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INVESTIGATION OF DESIGN, MAINTENANCE AND OPERATING PROCEDURES OF WHEEL CHAIR LIFTS ON TRANSIT BUSES

**FINAL REPORT
(Phase - III)**

by

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1.0 INTRODUCTION

This report describes the findings of a project conducted to investigate the design, operation and maintenance aspects of the wheelchair lifts. The project objective is to assess the nature of the problems pertaining to any one or the combination of the design, manufacturing, operation, maintenance of wheelchair lifts of transit buses and to propose upgrade needs or operational changes to alleviate these problems. The project was conducted in three Phases. The Phase I and Phase II reports have already been completed. This report covers the work done in the final Phase.

1.1 SYNOPSIS OF PHASE I REPORT.

The Phase I study completed during the 1989-90 can be categorised as a fact-finding mission designed to examine the serviceability of wheelchair lifts based upon an engineering analysis of the lift mechanisms. The approach taken to attain the Phase I objective can be described as a series of sequential steps as follows.

Step 1 - Operator Survey. A number of transit operators (mostly rural operators) were interviewed for their input to the problem identification process. For this purpose, a comprehensive questionnaire survey was prepared addressing issues of design, manufacturing, maintenance, and operation of wheelchair lifts. The survey was conducted on site with personal visits to transit operator offices.

Step 2 - Compiling Technical Information. Through a formal library search process, a variety of technical information on wheelchair lifts was compiled. Much of the technical data thus compiled was used in the understanding of the function of the structural components and in the development of the finite element model.

Step 3 - Manufacturer Survey. A limited survey among the major wheelchair lift manufacturers in the U.S. was conducted. The survey results were intended for reviewing the process of design and manufacturing of wheelchair lifts and their conformance to federal standards. Other objectives of this survey were to assess the manufacturers' perception on the causes of lift failure and to determine the possible impact of emerging technologies on the design and manufacturing process of these lifts.

Step 4 - Engineering Analysis of Structural/Mechanical Components. The purpose of this task was to identify specific operating components of the wheelchair lifts where failure/malfunctioning is likely to occur. The structural, mechanical and sensing components of the lift were analysed. Also a computer-based finite element model was developed to analyse the structural components of the lift mechanism.

Step 5 - Analysis of Repair Data. Available data on maintenance / repair of wheelchair lifts was collected from two operating agencies in south-east Michigan. The data was analysed to discern possible patterns in the maintenance needs of the wheelchair lifts. Also, the framework of a reliability model was established using available repair data on wheelchair lifts.

In summary, the completion of Phase I study allowed the investigators to develop the foundation for assessing the nature of problems that affects lift performance. This was accomplished using two independent methodologies based on the following models.

Statistical Model for Lift Reliability. This model was based on lift repair data acquired from transit agencies. A preliminary methodology was developed with the objective of predicting failure rates of different lift models used in transit buses.

Structural Engineering Model for Lift Reliability. This model was based on a finite element description of the lift structural system. The model was formulated from engineering representations of the structural properties and topologies of various structural components in fully-deployed position. The model was used in Phase I for assessing the structural performance of the lift under specified demand conditions.

1.2 SYNOPSIS OF PHASE II REPORT.

In Phase II, the modelling work (both structural and statistical reliability) was continued in an effort of refine the models and to calibrate various model parameters. Also, an experimental investigation of the operation of the wheelchair lifts was initiated to assist in the development of modifications of structural specifications.

The approach taken to attain the Phase II objective was a series of sequential steps described as follows:

Step 1 - Literature Review. A comprehensive literature review was conducted to compile the specifications pertaining to not only to wheelchair lifts but to all lift systems for moving people. The literature provided a base line data in establishing allowable lift deformation, velocity, acceleration and jerk.

Step 2 - Developed Realistic Design Load Demands. The demands on lifts could vary widely depending on the type of use, environmental conditions and other factors. While normal loads are likely to prevail during much of the useful life of the lift, performance should also be specified under unusual loads. A set of realistic load demands and the lift performance expectations under a varying set of load conditions were developed based upon information obtained from literature search and interview with transit agencies.

Step 3 - Survey of Transit Agencies. A set of surveys were conducted during Phase I among the transit agencies in Michigan (both rural and urban operators). The purpose of the survey was to obtain original information on issues related to the problems associated with wheelchair lifts. A number of other agencies identified in co-operation with the MDOT were visited during Phase II to increase the data base on wheelchair lift reliability.

Step 4 - Structural Model Refinement. The structural model developed in Phase I was further refined to ensure that : a) the various load demand conditions developed in step 2 can be accommodated in the model and b) the model output can be used to analyse the stress and deformations of the lift structural components.

Step 5 - Structural Analysis Model of Folding Platform Lift. The model development describing the structural components of a typical folding platform lift was initiated in Phase II. The model thus developed can be utilised in identifying possible weak links in the lift structure.

Step 6 - Lift Statistical Reliability Model Refinement. The reliability model was developed in Phase I for step lifts with limited data obtained from the regional transit operator in south-east Michigan, Suburban Mobility Authority for Regional Transportation (SMART). The model did provide a viable statistical approach towards analysing repair data. In Phase II, the model was calibrated / refined with additional data and efforts were made to incorporate other pertinent variables. Additional data on lift repair from operators other than SMART were collected in order to refine the reliability model.

Step 7 - Developed Experimental Procedure. An experimental procedure was developed for assuring the compliance of the automatic rigid platform lifts with the structural specifications.

Step 8 - Procurement of Lifts for Testing.

Two rigid-platform lifts that completed their life cycle were procured through the assistance of MDOT as the specimens of the initial load testing. The lift brands were the most commonly used by rural transit agencies in Michigan. The primary purpose of the preliminary test was to ensure that the experimental procedure developed in step 7 can be implemented in a practicable manner.

1.3 SCOPE OF PHASE III STUDY.

The major objective of the Phase III study is to proceed with obtaining dynamic analysis parameters and non-destructive experimental testing of the active wheelchair lifts. The specific objectives of the Phase III study were to:

- i) Review the Americans With Disabilities Act (ADA).
- ii) Continue the non-destructive experimental evaluation of two active wheelchair lifts.
- iii) Initiate the experimental evaluation of the dynamic analysis parameters of the fully stowed lift.
- iv) Provide guidelines for the development of functional performance criteria and certification procedure for the wheelchair lifts.

Task 1 - Review of ADA.

Review of the ADA is performed to understand the clauses provided by the Architectural and Transportation Compliance Board. The FAT regulations were also reviewed as and when required.

Task 2 - Non Destructive Experimental Testing of Active Lifts.

The experimental evaluation of the lift is performed for the two different cases. The first is the testing for the analytical model parameters and the second is the testing for reliability parameters.

The testing for the analytical model parameters includes the testing of lift in fully stowed condition. The lift is in fully stowed position while the vehicle is in motion. The structural parameter flexibility (explained in chapter 2) is obtained for fully stowed position. The flexibility parameter is the required input to the structural model of fully stowed lift for the purpose of dynamic response analysis.

The experimental evaluation for the reliability parameters includes the loading of the lift platform. The flexibility of the lift is evaluated for the cases when lift in semi-deployed and fully-deployed position.

Task 3 - Dynamic Analysis Parameters of the Active Wheelchair Lift.

A dynamic analysis model of the active wheelchair lift in stowed position is developed. The analytical model parameters consists of stiffness and mass. The lift stiffness in various directions is obtained experimentally will be used as input to the dynamic analysis that will be conducted in future studies.

Task 4 - Development of Functional Performance Criteria and Certification Procedure.

Conclusions are drawn from the results obtained and compared with the functional performance criteria, obtained from ADA. The need for a certification procedure is described.

2.0 EXPERIMENTAL PROCEDURE.

2.1 INTRODUCTION.

The primary objective of the experiments is to appraise the mechanical characteristics of the lift structure. These experiments are helpful in understanding the structural behavior and reliability. The experiments are also useful for : the evaluation of functional performance, establishing design specifications, defining a product certification procedure and quality control.

During the analytical investigation of structure and material, the designer makes certain assumptions, relative to the structural behaviour and solution of the governing equations. Sometimes uncertainties associated with these assumptions lead to errors. To overcome these theoretical errors and for verifying the assumptions, experimental investigations are essential.

Fundamental mechanical parameters of a structural system are strength, stiffness, deformability, energy absorption and energy dissipation capacity. These are evaluated by applying specific loads to the wheelchair lift structure. The parameters that are used in specifying the fundamental mechanical parameters are defined below.

Strength is the ability of structure to resist loads. The strength supply of a structure must exceed the strength demand. The ratio of strength supply and strength demand is called ultimate limit state factor of safety and must be much greater than one.

Stiffness is the structural resistance to deformation.

Flexibility is a measure of structural deformability which is inversely related to structural stiffness.

Energy absorption is a measure of structural durability. When a force is applied to the structure, the structure deforms. During the process the structure absorbs energy and stores it as strain energy and dissipate it by yielding. Strain energy is the area under the force deformation curve of the structure at the point of failure.

In the experimental investigation, the structure is loaded using externally controlled devices and the response functions and applied force are measured. The response functions in this case are selected displacements of the lift structures.

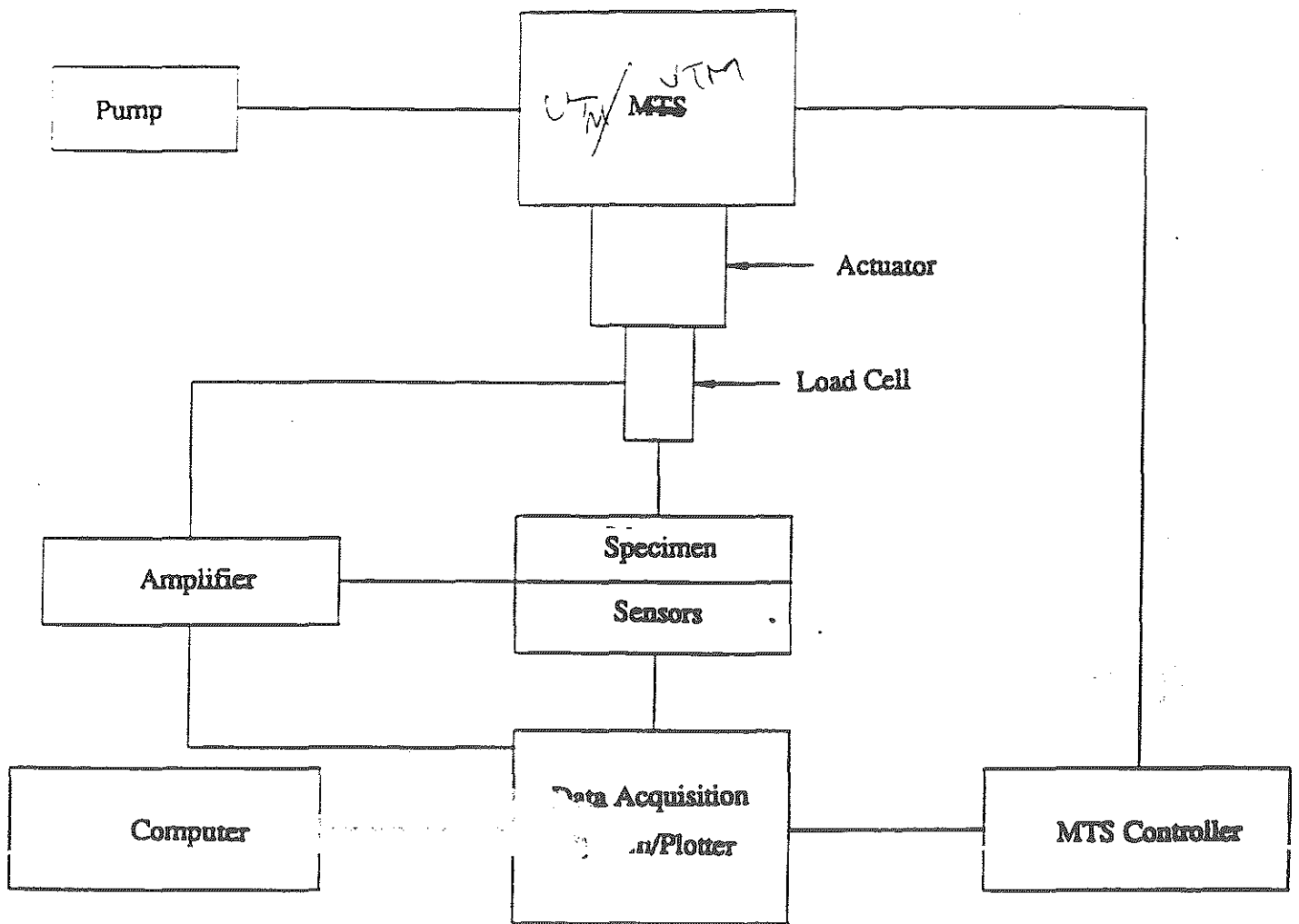
Figure 1 describes the general architecture of the testing set up. An uniaxial testing machine (UTM) is used to apply an uniaxial force on the specimen. An electric pump is used to supply the hydraulic pressure to the UTM. The load cell is connected between the actuator of the UTM and the specimen. The displacement transducers represented as sensors in figure 1, are attached to the wheelchair lift structure. The force and various displacements are recorded with the help of digital data acquisition units controlled by the computer. The testing apparatus, its operational principles and specifications are described in the following section.

2.2 EXPERIMENTAL APPARATUS.

The components of the apparatus are : mounting frame, uniaxial testing machine, controller, sensors and acquisition system.

2.2 (a) Mounting Frame.

The mounting frame is a 'H' frame made from structural steel W sections. The height of the frame is 12 feet above the UTM table. It is supported by two bottom beams parallel to the ground supported by two stands. The frame is braced with angles. These braces prevent



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Figure 1 Testing System Architecture. (UTM)

Universal Testing Machine (UTM)

FIGURE 1 TESTING SYSTEM ARCHITECTURE.

the swaying of the H frame. The wheelchair lift is mounted on a horizontal I beam in a manner that simulates the lift mounting on the bus floor.

2.2 (b) Uniaxial Testing Machine (UTM).

The UTM actuator applies uniaxial tensile or compressive loads to the specimen. The UTM actuator is controlled by a microconsole of the MTS corporation (Minnesota Testing System).

The microconsole consists of three signal conditioners for displacement, load cell (also called delta p) and the strain devices. The controls work on the basis of percent full scale. This gives versatility of changing the effective range of the transducers. The components of the UTM are frame, crosshead, table and actuator shown in figure 2.

2.2 (b1) Frame.

The UTM frame consists of four cylindrical steel columns 12 feet high above table. The diameter of the column is 6 inches. These columns support the crosshead and also permit the vertical movement of the crosshead.

2.2 (b2) Crosshead.

Crosshead supports the actuator and transfers the load to the four columns connecting the table to the crosshead (Figure 2). It can be moved to accommodate various specimen sizes providing a test bed of up to ten feet height. The transducers and hydraulic equipment are mounted on the crosshead. The actuator moves vertically through the crosshead. The crosshead is hydraulically secured by locks mounted on each column.

2.2 (b3) Table.

A steel base (4 feet by 4.5 feet and 1 foot thick) located under the crosshead serves as the table. To fix the test specimen for tensile testing threaded arrangement is provided in

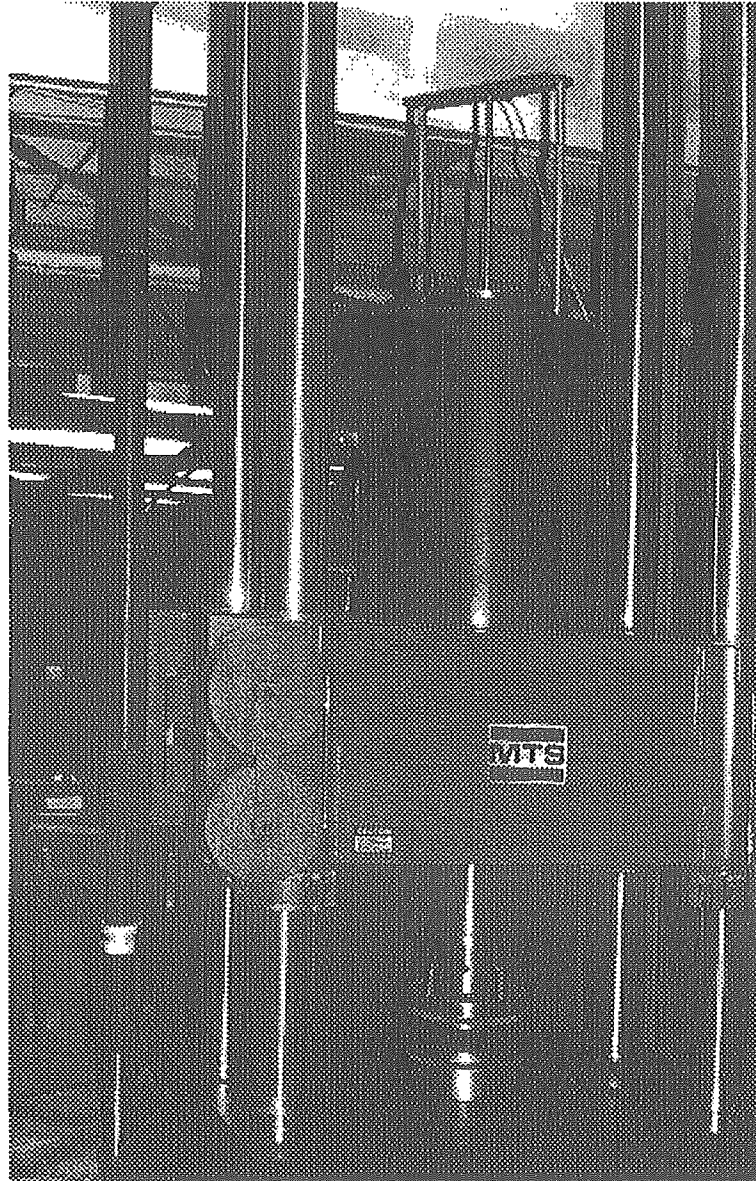


Figure 2 : Universal Testing Machine

the centre of the floor. The steel columns are attached to the table which is extended all the way to the foundation.

2.2 (b4) Actuator.

The UTM has a hydraulic actuator with a total stroke of twenty inches in any one direction. The actuator can travel twenty inches upwards from the lowest position or twenty inches downward from the highest position. It is possible to change the zero position of the actuator to any arbitrary location to accommodate the loading in both directions.

2.2 (c) UTM Controller.

The UTM controller is shown in figure 3. It controls the displacement transducer, force transducer and strain transducer. UTM controller also consists of microprofiler controls the hydraulic pressure with time, rate and amplitude.

The displacement transducers are calibrated for various ranges which are of +/- 1 inch, +/- 2 inches, +/- 4 inches, +/- 20 inches. Thus the displacement range can be adjusted according to the expected demand. The UTM load cell or delta p is calibrated for the range of +/- 100 kips, +/- 250 kips, +/- 400 kips, +/- 500 kips. The strain transducer calibration ranges are +/- 5%, +/- 10%, +/- 25 %, +/- 50%. cartridges.

These three transducers can be controlled by either serial interface or with the help of a built-in microprofiler. The microprofiler allows programming of signals to control the actuator movement. In our case the microconsole is controlled by the microprofiler. Actuator control programmes are written as a triangular pulse and a sinusoidal pulse with one or more segments.

