REPORT ON DEVELOPMENT OF
SPECIFICATION FOR DESIGN AND PERFORMANCE OF
40 FT. TRANSIT BUSES

Prepared For

U.S. DEPARTMENT OF TRANSPORTATION

CONTRACT DOT–UT–10009

B y

SIMPSON & CURTIN
Transportation Engineers
Philadelphia, Pennsylvania 19102

In Association With

BOOZ, ALLEN APPLIED RESEARCH, INC.
Bethesda, Maryland

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1.0 GENERAL

1.1 Purpose

Notwithstanding the many shortcomings of bus travel, it can hardly be said that the motorbus industry should be faulted for planned obsolescence or the lack of durable vehicles. The present "new look" bus first appeared on the streets 11 years ago. The prior model was introduced 19 years earlier, in 1941. Unlike its competitor, the automobile, style changes for buses occur at 15-20-year intervals; this is also the service life of these vehicles in everyday stop-and-go operation.

The federal government as well as transit operators agree that the time is due for a new transit bus. The purpose of this specification is to define the performance requirements of the standard vehicle -- the 40-foot transit coach -- intended to revitalize urban bus fleets over the near-term future.

This contract called for the performance requirements for a large passenger transit bus (45-55 passengers). The 40-foot bus was selected as the basis for this specification because: (a) this is the bus in broadest general use throughout the North American continent today and a replacement of similar size is needed; (b) 40-foot-length buses are the largest legally permitted in a majority of states; and (c) the 40-foot bus shell is consistent with accommodating 45-55 passengers at acceptable levels of comfort.

This specification defines the function these vehicles are intended to perform, instead of describing the vehicle itself. The document sets out performance requirements, defining the interface with the operating property, the passengers, and the community, and the fulfillment of legal requirements. For example, rather than specifying a particular power plant, requirements for vehicle speed, noise, exhaust emissions, reliability, and other measures of engine performance are defined. This leaves the choice of engine to the vehicle supplier, giving him the option of reaching the same result in another and, hopefully, more efficient way.

This bus is to be used for city-suburban express service and, with optional features, for general service on urban arterial streets. The 40-foot shell is suitable for both these functions although different power plant and interior appointments may be desirable in the different modes of operation. These specifications define the maximum performance and the minimum level of comfort necessary for the 40-foot bus to accommodate the suburb to city center express service. If an operator elects to use the bus only for operation on city streets he may specify a lower top speed and lower level of seating comfort.

1.2 Rationale

The first step in developing these specifications was to formulate a rationale regarding the type of bus required to replace the present 40-foot transit bus. For this purpose, bus markets and the trends to date were examined.

Buses not only have the largest share of the transit market at present but also the potential to increase that share by the use of innovative approaches to modes of operation and bus service. A series of bus design attributes was therefore developed to accomplish that objective.

1.2.1 Bus Markets

Cities are the primary market areas for bus transit, in particular those cities over 100,000 population. At the 1970 census there were 153 of these cities in the United States, which together account for 27.6 percent of the total population. Only five of these cities have a rail rapid transit system. Another five cities have advanced plans for rail systems which may be operational by 1980. Thus, between now and 1980, 143 cities will be wholly dependent on buses for mass transit. In addition, in those 10 cities which have, or will have, rail rapid transit, the bus will continue to form a significant part of the overall transit system by performing feeder services to rapid transit stations.

In spite of the overall growth of cities, bus travel has been declining steadily and persistently for the past 20 years. This trend is shown in Table 1 and graphically in Figure 1. Since 1950, bus passengers have dropped 47%,

T A B L E 1

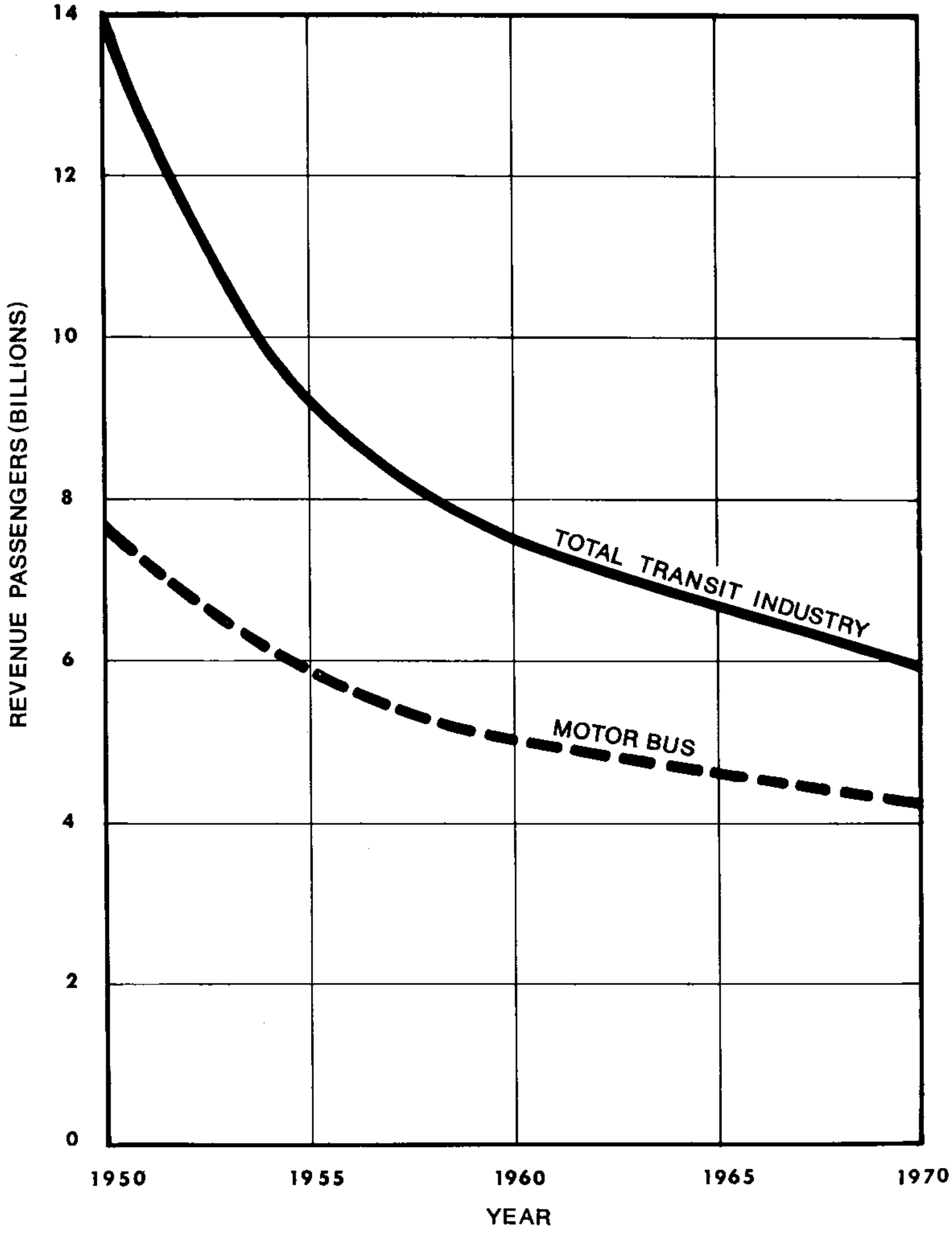
REVENUE PASSENGERS

	Revenue Passengers (Billions)	
Year	**Motor Bus**	**Total Industry**
1950	7.681	13.845
1955	5.734	9.189
1960	5.069	7.521
1965	4.730	6.798
1970	4.058	5.931

SOURCE: *1970 – 1971 Transit Fact Book, American Transit Association.*

FIGURE 1

TREND OF TRANSIT REVENUE PASSENGERS



while the transit industry as a whole declined 59%.

One of the goals of these specifications is to provide a bus capable of reversing this downward trend.

1.2.2 Major Urban Bus Uses

The inherent flexibility of a bus enables it to perform a variety of tasks in the urban environment. This specification is intended to optimize as well as to enlarge upon that capability.

Two distinct functions can be identified for large-capacity bus: (a) operation on urban arterial streets; (b) operation on an express suburbs-to-city center service. These two functions are often performed by identical buses at present, although designs for both functions are not always compatible. Both functions involve moving large numbers of passengers at one time; thus, a 40 ft x 8 ft 6 in shell is suitable for both. However, the express service may use an exclusive bus lane or a freeway with mixed traffic where requirements for speed, acceleration and gradeability are considerably higher than those for the bus operating exclusively on urban arterial streets. In addition, the number of seated passengers as well as seat comfort offered should be greater in the express service, since passengers are apt to be traveling for a longer period.

These specifications are intended to form the basis for the design of a 40-foot bus having the required performance characteristics for express service. On the other hand, an operator may adapt this specification specifying lower levels of power output and comfort if he intends to use the vehicle exclusively on urban arterial streets.

Other tasks for buses include city center circulation, rail rapid transit feeder and suburban neighborhood convenience service. In these operations, however, passenger loads are considerably less so that the large passenger transit bus is not suited to this type of operation.

1.2.3 Bus Design Attributes

The primary objective is to reverse the present downward trend in bus ridership. To accomplish this, it is necessary to reexamine the traditional priorities in bus design. For many years the emphasis has been on management accommodations -- fuel economy, low maintenance expense -- often at the expense of passenger amenities. The philosophy in development of these specifications has been to reverse these priorities and place the bus design attributes in the following order:

1.	Speed	
2.	Passenger Comfort and Safety	Passenger Appeal
3.	Aesthetic Appeal	Community Acceptance
4.	Environmental Adaptation	
5.	Maintainability and Reliability	Management Accommodation
6.	Economy	

Speed

Minimum journey time is the foremost consideration in selection of travel mode for home to work and for other dominant travel purposes. Opportunities for increasing average speed include higher top speed, higher acceleration and reduction of dwell time. These three areas have been addressed in various parts of the specifications.

The top speed is one component which will contribute toward reduced portal-to-portal travel time. This will be most significant on the express operation on a freeway or exclusive busway, where the highest legal speed should be attained by the bus.

A high acceleration is desirable in both express service and operation on urban streets. Acceleration is limited by considerations of passenger comfort and safety, but within these limitations should be as high as possible. The rationale for the relatively high acceleration in the lower speed range is to increase average speed in stop-start operations on arterial city streets, while the acceleration requirement over the higher speed range is to improve the safety of the freeway high speed merge.

Perhaps the most significant area in which overall journey time can be reduced is that of dwell time. It is essential that passengers be able to board and alight faster than at present, to avoid delaying both the passengers already on the bus and those waiting in line at the stop. Three features contributing to the reduction of dwell time which will be included in the bus are wider doors, fewer and smaller steps, and improved fare collection equipment.

Passenger Comfort and Safety

In recent years the automobile has been offering increasingly higher standards of comfort and safety. On buses the standard has generally been declining. In order to attract passengers from cars, the bus must offer comfort factors such as large seat size, adequate knee room, ease of circulation within the bus, good visibility and a pleasant environment, particularly with respect to ride quality, noise, lighting, and interior climate control.

A high degree of passenger safety is required. Design features to be included in the bus which are directly related to passenger safety include:

- Low floor heights (17 inches) and wide entrance doors (40 inches) to improve passenger safety during loading

- Reduced jerk during acceleration

- Removal of obstructions under seats

- Improved braking system requirements for efficient controlled and emergency stops

- Improved passenger safety in a seated configuration, including high seat backs and lateral support

- Fire-retardant interior materials

- Non-skid aisle and step surfaces

- Grab rail design to minimize injury

- Improved glazing material strength, and retention of windows

Aesthetic Appeal

A new vehicle designed to attract passengers must be aesthetically pleasing both outside and inside. The exterior styling should be sleek with a low profile, smooth clean lines and an absence of superficial design motifs. The vehicle must also have a distinct identity so that the passenger has no difficulty recognizing it in a traffic stream. At the same time the vehicle must not appear obtrusive or objectionable to the residents of the communities through which it operates.

The interior decor should create an image which suggests luxury, individuality, good taste and convenience. The interior should be designed as a cohesive whole, rather than an agglomeration of unrelated parts. Colors should be restful or exciting, in measured proportions. Textures and finishes should be combined to provide a warm, inviting appearance. The overall impression should be visually and audibly appealing and might simulate the interior of an airliner.

Environmental Adaptability

The bus must be in harmony with the environment in which it operates. Present buses emit noise, noxious gases and odors which are objectionable to individuals and contribute to the general pollution of the atmosphere. The State of California has developed pollution standards to be enforced on all vehicles in that state in 1973 and more stringent standards for 1975. Federal standards applicable throughout the United States are also being developed for emissions control. The most severe legal standards in force will be the basis for bus emission standards.

The dimensions and weight of the bus must also be within the legal requirements for the operating environment.

Temperature, humidity and altitude have wide variations in the North American Continent. It is desirable that the bus be able to adapt to these variable climatic conditions. It is unrealistic to expect full performance under all conditions, but the ability to carry passengers with reasonable standards of both comfort and reliability under all conditions is essential.

Maintainability and Reliability

During the slow design evolution of the present urban transit bus, the designers have been under constant pressure for improved durability and reduced operating costs. This has resulted in a remarkably reliable vehicle. In this new vehicle, it is essential the present high reliability characteristic is maintained or improved. It is an objective that the maintenance intervals be increased and that the skill levels required to perform the maintenance tasks be lowered.

Since these specifications are performance-oriented, no detailed hardware items are called out. This deletion of references to specific components, in which the transit property has gained confidence through experience, invites substitution of inferior parts if other, quantitative measures of quality, are not used as a safeguard.

In these specifications, components related to safety, potential revenue service interruption, and passenger comfort and convenience have been required to demonstrate increased mean times between failures. In addition, maintainability requirements involving reduced mechanics' skill, improved accessibility, improved diagnosis, and modular replacement have been specified.

Economy

While economy has been placed sixth in order of priority, it should not be interpreted to mean that capital and operating costs may be unlimited in the manufacture and operation of the vehicle. In fact, each of the other attributes must be measured in terms of economy and trade-offs made between initial capital cost and cost of operation, to achieve optimum overall cost, but not necessarily the cheapest possible cost.

