- o March, 1983 -- Lift installed in LRV for testing.
- o March 7 through July 7, 1983 -- Maintenance records kept for lift on a daily basis, with lift cycled daily by maintenance staff.
- o March 14 through June 29, 1983 -- Field testing of lift.
- o June 3, 1983 -- Lift publicly demonstrated as part of a demonstration and workshop on handicapped access to light rail systems sponsored by the San Francisco Municipal Railway. Forty-three persons participated in this demonstration.

5.2.4 Installation and Removal of the Lift

The lift was installed by personnel of MUNI Electrical Equipment Maintenance Department, under supervision of personnel of the Budd Company (Mr. Arthur Lancaster) and of the USDOT Transportation Systems Center (Mr. Jason Baker). Several minor modifications were made to the front of the test LRV as part of the installation process. In addition, as part of the retrofit, the redesigned bottom guide to the front door discussed in Section 4.1 was installed on the door, replacing a guide affixed to the car body.

As part of the demonstration on June 3, 1983, MUNI maintenance personnel demonstrated removal of the lift module, its replacement with a step module, removal of the step module, and then re-installation of the lift module. This entire procedure took 44 minutes and was only the second time that the personnel had performed this sequence. The actual times for each step in the sequence was as follows:

Remove Lift from Vehicle	14 minutes
Install Step Module in Vehicle	8 minutes
TOTAL	22 minutes

Remove Step Module from Vehicle	7 minutes
Install Lift in Vehicle	15 minutes
TOTAL	22 minutes

Figure 5-4 illustrates the lift installation process.

5.2.5 Maintainability and Reliability

The lift was cycled at least daily during the test period. The test LRV participated in normal peak hour service and in a normal share of non-peak hour service as well as in the non-revenue testing sessions. Lift testing sessions were conducted during off-peak hours on weekdays between 9 a.m. and 3 p.m. A daily log was kept of mileage, number of cycles of lift, and preventive and corrective maintenance actions. The only corrective maintenance required was replacement of one of the two plastic guides used for the kickplate behind the lift mechanism.

5.2.6 Field Testing Procedures and Results

Field testing was conducted between March 14 and June 29, 1983, during eight sessions. In each case, the test LRV had been returned to Metro Center from its morning peak runs. If necessary, the car was wyed so that the lift would be in the forward end during the test session. The test LRV was invariably preceded and followed by LRVs in regular revenue service, which operate on six minute headways. Thus the test LRV could stop for testing only in situations where this would not delay the following car. It was found that this did not present a serious problem since tests were conducted rapidly due to short lift cycle times.

Temperatures were moderate during all testing sessions. Weather conditions ranged from light showers during one test to overcast or clear skies during the other tests.

Photograph courtesy of San Francisco Public Utilities Commission, Photo Division.

FIGURE 5-4. FIELD INSTALLATION OF LIFT MODULE

5.2.6.1 Test Cycles and Conditions

The lift was cycled 134 times in field conditions of which sixty-one (61) times were with volunteers who were wheelchair users. During the remaining 73 cycles, either staff served as "load" on the lift or there was no load. Actual load ranges were:

Load	Cycles
no load	59
100-149 lb.	4
150-199 lb.	31
200-249 lb.	4
250-299 lb.	29
300-399 lb.	5
400-425 lb.	2

The lift was cycled 101 times on revenue tracks and 33 times on non-revenue tracks (27 at Metro Center and 6 on storage tracks at the outer ends of the N-Judah and L-Taraval lines). Distribution of the cycles by line was as follows:

Line	Cycles
J-Church	7
K-Ingleside	28
L-Taraval	32
M-Ocean View	9
N-Judah	25
Metro Center	33

These lines presented a variety of grade conditions during the cycles which may be summarized as:

Grade	Cycles
No measurable grade	72
1-5%	46 (25 up hill, 21 down hill)
5-10%	16 (7 up hill, 9 down hill)

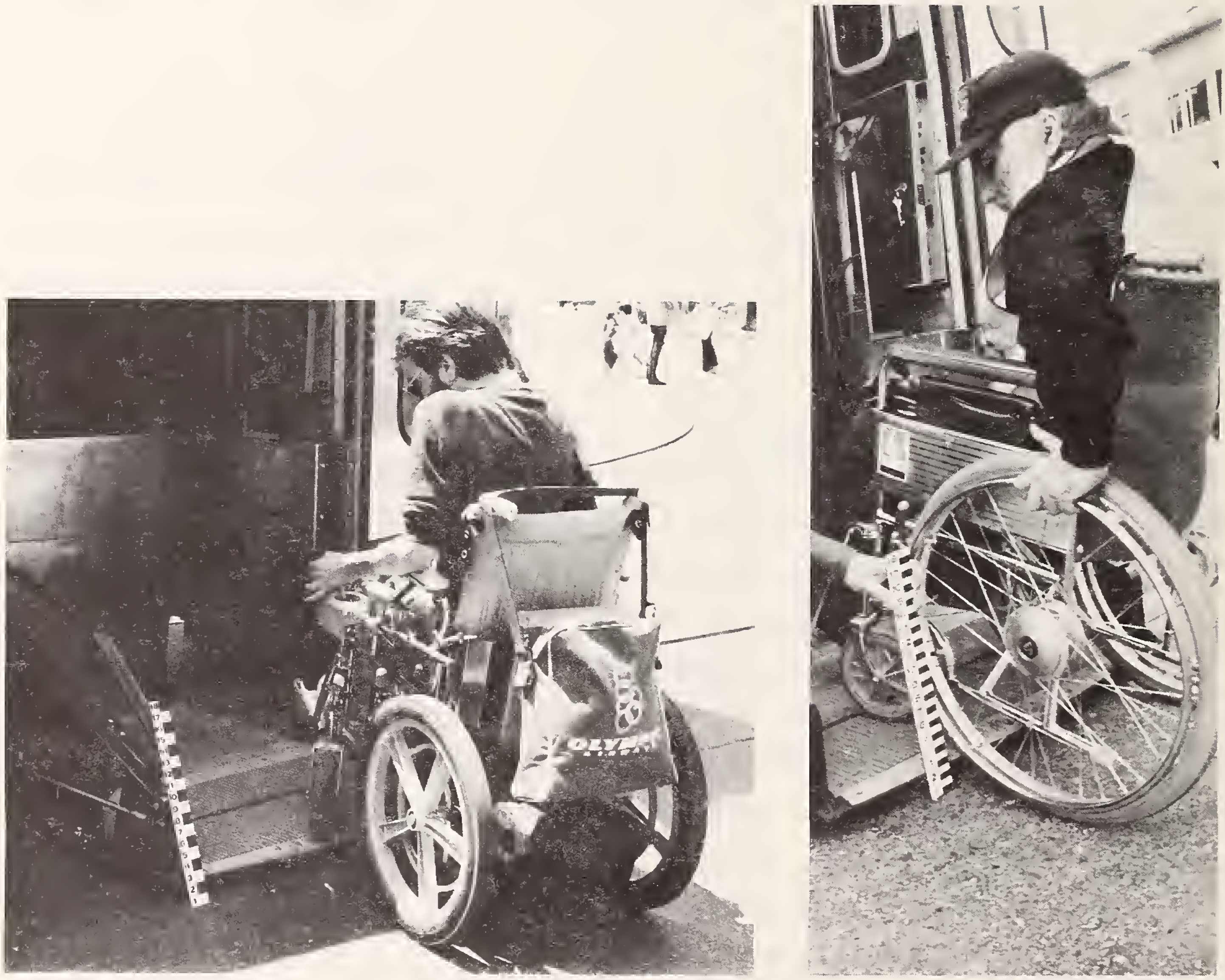
The lift was deployed both at regular marked stops and also at a variety of other sites which presented interesting deployment conditions. The 134 test cycles included 90 onto street pavement and 44 onto passenger boarding islands.

In addition, varying degrees of flat to positive street crowns (street center higher than the edges) were encountered. No negative street crowns were encountered on MUNI rights-of-way. The San Francisco Department of Public Works reports that average street crowns on streets with MUNI Metro tracks are .6% to 1.0% of crown relative to street width. A 40 foot wide street with a 1% crown would thus be 4.8 inches higher at the center of the street than at the curb.

Although the lift is capable of being adjusted to handle significant street crowns, the testing was done without adjustment. An excessive positive street crown would result in the lift platform making contact with the street beneath the LRV, but failing to lie flat on the street at its outer lip. MUNI feels as a result of the testing that many wheelchair users could readily negotiate a one inch "gap" between the street pavement surface and the upper surface of the lift platform, in order to board (Figure 5-5). Excessive street crowns were, therefore, defined as those that would cause more than a one inch gap. Street crowns were found to cause an excessive gap during only nine of the 90 street pavement tests and occured at seven different sites. The nine situations with excessive gaps included six in the 1-2 inch gap range, two in the 2-3 inch range, and one of nearly 4 inches (Figure 5-6).

No other problems were noted in deploying the lift onto a variety of street surfaces, including blacktop and brick.

The lift was cycled 44 times at passenger boarding islands located adjacent to Metro tracks in a variety of exclusive, semi-exclusive, or non-exclusive rights-of-way. One or more lanes of vehicular traffic were invariably present on



Photographs courtesy of San Francisco Public Utilities Commission, Photo Division.

FIGURE 5-5. WHEELCHAIR USERS NEGOTIATING 2" GAPS

Photograph courtesy of San Francisco Public Utilities Commission, Photo Division.

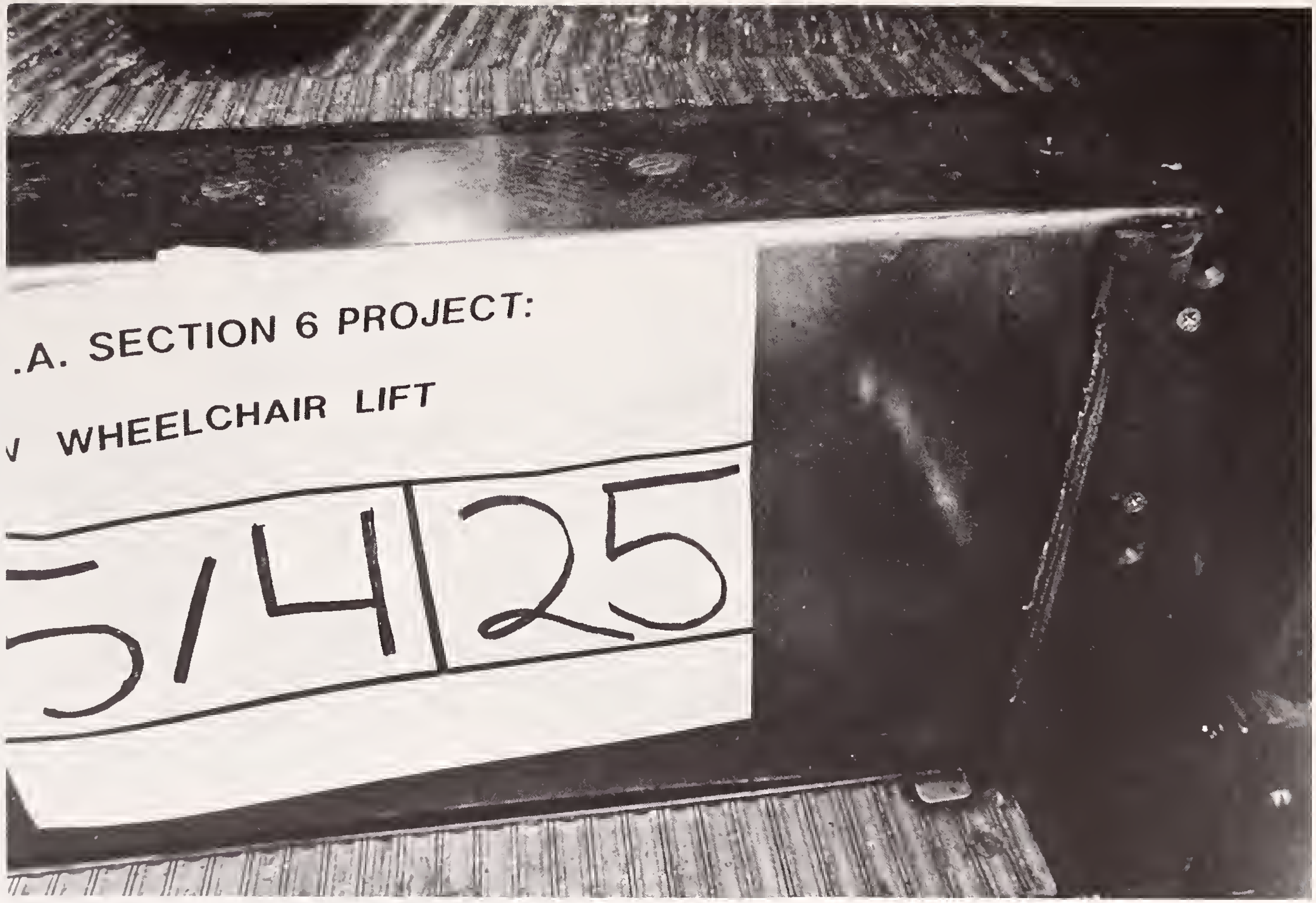
FIGURE 5-6. MAXIMUM GAP ENCOUNTERED DUE TO ROAD CROWNING the side of the island opposite from the trackway and in some cases, the islands had railings on the opposite side. The width of the islands varied from 45 inches to 90 inches depending on the width of the street and the competing space demands of automotive traffic lanes.

Boarding island heights above the street surface averaged 6 inches and varied from 3 inches to 12 inches (in Metro's highest platform, on the J-Church line at 20th Street in Dolores Park). The lift platform invariably lay flat on the surface of each boarding island. During the 44 island tests, the 1 inch limit between island surface and platform surface was never exceeded and was reached in only two tests. Depending on the configuration of the passenger islands, the deployed lift covered from 15 to 19 inches of the island surface.

5.2.6.2 Test Results

The lift performed well under all load and grade conditions, including grades in excess of 1:12 which would normally be considered excessively steep for wheelchair users. A tendency for the kickplate behind the lift mechanism to rub against its forward plastic guide (one of two such guides) was noted when the LRV pointed down hill and/or the load on the lift platform was offset toward the forward side of the platform (i.e. toward the side facing the direction of travel). In one instance which occurred while boarding a volunteer in a wheelchair, the kickplate engaged the plastic guide and created sufficient resistance to bring the lift to a halt before the platform was completely raised. The lift was recycled three times before the problem was fully identified and corrected by shifting the load toward the rear edge of the platform. (This site also had an excessive street crown, discussed below.) There was no instance in which the lift failed to fully cycle during the other 60 cycles using volunteers, nor during the 73 cycles when volunteers were not present. The worn kickplate guide (Figure 5-7) was eventually replaced.

In three of the nine instances where excessive crown was encountered volunteers were participating in the testing. In each case, the volunteers were in fact able to mount the lift platform successfully, but MUNI feels this would have been unsafe in revenue operation. Therefore, either the lift must be



Photograph courtesy of San Francisco Public Utilities Commission, Photo Division.

FIGURE 5-7. WORN FORWARD KICKPLATE GUIDE provided with adjustment for such operation or LRV operators must assure that excessive street crowns are avoided at those designated stops where the lift is deployed directly onto the street pavement.

Passenger island widths were a cause of concern. The results using three volunteers in 13 tests at a variety of islands are summarized as:

Platform Width	Lift Intrusion	Free Platform Length	Acceptability
45"	17"	28"	Unable to deboard in a manual chair
50"	16"	34"	Just able to deboard in manual chair. Concern over projection of feet into street lane during turning
≥60"	17"	≥43"	No difficulty with manual or powered chairs

The limitations imposed by the narrowest islands is shown in Figure 5-8. Platforms which are at least 60 inches wide, with at least 42 inches remaining for maneuvering when the lift platform is deployed on the island surface, would appear to be a minimum width for the standard wheelchair sizes readily accommodated by this lift. It is recommended that railings be installed on the side of the island adjacent to vehicular traffic, although this is more important on hilly than on flat terrain. When space permits, islands should be at least 72 inches wide for this type of lift.

5.2.6.3 Stopped Time

Tests were run to determine the amount of stopped time needed for a wheelchair user to board or alight with the test lift. The time is defined as the period during which the vehicle must remain stopped to board or deboard a passenger. It includes the time it takes to open the door, deploy the lift, board or deboard the passenger, stow the lift, and close the door prior to being ready to resume forward motion. During these tests, the wheelchair users were positioned within five feet of the lift when intending to board the LRV, or

FIGURE 5-8. LIMITATIONS OF NARROW PASSENGER ISLANDS

within 15 feet of the lift when intending to deboard. As one volunteer observed, "There is very little difference when the wheelchair user is in the car, as I can move to the door (at the lift) as the lift is being raised." That is, under these test conditions without standees, the wheelchair user could travel to the lift area while the door was being opened and the lift platform deployed in a raised position. The results for a number of different chair and numbers of persons boarding may be summarized as:

Number of Persons	Chair	Stopped Time (seconds) Board	Deboard
1	Power	48*	44*
1	Manual	45	52
1	Manual	44	42
2	Manual	82	73
4	Manual	180	152

*Average of two tests.

None of these volunteers had previously used a lift on an LRV. Some had considerable experience using various bus lifts. The volunteers appeared motivated to quickly board and deboard the LRV, as would be the case with most revenue passengers. Significantly, volunteers involved in a series of tests tended to shorten their boarding/deboarding time by "learning the ropes" on the first try.

In separate tests, measuring ingress and egress time from the passenger's viewpoint (i.e. excluding the time required to stow the lift, close the door, and prepare to resume forward motion) it was determined that a single volunteer using a manual chair took 29 seconds to exit the vehicle, averaging 6 tests, and 30 seconds to enter the vehicle, averaging 5 tests. These times together with the fact that the unloaded lift was set to completely cycle in 32 seconds indicate that the times measured are probably representative of what would be encountered in revenue service.

5.2.7 Conclusions and Recommendations

The modularized TransiLift used in the field testing performed reliably and without breakdown over a period of four months and under a range of environments which include most of the situations which would face such a device in actual operating conditions. Although not tested in revenue service, the vehicle and the lift were subjected to all the normal wear and tear of such service over a 120 day period without evidence of damage to the lift. In addition, it was demonstrated that the lift module could be removed at the MUNI Metro shop, replaced with a fixed steps module, and the car quickly returned to service if there had been a need for major repair. The lift functioned effectively throughout 134 field tests, 120 daily maintenance cyclings, and well over 100 additional cyclings in connection with installation and training of operators.

Observations by staff, and by volunteers who are wheelchair users, reinforced a perception that the lift is well designed for safe reliable operation. Problems which are sometimes encountered with some bus lifts were absent. The outer safety barrier performed well in all tests. The lift platform lay flat on street or passenger island surfaces with no tendency to buckle. The platform of the lift maintained a safe angle parallel to the plane of the tracks and the LRV floor. The lift controls were simple to operate. When deployed, the lift platform always stopped smoothly when it reached the street or passenger island surface, with no tendency to "jack" the vehicle. Only two minor problems surfaced during the testing.