The test using the UTM actuator is conducted by selecting displacement, force as the feedback sensor. The tests described here are conducted in the displacement control. In

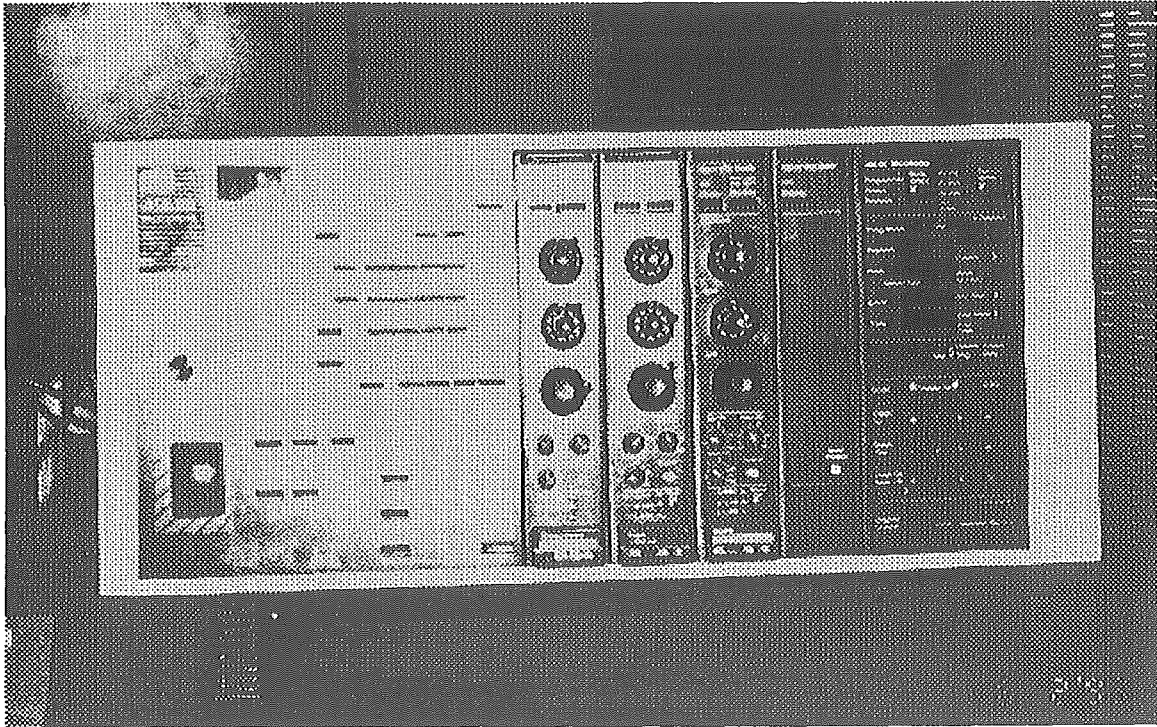


Figure 3 : UTM Controller

other words, the actuator piston displacement is controlled through the displacement transducer and corresponding force is recorded through force transducer as the wheel chair lift is subjected to a programmed displacement cycle. In these tests displacement transducer is the controlling transducer and the force transducer is feedback transducer. All sensors are recorded in the computer disc using a data acquisition system.

2.2 (d) Instrumentation.

2.2 (d1) Load Cell.

A load cell is a sensor to which strain gages are permanently attached. It converts a known force to equivalent electrical signals. These signals when properly calibrated, are proportional to the force.

Figure 4 shows the load cell attached to the actuator. The load cell consists of bonded foil strain gages with a bridge resistance of 350 ohms. The term bridge resistance is related to the Wheatstone bridge assembly, which is an electrical circuit measuring the unknown resistance with three known resistance arranged in a bridge configuration.

The SENSOTEC load cell with a range of 50000 pounds (tensile or compressive) is used for the testing. The load cell excitation voltage is ten volts and the load cell output is three millivolts per volt at full scale (50,000 pounds). Thus, under 50,000 pounds load the load cell voltage output will be 30 millivolts at ten volts excitation. The load cell excitation voltage is kept constant at ten volts during the experiment. The load cell calibration coefficient is then computed as 1666.7 pounds per millivolts.

The load cell consists of two stabilising diaphragms, which are welded to the sensing member to reduce off-centre and side loading effects. It has two threaded holes at the top and bottom for mounting the specimen. For better accuracy it should be used on a flat,

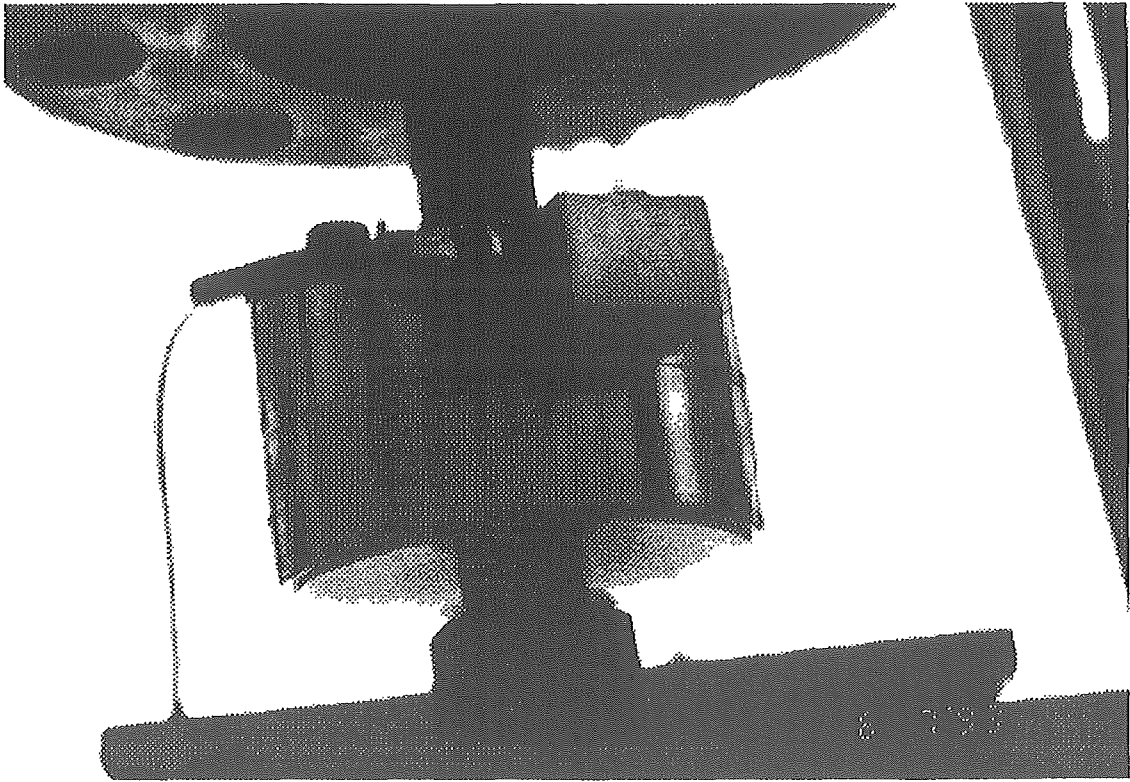


Figure 4 : Load Cell

smooth surface. The load cell electronics wiring is accessed with a six pin connector. Two of the pins are for excitation volts and one pin is for ground connection. The remaining four pins are used for the signal and excitation voltage sensing by the data acquisition system.

2.2 (d2) Direct Current Displacement Transducer (DCDT).

A DCDT is similar to a linear variable differential transducer (LVDT). A LVDT outputs alternating voltages and is excited by alternating voltage. A DCDT converts the excitation voltage to alternating voltage internally and converts the output to DC voltage also internally. It consists of a core with magnetic flux, a magnetic casing and four cables. Figure 5 shows the DCDT mounted on a lift.

The casing consists of three wire coils wound on an insulated cylindrical shell. The core moves inside the cylinder. The core magnetically couples with the centre primary coil to two adjacent coils. When the core is at magnetic centre, it produces zero output voltage. Displacement of the core from this centre position causes a linear output voltage in both the directions.

The four output cables are for positive and negative excitation voltage and high and low signal output. The DCDT's are calibrated by applying known displacements. The voltage is measured for an excitation voltage of 10 volt. Figure 6 to 13 show the calibrations results of the DCDT's used in the experiments and summarised in Table 1.

2.2 (e) Data Acquisition.

2.2 (e1) Amplifier.

An amplifier increases a low-level transducer output signal to a level sufficient for use by a voltage measurement device. The basic purpose of an amplifier is to adjust the relationship

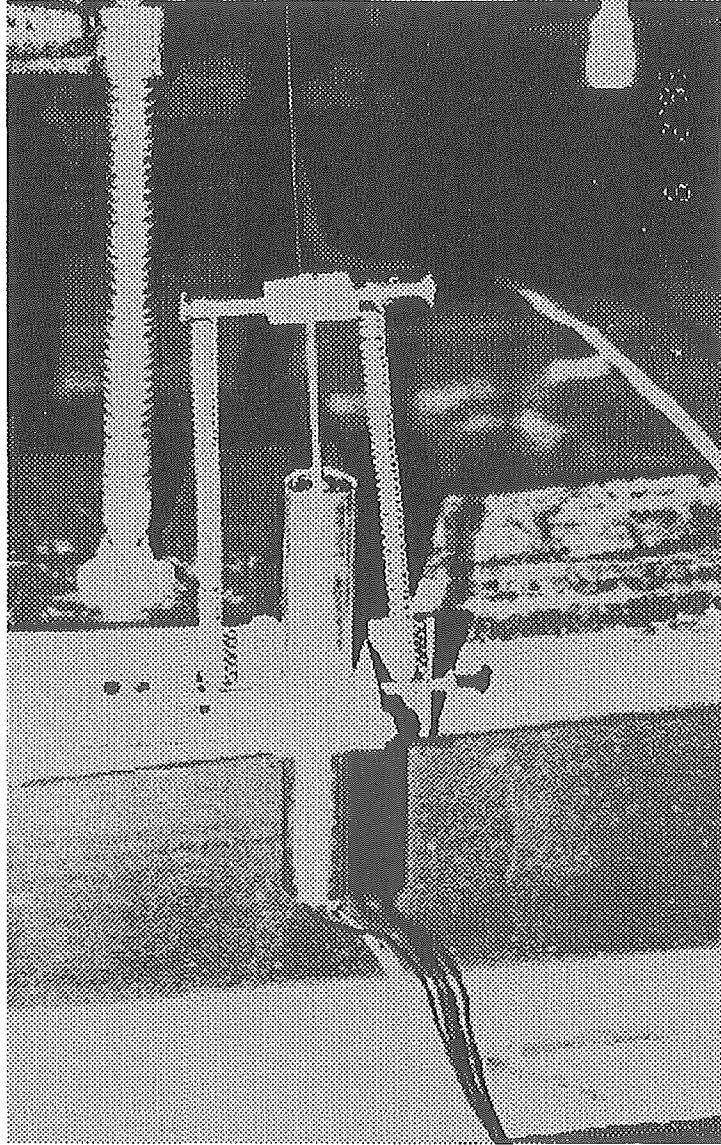


Figure 5. DCDT Arrangement

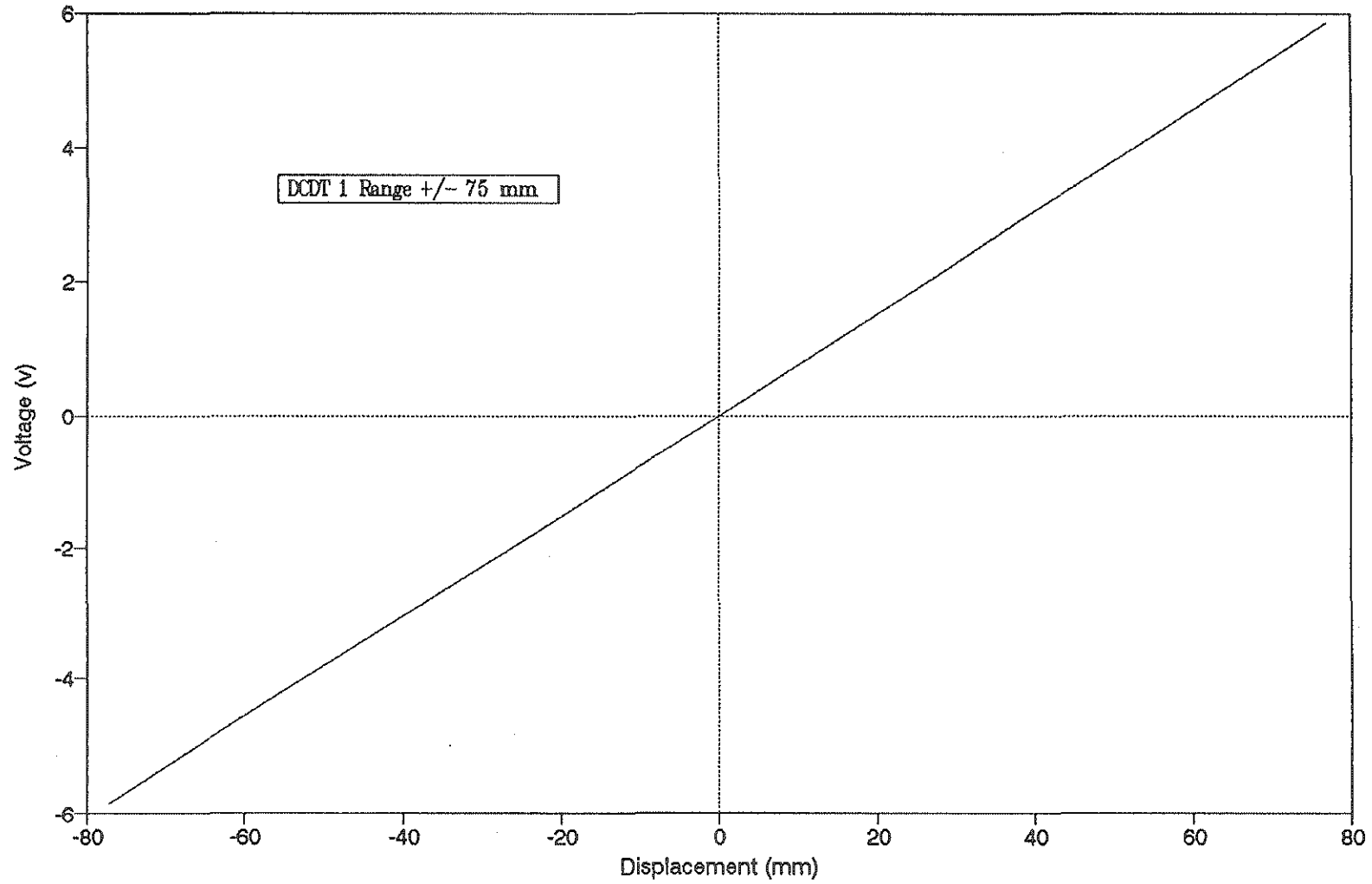


Figure 8 : Calibration Of DCDT 1

b)