1.3 Hardware/Requirements Matrix

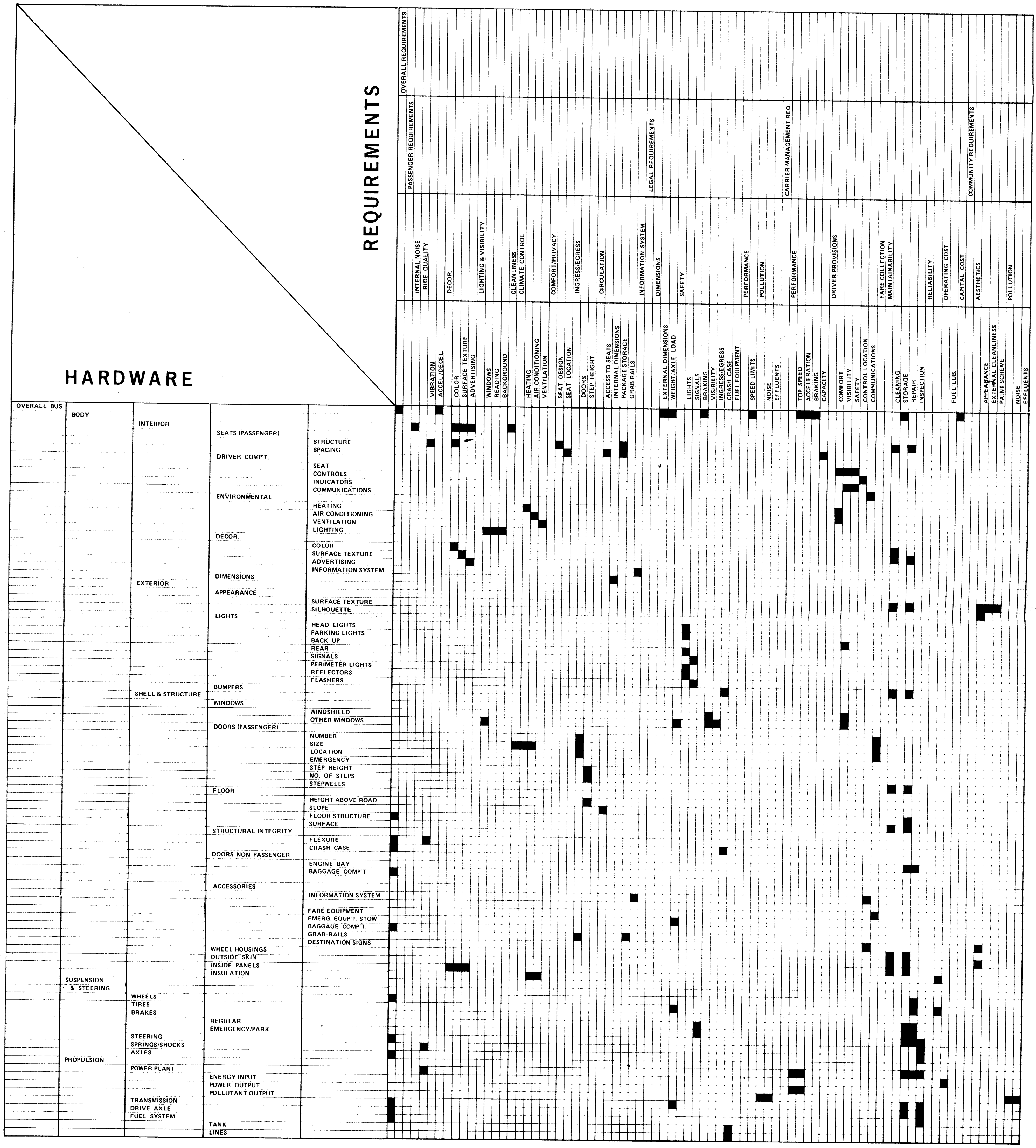
In order to compile a performance specification, it is necessary to break down the hardware only in sufficient detail that performance requirements can be assigned to each component. This hardware breakdown must be generalized in nature consisting of components and subsystems which appear on every bus. A "hardware tree" method was used as a means to make this breakdown logically. Five subdivisions proved sufficient to obtain the required level of detail. A further level of detail would tend to show components which might be so specific that possibly only one or two proprietary items would meet the requirements. This would defeat the objective of a performance specification, since all scope for innovative design would be lost and the document would become a detailed design specification.

The requirements for each item of hardware may initially be identified in terms of what performance is required by various people who will in any way be associated with bus operation. For this purpose the people were divided into four separate groups: Passengers, Legislators, Carrier Management and Members of the Community through which the bus operates. The overall requirements of these groups and their relative priority were established in the rationale in Section 1.2. The requirements of these human groups as they relate to bus components can be broken down into four levels of detail. A useful tool in interrelating the human requirements with the hardware was the matrix shown in Figure 2. The five columns on the left of the figure represent a bus hardware breakdown in five successive levels of detail. The overall bus has three major components: body, suspension and steering, and propulsion system. The body may be subdivided into interior, exterior and the shell and structure. The top four rows of the matrix break down the requirements in terms of the four human groups who may be associated with the operation of buses.

As an initial approach, each item of hardware at the 5th level of detail was examined in terms of what

FIGURE 2

BUS HARDWARE / REQUIREMENTS MATRIX



performance was required of that piece of hardware from the viewpoint of each of the four human groups. Certain items are only required by one group -- for example driver comfort is the concern only of the carrier management. There are no legal requirements, and the passengers and community are not concerned with this particular feature. Other hardware items have different requirements by different groups. For example, certain acceleration and braking performance is required of the overall bus. However, the passengers require one standard, a legal braking standard is required, and the carrier management may require a third standard.

One use of the matrix as a tool in the development of the specification is to identify any conflicts among the requirements of the various groups. These conflicts may then be resolved by applying the rationale developed in Section 1.2. Even where no conflicts exist, identifying hardware performance in terms of the human group which requires that performance provides a guideline as to the relative priority that should be assigned to the design of that particular piece of hardware.

The matrix can be used as a checklist to ensure that both hardware and human requirements have been adequately covered. It is emphasized that this matrix was an initial approach and the hardware checklist is not necessarily exhaustive. In subsequent development of the specifications, requirements for other hardware items were specified, and some items deleted.

1.4 Development Process

The Development Process for these specifications included many discussions with groups, agencies and companies which are highly skilled and knowledgeable on all aspects of design, manufacture, operation and safety of buses.

All-day discussions were held with, and written comments received from, representatives of the bus manufacturing industry. Safety requirements were discussed with government agencies including the National Highway Traffic Safety Administration (NHTSA) and Federal Highway Administration (FHWA). The transit needs of the handicapped were discussed with representatives of the President's Committee for the Employment of the Handicapped.

The operating industry was represented by a committee assembled by the American Transit Association, and designated the Bus Technology Committee.

The members of this committee and their affiliation are shown in Table 2. These members represent a large proportion of the total bus operation in the North American continent and between them they have had a great many years' experience in the actual day-to-day operation of buses. An important feature of these specifications is that this wealth of experience has been tapped and used to define a bus which is truly practical while at the same time an advancement in the state-of-the-art of bus manufacture.

The first significant meeting with this committee was held at the Royal Inn, San Diego, on August 4, 1971 (minutes of the meeting included in Appendix A). The rationale outlined in 1.2 and the matrix in 1.3 of this report were presented at this meeting. The matrix formed the basis for the detail discussion and initial performance requirements for certain hardware items were established.

TABLE 2

AMERICAN TRANSIT ASSOCIATION

BUS TECHNOLOGY COMMITTEE

Member	Company
R. Pollock (Chairman)	Cleveland Transit System
A. L. Bingham (Vice-Chairman)	AC Transit, Oakland, California
L. W. Bardsley	Toronto Transit
J. D. Belsky	New York City Transit Authority
R. Booth	Tri-State Transit, Portland, Oregon
H. Chaput	Ottawa Transportation Commission
G. J. Clark	Chicago Transit Authority
S. H. Gates	Rapid Transit Lines, Houston, Texas
C. I. Guiliani	Milwaukee and Suburban Transport Corp.
G. W. Heinle	Southern California Rapid Transit District
L. C. Huffman	Cincinnati Transit Commission
P. B. Rockwood	Cleveland Transit System
E. Tansky	Niagara Frontier Transit System, Inc.
J. Schnell (Secretary)	American Transit Association, Director of Research

Subsequently, the technique employed with the ATA Committee was to circulate a draft copy of the specifications to each member. The members reviewed the documents both individually by offering written comments to the contractor, as well as jointly at two all-day meetings* including as many of the members as were able to attend. At these sessions, the current draft of entire specifications was discussed in detail. Separate minutes of these meetings were not kept but the committee comments were recorded in a master copy of the specifications. References to these comments will frequently be made in this report.

There was not always a full consensus of opinion on each issue. Many operators had had different experiences with various pieces of hardware and wanted other features to be available on their particular bus. However, throughout the preparation of the document, valuable guidance was received both from the unanimous opinions as well as from the discussions during which an acceptable middle ground was reached.

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*Both held at ATA Headquarters, Washington, D. C., on August 31, 1971 and November 1, 1971.

The second and third drafts of the specifications were also circulated to representative manufacturers who examined each clause with a view to actually making a vehicle to these requirements. Some of the manufacturers held all-day meetings with representatives of the contractor to discuss the draft documents in fine detail. The appropriate comments were included in the subsequent draft of the document.

In parallel with this process the rationale was reviewed with NHTSA and FHWA. At these meetings*, certain legal and safety requirements were established which were mandatory to both manufacturers and operators. These requirements were included in the drafts of the specifications as the information became available.

This process of continual review and distillation of information from representative cross sections of both operating industry and the manufacturers was a powerful tool in developing the specifications and resulted in a document that is realistic while at the same time advancing the state of the art.

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*See minutes, Appendix A.

1.5 Mandatory Requirements

Prior to the publication of the third draft of the specifications, discussions with the manufacturing industry and members of the ATA committee led to the concept of identifying which items in the specifications are mandatory requirements from which no deviation is permitted, and which requirements are goals or guidelines to be approached as nearly as possible. In the third and final drafts, the mandatory requirements were marked ** by each paragraph number.

The criteria for determining mandatory requirements were legal, safety, and interface dimensional requirements. For example length and width are legal requirements and therefore mandatory. Approach, departure and ramp breakover angles, and turning radius are interface dimensional requirements and are also mandatory. The floor height of 17" above the level road is not mandatory but is a desirable goal to be approached as nearly as possible, consistent with the mandatory items and based on trade-offs among the other goals.

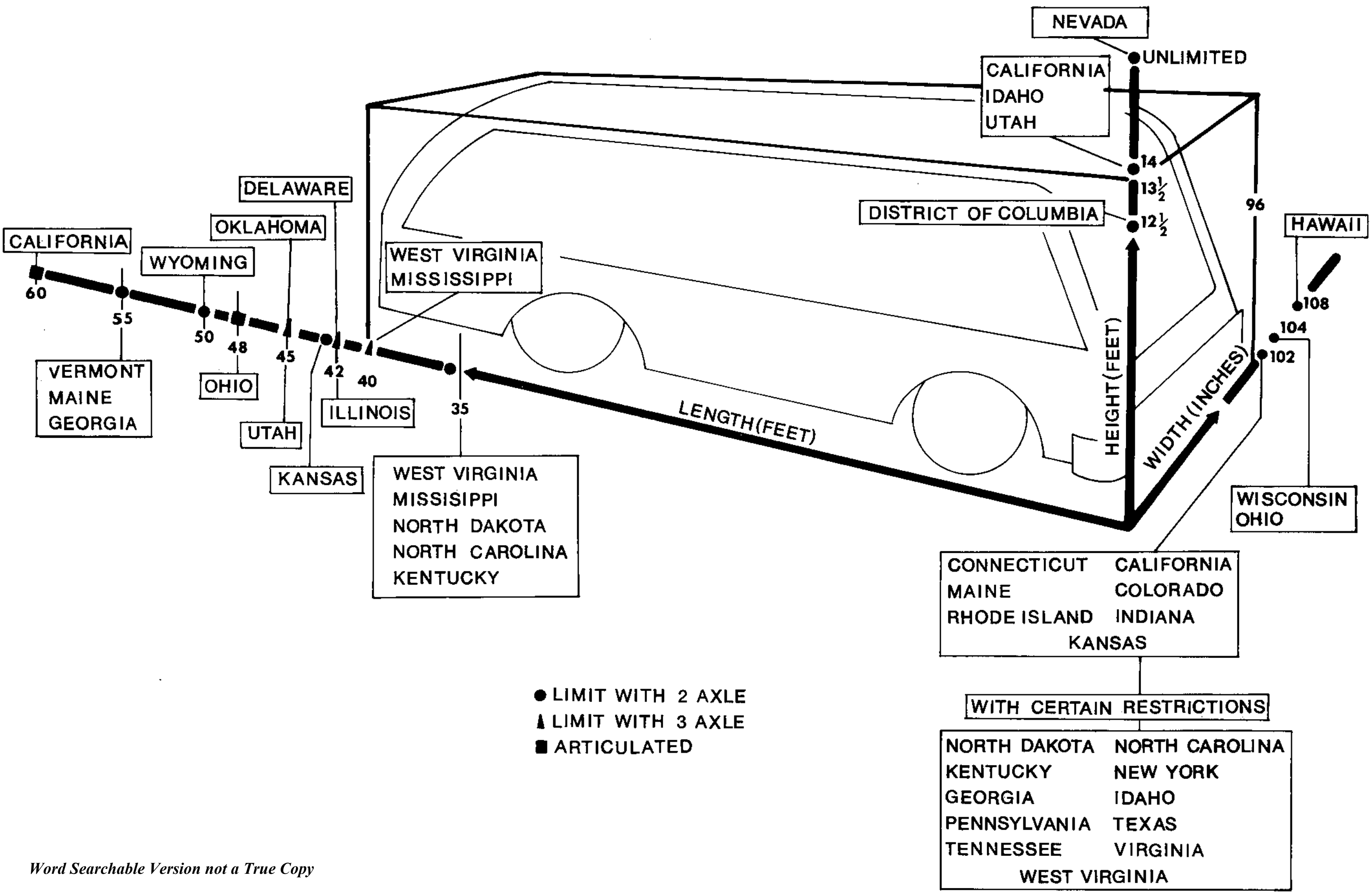
2.0 OVERALL REQUIREMENTS

2.1 Dimensions

From an examination of the legal requirements on the overall size of vehicles in the various states the 40-foot length dimension was obtained. This is the legal maximum for buses in a majority of states. Some states permit buses to exceed this dimension, notably Vermont, Maine and Georgia, which allow 55-foot length. Relatively few states require a length shorter than 40 feet, except North Dakota, North Carolina and Kentucky, which permit only 35 feet. West Virginia and Mississippi limit buses to 35 feet unless rear tandem axles are used, in which case the standard 40-foot length is permitted.