1) Binding of the kickplate against a plastic guide when the load on the deployed lift platform is centered toward the forward edge of the platform and/or the platform is being raised under load with the LRV in a downhill position. This can be cured by increasing the clearances in a production design.

2) When raised under load, the lift platform often stopped approximately 1/2 inch short of the LRV floor. While this never interfered with boarding by volunteers, the operator would have to correct for this after the load was removed by lowering the platform a couple inches and raising it without load. This procedure took perhaps two seconds and invariably the lift would then be properly aligned with the LRV floor. This problem can be corrected by adjustments to the individual platform chain settings.

APPENDIX A

LRV LIFT PROJECT TECHNICAL COMMITTEE

APPENDIX A

LRV LIFT PROJECT TECHNICAL COMMITTEE

COMMITTEE MEMBERSHIP

The committee was formed from representatives of transportation authorities with present or planned light rail operations and from consumer representatives with knowledge and experience in accessible transportation issues and accessible rail transportation in particular. The systems and representatives are listed in Table A-1. All of the systems were light rail operators except for NFTA, Buffalo, New York and TRI-MET, Portland, Oregon, which were in the planning and construction stages. San Diego, California, which was operating a light rail system with vehicle mounted lifts was invited, but was unable to participate.

COMMITTEE MEETINGS

Two full meetings of the committee were held. The first meeting took place at the Transportation Systems Center, Cambridge, Massachusetts on February 4, 1982 and included a full review and discussion of the lift design criteria and installation evaluations.

The second meeting took place at the Technical Center of the Budd Company at Fort Washington, Pennsylvania on August 4, 1982 and included a full review of the program to date and the activities planned through the completion of the project. Two working TransiLift configurations were available for inspection and demonstration. The modified, so called three-step version with the longer platform was installed in the shell of the Boeing LRV supplied by the MBTA. The basic TransiLift with a wide, but shorter platform was installed in a test rig adjacent to the other installation. In addition to actual operation, the ease with which the modular installation concept allowed the lift to be removed was demonstrated. Removal was accomplished in 6.75 minutes.

The full minutes of both meetings follow.

TABLE A-1. TECHNICAL COMMITTEE ATTENDEES

Transit System	Representative	Meeting #1	Meeting #2
Massachusetts Bay Transportation Authority	Bruno Pawlowski	X	X
San Francisco Municipal Railway	Carl Martz	X	X
	Jack Weigel		X
	Thomas Jordan		X
Niagara Frontier Transportation	Fred Dell'Amico	X	
	Kenneth Melston		X
Port Authority of Allegheny County County	Robert Sedlock	X	
	Thomas Letky		X
Greater Cleveland Regional Transit Authority	Theodore Donahue	X	X
TRI-MET, Portland, Oregon	Scott Farnsworth	X	

Consumer	Meeting #1	Meeting #2
John Edmonds, San Francisco, CA	X	X
Terry Moakley, New York City, NY	X	X
Thomas O'Brien, Danvers, MA	X	
(Tony Kinahan, Sub.)		X
Joseph Saylor, Roslindale, MA	X	
Sigi Shapiro, Philadelphia, PA	X	X

U.S. DEPARTMENT OF TRANSPORTATION/UMTA/TSC

LIGHT RAIL VEHICLE LIFT PROJECT

MINUTES OF TECHNICAL COMMITTEE MEETING

NO. 1

BACKGROUND

The Technical Committee for the Light Rail Vehicle Lift Project was formed to provide a mechanism for consumer and transit operator input. Transit operators were selected on the basis of their experience and familiarity with light rail vehicle operations. The cities selected for representation on the Technical Committee include Boston, San Francisco, Cleveland, Pittsburgh, Buffalo and Portland.

Consumer representatives were selected on the basis of their understanding of the issues associated with vehicle accessibility. The consumer representatives were from Boston, San Francisco, New York City and Philadelphia.

The first meeting of the Technical Committee was held on February 4, 1981 at the USDOT Transportation Systems Center in Cambridge. All representatives were in attendance at the meeting with the exception of the member from Buffalo. The meeting agenda included presentations by members of the project study team and a substantial amount of time for comments, question and answer, and general discussion. The purpose of the first meeting was a review of the results of the Phase I work activity on the project. Phase I involved the review of all currently available lift designs that can be retrofitted to existing light rail vehicles. The evaluation was expected to lead to the identification of those lifts which are suitable for installation in an LRV without major modification to either the vehicle or the lift.

The following discussion presents the questions, reactions and comments of the Technical Committee as a result of the technical presentation at the meeting. The comments have been organized into two categories representing consumers and operators. Within each category the comments and reactions are arranged on the basis of their impact on the project and the decisions to be made in later phases. The specific comments and questions are preceded by some general observations about the first meeting.

GENERAL OBSERVATIONS

The Technical Committee (TC) generally agreed with the overall direction and results of the study to date. A substantial number of the specific comments and questions from the TC had to do with issues that were beyond the scope of the contract work activity. The majority of questions came from the transit operators who were interested in finding different solutions to the problem of handicapped accessibility on light rail systems. During the session it was pointed out that the lift solution was the only practical one in most instances for existing light rail systems. The scope of work for the LRV lift project was presented clearly in the agenda materials which were sent out to the committee members and in the early portion of the presentation. It appears that a document which briefly summarizes all of the current TSC-sponsored research dealing with accessibility issues, and which shows the inter-relationships between various research projects would have been very useful to all members of the TC.

Some of the issues which were brought up by the TC, that are not directly related to the installation of a lift on an LRV, are briefly summarized below in order to provide a more complete sense of the results of the meeting.

1) There was a great deal of questioning and discussion on the rationale and alternatives to a lift on a light rail vehicle including such issues as the use of mini-platforms, sliding high-low platforms and a general discussion of platform-vehicle gaps.

2) A number of discussion items were centered on a broadening of the criteria, which were being used to assist in the selection of a lift, to include operations factors involving the overall performance of light rail systems. The essence of the discussion/question involved the suitability/feasibility of using a lift (with its attendant cycle time) in an actual operation with vehicles operating on very short headways.

3) The question of development of new lift technology versus the use of existing lift designs came up numerous times. One consumer member of the TC was particularly concerned that this project was

not looking ahead to the future. There was an underlying concern that the overall approach to using lifts on light rail vehicles might be compromised by the use of existing technology.

These issues should be addressed more completely prior to the next Technical Committee meeting to ensure that the maximum amount of meeting time is devoted directly to the project itself.

CONSUMER COMMENTS

1. Physical Dimensions of the Lift

The major concern with regard to dimensions was the length of the lift platform. The technical presentation brought out the major tradeoffs between short and long lift platforms. A short length is more easily accommodated in the vehicle and provides for easier boarding in island platform situations. A longer platform accommodates a much larger range of wheelchair sizes, allows for an accompanying person and generally provides for a faster boarding and alighting time due to easier positioning of the wheelchair on the platform.

The predominant reaction from the consumers was one of trying to establish a reasonable compromise on this dimension. In effect, they were willing to accept a platform length which allows for a simple and reliable design. They questioned the need for accommodation of an attendant on the lift platform. There was a general agreement that, over time, members of the disabled community would have to adjust to some of the physical constraints such as a shorter platform length especially in order to reduce the cost and complexity of an LRV lift. The guidance resulting from the consumers was interpreted by the project team to mean that Phase II should proceed with the longest platform length consistent with sound engineering practice and existing lift technology.

Other issues brought up included the height of the safety barrier and consideration of disabled users, other than those in wheelchairs. The project team noted that the height of the safety barrier was an adjustable dimension in most lift designs and that most existing lifts had safety barriers which were longer then required for safety purposes. The consumers were also assured that the needs of many disabled users had been considered in the development of the design criteria. As an example it was pointed out that the doorway height had been specified to provide sufficient clearance for a person who may be standing on the lift.

2. Performance and Costs

There were relatively few questions in the area of performance and costs. One question concerned any differences in cycle time between the various lifts which were considered. It was pointed out that the cycle time variations between lifts was quite small, particularly when compared to the variation in total cycle time for persons with different levels of skill and experience. Another question in the general area of performance included the possibility of user operation of the lift. This was discouraged based on problems with insurance liability, union contracts and work rules, potential vandalism, and for those disabled persons who would have great difficulty in actuating any controls.

Consumer representatives raised the issue of potential costs of any LRV lift. The project team responded with some rough estimates based on current technology in the range of $15,000 to $20,000. It was made clear that this was an estimate (based on current dollars) of an eventual cost once there had been sufficient numbers of installations and experience with LRV lifts. Other members of the TC pointed out that custom devices or manufactured devices in small quantities will always be more costly so that we should not expect costs comparable to those for bus lifts.

3. Miscellaneous Issues

There were a number of comments dealing broadly with the overall scope of the project activities. Some of the questions centered on the limited number of vehicles that were being considered. It was pointed out that the project scope called for evaluation of the PCC, Boeing, Breda and Kawasaki cars. All of the vehicles were evaluated except the Kawasaki car, which had to be excluded because the project team was unable to obtain detailed vehicle drawings. The drawings were considered proprietary by the manufacturer. There was no basis for selecting any other foreign-manufactured vehicle for evaluation since it was not clear which, if any, might be selected by some city in the future. There was also a concern about the rejection of the Lift-U design as a prime candidate for installation in an LRV. The project team reiterated its concerns regarding the problem of physical interference with the vehicle structure. It was also pointed out that all lift manufacturers were invited to react to the concerns of the project team regarding problems with the feasibility of installation. Therefore Lift-U would have the opportunity to present alternatives for solving any installation problems if they desired to do so.

OPERATOR COMMENTS

1. Reliability, Maintainability and Durability

These issues were of primary importance to the operators. There was a very great deal of concern about a possible failure of the lift which would interfere with overall system operations. Project team members noted that the lift installation would be made on a modular basis such that the lift could be pulled as a unit if there was a problem which would not allow for movement of the vehicle. A manual back up system is also a part of the lift installation requirements so that even under conditions of a power failure in the lift actuating system it will be possible to move and lock the lift into a stowed position. The question of an acceptable mean time between failure for the lift system was presented to the operators for their response. One answer to this was that the lift system should not fail more often than any other major subsystem on the vehicle. Another operator responded that they set a target of at least 2000 miles (on the average) for a vehicle before it is taken out of service. The mean time between failure for a system as complicated as a light rail vehicle is very difficult to define, as evidenced by the lack of any standards which could be identified by the operators. The general consensus of the operators was one of great concern over the possibility that the lift could become a major maintenance and reliability problem which could add to their existing maintenance work loads.

The issue of lift maintenance was linked to the attitudes of shop personnel by some operators. There was a concern that the lift may not be cycled on a regular schedule by the operators or maintenance personnnel thus leading to long term maintenance problems. The response from the project team to most of the concerns about reliability and maintainability was simply one of acknowledging that a potential problem exists with any piece of mechanical equipment. The project team noted that particular attention will be paid to these concerns during Phase II when the design and specification for the lift is being developed. In addition the test plan for the lift will emphasize the issues of reliability, maintainability and durability. It was further noted that plans will be developed for both laboratory testing and for transit system testing.

2. Use of Hydraulics

There was a lengthy discussion of the pros and cons of installing a lift powered by hydraulics into an LRV. Of the two vehicles under extensive consideration, the Boeing LRV only uses hydraulic in the braking system and the Breda LRV has none. The major concerns with hydraulics are possible problems with leakage and water infiltration into the system. It was pointed out that the lift hydraulics could be a self-contained unit requiring no hydraulic interconnections to the vehicle. The project team also noted that virturally all lifts in extensive use in transit buses were hydraulically powered. It was suggested that the project team look into the possibility of using an all electric or air motor system.

There was no clear consensus from the operators regarding the issue of hydraulics. Some were opposed to the concept of hydraulic powered lifts while others were neutral. It is apparent that this concern of the operators should be given some further consideration in Phase II.

3. Structural Modifications to the LRV

As part of the presentation, the possibility of structural modifications to the LRV was brought up. The structural modifications are associated with the installation of a long platform lift. There was considerable concern about any lift installation solution which would involve frame modifications. The operators were unanimous in agreeing that any modification of their existing vehicles was highly unlikely. Budd Company representatives at the meeting speaking from their experience as a car builder also expressed considerable skepticism regarding the willingness of any LRV manufacturer to make substantial modifications to the frame. They noted that modifications may be technically feasible however the financial impacts may be very severe. The consensus of the operators was that any lift design requiring major structural modifications of the vehicle should not be recommended.

4. Miscellaneous Operator Concerns/Comments

Some of the other issues that were brought up at the meeting by the operators included the reason for the modular design of the lift installation. The project team made it clear that a modular unit would allow for rapid replacement of a damaged lift particularly in those situations where a line had to be cleared to permit system operation. Modularity will also facilitate the maintenance process in those instances where major repair work is necessary.

Some time was also spent in discussing the general problem of movement through the car when boarding and alighting takes place on opposite sides of the vehicle. This was of particular concern for the Boeing LRV configuration used in the San Francisco MUNI system since there is inadequate aisle space to accomodate the movement of wheelchair passengers. The project team presented one solution to the aisle space problem which involved a reduction in the seat width on both sides of the aisle. This solution seemed to be acceptable to the operators although it was recognized that the passengers using the smaller seats may react negatively. The problem of the layout of the San Francisco car was clearly a subject which should be reviewed in Phases II and III.

U.S. DEPARTMENT OF TRANSPORTATION/UMTA/TSC

LIGHT RAIL VEHICLE LIFT PROJECT

MINUTES OF TECHNICAL COMMITTEE MEETING

NO. 2

MEETING ACTIVITIES

An informal introductory buffet dinner session for the members was held at the Valley Forge Sheraton Hotel. This hotel was the closest one which had been able to guarantee the anticipated numbers of handicapped accomodations. Accessible transportation between the hotel, the Budd Technical Center, and the 30th St. Station and Philadelphia Airport was provided by Montgomery Paratransit Services, Inc.

The main activities occurred at the Technical Center on Tuesday, August 3rd as follows:

Introduction to the Program	Mr. J.G. Mora, UMTA Mr. J.B. Baker, TSC	9:45
Review of Phase I	Mr. F. Varker, ARI/KETRON	10:00
Review of Phase II	Mr. A. Lancaster, Budd	
Description of Lift Installation	Mr. A. Lancaster	10:30
Demonstration of Lift Operation and Inspection of the Unit		11:00
Lunch Served in the Cafeteria		11:30
Demonstration of the Lift Module Removal		12:15
Review of Phase III	Mr. A. Lancaster	12:45
Discussion of Program Direction and Future Plans		1:15

SUMMARY OF TECHNICAL PRESENTATIONS AND DISCUSSIONS

The TransiLift installed in the vehicle had been selected as the best overall design for this particular vehicle although all the elevator type lifts were suitable for light rail vehicle installation. Budd developed two TransiLift design modifications for review which are referred to as the 2 and 3 step arrangements. The 3 step arrangement was developed to satisfy some concerns about platform length. The differences between the two arrangements may be summarized as follows:

2 STEP - This is essentially the standard TransiLift with a platform length of approximately 46" (barrier down) and 43.5" (barrier up). Budd has this lift installed in a test stand. The test stand version is several inches wider than would be allowable for vehicle installation because of door clearance and the pod mounting structure.

3 STEP - The actual number of steps in the doorwell has not been changed but the platform length has been increased by incorporating the first 8 inches of the passenger compartment threshold (3rd step) into the lift platform so that it moves up and down with the lift. This provides a longer platform without increasing the protrusion beyond the vehicle. For this installation a body structural member must be moved back and rewelded and adjustments made to underfloor equipment housings. This configuration had been installed into the front half of a Boeing LRV loaned to the program by the MBTA.

Detailed engineering continues on a number of areas (work on the hardware installation only started in June, 1982) including:

1. Increased restraint for the lower edge of the door under crush loading conditions. The lower edge of the door has been reconfigured because of the need to provide a clear opening for the lift. The original door panels had rollers which ran on a fixed locating track under the bottom step tread. For the lift installation this has been reversed and the track is attached to the door with the roller on the vehicle outboard of the doors. The resulting installation is somewhat more flexible than the original installation.

2. The hinged lid to the breaker box located in the forward wall of the stepwell must be redesigned. At present it cannot be opened with the lift in the stowed position.

3. Some of the exposed hose runs need to be made less prominent. They presently have an armored covering.

4. A shield needs to be developed for the inboard end of the lift platform.

   The lift is powered by a self contained electric motor/hydraulic pump sytem which has been modularized and is installed under one of the single seats adjacent to the doorway. To accommodate the unit the seat has been moved inboard about one inch.

The next phases of the program were outlined covering the testing and demonstration procedures which are planned. The testing (see Appendix A) includes operational tests to verify basic functions, proof tests for structural integrity and environmental acceptability, simulation of 3 years service using vibration levels recorded on MUNI tracks, and a four month field test at MUNI. The latter item will include normal mileage accumulation plus boarding/alighting demonstrations at selected locations. The proposed schedule for the remaining activities is appended.

Both lifts were demonstrated to the members of the TAC. Unfortunately due to insurance limitations only Budd personnel were allowed to ride on the lift. Budd had tried to get a special one day event policy but had been unsuccessful in this. To simulate an island platform situation a chalk line was drawn on the floor 60" from the outside of the vehicle. All three wheelchair users (who had manual chairs) were able to maneuver on and off of the lift within this boundary.

On the wider uninstalled STEP 2 lift it appeared practical for the wheelchairs to be aligned on one side of the platform. This would allow any attendant or companion to stand alongside rather than behind the wheelchair. However this might not be so practical with a powerchair (which is less maneuverable than the manual chairs) on the narrower platform of the actual installation.

The need for better handholds for use by the semi-ambulatory was emphasized. The current installation features the original design of TransiLift handrails which are designed for wheelchair users. Later TransiLifts had a revised design (see attached Figure) which are designed to accomodate a broader range of users. A similar modification could be incorporated in this installation. An alternative approach suggested was to provide a loop or shepherds crook attached to the lift mechanism so that it moved up and down with the lift. This approach has been used on many other lifts.

All the wheelchair users were satisifed with the barrier arrangement although that on the 2 STEP appeared to be stiffer. This was attributed to the cable tension and was a matter of adjustment. Other safety related issues raised during the review and discussion were:

- provision of a flip-over switch cover on the control panel so that only one mode switch was exposed at anytime;
- provision of sensitive edges;
- the load that would be applied to a foot caught under the platform before the motion was cut off; and
- the need for some form of warning for other vehicles on the inside lanes who might try and pass by.

The modular concept of the lift installation met with universal approval and was very favorably commented upon. The demonstration removal was accomplished by two mechanics in 6.75 minutes. Essentially this requires the removal of 4 bolts on each side and under the threshold and disconnection of 4 hydraulic lines (snap disconnects). The need to remove the threshold treadplate to access the threshold bolts was commented upon. The Phillips head screws securing this would become worn and dirt filled in service and, therefore, difficult to remove. It was felt that if the lift is adequately supported elsewhere some form of tongue-in-groove or tab and slot arrangement could be used to provide location of the lift. Removal would not then require disturbing the threshold. It was also suggested that the routing of the hydraulic lines should be such that after the module has been moved a few inches the lines could be accessed and separated. At present they must be disconnected from under the vehicle or closer to the power module. The latter procedure results in lengths of hydraulic hose being pulled out with the lift.