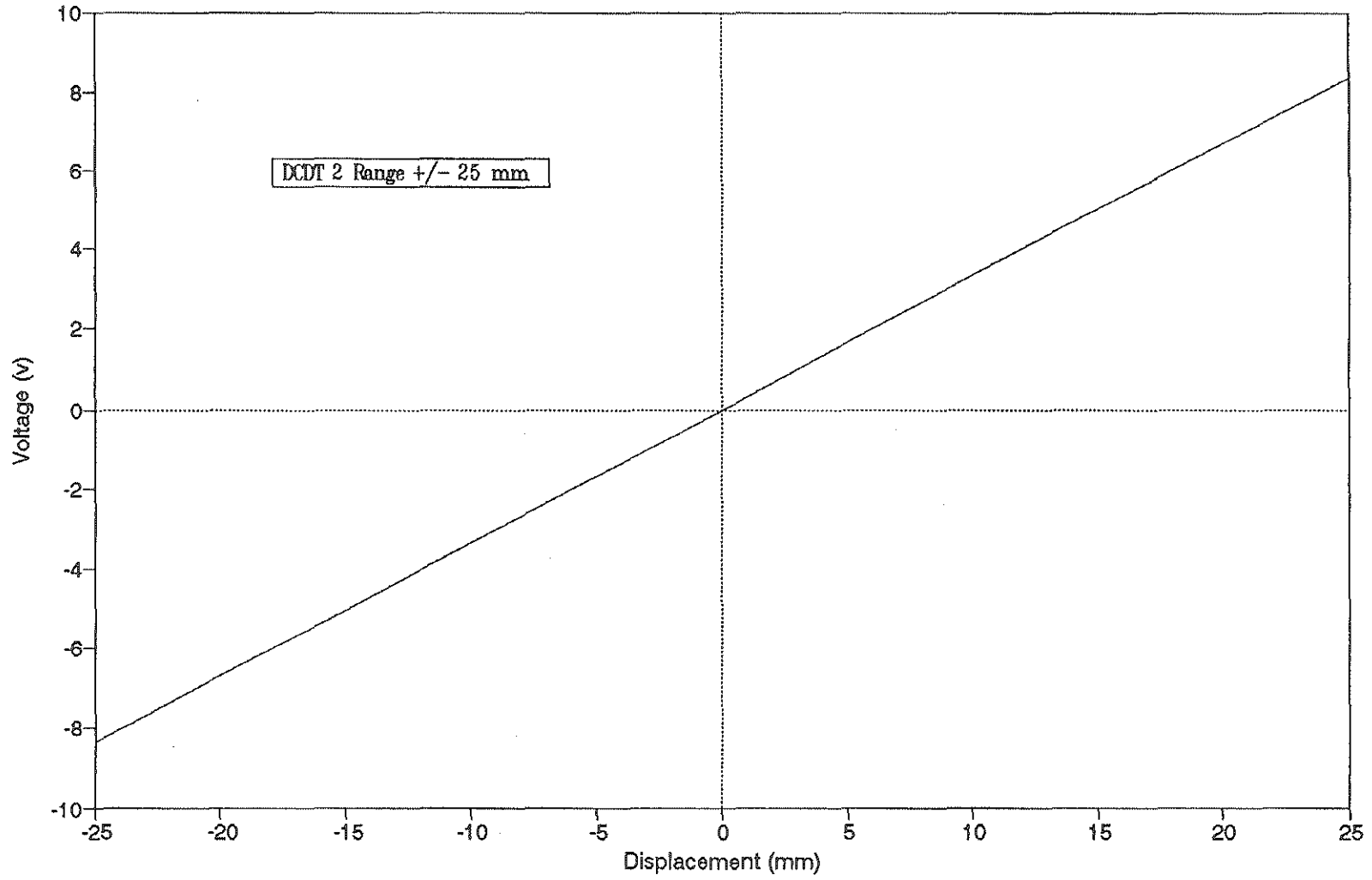


Figure 7 : Calibration Of DCDT 2

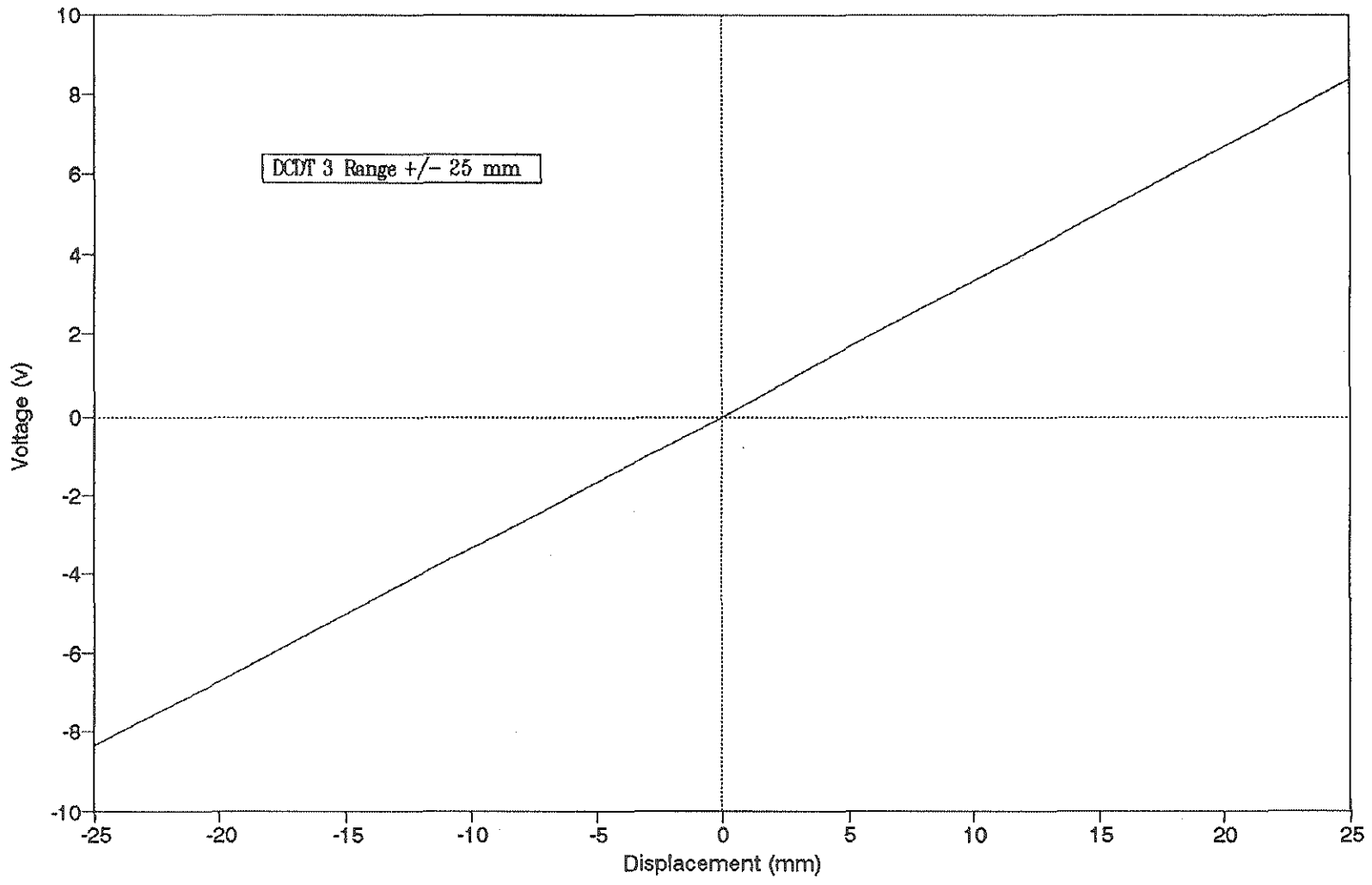


Figure 8 : Calibration Of DCDT 3

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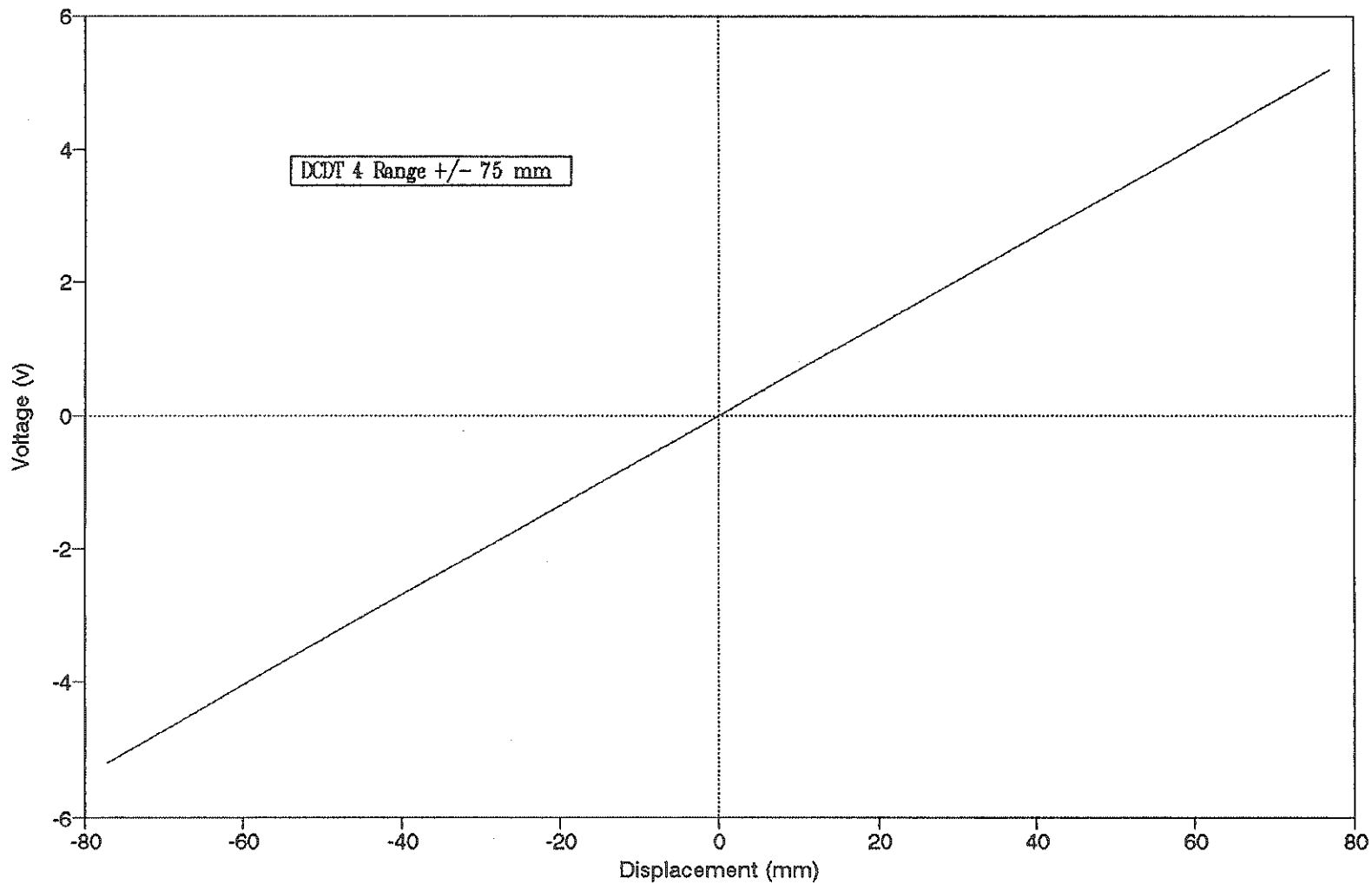


Figure 9 : Calibration Of DCDT 4

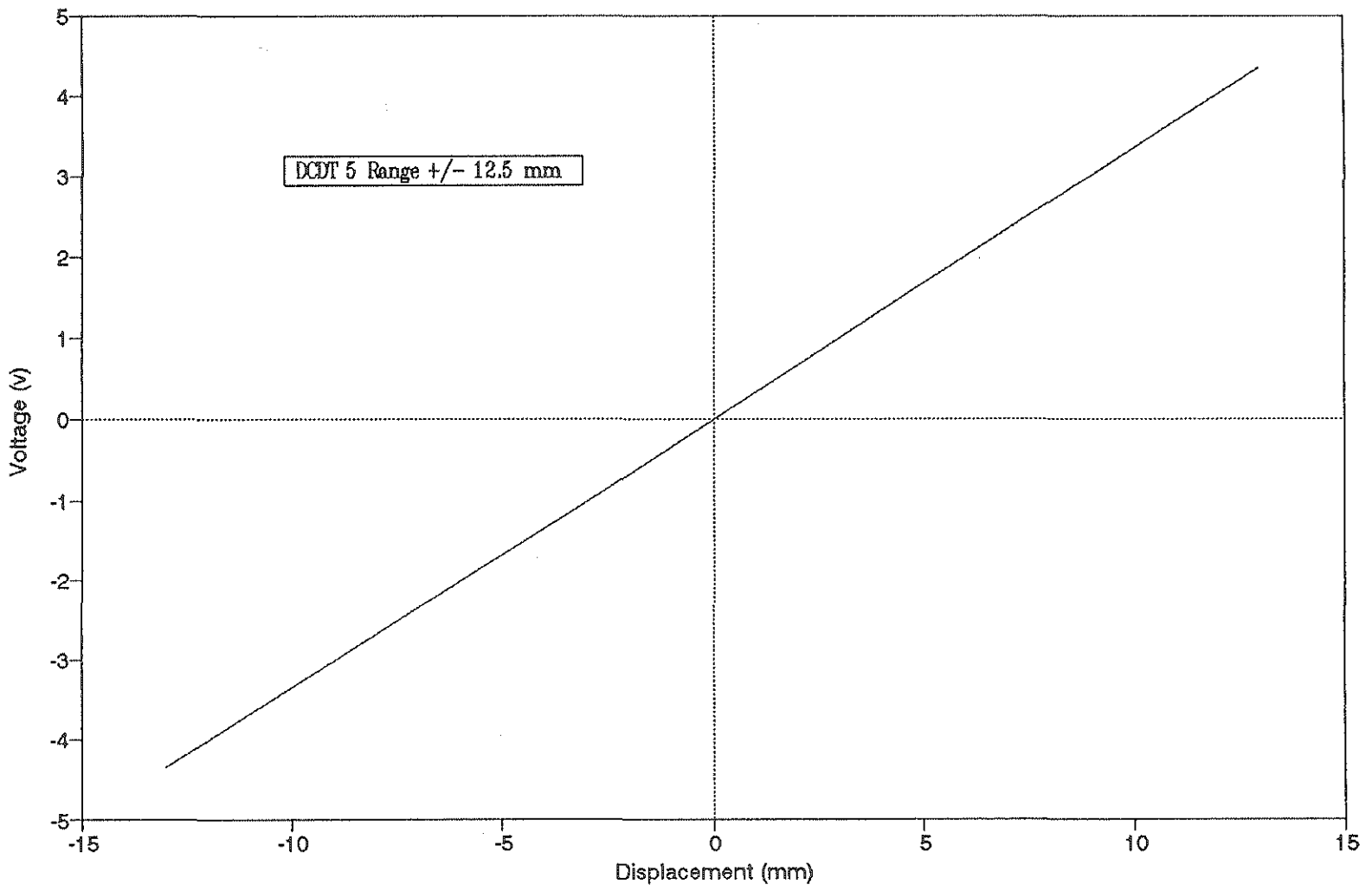


Figure 10 : Calibration Of DCDT 5

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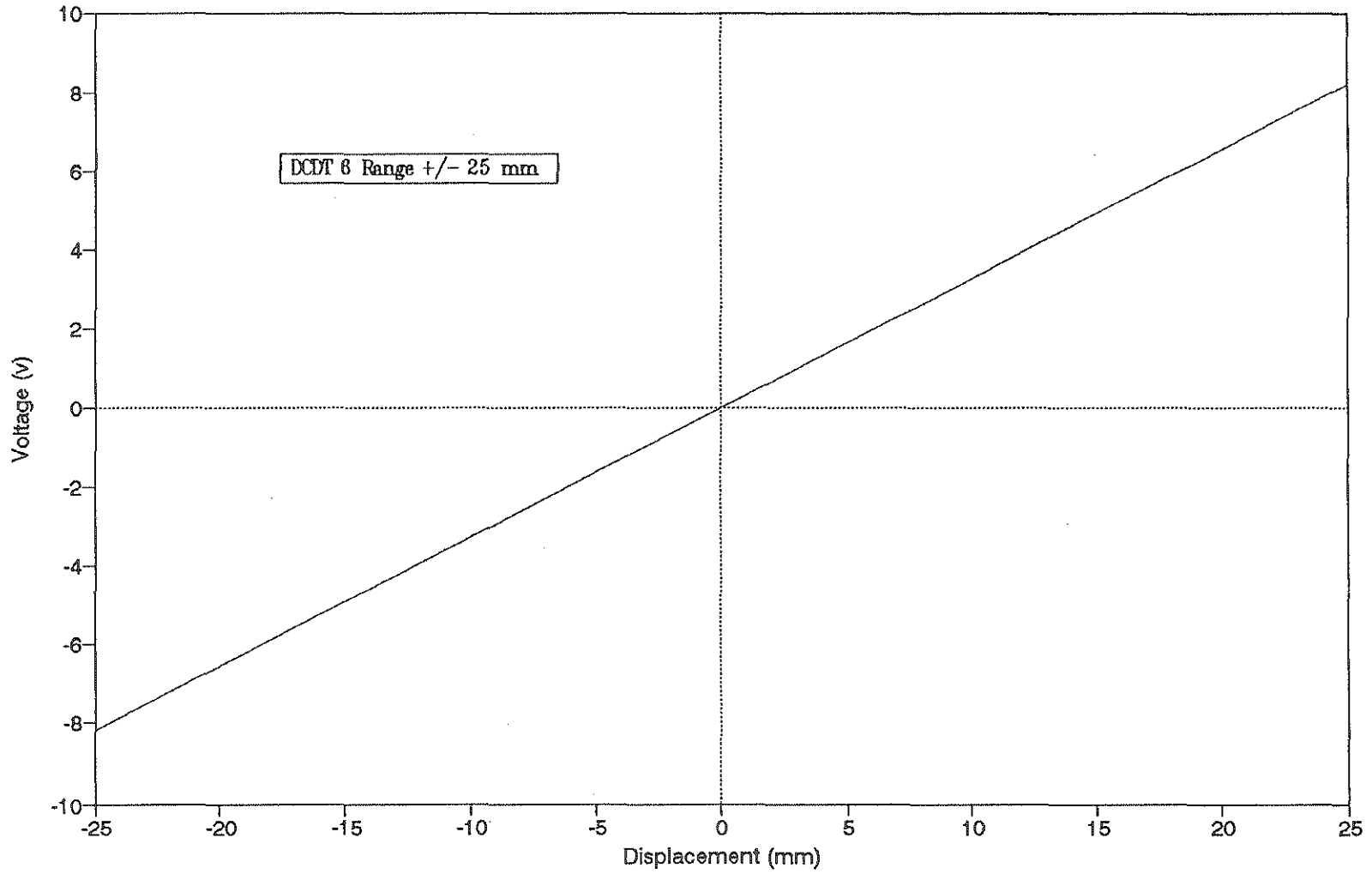


Figure 11 Calibration Of DCDT 6

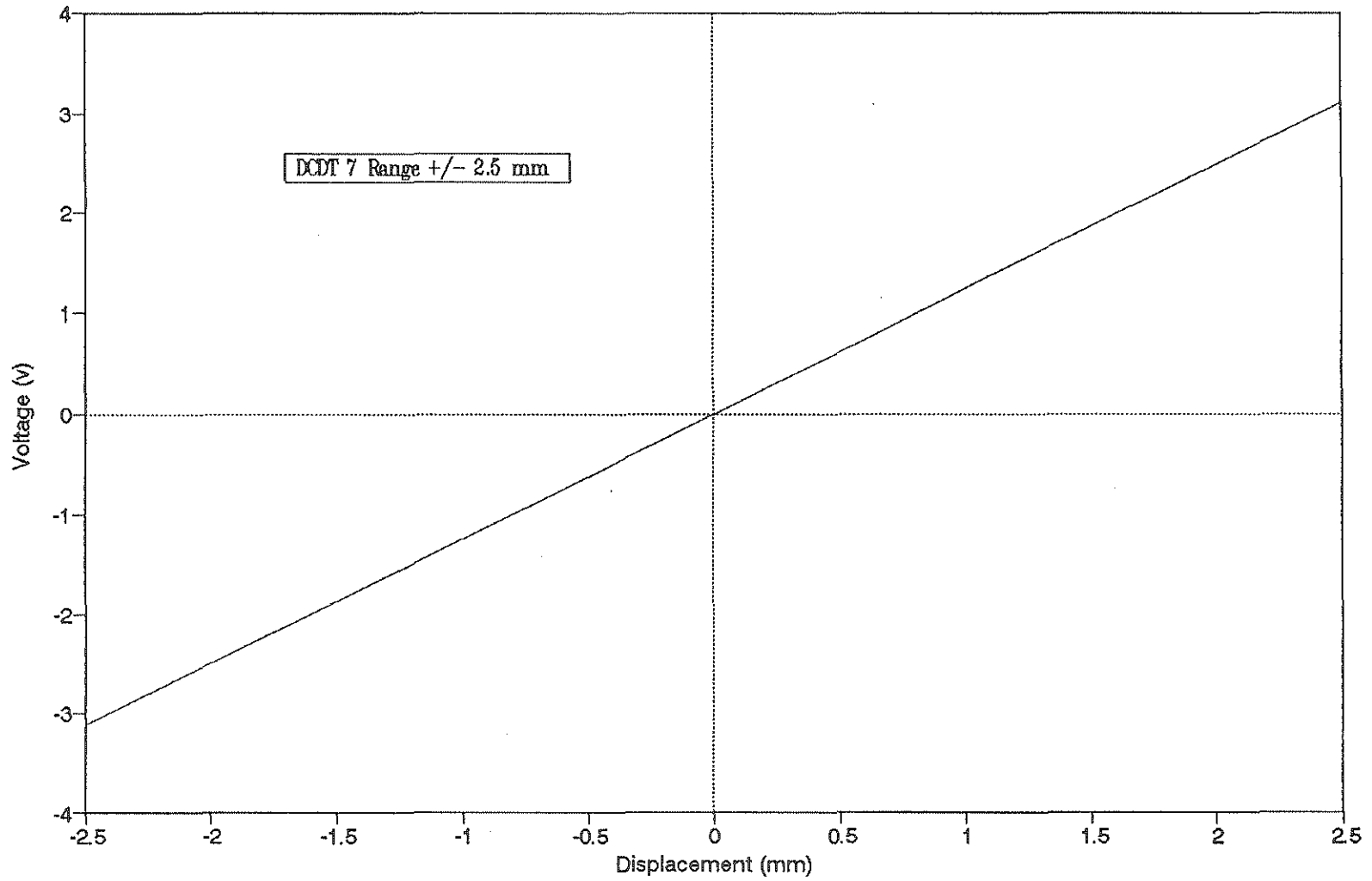


Figure 12 : Calibration Of DCDT 7

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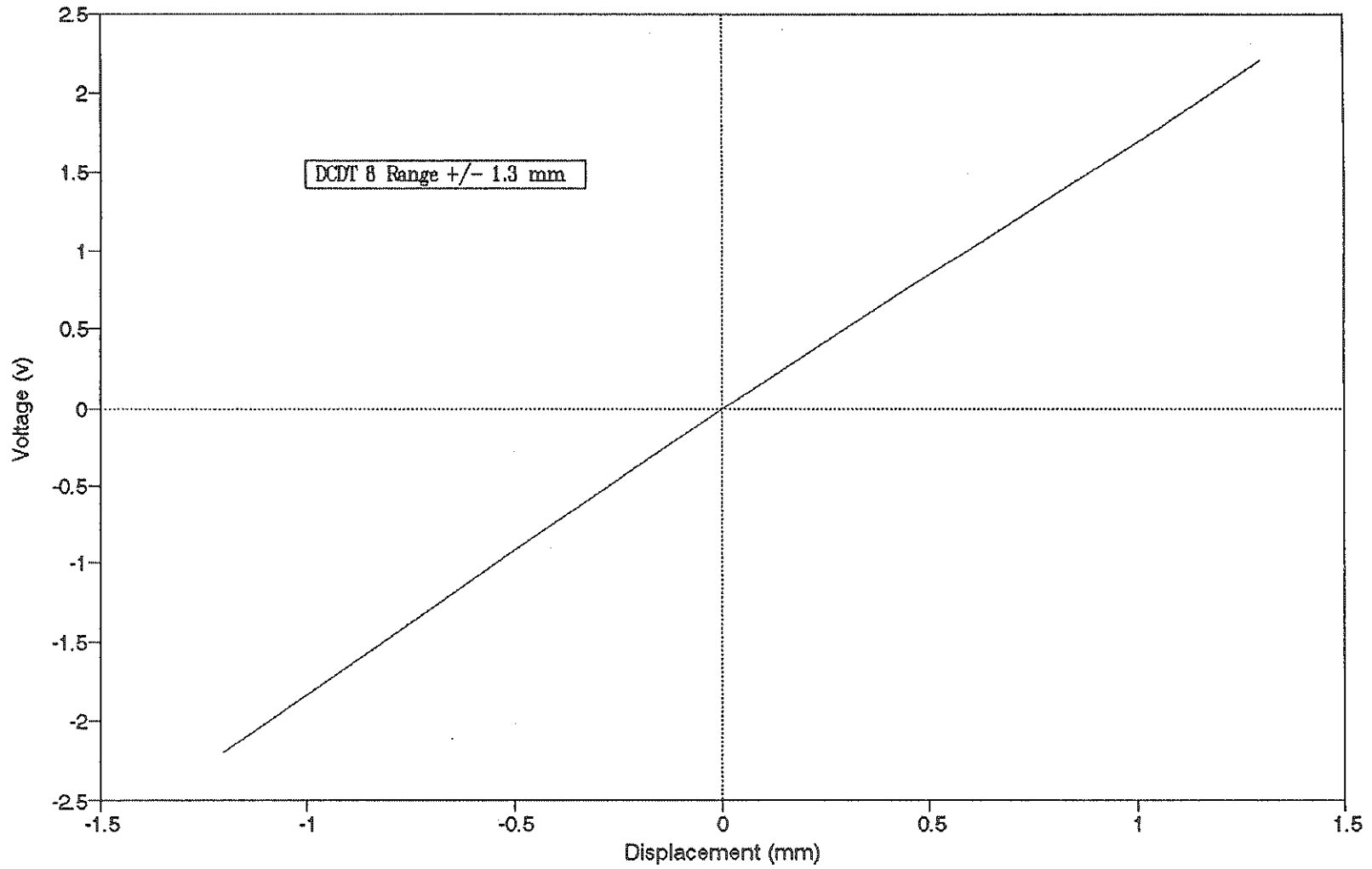


Figure 13 Calibration Of DCDT 8

Table 1 Calibration Data For Sensors.

Instrument	Model No	Range	Calibration Ratio	Excitation Volt
MTS LOAD	66Q23A-02	0-500 KN	10.0	+/- 10 V
MTS DISP.	LVDT	+/- 10 Inch	2.0	+/- 10 V
LOAD CELL	41/573-01	0-50 KN	500.0	+/- 10 V
DCDT-1	246-000	+/- 3 Inch	0.522	+/- 10 V
DCDT-2	244-000	+/- 1 Inch	0.121	+/- 10 V
DCDT-3	244-000	+/- 1 Inch	0.123	+/- 10 V
DCDT-4	246-000	+/- 3 Inch	0.590	+/- 10 V
DCDT-5	243-000	+/- 0.5 Inch	0.120	+/- 10 V
DCDT-6	244-000	+/- 1 Inch	0.116	+/- 10 V
DCDT-7	241-000	+/- 0.1 Inch	0.033	+/- 10 V
DCDT-8	240-000	+/- 0.05 Inch	0.030	+/- 10 V

between the signal and the frequency response. Frequency response of the signal is a measure of gain change with frequency of the input voltage signals.