A majority of states still limit width of buses to 96". However, there is a strong lobby urging that this be changed to at least 102", and Federal legislation is pending to permit this width on interstate highways. Some states allow a greater maximum width, notably Ohio and Wisconsin, which allow 104", and Hawaii, which allows 108". A summary of the legal dimensional limits for the various states is presented in Figure 3.

FIGURE 3
DIMENSIONAL LIMITS



No attempt was made to take the investigation of legal dimensional requirements to a greater level of detail -- e.g., to examine local ordinances in various cities -- since the overall philosophy of the program is to define a bus which will be able to serve both the suburb to downtown service as well as operation on city streets.

At the ATA meeting on August 31 in Washington, the length of 40 feet was considered acceptable to most properties. Most properties favored a width of 102" but some still preferred the 96" width from a viewpoint of maneuverability within the cities. This led to the footnote that the bus should be designed so that it may be constructed in either 96" or 102" configuration. While all the operational performance requirements may be met with the narrower bus, the seat and aisle width may be compromised.

At the same ATA meeting, the members took universal exception to the legal height limitation of 13 feet, 6 inches. They did not want a bus approaching this height.

The height limitation was governed by the requirements of the operator's maintenance shops, bus barns and automatic bus washers. For compatibility in this respect, the height should be no more than 10 feet, 3 inches. Other requirements in the bus design indicate that the overall height may be considerably less than this. If the required 17" floor height is achieved, together with an 80" internal ceiling height, then the overall height may be as low as 100", or 8 feet, 4 inches.

Initially, a linear dimensional road clearance of 11 inches was set. After discussion with the ATA and representatives of various manufacturers, an angular clearance in terms of approach, departure and ramp breakover angles was set, in accordance with SAE standard practices.

The turning radius of 42 feet was originally based on the present GM coach (see Ref. 10). The operating properties expressed a desire for less than this and the present Flxible Coach, of 40-ft. length, 102-in. width, has a turning radius of 41 feet (see Ref. 11). Most properties can operate with 42 feet. In view of the radical new design of suspension and steering necessary to achieve the low floor height, the turning radius was set at maximum of 42 feet. Manufacturers would be encouraged to reduce this dimension if possible.

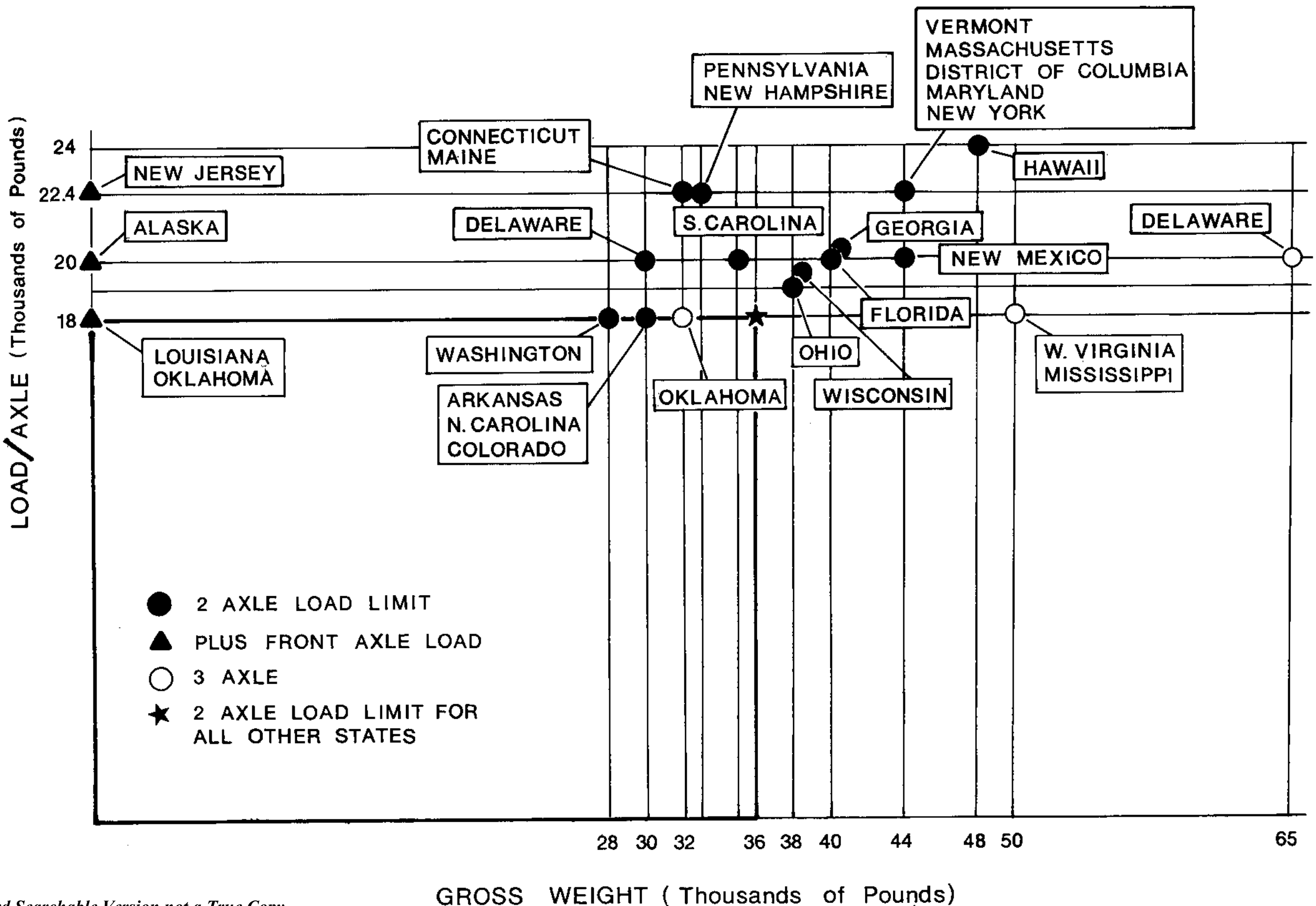
2.2 Weight

An investigation was made of the legal weight limits for the various states. An appreciable number of states set limits of gross overall weight at 36,000 lbs. (2 axles) and axle loading of 18,000 lbs. No state has an axle load limit below this value. Nine states and the District of Columbia have an axle load limit of 22,400 lbs.

A summary of the legal weight and axle load limits for the various states is given in Figure 4. The local ordinances on weight limitation were not investigated. From this summary, the axle loading was set at 18,000 pounds and the gross overall weight for 2-axle units at 36,000 pounds.

At the ATA meeting in Washington on August 31, it was pointed out that the front axle was generally not designed to carry the same load as the rear and also it was not desirable to have the weight distributed in that way. The recommended gross overall weight was 32,000 pounds, with a maximum of 23,000 pounds on the rear axle. Some cities allow this axle loading by special ordinance, but once the buses leave the city limits

FIGURE 4
LOAD LIMITS



Word Searchable Version not a True Copy they may be technically breaking the law. To avoid these legal implications, the bus could be designed with tandem rear axles. The drawback to this configuration is the reduction in seating capacity due to large rear wheel wells.

At the subsequent ATA meeting on November 1 in Washington, the subject was again discussed and a compromise reached. The axle loading will be 18,000 maximum for the fully loaded, all seated condition. Thus, if a bus is overloaded with standees, the operator may be technically breaking the law rather than the bus designer. This still does not eliminate the designer's option of using tandem rear axles, nor his obligation to reduce structural weight as far as possible.

2.3 Capacity

Passenger comfort and safety is a bus attribute second in importance only to speed. Initially a high level of comfort with a single seating configuration was specified. This seating configuration was based on transverse, forward-facing seats, and was selected as being the most practical seating arrangement for general transit purposes, based partly on a study by Renssalaer Research Corporation (Ref. 3), and partly on traditional seating arrangements. Seat spacing and passenger knee room were also examined in the RRC study and their recommendations were adopted as a base-line. The dimensions were checked against recommendations in other pertinent literature (e.g., Refs. 2 and 4) and practice in other modern transit operations.

At the ATA meeting in Washington on August 31, the members generally disapproved of having only one seating configuration available. This lead to the definition of a Standard Seating Arrangement with the bus adaptable to other arrangements as specified by the customer properties (see Section 5.2).

The bus is designed to replace the present 50-passenger transit bus. However, a higher standard of passenger comfort and safety is required than at present. This comfort may be measured in terms of additional knee room and wider seats. Safety is addressed in terms of lower floor giving safer and faster access and egress, and in higher seat backs of padded design to minimize seated passenger injury in the event of severe braking. These features, which are regarded as high priority in attracting passengers, force a reduction in the overall number of seats which can be fitted in a 40' x 102" bus shell. A target capacity of 45 passengers is set. It is desirable to increase this if possible without compromising the standard of comfort.

2.4 Performance

In order to achieve the stated objective of decreasing portal-to-portal journey time, higher performance is needed in the areas of top speed, gradeability, and acceleration. This may require a propulsion system of higher power output than is presently used.

While a high top speed is necessary for expressway operation, high acceleration is also desirable for operation on urban streets. Good gradeability is desirable in both types of operation. The top speed capability should be available to an operator who requires use of the bus in a suburb to city center express mode. An operator who expects to use the vehicle exclusively on urban streets has the option of specifying a lower power propulsion system.

The power plant must be capable of delivering sufficient power not only to propel the vehicle in accordance with the performance requirements but also to operate all appropriate accessories within the environment specified. This applies particularly to the heating or air-conditioning system, whose continuous operation is required without degradation. In addition, the power plant must be capable of driving all other accessories which may only operate intermittently but must operate at full performance when required.

The definition of exactly which accessories are to be operating at one time is contrary to the general philosophy of a performance specification. A manufacturer must first determine which accessories will be included in the bus and then ensure that the power plant has sufficient capacity to drive them, or provide an auxiliary power plant if warranted.

2.4.1 Top Speed

In order to take maximum advantage of operation on an exclusive bus lane, the bus must be designed for at least the highest legal speed. This speed, on most interstate highways, is 70 mph. The bus must achieve at least this speed and preferably have the ability to exceed it. This then allows operation at higher speeds on exclusive bus ways where a special legal limit may be allowed.

It is unlikely that standees would be permitted in an operation of this type; therefore, the top speed must be reached with a full load all seated. The power plant must be capable of propelling the vehicle at this speed with all the appropriate accessories working normally within the environment range specified.

2.4.2 Gradeability

For operation on a freeway with mixed traffic, it is essential that the bus, even when fully loaded (all seated), does not impede other traffic while climbing an average grade. Initially the requirement was set at 65 mph while climbing a 5% grade. Discussions with various manufacturers indicated that no engine suitable for buses had the power output required for this at present and no engine in an advanced state of development was available for the near future. A second drawback to this requirement was that the safety of the passengers and other road users might be compromised if that amount of power were available to a driver operating a nearly empty bus.

Discussions with a diesel engine manufacturer indicate that the power output to drive the bus with a fully seated load up a 2½% grade at 55 mph is obtainable from an existing diesel engine with modifications. Most vehicles maintain an average of 55 mph on such grades on freeways, and the bus should therefore be able to maintain at least this speed. This, then, represents a reasonable compromise between power available and the performance required.

2.4.3 Acceleration

Acceleration is one component which can contribute to a higher average speed for an overall journey. Acceleration is limited by considerations of passenger comfort and safety, but within these limitations should be as high as possible. An acceleration of 0.1g (or 2.2 mph/sec) has been used in rail rapid transit operations in the past and has been demonstrated on the Transit Expressway experimental installation in South Park Pittsburgh. This acceleration is high enough to be acceptable for bus operation while demonstrating reasonable safety for standee passengers, provided jerk (rate of change of acceleration) is minimized.

In the Transit Expressway the acceleration is controlled electronically whereas in a bus the driver has primary control of acceleration. It is desirable that the maximum acceleration of 0.1g should not be significantly exceeded but should be approached irrespective of the bus load. This, together with the minimization of jerk rates will require development in the areas of transmission and controls for buses.

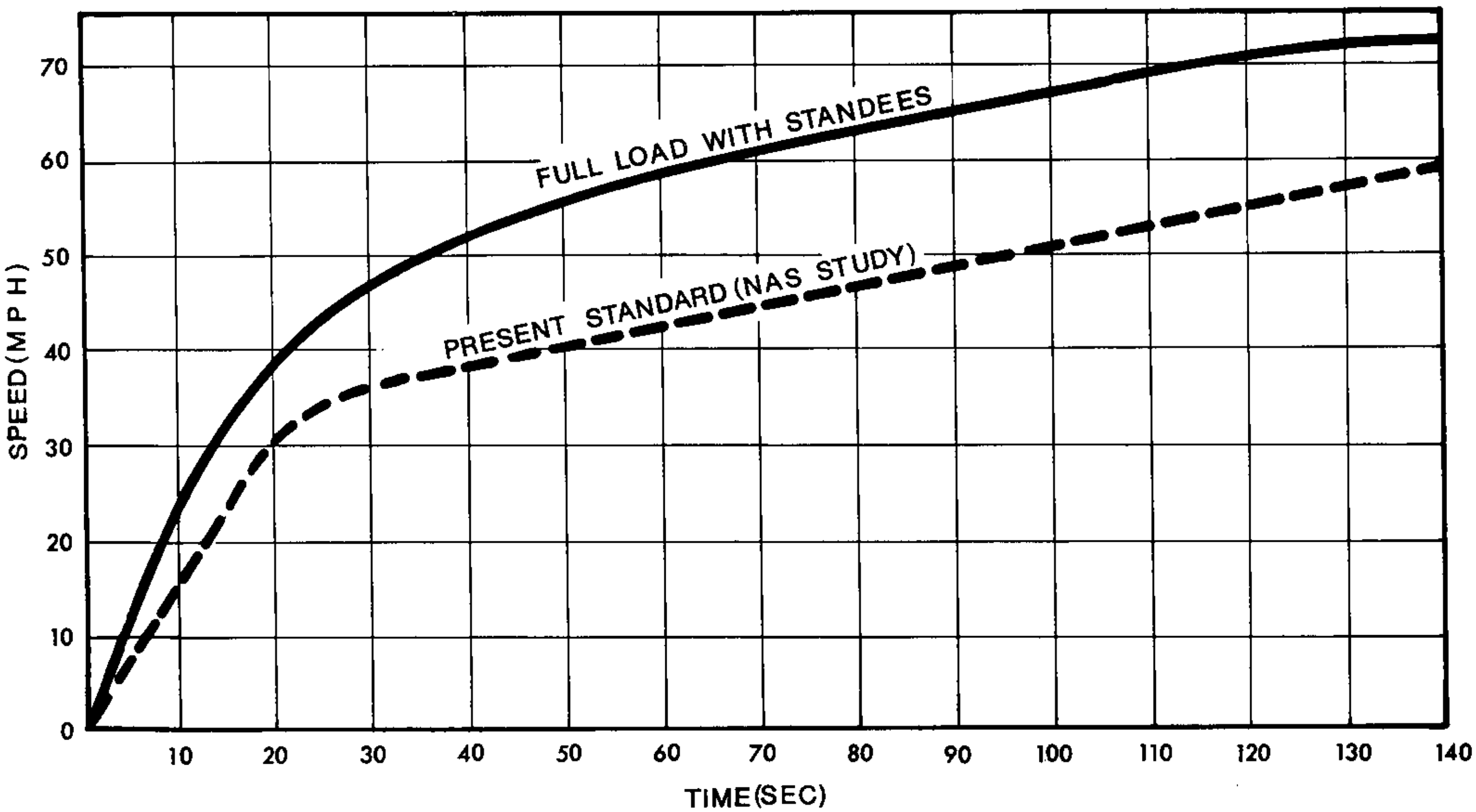
The rationale for the relatively high acceleration in the lower speed range is to increase average speed of stop-start operations on city streets, while the acceleration requirement over the higher speed range is to improve the safety of the freeway high-speed merge. The required acceleration characteristic is shown in Figure 5 and the present standard is included for comparison. The present standard is taken from Ref. 2.