The need to lift out the power module (150 lb.) was also commented upon from the maintenance aspect. Some form of slide out to avoid lifting would be preferred. Provision should also be made for easy verification (and top-up) of hydraulic fluid levels. The question was raised of how many BTU's of heat would be released by the unit in operation. The concern being for additional heat release in subway situations.

As at the previous meeting, the question of platform length was the most discussed. Generally the shorter platform of the 2-STEP lift was favored because it required the minimum structural modification to the vehicle, but only if it could be shown that this would adequately accommodate the powered wheelchairs. Unfortunately, none of the attending TAC members were using powered chairs and it was agreed that the Budd Company would make arrangements in cooperation with Ms. Shapiro for some local users of powered chairs to evaluate the installations. The point was made that in this demonstration program it would be preferable to provide the largest platform possible. A smaller platform could then always be simulated and evaluated locally, whereas the converse would not be possible.

APPENDIX B

LIFT REQUIREMENTS CRITERIA

A COMPILATION OF EXISTING CRITERIA
TO SUPPORT A PROGRAM
FOR THE INSTALLATION OF EXISTING
LIFT SYSTEMS ON LIGHT RAIL VEHICLES

1. INTRODUCTION
2. CONSUMER FACTORS
3. LIFT MECHANISM FACTORS
4. VEHICLE INSTALLATION FACTORS
5. OPERATIONAL FACTORS

APPENDIX B

LIFT REQUIREMENTS CRITERIA

1. INTRODUCTION

The requirements analysis may be broadly divided into four areas, all of which will interact to a certain degree. These areas may be defined as:

- o <u>Consumer (User) Factors</u> covering such areas as boarding and alighting ease, safety, maneuverability, and companion capability.
- o <u>Lift Mechanism Factors</u> covering mechanical and systems design factors, practices and standards, and physical requirements arising from the intent to use off-the-shelf hardware where possible.
- o <u>Vehicle Lift Installation Factors</u> such as structural integrity, location and relocation of equipment, interference with or alteration to major subsystems.
- o <u>Operational Factors</u> such as single or double ended operation, high or low platform, street, and dedicated right-of-way operation, left or right side boarding, environmental conditions, fare collection.

In the past, when the PCC car was virtually a standard configuration, the interaction between vehicle and operational factors could have been resolved relatively easy. Recent light rail developments have, however, led to a much wider variety of vehicle/operational situations which will require lift installation configurations to be determined on a case-by-case basis.

A significant body of research already exist in many of these areas, although it is not all specifically related to LRVs and operations. Primary source documents used as references herein are:

1) A Requirements Analysis Document for Transit Vehicle Wheelchair Lift Devices - Canyon Research Group, Inc.

2) Recommended Safety Guidelines for Lifts on Public Transit Vehicles - California Department of Transportation.

3) Evaluation Report on Five Wheelchair Lift Options for Installation on Transit Coaches - Seattle Metro.

4) Evaluation of the St. Louis Accessible Bus Service - Applied Resource Integration, Ltd.

5) The Feasibility of Retrofitting Elderly and Handicapped Lifts on Commuter and Light Rail Vehicles - Technology Research and Analysis Corporation.

6) Standard Design and Test Criteria for Safety and Quality of Automatic Wheelchair Lift Systems for Passenger Motor Vehicles - Veterans Administration.

7) California Highway Patrol Regulations - July 1979. These regulations must be compiled with for lifts on buses in California.

8) Section 321(b) Study.

9) Relevant documents, drawings, and specifications from lift and vehicle manufacturers.

The following subsections present some basic requirements for a satisfactory lift installation in the four areas outlined above, accompanied by specific recommendations whenever possible.

2. CONSUMER FACTORS

2.1 DIMENSIONAL CONSIDERATIONS

The ease and safety of use of the lift system must be a primary consideration in the design and installation of the platform and its immediate environment. This in turn will be influenced by the range of the wheelchair population to be considered.

2.1.1 Wheelchair Size

Reference 1 presents an analysis of wheelchair population sizes with a recommendation that the 90th percentile (%ile) chair should be the design standard. However, ambulatory design standards are most commonly based on the 95th %ile. This higher level criteria is also used in Reference 1 and 2 for the weight requirements.

Reference 1 indicates that this change would only add 0.75 inches to the overall length and 0.375 inches to the seat height requirements and would not change any other dimensions at all. Therefore, the 95th %ile chair is recommended as the design size for this requirements study with the following dimensions:

Overall Length	43.25 inches (includes footrigging)
Overall Width	26.25 inches
Overall Height	38.57 inches
Seat Height	20.50 inches
Armrest Height	30.25 inches

2.1.2 Platform Dimensions

The width and length of the platform together with the ramp angle necessary to access it, the height of the safety barrier, and the size and location of handholds on the platform are all primary concerns.

2.1.2.1 Platform Length

Two underlying assumptions will be that the chair is wheeled onto the platform in a forward direction and that an attendant can stand on the platform with a manual chair. Allowing 2.5 inches for the normal extension of the feet beyond the rigging (Reference 1) and 13 inches for attendant (Reference 1) would dictate a minimum platform length of 58.75 inches. This should be exclusive of any movable portion such as a ramp or safety barrier. While an attendant with a manual chair will not always require the full 13 inches, the possible presence of an attendant with a person in a powered or special configuration chair should be the controlling factor. Therefore, consistent with Reference 1, and with the appropriate adjustment for the 95th %ile wheelchair size, it is recommended that the length of the lift platform should be a minimum of 59 inches exclusive of ramps and safety barriers.

2.1.2.2 Platform/Doorway Width

Maximizing platform width reduces the requirement for precision in wheeling on to or off of the platform. It may also increase the available space for maneuvering in the vehicle vestibule depending upon the particular lift design. The net result will be reduced dwell time at the stop. Since LRVs commonly feature double width doors, platform width should not be a problem except where an installation in part of the doorway is contemplated or where an active lift (with separate entryway) appears to be the only feasible solution. It should be noted that the platform width and the required clear doorway opening are virtually synonymous for passive lifts.

Reference 1 indicates that other sources have produced recommendations for platform width varying from 29 to 40 inches and for doorway widths of 34 to 40 inches. Recommendations from Reference 1 are for 35 inch platforms and 36 inch doors with minimum of 30 and 33 inches respectively. It should be noted that the ANSI minimum wheelchair clearance standard for a clear doorway opening is 32 inches. Given the greater need for flexibility in maneuvering requirement in a transit setting as opposed to the architectural environment, there would seem to be no reason to deviate from the recommendation of Reference 1 of:

Lift platform width	35" recommended with a minimum of 30"
Doorway opening width	36" recommended with a minimum of 33"

2.1.2.3 Safety Barrier Height

In tests sponsored by the Veterans Administration (Reference 6), it was demonstrated that a barrier at least 3 inches high is necessary to detain an occupied powered wheelchair (375 lb.) after rolling 3 feet down a 3 degree slope. Contact with 24 inch diameter wheels is assumed. This recommendation may, therefore, be adopted without change. Recommended Safety Barrier Height is 3 inch minimum over the whole width of the platform.

2.1.2.4 Side Plate Height

Reference 2 recommended that portions of the lift platform that project outside of the bus should have vertical side plates no less than 2 inch high. This recommendation is based on demonstrations conducted by the California Department of Transportation. Given the misalignment possible in maneuvering in the transit environment, or alternatively, the need to align the wheelchair on to a narrow platform, this seems to be a reasonable requirement and should be adopted. Recommended Side Plate Height is 2 inches over those portions of the deployed platform that project beyond the vehicle.

2.1.2.5 Platform Ramp Angle

Excessive ramp angles at the ends of platforms have caused several accidents as noted in Reference 3. The only specific recommendations found in the literature were in Reference 6 which calls for a maximum 1:6 (9.4 degrees) provided that the ramp is not so long as to allow both sets of wheels upon it. Under these latter circumstances, the architectural standard of 1:12 (4.8 degrees) would apply. Experience has shown that existing lifts with entry ramp angles substantially in excess of the higher of the above recommendations have been strongly criticized and, therefore, a value of 1:6 appears to be an acceptable upper limit. Recommended Ramp Angle = 1:6 (9.4 degrees) maximum.

2.1.2.6 Platform Vertical Discontinuity

Wheelchairs, particularly manually operated ones, are very sensitive to vertical discontinuities whether they be depressions or steps. References 2 and 7 call for a maximum discontinuity of 0.25 inches. Reference 6 reports that subjective tests indicate that the maximum step height climbable with a manual chair is 0.625 inches. However, as noted in the previous paragraph, this same source indicated that short ramps (approximately 3 inches) with slopes in excess of 1:6 were difficult to climb with manual chairs and jolted the occupants of electric chairs. They postulated that this was because such short ramps had more of the characteristics of a step rather than a slope. The "step" approximated to 0.5 inches, thus the practicality of the figure of 0.625 inches from the same reference must be treated with some reservation.

The ANSI standard is 0.5 inches maximum. The 321(b) Rail Retrofit Evaluation Summary Report - Light and Commuter Rail Systems (Reference 8) also established a maximum standard of 0.5 inches based upon geometrical analysis and the application of upper limit forces from the forearms when applied to the wheel rims. Since experience has shown that this dimension is extremely critical to easy use of the lift, the lowest value should be used. <u>Recommended Vertical Discontinuity = 0.25 inch maximum</u>.

2.1.2.7 Platform Horizontal Discontinuity

Reference 2 recommends a maximum value for a horizontal gap of 0.625 inches. Based on its own tests, the V.A. (Reference 6) recommends that any gap reject a 0.75 inch diameter steel ball. This is also the value used elsewhere to define maximum grating openings that will reject a walking aid. The ANSI standard is 1.0 inches. Given that the gap is likely to increase with wear and tear on the vehicle it would seem prudent to select the lowest possible initial value. <u>Recommended Horizontal Discontinuity = 0.625 inch maximum</u>.

2.1.2.8 Handrail Dimensions

It is generally accepted that handrails should be provided that may be used by both seated and standing passengers on the platform. This implies a vertical height range. The lower limit is set by considering the armrest height of the wheelchair (approximately 30 inches for most chairs) plus clearances and allowance for the thickness of the arm and gripping. Reference 1 allows 5 inches for clearances/allowances which leads to a minimum height of 35 inches. Handrail structure for support can be provided below this height provided the design does not allow a chair to become jammed in it or unnecessarily restricts the effective platform width. The upper limit would be set by the comfortable standing grip for a 95th %ile male and would be in the range of 50 inches assuming a horizontal forearm. The depth (from the in-board end of the platform) should allow for an easy grip by a wheelchair user facing in either direction. The position of the hand will be in the range of 25-30 inches forward of the rear wheel extremity and 15-20 inches behind the footrest extremity. The larger dimension is the governing one which represents the minimum distance necessary to afford grip to an outward facing wheelchair user.

The size and cross section of the handrail will be a compromise between a number of requirements. Larger flatter surfaces are better suited for gripping by those with arthritis or larger stature. Smaller sizes are required where hand size is not large. The generally accepted norm is a 1.5 inch diameter tube. This is the recommended size, but the rail can also be padded to provide an increased diameter grip at strategic points.

Recommended Handrail Height Range	=	35 to 50 inches
Recommended Handrail Depth	=	30 inches minimum forward of the rear of platform
Recommended Handrail Size	=	1.5 inches minimum with some areas padded to 2.5 inches

2.2 MOTION RELATED CONSIDERATIONS

The quality of the ride experienced upon the lift platform under steady state and acceleration conditions is a major factor in determining the acceptability of the installation by consumers.

2.2.1 Platform Flexibility

The overall stiffness of the platform when raised above ground level will control the degree of droop and springback experienced by a rider. Both are psychologically distressing in themselves and could induce unwanted motion of the chair and its occupant. Reference 2 recommends a slope no greater than 1:24 with a uniformly distributed load of 395 lb. for an unattended chair. It is assumed that with the extra security of an attendant a greater slope would be tolerable. Reference 6 recommended 1:16 with a 400 lb. load at the center of the platform, primarily on the basis that this slope was significantly less than the maximum ANSI ramp angle (1:16). The author's own experience indicates that slopes of the order of 1:30 can induce motions in a manual chair and occupant weighing 200 lb. Therefore, the stricter standard of Reference 2 is recommended.

Recommended Maximum Droop of a Raised, Extended Platform on a Level Vehicle is a slope of 1:24 with a uniformly distributed 395 lb. load.

2.2.2 Tread Flexibility

Where a passive lift is composed of the step tread and riser elements it is necessary to maintain the stiffness of the tread as the unsupported width increases. This must be done for the security of both ambulatory and wheelchair persons. No account of this factor was found in the literature, but it can become of increasing significance in the wider doorways of LRVs, since deflection is proportional to the cube of the unsupported span. This could result in deflections five times greater than now experienced. As a minimum, the deflection should not induce a vertical discontinuity greater than the 0.25 inches, as recommended in 2.1.2.6 by either a footload in the lift in the stowed position or a wheelchair when the lift is deployed. In practice, the stiffness may well be determined by considerations of fatigue loading and, hence, component longevity.

2.2.3 Platform Speed

Consideration must be given to normal operational speed and to free fall speed in the event of a major system failure.

2.2.3.1 Normal Operating Speed

Reference 1 quotes two sources with a maximum recommended speed of 20 and 11.8 feet per minute. The higher speed is recommended provided it can be easily obtained without exceeding the acceleration levels quoted later. The higher speed will minimize the lift cycle time.

Recommended Maximum Lift Speed = 20 feet/minute

2.2.3.2 Free Fall Speed

Reference 2 defines the free fall speed as twice the normal operating descent speed. Reference 1 reduces this factor to 1.5 based upon an operating speed of 20 feet per minute. Both assume a design load of 600 lb. Either would result in quite a hard landing although it is unlikely that the design load will be in place. The lower factor is recommended to minimize any chances of injury.

Recommended Maximum Free Fall Speed = 30 feet/minute with a 600 lb. design load in place

2.2.4 Platform Acceleration and Jerk

Motion of the platform should at all times be free from jerking. All references have adopted the value arrived at by the VA in its tests of a maximum of 0.3 g in the vertical or horizontal direction with loads of the order of 375-400 lb.

Recommended Maximum Acceleration Level is 0.3 g with a 375 lb. design load

2.3 INSTALLATION RELATED CONSIDERATIONS

A number of general recommendations may be stated from the literature that relate to the users' safety and well being.

2.3.1 Avoid shear areas or pinching action mechanisms wherever possible in the lift design and installation. Where unavoidable they should be separated by a physical barrier or enclosure. Alternatively, safety stop switches restricting the operating force of the mechanism involved below that which would cause injury should be installed.

2.3.2 Avoid sharp protrusions or moving parts that can snag on clothing.

2.3.3 Avoid exposed bearing surfaces, chain and cables etc. that can deposit dirt, oil, grease upon users.

2.3.4 Lift platform surfaces must be of non-skid material.

2.3.5 Lift platform edges should be boldly color discriminated.

2.3.6 Any exposed edges or hazardous protrusions within the passenger compartment must be padded.

2.3.7 The deployed platform in the down position shall have no less than 3 foot candles of illumination at the platform surface.

2.3.8 An auditory and visual warning system shall be installed and activated 3 seconds prior to and throughout the lift cycle.

2.3.9 The vehicle will be prevented from moving by a positive interlock whenever the lift system is activated.

3. LIFT MECHANISM FACTORS

The main concern with the assessment of lift design integrity is in establishing consistent and realistic criteria for design loads, design safety factors based upon accepted engineering practice for the various types of mechanisms, and proof and endurance testing procedures to ensure a reliable product.

3.1 DESIGN LOADS

References 1, 2, and 6 have all addressed the question of appropriate design load and safety factors for the wheelchair lift structure and mechanism, using essentially the same data sources. Differences arise, however, from the way the data is interpreted. The California Highway Patrol's Adopted Wheelchair Lift Regulations for Buses, July 9, 1979 (Reference 7) also addresses these issues and compliance with its code is a minimum standard for operation within the State of California. The work of the Veterans Administration (Reference 6) represents a different perspective because it was directed toward lifts for use in converted vans for personal transportation.

3.1.1 Design Lifting Load

There is general agreement (References 1, 2, and 7) that 600 lb. representing a powered chair, occupant and attendant is a satisfactory design lifting load. Therefore, this criteria is adopted.

3.1.2 Platform Static Deformation Load

Reference 2 developed the criteria for platform static droop previously discussed in Section 2.2.1. The load of 375 lb. is based on a 95th %ile male in a powered chair, and the load is uniformly distributed.

3.1.3 Safety Barrier Load

The Veterans Administration (VA) concluded after a series of tests that a 3 inch high barrier was the minimum needed and calculated a force at the barrier lip of 267 lb. with an electric wheelchair with 20 inch tires and a 170 lb. occupant (Reference 6). Scaling proportionally for a 225 lb. (95th %ile male) occupant would result in a force of 313 lb., all other factors remaining unchanged. The California Highway Patrol (Reference 7) adopted a force of 300 lb. applied 2.8 inches above the platform. A load is not defined by Caltrans in Reference (2), but it does define a performance standard for the restraint of a rolling wheelchair which may be compared to that of the VA as follows:

Reference	2 (Caltrans)	6 (VA)
Weight of Chair and Occupant	375	320 (estimated)
Slope Gradient (degrees)	3	5
Distance Traveled (feet)	3	1
Terminal Velocity (ft./sec.)	2.6 (estimated) (approx.)	3-3.6
Wheel Diameter (inches)	24	20

Overall it would appear that the two tests would be expected to yield similar results allowing for the differences in weight, velocity, and wheel size. Since this is such a critical safety area, it is prudent to err on the side of caution and, therefore the adopted minimum load criteria should be 300 lb. (Reference 7).

All the references assume that the height of the safety barrier will be approximately 3 inches and, consequently, apply the test load at this height and parallel to the lift platform surface. Several instances do exist, however, of barrier that are significantly higher than 3 inches. In these cases, the barrier would experience the same 300 lb. load in stopping the chair, but the torque reaction applied to the barrier would be increased in proportion to the height of the point of impact above the lift platform. Since a maximum wheel diameter of 24 inches must be considered, it is safe to assume that the contact point will be the upper edge of the safety barrier regardless of its height and, therefore this should be the point of load application.

Recommended application of the safety barrier test load is parallel to the lift platform at a height above the platform equal to that of the safety barrier lip. This will provide a criterion more conservative than current standards.

3.2 DESIGN FACTORS

References 1, 2, and 6 cite a number of mechanical and structural design safety factors based on existing ANSI standards. Since these standards use different values depending on the type of mechanism, material, and structure used, the references cite average values. The differences between the cited safety factors arise from individual judgements on an acceptable margin for use in wheelchair lifts. The major standards may be summarized as follows:

- ANSI A17.1-1971 (Elevators, Dumbwaiters, Escalators, and Moving Walks)

This standard cites the following factors of safety for elevator structural component regardless of elevator speed.

a. Five (5) for frame members and their connections.

b. Four and four-tenths (4.4) for platform framing.

c. Three and six-tenths (3.6) for platform stringers.