The amplifier consists of an input socket receiving signals from the instruments and transmitted to a recording device through output socket after conditioning and amplifying.

For example, the SENSOTEC load cell gives 30 millivolts output at peak loads without amplification. If the amplification gain is adjusted to 333 the output at maximum will be 10 volts. The output, after amplification, is the product of gain, and load cell output.

The fact remains that the amplification of signals also amplifies its error. To eliminate this error the output is averaged within a specific time increment.

2.2 (e2) Data Acquisition System.

The output signals transmitted from different transducers are read and stored by the data acquisition systems. The data acquisition system performs the following function.

- i) Data acquisition.
- ii) Data storage.
- iii) Data processing.

The data acquisition task measures data inputs from a collection of analog signals and stores it digitally. The data is then transferred to a computer through serial interface and stored in a file in a tabular fashion. The data is later analysed using spread sheet programs and can also be represented graphically if needed.

For the lift testing, two different data acquisition systems are used as shown in figure 14 and figure 15. (The HP-3497A and HP-7475A). HP-3497A is a unit with a capacity to measure 20 channels. The unit is controlled by a computer with a serial interface. The

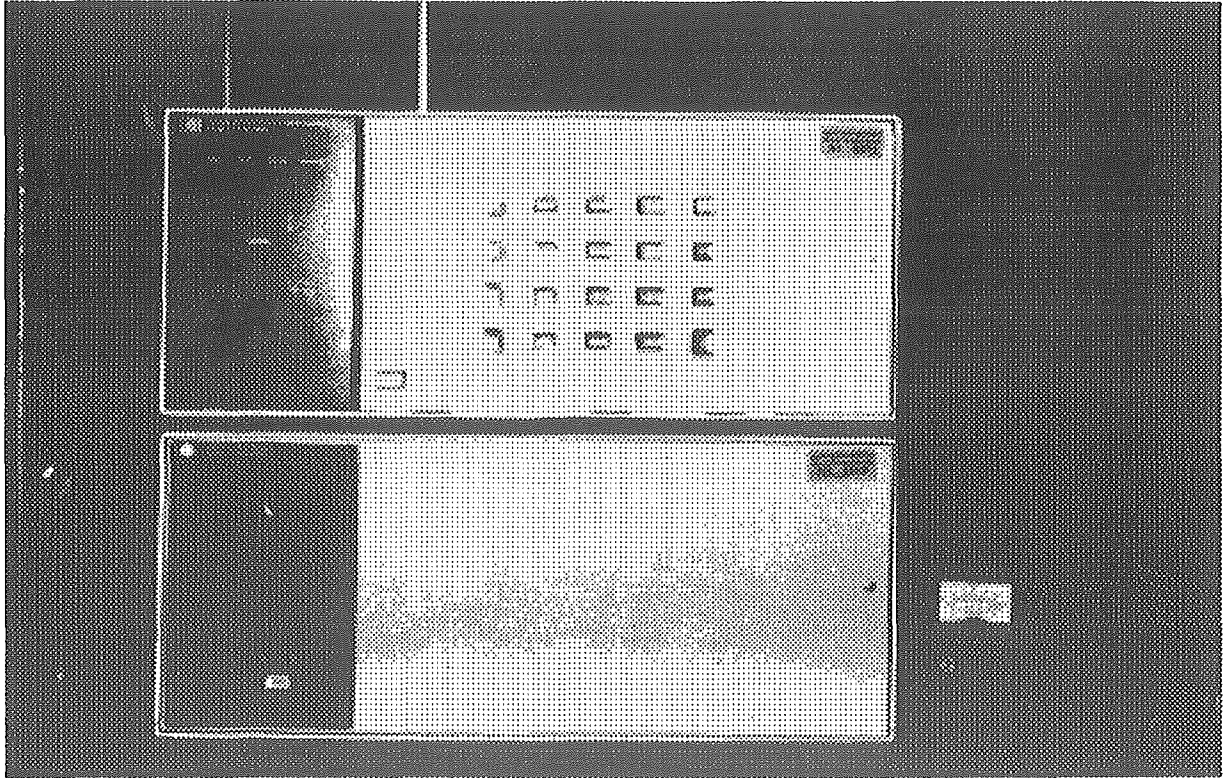


Figure 14 : HP - 3497 A

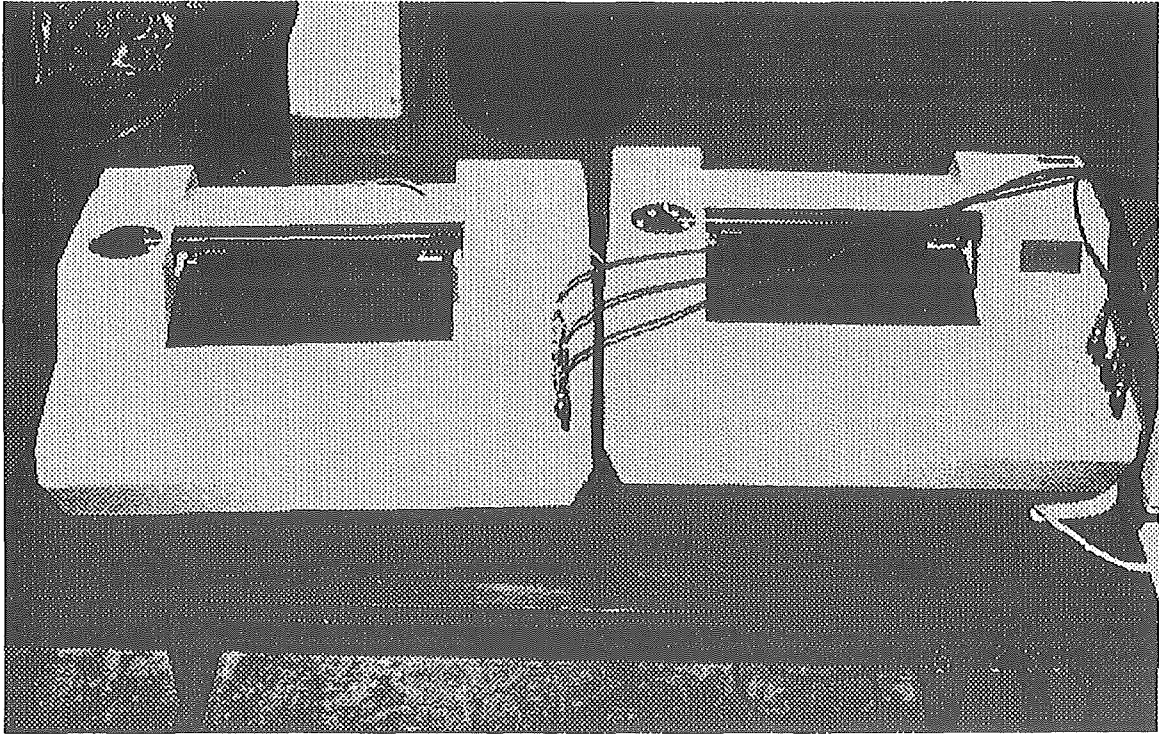


Figure 15 : HP - 7475 A

channels are closed sequentially to read the data. The HP7475-A works with the same principle but its capacity is limited to six channels.

2.2 (f) Data Processing.

Data acquired in the data acquisition system is stored in the computer in the ASCII format. The data files are later imported to the spread-sheet software, and processed by knowing the initial bias and by filtering. Finally the data is presented in the tabular or graphical fashion.

2.3 EXPERIMENTAL PROCEDURES.

The experiments performed on platform lifts are grouped as follows:

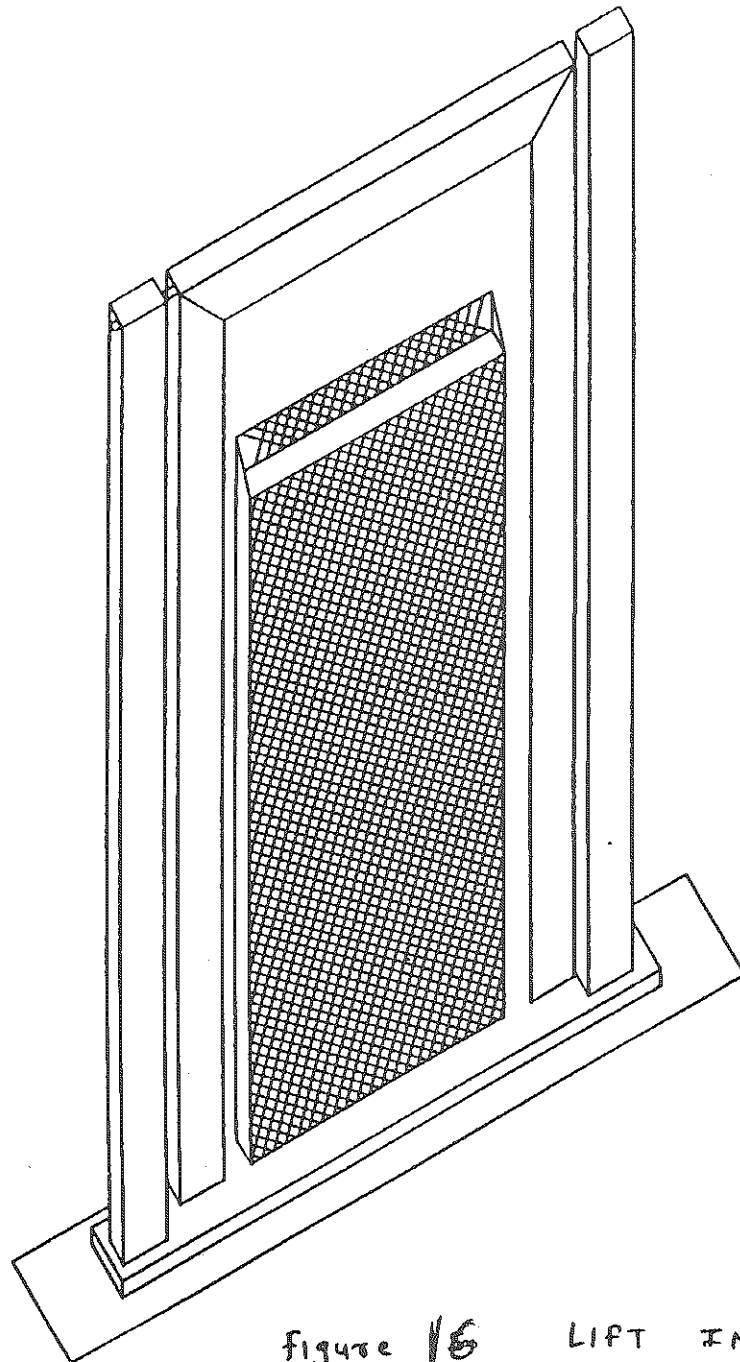
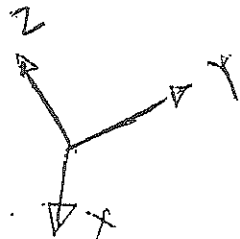
- 1) Structural property determination experiments.
- 2) Structural reliability and serviceability evaluation experiments.

2.3 (a) Experiments For Structural Property Determination.

In these tests the flexibility of the lift is obtained in fully stowed position. The objective of the testing is to determine the stiffness properties of the lift for computing its vibration response during bus motion.

Figure 16 shows the lift model used for the experiments. A model with three degree of freedom is used as explained in chapter 3. The first and second degrees are to represent the flexibility in positive and negative x-directions respectively. In other words, they are in the perpendicular direction of bus motion at platform centre. The third degree of freedom is in the direction of bus motion at the top of the lift portal. Figure 17 shows the instrumentation attached to the fully stowed lift. Four DCDT's are attached to the lift for measuring the displacement response function.

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figure 16 LIFT IN STOWED POSITION

Three different experiments are conducted, by applying a known force of 100 pounds in the direction of each degree of freedom and the displacements at all the three degree of freedom are measured. The stiffness is computed by dividing the applied force by the measured displacements.

2.3 (b) Experiments for reliability and serviceability evaluation.

In testing for reliability and serviceability the lift is tested in semi-deployed and fully-deployed position. The objective is to obtain the deformability and load versus displacement response relationship of the lift structure. Deformability is determined from static flexibility experiments. Load versus displacement response is determined from quasi-static loading and unloading experiments. The testing is done in two stages for the static flexibility and loading / unloading response.

The lift properties are described in one discrete point on the platform centre with three degrees of freedom. The three degrees of freedom at the lift platform centre are the vertical and the two horizontal displacements in longitudinal and the lateral directions respectively. For the vertical flexibility test, the vertical load of 100 pound each is applied at the centre of the side beams and back beam. For the horizontal flexibility test the horizontal load of 100 pounds is applied in the corresponding degree of freedom.

The objective of loading/unloading testing is to obtain the initial stiffness of the lift structure and the non-linear load displacement behavior. This test also measures the slack or lack of tight fit between lift structure components. This lack of tight fit will appear as a slip in lift displacement with no change in load around zero load. The test is conducted by applying a prescribed displacement through UTM actuator and recording the measured force.

3.0 EXPERIMENTAL EVALUATION OF THE LIFT STRUCTURE.

3.1 INTRODUCTION.

The structural evaluation of lifts can be performed both analytically or experimentally. Analytical results may not exactly match its experimental counterparts due to the approximations in the analytical assumptions and due to experimental errors. As an example of analytical approximations, for the analysis of the lift in the stowed position the lift mechanism is assumed clearance free. This is not the case in reality as is observed during experiments. Also, the lift connection to the bus floor is assumed fixed. In reality, the base is not fixed but allows some rotation which amplifies the lift platform displacement. These and similar assumptions are verified by the experiments on the wheelchair lift structure.

The analysis of the lift structure showed significant platform tip displacements. Experiments on the lift structure also included the verification of these displacements for the lift serviceability and reliability. Thus the reasons for testing wheelchair lifts are categorised as:

- 1) Testing for analytical model parameters.
- 2) Testing for reliability indicators and serviceability measures.
- 3) Establishment of the functional performance criteria.

In the analytical model parameter testing, the lift is tested in the fully stowed position. The objective is to extract the stiffness properties of the lift with the intention of simulating the effect of bus motion on the lift. The dynamic actions observed by the lift during the bus motion is obtained from literature. The effect of this action is determined from the analytical model using experimentally obtained stiffness properties.

In the serviceability and reliability testing the characteristic of the lift platform is evaluated in all three directions, the vertical axis, the lift axis and lift platform perpendicular direction. Flexibility provides a measure of its resistance to load.

3.2 EXPERIMENTAL EVALUATION.

3.2 (a) Testing for Analytical Model Parameters.

The fully stowed lift is modelled as a three degree of freedom structure as shown in figure 16. In structural dynamics, the term number of degree of freedom is defined as the number of independent co-ordinates necessary to specify the deformed configuration or position of the structure at any time. Theoretically, modelling of any structure requires infinite number of degree of freedom. The selection of appropriate mathematical model permits the reduction in the number of degree of freedom and accordingly three degree of freedom model is selected by assuming : (1) the platform is a rigid plate that contains all the lift inertia and (2) the supporting structure is weightless.

The first degree of freedom is in the perpendicular plane to the lift platform (positive x-direction) . The second degree of freedom is in the reverse X-direction (negative x-direction) . These two degrees of freedom are for simulating the dynamic response of the lift platform with respect to the lift frame during the bus motion. The third degree of freedom is in the plane of the platform and parallel to the ground (Positive Y-direction).

The testing is performed to obtain the structural stiffness or flexibility matrix that are equal to each other in inverse

The instrumentation is shown in figure 17. The DCDT's are placed for measuring the displacements of four locations on the lift. These points where displacements are monitored correspond to : (1) the top right corner of the vertical column of the lift, (2) the mid point of

the horizontal top beam, (3) the top left corner of the vertical column of the lift and (4) the centre of the lift platform to measure the transverse displacement. The first three DCDT's measure the lateral displacement in a plane parallel to the lift platform. A force of 100 pounds is applied at a specific degree of freedom and the response of the DCDT's are measured.

Following are the experimental flexibility matrices obtained for the two lifts tested in this study.

For lift 1

$$F = \begin{bmatrix} 0.0015 & 0 & 0 \\ 0 & 0.0056 & 0 \\ 0 & 0 & 0.0115 \end{bmatrix}$$

For lift 2

$$F = \begin{bmatrix} 0.0006 & 0 & 0 \\ 0 & 0.0076 & 0 \\ 0 & 0 & 0.0153 \end{bmatrix}$$

The terms f_{11} and f_{22} are in inch per pound. Term f_{33} is rotational degree of freedom represented in units of radian per pound. f_{ij} indicates the term in the F matrix at i^{th} row and j^{th} column. The experiments indicate that the degrees of freedom of the lift are not coupled and the flexibility matrix is a diagonal matrix with zero off diagonal terms.

Larger flexibility values indicates softer structure in that degree of freedom. From the matrices obtained, one can see that the translation of the first lift platform is more flexible

than the second lift platform. On the other hand second lift's rotational degree of freedom is more flexible than the first lift.

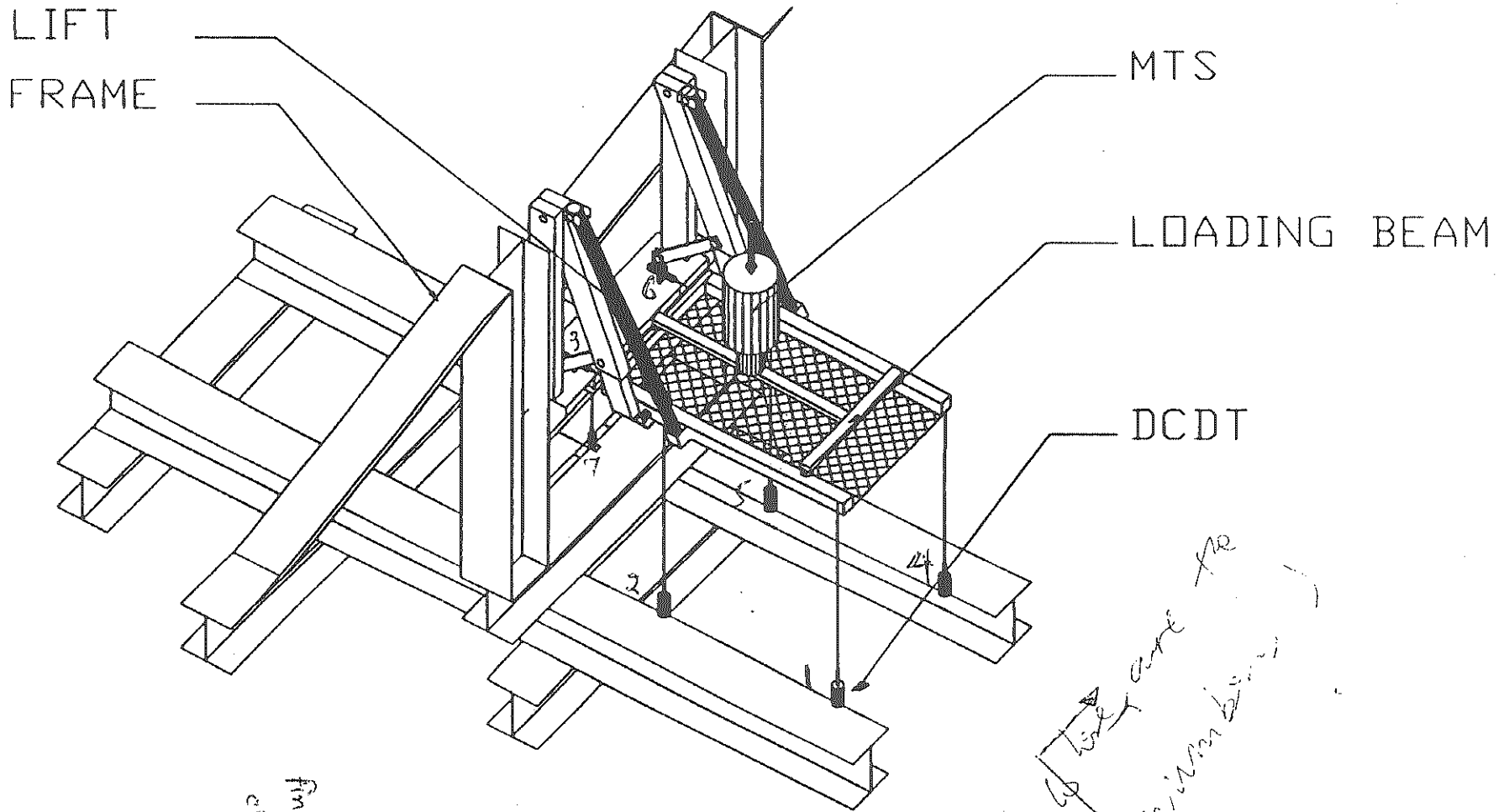
3.2 (b) Testing for Serviceability and Reliability Parameters.