2.4.4 Deceleration

The NHTSA has recently developed rule-making actions to govern the performance of braking systems on buses and other heavy vehicles. These rule-making actions were discussed at the meeting with the Office of Operating Systems of NHTSA on September 27, 1971 (see minutes, Appendix A). The bus design must incorporate the intent of the rule-making, especially in regard to anti-skid devices.

Discussions with the bus manufacturers indicated that they were aware of the rule-making actions and are prepared to meet the requirements.

FIGURE 5
ACCELERATION REQUIREMENTS



2.5 Structural Integrity

It is essential that the basic structure of the bus be strong enough to withstand the standard operating loads without permanent deformation nor large elastic deflection. In particular, elastic deflection must not impair operation of doors or other mechanical devices, nor alarm the passenger.

Furthermore a fatigue failure of the basic structure during the design life of the bus is unacceptable.

The load factors to be applied to the static loads for design purposes in the six principal directions are similar to those used in present bus design and are generally regarded as adequate. These load factors were established after discussion with several manufacturers, but certain higher load factors may be required at key points, such as points of connection between suspension and body.

In addition to withstanding this operation load, the basic structure must be designed for certain crash loads. The primary consideration in this respect is the safety of the passengers. Two structural design

factors can contribute to this: (a) passengers must not be thrown clear during a crash; they should be retained within the bus shell, and (b) the structure must not collapse during a roll-over crash, thereby crushing passengers. (Protection of the passenger during a crash will be discussed in 5.0, Interior.)
In order to avoid passengers being thrown clear during a crash, certain basic requirements with respect to the retention of windows must be met. Federal standards have been developed for this and are discussed in 3.1.

A second design crash case is that of broadside collision. In view of the low floor design, special steps must be taken to protect the bus passenger, since car bumper height will be only slightly below bus floor level. At the same time it is undesirable for the other vehicle (e.g., passenger car) to strike an essentially rigid object, thus some resiliance is desirable. For the bus passenger, injuries sustained below the hips are less severe than those sustained above this area. Consideration of these factors led to the compromise design guideline of a structural deformation of no more than 3 inches at passenger hip height when struck by a 4,000-pound object simulating an automobile at 25 mph. Other structural design considerations include the avoidance of resonant vibrations of various parts of the structure as a result of excitation frequencies of road surface at various vehicle and engine speeds.

2.6 Service Life and Maintenance

The service life and maintenance requirements are impossible to define precisely and thus are stated in the form of goals or guidelines. It is necessary to give a manufacturer a goal for the life of the bus. Discussions with the ATA Committee indicated that 12 years was a suitable guideline. However, the end of bus life cannot be exactly defined, particularly during the design phase. The approaching end of bus life is apparent to an operator when it becomes uneconomical to continue maintenance for that particular bus. As this end approaches the operator may alter the duty cycle of the particular bus to prolong its life if necessary.

Power plant life does not usually govern vehicle life since standard procedures are employed to change power plants and the operation is relatively fast. The usual characteristic governing life is the deterioration of the body. By comparison with the change of power plant, this operation is a lengthy process often requiring highly skilled personnel.

A designer cannot predict exactly when the bus body will deteriorate to a point where it is uneconomical to repair it. However he can make sure in design that this does not happen in, for example, seven years provided maintenance procedures are followed, and no severe crash is experienced. Similarly the designer should not overdesign the vehicle so that it will last for 30 years as in the design of rail rapid transit cars, since this tends to limit the infusion of new technology into bus design.

In discussions with the ATA Committee, the possibility of manufacturers providing warranty for 12 years was suggested. This was rejected on the basis that the manufacturer would probably quote an unacceptably high capital cost for such a vehicle because (a) it would almost certainly be overdesigned and last considerably longer than 12 years, and (b) the manufacturer would anticipate considerable work under warranty when quoting his initial cost.

Since the designer is required to make an estimate of bus life, it is most important that he also define the maintenance procedures to achieve this life. It is desirable in view of increasing labor costs and the shortage of skilled mechanics that all maintenance be such that it may be done by personnel of skill levels no higher than 3M - Service Mechanic. This puts an onus on the designer to develop parts and subsystems that are simple and easy to maintain. A generally stated objective is to use plug-in components which may be removed and replaced with the minimum of tools. The failed component can then be repaired on the bench without immobilizing the bus.

A reliability no lower than that presently experienced on buses is required. In particular, new emphasis is placed upon:

- Minimizing failures which result in (a) safety hazards, (b) the interruption of revenue service, and (c) discomfort or inconvenience to the passenger.

- Improving the maintenance characteristics of the vehicle by improving accessibility, reducing maintenance skills required for service, increasing the use of modular components, and providing for easy diagnosis of key components.

In the definitions, four classes of failures were defined, in relation to safety hazards, revenue service interruption failures, passenger discomfort failures, and other failures. A mean mileage to failure for the bus was assigned to each failure class, with special emphasis on Class 1 -- safety hazard type failures for which a 1,000,000-mile failure mean was specified. To determine the mean mileage to failure, the failure incidence of a whole fleet of buses, based on the mileage of each individual bus at the time of a failure incident, can be plotted against mileage. From this curve, the variation of probability of a single failure with mileage can be derived. This might take the form:

$$P = \frac{e^{-kt}}{k}$$

where P = Probability of Class 1 failure

t = Mileage at which failure occurs

k = Constant based on the fleet incidence of failures

The mileage at which this Probability reaches 0.50 is the mean mileage to failure.

A goal for the mean mileage to failure for safety-related failures (Class 1) is twice the specified life of the vehicle. Thus the incidence of safety failures in service is expected to be very low; this incidence depends, however, upon the distributional properties of Class 1-type failures.

Mean mileage for Classes 2, 3 and 4 are sufficiently short compared with vehicle life that they are interpreted as mean mileage between failures.

The actual mean mileages assigned were the subjects of discussion at the ATA committee meetings, and at meetings with manufacturers' representatives. The two factions hold opposite views with the ATA desiring longer mileages while the manufacturers have difficulty meeting the stated requirements. The resulting requirements are a reasonable compromise, which advances the state-of-the-art without setting impossibly high ideals.

The actual repair time for various components and subsystems should not exceed that for analogous truck components. As stated this is not a severe requirement and does not tend to advance the state-of-the-art in repair technology. In early drafts of the specifications comparison with the analogous automotive repair times was required. This goal was reasonable since automotive repair is primarily conducted in small craftsmanlike service operations, while bus maintenance involves large fleet maintenance with repetitive operations in a factory-like atmosphere. At the same time the state-of-the-art should be advanced since automotive components are smaller and simpler to maintain. After discussions with ATA and the manufacturers, the comparison with automotive practice was rejected since interpretation of analogous parts was not clear. (For example, is a bus alternator really analogous to an automobile alternator?) By contrast, analogous truck parts occur more frequently on a one-for-one basis. Where analogous components do not exist, repair times will be defined by the manufacturer for the individual component.

In regard to improved maintainability characteristics, substantially improved diagnostic features are specified for the bus, particularly for components whose failure presents a safety hazard or interrupts revenue service. Self-diagnosing components and plug-in diagnostic instruments are specified. In addition, component designs should permit all maintenance operations to be adequately performed by lower-skill level mechanics than are typically employed today.

At the ATA committee meeting on August 31, 1971 in Washington, considerable discussion took place on relative merits of diagnostic equipment. No general agreement was obtained at that time.

At the subsequent meeting November 1, 1971 in Washington, the members generally approved the concept but required more detail of which systems would be monitored and how much such monitoring would cost. Identifying certain systems for the bus would imply that such systems would be present on the vehicle, which would be contrary to the general rationale of the document. The wording of the specification is thus in the form of a conceptual goal (see 2.6.5), and the manufacturers will define which systems are to be monitored and the cost of such devices.

Maintainability improvements can also be achieved through improved component accessibility and modular component replacement. Accessibility requirements are specified for components requiring frequent periodic maintenance and those whose failure is safety-related or will interrupt revenue service.

2.7 Operational Environment

This bus is intended for use in all parts of the North American continent. A wide variation of weather conditions and altitudes are experienced over this area. The SAE Standards for performance tests are corrected to a temperature of 85°F and altitude of 500 feet. A range of temperatures of 25°F above and below the standard 85°F covers temperatures which frequently occur, particularly in the Southern States. Outside this temperature range or above 500 feet altitude, it is reasonable to allow some degradation in performance. However it is essential that the bus shall operate as nearly as possible at full performance in, for example, Denver (altitude 5,200 feet) and in Minneapolis in winter (lowest recorded temperature -41°F.)

Under these adverse environmental conditions, passenger comfort and safety must be maintained to the highest possible standards. For example, with an outside temperature of −40°F, heating system total failure is unacceptable, while any degradation should be limited to providing a cabin temperature of no less than +55°F.

From a safety viewpoint, under such conditions total failure of, for example, a brake system compressor, is unacceptable, while any degradation should be limited to requiring longer to charge up the air reservoir.

3.0 BODY

3.1 Windows

The primary requirement for windows is to provide good visibility for the passenger, whether seated or standing. Since both wide vertical members between glazing material and separate windows for seated and standee passengers are undesirable, large side windows were required. A guideline for the window area is established at 16,000 square inches of glazing material on each side of vehicle.

Windows must not permit leakage of either air or water, even under the most severe wet weather conditions and high speed operation.

The transmittance of visible, infrared and ultra-violet light must be low to avoid discomfort to the passenger with respect to both heat and bright light. This transmittance must not be so low, however, that unlighted signs outside the bus cannot be read by a passenger on a dull day. Twenty-three percent transmittance is a suitable compromise which has become accepted in some modern raid rapid transit car designs.

Both ATA and the manufacturers were in general agreement with the above requirements for windows. ATA, however, expressed serious concern over the problem of window breakage due to vandalism, and pointed out that large windows, as specified, would increase replacement costs. Discussions with the NHTSA Office of Crashworthiness revealed that several new glazing materials of superior strength chacteristics are available. These materials also meet the safety glazing requirements of USA Standard Z 26.1. Certain polycarbonates have been tested using a 5 lb. steel ball drop test in accordance with USAS Z 26.1, Test No. 26, in which no breakage was experienced at 20-foot drop height. Results of this investigation are given in Ref. 8.

Two inherent defects are apparent in some of these materials: (a) they may be flammable, and (b) they may be easily scratched, if not coated with a suitable material. Minimum standards for both these possible defects are defined in USA Standard Z 26.1.

At the ATA Committee meeting on November 1st in Washington, the subject of fixed versus sash windows was discussed. The point was made that, in view of the poor reliability record of air conditioning systems, fixed windows which could not be opened for ventilation in the event of air conditioner failure would be undesirable. Such failure would immediately render a bus inoperative. Further, fixed windows are less desirable when the "cyclone" bus cleaner device is to be used.

Some members favored the concept of fixed windows both because no maintenance of the sash mechanism is required and because the possibility of accidents due to passengers leaning out of the windows is reduced.

A compromise was reached, in that windows would be fixed (consistent with emergency escape requirements) but the bus ventilation system would include a backup system which would introduce fresh air into the cabin in the event of air conditioner failure. In addition, special access panels would be provided for the cyclone cleaner.

Rear windows were discussed briefly by the ATA. The general opinion was that, at present, visibility for the driver through rear windows is poor in an empty bus and completely occluded in a bus fully loaded with standees. Outside mirrors are more effective devices for the driver's rear vision. Standards for the outside mirrors will be discussed in Section 4.3. Thus, inclusion or omission of a rear window became the option of the manufacturer.

Window retention and release was one of the subjects discussed at a meeting with the NHTSA Office of Crashworthiness (OOC), September 22, 1971 (see Minutes, Appendix A). Provision must be made to permit passengers to escape after the bus has come to rest in any orientation following a crash. Federal Motor Carrier Safety Regulations concerning this are soon to be supplemented by the NHTSA rule-making action for window retention and release (see Docket #2-10). To meet escape requirements, buses of European design often incorporate one or more glazed hatches in the bus roof. Thus, should the bus come to rest on its side, these hatches form a more practical escape route than the windows of the uppermost side of the bus which are 8'6" above the lower side. If adopted, this feature becomes part of the minimum window area to be of push-out design. The OOC was favorable toward this design feature but had no legal action pending on it at present. No objection to the concept was expressed by either ATA or the manufacturers.

The primary requirement for the windshield is to give the driver the maximum possible range of vision - - ideally a complete hemisphere centered at the driver’s eye and extending forward. Since practical considerations prevent this ideal from being achieved, the requirements quoted represent a reasonable compromise. However, manufacturers anticipated difficulty in meeting the 75° horizontal requirement, particularly if a center divider were used in the windshield.

The windshield must be of suitable material as required by USA Standard Z 26.1 and have high transmittance over its area with the exception of a shaded band at the upper edge to reduce direct sun glare for the driver. The windshield must not leak either water or air even under severe weather conditions and at maximum vehicle speeds.