- ANSI, A10.4-1975 (Safety Requirements for Personnel Hoists): which lists the following factors of safety for load bearing mechanisms.

a. Seven and four-tenths (7.4) for suspension rope with an elevator speed of 20 fpm (the approximate anticipated speed of wheelchair lifts).

b. Eight (8) for steel, bronze, or for other materials having an elongation of at least fourteen (14) percent in a length of two (2) inches.

c. Ten (10) for cast iron, or for other materials having an elongation of less than fourteen (14) percent in a length of two (2) inches.

Also cited by Reference 6 are:

ANSI B30.9-1971: Safety Standard for Cranes, Derricks, Hoists, Hooks, Jacks, and Slings

ANSI B153.1-1974: Safety Requirements for the Construction, Care, and Use of Automotive Lifts

which cite safety factors of 5 and 6 respectively.

Using the data above, Reference 1 adopted a mechanical design factor of 8 and a structural factor of 4 as minimum; Reference 2 and 7 adopted a minimum mechanical factor of 6 and a minimum structural factor of 3; and Reference 6 an overall factor of 6. The lower factor (as compared to the cited standards) are generally rationalized on the expectation of a less stressful operating environment for lifts based on their lower overall operating speed compared to that for elevators. At the present time, there is no established body of long term operating history for wheelchair lifts such as there is for elevators. Under these circumstances and given the need for rigidity and low stress levels to promote reliable operation and long life, the use of a factor as low as 3 would seem to err on the optimistic side. Therefore, it is recommended that a minimum overall design safety factor of 6 be used. Where compliance with a higher standard is clearly indicated that standard should be adopted for the item in question.

3.3 DESIGN TESTS

References 2, 6, and 7 address the question of proof tests for overall structural soundness and cyclic endurance testing to ensure overall product reliability and acceptability.

3.3.1 Static Load Test

The California Highway Patrol uses a proof load of 1.5 times the design load uniformly distributed around the center of the platform within an area not to exceed 24 inches by 24 inches. This gives a load of 900 lb. within the specified area.

The Veterans Administration specifies a static load of 2400 lb. which is based on a factor of safety of six times the rated load of 400 lb. The load is applied through a test pallet 23 inches by 24 inches at the centroid of the platform for not less than 2 minutes. This test is to be conducted after the cycling test (see next paragraph). This seems an excessively high load since the original safety factor was developed on the basis of ultimate material strength. Thus, although failure may or may not occur, permanent deformation could be induced which would inhibit or degrade future lift performance. Thus, satisfactory compliance with this test may not define the effective upper limit of useful lift structural capacity.

It is, therefore, recommended that the static load test should require that:

1) The lift should withstand a load of 4 times the design load without incurring permanent deformation or damage to render it inoperative when subsequently cycled (once) with the design load.

2) The lift should withstand a load of 6 times the design load without fracture when the load is applied to the deployed platform (at vehicle floor level) for not less than 2 minutes.

3) In both cases, the load will be uniformly applied over an area not to exceed 24" x 24" at the center of the platform.

3.3.2 Cyclic Load Test

Table B-1 summarizes the cyclic testing procedures proposed in the references. The CHP procedure is basically a rearrangement of that originally proposed by Caltrans. In both cases, the loaded only refer to vertical movement and the unloaded cycles to the stow/deploy motions. The total of 15,600 cycles is arrived at on the basis of 3 years at 5,200 cycles per year. This estimate is based on a three year useful life for a special services van making 20 wheelchair trips per day, 5 days per week and was derived following a limited telephone

TABLE B-1. CYCLE TEST PROCEDURES

REFERENCE NUMBER	CYCLES	LOAD	CONDITIONS
2 (CALTRANS) Caltrans	10,000 15,000 600	0 375 600	Test may be intermittent with $\leq$ 1 minute between every 10 cycles. Ambient temperature $\geq$ 110°F for at least 50% of cycles.
	10	0	Ambient temperature $\leq$ 20°F. Presoak for 5 hours. Rest for $\geq$ 30 minutes between each cycle.
	2	0	With limit switches inoperative. Power maintained for 5 seconds at rest positions.
7 (CHP) Sequence	600 15,000	595 375	Ambient temperature in first half of each of these tests will be at least 110°F. Tests may be continuous or intermittent with $\leq$ 1 minute between groups of $\geq$ 10 cycles. Vertical and horizontal accelerations shall not exceed (0.3 g) during first and last 5 cycles.
	10,000	0	Temperature and rest period as above.
	10	0	Ambient temperature $\leq$ 20°F. Presoak for 5 hours. Rest for $\geq$ 30 minutes between each cycle.
	2	0	With limit switches inoperative. Power maintained for 5 seconds at rest positions.
6 (VA) Sequence	100 100	400 0	Total of 4,400 cycles in alternating batches of 100 loaded and unloaded cycles with $\geq$ 6 minutes between each cycle. Ambient temperatures between 50° and 90°F.

survey of local operators. The VA figure of 4,400 cycles represents estimates of 2 years usage based on discussions with individuals with personal van installations. The anticipated per vehicle daily usage would be much lower than the above for transit services, but the expected operational life would be significantly greater.

The impacts of temperature are biased toward the high temperature range, and the impacts of precipitation in the form of snow or rain or road splash are not considered. This is hardly surprising, since such factors would be greatly influenced by the actual vehicle installation and the CHP/VA procedures are basically designed as tests of the lift and its systems only.

<u>Therefore, it is recommended that the initial criteria for basic acceptability for a lift to be adopted to the LRV is satisfactory performance of the CHP cycling test with the caveat that a further evaluation for other environmental impacts will be conducted by considering the proposed vehicle installation as a whole</u>.

3.4 DESIGN STANDARDS

The VA report (Reference 6) contains a detailed discussion of accepted industry standards, practices, and references for various components and materials. It would seem appropriate that compliance with these should constitute a set of evaluation criteria for individual design acceptability. Therefore, the discussion in Reference 6 is summarized in the following subsections.

3.4.1 Electrical Components and Wiring

Electrical components and wiring shall conform to the Society of Automotive Engineers Standards or Recommended Practices as applicable including those listed below:

- o SAE J258, SAE J553C: Circuit Breakers
- o SAE J537H: Storage Batteries
- o SAE J538a: Grounding of Storage Batteries

- SAE J554a: Electric Fuses
- SAE J556: Automobile Wiring
- SAE J561B, SAE J85a, SAE J928a: Electrical Terminals

3.4.1.3 Electrical components which are exposed to the environment outside the vehicle shall be protected by a suitable weatherproof enclosure.

3.4.1.4 Externally mounted wheelchair lift controls shall be installed so that they are weatherproofed by the use of inset compartments or protective coatings. Controls shall be protected from misuse or vandalism by the use of key locks or key switches. Controls shall be located so that the operator of the controls will be well clear of the moving doors and lift mechanisms and in a position which will allow observation of lift movement.

3.4.1.5 A solenoid or other device shall be designed into the power circuit to ensure that no electrical component on the lift has voltage applied to it until a lift operating control is actuated.

3.4.2 <u>Hydraulic Components</u>

3.4.2.1 Hydraulic components shall conform to the following Society of Automotive Engineers Standards or Recommended Practices as applicable.

- SAE J514h: Hydraulic Tube Fittings
- SAE J516a: Hydraulic Hose Fittings
- SAE J517c: Hydraulic Hose
- SAE J518C: Hydraulic Flanged Tube, Pipe and Hose Connections, 4-Bolt Split Flange Type

3.4.2.2 Hydraulic hoses shall be adequately supported and protected from bearing or rubbing on structural components.

3.4.3 Mechanical Components

3.4.3.1 Chain drive components shall conform to either: ANSI B29.1 - 1963 (R1972), Transmission Roller Chains and Sprocket Teeth (for standard base series chain), or other ANSI standards applicable to specialized use chains.

3.4.3.2 A power screw system even when disconnected from the driving source should not allow the platform to exceed the acceleration specification by more than 50%.

3.4.3.3 A power screw system shall transmit power in both directions. Power screws shall be of the Acme screw thread type in conformance with ANSI B1.5 - 1973, Acme Screw Threads, ANSI B1.8 - 1973, Stub Acme Threads, or equivalent. The 60 degree (V-type) thread shall not be used as a power screw.

3.4.3.4 The lift designer should ensure that the power screw is checked for long-column conditions and that an appropriate column design formula is used.

3.4.3.5 Wire rope systems shall be designed and fabricated using rope and support components of proper dimensions and arrangement. Industry standards and specifications relating to wire rope components are generally for larger, and higher capacity systems other than wheelchair lifts. However, the design principles of wire rope systems in general are applicable to wheelchair lifts; therefore, the principles given in the following documents should be employed in lift design.

o ANSI A120.1 - 1970 - Safety Requirements for Powered Platforms for Exterior Building Maintenance, Section 14.8, "Drums and Sheaves," and Section 15, "Hoisting Ropes and Rope Connections."

o ANSI B30.2.0 - 1967 - Overhead and Gantry Cranes, Section 2-1.10, "Hoisting Equipment."

o Mc Elroy, Frank E. (ed): Accident Prevention Manual for Industrial Operations. 6th Edition, National Safety Council, Chicago, IL, 1969, pp 641-657.

- Rossnagel, W.E.: <u>Handbook of Rigging</u>, 3rd Edition, McGraw-Hill Book Company, New York, NY, 1964, pp 41-83.

- Wire rope manufacturer's recommendations. If the manufacturer/designer chooses not to use the documents specified above for design guidance, then these specifications shall be used:

- Material. Wire rope material shall be galvanized carbon steel (aircraft cable quality), Type 302 stainless steel, or equivalent in strength and corrosion resistance and so certified.

- Construction. Wire rope shall be of 7 x 19 construction.

- Sheaves. Sheaves shall be grooved with a minimum groove diameter of 25 times the nominal wire rope diameter. Grooves shall be shaped so as to saddle the rope with a 150 degree arc of support. The radius of curvature of the groove shall be one-half the nominal rope diameter plus 1/32 inch (0.8 mm). The sides of the groove shall be tangent to the groove arc. The total depth of the groove shall be between 1.5 and 2.0 times the nominal rope diameter. Material shall be aluminium alloy 2024-TS, or equivalent.

- Attachments. When a wire rope is formed into an eye as a removable method of attaching the rope to equipment, a thimble shall be used inside the eye, and at least two U-bolt clips shall be attached to the doubled rope. The U-bolt portion of the clips shall bar upon the dead end of the rope, with clips spaced not less than six (6) rope diameters apart. One clip shall be as near to the thimble as possible.

- Fittings. The lift manufacturer shall provide, upon request, a rope manufacturer's certification that permanent rope fittings have not less than 90% of the rope manufacturer's stated rope strength.

- Drums. Drum diameter shall not be less than 25 times the nominal rope diameter. It is desirable that there be only one layer of rope on the drum, but the maximum number of layers shall be three. Helically grooved drums should be used to minimize crushing and excessive wear of the rope. The dimensions of such grooving shall be that of the sheave grooving, with the exception that the total depth should be approximately 0.2 times the nominal rope diameter. There shall be at least one turn of rope on the drum when the wheelchair ground plane is at ground level.

- Alignment. The drum and lead sheave shall be aligned to control lateral movement of a wire rope when winding on a drum. The flee angle shall not exceed 1 1/2 degrees. The same maximum angular relationship shall exist between centerlines of adjacent sheaves.

- Orientation. The design of the wire rope system should avoid reverse bending of the rope. The wire rope shall not bear on any portion of the lift framework.

3.4.4 Fabrication

3.4.4.1 Weldment design and fabrication used in a wheelchair lift shall conform to Sections 1, 2, 3, and 4 of the American Welding Society Structural Welding Code, D1.1-72 (for steel construction) or to the AWS Recommended Practices for Gas Shielded Are Welding of Aluminum and Aluminum Alloy Pipe, D10.7-60, as applicable. It should be noted that the AWS code D1.1-72 is for steel construction and D10.7-60 is for aluminum alloy pipe. However, code D10.7-60 is general enough relative to welding techniques, bead dimensions, filler materials, and other factors to be applicable here.

3.4.4.2 All fasteners used shall conform to the Society of Automotive Engineers Standards or Recommended Practices as applicable.

3.4.4.3 All fasteners used shall be designed or treated for resistance to vibration.

3.4.5 Coating and Finishing

Corrosion of ferrous metal wheelchair lift components can be expected as a result of contact with atmospheric moisture, road de-icing salt solutions, mud, and possibly other corrosive agents. Ferrous metals shall be protected from such corrosion by the application of protective coatings. The surfaces shall be prepared for the chosen coatings and the coatings applied in accordance with the following minimum requirements:

3.4.5.1 Surface preparation. Residues such as oil, grease, dirt, weld slag, mill scale, and rust shall be removed from the surface. Solvent or solvent vapor cleaning shall be used to remove residues prior to removal of rust and scale. The degree of rust and scale shall be determined by the methods of ASTM D2200-67 (1972), Pictorial Surface Preparation Standards for Painting Steel Surfaces. The surface shall be cleaned to condition "St 2" (Scraping and wire brushing, thorough) or "Sa 2" (Blast cleaning, thorough) as given in ASTM D2200-67 (1972). Surfaces, thus, cleaned shall be prime coated not more than twenty-four (24) hours later.

3.4.5.2 Primer coat. At least one primer coat containing rust inhibitive pigments shall be applied to the cleaned surface. A coating thickness of 1 mil (0.03 mm) to 1 1/2 mils (0.04 mm) is adequate.

3.4.5.3 Color coat. Two or more coats of corrosion and abrasive resistant flat finish shall be applied. Flat finish is preferred to minimize glare.

3.4.5.4 Finish coating colors which have a coefficient of absorption equal to or less than 0.55 shall be chosen to minimize solar radiation absorptivity of the lift framework (e.g. white (0.25), light cream (0.35), light yellow (0.45), light gray (est., 0.4), light green (0.50), aluminium (0.55)) wherever there is a significant possibility of contact with bare flesh.

4. VEHICLE INSTALLATION FACTORS

A number of factors must be assessed in evaluating the practicality and ease with which specific lift designs may be accommodated within a given vehicle. There will also be an interaction between the vehicle, the lift, and the operating system's requirements which will be addressed in a separate section of this analysis. This section will address the vehicle related issues under the headings of equipment, structural, and doorway considerations.

4.1 VEHICLE EQUIPMENT

A number of issues must be addressed with regard to the provision for accessibility equipment and possibly the relocation of existing installations.

4.1.1 Underfloor Areas

Depending on the specific lift design, a clear area under and around the existing steps will be required for two reasons. First, to provide room for the installation of the lift mechanisms, and second to allow unimpeded motion of the lift when it is deployed. These must be evaluated for each lift design to allow for those requirements that are unique to each design and its type of movement (e.g. vertical elevator or deployed platform motions). The most critical installation will generally be one involving a front door where clear space will be limited by bogie and coupler movements, major structural components, and equipment items. The situation is often further complicated by the front end taper to reduce the swept area for which clearance must be provided in tight turns. Minimum underfloor space requirements for the lift will, therefore, be an important assessment criterion for a specific lift design/vehicle combination.

Underfloor space is also required for control and power systems. The major lift candidates are all hydraulically operated and power on bus installations is generally derived by tapping into a power steering system or by providing a separate circuit and pump system. LRVs do not generally use hydraulic systems (the Boeing LRV has a hydraulic braking system) and, therefore, space will have to be provided for a motor/pump/reservoir system powered from the vehicle electrical system. The preferred location would be an underfloor installation, but an underseat installation could be considered if a suitable external access panel can be provided to allow accessibility for maintenance purposes.

4.1.2 Passenger Compartment Areas

All installations may require some rearrangement of the passenger compartment to provide wheelchair stations and tie-downs. The interior arrangement will be largely independent of the individual lift design except for the elevator type. Elevator type lifts require towers that protrude into the doorway areas. Their presence, particularly in tapered front end installations, could significantly influence the maneuvering space and requirements for a wheelchair.

In most LRVs, there are existing seats where the underseat area is being used for some other functional purpose (e.g. sandboxes, signal, and control equipment). The impact on the lift installation, in this case, is not on the lift itself, but rather on the choice of doorway for an installation that will minimize the equipment relocation needs.

4.1.3 Vestibule Areas

Installation of a lift in the front door of an LRV could have an impact on driver visibility, fare collection, emergency equipment storage, and other activities in the vestibule area. Each of these activities should be assessed as part of the installation considerations.

Driver visibility is an important consideration. The presence and location of towers or other equipment that interfere with the driver's vision must be carefully assessed. This is true for a remote center door as well as for a front door installation, since in the former case the drivers view of normal center door usage by ambulatory passengers could be hindered.

All U.S. light rail systems feature onboard fare collection on some parts of their routes. Payment may be made upon boarding or alighting, thus, requiring right or left hand access to the farebox by a forward moving wheelchair patron. The fare box itself has a significant space requirement and location priority to ensure effective monitoring by the driver.

The area immediately ahead of the stepwell may also be used to house or provide access to a variety of equipment, including fire extinquishers or other emergency equipment, pantograph operators, control circuits, fuse boxes, headlights, etc. Maintaining quick and easy access to this area is an important criterion against which to assess the suitability of individual lift/vehicle installation combinations.

4.2 DOORWAYS

A number of aspects must be considered in assessing the ease with which a passive lift may be installed within an existing doorway and which, therefore, will have a bearing on the overall suitability of the design for this purpose.

4.2.1 Doorway Clear Opening

The doorway must be adequate to allow installation of platforms with widths consistent with the dimensions established in Section 1 of this report. Generally speaking, doorway width is not a problem since most LRVs feature double width doors for ease of loading. The known exceptions are the Kawasaki cars purchased by SEPTA, where two adjacent, but structurally separate, single bay doors are used, neither of which is of adequate width for a lift installation. However, none of the double doors on any vehicle appear sufficiently wide to allow an adequate wheelchair lift installation in one half of the door.

4.2.2 Doorway Height

The height of the doorway above the vehicle floor line is critically important because it determines the clear headroom with the lift platform in the raised position and hence allows the use of the lift by ambulatory and attendant persons. A minimum of 78 inches which is consistent with normal transit vehicle interiors would be an acceptable criterion against which to assess existing configurations. Failure to meet this criterion would require changes in door structures, operating mechanisms, and controls. Doorway height is, however, a function of only the vehicle design and not of the wheelchair lift design.

4.2.3 Doorway Orientation

The effective width of the end doorway available for a lift installation may be reduced by the vestibule and stepwell configuration on an LRV with tapered ends. The taper will also affect the extent to which the platform protrudes beyond the vehicle and hence its ability to bridge a gap to an island curb or to reach level ground outside of the vehicle railbed.

4.2.4 Tread and Riser Configuration

There are various types of lift designs including those that use a two and three step/riser configurations, and those that deploy platforms and are, therefore, independent of the stepwell configuration. Similarly, LRV designs vary between two and three step configurations. Thus, the adaptation of specific passive lifts may vary between the individual LRV designs. Since adoption of existing designs or at most minimum changes is the goal of this project, the ease of mating of designs and step configurations will be an important assessment criterion.