Testing for reliability covers the evaluation of the platform flexibility under passenger load, loading and unloading response obtained from quasi-static testing. The lift flexibility is evaluated for two cases ; platform in semi-deployed position and in fully-deployed position. For both cases a model with three degrees of freedom is assumed. The degrees of freedom are the displacements at lift platform centre in the three directions. The mathematical model used in flexibility experiment is also used for the lift platform loading and unloading response.

Figure 18 shows the instrumentation used in the testing. The lift is mounted on a steel 'H' frame representing the bus. The displacements of the lift at eight locations are monitored. These locations are selected using the results of the analytical work on the lifts.

Two DCDT's with a range of +/- 3 inches are fixed at the toe of the lift platform side beam to measure the vertical downward displacement of the platform. These locations are marked as 1 and 4 in Figure 18. Two DCDT's numbered 3 and 6 in figure 18, of the range of +/- 25 millimetres are fixed at the platform heel to measure the lateral displacement of the lift platform in a direction normal to the bus axis. Two DCDT's numbered as 2 and 5 with a range of +/- 1 inch and +/- 0.5 inch are fixed to the platform heel and measuring vertical displacements. The DCDT's numbered as 7 and 8 are attached on each side of the lift base to measure the lift platform displacement due to base rotation. The range of DCDT's marked 7 and 8 is +/- 0.1 inch and +/- 0.05 inch respectively.

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Final figure will be clean in AutoCAD

Figure 18 Instrumentation For Reliability Model Parameters

The SENSOTEC load cell of 50000 pounds capacity is used to measure the load. The response obtained from the load cell is amplified by 3333 times with the help of the amplifier. The load cell is used to obtain only loading and unloading response of the lift platform.

3.2 (b1) Static Flexibility Tests.

The static flexibility tests are performed for both semi-deployed and fully-deployed position based on a model with three degrees of freedom located at the centre of the platform with one vertical displacement and two lateral displacements. The tests are referred to as the vertical flexibility test and horizontal flexibility test based on the direction of loading.

3.2 (b2) Vertical Flexibility Tests.

The instrumentation is mounted as shown in figure 18. A static load of 100 pounds is applied at the middle of the side platform beams and at the middle of the back beam totalling 300 pounds. The displacement at all eight locations are measured and are superimposed to obtain the platform response. The vertical displacement at the platform centre is obtained by linear interpolation of displacements along platform side beams. Tables 2 and 3 show the displacements measured at locations for the lift in the semi-deployed position and fully-deployed position respectively.

In table 2 and 3 , the displacements measured at platform heels are due to applied static load. The displacement at platform toe includes both; displacement due to applied static load and due to platform rotation. The vertical displacement at platform heel and toe is 0.145 inch and 0.593 inch respectively for lift 1. For the second lift the corresponding numbers are 0.191 and 0.777 inch respectively.

Table 2 Lift In Semi-Deployed Position Under 300 Pound Vertical Static Load.

Location	Lift 1 Displacements (Inches)	Lift 2 Displacement (Inches)
Vertical Displacement At Platform Heel	0.145	0.191
Vertical Displacement At Platform Center	0.359	0.484
Vertical Displacement At Platform Toe	0.593	0.777
Horizontal Displacement At Platform Heel	0.016	0.011

Table 3 Lift In Fully-Deployed Position Under 300 Pound Vertical Static Load.

Location	Lift 1 Displacements (Inches)	Lift 2 Displacement (Inches)
Vertical Displacement At Platform Heel	0.227	0.410
Vertical Displacement At Platform Center	0.524	0.774
Vertical Displacement At Platform Toe	0.806	1.138
Horizontal Displacement At Platform Heel	0.420	0.244

For the semi-deployed position, the vertical displacement of lifts 1 and 2 at the platform centre is 0.3591 inches and 0.4835 inches respectively and hence the corresponding flexibilities are computed as 1.8×10^{-3} inch per pound and 2.58×10^{-3} inch per pound respectively. This indicates that the platform of lift 2 is more flexible than the platform of the lift 1. Moreover the lift platform horizontal displacements is found to increase in fully-deployed position compared to semi-deployed position.

3.2 (b3) Horizontal Flexibility Tests.

The horizontal flexibility of the lift platform is measured along the direction of bus axis and also in a direction perpendicular to bus axis. It is measured for both semi-deployed and fully-deployed lift position. Two DCDT's are placed to measure lateral displacement in the direction perpendicular to bus axis. The other two DCDT's measure lateral displacement in the direction along the bus axis.

A load of 100 pounds is applied at the centre of the platform back beam and the displacements are measured. The horizontal lift flexibility in the perpendicular direction is measured as 0.00278 inch per pound and 0.00050 inch per pound in semi-deployed position for lift 1 and lift 2 respectively. For the fully-deployed position, the corresponding flexibilities are 0.00620 and 0.00112. The results are tabulated in table 4 as x-direction.

The load of 100 pounds is also applied at the centre of the lift platform right side of beam to obtain the lift platform flexibility in the direction of bus motion. These numbers for semi-deployed position is measured as 0.00567 inch per pound and 0.001 inch per pound for lift 1 and lift 2 respectively. For the fully-deployed position the corresponding numbers are 0.00980 and 0.00588 respectively. The results are tabulated in table 4 as y-direction.

Table 4 Horizontal Flexibility of Lift Platform Under 100 Pound Load.

Semi-Deployed Position	Lift 1		Lift 2	
	Displacement (Inches)	Flexibilities (Inch/Pound)	Displacement (Inches)	Flexibilities (Inch/Pound)
X Direction	0.312	0.003	0.053	0.0005
Y Direction	0.635	0.006	0.426	0.004
Fully-Deployed Position				
X Direction	0.680	0.006	0.120	0.001
Y Direction	1.100	0.010	0.588	0.006

3.2 (b4) Loading And Unloading Response.

The displacement instrumentation is the same as the vertical flexibility test. The only addition in the instrumentation is the load cell for measuring the force.

The testing is conducted in the displacement control. The UTM actuator is programmed for a triangular pulse as shown in figure 19. The abscissa is the time in seconds and the ordinate is percent full scale of the UTM actuator displacement range. The total range is 20 inches and corresponds to 100 percent. The pulse is programmed for a peak of 0.5 inches. The UTM actuator moves 0.5 inches on 2.5 percent of full scale in 60 seconds and returns to the original position in next 60 seconds.

The 'T' shape loading device is designed to simulate the tri wheelchair. The 'T' has a dimension of 25.5 inch by 27 inch. The loading 'T' is connected to the load cell with two plates that can slide in the direction perpendicular to the bus motion to maintain the same position of the loading 'T' during semi-deployed and fully-deployed position.

During the testing the force is measured and all the eight displacements are recorded at their respective locations. Tables 5 shows the toe displacement and corresponding force for both; semi-deployed and fully-deployed position. Lift 1 experience 0.316 under the load of 61 pounds and hence the flexibility is 0.005 inch per pound, in semi-deployed position. The corresponding numbers for fully-deployed position is 0.278 inch, 74 pounds and 0.004 inch per pound. Lift 2 experience 0.406 under the load of 115 pounds and hence the flexibility is 0.004 inch per pound, in semi-deployed position. The corresponding numbers for fully-deployed position is 0.382 inch, 110 pounds and 0.004 inch per pound.

The lift platform centre displacement is interpolated from the recorded displacement of the heel, toe and the base rotation. Table 6 shows the flexibility of lift platform centre when lift is

Table 5 Lift Flexibility at Platform Toe.

	Semi-Deployed Position		Fully-Deployed Position	
	Lift 1	Lift 2	Lift 1	Lift 2
Toe Displacement (Inches)	0.316	0.406	0.278	0.382
Observed Force (Pounds)	61.0	115.0	74.0	110.0
Flexibility (Inch/Pound)	0.005	0.004	0.004	0.004

in semi-deployed position. Lift 1 experiences 0.16 inches vertical displacement under a 65 pound force, that results in a vertical flexibility of 0.0025 inch per pound. For the second lift, the corresponding flexibility is 0.0022. The horizontal flexibilities of lift 1 and lift 2 are 0.0008 and 0.0002 inch per pound respectively. Table 7 shows the flexibility of lift platform centre when lift is in fully-deployed position. Lift 1 experiences 0.15 inches vertical displacement under a 70 pound force, that results in a vertical flexibility of 0.0021 inch per pound. For the second lift, the corresponding flexibility is 0.0022. The horizontal flexibilities of lift 1 and lift 2 are 0.0025 and 0.0015 inch per pound respectively.

Figures 20 through 27 are the force displacement relationship for the lift platform. The abscissa represents the displacement of the lift platform centre either in vertical or horizontal direction and ordinate represents the corresponding measured force. The slope of the curve gives the stiffness of the lift platform.

Figure 20 shows the force versus vertical displacement relationship when the lift 1 is in semi-deployed position. From the figure 20 it is seen that at 0.11 inches of displacement, the structure stiffens. The initial stiffness is 275 pound per inch. After the initial slack it increases to 500 pounds per inch. Thus a 0.11 inch of slack is observed which is due to joints that are not tight fitting.

Figure 21 shows the force versus horizontal displacement relationship for the lift 1 in semi-deployed position. The initial stiffness and the stiffness after the slack is 4300 pound per inch and 31000 pounds per inch. In these figures, it is also observed that the lifts have a non-linear behaviour and the loading and unloading curves do not follow the same path.

Figure 22 shows the force versus vertical displacement relationship when the lift is in fully-deployed position. The platform centre observes 0.15 inch displacement at 74 pound force.

Table 6 Lift Flexibility At Platform Center In Semi-Deployed Position.

	Lift 1	Lift 2
Vertical Displacement At Platform Center (Inches)	0.16	0.24
Observed Force (Pounds)	65.0	110.0
Flexibility Inch / Pound	0.0025	0.0022
Horizontal Displacement At Platform Center (Inches)	0.055	0.022
Observed Force (Pounds)	65.0	110.0
Flexibility Inch / Pound	0.0008	0.0002

Table 7 Lift Flexibility At Platform Center In Fully-Deployed Position.

	Lift 1	Lift 2
Vertical Displacement At Platform Center (Inches)	0.15	0.24
Observed Force (Pounds)	70.0	110.0
Flexibility (Inch / Pound)	0.0021	0.0022
Horizontal Displacement At Platform Center (Inches)	0.19	0.17
Observed Force (Pounds)	75.0	110.0
Flexibility (Inch / Pound)	0.0025	0.0015

LIFT-1 FLEXIBILITY (V)
SEMI DEPLOYED POSITION

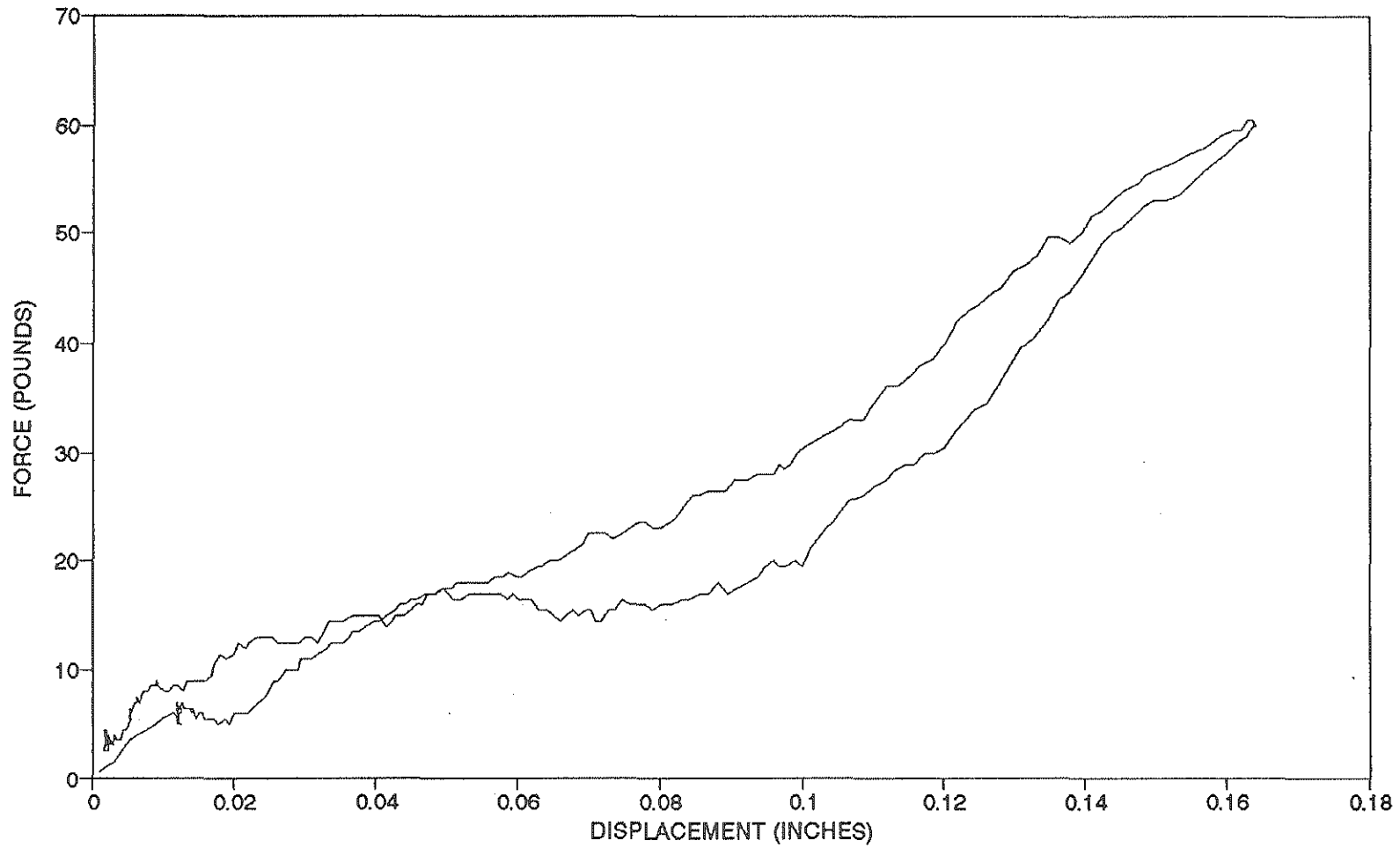
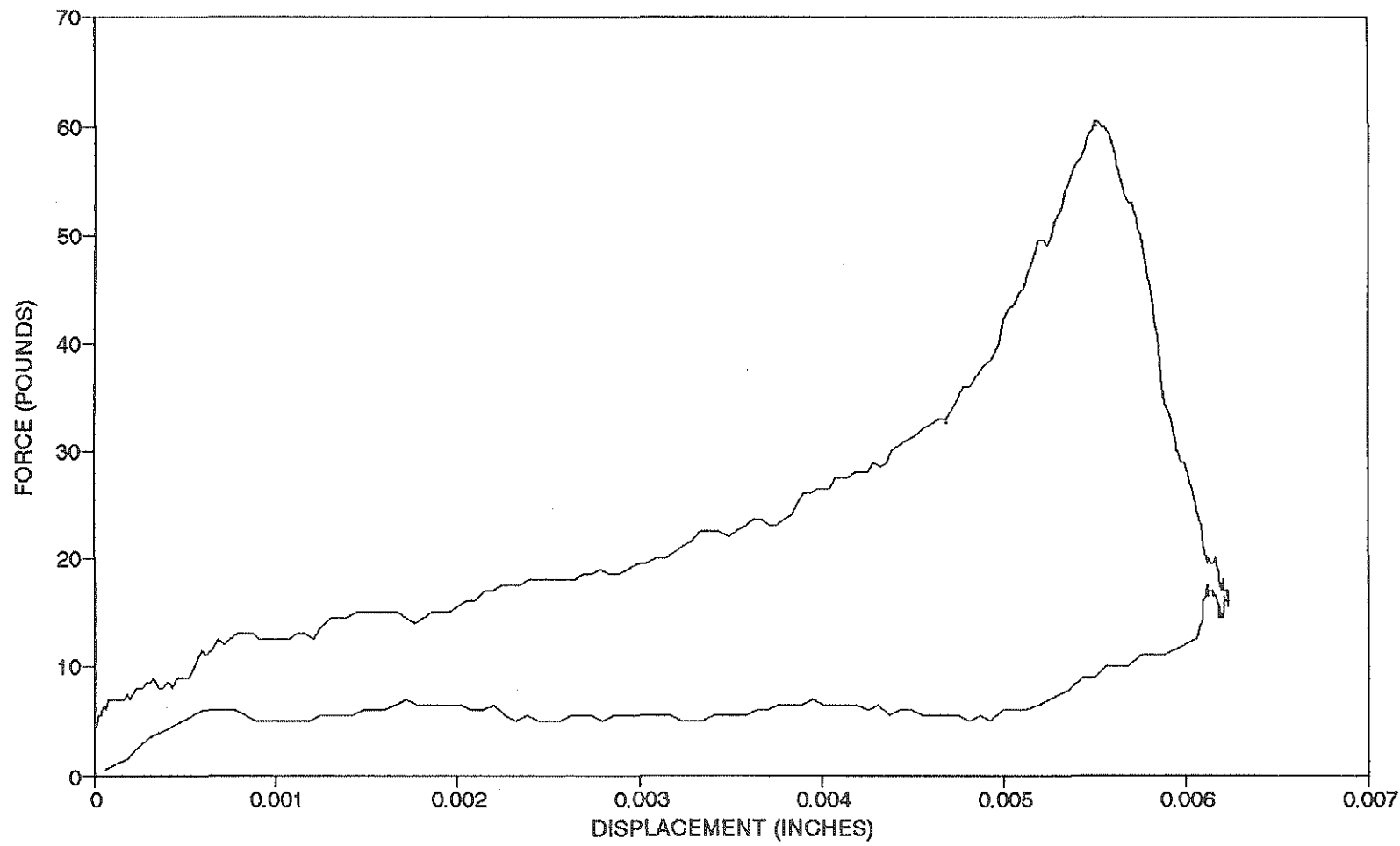


Figure 20 : Force Vs. Vertical Displacement For Lift 1

LIFT-1 FLEXIBILITY (H)
SEMI DEPLOYED POSITION



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Figure 21 : Force Vs. Horizontal Displacement For Lift 1