In addition, Motor Vehicle Safety Standards require the inclusion of wiper/washer and defog/defrost devices.

3.2 Doors

One of the most significant factors for decreasing overall journey time is reduction of dwell time. It is essential to make provision for passengers to board and alight faster than at present. The present average boarding time of 3 seconds per passenger could be reduced to 1.5 seconds per passenger with wider doors which permit two lines of passengers to board at the same time. The door width of 40" is based on this premise.

The ATA members had some reservations about such a door, predicting a greater fare leakage than at present. This will be discussed further under 3.11, Fare Collection Equipment.

Representatives of the President's Committee for the Employment of the Handicapped were favorably impressed with the concept of wide doors since this feature would make boarding easier for certain classes of handicapped. For example, if steps were eliminated at the entrance, this door width would be ample for a wheel-chair passenger to board unaided.

The front entrance door should be glazed in both upper and lower halves to enable the driver to observe pedestrians about to board the bus. The exit door should be glazed over its upper half to enable alighting passengers to see out as the bus is approaching their stop.

The doors must be operable by the driver without leaving his seat. While it is desirable that the driver be unable to move the bus while either door is open or partly open (preventing the possibility of a person being caught in the doors and dragged along when the bus starts), some states require travel with doors open under certain circumstances -- e.g., when crossing railroad grade crossings. Thus, it is necessary to provide an override switch which will allow bus to operate with doors fully open. The ATA Committee expressed a desire to make an accelerator interlock a part of this feature.

Other safety features of the doors are related to prevention of injury to a passenger should doors close upon him. The edges of the doors should be designed so that a person may easily disengage himself in this event.

The doors must operate at curb heights which vary among the cities and suburbs of the United States. These heights rarely exceed 8", and the doors must operate satisfactorily at curbs lower than this height. However, since the road may be cambered at up to 5° approaching the curb, the doors must be operable while the bus is standing near an 8" curb and on a 5° camber.

It is undesirable for the opened doors to project a significant distance from the side of the bus, risking injury to pedestrians standing near the bus door. A limitation of 8 inches is set for this dimension.

The doors must be designed to be opened manually in the event of emergency with force of no more than 12 lb. This is in accordance with present practice (see Ref. 9).

3.3 Floor

Structurally, the floor must support the loads imposed upon it, both with respect to the passenger loading and the operational loads transmitted through the basic structure. In addition to the absence of permanent deformation, the elastic deflection must be kept to an amount which is almost imperceptible to a passenger. Care must be taken in design to avoid large deflections of the floor under point loads.

The location of the floor relative to a level road has an important bearing on the speed and safety of access and egress. A goal for floor height is 17 inches above the level road. This 17" dimension is derived from the two step heights of 10" and 7" and an overall requirement of approximately half the present floor height. The floor height should be achieved in the static condition for the purpose of easy boarding and alighting. However, if some quick, safe method of causing the bus to "kneel" should be developed, the requirement for floor height in the dynamic condition becomes less important. It is highly desirable to lower the floor below this level in the static condition if practical, to improve further access for the elderly, the young and the handicapped.

There is general agreement that a low floor is an excellent feature in the new bus design but manufacturers have reservations due to the extreme technical difficulties of meeting these requirements. The ATA members were also well aware of these technical difficulties and questioned whether the benefits really justified the costs and technical risks.

At the ATA meeting on August 31st, the subjects of a sloping floor and a floor with interior steps were discussed. The opinion was expressed that in buses of such design in the past a significant incidence of passenger injury has been experienced as a direct result of these features. Thus, no appreciable slope and no steps became a mandatory requirement. Subsequently, one member expressed surprise that such an important matter was so quickly dismissed, and suggested further investigation. He based his remarks on British practice where both sloped floor buses and those with a step forward of the rear wheels are in use.

The requirements for the floor location were relaxed to become goals rather than mandatory requirements. Thus, the 17" height should be approached as nearly as possible consistent with the technical risks and cost. Some buses may be built with a step in the floor and some with a slope greater than 3°. All these features can then be evaluated on a logical engineering basis.

Further safety features pertaining to the floor include a non-skid surface and flame retardant material for floor covering. This allows a wide range of options for materials including carpet and rubber. It may be desirable to have different materials at different times of year – - e.g., carpet in summer and rubber in winter – - in which case, it should be made relatively simple to change the floor covering.

It is highly desirable that the floor be easy to clean. Cantilever-type seating can contribute to both ease of cleaning and changing floor covering since there is a complete absence of structure under the seats in this design. An appreciable blend radius at meeting of wall and floor is desirable to avoid providing a harbor for dirt in a sharp right-angle corner. This design easily enables the floor covering material to extend around the radius and a certain distance up the walls.

3.4 <u>Steps and Stepwells</u>

The steps at entrance and exit should be as few as possible and no higher than the architectural standard riser height of 7". Due to ground clearance requirements, the initial step up from the road may have to be greater than this (approximately

10"). However, the varying curb heights experienced in cities will reduce the actual distance passengers have to step up or down provided buses pull in close to the curb.

This goal is desirable as a component to faster, safer boarding. While it would be highly desirable to eliminate steps entirely as a means of entering and leaving a bus, this should not be at the expense of the speed of boarding and alighting. The concepts of a kneeling bus, hydraulic lift, gangplank, or raised platforms at bus stops should be investigated, but the speed and safety of operation of these concepts should be of prime importance. If a concept involving a slope is considered, this slope should be no more than 8% to enable wheel-chair passengers to board unaided. While the elimination of steps may make it possible for wheel-chair passengers to board, the benefits are not limited to this section of the community. The elderly, the young and the ambulatory handicapped also would benefit from the reduced risk of accidents.

Other step requirements recommended by ATA members pertaining to the safety aspects included the non-slip surface on the steps and the elimination of a step "nose", thereby removing a possible tripping hazard. The edges of the steps should be of a bright contrasting color to improve the safety of passengers with poor eyesight. Structurally, the step wells should be of a corrosion resistant material of strength suitable to avoid perceptible deflection under normal passenger loading.

3.5 Exterior Panels

While the specifications are not intended to dictate the nature of the structural design of the bus, the design of the panels will be highly dependent on the design scheme selected. It is necessary to specify the strength of the panels for the extremes of design and the replacement time in the event of damage to panels which are not basic structural members. All exterior panels must be corrosion resistant and options may include stainless steel, fiberglass and other materials.

A standard ASTM corrosion resistance (salt spray) test is required for panel materials.

An access panel must be included near the rear of the bus so that the cyclone bus cleaner can be used. The present practice is to open a rear window for this purpose but on this bus all windows will be fixed except for emergency egress.

3.6 Bumpers

The primary purpose of bumpers is to provide protection for the bus in the event of collision with a fixed or moving object. In addition to protecting the bus, it is desirable that damage to the object is minimized. This tradeoff must be made in bumper design. Compatibility in height between car and bus bumper is a step toward minimizing crash damage to either vehicle. Since an appreciable number of crashes involve the corner of the bus, the bumper should give protection up to 30° from the longitudinal centerline of the vehicle. Manufacturers have indicated the difficulty of meeting the requirements for the 30° protection, but generally agree that it is a desirable goal.

3.7 Wheel Housings

Certain essential performance requirements must be met in the design of wheel housings. Primarily, they must protect the passenger from (a) injury due to stones thrown up by the wheels or loose tire chains, and (b) splashing with water, mud, etc. A second requirement is that of minimal maintenance. The existing design of wheel housings is satisfactory from both these viewpoints, and the specification requirements are based on this design.

The SAE have developed some guidelines on clearance between wheels and housings and these should be used in design of suspension, tires, and housings.

With the enforcement of the proposed federal requirement for the minimization of the spray arising from wheels in wet weather at high speeds, it is possible that the wheel housing design may enclose the wheel more than at present. This could give rise to a serious tire ventilation problem. Therefore, in the design of the wheel housings, care must be taken to ensure adequate ventilation for the tires.

3.8 Interior Panels

The principal requirements for the interior panels are adequate strength to resist vandalism, resistance to scratching or marking by passengers, and easy maintenance by carrier management. The maintenance includes cleaning the surface as well as replacement in event of damage. Moreover, panels should be fastened in such a way that the passengers cannot readily remove them. In addition, since the windows will all be fixed, an access panel must be provided to accommodate the "Cyclone" cleaner device.

3.9 Insulation

The insulation has two main purposes – - reduction of propogation of heat and sound. It is desirable that the passenger compartment neither gain nor lose heat too rapidly, both to maintain passenger comfort and to prevent placing excessive loads on the heating and air conditioning units. The present bus is considered adequate in terms of heat transfer. One operating property (Ref. 7) quotes the value given in the specifications and this value is acceptable to both ATA and manufacturers. Since the power plant is apt to generate considerable heat, particular attention must be given to the design of insulation between it and the nearest seats.

The ambient noise level on average city streets is often of the order of 80 dBA. It is desirable that the insulation be sufficient to reduce this sound level to an acceptable level for passenger comfort (65 dBA), exclusive of any noise made by the bus.

Selection of the insulation material must take into account resistance to moisture and fire. Concerning the former, it is undesirable that moisture be allowed to accumulate in the insulation material in sufficient quantities to cause degradation of the insulation material. Concerning the latter, federal standards have been defined for the fire retardant qualities of interior materials, and insulation is regarded as interior material for this purpose.

Throughout the operational life of the bus, there will be a continuous random vibration in the structure. The insulation material must be packed in such a way that no degradation of the insulation properties occurs as a result. ATA members mentioned insects living in the structure of buses on several properties. Therefore, in design, precautions should be taken to avoid providing a suitable harbor for insects.

3.10 Electrical System

The electrical system has traditionally been a source of failures, which frequently require a long time and a fairly highly skilled mechanic to diagnose and correct. The design of a new bus is a good opportunity to include features which will both reduce the failure rate and make it easier to detect and correct any failures that do occur. Two innovations from aerospace technology should be examined for applicability in this area: modular design and diagnostic testing. A trade off must be made between the cost of these items against the saving of maintenance time.

Since it is of the utmost importance to keep buses operational, it is desirable that electrical parts be so designed that they may be unplugged and replaced quickly. The failed part may then be repaired without immobilizing the bus.

The diagnostic system might use an umbilical which could plug in to each bus one by one, thus determining the status of various components for that particular bus. These two design features need not be prohibitively expensive if included from the initial conceptual design.

The actual wiring system may be designed on a modular basis so that a bundle of wires containing one or more failures may be removed and replaced as a complete unit. The failed bundle may then be either repaired or discarded, as dictated by policy of the operating property.

Batteries are not a requirement in the bus design although most propulsion systems, including diesel, gas turbine and steam, require some kind of battery power for starting. The capacity of the batteries (if used) should be no less than present practice (200 amp-hrs.). Any improvements in battery technology should be examined for their applicability to the bus design.

3.11 Accessories

3.11.1 Fare Collection Equipment

The primary objective of development of fare collection equipment is speed in handling fares, to avoid delaying the bus trip while fares are collected. To achieve this, it is desirable ultimately to relieve the driver of all fare collection duties. However, no automatic method of "metering" people has yet been developed which is suitable for use in buses. Another approach - - installation of turnstiles on buses - - was discussed both at the ATA meeting in San Diego on August 4th and subsequently in Washington on August 31st. This concept has been implemented in the United States, but discarded for lack of reliability. In Europe, the use of turnstiles is again the subject of demonstration studies (e.g., some routes in London Transport). A major obstacle remains: even given an adequate level of reliability, the present concept of a turnstile is still too slow for the basic objective of boarding at rate of 1.5 seconds per passenger.

More development is urgently needed. Although no subsystem manufacturer working in this area has been contacted as part of this program, development of fare collection equipment is being investigated as part of the Bus Operations Systems management Contract and communications have been received from that contractor.

For the purpose of the present specification, it is only necessary for the bus manufacturer to make provision for an advanced fare collection system. However, since it is specified that two lines of passengers are expected to board simultaneously, provision should be made for two independent fare collection systems to be installed. With dual systems, potential fare leakage may be curtailed, thus overcoming the objections to wider doors put forward by some of the ATA committee.

Fare collection devices might include "people meters," change makers, token machines, and other equipment designed to minimize or eliminate the need for the driver to handle fares. It is desirable that change-making devices respond to both coins and notes, and that the "people meter" concept take into account the needs of the elderly and handicapped.

A number of advanced methods of fare collection have been developed for use on rail rapid transit, some of which might be adapted for use on a bus. It is conceivable that a prepaid plastic card with the number of journeys remaining magnetically imprinted on it (comparable to that developed for the PATCO high-speed transit line) might be used in conjunction with a coach-mounted card reader.

A further consideration applies to any devices which accept cash fares - - they must be so designed that carrier management may empty the cash boxes at the end of a run quickly and easily.

3.11.2 Passenger Information System

A deterrent to the use of bus transit at present is the lack of information available to a passenger both inside and outside the vehicle. Needed information may be disseminated visually, audibly or both. It is highly desirable that the passenger have, or be able readily to obtain, specific information about the route he will travel - - not simply the ultimate destination of the bus as posted on the front of the coach. Public address systems have been used successfully on transit (on PATCO trains between Philadelphia and New Jersey; on New York City to Washington Metroliner trains; and on Greyhound and Trailways long-distance buses), and are therefore state-of-the-art. This type of system should be installed as a minimum requirement.

Development of visual information systems, perhaps incorporated with the bus interior advertising, should be encouraged and included on future buses. Discussions with representatives of ATA indicated their readiness to investigate innovative methods of presentation of public service and advertising material.

3.11.3 Driver communication System

The operating properties, as represented by members of the ATA Bus Technology Committee consider a communication system between driver and carrier management a highly desirable feature. Some properties (e.g., Chicago Transit Authority) at present use such a system and therefore no advancement of the state-of-the-art is required. Provision must be made in the bus design for such a system to be included.

3.11.4 Destination signs

As in the case of the interior passenger information system, exterior signing can have an influence on the decision whether or not to take transit. The present visual display of route and ultimate destination is considered by both operating properties and public to be inadequate.

Discussions at the ATA meetings resulted in a general concensus that destination signs should be displayed on at least three sides of the bus.

From the carrier management viewpoint, the curtain-type device currently used is unsatisfactory for two reasons: (a) an insufficient number of destination postings is available on one curtain, and (b) it is an unnecessarily long process to introduce or delete a destination from a given curtain. A meeting with a manufacturer of destination signs included counter arguments to both these objections while still retaining the curtain-type sign concept (see Appendix A). One of the principal problem areas for the sign manufacturer is that of making a sign which is visible in bright daylight equally brilliant when artificially lighted at night.