4.3 STRUCTURAL INTEGRITY

The LRVs under consideration feature a diversity of construction techniques and materials, including stainless and corrosion resistant steels, carbon steels and aluminum alloys. Therefore, there is a corresponding variation in contributions of underframe and body structures to the static and dynamic strengths and stiffnesses. Experience with transit buses shows that installing wheelchair lifts generally result in some loss of strength around the door areas. This is particularly critical in front door installations where the susceptibility to collision damage may be substantially increased. Thus, a primary criteria in assessing the acceptability of a lift installation will be the magnitude of the modifications to maintain adequate structural integrity.

5. OPERATIONAL FACTORS

This discussion centers on the selection of the most suitable location for a lift in an LRV. In those situations where more than one lift is required on an LRV, it is necessary to consider both operational factors and user convenience. Any lift installation will require consideration of a number of internal configuration (e.g. seating) changes. If the mechanical complexity and cost of installing a lift is substantially different for various locations, the decision is likely to be the simplest and lowest cost installation. Otherwise, there are enough variables and site specific factors which require trade-off analyses by a purchaser. Some of the major considerations in the placement and selection of lifts for LRVs have been developed by McInerney (Reference 5), and the following discussion draws and builds upon that work.

Vehicle operational impacts are based upon the physical characteristics of the vehicles which are currently in use and those which are expected to be in use in the near future. The vehicles considered in the requirements analysis for this study include PCC cars, Boeing, Breda, DuWag, and Kawasaki LRVs. These cars can be divided into the non-articulated -- PCC and Kawasaki -- and the articulated -- Boeing, Breda, and DuWag.

The PCC cars in all locations, except Boston and the Media/Sharon Hill lines in Philadelphia, are configured for uni-directional operation and single side entry. These vehicles have two doors as shown in the graphic representation in Figure B-1. The Boston PCC cars are configured with two center doors, as represented in Figure B-2, because they operate in an LRT system with either side entry. The Philadelphia (Media/Sharon Hill) cars (which are really considered quasi-PCCs) are configured with doors on the left hand side behind the driver as represented in Figure B-3. These cars are bi-directional and must provide for either side entry due to operating conditions. (In fact, the Media/Sharon Hill Fleet in Philadelphia is of little interest since the vehicles have been retired with new Kawasaki double-ended vehicles now in service.) The representation in Figure B-3 is also valid for these new Kawasaki cars. Another new non-articulated vehicle is the Kawasaki single-ended car which has been placed in service on those segments of the Philadelphia system which previously used the single-ended PCC cars. The single-ended Kawasaki car is represented by the diagram in Figure B-1.

The articulated cars all have similar physical configurations -- there is one door at each end and four center doors. This vehicle and door arrangement is shown graphically in Figure B-4. This type of door arrangement allows for considerable flexibility since the vehicle can be used in any type of operational situation.

The requirements for the single side entry uni-directional vehicle (Figure B-1) are completely straightforward. Only one lift is required with the preferred location at the front entrance. A front entry installation allows the driver to observe and monitor the lift operation without having to move from the seat.

The either side entry uni-directional PCC car used in Boston (Figure B-2) requires that a lift be placed at the front of the vehicle and one at the center door on the opposite side. The crossover path length for a wheelchair user is

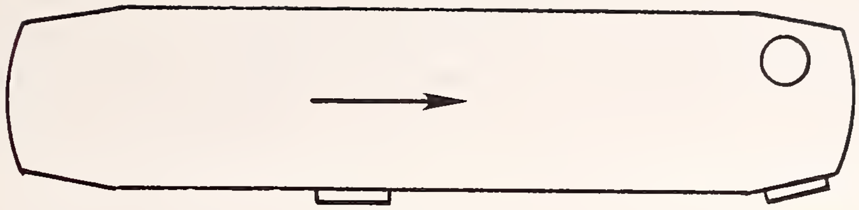


FIGURE B-1

UNI-DIRECTIONAL SINGLE SIDE ENTRY
(PCC, KAWASAKI - PHILADELPHIA CITY TRANSIT DIVISION)

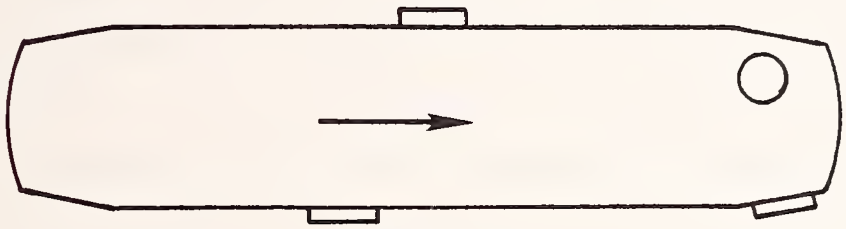


FIGURE B-2

UNI-DIRECTIONAL EITHER SIDE ENTRY
(PCC BOSTON)

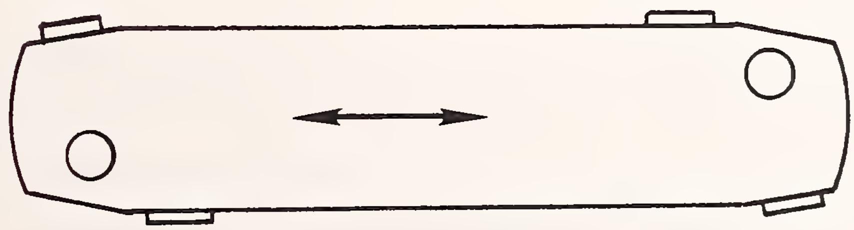


FIGURE B-3

BI-DIRECTIONAL EITHER SIDE ENTRY
(PCC, KAWASAKI-PHILADELPHIA RED ARROW DIVISION)

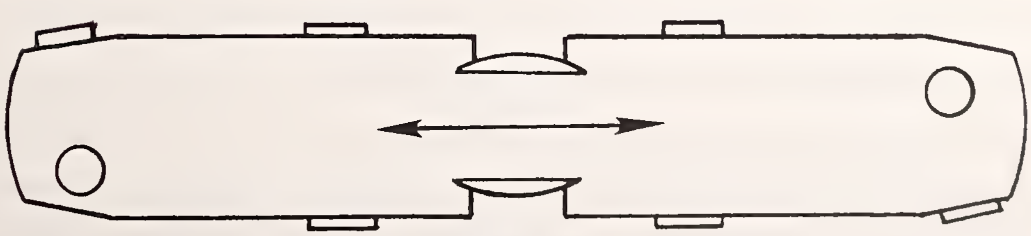


FIGURE B-4

ARTICULATED BI-DIRECTIONAL EITHER SIDE ENTRY
(BOEING, BREDA, DuWag)

the distance from the front entryway to the side entryway. A short crossover path length is more convenient for the wheelchair user, especially when the vehicle is crowded.

The bi-directional Kawasaki vehicle (SEPTA-Red Arrow Division) illustrated in Figure B-3 requires lifts on both sides of the vehicle. The recommended locations for the lifts are at the ends of the vehicle. The very narrow door directly behind the driver's seat makes it extremely difficult to install a lift of reasonable dimensions without extensive structural change. The use of left side entry at SEPTA is limited to only two stops. Therefore, it may be possible to avoid having the wheelchair user traverse the entire vehicle length at those two stops by making some small changes in operating procedures.

The articulated Boeing LRV is used in Boston as both a uni-directional and bi-directional vehicle depending upon the particular route. The requirement for either side boarding automatically means that lifts must be installed on both sides of the vehicle, and wheelchair users will have to crossover when using certain station pairs.

The trade-off is basically between installation of lifts at the ends of the vehicle with a long crossover path, and the placement of lifts at opposing center doors to minimize the path length. A hybrid solution involving one front and one center installation is not recommended because it would not resolve the trade-off, and it would result in a change of boarding/alighting locations for wheelchair users when the vehicle is used in a bi-directional mode. Similarly, a solution which involves the use of four lifts is seen as an excessively expensive approach.

It appears that the installation of a lift for both the front and the center door should be considered for the Boston situation. If the complexity and costs for either installation are relatively close then it is recommended that the front door installations be considered as the best choice. In most instances, the crossover situation will not be encountered, and when it is, the driver may have to leave his/her seat to create a clear path for movement of the wheelchair. Under crowded situations the movement of a wheelchair along the whole length of the vehicle is seen to be only slightly more onerous than a movement across nearly one-half the vehicle length. There will probably be some degree of self-regulation on the part of wheelchair users to avoid peak periods.

If the center door location for the lift installation is found to be considerably less complex and costly, the above recommendation may have to be reconsidered.

The situation with the Boeing LRVs in Muni-San Francisco is unique. The center doors are equipped with a special high/low entry arrangement where the steps for low platform entry can be converted into a level entry floor for high platform operation. The use of a lift in conjunction with the high/low entry arrangement would require consideration of new lift mechanisms which are beyond the scope of the present project. Therefore, the Muni LRVs will require a lift at each end of the vehicle to satisfy requirements for bi-directional operation. The only crossover which will be required in that system is a movement to the closest level entry center door which will automatically provide the shortest path length.

The physical configuration of the Breda vehicle (Cleveland) is generally the same as the Boeing LRV with the exception that the front door entry area is parallel with the rest of the vehicle rather than being on a taper. The operating situation in Cleveland is uni-directional with a single side entry. Under this operating condition only one lift is required per vehicle, and the preferred location for the lift is at the front.

In summary, the non-articulated vehicles require front door lifts for all single side entry vehicles. Boston PCCs require lifts at the front and the left side center door locations. Bi-directional vehicles, such as the Kawasaki vehicle for Philadelphia require lifts at both car ends. End door lifts are also the preferred location in all situations involving articulated LRVs. In the unlikely event that a center door installation is found to be considerably less complex and costly than an end door location, the Boston LRVs (as an exception) should have opposing center door lifts.

APPENDIX C

LIFT INSTALLATION ON BREDA LRV

APPENDIX C

LIFT INSTALLATION ON BREDA LRV

The six doorways all have the same dimensions and orientation on the Breda LRV, and the frame structure is the same relative to each stepwell. Thus, lift installation would be the same at any doorway. Cleveland, at present, is the only U.S. operator of Breda LRVs. The Cleveland system does not have any high platforms, but has some left side boarding situations. The two possible alternatives for lift arrangement or other accessibility arrangements are basically the same as those discussed in the report. One alternative is front door lifts for right side accessibility and lifts at the closest left center door for left side accessibility for a total of four lifts per vehicle. The other alternatives are front door lifts and mini-platforms or wayside lifts for the few left side boarding locations. Potential problems with these approaches are discussed in the report.

The internal changes required on the Breda LRV are straightforward. As Figure C-1 shows, with a front door lift the 2+2 seating must be changed to 1+2 seating between the front and center doorways if left side accessibility is provided and some seats must be completely removed to provide a wheelchair securement area. These internal changes are required for either left side lifts or left side mini-platforms. Alternatively, providing both left and right side accessibility at the center doors, with lifts or platforms, would reduce the number of seats to be removed. However, front door lifts would be preferred by most operators so that the driver would not have to leave his station to operate a lift in the majority of cases (i.e. right side boarding/exiting).

The TransiLift unit and the proposed modifications were considered for installation in the Breda LRV. As with the Boeing installations, two principal versions could be considered for use on the Breda LRV. The basic bus unit, which produces a platform approximately 42 inches long, could be installed in any of the Breda doorways without major modifications to the frame structure. The installation of the long platform TransiLift arrangement will require substantial modification to the Breda frame structure. Figure C-2 shows the long platform

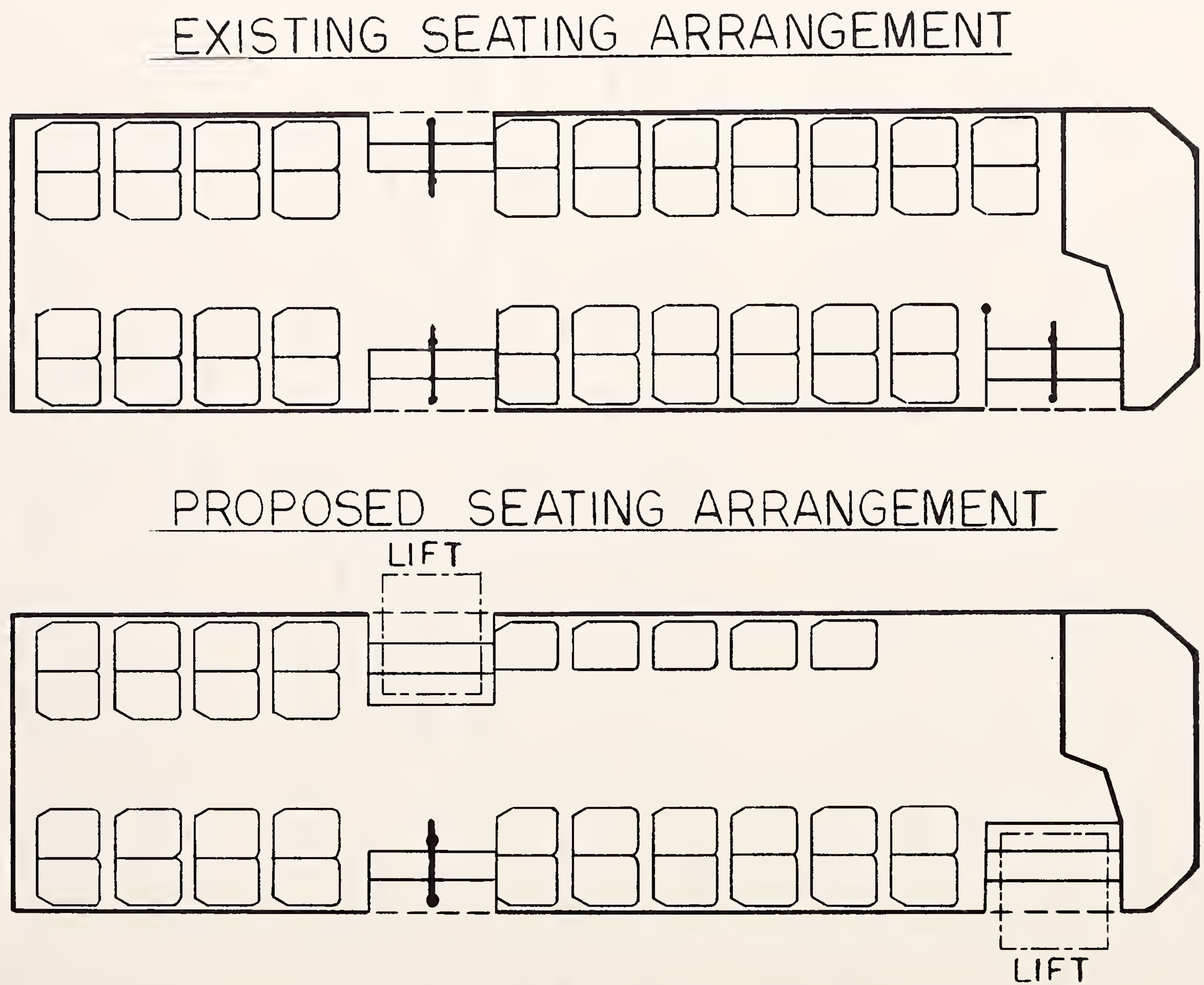


FIGURE C-1. BREDA SEATING ARRANGEMENT RIGHT AND LEFT SIDE BOARDING

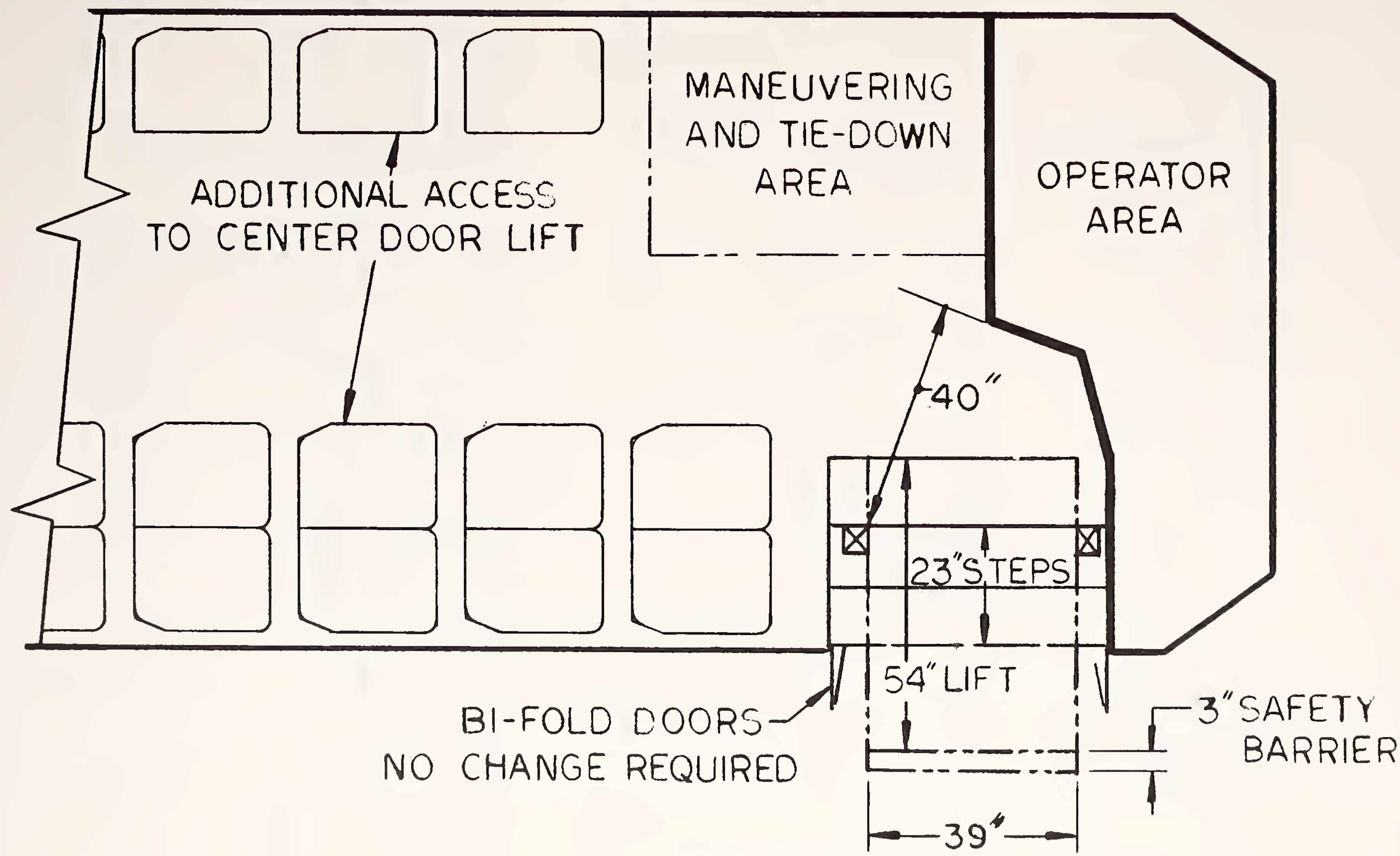


FIGURE C-2. BREDA LIFT ARRANGEMENT AT FRONT DOORS

(54 inches) TransiLift in the front doorway of a Breda vehicle while Figures C-3 and C-4 show the frame modifications that would be required in the area of the front doors and center doors respectively.