LIFT-1 FLEXIBILITY (V)
FULLY DEPLOYED

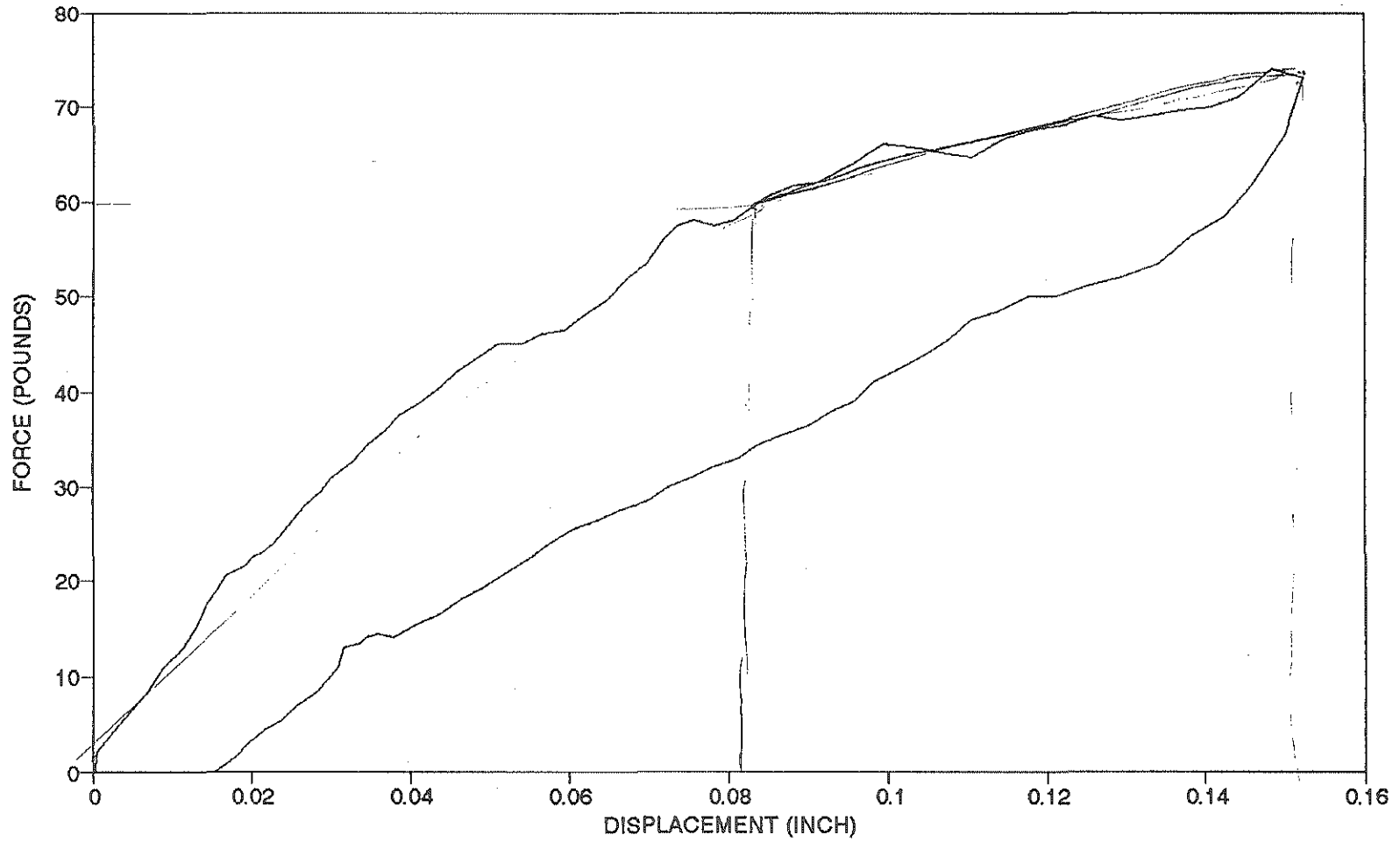


Figure 22 : Force Vs. Vertical Displacement For Lift 1

LIFT-1 FLEXIBILITY (H)
FULLY DEPLOYED

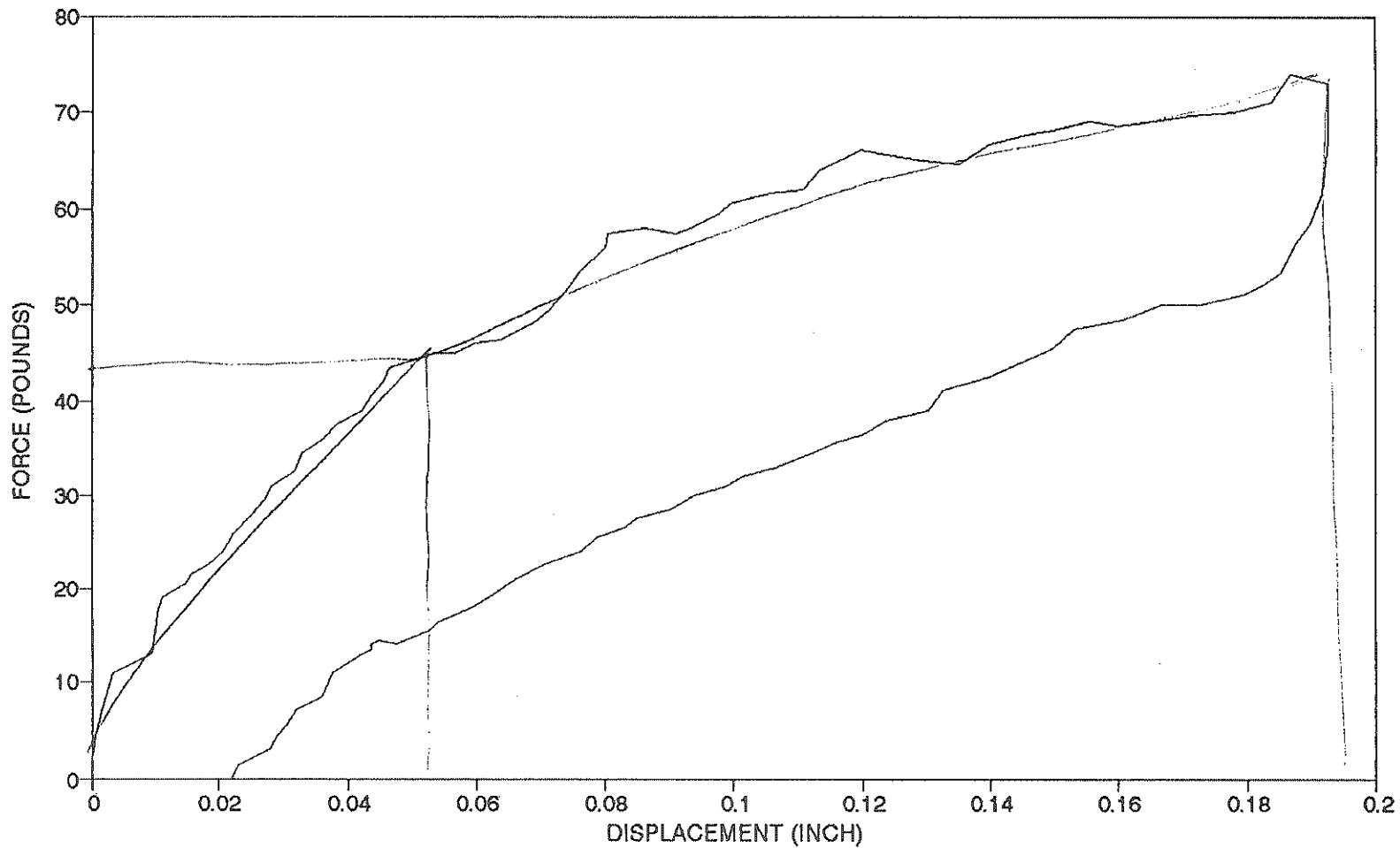


Figure 23 : Force Vs. Horizontal Displacement For Lift 1

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LIFT-2 FLEXIBILITY (V) SEMIDEPLOYED POSITION

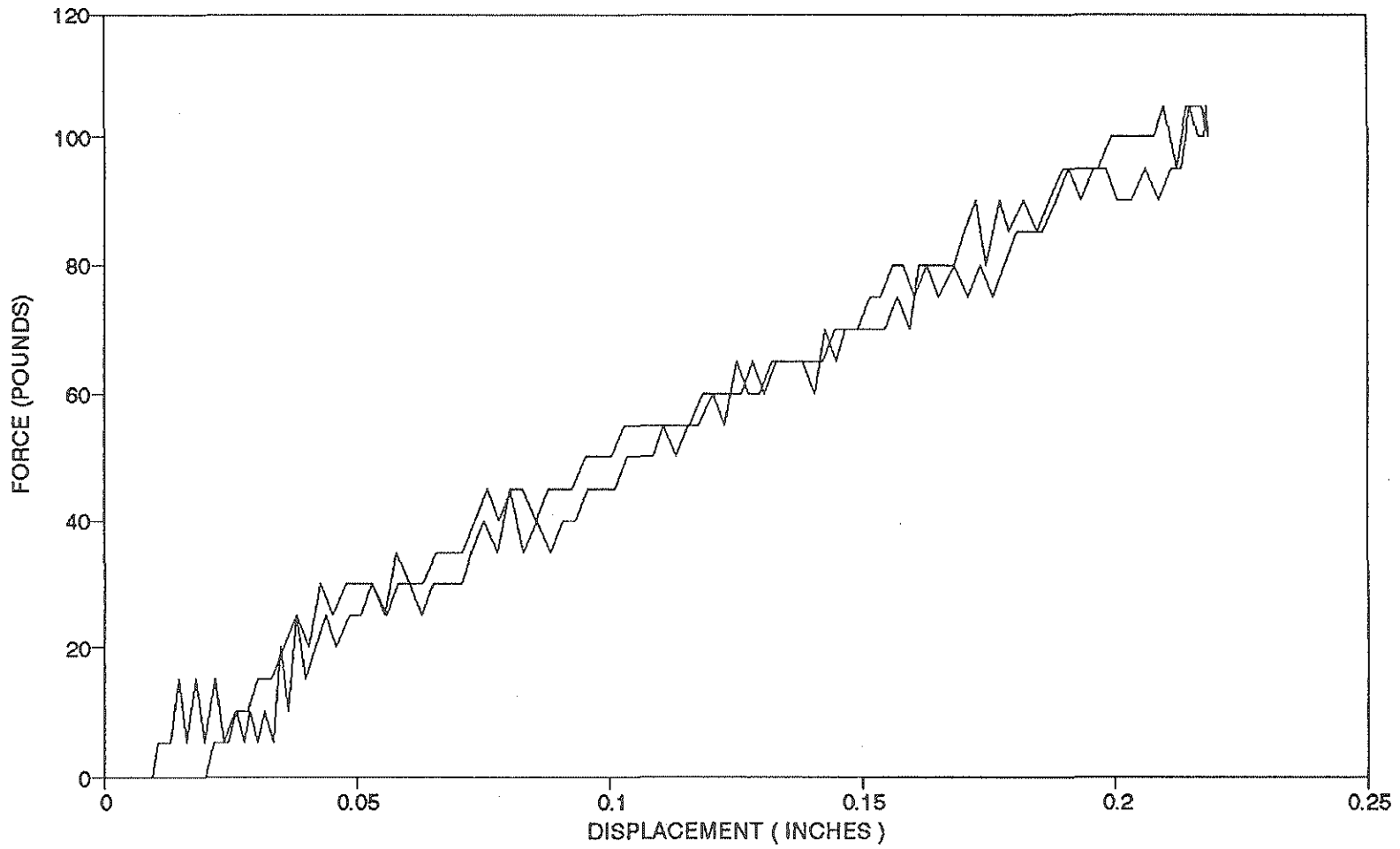


Figure 24 : Force Vs. Vertical Displacement For Lift 2

LIFT-2 FLEXIBILITY (H)
SEMIDEPLOYED POSITION

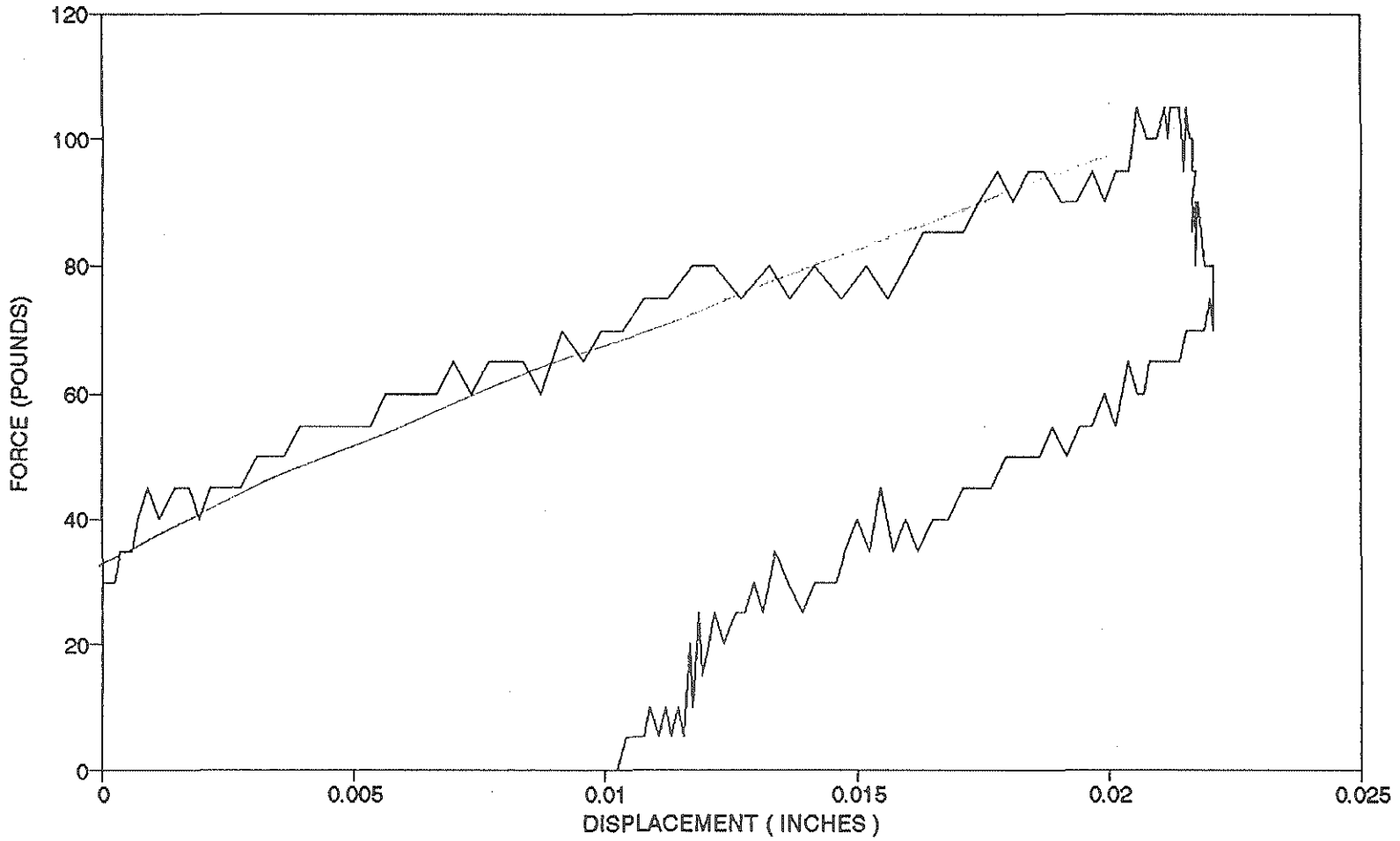


Figure 25 : Force Vs. Horizontal Displacement For Lift 2

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LIFT-2 FLEXIBILITY (H)
FULLY DEPLOYED POSITION

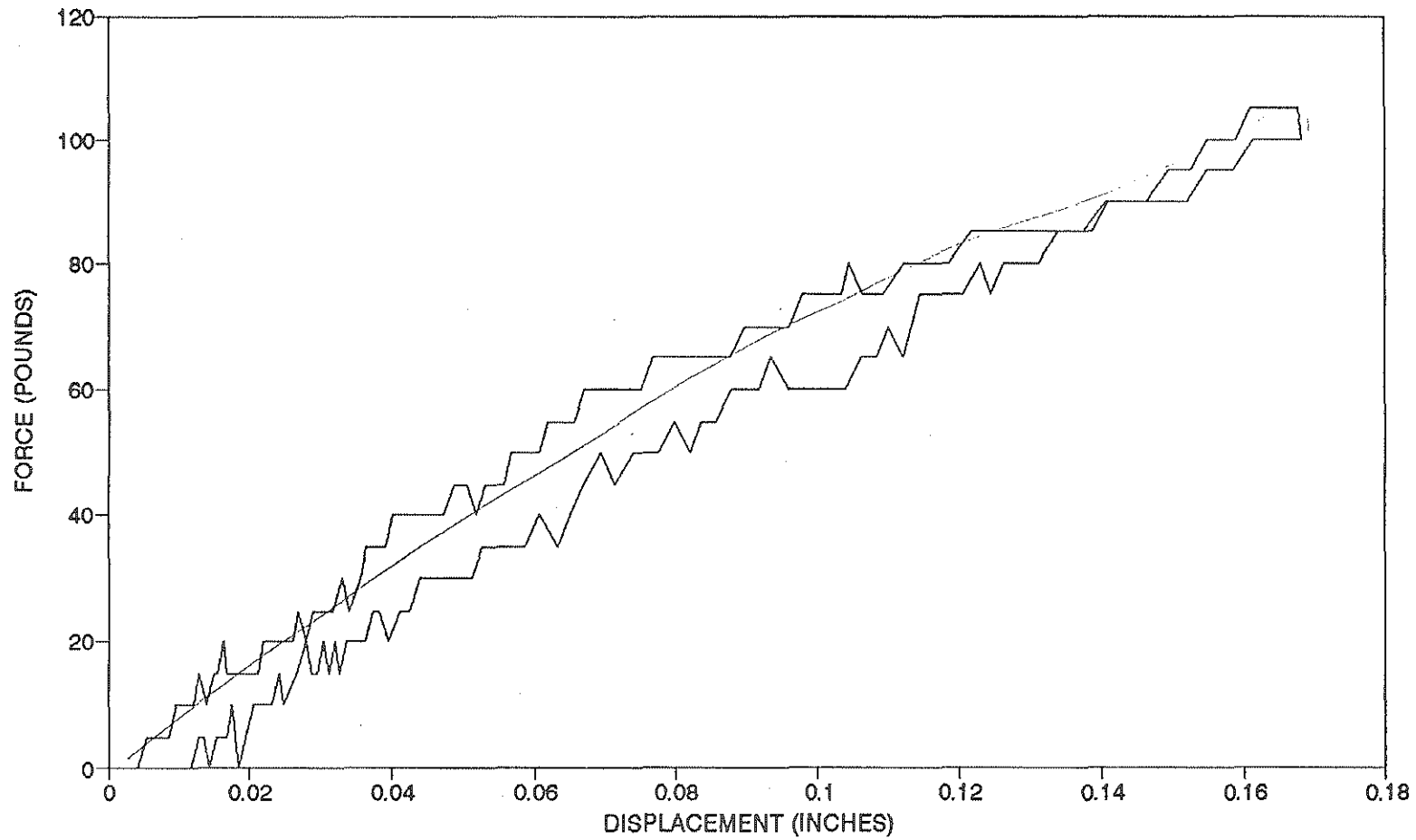


Figure 27 : Force Vs. Horizontal Displacement For Lift 2

SS

The observed initial stiffness is 730 pound per inch and final stiffness is 220 pound per inch. Here also the structure does not follow the same path during unloading. In other words, it observes non-linear behavior.

Figure 23 shows the force versus horizontal displacement relationship when the lift 1 is in fully-deployed position. The platform centre observes 0.19 inch displacement at 70 pound force. The observed initial stiffness is 830 pound per inch and the final stiffness is 190 pound per inch. Here also the structure does not follow the same path during unloading. In other words, it observes non-linear behavior. Figures 24 to 27 shows the same graphs for the second lift.

Table 8 summarised the lift platform stiffness at various configurations for both lifts.

3.2 (c) Functional Performance.

As is discussed in sections 3.2 (a) and 3.2 (b), the lifts are tested for analytical model parameters, serviceability and reliability indicators. The analytical model parameters shows the flexibility of the lift portal while the other parameter describes the lift platform behaviour.

The lift platform behaviour is studied in two different positions corresponding to; semi-deployed and fully-deployed. The lift has an initial slack, which reduces the platform stiffness. The slack is increased in fully-deployed position.

Table 8 Summary of Stiffness.

	Lift 1		Lift 2	
	Initial Stiffness Pound/Inch	Final Stiffness Pound/Inch	Initial Stiffness Pound/Inch	Final Stiffness Pound/Inch
Semi-Deployed Vertical Stiffness	275	500	450	450
Semi-Deployed Horizontal Stiffness	4286	31000	5000	5000
Fully-Deployed Vertical Stiffness	730	220	480	380
Fully-Deployed Horizontal Stiffness	830	190	650	650

4.0 SUMMARY CONCLUSION AND SUGGESTION FOR FURTHER RESEARCH.

4.1 SUMMARY.

Phase I of this study was conducted as a fact finding mission. Transit operators across the state were surveyed. Technical information on wheelchair lifts was compiled through library search and lift manufacturers were surveyed. An engineering analysis of lift components was initiated. The engineering analysis included the framework of a finite element model of the lift structure and the analysis of repair data and mathematical model for lift reliability.

Phase II was focused on engineering analysis of the lift reliability. Survey of transit agencies was continued and reliability analysis was performed with repair data collected from various agencies. For the structural analysis, design load demands were developed and further structural analyses were performed. Also a preliminary experimental procedure for load testing was developed.

Phase III is focused on the experimental lift evaluation. Two new lifts, that are typically used in Michigan transit buses are selected for testing. The behaviour of lift components is studied for stowed, semi-deployed and fully-deployed positions. Lift flexibility measurements are obtained in various directions and in various lift positions. The summary of results are developed and are compared with the ADA stipulations.

4.2 Results Evaluation

4.2.1 Dynamic Model Parameters

The weight of lift platform and contributing components is computed as 100 pounds which generates a mass of 0.259 pound - second² per inch. The observed stiffness for lift 1 in

positive x-direction is 670 pounds per inch, in negative x-direction 180 pounds per inch and the rotational stiffness is 90 pounds per radian. Corresponding numbers for second lift is 1670, 130 and 65. Thus lift 1 is softer than lift 2 in positive x-direction. While lift 2 is softer than lift 1 in negative x-direction and y-direction. ADA does not comment on stiffness or flexibility parameters.