The requirements in the specifications do not eliminate the curtain-type device but encourage the development of new devices which will overcome the carrier management objections while at the same time giving the passengers more complete information.

3.11.5 Emergency Equipment Stowage

All buses are required by the Motor Carrier Safety Regulations to carry emergency equipment including, but not limited to: fire extinguishers, warning devices for stopped vehicles, hand axe, and first aid kit in suitable steel box. A suitable stowage cabinet for these and other emergency items must be provided on the bus.

3.11.6 Passenger Surveillance

It is necessary for the bus driver to be able to observe passengers at certain points in the bus without his eyes leaving the road for more than a few seconds. The state-of-the-art of technology for this purpose is simply the provision of mirrors at the key points near the rear steps and near the rear of the bus. This arrangement is not entirely satisfactory since, in a crowded bus, standees may obscure the line of vision between mirrors. The possibilities and cost-effectiveness of such devices as closed circuit TV and fiber-optic technology might be explored for this application.

3.11.7 Horn

A horn is required by law on buses and all other vehicles. The SAE has developed satisfactory standards for the design of this item; no additional requirements are to be included in horn design for this bus.

3.12 Tow Devices

An operator may have occasion to tow a bus either backward or forward. Since towing forward often necessitates lifting the front end of the vehicle, tow devices must be strong enough to withstand these loads. When towing from the rear is required, it is seldom necessary to lift the back of the bus by the tow devices; the task is generally accomplished by other methods.

3.13 Jacking Plates

While it is unnecessary for a bus to carry a jack as part of its equipment, it is necessary to have clearly defined points on the structure where jacks may be applied. The strength of the jacking plates and the surrounding structure must be sufficient to lift the bus without permanent deformation of plate or structure.

4.0 EXTERIOR

4.1 Exterior Appearance

The requirements for exterior appearance are largely aesthetic: the vehicle should be styled with simple lines, derived from the function it is to perform. Superficial design motifs are undesirable and exterior materials must present a clean, smooth appearance. Such materials must also be durable, easy to maintain, and available in various colors suitable for a large number of operating properties.

The operating properties at present derive considerable revenue from advertising - - exterior advertising in particular - - and are resistant to substituting aesthetic appeal. for this revenue. Thus, while it is unlikely that advertising can be eliminated, it is desirable that the advertising blend with the bus styling rather than appear to be added haphazardly. Molding strips are generally undesirable as an edge feature for advertising cards. Instead, the edges of the cards should coincide with a natural boundary in the styling of the bus, e.g., where the windows meet the skirt panels. Lighted signs standing on the roof of the bus radically alter the silhouette from an aesthetic view point, but the bus designer cannot prevent a property using this type of advertising.

An overall safety requirement in the general exterior design is absence of large protrusions which could cause injury to pedestrians. In meeting the objective of smooth clean lines, such items would be precluded and the attendant danger obviated.

4.2 Exterior Lights and Reflectors

The number and arrangement of exterior lights and reflectors is a legal requirement defined initially in the Federal Motor Carrier Safety Requirements and now supplemented by the requirements of the NHTSA Motor Vehicle Safety Standards.

Headlights are a frequent source of failure legally defined as Class 2 since the bus should immediately go out of service in the event of loss of headlight illumination. It is evident that the concept of redundant headlamps should be examined for cost effectiveness. One manufacturer expressed the view that the redundant bulbs cannot be placed in the same sealed beam unit since, geometrically, both cannot be at the focal point of the reflector at the same time. However, since full and low beams have both been placed in the same unit for many years, one possible solution is to have two head-lamps on either side of the bus with full and low beams in each.

A visible and audible reversing warning is essential from a safety viewpoint, particularly if the rear window is omitted. Even with that window, a pedestrian behind the bus would in most cases not be visible to the driver. Moreover, the exterior mirror system has a blind spot immediately behind the bus.

4.3 Mirrors

External rear-view mirrors are likely to be a legal requirement of the Federal Motor Vehicle Safety Standards in the near future since a proposed rule-making was recently published in the Federal

Register (see Vol. 36, No. 16, January 23, 1971). In the past, many operating properties fitted mirrors only on the left side of the bus. Recently, however, the tendency has been to affix two mirrors, one on each side of the coach. Indications by the ATA committee that adjustment of the right-hand mirror has often been neglected by drivers led to the requirement that both mirrors be adjustable from the driver's seat. Since the mirrors create an inconvenient protrusion while the bus is going through the washer, the requirement that they may be folded flat against the sides or front of the bus is included. Manufacturers have expressed difficulty in meeting these requirements but appreciate the desirability of the goals.

With the low profile of the bus, the mirrors could injure pedestrians if mounted too low on the bus side. This consideration led to a minimum height requirement for the mirror mounting position.

4.4 Airborne Noise

It is generally acknowledged that the present buses contribute considerably to the general noise level in an average city. The design of the new bus presents an opportunity to make a quantum improvement in lowering the noise level of buses. Manufacturers have expressed the opinion that the requirement of 75 dBA at 50 feet is very severe for the two high power output conditions. However, fulfillment of the requirements should be feasible with careful design of power plant, its mountings and compartment.

At 65 mph, the noise level is likely to be primarily a function of the tire motion. Thus, a trade-off between tread design for safety and for low noise level may have to be made. While it would be desirable to have both safety and quiet ride, the former cannot be compromised in favor of the latter.

5.0 INTERIOR

5.1 Decor

As in the case of the exterior appearance, precise definitions of aesthetic requirements for interior decor are almost impossible since the appreciation of appearance is largely subjective. However, some guidelines for interior decor, based on providing a simple functional design, are provided in the specifications: the overall effect must be inviting and present an attractive environment in which to ride; materials must be pleasant to look at and to touch; and, use of sound absorbing material is encouraged. In addition to the attractiveness, design for passenger safety is of extreme importance inside the vehicle. All fittings, armrests and other items must be so constructed and installed as to minimize potential injury to passengers.

Most discussions with both ATA and manufacturers indicated acceptance of the concepts for interior decor. However, so many operating properties have been plagued with vandalism that selection of materials throughout the interior of the bus must take this hazard into account. Surfaces must resist scratching and marking; panels and lighting fixtures must not be easily removable; and, fixtures and fittings should appear to be integral with the interior design.

Provision for interior advertising is desired by many properties. The large windows will generally preclude the present practice of displaying cards above the windows. Such locations as the bulkhead behind the driver and the rear bulkhead (if the rear window is blanked off) should be examined for suitability to advertising. innovative methods of presentation of material, such as changing slides, might be explored.

5.2 Passenger Seats

As discussed under Section 2.3, Capacity, discussions with the ATA led to the definition of a Standard Seating Arrangement, which must be available to all operators as one option. The bus must be designed to accept other seating arrangements as purchasers' options – - e.g., all perimeter seating, thereby allowing maximum standees, or, at the other extreme, individual seats and perhaps a table with each seat. The Standard Arrangement also specifies the comfort standard to be offered as a base line. Other seating options will have an effect on the capacity of the vehicle and on the comfort level (lower if the property wishes to carry 55 or more seated passengers).

In the Standard Seating Arrangement, a target capacity is 45 seated. Achievement of this target will be based on the configuration selected by the designer for other components of the bus. In discussions with manufacturers, it was indicated that some of the factors among which trade-offs would be made to achieve the required 45 passengers would include tandem or single rear axle, tire size, location of rear bulkhead, location of fare collection devices, location of front axle, and actual floor height.

5.2.1 Standard Arrangement

The Standard Seating Arrangement is based on transverse forward-facing seats. This has been the traditional arrangement in transit buses for many years. In a study of seating arrangements for small buses (Ref. 3), this was found to be the most suitable for general transit purposes, based on such criteria as total number of seated passengers, knee room, seat privacy, seat width, seat orientation, and other factors. The designer may arrange seats as required at bulkheads, wheel wells and other points where special conditions obtain.

The transverse forward-facing seats should accommodate no more than two adult passengers, except at the rear bulkhead where the standard five-across seat may be included if this is consistent with other factors in the designer's layout.

Although the aisle width was initially set at 20 inches based on a dimension given in Ref. 4, discussions with the ATA revealed the desirability of a wider aisle than this.

From a passenger comfort standpoint, it was undesirable to reduce the seat width below 18". This dimension, plus allowance for 4" thickness of structure on each side of the vehicle, resulted in an aisle 22 inches in width. While finding this acceptable, ATA members still expressed preference for a greater width. This consideration led to the seat back being shaped to give a 26" aisle width at standee passenger hip height.

The aisle height of 80" is standard for present practice (see Ref. 10), and is recommended in the NAS Study (Ref. 2) as being sufficient for a 95th percentile male wearing a hat to stand upright.

5.2.2 Seat Dimensions

In accordance with the general rationale of these specifications, the seat dimensions given are for a standard of comfort higher than that presently offered on transit buses. There is general agreement that the seats should be no less than 18" in width per passenger. This was specifically taken from the NAS Study (Ref. 2) and was confirmed in discussions throughout the program. Other seat dimensions represent a compromise among recommendations from various sources including industrial designers experienced in the transit field.

Knee room of 10" is also generally agreed to be the minimum allowable dimension.

5.2.3 Materials

In the Standard Seating Arrangement, the seats are to be fully upholstered, and padded with urethane foam. This standard, while consistent with comfort, is not consistent with resistance to vandalism. Despite encouragement to manufacturers, seats which are both comfortable and vandal proof have yet to be designed. Until they are, operating properties harassed by vandalism may have to sacrifice comfort for toughness of materials.

Materials must be pleasing to see and feel, yet be fire retardant and hard-wearing. In addition, materials must be selected to avoid those in which a loss of fire retardance over a prolonged period has been experienced.

5.2.4 Structure

The basic structure for the transverse seats is to be of cantilever form leaving the space beneath the seat completely free of structure. A similar concept is used in the BART rail rapid transit cars. The advantages of this type of design include ease of cleaning and replacement of floor covering.

This structure places considerable loads on the walls of the vehicle. For design purposes, the standard passenger load of 150 lb. was increased to 200 lb. as a safety factor and then factored by the load factors given in Table 2 of the specifications in the directions of the principal axes of the vehicle. For test purposes, shock and fatigue loading tests were prescribed in accordance with standard industrial design techniques for transit vehicles.

At two of the ATA meetings, the subject of armrests was discussed - - on both occasions, universal dislike of these features was expressed. The NHTSA desire some lateral support for a seated passenger in a crash or severe maneuver situation. A compromise was reached by specifying no armrests on the transverse seats but requiring bucketing of the upholstery to provide a certain amount of lateral support.

The seat structure should be of, or coated with, an easily-maintained, corrosion-resistant material. Seat cushions should be securely attached to the seat structure, separable only with a special tool, as a safeguard against removal by vandals.

A handhold on the back of each seat is desirable both for use by standee passengers and for access and egress to the seat. The handhold should be so designed as to avoid presenting a safety hazard to seated passengers in the event of severe deceleration of the vehicle. The concept of a padded handhold was suggested at an ATA meeting but met with universal disapproval owing to the increased maintenance required. ATA reports minimal incidence of facial injuries to seated passengers from existing unpadded handholds, in contrast with similar experience with such injuries in school buses.

5.3 Environmental Control

Part of the basic rationale of these specifications is to provide a pleasant environment for a passenger. Since most parts of the United States record high temperatures in summer, often with high humidity, air conditioning is a basic requirement. Supporting this requirement is the concept of fixed windows. At present, where windows are under passenger control, all benefit of the air conditioner may be lost when a rider opens a window. However, high reliability of the air conditioner is essential in a vehicle with fixed windows. (Discussions with the ATA on this subject were reported in Section 3.1.) As a backup in the event of air conditioner failure, the ventilation system must introduce fresh (but not conditioned) air at the required rate.

The temperatures selected for passenger comfort are those defined by the ASHRAE (65-75°F and below 50% humidity). Initially a temperature differential of 25±5°F between interior and ambient temperature was specified. This was undesirable in the very low temperatures in which the bus may be required to operate. This consideration led to specification of the minimum interior temperature of 55°F which, although outside the standard comfort zone, offers a reasonable differential between very low ambient temperatures and acceptable traveling conditions. Passengers would be warmly clad in temperatures near 0°F and entering a 55°F environment would not be unpleasant.

The comfort level temperatures must be maintained in all parts of the bus. This may require special insulation between the power plant and adjacent seats.

The ventilation requirement of 20 $ft.^3$ per minute per person of conditioned air is taken from ASHRAE Standards for buildings. If this were all conditioned outside air, it would impose an unacceptable load on the refrigerator plant on the vehicle. Thus, 75% of the air may be recirculated. The air flows should be distributed evenly around the passenger compartment. Preferably, the cool air should be distributed above the passenger and warm air near the floor.
Rapid movement of cool air near a passenger is generally undesirable.

Air intakes must be located to avoid ingestion of exhaust gases from the bus and other vehicles. Air must be baffled and filtered to reduce the entry of both large and small particulates, and moisture, into the passenger compartment.

5.3.1 Internal Noise Level

An unpleasant aspect of a bus transit journey at present is the interior noise level. The noise level for the specified, vehicle is set at 75 dBA for four high power output conditions. It is generally agreed that this is a desirable requirement but manufacturers have expressed difficulty in meeting it, particularly in rear seats near the power plant. New types of power plant with advanced methods of mounting and sound insulation should contribute to meeting this lower sound level requirement.

5.3.2 Passenger Lighting

Good visibility for passengers is desirable for both day and night operation. While the large windows should give adequate lighting by day, sufficient lighting must be provided at night for a passenger to read easily at the normal plane (lap level). Additional lighting must be provided at key points in the bus for the safety of passengers, e.g., in aisles and stepwells. Background lighting need not be very bright but is desirable for passenger safety while circulating within the bus. Lighting fixtures should be, as far as possible, vandal-proof.

5.4 Ride Quality

The vibration experienced by a bus passenger should be minimized, particularly in the low frequency 4-8 Hz range, the resonant frequency for certain organs of the body. Sensitivity to vibration has been measured subjectively by a number of investigators. In addition, a literature survey of this work was performed by APL-Johns Hopkins University (Ref. 5). The vibration requirement is taken from work done by the International Standards Organization and defines the comfort level for an eight-hour exposure.