At any of the doorways, it would be necessary to move the I-section frame member laterally toward the center of the vehicle to provide sufficient stepwell depth for the modified lift. At the front doorway, moving the center sill laterally is a major modification. Comparison of the existing and proposed arrangements of Figures C-3 and C-4 indicates the approximate magnitude of the structural modifications required.

Offsetting the beam axis abruptly causes the moment in the beam to appear as a torsional force in the connecting lateral member, also an I-section, which is not well suited to torsional loading. The torsional loading must be resisted by the addition of structure, as in Method B (Figure C-4). Offsetting the beam end does not eliminate the torsional couple and the existing lateral member must be replaced by a more substantial member, identified as a torsional restraint. The existing lateral members adjacent to the stepwell are adequate for the bending moments induced in them. It would be desirable to treat the right side of the frame in a similar manner to keep the lateral neutral axis of the frame on the center line of the vehicle.

The frame modifications depicted are unquestionably major changes. Although the changes might be acceptable if incorporated into the vehicle at the design and construction stages, they are of doubtful practicality on existing vehicles. The Cleveland Breda frames have all been fabricated so that the only practical solution for a lift installation would be the use of the short platform version of the TransiLift.

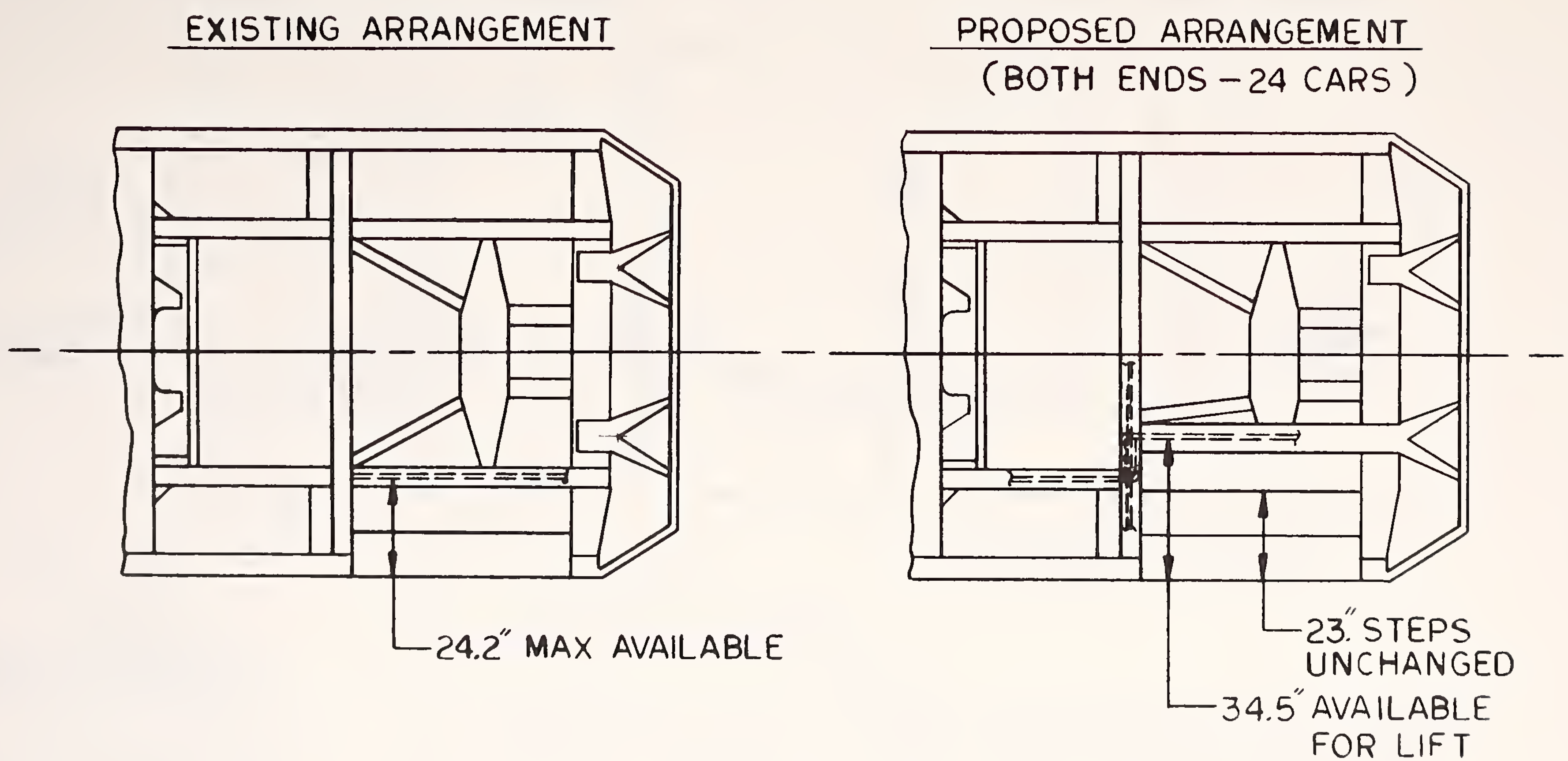


FIGURE C-3. BREDA FRAME STRUCTURE AT FRONT DOORS

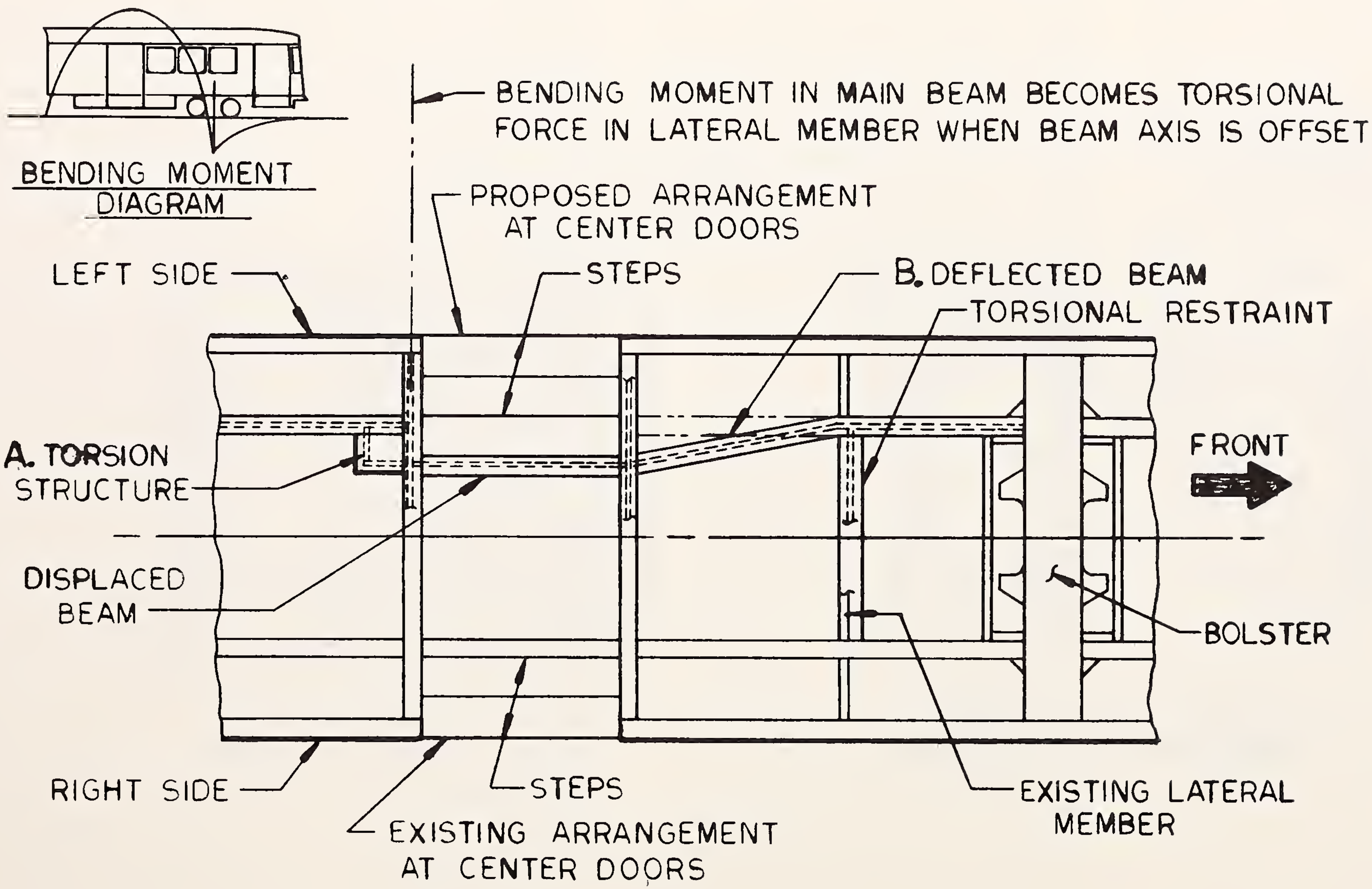


FIGURE C-4. BREDA FRAME STRUCTURE AT CENTER DOORS

APPENDIX D

LRV LIFT: FIELD TESTING

TEST RESULTS

APPENDIX D

LRV LIFT: FIELD TESTING

TEST RESULTS

Summary

A modularized TransiLift installed in the front end of an LRV operated by the San Francisco Municipal Railway was tested with and without wheelchair user volunteers in non-revenue service. The lift performed well throughout the March 7-July 7, 1983, test period. 134 field tests were conducted at more than 60 locations on all five of Muni Metro's surface lines.

Introduction

BACKGROUND

The federal Department of Transportation, working through its Transportation Systems Center in Cambridge, Massachusetts, contracted with The Budd Company to modify and evaluate a wheelchair lift for a light rail vehicle.* A TransiLift wheelchair lift was selected, modified, retro-fitted, and tested in a climatic chamber on a Boeing LRV by The Budd Company at its factory in Pennsylvania. It was then

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* The need for this project was a finding of studies conducted under Section 321 of the 1978 Surface Transportation Assistance Act. Investigation of on-board lifts was also recommended by the <u>Muni Metro Accessibility Study</u>, June, 1977, by MBT Associates, Tudor Engineering Company, and Barrier Prevention Associates. Field testing was funded by UMTA Section 6 research and development funds, including a testing and evaluation grant to the San Francisco Municipal Railway.

disassembled and shipped to San Francisco, where it was installed on a Boeing LRV operated by the San Francisco Municipal Railway for testing under field conditions in non-revenue service. Testing included operation with wheelchair users who served as volunteers in order to simulate actual working conditions. The dimensions of the lift are such that it will take all standard size wheelchairs. Testing included volunteers using manual and power wheelchairs.

The purpose of the field testing was national in scope. A number of American cities are considering light rail systems to complement their bus systems. The results of the LRV wheelchair lift test will assist these cities to evaluate whether a device of this type is appropriate to provide on-board accessibility. Other approaches to providing light rail accessibility are also being considered by various cities. In San Francisco, the Municipal Railway has initiated a program to provide wayside structures (platforms or lifts) at key sites in order to provide handicapped access to Muni Metro's light rail vehicles.

THE SAN FRANCISCO MUNICIPAL RAILWAY

In many ways, the San Francisco Municipal Railway has provided an ideal locale for testing under a broad spectrum of conditions which may occur with light rail systems. Muni operates a mixed fleet of 1,000 diesel coaches, electric trolley coaches, light rail vehicles, and cable cars. The light rail fleet, comprised of 130 vehicles, operates in a five mile subway tunnel with nine underground stations, seven of which are located under Market Street.* LRV lines emerge from subway to surface level operation at the Duboce Portal

* Four of these stations are shared with BART. Eight of the nine Muni subway stations are wheelchair accessible and the ninth will become accessible upon completion of current construction in 1984. A map of Muni Metro routes is found in Appendix D2.

(where they divide into the N-Judah and J-Church lines) and from West Portal at the end of the Twin Peaks Tunnel (dividing into the L-Taraval, K-Ingleside, and M-Ocean View lines). These surface lines evolved over a period of several decades, with the Twin Peaks Tunnel itself being opened to streetcar traffic in 1917. While modernized in many respects, the Muni Metro reflects the compromises which must be made in a dense and compact urban environment with a wide variety of terrain. Metro surface lines operate on both flat terrain and steep hills. They are found in exclusive, semi-exclusive, and totally non-exclusive rights-of-way. Where street width has permitted, passenger loading islands of varying heights and widths have been constructed. Other streets are narrower and passengers must board directly from the street pavement. These street surfaces represent a variety of street crown conditions.

MUNI'S BOEING LIGHT RAIL VEHICLE

Muni operates a fleet of 130 Boeing Vertol articulated light rail vehicles. This vehicle is a 73-foot long six-axled double-ended car which can be operated as a single unit or in trains of up to four cars. Each car has six double-doors. Four of the doors are found in two sets toward the center of the car and are equipped with high-low steps so that they can operate adjacent to high platforms at subway stations (on either side depending on platform position and/or train direction) or lower to provide access from the street surface. Two double-doors are located diagonally at either end of the vehicle. These doors are permanently equipped with fixed steps and are used only in street-level service. Operator cabins and fare boxes are adjacent to these two doors.

The test lift device was installed in one of these step wells at the end of an LRV. Muni employs a cross-over rather than a turnaround at its downtown subway terminal and thus two lifts per LRV would be required for revenue service. See Appendix D3 for LRV design and operating characteristics.

The interior of Muni LRVs seat 68 persons in most cars or, in some cases, 52 persons. The higher seat capacity vehicle has rows of double transverse seats on both sides and a 27 inch aisle which is only marginally adequate for wheelchairs which average 24-25 inches wide.* The lower seat capacity vehicles have double transverse seats on one side and a row of single transverse seats on the other side. Their wider aisle easily accommodates wheelchairs in the absence of standees. A car of this type was chosen, largely because it was already being considered for other tests. Wheelchair users on Muni LRVs are requested to station their chairs in a center stairwell area on the side with raised stairs, adjacent to the forward wind screen where they receive maximum protection in case of a sudden stop. This area is 15 feet from the test site located in the front doorwell. See Appendix D4 for seating plan details, as well as the photo in Appendix D1.

DESCRIPTION OF THE TEST TRANSILIFT

Since the final report by The Budd Company will fully describe this lift, it will only be noted here that the modified TransiLift is a passive hydraulic lift mounted in the stepwell area at one end of the LRV chosen for this test. The lift forms a platform 36 inches wide and 45 inches long, and projects, when deployed, 20 inches beyond the stepwell. The length of the lift, and the interior dimensions of any LRV upon which such a lift were to be installed, would form the limiting factors concerning the size of wheelchair which

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* Since Muni's high-level subway platforms serve the center doors, wheelchair users enter the car and station themselves in the opposite center doorway area. Thus they have no need to use the aisle when riding an LRV in revenue service.

could be handled by this device.

The lift operates in four phases:

1. Form platform. (The two steps in the stairwell form a raised platform.)
2. Lower platform. (The platform is lowered to the street pavement or to the surface of a passenger boarding island. The raised barrier at the end of the platform automatically lowers when the platform comes to rest upon the pavement or boarding island surface.)
3. Raise platform. (The barrier automatically is raised and the lift is raised until its platform abuts against the floor of the LRV.)
4. Make steps. (The platform is formed into a step configuration, making the entrance again available to ambulatory passengers.)

Project benchmarks

February, 1983 - Lift received from The Budd Company
March, 1983 - Lift installed in LRV for testing
March 7-July 7, 1983 - Maintenance records kept for lift on a daily basis, with lift cycled daily by maintenance staff
March 14-June 29, 1983 - Field testing of lift
June 3, 1983 - Lift publicly demonstrated as part of a demonstration and workshop on handicapped access to light rail systems, sponsored by the San Francisco Municipal Railway. 43 persons participated in this demonstration. (See Appendix D6 for list of participants.)

Maintenance

The lift was installed by maintenance personnel of Muni Electrical Equipment Maintenance, under supervision of personnel of The Budd Company (Mr. Arthur Lancaster) and of the Transportation Systems Center (Mr. Jason Baker). Several minor modifications were made to the front of the test LRV as part of the installation process. In addition, as part of the retrofit of the Muni LRV, a redesigned bottom guide to the front door was installed on the door, replacing a guide affixed to the car body. The door would not at times seat itself properly upon closing during the initial testing sessions. Once identified, the problem was resolved by maintenance staff and was not observed during the final three testing sessions. The malfunction was remedied by the operator in a few seconds when it occurred during field testing during a dozen door closings after lift cycles.

Field testing tasks included endurance and reliability testing accomplished by keeping the test vehicle in regular scheduled service during the 120 day test period. The test LRV participated in normal peak hour service and in a normal share of non-peak hour service as well as in the non-revenue testing sessions. Testing sessions were conducted during off-peak hours on weekdays between 9 a.m. and 3 p.m. A daily log was kept of mileage, number of cycles of lift, and preventive and corrective maintenance actions. A copy of this log is enclosed with the original copy of this report of test results sent to The Budd Company. The only corrective maintenance required was replacement of one of two plastic guides for the kickplate behind the lift mechanism, which reflected a design concern about the kickplate which is discussed below.

A key component of the testing was to assess the impact of lift modularization on maintenance in the event of a severe problem with the lift. As part of a workshop and demonstration conducted on June 3, 1983, Muni maintenance personnel demonstrated removal of the lift module, its replacement with a steps module, and then re-installation of the lift module. This entire procedure took 44 minutes. The lift module was removed in 14 minutes by a maintenance team which was prepared and on hand with a fork truck to perform this task. The stairs module was installed and removed in 15 minutes, and the lift module was reinstalled and working in another 15 minutes. While such conditions represent an "ideal case," clearly the modularization of the lift has succeeded in making it possible to remove a lift for repair and to restore an LRV to service with replacement stairs or lift, with only minimal delay once the LRV is at the shop. (See photos D1-1, 2, 3, 4) Muni maintenance personnel, it should be noted, had only removed and reinstalled the lift once prior to the June 3 test.

Field testing procedures and results

Field testing was conducted between March 14 and June 29, 1983, during eight sessions. In each case, the test LRV had been returned to Metro Center from its morning peak runs. If necessary, the car was wyed so that the lift would be in the forward end during the test session. The LRV was then field tested on one or more of the five Metro surface lines. The test LRV was invariably preceded and followed by LRVs in regular revenue service, which operate on six minute headways. Thus the test LRV could stop for testing only in situations where this would not delay the following car. It was found that this did not present a serious problem since tests were conducted rapidly due to short lift cycle times. Some measurements were taken by hand and others, to save time, were recorded by photographs of each test.