4.2.2 Static Load Test.

The vertical stiffness of platform centre for lift 1 in semi-deployed position is 560 pounds per inch, for the lift 2 the same number is 390. Thus the platform of second lift is softer than the first lift. The corresponding numbers for fully-deployed position is 570 and 390. The maximum vertical observed displacement for lift 1 and lift 2 at platform toe is 0.806 and 1.138 under 300 pound load. The ADA stipulates the maximum of 3 degree rotation under the service load which is 600 pounds. The length of the platform is 48 inches and hence the maximum allowable displacement under 600 pounds is 2.512 inches. The linearly interpolated displacements for lift 1 and lift 2 under 600 pound load is 1.612 inches and 2.275 inches. Thus the displacement is very critical.

4.2.3 Stiffness in Loading / Unloading Response.

Table 8 describes the stiffness for loading / unloading response. The horizontal stiffness is larger than the vertical stiffness.

4.3 CONCLUSIONS.

Two active lifts are tested for analytical and reliability model parameters. The analytical model parameters are needed to simulate the dynamic response of the fully stowed lift while the bus is in motion. The reliability model parameters includes the displacement versus force behavior of the semi-deployed and fully-deployed lift.

4.3.1 ANALYTICAL MODEL PARAMETERS :

The analytical model parameter experiment results cannot be directly used to evaluate the lift characteristics. The lift stiffness will be used in a dynamic model for the lift response analysis during bus motion and the lift integrity during an accident.

4.3.2 RELIABILITY MODEL PARAMETERS :

Reliability model parameters are obtained in two different formats, described as the static flexibilities and the loading and unloading response. Static flexibilities are obtained in the vertical direction, in the horizontal directions along the bus axis and normal to the bus axis. Lift 2 is softer in terms of the platform structure.

Loading and unloading responses show that the lift initial stiffness increases after a slip of about 0.1 inch displacement. This initial slack introduces additional flexibility to the lift platform. The slack also implies that the joints are not tight fitting. The loading and unloading response also shows the importance of the load duration because of the cylinder viscous response. The non linear elastic behaviour of the platform structure is observed during the quasi loading experiments.

4.3.3 : LIFT DESIGN SPECIFICATIONS :

Load demands on lifts were developed during Phase II study. This included the service and ultimate load demand conditions. As described in the conclusions of the Phase II study, in the opinion of the investigators, the ADA design load stipulation does not reflect the realistic conditions.

In these experiments the lift component flexibilities are measured to be more than the ADA stipulation. More strict flexibility guidelines for different lift components should be developed.

4.3.4 : SUGGESTIONS ON STATISTICAL LIFT RELIABILITY :

Counters should be installed on each lift for keeping a record on lift usage. The data should be collected of mileage and the lift maintenance. Detailed history of the lift maintenance and the repair should be maintained. This will be very useful for further documentation of lift reliability.

For developing accurate load demands a sample of lifts should be instrumented to record loads, stresses, and other actions the lift goes through over a specific time span.

4.4 SUGGESTIONS.

Further non destructive and destructive testing on the lifts must be carried out in order to understand the lift behaviour. These experiments should include shake table testing of fully stowed lift to simulate the lift behaviour during the bus motion.

The two lifts tested in this programs show significant variability in their load response relationships. The parameters that affect the reliability of the lift is postulated as the flexibility. In this report, certification program requiring the testing of each lift model used in transit buses will be a good idea.

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APPENDIX A

ARCHITECTURAL AND TRANSPORTATION BARRIERS

COMPLIANCE BOARD

INTRODUCTION.

The passage of the Americans with Disabilities Act of 1990 (ADA), a comprehensive civil rights law, is designed to remove barriers to equal opportunity and to provide full societal access for all individuals with disabilities (1). The ADA, divided into four major titles, is intended to prohibit discrimination against persons with disabilities in :

- Employment (Title 1).
- State and local government service and public transportation (Title 2).
- Public accomodation (Title 4).
- Telecommunications (Title 4).

An individual with disability is defined in ADA as a person with physical or mental impairment that substantially limits one or more major life activities (e.g. seeing, hearing, speaking, walking etc). A non-exhaustive list of physical and mental impairments is presented in the ADA, that include those caused by orthopaedic, visual, speech, hearing, mental retardation, emotional illness and a variety of medical related factors. Further, in Title 2, Subtitle A, Section 201, a qualified individual with a disability is defined as (5) :

"An individual with a disability who, with or without reasonable modifications to rules, policies or practices, the removal of architectural, communication, or transportation barriers or the provision of auxiliary aids and services, meets the essential eligibility requirements for the receipt of services or participation programs or activities provided by a public entity".

It is estimated that the above definition covers 43 millions Americans, and is likely to increase, given the increasing aging population and escalating number of persons with various diseases and medical conditions.

Among the four titles mentioned above Title 2 covers public transportation facilities and mandates that the state and local governments are required to make all services and programs available and accessible to people with disabilities in the provision of public transportation, including buses and rails. While the provision of access to transit vehicles to the disabled through wheelchairs is of immediate concern to transit operators, ADA means much more than ramps and securement devices for wheelchairs. It also provides a wide variety of assistance for people with disabilities (as encompassed by the non-exhaustive list of impairments stated earlier) such as : signs with raised letters and in braille, pathways and bus stops with appropriate arrangements, door hardware, improved lighting and so on. ADA title 2 will have a long term impact on the way transportation providers will administer their programs. ADA requires that public operators make their services/vehicles, facilities and communication systems accessible to persons with disabilities.

Vehicles : The law requires that effective august 26, 1990, fixed route operators purchase or lease accessible vehicles exclusively. Rail, commuter and AMTRAK vehicles (new or leased) must have at least one car per train accessible by the year 1995. Demand responsive operators are also required to acquire accessible vehicles unless their system, when viewed in entirety provide equivalent levels of service for people with disabilities.

Facilities : Any facility used in providing public transportation (fixed route or demand-responsive) constructed or altered after January 26, 1992, must be accessible to

individuals with disabilities. Time extension of varying degrees are provided for stations on rapid rail, light rail and commuter rail systems.

Communications : Transit systems are required to ensure effective communication with persons with disabilities, including physical, sensory and cognitive impairments. Means of communications include: on-board announcements, public address system, visual displays, teletype writers and audio cassette tapes.

The Architectural and Transportation Barriers Compliance Board (ATBCB) is the designated agency to develop technical guidance for accessibility to facilities. Although ATBCB plays a major role in implementing ADA, the final determination on accessibility rests with the U.S. Department Of Justice (DOJ). The following explanations are provided from the final guidelines developed by the ATBCB on ADA, as reported in the Federal register (Vol. 56, No. 173) on September 6, 1991 (36 CFR Part 1192, Document No. 90-3, RIN 3014-AA09). Wherever necessary, appropriate reference was drawn to Appendix B, part 37, Rules and Regulations of the aforementioned Federal register. On occasions direct quotes from the register are also cited.

BACKGROUND.

Title II of the ADA prohibits discrimination on the basis of disability in service, programs, and activities provided by public entities, including units of states and local government and the National Railroad Passenger Corporation. Title II contains provisions for making fixed route bus, rapid rail, light rail, commuter rail, and intercity rail systems operated by public entities, and persons under contract with such entities, readily accessible to and usable by individuals with disabilities, including individuals who use wheelchairs.

Following are the requirements of Title II.

1. New vehicles purchased or leased after August 25, 1990 must be accessible, unless the system provides to individuals with disabilities, a level of service equivalent to that provided to general public.
2. If used vehicles are purchased or leased after August 25, 1990, "good faith" efforts must be made to obtain accessible vehicles.
3. Buses remanufactured after August 25, 1990 to extend their useful life for 5 years or more, must be accessible to the disabled.
4. Public entities that operate a fixed route bus service must provide paratransit and other special transportation services to individuals with disabilities, beginning January 26, 1992, to the extent that providing such services would not impose an undue financial burden.

Title III of ADA prohibits discrimination on the basis of disability by private entities in places of public accommodation. The services offered by private agencies shall be readily accessible to and usable by individuals with disabilities including wheelchair users.

Following are the requirements of title III ADA for the agencies not involved in transporting people such as hotels, shopping centres and recreational facilities:

1. New vehicles with a seating capacity in excess of 16 passengers (other than an over-the-road bus, vans with seating capacity less than 8 or automobile) purchased or leased after August 25, 1990 for use in a fixed route system must be accessible unless the system provides a level of service, to individual with disabilities, equivalent to that provided to general public.
2. New vehicles with a seating capacity of 16 passengers or less purchased or leased after August 25, 1990 for use in a fixed route system must be accessible unless the system

provides to individuals with disabilities a level of service equivalent to that provided to general public.

Title III of the ADA also contains provisions regarding access to over-the-road buses. It requires the Office of Technology Assessment (OTA) to study the access needs of individuals with disabilities. However these changes are required after July 26,1997 for small providers and after July 26,1996 for other providers. The US President may extend those dates by one year.

PROPOSED GUIDELINES AND COMMENTS.

The ADA contains nine subparts according to type of transportation vehicles and system as follows.

Subpart	Description
A	General.
B	Large Buses and Systems.
C	Rapid Rail Vehicles and Systems.
D	Light Rail Vehicles and Systems.
E	Commuter Rail Cars and Systems.
F	Intercity Rail Cars and Systems.
G	Vans and Small Buses.
H	Over-the-Road Buses and Systems.
I	Other Vehicles and Systems.

Each system covers essential aspects of accessibility requirements including level-change mechanisms or boarding devices for mobility aid accessibility, doors, floor steps,

thresholds, interior circulation, handrails and stanchions, lighting, public information systems, priority seating signs, and destination and route signs.

From above subparts, we are only concerned about subparts A and B.

A discussion of these subparts is presented below :

SUBPART A - GENERAL.1192.1 PURPOSE.

"This part provides minimum guidelines and requirements for accessibility standards to be issued by the Department of Transportation in 49 CFR part 37 for transportation vehicles required to be accessible by the American with Disabilities Act (ADA) of 1990 (42 U.S.C. 12101 et seq.)"

Section 504 of ADA states the ATBCB is the agency to provide minimum guidelines and accessibility requirements for vehicles and facilities for the disabled. These guidelines will be helpful to the Department of Transportation (DOT) for defining the final rules.

1192.2 EQUIVALENT FACILITATION.

It is mentioned that "Departures from particular technical and scoping requirements of these guidelines by use of other designs and technologies are permitted where the alternative designs and technologies used will provide substantially equivalent or greater access to and usability of the vehicle. Departures are to be considered on a case-by-case basis by the Department of Transportation under the procedure set forth in 49 CFR 37.7".

The board and DOT agree that there is a need for some flexibility in guidelines for special cases. These cases may arise due to alternative means used at the local level or because of old facilities being upgraded up to the extent that the new system can be implemented.

To incorporate these the section of "Equivalent Facilitation" has been added.

In such cases the DOT will consider the situation on a case-by-case basis. In the case of use of alternative technology, the entity must provide the accessibility services of equal or higher standards. No lesser standards will be accepted nor any waiver will be given. The board strongly encouraged entities to consult the facility user and their organizations prior to providing of alternative technology.

1192.3 DEFINITIONS.

The definitions used are same as the DOT documents.

Automated guideway transit (AGT) system : A fixed-guideway transportation system which operates with automated (driverless) individual vehicles or multi-car trains. Service may be on a fixed schedule or in response to a passenger-activated call button. Such systems using small, slow moving vehicles, often operated in airports and amusement parks, are sometimes called "people movers".

Bus : Any of several types of self-propelled vehicles, other than an over-the-road bus, generally rubber tired, intended for use on city streets, highways, and busways, including but not limited to minibuses, forty-and thirty-foot transit buses, articulated buses, double-deck buses, and electric powered trolley buses used to provide designated or specified public transportation services. Self-propelled, rubber tired vehicles designed to look like antique or vintage trolleys or streetcars are considered buses.

Common wheelchairs and mobility aids : Belonging to a class of three or four wheeled devices, usable indoors, designed for and used by persons with mobility impairments which do not exceed 30 inches in width and 48 inches in length, measured 2 inches above the ground, and do not weigh more than 600 pounds when occupied.

Demand responsive system : Any system of transporting individuals, including the provision of designated public transportation service by public entities and the provision of transportation service by private entities, including but not limited to specified public transportation service, which is not a fixed route system.

Designated public transportation : Transportation provided by a public entity (other than public school transportation) by bus, rail, or other conveyance (other than transportation by aircraft or intercity or commuter rail transportation) that provides the general public with general or special service, including charter service, on a regular and continuing basis.

Fixed route system : A system of transporting individuals (other than by aircraft), including the provision of designated public transportation service by public entities and the provision of transportation service by private entities, including but not limited to specified public transportation service, on which a vehicle is operated along a prescribed route according to a fixed schedule.

New vehicle : A vehicle which is offered for sale or lease after manufacture without any prior use.

Over-the-road bus : A vehicle characterized by an elevated passenger deck located over a baggage compartment typically used for inter-city travel.

Remanufactured vehicle : A vehicle which has been structurally restored and has had new or rebuilt major components installed to extend its service life.

Specified public transportation : Transportation by bus, rail, or any other conveyance (other than aircraft) provided by a private entity to the general public, with general or special service (including charter service) on a regular and continuing basis.

Used vehicle : A vehicle with prior use.

1192.4 MISCELLANEOUS INSTRUCTIONS.

A new section named "Miscellaneous Instructions" with an appendix was added to eliminate any confusion in understanding and in implementing ADA. It covers dimensional conventions and tolerances, and general terminology. The appendix contains additional information, explanation and advisory material.

Expansion or contraction of material due to temperature changes or during curing or drying affects dimensional tolerances. Due to this, close tolerances can not be ensured as per the specified standards. For example, the cable of the cable-driven historic inclined system in Pittsburg may be considered. The cable experiences significant uncontrollable stretch especially during hot weather. The cars generally provide level entry in the morning, but may be significantly out of alignment by the end of the day.

Such parameters, out of the control of the operator, do not constitute a violation of the guidelines.

However this clause does not give an excuse for improper or deferred maintenance, or poor design or construction method.

For example, the excuse of the dimensional tolerances could not be made for a lift that fails in meeting the vehicle floor within the specified limits of the guidelines.

Also a group of manufacturers, operators or designers can not decide to adopt lower standards. In such cases they have to comply with "acceptable industry standards or practices". Moreover, an agency could not justify a wider horizontal gap as being within dimensional tolerances because it did not specify its vehicles to be within achievable limits for sway or stability.

SUBPART B - LARGE BUSES, VANS AND SYSTEMS.1192.21 GENERAL.

This article consists of part a and part b as follows.

"(a) New, used or remanufactured buses and vans (except over-the road- buses covered by subpart G of this part), to be considered accessible by regulations issued by the Department of Transportation in 49 CFR part 37, shall comply with the applicable provisions of this subpart."

"(b) If portions of the vehicle are modified in a way that affects or could affect accessibility, each such portion shall comply, to the extent practicable, with the applicable provisions of this subpart. This provision does not require that inaccessible buses be retrofitted with lifts, ramps or other boarding devices."

A generalized statement is made that all the vehicles used for transportation must be accessible as per the DOT rule 49 CFR part 37. The primary concern was the classification of the buses in the separate subparts. NPRM suggested separate subparts for large buses (subpart b) and small buses (subpart g) based on gross vehicle weight rating (GVWR). Certain other agencies suggested a single subpart with exceptions in various sections for passenger capacity, type of lift, and type of service.

The board decided that the NPRM subparts were identical in many ways and the distinction based on GVWR was not necessary. Also public address system, or route and destination signs were unnecessary.

The board decided to have single subpart with exception in various sections for both length and type of services. This is the most "user friendly method", a method which will ensure uniform application of the rule.

The differentiating length of the vehicle was 22 feet used in the existing DOT regulations at 49 CFR 609.15. Passenger capacity depends on whether the vehicle has been modified to accommodate the wheelchair.

1192.23 MOBILITY AID ACCESSIBILITY.

"(a) *General* : All vehicles covered by this subpart shall provide a level-change mechanism or boarding device (e.g. lift, or ramp) complying with paragraph (b) or (c) of this section and sufficient clearances to permit a wheelchair or other mobility aid user to reach a securement location. At least two securement locations and devices, complying with paragraph (d) of this section, shall be provided on vehicles in excess of 22 feet in length; at least one securement location and device, complying with paragraph (d) of this section, shall be provided on vehicles 22 feet in length or less."

The primary concern of this section was to provide number of spaces for the wheelchair. Several comments of denying the service to the users because of no space even in the case of two accomodation. The board has decided to have two spaces for the wheelchair users for the large buses i.e. for the buses larger than 22 feet. For the small buses there should be minimum one space even though the board expects that demand-responsive operators could operate certain buses with more than one space to meet the demand of the wheelchair and mobility aid user.

The NPRM required provision of sufficient clearance to reach a securement location by the mobility aid user. In order to compensate the decrease in seating, the guidelines requires only "sufficient" clearance to enter into the vehicle and to reach the securement location. The clear floor space needs to be provided is 30 inch by 48 inch. This floor space is allowed to overlap or to share an adjoining access aisle.

(b) Vehicle Lift.

"(1) *Design load* : The design load of the lift shall be at least 600 pounds. Working parts such as cables, pulleys, and shafts, which can be expected to wear, and upon which the lift depends for support of the load, shall have a safety factor of at least six, based on the ultimate strength of the material. Nonworking parts, such as platform, frame and attachment hardware which would not be expected to wear, shall have a safety factor of at least three, based on the ultimate strength of the material."

The design load for lifts is 600 pounds. The lift support components i.e. lift cables, pulleys and shaft must support the design load with a factor of safety of six. That is the ultimate load is 3600 pounds. The other components i.e. platform, frame, attachment hardware must support the design load with a factor of safety of three which means the ultimate load is 1800 pounds.

(2) Controls.

"(i) *Requirements* : The controls shall be interlocked with the vehicle brakes, transmission, or door, or shall provide other appropriate mechanisms or systems, to ensure that the vehicle can not be moved when the lift is not stowed and so the lift can not be deployed unless the interlocks or the systems are engaged. The lift shall deploy to all levels (i.e. ground, curb, and intermediate positions) normally encountered in the operating environment. Where provided, each control for deploying, lowering, raising, and stowing the lift and lowering the roll-off barrier shall be of a momentary contact type requiring continuous manual pressure by the operator and shall not allow improper lift sequencing when the lift platform is occupied. The control shall allow reversal of the lift operation

sequence, such as raising or lowering a platform that is part way down, without allowing an occupied platform to fold or retract into the stowed position."

The vehicle must have devices to stop the bus motion in the deployed position. The devices may be installed at brake, transmission or at door or may be some other mechanism. The term "fail-safe" was removed because of its special meaning in reliability engineering. The removal of the term "fail-safe" does not mean the acceptance of the lower standards.

Also the lift must be deployed at any position, at ground level, at curb or at any intermediate position. An auditory alarm is likely to alert other passengers and hence is not a part of the accessibility system and hence not required.

(ii) *Exception* : Where the lift is designed to deploy with its long dimension parallel to the vehicle axis and which pivots into or out of the vehicle while occupied (i.e. rotary lift), the requirements of this paragraph prohibiting the lift from being stowed while occupied shall not apply if the stowed position is within the passenger compartment and the lift is intended to be stowed while occupied."

(3) *Emergency operation* : " The lift shall incorporate an emergency method of deploying, lowering to ground level with a lift occupant, and raising and stowing the empty lift if the power to the lift fails. No emergency method, manual or otherwise, shall be capable of being operated in a manner that could be hazardous to the lift occupant or to the operator when operated according to the manufacturer's instructions, and shall not permit the platform to be stowed or folded when occupied, unless the lift is a rotary lift and is intended to be stowed while occupied."

All the lifts used in the accessible vehicles must have emergency operation methods for deploying raising or lowering particularly in case of power failure.

(4) *Power or equipment failure* : "Platform stowed in a vertical position and deployed platforms when occupied, shall have provisions to prevent their deploying, falling, or folding any faster than 12 inches/second or their dropping off an occupant in the event of a single failure of any load carrying component."

(5) *Platform barrier* : "The lift platform shall be equipped with barriers to prevent any of the wheels of a wheelchair or mobility aid from rolling off the platform during its operation. A movable barrier or inherent design feature shall prevent a wheelchair or mobility aid from rolling off the edge closest to the vehicle until the platform is in its fully raised position. Each side of the lift platform which extends beyond the vehicle in its raised position shall have a barrier of a minimum of 1.5 inches high. Such barrier shall not interfere with maneuvering into or out of the aisle. The loading-edge barrier (outer barrier) which functions as a loading ramp when the lift is at ground level, shall be sufficient when raised or closed, or a supplementary system shall be provided, to prevent a power wheelchair or mobility aid from riding over or defeating it. The outer barrier of the lift shall automatically be raise or close, or a supplementary system shall automatically engaged, and remain raised, closed or engaged at all times that the platform is more than 3 inches above the roadway or sidewalk and the platform is occupied. Alternatively, a barrier or system may be raised, lowered, opened, closed, engaged, or disengaged by the lift operator, provided an interlock or inherent design feature prevents the lift from rising unless the barrier is raised or closed or the supplementary system is engaged."