As yet, no standard input vibration has been defined to correspond with various road surfaces. The Belgian Block is used as a severe test at most automobile proving grounds, and may be regarded as one standard. Concrete freeway road surfaces have tar strips between the concrete blocks. These may approach 0.5 inches in height and such strips may give rise to regular periodic input vibration.

Above 100 Hz, the human body as a whole is less sensitive to vibration and the suspension system and seat upholstery tend to damp out these frequencies.

5.5 Grab Rails

Grab rails must be provided at convenient points throughout the bus, suitable for the 95th percentile male as well as the 10th percentile female. Too many grab rails can be almost as dangerous as too few; thus, an optimum number consistent with a logical safety analysis should be sought by the designer. Severe injuries have been experienced in a crash situation where grab rails have broken leaving sharp jagged edges. This possibility should be considered and potential danger minimized in the grab rail design.

5.6 Driver Provisions

The carrier management must provide comfortable conditions for the driver, together with good visibility and safety.

5.6.1 Seat

The driver's seat should be adjustable fore-and-aft and vertically to accommodate as wide a range of sizes of drivers as possible. For additional comfort, adjustment of the back relative to the seat should have a range of 15°. Certain operators report injuries to drivers' fingers when adjusting the seat. This should be eliminated with suitable design.

The driver centerline (and standard line of sight) is 23 ± 1 inches to the left of, and parallel to, the bus longitudinal centerline. Initially, this was set at 18 inches from the left-hand wall of the bus in accordance with SAE Standard practice for heavy vehicles. Subsequent discussion with ATA and manufacturers indicated that the given requirement is both desirable and realistic.

Since the driver is located close to the front windshield, he is in danger of being propelled through it in the event of a crash or severe deceleration. Provision of a seat-belt for the driver is a legal requirement.

5.6.2 Driver Controls and Instruments

SAE Standard Practices specify the general location of the various controls and instruments for heavy industrial vehicles. It is desirable that the detailed location of these items on all makes and models of buses be standardized. This may be accomplished after prototypes from several manufacturers are evaluated, and an optimum arrangement agreed upon with the operating industry.

Controls and instruments in use today will be required on the vehicle, as listed in the specification. These requirements provoked little discussion with the ATA or the manufacturers. At one ATA meeting, it was suggested that a light, indicating low air compressor pressure, should be included. This is met by requiring indication of all malfunctions which could give rise to Class 1 failures.

5.6.3 Driver Barrier

A barrier between driver and passengers is desirable. This may be glazed or provide mounting for interior advertising.

6.0 SUSPENSION AND STEERING

Since this is a performance specification, no details of the type of suspension or steering mechanism are included. The suspension system should be designed to support the full service loads factored by given load factors, to minimize sway and roll and to meet the ride quality requirements specified in Section 5.4. Any type of suspension which will meet these requirements is acceptable. Due to the low floor design, the steering mechanisms presently available may not be suitable. Any new design must meet the steering requirements of Section 6.3.

6.1 Wheels and Tires

In the fulfillment of the low floor requirements, the selection of tires is likely to be critical. Discussions with manufacturers indicate that no tire of the required size and load carrying capacity presently exists. Therefore, a new tire may have to be developed. Tire manufacturers did indicate that low profile tires show some promise of providing a small outside diameter and high load capacity. The Federal Motor Vehicle Safety Standard quotes specific size and load limitations on presently available tires. This may have to be amended if a new tire is developed.

Small wheels and hubs present little difficulty in design or manufacture, with the exception of brake drum or disc size.

6.2 Brakes

No specific design of braking system is required; however, Federal Standards govern Air and Hydraulic brake systems, and the designer has the choice between these. The hydraulic brake requirement implies the inclusion of an anti-skid device, since the bus must stay within a 12-ft. lane under any road conditions. At present, however, available anti-skid devices are primarily limited to disc brakes. It is desirable to advance the state-of-the-art in brake design and the new Federal Standards impose severe performance requirements to be met. The manufacturers have indicated that they are aware of these standards and are preparing to meet them.

The ATA has indicated at the various meetings that brake adjustment and relining use a significant portion of the maintenance time. A target for replacement life of friction material is 100,000 miles or approximately double present life. Self-adjustment throughout this period is desirable, a feature which can easily be included if disc brakes are selected. In addition, replacement of the pads is a simple process compared with relining drum brake shoes.

The operational cycle for the 100,000 miles was derived according to the following rationale: 25% of the distance would be on city-suburban express runs where an average of one routine stop every 10 miles from 50 mph at 0.1g deceleration would be experienced, together with one emergency stop every 1,000 miles. For the other 75% of the distance, with operation on city arterial streets, one routine stop every 0.5 miles from 20 mph at 0.1g would be experienced, together with one emergency stop every 100 miles.

Federal Standards define the requirements for a parking brake to be included in the bus.

6.3 Steering

Steering mechanism is subjected to high and frequent road shocks in service. Since failure of any steering component will generally be classified as Class 1, high reliability is required.

Large forces required by the driver to steer the vehicle are undesirable; thus, power-assisted steering is likely to be necessary to meet the requirements.

The gearing is set at seven turns lock-to-lock so that failure of the power assist does not lead to loss of control. The ATA expressed general approval of power steering particularly since, with this mechanism, it is usually possible to retain control when a front tire blow-out occurs.

The caster angle should be selected so that the wheels tend to return to the straight ahead position. Discussions with manufacturers indicated that full positive return was generally impossible by caster angle alone, so minimal assistance from the driver may be required.

Automatic lubrication of suspension and steering system has been a feature on buses for some years. Although properties expressed mixed feelings as to its merits, it should be available as an operator option.

6.4 Springs and Shock Absorbers

In accordance with the philosophy of the specifications, details of the suspension system are not defined. The words "springs" and "shock absorbers" are interpreted broadly to mean the suspension items performing these functions. The length of bump and rebound travel is standard in today's transit buses, and must be achieved with full standee load.

Shock absorbers have required considerable maintenance in the past, and replacement life has been low. A target for replacement is set at 100,000 miles. In conventional shock absorbers, the end of useful life cannot be exactly determined, since the deterioration of performance is gradual. The distance quoted is a target to encourage a quantum step in the design of this component.

7.0 PROPULSION SYSTEM

In accordance with the general rationale of these specifications, the exact nature of the power plant is not defined, except in terms of the performance required and the pollutant and noise output. The conventional diesel may meet these requirements with minor modifications. However, it is an intent of these specifications to encourage the development of new types of power plant including gas turbines, liquid natural gas engines, steam reciprocating engines, steam turbines and stored energy systems.

7.1 Power Requirements

The maximum power requirements have been defined in the overall performance of the vehicle (see Section 2.4). An additional requirement associated only with the power plant is that the accessories must operate satisfactorily with the power plant idling. This is based on providing comfort and safety for the passenger with regard to, for example, air conditioning system and air compressor system. In view of the fixed windows, it is undesirable for the air conditioner performance to be degraded while the bus is stationary with the engine idling, and from the safety viewpoint, it is essential that the air compressor (if an air brake system is used) operate satisfactorily with the engine idling.

7.2 Power Plant Mounting

The specifications define the location of the power plant relative to passenger circulation within the bus. The power plant must not, for example, cause a large obstruction in the bus floor. Therefore, it may be mounted at the rear in the present conventional location or may be designed in a flat configuration to go under the floor. Power plant location at the front is not precluded, but the driver must be in a position to collect, or monitor the collection of, fares. Since the inclusion of rear windows is optional, larger power plants may occupy a compartment comprising the full height and width of the bus at the rear, although the center of gravity of the overall bus should be as low as possible to retain satisfactory handling characteristics.

When selecting the location of the power plant, accessibility for maintenance is an important consideration. The skill levels required to maintain the power plant must be minimized.

7.3 Energy Input

Since the nature of the power plant is not specified, neither can the type of energy used be specified. However, the basic requirement is simple - - energy requirements must be minimized. There are several options for energy sources, varying widely in cost and accessibility in different parts of the United States. Actual volume requirements for fuel consumption are not detailed since specific power output from various fuels differs. Diesel fuel is relatively cheap and obtainable in all parts of the country with minimal variation in price. However, a conventional diesel engine may have difficulty in meeting the pollution output requirements.
If diesel fuel is used in an external combustion engine, pollutant output is considerably reduced.

Because of the wide range of options of fuels, their costs and availability, no specific consumption requirement is stated in the specifications. The manufacturer must trade-off the performance requirements, pollutant and noise outputs and availability of the fuel in his selection of fuel and power plant. However, certain requirements must be met in the selection of fuel, as presented in Section 7.3.1. of the specifications. Most of these requirements are self-evident but the range requirement gave rise to discussions with both manufactureres and ATA. Initially, the range was set at 200 miles per fillup of fuel or recharge operation. This was unacceptable to ATA members who wanted buses to run three days in normal operation without refueling. Manufacturers, on the other hand, anticipated difficulties in providing a tank which would be big enough, particularly in view of the low floor design. A target figure of 400 miles range was set. The operating profile for this range was based on 25% use in suburban-city center express service with journeys of 10 miles each and remainder on city arterial streets with stops 0.5 miles apart.

The Federal Motor Carrier Safety regulations have defined standards for the location of fuel tanks and exhaust systems relative to the passenger compartment on buses.

7.4 Pollution Output

The standards for vehicle pollution output have been promulgated by the State of California for 1973 and 1975. More severe standards have been defined by the Federal Environmental Protection Agency in the form of a proposed rule-making (Federal Register Vol. 36, No. 193, Oct. 5, 1971). If the rule-making is adopted in present form, these standards will become mandatory throughout the United States and must be met by the bus.

Odor cannot yet be measured quantitatively by any device. The present method of measuring odor is subjective, using a human panel. Standards for this have been developed by the USDHEW and these methods will be used in verification of odor output.

APPENDIX A - MINUTES OF MEETINGS

1. ATA San Diego 8/4/71
2. NHTSA Crashworthiness Office 9/22/71
3. Bureau Motor Carrier Safety 9/24/71
4. NHTSA operating Systems 9/27/71
5. TRANSIGN Meeting 10/28/71

DOT BUS TECHNOLOGY PROGRAM
Project 9073-047

CONFERENCE REPORT

AMERICAN TRANSIT ASSOCIATION

Conference Date: August 4, 1971

Place: Royal Inn
San Diego, California

ATA BUS TECHNOLOGY COMMITTEE

Participants: Mr. J. B. Schnell, ATA

Mr.,A. Bingham, Alameda-Contra Costa Transit District

Mr. L. Bardsley, Toronto Transit Commission

Mr. J. Belsky, NYC Transit Authority

Mr. L. Huffman, Cincinnati Transit, Inc.

Mr. G. Heinle, Southern California Rapid Transit District

Mr. R. Booth, Tri County Metropolitan Transp., Portland, Oregon

Mr. P. Rockwood, Cleveland Transit System

Mr. A. Lucchesi, AC Transit

DOT/UMTA

Mr. C. J. Daniels

BOOZ, ALLEN & HAMILTON

Mr. J. F. Curtin, Simpson & Curtin

Mr. E. J. Harding, Simpson & Curtin

Mr. R. J. Ross, Booz, Allen Applied Research

Mr. R. J. O'Brien, Design and Development

Mr. C. Pappas, Design and Development

I. PURPOSE

The main purpose of this conference was to review and discuss general performance guidelines (specifications) for new improved 40 foot buses and to encourage transit industry participation in the determination of these guidelines. The conference also served to outline the DOT/UMTA Bus Technology Program to the transit operations/ATA.

II. SUMMARY

1. Acting chairman, Mr. Bingham, began the meeting with an introduction of the ATA group and DOT/BAARINC group. He briefly described the purpose of the conference.

2. Mr. Daniels provided a brief description of the bus technology program and emphasized the immediate need for innovation in new large, urban buses. Mr. Daniels described the role that will be played by Booz, Allen Applied Research as systems manager of the Bus Technology Program. He pointed out that performance guidelines are being developed for prototype 40 foot buses. The first of these prototypes are planned to be delivered by the fall of 1972.

3. Mr. Ross provided a description of the various projects involved in the bus technology program. He provided a description of the program organization and introduced the individuals from BAARINC

who would participate in the program. Mr. Ross stressed the desire on behalf of the systems management group to develop a rapport with the transit industry and ATA in the development of performance requirements, and, in general, all matters relating to improvements in urban bus design.

4. Mr. Curtin gave a general background history relating the urgent need for improvements in urban bus systems and designs. He emphasized the need for reversing the downward trend in bus ridership which has persisted for the last two decades. Mr. Curtin pointed out six major requirements which must be considered in any new design bus. These are:

- Speed
- Riding comfort
- Aesthetic appeal
- Environmental adaptability
- Maintainability
- Economy of operation

5. Mr. Harding presented a performance requirements matrix for the 40-foot bus. Mr. Harding pointed out that the requirements matrix related hardware to certain "people" related requirements. The "people" related requirements are as follows:

- Passenger requirements
- Legal requirements
- Carrier management requirements
- Community requirements

Open discussion was held on an item-for-item basis related to the requirements matrix.

6. Plans for a next ATA/DOT/BAARINC conference were made to be held tentatively by the end of August, 1971. At that time the performance guidelines will be developed in detail.

III. DETAILED DISCUSSION

The items listed below are those which were discussed in some detail during the conference. The discussion following each item summarizes the responses of the ATA Bus Technology Committee during the meeting. Each of the items discussed were directed toward the 40-foot bus requirements.

1. Width	The maximum width of the bus should be 102 inches.
2. Seats (passenger)	Seats should be a cantilever-type design with no obstruction or supporting member attached to the floor to allow easy access for cleaning beneath the seats and package storage.

3. <u>Side Windows</u> — Windows should be fixed and should be constructed of a breakproof material. The windows should be capable of being pushed out, i.e., hinged, in case of emergency. Improved visibility is a requirement. (There is some concern that larger side windows may create greater reflection thus providing a safety hazard).

4. <u>Doors</u> — One entrance door and one exit door is desired. Exit door should be located as far back as possible. There is no strong desire for double-wide doors. ("Double wide doors are all right for experimental purposes, but should not be considered a standard requirement.")

5. <u>Floor</u> — A low floor which eliminates one step and provides lower risers is highly desirable. The floor should be level and not be recessed as in suburban coaches.

6. <u>Climate Control</u> — Air conditioning/year round temperature control should be standard.

7. <u>Advertising Space</u> — Transit operators may be willing to give up some inside advertising space. Exterior advertising space should be a requirement. Innovation in new techniques for advertising to be compatible with the new bus design may be needed.