The field testing team was comprised of a project director, a photographer, and a Metro driver during the first four test sessions. This team was supplemented by one or more volunteer wheelchair users in the last four test sessions. Field test participants are listed in Appendix D6. Test photos and maintenance logs are enclosed with the original test report to The Budd Company.

Temperatures were moderate during all testing sessions. Weather conditions ranged from light showers during one test, to overcast or clear skies during the other tests.

The lift was cycled 134 times in field conditions.

Table 1: Distribution of testing by Metro line

Cycles:	Line:
7	J-Church
28	K-Ingleside
32	L-Taraval
9	M-Ocean View
25	N-Judah
33	Metro Center (revenue and non-revenue tracks)

The lift was cycled 101 times on revenue tracks and 33 times on non-revenue tracks (27 at Metro Center and 6 on storage tracks at the outer ends of the N-Judah and L-Taraval lines).

The lift was cycled 61 times using volunteers who were wheelchair users. During the remaining 73 cycles, either staff served as "load" on the lift or there was no load.

Table 2: Testing under load

Cycles:	Load in lbs.:
59	no load
4	100-149 lbs.
31	150-199 lbs.
4	200-249 lbs.
29	250-299 lbs.
5	300-399 lbs.
2	400-425 lbs.

The lift performed well under all load conditions. Note that each test cycle consisted in 1) forming steps into platform, 2) lowering the platform, 3) raising the platform, and 4) forming the platform back into steps. Within a given cycle, both the lowering and raising of the platform between street-level and the LRV floor level normally occurred with a given load or with no load.

Table 3: Testing on grades

Cycles:	Grade conditions:
72	No measureable grade
46	1-5% grade (25 up hill, 21 down hill)
16	5-10% grade (7 up hill, 9 down hill)

The lift performed well under all grade conditions, including grades in excess of 1:12 which would normally be considered excessively steep for wheelchair users. A tendency for the kickplate behind the lift mechanism to rub against its forward plastic guide (one of two such guides) was noted when the LRV pointed down hill and/or the load on the lift platform was centered toward the forward side of the platform (i.e., toward the side facing the direction of travel). In one instance while boarding a volunteer wheelchair user, the kickplate engaged the plastic guide sufficiently to bring the lift to a halt before the platform was completely raised. The lift had to be recycled three additional times before this problem was fully identified and corrected by shifting the load toward the rear edge of the platform. (This site also had an excessive street crown, discussed below.) There was no instance in which the lift failed to fully cycle during the remaining 60 cycles using volunteers, nor during the 73 cycles when volunteers were not present.

Street and stop conditions

The lift was deployed both at regular marked stops and also at a variety of other sites which presented interesting deployment conditions.

Table 4: Deployment conditions

Cycles:	Condition:
90	Onto street pavement
44	Onto passenger boarding islands

STREET PAVEMENT

One of the main purposes of the test was to deploy the lift on a variety of surfaces, both at grade level and at raised passenger loading islands. In addition, varying degrees of flat to positive street crowns were encountered, with no negative street crowns encountered on Muni rights-of-way. The San Francisco Department of Public Works reports that average street crowns on streets with Muni Metro tracks are .6% to 1.0% of crown relative to street width. A 40 foot wide street with a 1% crown would thus be nearly 5 inches higher at the center of the street than at the curb.

Although the lift is capable of being adjusted to handle significant street crowns, the testing was done without adjustment. An excessive street crown would result in the lift platform making contact with the street beneath the LRV but failing to lie flat on the street at its outer lip. It was felt as a result of the testing that a wheelchair user could readily negotiate a one inch "gap" between the street pavement surface and the upper surface of the lift platform, in order to board or deboard. Excessive street crowns were defined as those that would cause more than a one inch gap. Street crowns were found to cause an excessive gap during 9 of the applicable 90 tests. (See photo, D1-9) These 9 cycles occurred at 7 different sites during the testing. The 9 situations with excessive gaps included 6 in the 1-2 inch gap range, 2 in the 2-3 inch range, and one of nearly 4 inches. In the field testing, 3 of these 9 instances occurred while volunteers were participating in the testing. In each of these 3 cases the volunteers were in fact able to mount the lift platform successfully, but clearly this would have been unsafe in revenue operation and either the lift must be adjusted for such operation or properties using such a lift must assure that excessive street crowns are avoided at those designated stops where the lift is deployed directly onto the street pavement.

No other problems were noted in deploying the lift onto a variety of street surfaces, including blacktop and brick.

PASSENGER BOARDING ISLANDS

The lift was cycled 44 times at passenger boarding islands located adjacent to Metro tracks running down the middle of streets. As previously noted, the tracks were in a variety of exclusive, semi-exclusive, or non-exclusive rights-of-way. One or more lanes of vehicular traffic were invariably present on the side of the island opposite the trackway. In some cases, the islands had railings on the side adjacent to this vehicle traffic. The islands were of varying width, depending on the width of the streets and the competing space demands of automotive traffic lanes.

Boarding island heights above the street surface averaged 6 inches and varied from 3 inches to 12 inches (the Metro's highest platform, on the J-Church line at 20th Street in Dolores Park). The lift functioned well on all the varying island heights.

The lift platform invariably lay flat on the surface of each boarding island. The problem of an occasional gap attributable to street crown did not occur. During the 44 island tests, the one inch limit between island surface and platform surface was never exceeded. It was reached in two tests.

Depending on the configuration of the passenger islands, the deployed lift covered from 15 to 19 inches of the island surface. (See photos, D1-8) Islands with widths from 45 inches to 90 inches were tested, including 13 tests using wheelchair user volunteers. No problems were encountered with the lift. However, passenger island widths were a cause of concern.

A volunteer using a manual wheelchair 24½" wide by 43" long was able to safely maneuver onto and off the lift platform when deployed on passenger islands 60 inches wide. The same volunteer was unable to deboard on a 45 inch wide island (of which 17 inches was covered by the lift platform, leaving only 28 inches free for the wheelchair). (See photo, D1-10) He was just barely able to deboard on a 50 inch wide island, with the lift platform projecting over 16 inches of the island. Although able to maneuver on a 54 inch wide island, concern was felt by staff that the feet of the volunteer projected beyond the side of the island over the street when making a turning motion in his wheelchair.

A second volunteer, using a power wheelchair 23½" wide by 45" long, maneuvered onto and off 60-72 inch wide islands without difficulty. The lift projected over 17 inches of these islands, leaving 43-55 inches for turning motions.

A third volunteer used a manual chair on an 82 inch wide island with no difficulty.

Platforms which are at least 60 inches wide, with at least 42 inches remaining for maneuvering when the lift platform is deployed on the island surface, would appear to be a minimum width for the standard wheelchair sizes readily accommodated by this lift. It is recommended that railings be installed on the side of the island adjacent to vehicular traffic, although this is more important on hilly than on flat terrain. When space permits, islands should be at least 72 inches wide when used for handicapped persons and of course may need to be still wider to handle non-handicapped passengers as well.* It must be stressed that these recommendations are based on very limited testing involving 13 tests using three volunteers.

Boarding times

Tests were run to determine the amount of time needed to board a wheelchair user with the test lift. Boarding time is defined as the period during which the vehicle must remain stopped to board a passenger. It includes the time it takes to open the door, deploy the lift, board or deboard the passenger, stow the lift, and close the door prior to being ready to resume forward motion. During these tests the wheelchair users were positioned within five feet of the lift

* Islands raised to the full height of the raised steps of an LRV may be narrower and permit safe operation, since a lift platform would not impede maneuvering room under such conditions of direct access with no level change.

when intending to board the LRV, or within 15 feet of the lift when intending to deboard. (See photo, D1-7 bottom) As one volunteer observed, "There is very little difference where the wheelchair user is in the car, as I can move to the door (at the lift) as the lift is being raised." That is, under these test conditions without standees, the wheelchair user could travel to the lift area while the door was being opened and the lift platform deployed in a raised position.

Table 5: Boarding/deboarding times

No. wheel-chair users	Seconds
1	42-52"
2	73-82"
4	152-180"

Commentary:

ONE WHEELCHAIR USER: A volunteer using a power chair boarded in 48 seconds (average of 2 tests) and deboarded in 44 seconds (average of 2 tests). Two other volunteers, both using manual chairs, had individual boarding times of 45 seconds and 44 seconds, respectively, and individual deboarding times of 52 and 42 seconds, respectively.

TWO WHEELCHAIR USERS: Two volunteers in manual chairs boarded in 82 seconds and deboarded in 73 seconds.

FOUR WHEELCHAIR USERS: A single test was run using four handicapped volunteers all using manual chairs. Boarding time was 180 seconds and deboarding time was 152 seconds.

Notes:

1) The lift was set to be completely cycled (make platform, lower platform, raise platform, make steps) in 32 seconds, without passengers.

2) In separate tests, it was determined that a single volunteer using a manual chair took 29 seconds to exit the vehicle, averaging 6 tests, and 30 seconds to enter the vehicle, averaging 5 tests, measuring ingress and egress time from the passenger's viewpoint and exluding time required to stow the lift, close the door, and prepare to resume forward motion.

3) None of these volunteers had previously used a lift on an LRV. Some had considerable experience using various bus lifts. The volunteers appeared motivated to quickly board and deboard the LRV, as would be the case with most revenue passengers. Significantly, volunteers involved in series of tests tended to shorten their boarding/deboarding time by "learning the ropes" on the first try.

4) This testing is based on only six volunteers and actual times would no doubt vary. However, boarding times in revenue service would probably approximate those observed in the testing.

Conclusions

The modularized TransiLift used in the field testing performed reliably and without breakdown over a period of four months and under a range of environments which include most of the situations which would face such a device in actual operating conditions. Although not tested in revenue service, the vehicle and the lift were subjected to all the normal wear and tear of such service over a 120 day period without evidence of damage to the lift. In addition, it was demonstrated that the lift module could be removed at the Muni Metro shop, replaced with a fixed steps module, and the car quickly returned to service if there had been a need for major repair. The lift functioned effectively throughout 134 field tests, 120 daily maintenance cyclings, and well over 100 additional cyclings in connection with installation and training of operators.

Observations by staff, and by volunteers who are wheelchair users, reinforced a perception that the lift is well designed for safe reliable operation. Problems which are sometimes encountered with some bus lifts were absent. The outer safety barrier performed well in all tests. The lift platform lay flat on street or passenger island surfaces with no tendency to buckle. The platform of the lift maintained a safe angle parallel to the plane of the tracks and the LRV floor. The lift controls were simple to operate. When deployed, the lift platform always stopped smoothly when it reached the street or passenger island surface, with no tendency to "jack" the vehicle.

Clearly, testing such as this is performed under somewhat idealized conditions. Maintenance concerns which might arise after several additional months or years of operation could not be evaluated. A single LRV operator participated in all the testing sessions. While his advice was valuable to the testing, staff had no opportunity to observe the reactions of operators who might have become unfamiliar with the lift operation over a period of time.

Although beyond the scope of this report, a comparison of LRV on-board lifts with bus lifts, on the one hand, and with other types of LRV accessibility, on the other, would reveal significant tradeoffs between each of these various approaches. LRV accessibility approaches include floor level platforms for all passengers (as in Muni Metro subway stations), ramped floor-level wayside platforms at key stops, and wayside lifts. These tradeoffs occur most significantly, of course, in the degree of accessibility provided, that is, the percentage of stops which are accessible. They also occur around issues of initial cost, reliability, boarding time, maintenance costs, potential for vehicle or line delay, degree to which handicapped persons are "mainstreamed" in boarding procedures, degree to which the environment is controlled for safety and reliability factors, and proximity of the access doorway(s) to secure wheelchair parking areas in the vehicle.

Recommendations

THE LIFT

1. The kickplate behind the lift should be modified to eliminate extra slack. This slack sometimes results in the kickplate rubbing or binding against a plastic guide when the load on the deployed lift platform is centered toward the forward edge of the platform and/or the platform is being raised under load with the LRV in a downhill position.
2. The deployed lift needs to be more visible to passing traffic, especially since it projects out from the normal silouette of an LRV (See photo, D1-10). This concern is especially critical at night. The lift should be painted in bright safety colors and should have a warning light(s) to get the attention of passing traffic.
3. When raised under load, the lift platform often stopped approx. ½ inch short of the LRV floor. While this never interfered with boarding by volunteers, the operator would have to correct for this after the load was removed by lowering the platform a couple inches and raising it without load. This procedure took perhaps two seconds and invariably the lift would then be properly aligned with the LRV floor (See photo, D1-9). The source of this problem should be investigated and corrected.

ACCESSIBLE STOPS

1. Boarding of passengers--including handicapped passengers--from street surfaces without passenger loading islands should be avoided when possible.

2. Special attention should be given passenger island width if on-board lifts are to be used, taking into account that the lift platform must project over a portion of the island, thus decreasing available space for wheelchair maneuvering. A minimum 60 inch width appeared appropriate. Guard rails and special lighting may also be indicated to promote safe use of passenger islands for all passengers.

3. If boarding from street surfaces is required, care must be taken to avoid excessive steet crowns which might result in the outer lip of the lift platform being raised more than an inch off the street surface.

Photograph courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-1. FREE STANDING LIFT MODULE

Photograph courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-2. LIFT MODULE BEING INSTALLED

Photgraph courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-3. FREE STANDING STEPS MODULE

Photograph courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-4. STEPS MODULE INSTALLED

Photograph courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-5. LRV WITH LIFT DEPLOYED

Photograph courtesy San Francisco Public Utilities Commission Photo Division

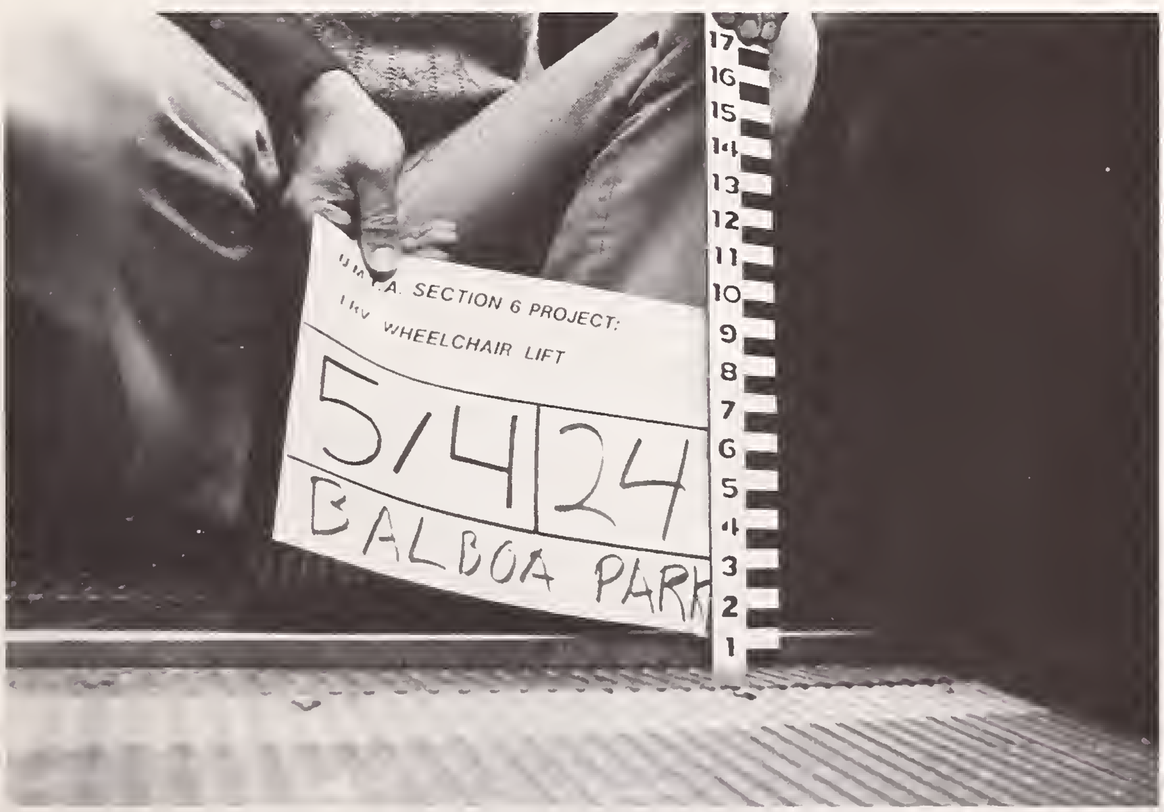
FIGURE D1-6. LIFT IN OPERATION

Photographs courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-7. LIFT IN OPERATION

Photographs courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-8. TWO VIEWS OF LIFT DEPLOYED ON PASSENGER ISLANDS



Photographs Courtesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-9. IMPACT OF EXCESSIVE STREET CROWN (TOP) INSTANCE OF RAISED PLATFORM UNDER LOAD NOT FLUSH WITH LRV FLOOR (BOTTOM)

Photographs coutesy San Francisco Public Utilities Commission Photo Division

FIGURE D1-10. a. VOLUNTEER CANNOT DEBOARD ON 45" WIDE PASSENGER ISLAND

b. SILOUETTE OF LIFT WHILE BEING STOWED (MAKING STEPS): NOTE NEED FOR SAFETY COLORS (BOTTOM)