The barrier requirement of 1.5 inch is considered sufficient to prevent the wheelchair from rolling out of the lift platform. The board did not provide any safety test requirements. The board understands that the National Highway Safety Administration (NHTSA) is the best authority to issue such standards. The board includes only performance requirements. Performance requirements refer to not only the prevention of rolling off of the wheelchair, but also to the occupant of the wheelchair or mobility aid user even though the chair is restrained.

(6) *Platform surface* : "The platform surface shall be free of any protrusions over 0.25 inch high and shall be slip resistant. The platform shall have a minimum clear width of 28.5 inches at the platform, a minimum clear width of 30 inches measured from 2 inches above the platform surface to 30 inches above the platform, and a minimum clear length of 48 inches measured from 2 inches above the surface of the platform to 30 inches above the surface of the platform. (See Fig. 1)"

(7) *Platform gaps* : "Any openings between the platform surface and the raised barriers shall not exceed 5/8 inch in width. When the platform is at vehicle floor height with the inner barrier (if applicable) down or retracted, gaps between the forward lift platform edge and the vehicle floor shall not exceed 0.5 inch horizontally and 5/8 inch vertically. Platforms on semi-automatic lifts may have a hand hold not exceeding 1.5 inches by 4.5 inches located between the edge barrier."

(8) *Platform entrance ramp* : "The entrance ramp, or loading-edge barrier used as a ramp, shall not exceed a slope of 1:8, measured on level ground, for a maximum rise of 3 inches and the transition from roadway or sidewalk to ramp may be vertical without edge treatment

unto 0.25 inch. Threshold between .25 inch and .5 inch high shall be beveled with a slope no greater than 1:2."

(9) *Platform deflection* : "The lift platform (not including the entrance ramp) shall not deflect more than three degree (exclusive of vehicle roll or pitch) in any direction between its unloaded position and its position when loaded with 600 pounds applied through a 26 inch by 26 inch test pallet at the centroid of the platform."

The lift deflection should not exceed three degree between its unloaded position and loaded position, loaded with 600 pounds applied through 26 inch by 26 inch test pallet at the centroid of the platform. This translates to a maximum platform tip deflection for a 48 inch long platform of 2.51 inches. The deflection of the lift platform should be tested by the manufacturer.

When the lift is loaded the vehicle will normally tilt because of the weight of the lift and occupant. This tilt will produce the slope away from the vehicle towards the barrier. To encounter this effect the vehicle slope has been limited.

(10) *Platform movement* : "No part of the platform shall move at a rate exceeding 6 inches/second during lowering and lifting an occupant, and shall not exceed 12 inches/second during deploying or stowing. This requirement does not apply to the deployment or stowage cycles of lifts that are manually deployed or stowed. The maximum platform horizontal and vertical acceleration when occupied shall be 0.3 g."

The above guidelines for the lift platform movement has been taken directly from the UMTA (FTA) sponsored guidelines. The FTA suggested the slower speed related to safety and comfort. Because of the lower rate of 6 inches/second the user waiting outside of the vehicle gets enough time to get out of the way of the lift. The rate of 12 inches/second for

the platform (deploying or stowing) is comfortable and not hazardous for the passenger near the lift in side the vehicle. The acceleration rate of 0.3g is directly taken from UMTA and is related to comfort.

The jerk rate is difficult to measure because it may be affected by other parameters not directly related to the rate of change of acceleration of the lift platform. Also the board could not find any research identifying acceptable jerk rates for the disabled and hence final guidelines did not specify any jerk rate.

(11) *Boarding direction* : "The lift shall permit both inboard and outboard facing of wheelchair and mobility aid users."

(12) *Use by standees* : "Lifts shall accommodate persons using walkers, crutches, canes or braces or who otherwise have difficulty using steps. The platform may be marked to indicate a preferred standing position."

(13) *Handrails* : "Platforms on lift shall be equipped with handrails on two sides which move in tandem with the lift and which shall be graspable and provide support to standees throughout the entire lift operation. Handrails shall have a usable components at least 8 inches long with the lowest portion a minimum 30 inches above the platform and the highest portion a maximum 38 inches above platform. The handrails shall be capable of withstanding a force of 100 pounds concentrated at any point on the handrail without permanent deformation of the rail or its supporting structure. The handrail shall have a cross sectional diameter between 1.25 inches and 1.5 inches or shall provide an equivalent grasping surface, and have eased edges with corner radii not less than 1/8 inch. Handrails shall be placed to provide a minimum of 1.5 inches knuckle clearance from the nearest

adjacent surface. Handrails shall not interfere with wheelchair or mobility aid maneuverability when entering or leaving the vehicle."

(c) Vehicle ramp

(1) "*Design load* : Ramps 30 inches or longer shall support a load of 600 pounds, placed at the centroid of the ramp distributed over an area of 26 inches by 26 inches, with a safety factor of at least 3 based on the ultimate strength of the material. Ramps shorter than 30 inches shall support a load of 300 pounds."

(2) "*Ramp surface* : The ramp surface shall be continuous and slip resistant; shall not have protrusions from the surface greater than 0.25 inch high; shall have a clear width of 30 inches; and shall accommodate both four-wheel and three-wheel mobility aids."

"Continuous surface" means a single uninterrupted surface from edge to edge as opposed to a platform with a gap in the middle. Ramps having two parts are permitted provided they are designed to have uninterrupted single surface.

(3) "*Ramp threshold* : The transition from roadway or sidewalk and the transition from vehicle floor to the ramp may be vertical without edge treatment up to 0.25 inch. Changes in level between 0.25 inch and 0.5 inch shall be bevelled with a slope no greater than 1:2."

(4) "*Ramp barriers* : Each side of the ramp shall have barriers at least 2 inches high to prevent mobility aid wheels from slipping off."

(5) "*Slope* : Ramps shall have the least slope practicable and shall not exceed 1:4 when deployed to ground level. If the height of the vehicle floor from which the ramp is deployed is 3 inches or less above a 6-inch curb, a maximum slope of 1:4 is permitted; if the height of the vehicle floor from which the ramp is deployed is 6 inches or less, but greater than 3 inches, above a 6-inch curb, a maximum slope of 1:6 is permitted; if the height of the

vehicle floor from which the ramp is deployed is 9 inches or less, but greater than 6 inches, above a 6-inch curb, a maximum slope of 1:8 is permitted; if the height of the vehicle floor from which the ramp is deployed is greater than 9 inches above a 6-inch curb, a slope of 1:12 shall be achieved. Folding or telescoping ramps are permitted provided they meet all structural requirements of this section." The information presented above is represented in the following tabular form.

Slope Description

1:4	deployed to the ground
1:4	maximum , ramp deployed 3 inches or less above 6 inches curb.
1:6	$3 < x < 6$ above a 6 inches curb.
1:8	$6 < x < 9$ above a 6 inches curb.
1:12	$9 < x$ above a 6 inches curb.

The above guidelines are extracted from the tests conducted as a part of the Transbus program. Practical difficulties involved in meeting common accessibility standards which are constrained by other factors such as maximum width, were given due considerations.

(6) "*Attachment* : When in use for boarding or alighting, the ramp shall be firmly attached to the vehicle so that it is not subject to displacement when loading or unloading a heavy power mobility aid and that no gap between vehicle and ramp exceeds 5/8 inch."

(7) "*Stowage* : A compartment securement system, or other appropriate method shall be provided to ensure that stowed ramps, including portable ramps stowed in the passenger area, do not impinge on a passenger's wheelchair or mobility aid or pose any hazard to passengers in the event of a sudden stop or maneuver."

This section was revised for stowage compartment, securement system, or other means of ensuring that the ramp does not pose a hazard. The portable ramp used is simply set in the passenger compartment, simply leaning against the passenger's mobility aid can cause injury to the passengers.

(8) "*Handrails* : If provided, handrails shall allow persons with disabilities to grasp them from outside the vehicle while starting to board, and to continue to use them throughout the boarding process, and shall have the top between 30 inches and 38 inches above the ramp surface. The handrails shall be capable of withstanding a force of 100 pounds concentrated at any point on the handrail without permanent deformation of the rail or its supporting structure. The handrail shall have a cross sectional diameter between 1.25 inches and 1.5 inches or shall provide an equivalent grasping surface, and have eased edges with corner radii of not less than 1/8 inch. Handrails shall not interfere with wheelchair or mobility aid maneuverability when entering or leaving the vehicle."

The above specifications for the handrails are same as the wheelchair lift. In the case of ramp, the board agrees that the handrails are not required for the "short" ramps and bridge plates. However it is very difficult to define the term "short".

(d)Securement devices

(1) "*Design load* : Securement systems on vehicles with GVWRs of 30,000 pounds or above, and their attachments to such vehicles, shall restrain a force in the forward longitudinal direction of up to 2,000 pounds per securement leg or clamping mechanism and a minimum of 4,000 pounds for each mobility aid. Securement systems on vehicles with GVWRs of up to 30,000 pounds, and their attachments to such vehicles, shall restrain

a force in the forward longitudinal direction of up to 2,500 pounds per securement leg or clamping mechanism and a minimum of 5,000 pounds for each mobility aid."

These guidelines are taken from the NPRM stating that the force experienced by the securement devices based on the g-force experienced by the various vehicles. The g-force depends on the gross weight, the crash profile of the vehicle and the observed acceleration of the vehicle. Since no significant research data is available the NPRM standards are retained.

(2) "*Location and size* : The securement system shall be placed as near to the accessible entrance as practicable and shall have a clear floor area of 30 inches by 48 inches. Such space shall adjoin, and may overlap, an access path. Not more than 6 inches of the required clear floor space may be accommodated for footrests under another seat provided there is a minimum of 9 inches from the floor to the lowest part of the seat overhanging the space. Securement areas may have fold-down seats to accommodate other passengers when a wheelchair or mobility aid is not occupying the area, provided the seats, when folded up, do not obstruct the clear floor space required. (See Fig.2)"

(3) "*Mobility aids accommodated* : The securement system shall secure common wheelchairs and mobility aids and shall either be automatic or easily attached by a person familiar with the system and mobility aid and having average dexterity."

(4) "*Orientation* : In vehicles in excess of 22 feet in length, at least one securement device or system required by paragraph (a) of this section shall secure the wheelchair or mobility aid facing toward the front of the vehicle. In vehicles 22 feet in length or less, the required securement device may secure the wheelchair or the mobility aid either facing toward the front of the vehicle or rearward. Additional securement devices or systems shall secure the

wheelchair or the mobility aid facing forward or rearward. Where the wheelchair or mobility aid is secured facing the rear of the vehicle, a padded barrier shall be provided. The padded barrier shall extend from a height of 38 inches from the vehicle floor to a height 56 inches from the vehicle floor with a width of 18 inches, laterally centred immediately in back of the seated individual. Such barriers need not be solid provided equivalent protection is afforded."

Due to the strong support of the rearward facing systems the board permits such systems with a padded barrier. As per the guidelines, vehicles longer than 22 feet must provide at least one forward facing system. Vehicles of 22 feet length or shorter may provide only rearward facing. However rearward facing is optional and the operator can provide only forward facing system.

The padded barriers need not be solid. Barriers provided on some vehicles consist of padded bars with space between for the ease of driver vision. The barriers may be removed or folded when the space is not occupied. However it is critical that the barrier be provided for rearward facing system to prevent severe, and possibly fatal, whiplash.

(5) "*Movement* : When the wheelchair or the mobility aid is secured in accordance with manufacturer's instructions, the securement system shall limit the movement of an occupied wheelchair or mobility aid to no more than 2 inches in any direction under normal vehicle operating conditions."

The 2 inch movement is only meant under normal operating condition. During the collision or the emergency stop some elasticity is required to absorb the shock.

(6) "*Stowage* : When not being used for securement, or when the securement area can be used by standees, the securement system shall not interfere with passenger movement,

shall not present any hazardous condition, shall be reasonably protected from vandalism, and shall be readily accessed when needed for use."

The operator makes the decision whether the area over the securement device when not occupied by the wheelchair of the mobility aid user can be used by standees. The guidelines are intended to provide the safe accessibility of the securement devices.

(7) "*Seat belt and shoulder harness* : For each wheelchair or mobility aid securement device provided, a passenger seat belt and shoulder harness, complying with all applicable provisions of 49 CFR part 571, shall also be provided for use by wheelchair or mobility aid users. Such seat belts and shoulder harnesses shall not be used in lieu of a device which secures the wheelchair or mobility aid itself."

A lap and shoulder belt system is required at each securement location on vehicles of any length. Particularly it is of more importance in the small vehicles experiencing more g-force.

1192.25 DOORS, STEPS AND THRESHOLDS.

(a) "*Slip resistance* : All aisles, steps, floor areas where people walk, and floors in securement locations shall have slip-resistant surfaces."

There are no specific guidelines imposed by the board regarding the slip resistance surface.

(b) "*Contrast* : All step edges, thresholds, and the boarding edge of ramps or lift platforms shall have a band of color(s) running the full width of the step or edge which contrasts from the step tread and riser, or lift or ramp surface, either light-on-dark or dark-on-light."

The Board deleted the contrast formula from the final guidelines because of certain objections. The provisions are moved to the appendix as an advisory material from the guidelines.

(c) "*Door height* : For vehicles in excess of 22 feet in length, the overhead clearance between the top of the door opening and the raised lift platform, or highest point of a ramp, shall be a minimum of 68 inches. For vehicles of 22 feet in length or less, the overhead clearance between the top of the door opening and the raised lift platform, or highest point of a ramp, shall be a minimum of 56 inches."

The board is allowing the standees to use the lift to avoid the provision of step and riser. The provision of step and riser needs many structural changes. The board may consider this issue further.

The ANSI standards for power doors (ANSI A156.10-1985, art 9.8 and 9.9) used inside the buildings and facilities, can not be applied because the vehicles are not stationary and door needs to be closed during the turn also. White book contains the closing force for the rear door but it does not apply to other doors. The issue of closing force is to be discussed further when board will upgrade the guidelines.

1192.27 PRIORITY SEATING SIGNS.

(a) "Each vehicle shall contain sign(s) which indicate that seats in the front of the vehicle are priority seats for persons with disabilities, and that other passengers should make such seats available to those who wish to use them. At least one set of forward-facing seats shall be so designated."

(b) "Each securement location shall have a sign designating it as such."

(c) "Characters on signs required by paragraphs (a) and (b) of this section shall have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:5 and 1:10, with a minimum character height (using an upper case "X") of 5/8 inch, with wide

spacing (generally, the space between letters shall be 1/16 the height of upper case letters), and shall contrast with the background either light-on-dark or dark-on-light."

The sign should be legible to the person with vision impairments. The provided signs should be relatively simple and brief. The judgement for priority signs will be made by the operator.

1192.29 INTERIOR CIRCULATION, HANDRAILS AND STANCHIONS.

(a) "Interior handrails and stanchions shall permit sufficient turning and maneuvering space for wheelchairs and other mobility aids to reach a securement location from the lift or ramp."

(b) "Handrails and stanchions shall be provided in the entrance to the vehicle in a configuration which allows persons with disabilities to grasp such assists from outside the vehicle while starting to board, and to continue using such assists throughout the boarding and fare collection process. Handrails shall have a cross-sectional diameter between 1.25 inches and 1.5 inches or shall provide an equivalent grasping surface, and have eased edges with corner radii of not less than 1/8 inch. Handrails shall be placed to provide a minimum 1.5 inches knuckle clearance from the nearest adjacent surface. Where on-board fare collection devices are used on vehicles in excess of 22 feet in length, a horizontal passenger assist shall be located across the front of the vehicle and shall prevent passengers from sustaining injuries on the fare collection device or windshield in the event of a sudden deceleration. Without restricting the vestibule space, the assist shall provide support for a boarding passenger from the front door through the boarding procedure. Passengers shall be able to lean against the assist for security while paying fares."

(c) "For vehicles in excess of 22 feet in length, overhead handrail(s) shall be provided which shall be continuous except for a gap at the rear doorway."

(d) "Handrails and stanchions shall be sufficient to permit safe boarding, on - board circulation, seating and standing assistance, and alighting by persons with disabilities."

(e) "For vehicles in excess of 22 feet in length with front-door lifts or ramps, vertical stanchions immediately behind the driver shall either terminate at the lower edge of the aisle-facing seats, if applicable, or be "dog-legged" so that the floor attachment does not impede or interfere with wheelchair footrests. If the driver seat platform must be passed by a wheelchair or a mobility aid user entering the vehicle, the platform to the maximum extent practicable, shall not extend into the aisle or vestibule beyond the wheel housing."

(f) "For vehicles in excess of 22 feet in length, the minimum interior height along the path from the lift to the securement location shall be 68 inches. For vehicles of 22 feet in length or less, the minimum interior height from lift to securement location shall be 56 inches."

The section 1192.29 states that there should be sufficient space for the interior movement of the handicapped passenger using wheelchair or mobility aid. The space from the lift or ramp to fare box and to the securement location must be clear.

Part b of this section clearly states the dimensional requirements of the handrails inside the vehicle. It has been revised in accordance with 49 CFR 609.15. Part c has been revised to be consistent with part b.

Part f has been added to incorporate the interior height clearance. These guidelines are directly taken from the UMTA. Accordingly 68 inches clearance is required for vehicles larger than 22 feet and for smaller vehicles, vehicles 22 feet or less, the corresponding dimension is 56 inches.

According to the board, it is desirable to have aisle width of 36 inches but it may not be possible to provide this dimension for all the cases.

1192.31 LIGHTING.

(a) "Any stepwell or doorway immediately adjacent to the driver shall have, when the door is open, at least 2 foot-candles of illumination measured on the step tread, or lift platform."

(b) "Other stepwells and doorways, including doorways in which lifts or ramps are installed, shall have, at all times, at least 2 foot-candles of illumination measured on the step tread, or lift or ramp, when deployed at the vehicle floor level."

(c) "The vehicle doorways, including doorways in which lifts or ramps are installed, shall have outside light(s) which, when the door is open, provide at least 1 foot-candle of illumination on the street surface for a distance of 3 feet perpendicular to all points on the bottom step tread outer edge. Such light(s) shall be located below window level and shielded to protect the eyes of entering and exiting passengers."

The above guidelines for lighting are in accordance with 49 CFR 609.15 for the buses larger than 22 feet length.

A proposal for heavy lighting was rejected because of following reasons. The high lighting level may cause adverse effects on the disembarking passenger's eyes, because it will not match with surrounding dark back ground. Also it creates reflection from the windows and thus high light level creates adverse effects.

1192.33 FARE BOX.

"Where provided the fare box shall be located as far forward as practicable and shall not obstruct traffic in the vestibule, especially wheelchairs or mobility aids."

1192.35 PUBLIC INFORMATION SYSTEM.

(a) "Vehicles in excess of 22 feet in length, used in multiple-stop, fixed-route service, shall be equipped with a public address system permitting the driver, or recorded or digitized

human speech messages, to announce stops and provide other passenger information within the vehicle."

1192.37 STOP REQUEST.

(a) "Where passengers may board or alight at multiple stops at their option, vehicles in excess of 22 feet in length shall provide controls adjacent to the securement location for requesting stops and which alerts the driver that a mobility aid user wishes to disembark. Such a system shall provide auditory and visual indications that the request has been made."

(b) "Controls required by paragraph (a) of this section shall be mounted no higher than 48 inches and no lower than 15 inches above the floor, shall be operable with one hand and shall not require tight grasping, pinching, or twisting of the wrist. The force required to activate controls shall be no greater than 5 lb(22.2 N)"

The stop request system should alert the driver that a wheelchair or mobility aid user is to alight at the next stop, particularly in the rear door lift or ramp. The provision of "dual" system only applies to the large buses, (buses larger than 22 feet).

1192.39 DESTINATION AND ROUTE SIGNS.

(a) "Where destination or route information is displayed on the exterior of a vehicle, each vehicle shall have illuminated signs on the front and boarding side of the vehicle."

(b) "Characters on signs required by paragraph (a) of this section shall have a width-to-height ratio between 3:5 and 1:1 and a stroke width-to-height ratio between 1:5 and 1:10, with a minimum character height (using an upper case "X") of 1 inch for signs on the boarding side and a minimum character height of 2 inches for front "headsigs", with "wide"

spacing (generally, the space between letters shall be 1/16 the height of upper case letters), and shall contrast with the background, either dark-on-light or light-on-dark."

The sign provision is based on the guidelines for buildings and facilities. These spacing and proportions were tested with blind and visually impaired persons and were found useful. The other suggested standards could not provide any justification and hence the "wide" standards prevail.