8. <u>Seat Belts</u> — Required for driver.

9. <u>Bumpers</u> — Some type of energy absorbing bumper is desirable.

10. <u>Brakes</u> — Disc brakes are desirable. Braking system should be improved to eliminate jerk during stopping. Anti-skid feature should also be incorporated.

11. <u>Windshield</u> — Windshield should provide good driver visibility.

12. <u>Grab-Rails/ Stanchions</u> — Grab-rails/stanchions should be provided. Placement should be such as to provide optimum passenger safety.

13. Fare Collection

Trend is definitely toward exact fare system. Mechanical turnstile is not a desirable feature. No indication given as to preferred method of fare collection or fare collection device.

14. Route/Destination Signs

Route/destination signs should be provided on all four sides of the bus. A projection type system would be desirable.

15. Information System

A CB two-way radio is considered a very effective feature for communication between driver and central station. Audio information to the passenger should not be considered a necessary requirement but is desirable.

16. Driver Seat

Ease of adjustment of driver seat is a concern.

17. Exterior Panels

Exterior panels should be easily repairable. Elimination of rivets is highly desirable provided panel replacement is not more complicated.

18. Interior Panels — Interior panels should essentially be maintenance free. They should also provide good acoustical, thermal insulation and fire resistant properties.

19. Power Steering — Power steering is not desirable from the reliability standpoint. It may become a necessary requirement with advent of women and minority group drivers.

20. Baggage Compartment — Not required.

21. Powerplant — Type of powerplant need not be specified. Power should be sufficient to permit top speed of from 70 to 75 mph, and low range acceleration of 3.5 to 4.0 mph/sec. Time required to reach freeway speed should be specified. The powerplant should provide adequate power for hill climbing at sufficient speed.

22. Pollutant Output — Emissions should meet proposed 1975 standards based on 13 mode California cycle.

Submitted by ______________________
Chris Pappas

BOOZ • ALLEN APPLIED RESEARCH, INC.

Memorandum

Bethesda
September 22, 1971

To: Bus Technology Systems Management Group

From: J. Mateyka

Subject: Meeting with National Highway Traffic Safety Administration (NHTSA) Office of Crashworthiness.

This morning John Harding (S&C) and I met with NHTSA personnel from the Office of Crashworthiness to discuss the Bus Specification for the 40 foot bus. The following DOT personnel were in attendance:

Stan Hindman (UMTA) representing Chuck Daniels

Jim Hoffaburger (NHTSA) new chief of Structures Division of the Office of Crashworthiness (OOC)

Leon Conners (NHTSA) Driver/Passenger Protection of OOC who called the meeting 426-2214

Alex Calaluca (NHTSA) Structures Division of OOC, in charge of bumper standard. 426-2264

Roy Dennison (NHTSA) of the OOC, in charge of glass standard. 426-2264

After a brief description of the Bus Technology Program and the background of the specification a discussion of pertinent standards was initiated. Leon Conners gave us a copy of a summary of safety rule makings in progress related to buses, which I had requested about 2 weeks ago. In addition the following major points were made by NHTSA personnel:

- Window retention rule making is very important - must contain passengers inside the bus in crashes

- Collapse of bus roofs not considered that important, present structure seems adequate. There is a roll procedure involving 1.5 g. load on roof for roof intrusion in rule making stage for standard 208 (Occupant Crash Protection)

- Many sharp edges in buses,particularly school buses, are caused by poor, cheap fastening techniques, not enough rivets

- Metal grab rails, rails by modesty panels, and grab rails on seats are unnecessary safety hazards - should be made of flexible materials

- New bumper standard for passenger cars (standard 215) may be applicable to buses with low deck. Thus low deck has crashworthiness feature in that it prevents the possibility of car/bus bumper match

- Our present requirement of no damage to bus in 5 mph wall crash may be excessive since this would convert bus into battering ram relative to autos. NHTSA suggested that a 4,000 lb. pendulum test simulating an auto impact up to a 30° angle would be more desirable

- In the bus interior, NHTSA recommended high back seats with padding on the back and the elimination of metal grab rails on the seats. Handholds of flexible material built into seat were considered preferable

- NHTSA considers driver belt important since he is in great jeopardy of flying through the window in a crash if not belted. Passenger belts were not considered to be of value in almost all cases

- Lateral seat supports were considered to be of some value in compartmentalizing passengers in the case of side impacts, but NHTSA felt that such seats would markedly reduce passenger carrying potential of buses

- Side impacts may be more important if deck is dropped to 17 inches. However, only leg injuries would tend to increase, fundamental safety is not severely impaired

- NHTSA felt that roof escape hatches were good design feature for rollover escape. They do not have any action pending in this area. At least 3 hatches/bus

- NHTSA felt that low floor/lower cg. should improve safety substantially by reducing potential to rollover. NHTSA would test this by handling tests, like U. of Michigan auto. test spec.

- Present rule 208 for passenger vehicles specifies acceptable g-loads for auto occupants in high speed crashes. Given the size of bus and the low incidence of high speed crashes these rules are too stringent for buses, especially urban buses

- NHTSA is very aware of glass vandalism costs in big city bus operations. (Detroit, $12,000/month; D. C. Transit, $30,000/month were figures quoted)

- D. C. Transit is thinking of going to coated acrylic using an abscite coating at about $\$1.50/ft^2$

- General Electric has come out with coated "Lexan" at about $\$2.00+/ft^2$ that is extremely resistant to drop test with 5 pound ball. NHTSA couldn't break it!!

- Both the coated acrylic and the coated polycarbonate "Lexan" plastics can pass the glass standard if the "removal with no tools" clause in the standard is liberally interpreted

- NHTSA stressed the importance of "common sense" safety design with regard to interior appointments. Said it was not possible to write an effective standard in this area but should be controlled in the design progress - "Bus Technology Safety Program?"

In addition to the rule making action summary (Attachment 1) we obtained the following detailed rule making actions:

- Window retention and release
- Auto bumper standard

The visit was very profitable. We should incorporate as much of these suggestions as possible into the specification. NHTSA inputs strengthen my opinion that a "Bus Technology Safety Program" as part of the prototype development is very important.

J.M.

cc: John Harding
Ron Ross
John Wing
Chuck Daniels (UMTA)

BOOZ • ALLEN APPLIED RESEARCH, INC.

Memorandum

Bethesda
September 27, 1971

To: Bus Technology Program Systems Management Group

From: J. Mateyka

Subject: Meeting with Mr. Donald Morrison, Bureau of Motor Carrier Safety, FHWA, DOT (September 24, 1971)

The Bureau of Motor Carrier Safety is responsible for in-use safety requirements for highway vehicles involved in interstate commerce. Unfortunately other members of the Booz, Allen team and UMTA representatives could not be present at this meeting due to a conflict with a meeting with the Office of Program Operations, UMTA.

Mr. Morrison, who is the Vehicle Requirements Branch Chief, Regulations Division, discussed Bureau of Motor Carrier Safety (BMCS) regulation of in-use vehicles which are involved in interstate commerce. He gave me the following documents:

- All BMCS regulations up to January 1, 1968 in booklet form. (Change first number up one digit, i.e., 294.4 to 394.4).

- All amendments to regulations from 1968 to the present.

- A set of all bus accident data summaries for Class 1 (interstate) carriers, 1967, 1968 and 1969 prepared by the Federal Highway Administration.

A new brake regulation is due out soon. Mr. Morrison will forward it to us. Most of Morrison's comments on bus safety are repeats of NHTSA comments. The meeting was useful, however, in getting us an up-to-date version of all BMCS regulations for the new Simpson and Curtin bus specification. Morrison suggested a Mr. Kidwell of his office as a safety contact, related to bus accident data summaries.

JM

cc: John Harding
John Wing
Ron Ross
Chuck Daniels (UMTA)

BOOZ • ALLEN APPLIED RESEARCH, INC.

Memorandum

Bethesda
September 27, 1971

To: Bus Technology Program Systems Management Group

From: J. Mateyka

Subject: Meeting with National Highway Traffic Safety Administration (NHTSA), Office of Operating Systems Personnel (September 27, 1971 - 11 A.M.)

This meeting was held to review the bus specification with NHTSA personnel and to solicit their comments regarding present and future safety standards applicable to buses. In attendance were:

Stanley E. Hindman	UMTA
John Harding	Simpson and Curtin
James Mateyka	Booz, Allen Applied Research
Elwood Driver	Head of the Office of Operating Systems (OOS), Motor Vehicle Programs - NHTSA
Roger H. Compton	Head of Engineering Systems Staff of Motor Vehicle Programs - NHTSA
John W. Carson	Chief of Controls and Displays Division (OOS) - NHTSA under Mr. Driver.
E. H. Wallace	Chief of Tire Division (OOS) - NHTSA under Mr. Driver
Charles A. Baker	Chief, Lighting and Visibility Division (OOS) - NHTSA under Mr. Driver
J. E. Leysath	OOS - NHTSA (Lighting)
Sid Williams	OOS - NHTSA (Brakes)
Kathy Soffer	Office of the Chief Counsel - NHTSA

Roger Compton mentioned that his staff had prepared a memorandum to the Bus Programs Branch, RD&D, UMTA on September 15, 1971, listing safety requirements for urban buses both present and proposed rules. A copy was obtained for use in the bus specification. Mr. Compton mentioned that Mr. Nelson Gordy of his office would be a good contact for future questions regarding standards.

Mr. Compton stressed that bus designs should be amenable to the incorporation of potential future standards, where possible. Mr. Driver indicated that new brake standards would essentially require anti-skid systems. (See Sid Williams, Rm. 5310 for details.) In the lighting area, NHTSA is researching the 3 beam/4 headlight concept, involving low, medium, and high beams. This is not a redundant system, but one intended to provide better illumination than the present 2 beam system, which allows overdriving of headlights at high legal speeds.

NHTSA has no standards rule makings in action in the bus driver controls area. Next action will be for passenger cars based on SAE eye ellipse standards, etc. They will be happy to review our work in this area. (John Carson). Vehicle handling standards are in a research phase and not expected for at least 2 to 4 years for passenger cars. Roger Compton recommended that handling and braking performance be specified at a tire tread depth of 1/16 inch, the legal minimum. These tests with bald tires on wet roads would simulate the scenario of numerous serious bus accidents.

It was mentioned that the low floor bus would require smaller tires. Mr. Wallace suggested that a contact with a major tire manufacturer might be in order to establish load factors. Smaller wheels would also present performance problems for drum brakes since the available size would be reduced. NHTSA has withdrawn a proposed acceleration standard based upon 200 lb. G. V. W./brake horsepower. Mr. Wallace suggested splash protectors for the bus. The American Truckers Association has collected data on the splash and mist from trucks.

NHTSA is sponsoring research in remote sensors for proximity sensing to the rear of trucks and buses. Windshield defrost and defog characteristics of buses is good since they run continuously. Roger Compton felt that an escape hatch, although not presently required, is a good idea.

We obtained a copy of an NHTSA notice of rule making action requiring plane and convex mirrors on the right and left side of a bus. NHTSA recommended cleaning external air, locating air intakes away from exhausts, and pricing of a CO warning sensor as part of the bus. NHTSA recommended high exits for exhaust pipes as in the EIP kits. Roger Compton also recommended passive reflectors to mark out the shape of the rear of the bus since buses often stop at night and sometimes fail on the road. Use of reflecting tape is possible.

JM

cc: Chuck Daniels
John Wing
John Harding
Ron Ross

BOOZ • ALLEN APPLIED RESEARCH, INC.

Memorandum

Bethesda
October 28, 1971

To: Bus Technology Program Systems Management Group

From: J. Mateyka

Subject: Meeting with TRANSIGN Representative: (October 28, 1971)

Mr. Del G. Fields the president of TRANSIGN met with John Harding and the undersigned to discuss transit sign technology: Mr. Fields saw four types of signs as possible with present technology:

- Automatic Curtain Signs
- Projective Signs
- Flip Type Signs
- Alpha numeric

Presently all buses use curtain signs. Most use a single curtain on the front of the bus above the window. These are typically cranked by hand. Motor driven signs were not available from TRANSIGN in production quantities until 1963. Fields indicated that he can get up to 150-200 destinations on a single curtain of Mylar (available after 1963). ABW bus company is the most progressive company with regard to signs that works with TRANSIGN. ABW has a triple sign in the front of the bus. Fields indicates that such a triple sign should be good for any bus properties for the next 10 to 20 years, with the possible exception of New York City. Also the hand crank approach is still standard. Motors are used for big properties only, small properties (10-20 destinations) use a-hand crank. The present state of the art is at the frontier of automatic selection. TRANSIGN approach features an indexing set of three thumb wheels that are dialed to selected route number (one digit of the three digit number on each wheel). A simple press of button will get any of 200 destinations in less than 50 seconds on as many signs as necessary.

TRANSIGN admitted that standard letter height was 4 inches, but they felt 8 inch height was required for the public. New York has gone to 3 inches in an attempt to cram on more information, as a result fewer people can read the sign. TRANSIGN felt color coding was highly desirable for each route, in addition to the numerical route description. TRANSIGN has designed front and side signs for the General Motors RTS. These are motor driven but not automatic. RTS has radical front styling resulting in an inset sign with poor visibility.

Mr. Fields stated that TRANSIGN was convinced that curtains were likely to be used for the foreseeable future. Both projective (projected from the rear) and flip-type (lighted from the front) were poor in bright sunlight. Alpha-numeric, like Times Square, was difficult to make legible in small sizes. It is apparent that no really new technology is available from TRANSIGNS. It is also clear that we are making a quantum jump in price for signs by requiring double signs at the front side and rear. In addition to destination signs, a route sign, in detail, in the external boarding area might be useful. This sign could be color coded to the basic route color and should also be displayed in the bus interior.

Based on these discussions, we should expand the specification to include route signs and to specify human factors criteria for visibility, etc. Fields said that they had already installed the signs in the RTS and were working with Flxible.

Fields supplied us with TRANSIGN specifications for coach signs (both side and front) and for automatic signs. He stated that both Toronto and Montreal have been discussing with GM the concept of bigger signs (8 inch letters) for 3 or 4 years. He also gave us a copy of a Washington Metropolitan Area Transit Commission study (INT-MTD-10) Feb. 1965, about Public Information regarding mass transit. The document supplied only indicates what was planned; it has no results. Suggest a contact with Washington Metro Area Transit Commission to get the rest of the report.

JAM

cc: J. Harding
R. Ross
J. Wing

APPENDIX B

References

APPENDIX B

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