APPENDIX D2

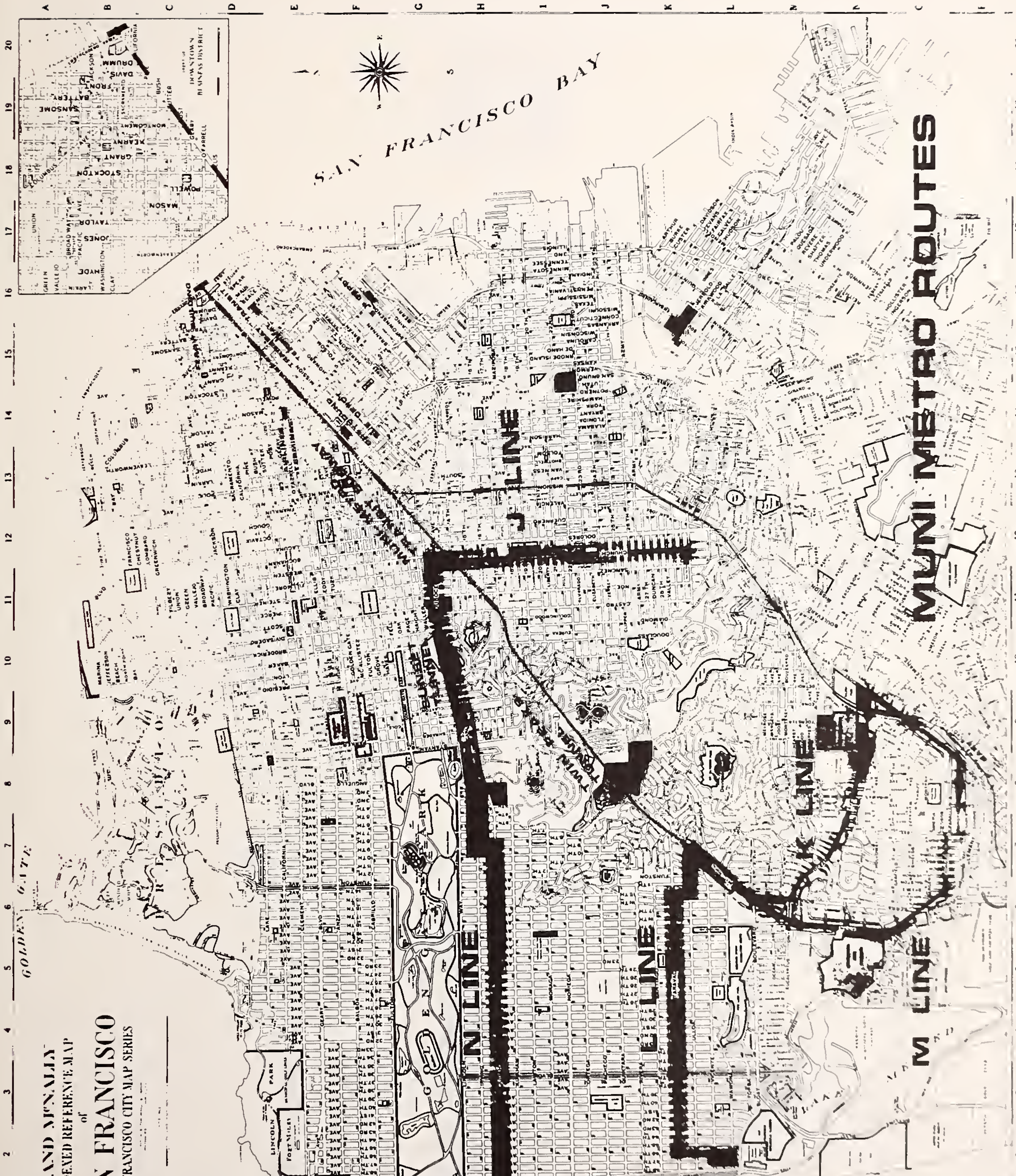
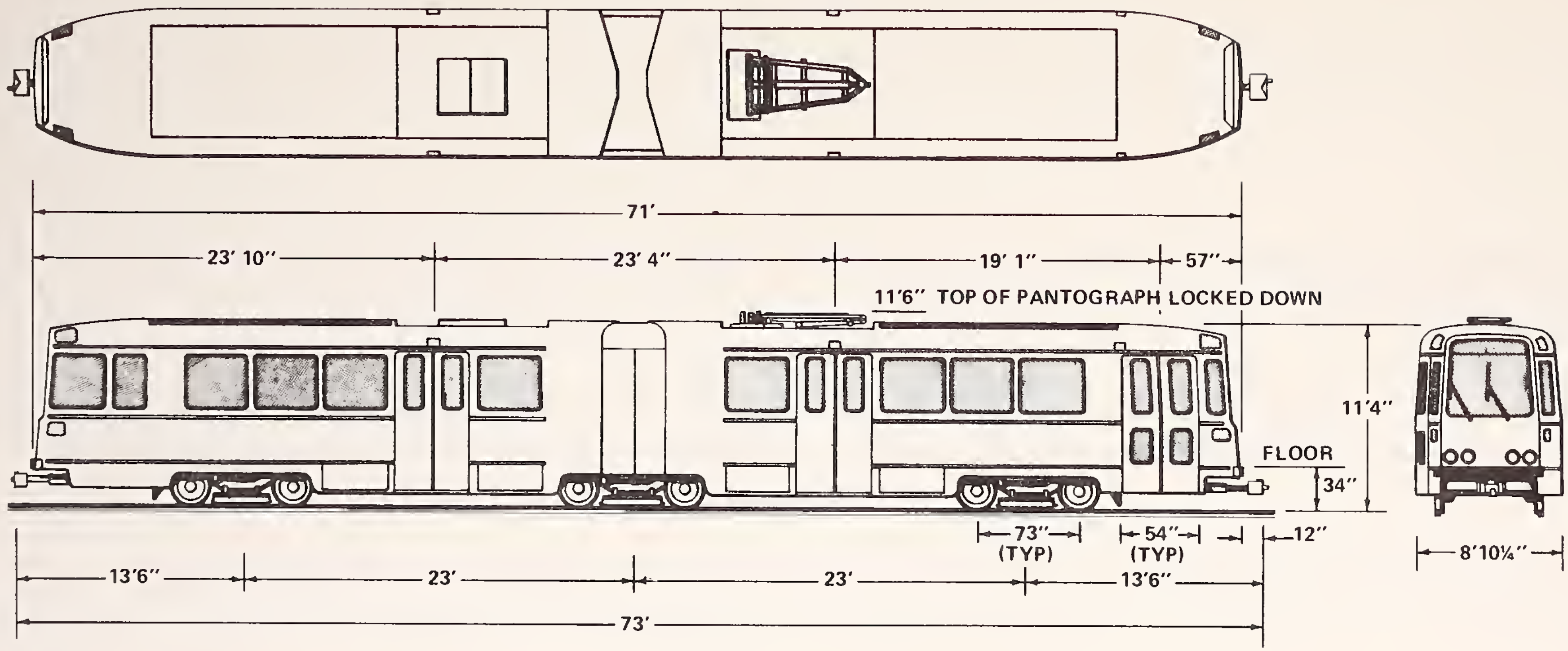


FIGURE D2-1. MAP OF MUNI METRO ROUTES



Length, over anticlimbers	71 ft
Height, from top of rail	11 ft 4 in.
Width, maximum	8 ft 10¼ in.
Weight empty	67,000 lb
Passenger capacity	
Seats – MBTA	52
Seats – San Francisco	68
Maximum capacity	219
Track gauge	4 ft 8½ in. (Std)
Track radius, minimum, horiz.	32 ft
Speed, maximum operating	50 mph

Acceleration, maximum	2.8 mph/sec ± 10%
Brake rate	
Service, nominal	3.5 mph/sec
Emergency, minimum	6.0 mph/sec (below 30 mph) 4.0 mph/sec (above 30 mph)
Jerk rate, nominal	2.5 mph/sec/sec
Wheel diameter	26 in.
Power, nominal	600 volts D.C.
Noise levels	
Interior, all systems operating	65 dBA
Wayside 50 ft at 40 mph	80 dBA

FIGURE D3-1. DESIGN AND OPERATING CHARACTERISTICS

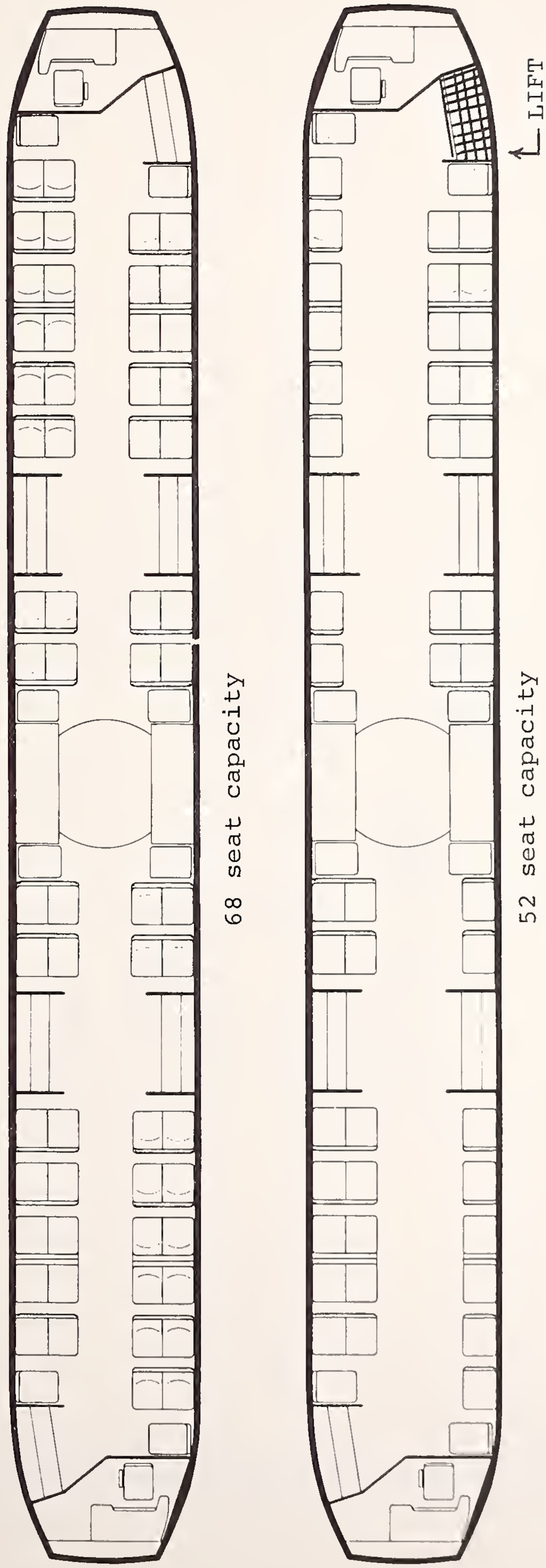
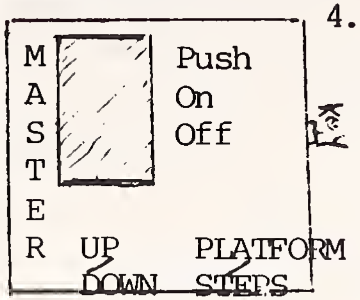


FIGURE D4-1. SEATING PLAN

ELAPSED TIME	MATERIALS REQUIRED	PROGRAM CONTENT	INSTRUCTOR ACTIVITIES
		<u>INTRODUCTION:</u> Budd's Wheelchair Lift Capacity: 400 lbs. Hydraulic operated <u>OPERATIONS:</u> 1. Turn key to On position 2. Push Master button to On position 3. To form a platform-lift safety lock toggle switch and push to platform position <u>BUDD'S LIFT CONTROLS:</u> NOTE: Lift's engine will stop when platform is completely formed. **For Normal Operation**  4. To lower platform - push toggle switch to Down position. Once platform is lowered to curb, barrier will unfold until contact is made with curb. NOTE: Lift's engine will not stop until toggle switch is released. 5. To raise platform, push toggle switch to Up position. NOTE: Lift's engine will stop when platform is in the complete raise position. 6. To form steps, pull up on Safety lock toggle switch and push down until steps	

ELAPSED TIME	MATERIALS REQUIRED	PROGRAM CONTENT	INSTRUCTOR ACTIVITIES
		are formed. NOTE: Lift's engine will stop when steps are completely formed. MALFUNCTION CONTROLS Platform / Steps Up / Down If normal controls are inoperative, located under the first right seat of the "B" section is the Malfunction Control unit. To operate, push toggle switches to desired position. NOTE: Keys are not necessary for this unit - it is ready for use as is. Trouble Shooting Lift A. Problem Lift malfunctions in raise platform position. 1. Push toggle switch to Down position, lowering platform to curb. After barrier unfolds to curb,	

ELAPSED TIME	MATERIALS REQUIRED	PROGRAM CONTENT	INSTRUCTOR ACTIVITIES

release switch.

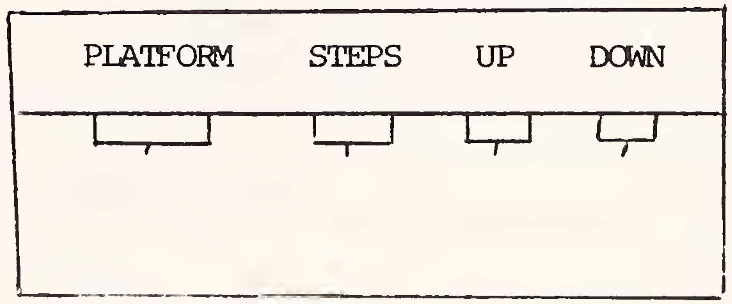
NOTE: Engine will not stop after any of the desired positions are completed. Be sure to release switch immediately upon completion of desired move.

2. To raise platform, push toggle switch to Up position.

3. To form steps, push toggle switch to steps position.

If normal controls fail after forming a platform and Malfunction Controls were inoperative, the manual pump must be used.

In the same section where the Malfunction Controls are located, there are hydraulic valves for the Manual pump hoses.



There are two hoses on the Manual Pump:

1. The working hose (red in color)
2. The non-working hose (black in color)

ELAPSED TIME	MATERIALS REQUIRED	PROGRAM CONTENT	INSTRUCTOR ACTIVITIES
		Operating instructions: Example: If lift is stuck in raise position and you wish to form steps: 1. Connect working hose (red) to the steps valve. 2. Connect non-working hose (black) to the platform valve. NOTE: The red hose is always connected to the valve that has the position desired and the black hose is connected to the opposite of that. EXAMPLE: If lowering of platform is desired, the red hose is connected to the valve marked <u>Down</u> and the black hose is connected to the valve marked <u>Up</u> and vice versa. If lift is stuck in raise platform position and step position is desired, connect red hose to step valve and black hose to platform valve and vice versa. SUMMARY: Remember - don't destroy lift's motor by holding toggle switches too long. The positions the engine will automatically stop are: in Normal operation, steps, up and platform. When moving to down position (under normal operation) the engine will not stop until toggle switch is released. When using the Malfunction Unit all toggle switches must be released soon after each position is formed in order to stop engine.	

ELAPSED TIME	MATERIALS REQUIRED	PROGRAM CONTENT	INSTRUCTOR ACTIVITIES
		The low voltage locker door, "B" section, of LRV cannot open completely because of the positioning of the lift. To alleviate this problem the low voltage locker door has been modified. Once door is open, Operator must pull door completely off the hinges and set on the floor while need for going into locker is completed.	

San Francisco Municipal Railway
Demonstration and Workshop: Handicapped Acccess to Light Rail Systems - June 3, 1983
Participants

Fred Barba, Instructor
SF Muni
949 Presidio - SF 94115

Billie Louise Bentzen
Orientation and Mobility Program
Boston College
Chestnut Hill MA 02167

Don Cruzan, Assoc. Trans. Supvr.
California PUC
State Building
SF CA 94102

Callier Beard/Trans. Planner
So. Calif. Rapid Transit Dist
425 S Main St
Los Angeles CA 90013

Merrill R. Cohn/Senior Engineer
UEB/SF PUC
693 Vermont St
SF CA 94107

Arthur Downes
Santa Clara County Transit
1555 Berger Drive
San Jose CA 95112

John Edmonds
252 Clarendon Rd
Pacifica CA 94044

Kevin Elcock Staff Engineer
Sacramento Transit Dev Agency
c/o CalTrans - P O Box 1499
Sacramento CA 95807

Scott Farnsworth
Banfield Light Rail Project
Tri-Met
421 S W Fifth St, #600
Portland OR 97204

Bernardine Frank
Ad Hoc Committee for Handicapped
215 Thompson Sq
Mountain View CA 94043

Harold Geissenheimer, General Manager
SF Municipal Railway
949 Presidio
SF CA 94115

Clayton Haven
Maintenance Supervisor
San Diego Trolley
45 12th St
San Diego CA

Wernfried Hiersche
Regional Sales Manager
Industrial Equipment Marketing Division
Siemens-Allis
860 Hinckley Rd
Burlingame CA 94010

Ernie von Ibsch
Senior Transportation Operations Supervisor
Rail Systems Safety Unit - Fox Plaza
California Public Utilities Commission
350 McAllister St
San Francisco CA 94102

John C James
Transportation Planner
CalTrans
P O Box 1499
Sacramento CA

Morgan Jones
The Budd Company
One Red Lion Road
Philadelphia PA 19115

Thomas Jordan, Director
Elderly and Handicapped Program
S F Municipal Railway
949 Presidio - SF 94115

Paul S Kalra, P.E., Chief Transit Sys Eng
Los Angeles County Transportation Commission
354 So Spring St, Suite 500
Los Angeles, CA 90013

Mike Kennedy, Program Manager
UMTA - U S Department of Transportation
Two Embarcadero Center
SF CA

Ken Larsen Assistant Safety & Training Supervisor
County of Santa Clara Trans Agency
2240 South Seventh St
San Jose, CA 95112

Alex E Lutkus
California PUC
State Building - 350 McAllister S
SF 94102

Lawrence Marcelino
National Federation for the Blind
3315 Cabrillo St
SF CA 94121

Nancy Meyer, Accessible Service Coordinator
Tri-Met
421 S W Fifth St
Portland OR 97204

Steve Miller, Trans Planner
CalTrans
P O Box 1499
Sacramento CA

Frances Nye
Elderly and Handicapped Program
SF Muni

Joe Pelayo
SF Muni

Jean Poelle
Santa Clara County Transit Comm
22241 Alamitos Rd
San Jose CA 95120

James W Rae, Chief
Track & Equipment Brqnch
Division of Mass Transportation
CalTrans
P O Box 1499
Sacramento CA 95807

Herb Reinl Sr Trans Planner
CalTrans
Address: same as above

Thomas E Rickert
Manager, Elderly and Handicapped Program
S F Muni

Peter Steinert
Transportation Planner
CalTrans
P O Box 1499
Sacramento CA 95807

Dan Rosen
S F Muni - 949 Presidio - 94115

Jeff Sada
S F Muni
Metro Maintenance

Louise Sass
County of Santa Clara Trans Agency
1555 Berger Dr
San Jose CA 95112

Dave Schumacher, Transportation Planner
San Diego Metropolitan Transit Development Bd
620 "C" Street, Suite 400
San Diego CA 92101

Dave Tannehill
Transportation Planner
CalTrans, District 4
1540 Market St
SF CA 94120

John Valsecchi
Sacto Transit Development Agency
1201 J Street
Sacramento CA

Guy Wright, System Safety
S F Municipal Railway - 949 Presidio - 94115

Michael F Wong, Transit Supervisor
Station Operations - S F Muni

Alec Peck, Ph.D
Boston College
Campion 103
Chestnut Hill, MA 02167

Hale Zukas
c/o Center for Independent Living
2539 Telegraph Avenue
Berkeley, CA 94704

Carmen Magana
S F Muni
949 Presidio Avenue, Rm. 110
San Francisco, CA 94115

Arthur Lancaster
The Budd Company
Technical Center
Fort Washington, PA 19034

APPENDIX D7

Field testing conducted by Elderly and Handicapped Programs, San Francisco Public Utilities Commission

Director, Thomas J. Jordan

Manager, Elderly & Handicapped Programs, Thomas Rickert

Field testing staff:

Thomas Rickert, director

Carmen Magana, field testing photographer

Josh Rostin, photographer

Ed Harrell, LRV operator

Fran Nye, workshop coordination, June 3, 1983, demonstration

Volunteers participating in field testing:

Paul Goodlataw, San Francisco

Skip Alunan, San Francisco

Joe Koontz, San Francisco

Maria Cavazos, San Francisco

John Edmonds, Pacifica

Edward Pittelkow, Santa Clara County

Elaine Casteel, Santa Clara County

Jean Poelle, Santa Clara County

Wally Skeels, Santa Clara County

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Photo credits: All photographs reproduced in Appendix D1 were taken by Carmen Magana, with the exception of photo D1-7 (bottom), by Josh Rostin.

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